PRADIS

REFERENCE BOOK ON THE ELEMENTS
BASE MODULE

THE SOFTWARE FOR SIMULATION OF NON-STATIONARY PROCESSES IN MECHANICAL SYSTEMS AND SYSTEMS OF OTHER PHYSICAL NATURE

VERSION 4.2

Contents

1. MODEL OF THE ELEMENTS, WHICH ASSIGN THE INITIAL CONDITIONS

2.1. SOME SPECIAL FEATURES OF COMPUTATIONAL ALGORITHM PRADIS, THE ENSURING POSSIBILITY TASKS OF THE INITIAL CONDITIONS

Before beginning integration by computational nucleus PRADIS are carried out the initializations of the necessary massifs. In this case the resetting to zero of displacements and speeds for all degrees of freedom of model occurs.

Thus, if user did not undertake additional actions, then the initial values of speeds and displacements are assumed to be equal to zero.

In PRADIS there is a group of models of the elements, which establish the initial values of speeds and displacements for the degrees of freedom selected by user. Initial conditions are assigned off the direct integration. It is considered that the speed or displacement, prescribed thus, are acquired by object to the zero time. According to these degrees of freedom the object moves evenly (i.e., initial acceleration equal to zero).

From entire aforesaid the following limitations down the use of the described group of the models of the elements follow:

1) with the aid of these elements it is possible to establish the values of displacements and speeds only at the initial moment of time. The attempt to change the value of initial velocity or initial displacement by means of the course of computation will cause the interruption of calculation with the delivery of the corresponding communications about the error;

2) the attempt with the aid of different programs to establish the contradictory initial values of speeds or displacements of what-or unit it will lead down the curtailment of calculation with the delivery of the corresponding communication about the error;

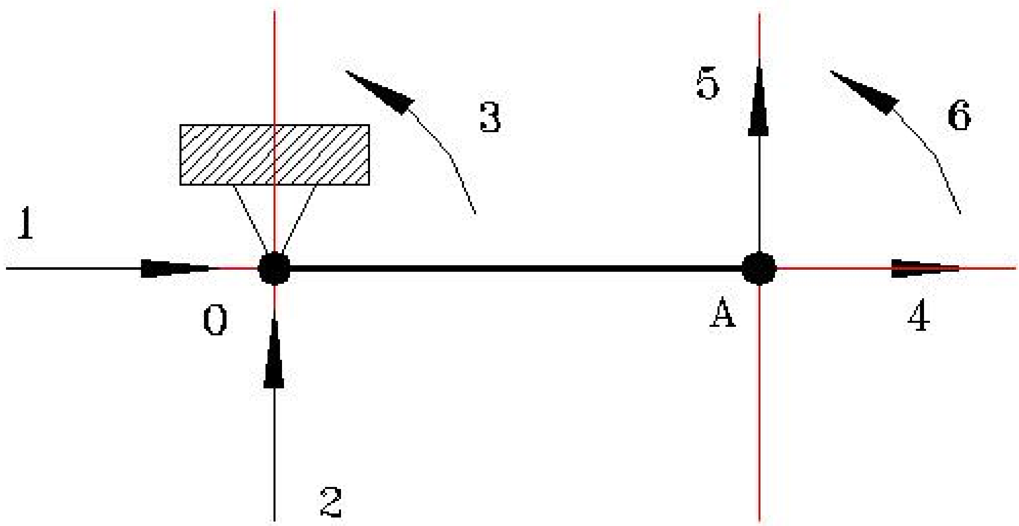


Fig. 1.1. The design diagram of pendulum, used before an example on the installation of initial angular velocity.

3) for the complex technical systems the installation of the initial velocities of separate degrees of freedom must occur in concord. For example, after establishing initial angular velocity according to the third degree of freedom for the pendulum (Fig. 1.1.), but without changing the initial velocities according to the remaining degrees of freedom, we will obtain at the initial moment of time impact process. It is caused by the disagreement of initial conditions for different degrees of freedom. At the initial moment of time the section of rod, which is adjacent down the support, begins turning, while point A is fixed. This causes the initial deformation of rod, which is the reason for impact process. Text before the input language *Of padiSLang*, which describes the mathematical model of pendulum (Fig. 1.1.) with the prescribed initial angular velocity according to the third degree of freedom, equal to 1, take the form:

```
I DATA:
    Point O = 0,0;
    Point A = 1,0
    Material = 1, 0.5, 1.E-5, 1.E-4, 2.E11
    Parameters of layer = 2, 0,0, 0, 0
    The initial velocity = 1
I FRAGMENT : Pendulum
   # BASE: 1,2
   # STRUCT :
    Pendulum 'BALKA (1 2 Oe 4 5 6; Point O, point A, material)
    The initial velocity 'VN (3; The initial velocity)
   # OUTPUT:
    Angular velocity 3 ' the V (3; 1); Angular velocity 6 ' the V (6; 1)
I SHOW:
    Pendulum 'LAYER (; Parameters of layer)
I RUN :
    Calculation 'SHTERM (END=0.01, DABSX=1.E-3)
I PRINT :
    Result 'DISP (;
    Angular velocity 3= (-2,1), angular velocity 6= (-1,2))
$ END
```

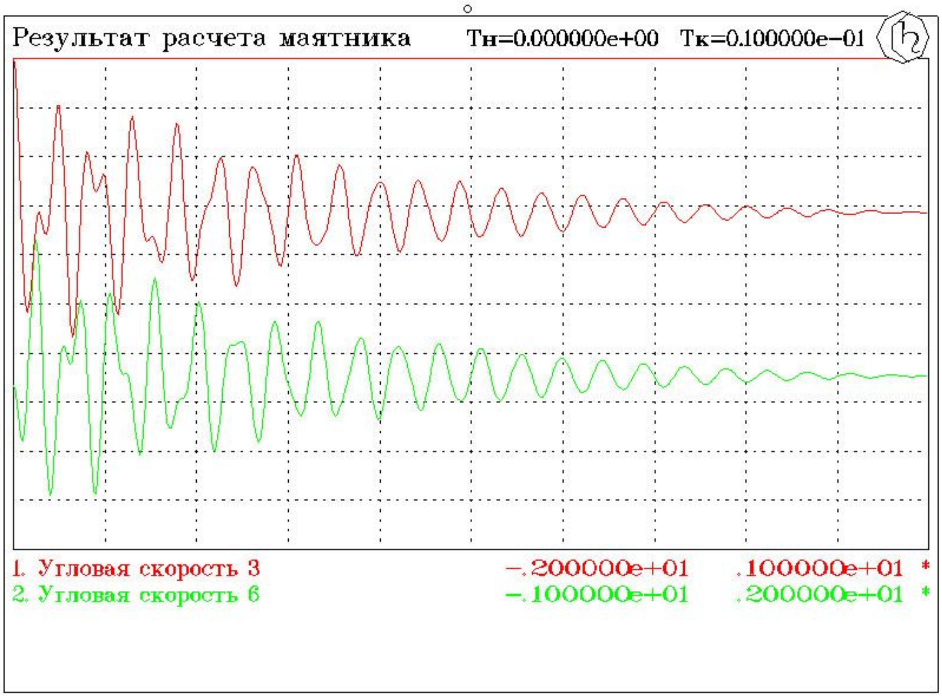


Fig. 1.2. The design diagram of pendulum, used before an example on the installation of initial angular velocity.

The results of calculation about this program are given before Fig. 1.2. Before the figure it is evident that for the initial oscillatory period the angular velocities of rod according to the third and sixth degrees of freedom change before the reversed phase. Steady value of the angular velocity of the rod - 0.06 rad/s. if user in this case wanted not to simply force rod to somehow move, but it is even to revolve with the angular velocity, equal to 1, then it did not achieve the desired goal.

The attempt to establish the same initial angular velocity and for the sixth degree of freedom does not solve problem completely, although back-and-forth amplitude decreases and the steady angular velocity of pendulum is 0.12 rad/s. for the unaccented task by initial angular velocity of pendulum 1 rad/it flogged before the example in question necessary to assign besides initial angular velocities according to the third and sixth degrees of freedom also the initial vertical velocity of point A (according to the fifth degree of freedom). Its value is obtained by the multiplication of initial angular velocity as far as the length of pendulum.

1.1.1D ELEMENTS

1.1.1.INITIAL VALUES OF THE SPEEDS

1.1.1.1.THE INITIAL VELOCITY OF DEGREE OF FREEDOM VN

Reflected properties:

Is assigned the initial value of speed for the degree of freedom indicated.

Degrees of freedom:

1 progressive or rotatory, on which is assigned the initial velocity.

Parameters:

N in sequence	Description	Dimensionality	Range
1	Value of the initial velocity	*m/s* or *rad/flogged*	*-Rlmax… +RLmax*

1.1.2.INITIAL VALUES OF THE DISPLACEMENTS

1.1.2.1.INITIAL DISPLACEMENT OF DEGREE OF FREEDOM SN

Reflected properties:

Is assigned the initial value of displacement for the degree of freedom indicated.

Degrees of freedom:

1 progressive or rotatory, on which is assigned initial displacement.

Parameters:

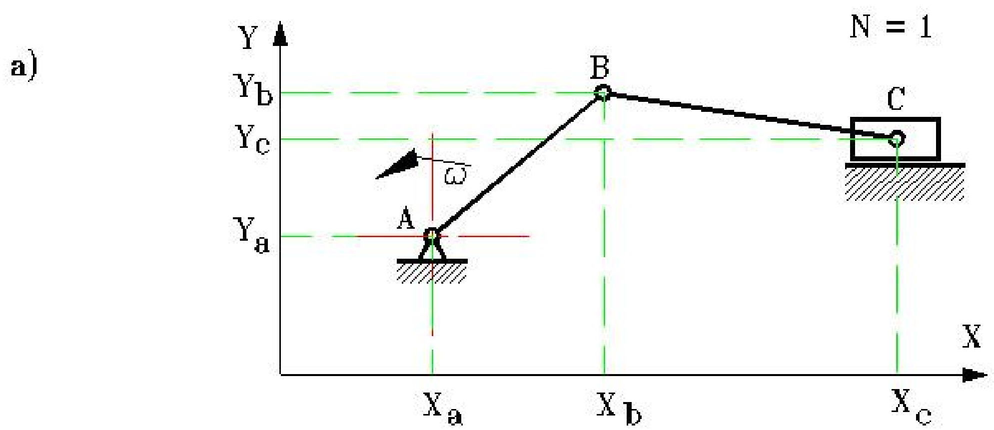
N in sequence	Description	Dimensionality	Range
1	Value of the initial displacement	*m* or *rad*	*-Rlmax… +RLmax*

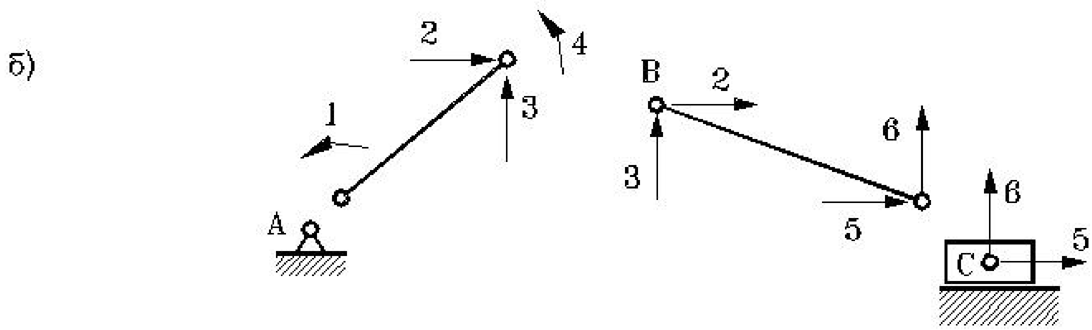
1.2.TWO-DIMENSIONAL ELEMENTS

1.2.1.INITIAL VALUES OF THE SPEEDS

1.2.1.1.MATCHED INITIAL VALUES OF SPEEDS FOR THE CRANK MECHANISM

VNKS





VNKS_1. Parameters and the degree of freedom of the model of the initial velocity of crank mechanism.

a) the parameters of the model:

Xa, Ya - the origin coordinates of point A;
Xb, Yb - the origin coordinates of point B;
Xc, Yc - the origin coordinates of point C;
The ordinal number of the coordinate axis, in parallel for the sake of which the slider moves, is n-th;
ω - the initial angular velocity of crank.

b) of the degree of freedom of the model:

1 crank angle at point A;
it is 2nd the displacement of point B by means of the x axis;
3- the displacement of point B by means of the y axis;
4 crank angle at point B;
it is 5th the displacement of slider by means of the x axis;
6 displacement of slider by means of the y axis;

Reflected properties:

Values of speeds for the degrees of freedom of crank mechanism matched with the angular velocity of crank are assigned the initial, it is sectional on the basis of the condition of its nondeformability.

Note. Here it is below, with the description of the work of element are used the designations of points and degrees of freedom of crank mechanism such, as before Fig. VNKS_1:

- point A - fixed crank hanger;
- point B - joint is the crank-the connecting rod, which accomplishes the plane motion;
- point C - joint is the connecting rod-the slider, moving in parallel to one of the coordinate axes.

The turning of crank at point A is described by one rotational degree of freedom, the motion of point B - by two progressive and with one rotational degree of freedom, the motion of point C - with two translational degrees of freedom.

Degrees of freedom:

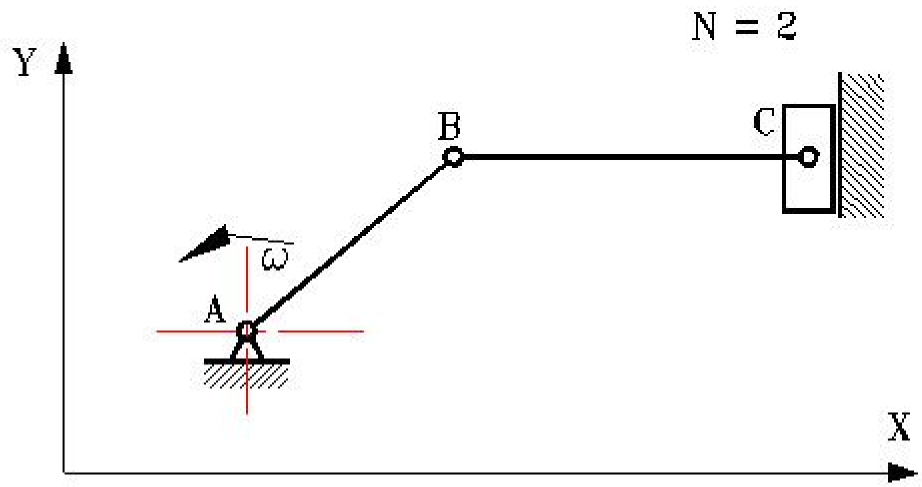
1	rotatory of crank (component AB) based on the side of point A;
2, 3-	progressive points B across the axes OX, OY;
4	rotatory of crank (component AB) based on the side of point B;
5, 6	progressive points [s] across the axes OX, OY.

Parameters:

N in sequence	Description	Dimensionality	Range
1,2	The origin coordinates of point A (Xa; Ya)	*m*	*-Rlmax… +RLmax*
3,4	The origin coordinates of point B (Xb; Yb)	*m*	*-Rlmax… +RLmax*
5,6	The origin coordinates of point C (Xc; Yc)	*m*	*-Rlmax… +RLmax*
7	The ordinal number of the coordinate axis, in parallel by which is moved point C: 1 across the x axis; it is 2nd across the y axis		*1* or *2*
8	Initial angular velocity of the crank	*rad/flogged*	*-Rlmax… +RLmax*

Special situations:

There are initial positions of crank mechanism, for which with the given speed of crank and on the basis of nondeformability condition it is sectional, it is not possible to determine the speed of slider. An example of this case is depicted beyond Fig. VNKS_2. This is possible only for the degenerate mechanisms (i.e., such, which they cannot without the deformation it is sectional accomplish the complete revolution of crank).



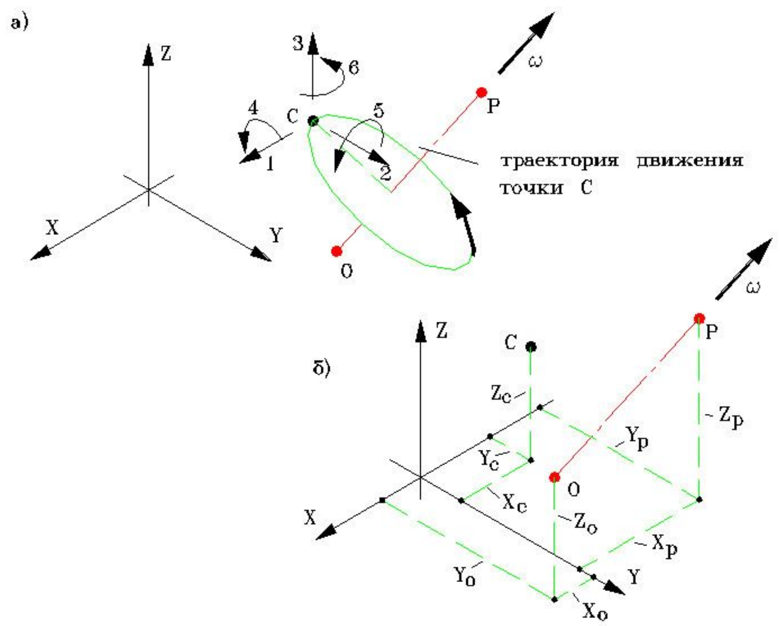
VNKS_2. One of the possible initial positions of the crank mechanism, before which the motion cannot be begun without the deformation it is sectional.

In the case of detecting this error the model of element VNKS gives the appropriate communication. The fulfillment of calculation ceases emergency. Before this situation the user must correct the initial position of crank mechanism so that it could begin the motion. If this is impossible, i.e., to you actually it is necessary to calculate this case, then for the task of the initial motion of mechanism it is necessary to use other models of elements.

1.3.Three-dimensional elements

1.3.1.Initial values of the speeds

1.3.1.1.Initial linear and angular velocities of point with its turning around the three-dimensional axis VWN3D



VWN3D_1. Degrees of freedom and the parameters of the model of element, which assigns the initial linear and angular velocities of the point C, which accomplishes rotary motion around the axis OP.

a) of degree of freedom:

1,2, 3- the translational degrees of freedom of point [s] before the reference direction of the X, Y and Z;

4, 5, 6 the rotational degrees of freedom of point based on the all around coordinate axes of the X, Y and Z;

b) the parameters of the model of element VWN3D:

Xc, Yc, Zc - the origin coordinates of point C;

Xo, Yo, Zo - the origin coordinates of point O;

Xp, Yp, Zp - the origin coordinates of point P;

ω - the initial angular velocity of point C around the axis OP.

Reflected properties:

Are assigned the matched initial velocities about the translational and rotational degrees of freedom for the point C, which accomplishes rotary motion around the three-dimensional axis OP.

Note. Here it is below, with the description of the working model of element are used the designations of points and degrees of freedom, explained of [ris].VWN3D_1:

- point C - point, the initial velocities, motions by which are assigned;
- point O, P - the points, which determine the attitude of the axis, around which occurs the rotation.

As the positive direction of rotational axis the direction from one point O to the next P starts.

Degrees of freedom

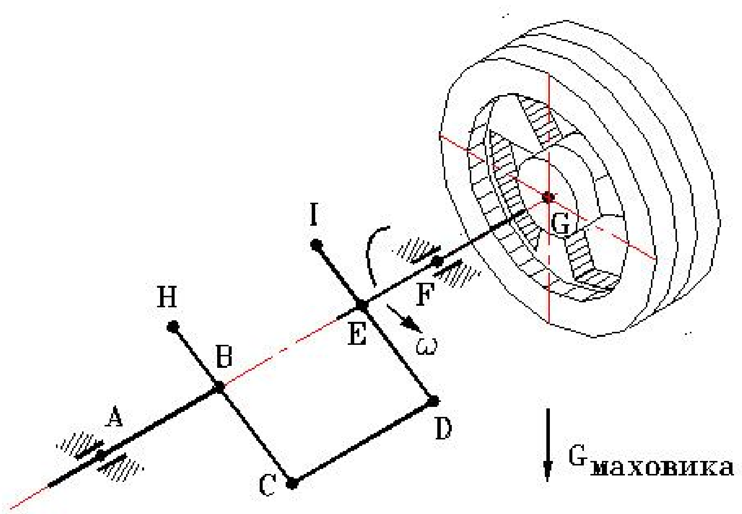
1,2, 3- the translational degrees of freedom of point C along the coordinate axes of the X, Y and Z;

4, 5, 6 the rotational degrees of freedom of point C around the coordinate axes of the X, Y and Z.

Parameters:

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point C (XC; YC; ZC)	*m*	*- Rlmax… +RLmax*
4,5,6	The origin coordinates of point O (XO; YO; ZO)	*m*	*- Rlmax… +RLmax*
7,8,9	The origin coordinates of point P (XP; YP; ZP)	*m*	*- Rlmax… +RLmax*
10	Initial angular velocity of point based on all around the axis [OR]	*rad/flogged*	*- Rlmax… +RLmax*

Example of the use:



VWN3D_2. The design diagram of the crankshaft, which revolves with the prescribed

initial velocity.

Is solved the problem of the analysis of the rotation of crankshaft with the prescribed angular velocity (Fig. VWN3D_2). The origin coordinates of points A… H:

```
Point X Y Z
A % 0 0
B 0.2 % 0
C 0.2    -0.05    -0.12
D 0.3    -0.05    -0.12
E 0.3 % 0
F 0.5 % 0
G 0.6 % 0
H 0.2 0.03 0.06
I 0.5 0.03 0.06
```

Shaft revolves with the angular velocity I rad/it flogged before the direction, indicated before Fig. VWN3D_2 as far as pointer. At point The shaft rests beyond the ball radial bearing, at point G bearing ball it is radial-persistent. Diameter of shaft under the bearing - 30 mm. at point F is located the flywheel, which has the moment of inertia relative to the rotational axis of the shaft of 0.3 [kg]*[m]2, relative to the transverse axis - 0.12 [kg]*[m]2 and mass 22 kg.

With practical accuracy it is possible to consider that the sections of crankshaft AB, CD, EG - the steel rods of the round cross section, whose mean diameter 32 mm, sections CH and DI - the steel rods of rectangular cross section. Height of rectangle before the direction, which coincides for the sake of the direction of the axis of the shaft - 0.03 m, before the direction, [perpendekulyarnom] of the axis of shaft for the sections BC and ED to accept the width of rod 0.1 m, for the sections BG and EH - 0.05 m. the force of gravity, which acts in the sections of rods AB and EG, to disregard, at points C and D to accept the amount of the force of gravity equal to 14 N, at points B and E - 21 N, at points G and H - 7 n.

Note. For the simulation of the pivotal sections of construction we will use three-dimensional girder elements, for the simulation of the supports - three-dimensional cylindrical joint, flywheel before the model will be point three-dimensional inertia element. The initial velocities of all elements of construction will be assigned with the aid of the element VWN3D. For the simulation of gravitational force, which acts beyond the flywheel, we will use an element of gravitational force, which acts beyond the mass (FG), for remaining gravitational forces - the model of element F. after the preparation of initial data for the model should be tested, is it possible to use for the simulation of pivotal sections an element "long girder", or in this case is required already the element, which considers the influence of tangential bending strain ("short girder").

1) the parameters, which characterize the rigidity of the sections of the crankshaft:

Section	Length	Area transverse section, [m]2	Geometric second moments of area, [m]4		
			down the bend relatively		on the twisting
			1[oy] of the principal axis	2[oy] of the principal axis	
AB	0.2	7.1e-4	3.9 e-8	3.9 e-8	7.8 e-8
BC	0.13	30.0e-4	250.0 e-8	22.5 e-8	72.6 e-8
CD	0.1	7.1e-4	3.9 e-8	3.9 e-8	7.8 e-8

Section	Lengt h	Area transverse section, [m]2	Geometric second moments of area, [m]4		
			down the bend relatively		on the twisting
			1[oy] of the principal axis	2[oy] of the principal axis	
DE	.13	0.0e-4	250.0 e-8	22.5 e-8	2.6 e-8
EF	.2	7.1e-4	3.9 e-8	3.9 e-8	7.8 e-8
FG	.1	7.1e-4	3.9 e-8	3.9 e-8	7.8 e-8
BH	.067	5.0e-4	31.2 e-8	11.2 e-8	8.0 e-8
EI	.067	5.0e-4	31.2 e-8	11.2 e-8	8.0 e-8

The first principal plane of inertia for the sections CH and DI is determined as far as vectors BC and AB (thus, 1-y principal moment of inertia down the bend for the sections of shaft BC, DE, BH and EI determines the flexural rigidity of these rods with the bend by the moments, which revolve around the axis AB). For all sections of shaft as the point, which determines the position of the first principal axis of inertia, it is possible to select point A.

The relationship is fulfilled for all sections of shaft:

$L > 1000 * J^{\text{OF [IZG].}}$

, where L the length;

$J^{\text{OF [IZG].}}$ - the moment of inertia down the bend.

Therefore for this task sufficiently using an element BAL3DJ (“long girder”).

Steel density we assume equal to 7800 [kg]/[m]3, moduli of elasticity - 2.e11 pA, Poisson ratio - 0.3.

2) the parameters, which characterize the rigidity of bearings.

For the supports we select the bearings of a especially light series. Before the support A - bearing N 106, before the support F - N 46106 [3].

<u>Reference data for these bearings are brought down the table:</u>

Suppo rt	Nominal static load capacity, *N*	Quantity of the balls	Diameter of ball, *m*	Angle of contact, *deg.*
A	5 040	11	7.1 e-3	0
F	8 030	18	7.1 e-3	26

The radial rigidity of radial and it is radial-ball thrust bearing we determine on the dependence [6]:

$$c = 7.6e6 * \sqrt[3]{W_O * Z^2 * cos^2 \phi * D_{III}}$$

, where *W[o]* - medium load beyond the bearing;

Z - the total number of rolling contacts;

D[SH] - the diameter of the ball;

$\tau\eta\varepsilon\ \phi$ - the angle of contact.

Axial rigidity it is radial-thrust bearing we will determine, correspondingly, on the dependence:

$$c = 7.6e6 * \sqrt[3]{W_O * Z^2 * sin^2\phi * D_{Ш}}$$

The models of the three-dimensional joints, utilized before the task in question, have linear rigid characteristics. Therefore stiffness coefficient for the first calculation can be accepted equal down the value, which corresponds to rigidity with nominal static load. Subsequently the rigidity of bearings can be refined.

Rigidity of bearing before the support A:

$$c = 7.6e6 * \sqrt[3]{5040 * 11^2 * 7.1e-3} = 1.24e8$$

Radial rigidity of bearing before the support F:

$$c = 7.6e6 * \sqrt[3]{8030 * 18^2 * 7.1e-3 * cos^2 26^O} = 1.94e8$$

Axial rigidity of bearing before the support F:

$$c = 7.6e6 * \sqrt[3]{8030 * 18^2 * 7.1e-3 * sin^2 26^O} = 1.53e8$$

3) the parameters of element VWN3D.

The initial angular velocity, given by element, I is glad/besides s. if we assign the positive value of angular velocity, then the direction of rotational axis should be assumed from F to A (respectively, if we assume the direction of rotational axis from A to F, then so that the shaft it would revolve before the direction, shown before Fig. VWN3D_2, the value of angular velocity should be assigned negative).

Text of the model of crankshaft before the input language PRADIS:

```
I DATA :

    Point A = 0, 0, 0
    Point B = 0.2, 0, 0
    Point C = 0.2,   -0.05,   -0.12
    Point D = 0.3,   -0.05,   -0.12
    Point E = 0.3, 0, 0
    Point F = 0.5, 0, 0
    Point G = 0.6, 0, 0
    Point H = 0.2, 0.03, 0.06
    Point of the I = 0.5, 0.03, 0.06

    Steel = of 2.e11, 0.3, 7800

    Section AB = of 3.9 e-8, 3.9 e-8, 7.8 e-8, 7.1e-4
    Section BC of =250.0 e-8, 22.5 e-8, 72.6 e-8, 30.0e-4
    Section CD = of 3.9 e-8, 3.9 e-8, 7.8 e-8, 7.1e-4
    Section DE of =250.0 e-8, 22.5 e-8, 72.6 e-8, 30.0e-4
    Section EF = of 3.9 e-8, 3.9 e-8, 7.8 e-8, 7.1e-4
    Section FG = of 3.9 e-8, 3.9 e-8, 7.8 e-8, 7.1e-4
    Section BH = of 31.2 e-8, 11.2 e-8, 28.0 e-8, 15.0e-4
    Section EI = of 31.2 e-8, 11.2 e-8, 28.0 e-8, 15.0e-4

    Rigidity of support A = 0, 1.24e8, 0, 0;
    Rigidity of the support F = of 1.53e8, 1.94e8, 0, 0;

    Initial angular velocity = 4;
    Rotational axis = point F, point A;
    Mass of flywheel = 22
    Moments of the inertia of flywheel = 0.12, 0.12, 0.3
    Parameters of image = 0.6, point B,
                                     -0.5, -0.5, 0.5,
```

```
                                   0.5, -0.5, 0, 0
I FRAGMENT :
   # BASE   :  100, 101, 102, 103, 104, 105
   # STRUCT :
                      {Crankshaft}
      Section AB 'BAL3DJ (1 2 Oe 4 5 6 7 8 9 10 11 12;
                      Point A, point B, point A, [Uchastok] AB, steel)
      Section BC 'BAL3DJ (7 8 9 10 11 12 13 14 15 16 17 18;
                      Point B, point C, point A, [Uchastok] BC, steel)
      Section CD 'BAL3DJ (13 14 15 16 17 18 19 20 21 22 23 24;
                      Point C, point D, point A, [Uchastok] CD, steel)
      Section DE 'BAL3DJ (19 20 21 22 23 24 25 26 27 28 29 30;
                      Point D, point E, point A, [Uchastok] DE, steel)
      Section EF 'BAL3DJ (25 26 27 28 29 30 31 32 33 34 35 36;
                      Point E, point F, point A, [Uchastok] EF, steel)
      Section FG 'BAL3DJ (31 32 33 34 35 36 37 38 39 40 41 42;
                      Point F, point G, point A, [Uchastok] FG, steel)
      Section BH 'BAL3DJ (7 8 9 10 11 12 43 44 45 46 47 48;
                      Point B, point H, point A, [Uchastok] BH, steel)
      Section EI 'BAL3DJ (25 26 27 28 29 30 49 50 51 52 53 54;
                      Point E, the point of the I, point A, [Uchastok] EI,
steel)
                      {Supports}
      Support A 'SH3CP (100 101 102 103 104 105 1 2 Oe 4 5 6;
                      Point A, point B, the rigidity of support A)
      Support F 'SH3CP (100 101 102 103 104 105 31 32 33 34 35 36;
                      Point E, point F, the rigidity of support F)
                      {Flywheel}
      Flywheel 'MJ3D (49 50 51 52 53 54;
                        Point of the I, point F, point F,
                        Mass of flywheel,
                        Moments of the inertia of flywheel)
                 {The elements, which assign the initial velocity}
      The initial velocity of point A 'VWN3D (1 2 Oe 4 5 6;
                                        Point A, rotational axis,
                                        Initial angular velocity)
      The initial velocity of point B 'VWN3D (7 8 9 10 11 12;
                                        Point B, rotational axis,
                                        Initial angular velocity)
      The initial velocity of point C 'VWN3D (13 14 15 16 17 18;
                                        Point C, rotational axis,
                                        Initial angular velocity)
      The initial velocity of point D 'VWN3D (19 20 21 22 23 24;
                                        Point D, rotational axis,
                                        Initial angular velocity)
      The initial velocity of point E 'VWN3D (25 26 27 28 29 30;
                                        Point E, rotational axis,
                                        Initial angular velocity)
      The initial velocity of point F 'VWN3D (31 32 33 34 35 36;
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                                    Point F, rotational axis,
                                    Initial angular velocity)

    The initial velocity of point G 'VWN3D (37 38 39 40 41 42;
                                    Point G, rotational axis,
                                    Initial angular velocity)

    The initial velocity of point H 'VWN3D (43 44 45 46 47 48;
                                    Point A, rotational axis,
                                    Initial angular velocity)

    The initial velocity of the point of the I 'VWN3D (49 50 51 52 53 54;
                                    Point of the I, rotational axis,
                                    Initial angular velocity)

  # OUTPUT :
    Radial reaction at point A'X (W: Support A (6); 1)
    Radial reaction at point F'X (W: Support F (6); 1)
    Axial reaction at point F'X (W: Support F (5); 1)

I SHOW :
  Image of crankshaft 'SHOW (; Parameters of image)
```

2. THE ACTION

2.1.General information about the sources of action and them the classification accepted

The elements, described before the present division, serve for the task of external action beyond the analyzed object. All these elements are the sources of effort (moment). The instantaneous value of the effort applicable to the object can be determined as far as the current time, prescribed as far as the characteristic of element and as far as other factors.

The models of the elements, which realize actions beyond the analyzed object, can be conditionally divided beside three groups.

The first group includes the elements, which realize the prescribed dependence of effort beyond the time *F (t)*. The value of the effort, generated by these elements, it does not depend on what-or other factors. At each moment of time the element generates **accurately** that value of effort, which is determined as far as dependence *F (t)*.

The second group includes the sources of kinematic actions. These elements generate force or moment, directed down to the maintenance of the prescribed by user law of variation in the displacement, speeds or accelerations. The instantaneous value of the generated by element effort depends on several factors. First, this is the prescribed by user law of variation in what-or by kinematic variable from the time. The value of effort in the second place, affects the current actual value controlled kinematic variable and the value of constant of proportionality between effort and deviation of the actual value of kinematic variable from the given one.

For example, if against current time the difference between the speeds before what-or to two degrees of freedom of element it must be $\Delta\varsigma$ *(t)*, the actual value of this quantity - $\Delta\varsigma\phi$, and the value of constant of proportionality - μ, then at the moment of time in question element will generate the effort:

$$F = \mu * (\Delta\varsigma\,(t) - \Delta\varsigma\phi)$$

directed in such a way as to destroy the difference between the actual and desired value of speed.

Thus, the elements, which realize kinematic actions, is supported reference input not accurately, but with what-that by approximation. The higher the value of constant of proportionality between the deviation of kinematic variable from the given value and the force, the **more precise** the element will perfect the prescribed dependence of displacement, speed or acceleration beyond the time.

All models of elements, which realize kinematic actions, are had the working vector, which consists, as a minimum, besides two elements. The ideal (accurately corresponding to the prescribed by user shape of pulse) value of displacement, speed or acceleration is the first element of working vector. By the second element of working vector is the difference between the instantaneous value of kinematic variable for the prescribed degree freedom, and the value, prescribed by user.

To **the third group** of the sources of action before this reference book are referred “the engines”, i.e., the sources of efforts (moments), whose instantaneous value of the generatable effort is determined as far as the mechanical characteristic (dependence of effort or moment beyond the speed) prescribed by user.

In the library of the models of the elements of complex PRADIS there are sources of the power and kinematic actions of several standard forms:

- THE SOURCES of a constant action (F, AC, VC0);

- THE SOURCES of the action of sinusoidal form (FSIN, ASIN, VSIN0, SSIN0, see [ris].2.1.);

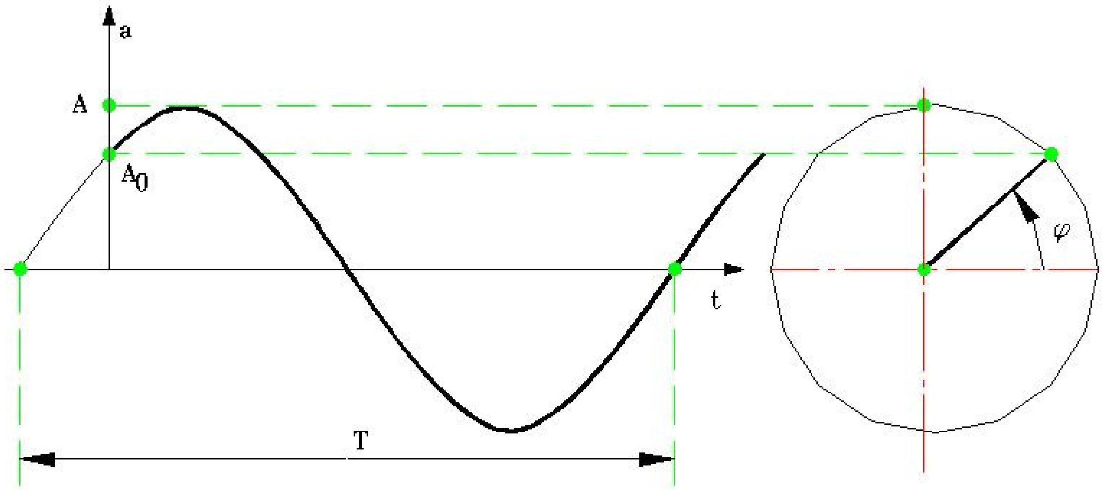


Fig 2.1. Parameters of the model of the element, which assigns the sinusoidal effect:
A - the amplitude of the action;
T - the period;
φ - initial phase.
NOTE. With the prescribed initial phase the level of initial action A0 is determined according to this figure.

- THE SOURCES of the pulse, whose form is assigned tabular depending on time (FTABL, ATABL, VTABL0, STABL0, see [ris].2.2.);

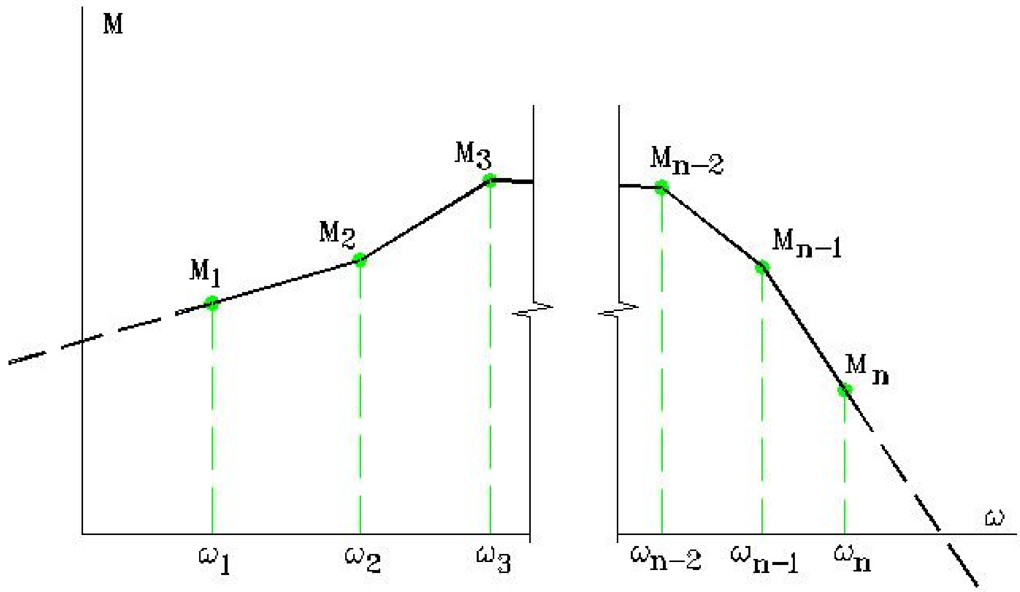


Fig 2.2. The parameters of the model of the element, which assigns the tabular dependence of external action beyond the time, each point of graph is determined as far as pair of numbers t - Ai.

- THE SOURCES of the pulse of trapeziform form (FTR, ATR, VTR0, STR0, see [ris].2.3.);
- THE SOURCES of the pulses of trapeziform form, which are repeated cyclically (FTRC, ATRC, VTRC0, STRC0, see [ris].2.3.).

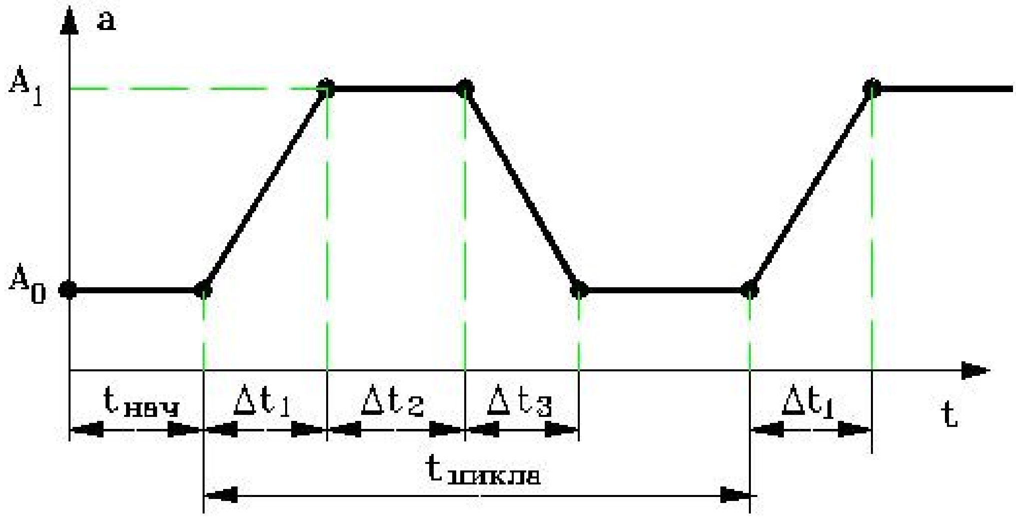


Fig 2.3. Parameters of the elements, which assign the trapezoidal pulse of the external action:
A0 - the initial level of the action;
A1 - action level for the pulse apex;
t[nach] - moment of the time of the beginning of an increase in the pulse;
Δt1 - the duration of leading impulse front;
Δt2 - the duration of the horizontal section;
Δt3 - the duration of trailing edge of pulse;
t[tsikla] - the duration of cycle (for FTRC, ATRC, VTRC, STRC)

The pulse of any arbitrary form can be obtained as far as the summing up of action based on several sources. The methods of summing up for the power and kinematic actions are distinguished.

Let us examine the example, before which it is necessary to obtain the pulse of the action in the form of the sum of three sinusoidal pulses. Power actions if are summarized, then the models of elements FSIN are joined by the appropriate branches down the necessary degree of freedom of object (i.e., it occurs the parallel connection of the sources of effort). The method of the summing up of power actions is illustrated [ris].2.4.

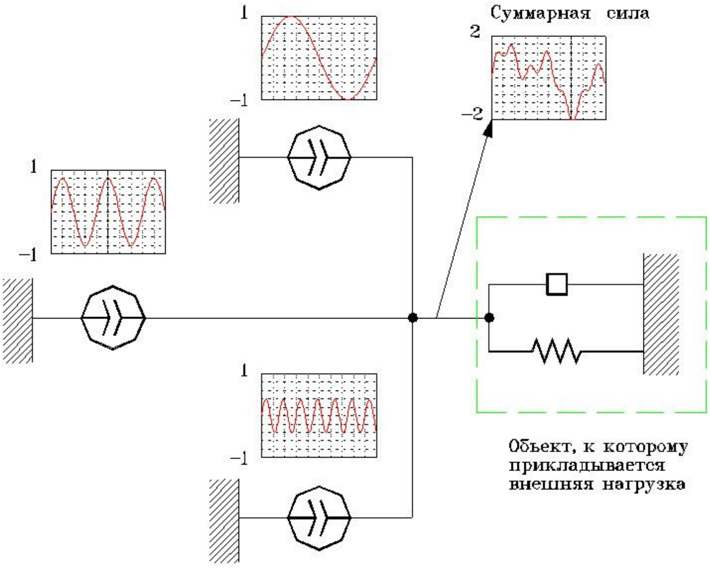


Fig 2.4. Summing up of power actions.

If at the point of user it is necessary to summarize the kinematic actions (for example, speed), then the model of the sources of action (in this case - VSIN0) are connected **consecutively**. This method of the summing up of external actions is represented before Fig. 2.5. In this case before the analyzed object can appear the degrees of freedom with the indeterminate inertial characteristics (this it will occur, if the combinable elements - the sources of speed or displacement). For the degrees of freedom with the indeterminate inertial characteristics possible the abrupt change in the speed what is the undesirable phenomenon. If before your calculated practice this case was encountered, try to determine the inertial characteristics of the newly emergent degrees of freedom. As a rule, the elements, which assign the laws of variation in the speeds or displacements before the real object, have masses and moments of inertia, which can be approximately distributed according to the degrees of freedom.

If we it is impossible assign inertial characteristics, it is necessary not to forget, that with the calculation of the objects, which have such degrees of freedom, usually is used the key parameter of the program of integration CONTROL.

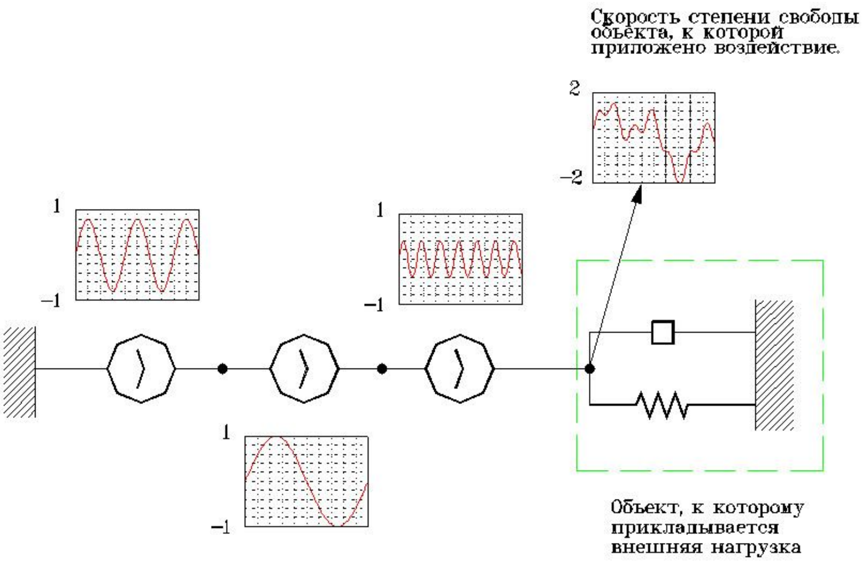


Fig 2.5. Summing up of kinematic actions.

For the sources of actions, which assign the specific shape of pulse depending on time, the task of the precise reproduction of the required shape of pulse is important. It is possible to isolate two sources of the distortions of the assigned shape of pulse.

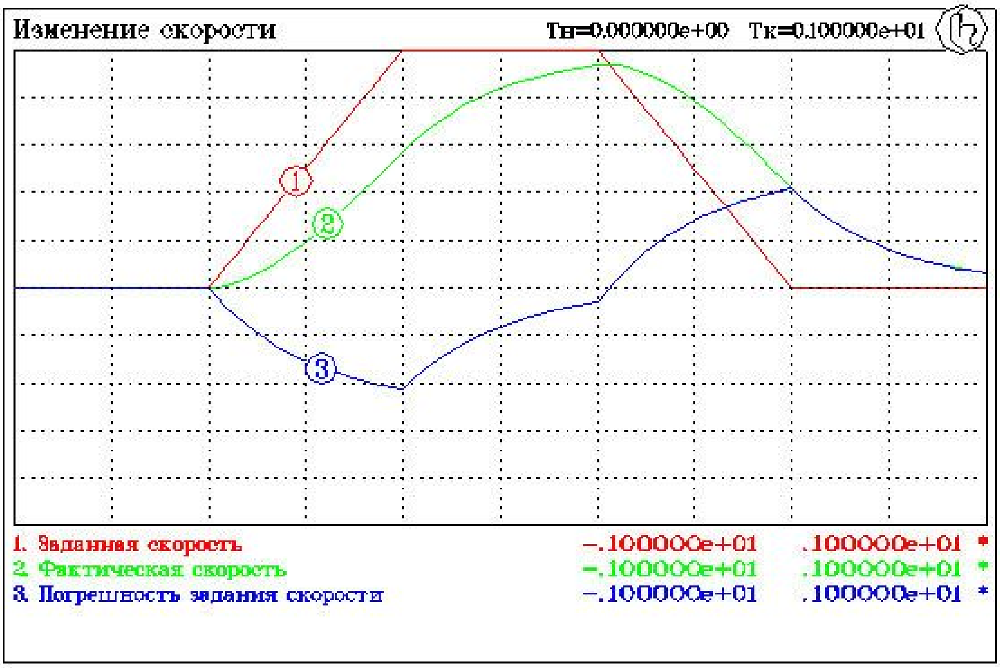
First, for the sources of kinematic actions the shape of the assigned pulse can be distorted because of the insufficient value of constant of proportionality between effort and deviation of the actual value of controlled variable from the given one.

As an example let us examine the model of the simple system, before which the speed of point inertia element is assigned in the form the pulse of trapeziform form. The instantaneous value of speed, the value of speed, prescribed by user and the difference between the current and given value of the speed are output variables:

```
I DATA:
   Mass = 1;
   Speed = 0, 1, 0.1, 0.1, 0.1;
   MU = 10
I FRAGMENT:
   # BASE: 1
   # STRUCT:
      Mass 'M (2 1; Mass)
      Source of speed 'VTR (2 1; Speed, MU)
   # OUTPUT:
      Actual [skorost]'V (2; 1)
      Given speed 'the X (W: Source of speed (1); 1)
      Error in the task by speed 'the X
                                (W: Source of speed (2); 1)
I RUN:
   Test calculation 'SHTERM (END=1)
I PRINT :
   Velocity change 'DISP (END=1;
   Actual speed = (-1, 1),
   Given speed = (-1, 1),
   Error in the task by speed = (-1, 1))
$ END
```

The results of calculation are given before Fig. of 2.6.[a]. evident that the shape of the pulse of speed obtained here noticeably differs from trapeziform. [Ris].2.6.[b]. illustrates the influence of constant of proportionality μ beyond the precision of the adjustment of the prescribed by user law of variation in the speed before the example in question.

а)



б)

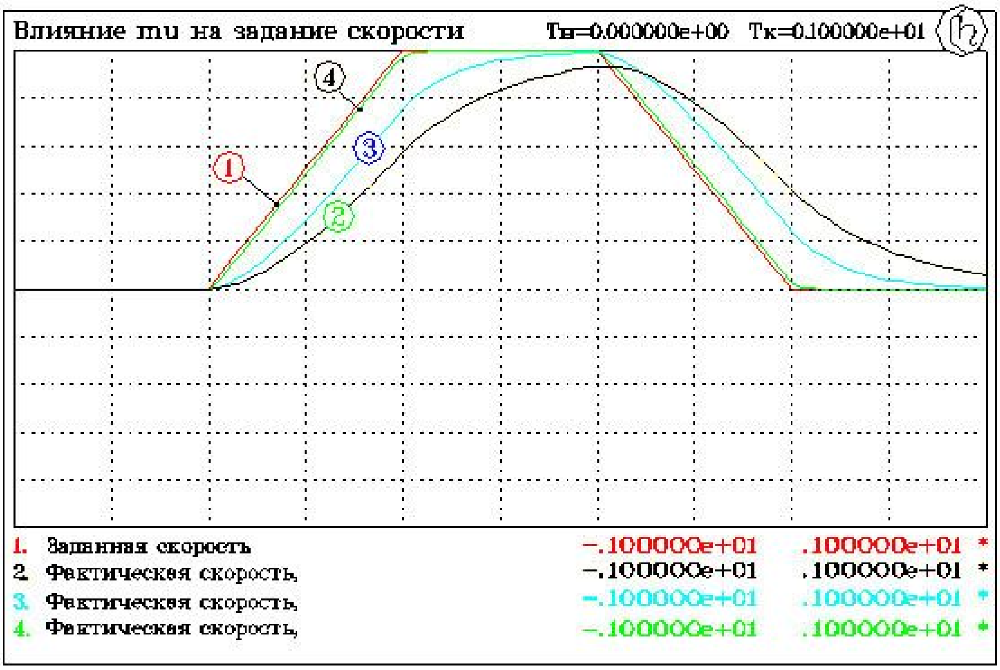


Fig 2.6. Task by speed of point inertia element with the aid of the source of the pulse of the speed of the trapeziform form:
a) the mass of the element - 1 kgf, μ - the source of the pulse - 10 [N]*[m]/[sek]
b) influence mu beyond the accuracy of reproduction of the shape of pulse (mass of the driven away element the same).

The high value of the step of the integration (see [ris].2.7.[a].) **in the second place,** can be one of the possible sources of the distortion of the shape of pulse. This figure depicts the case, when the selection of the step of integration is produced only from the considerations of local precision and in no way is considered the special feature of the model of element, which generates reference input of trapeziform form. Then adjacent moments of time, against which occurs the turning to the model of element, can be located in the adjacent sections of power characteristic, which leads down “cutting of angles”, distortion of the slope of a front of pulse and errors in the task of its length. But if the value of the step of integration will exceed the length of pulse, then working program can not at all “note” and rush by it.

Similar problem can arise, also, in the case, when input action has a form of sinusoid. Too great a value of the step of integration can lead down the fact that the source of action will not perfect the assigned magnitude of the amplitude of action and distort its form (Fig. of 2.7.[b]).

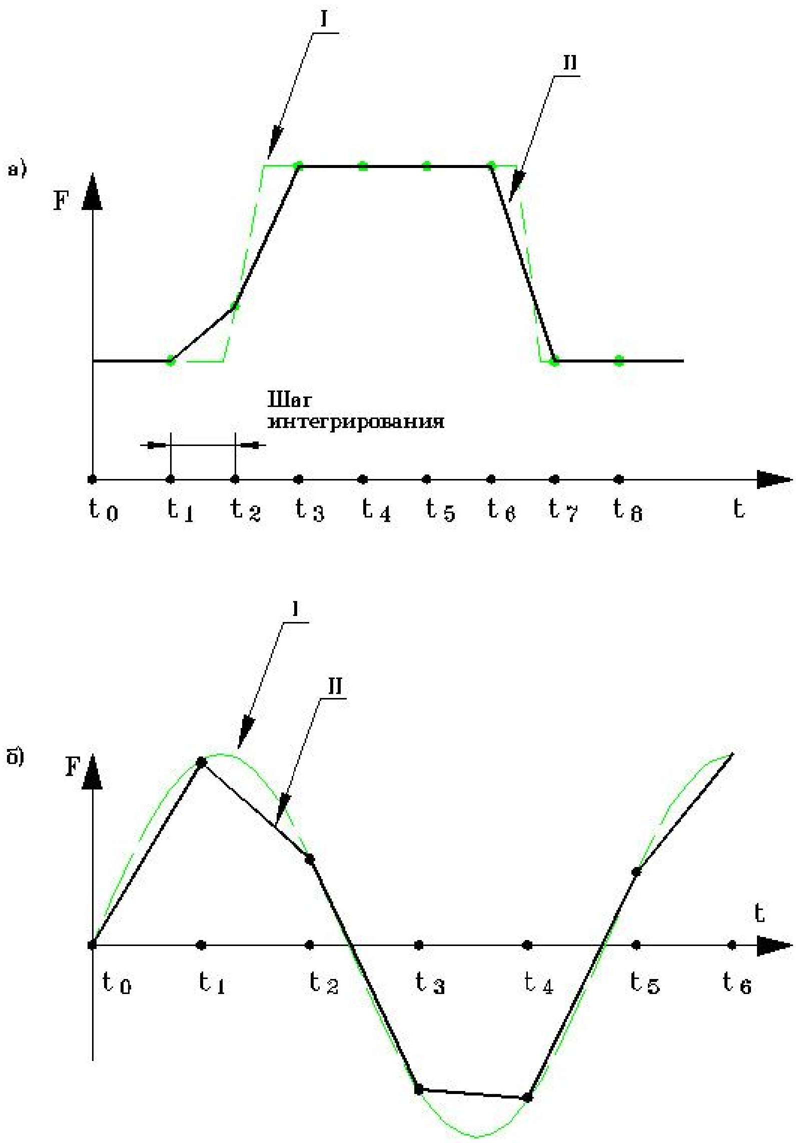


Fig 2.7. Possible distortion of the shape of pulse with the steep pitch of integration.
It is i-th the shape of pulse, prescribed by the user;
IT IS IIND the distorted shape of pulse.
a) the pulse of the trapeziform form;
b) sinusoidal pulse.

Therefore the models of the elements, which assign power and kinematic actions, recommend to working program the specific value of the step of integration. Models of the elements, which realize piecewise-linear actions depending on time, recommend this value of the step of integration in order accurately to fall beside the salient points of the prescribed dependence. For the sources of the action of sinusoidal form the step of integration recommended for the sake of element ensures turning to it, as a minimum, at the moments of time, for which the argument of sine is multiple π /8.

If calculation is conducted with the value of the key parameter of the program of integration IGNORE=1 given by user, then the recommendations of the models of elements up the selection of the sequential step of integration be considered will not be. In this case the user must be finished at the point of the possible distortions of the form of the actions, connected for the sake of the value of the step of integration.

And one additional moment, which is, before our opinion, important. It is necessary to have in mind that the generatable initial effort is applied by element to the object instantly at the initial moment of time. Therefore, even if initial action is assigned in the form the source of constant force, this will cause at the initial moment of time the impact process (it is considered that beside the time interval, which preceded zero time, beyond the object it acted no efforts). Such impacts can cause before the designed object different transient processes, including of fluctuation.

Even more serious consequences for the designed object can cause the impacts, determined as far as initial displacements or speeds according to one or other degree or another of the freedom of object. Therefore many elements, which assign kinematic actions, accomplish testing the coordination of initial conditions for the appropriate degree of freedom (the initial velocity, initial displacement) and initial values of the rate (displacement), given by element. Which of the elements accomplish this testing, it is said with the description of equivalent component.

If initial conditions for what-that the degrees of freedom of object do not correspond to the assigned law of variation in the speed or displacement, occurs the emergency interruption of calculation with the delivery of communication about an attempt at the repeated initialization of the initial value of potential variable.

Therefore, if the required law of variation in the displacement (speed) assumes the nontrivial initial value of displacement (speed), then together with the required source of kinematic action for the appropriate degree of freedom of object it is necessary to assign initial conditions with the aid of one of the models of elements SN, VN and so forth it is in certain cases difficult to calculate the precise initial value of speed or displacement, which it is required to transmit as the parameter of the model of element, which assigns initial conditions. For example, for the sinusoid with the initial phase of 60 degrees the initial value of action will be proportional $\sqrt{3/2}$, i.e., it is not expressed by terminating decimal fraction. Therefore all elements, which assign the laws of variation in the speeds or displacements, produce the comparisons of the assigned law for the sake of the initial conditions as follows:

- the difference between the initial value of the speed (displacement), determined as far as the prescribed law of its change, is calculated with the prescribed initial conditions;
- the obtained difference is multiplied as far as the constant of proportionality between the deviation of displacement (speed) and the generatable effort, which gives the value of the effort, generated by element at the initial moment of the time,;
- the initial value of effort is compared with the given value of the key parameter DABSI. If it exceeds the value of the key parameter, then it is considered that the assigned value of speed or displacement does not correspond to initial conditions.

2.2.1D ELEMENTS

2.2.1.Models of the power actions

2.2.1.1.Source of a constant effort (moment) according to one degree of freedom F

Reflected properties

Is assigned the constant value effort or moment, which affects according to one degree of the freedom of object.

Degrees of c[vobody]

1 progressive or rotatory, on which acts the assigned effort or moment.

Parameters

N in sequence	Description	Dimensionality	Range
1	Value of the effective effort or moment	*N* or *[N]*[m]*	*-Rlmax… +Rlmax*

2.2.1.2. Source of the mechanical force (moment), which is changed about the sinusoidal law FSIN

Reflected properties

Is assigned the power action beyond the object, which is changed about the sinusoidal law with the parameters prescribed by user. The initial value of effort is determined as far as the parameter “initial phase” (see Fig. 2.1.).

Degrees of freedom

1	progressive or rotatory, on which acts the assigned effort or the moment;
it is 2nd	the degree of freedom, beyond which the element “rests”; the effort of opposite sign will act according to this degree of the freedom of element.

Parameters

N in sequence	Description	Dimensionality	Range
1	Amplitude value of effort or moment	*N* or *[N]*[m]*	*- RLmax… +RLmax*
2	Period of a change in the power factor	*it flogged*	*Smin…. +Rlmax*
3	Initial phase	*deg*	*- RLmax… +Rlmax*

2.2.1.3.The source of mechanical force (moment), for which is assigned the tabular dependence of power factor beyond the time FTABL

Reflected properties

It assigns piecewise-the linear pulse of power action, determined as far as an arbitrary quantity of points (Fig. 2.2.). For describing each point two parameters are used: 1 moment of the time; it is 2nd the amount of force. Thus, for this element must be prescribed an even quantity of parameters. The assigned points must be regulated on the growth of time.

If the initial moment of time, prescribed before the table, exceeds the current model time, or the current model time left at the point of the time interval, at the point of elongation of which the table of efforts was defined, the current effort is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. 2.2. In connection with this **two first** and **two last** points of characteristic must not determine the different values of effort for one and the same moment of time. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of force beyond the time.

Degrees of freedom

1	progressive or rotatory, on which acts the assigned effort or the moment;
it is 2nd	the degree of freedom, beyond which the element "rests"; the effort of opposite sign will act according to this degree of the freedom of element.

Parameters

N in sequence	Description	Dimensionality	Range
1	*t1* - moment of time, which determines the first point of the dependence of effort beyond the time	*it flogged*	*0... +RLmax*
2	*F1* - force (moment) for moment of time *t1*	*N* or *[N]*[m]*	*- RLmax... +RLmax*
	…..		
2*i-1	*ti* - moment of time, which determines *i*-yu the point of the dependence of effort beyond the time	*it flogged*	t_{i-1} ... *+RLmax*
2*i	*Fi* - force (moment) for moment of time *ti*	*N* or *[N]*[m]*	*- RLmax... +RLmax*
	…..		

N in sequence	Description	Dimensionality	Range
2*n-1	*tn* - moment of time, which determines *n*-yu the point of the dependence of effort beyond the time	*it flogged*	tn_{-1} ... +*Rlmax*
2*n	*Fn* - c[ila] (moment) for moment of time *tn*	*N* or *[N]*[m]*	- *RLmax*... +*Rlmax*

2.2.1.4.Sources of the mechanical force (moment), which are changed about the trapeziform law FTR, FTRC

Reflected properties

Is assigned the pulse of power action beyond the object, which is changed about the trapeziform law (Fig. 2.3.). Element FTR adapts for the task of single, and FTRC - the cyclically repetitive action.

Degrees of freedom

1	progressive or rotatory, on which acts the assigned effort or the moment;
it is 2nd	the degree of freedom, beyond which the element “rests”; the effort of opposite sign will act according to this degree of the freedom of element.

Parameters

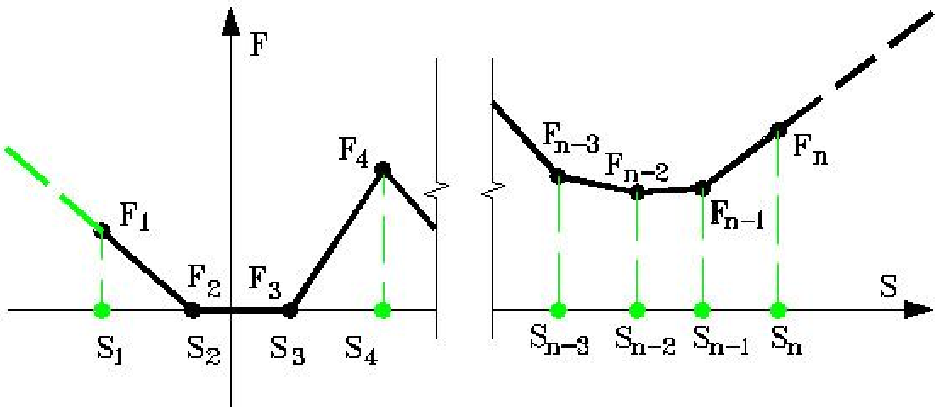
N in sequence	Description	Dimensionality	Range
1	Initial level of force (moment)	*N* or *[N]*[m]*	*- RLmax… +Rlmax*
2	Level of force (moment) for the pulse apex	*N* or *[N]*[m]*	*- RLmax… +RLmax*
3	Moment of the time of the beginning of an increase in the pulse	*it flogged*	*0… +Rlmax*
4	Duration of leading impulse front	*it flogged*	*0… +RLmax*
5	Duration of pulse apex	*it flogged*	*0… +Rlmax*
6	Duration of trailing edge of pulse	*it flogged*	*0… +Rlmax*
7 (only for FTRC)	Duration of the cycle	*it flogged*	*(PAR (4)+ PAR (5)+ PAR (6)+ (RLmin… RLmax)*

2.2.1.5.The source of mechanical force (moment), for which is assigned the tabular dependence of power factor beyond the displacement (angle of rotation) of the manager of degree of freedom FTABLS

Reflected properties

It assigns piecewise-the linear pulse of power action, depending on the displacement of the manager of degree of freedom (FTABLS_1). Pulse is determined as far as an arbitrary quantity of points. For describing each point two parameters are used: 1 extent of the movement of the manager of the degree of freedom, multiplied as far as the scaling coefficient; it is 2nd the corresponding to it amount of force. Points must be regulated on the growth of displacement.

Before the calculations Of pradis are used the values as far as dimensionality before the system OF SI. For convenience in the user before this model is realized the possibility of the task of the table of efforts depending on the displacement, expressed before another system of [edenits]. For this purpose before the list of the parameters of element the scaling coefficient is present. The scaling coefficient shifts the dimensionality OF PRADIS (*m* or *rad*) beside the user. FOR EXAMPLE, the table of efforts is prescribed depending on the angle of rotation of the manager of degree of freedom, expressed before the degrees. IN ORDER to get rid besides the conversion of the table of values, it is necessary to assign the value of the scaling coefficient, to the equal to 180π = 57.2957….



FTABLS_1. Graph of the tabular dependence of effort beyond the displacement for the model of element FTABLS. Each point of dependence is assigned by the pair of values "the displacement-effort".

Thus, for this element must be prescribed an odd quantity of the parameters - the scaling coefficient and an even quantity of parameters, which determine the dependence of effort beyond the displacement.

If the current displacement of the manager of degree of freedom exceeds the scope of the tabular dependence of effort beyond the displacement, then the current effort is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. FTABLS_1. In connection with this **two first** and **two last** points of the assigned table must not assign the different values of force for one and the same value of displacement. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of force beyond the displacement. Element recommends to the program of integration the decrease of the step of integration before the environment of the salient points of the prescribed dependence of effort beyond the displacement.

Degrees of freedom

1 progressive or rotatory, on which acts the assigned effort or the moment;

it is 2nd the degree of freedom, beyond which the element "rests" ; the effort of the opposite sign will act according to this degree of the freedom of element;

3- the controlling degree of freedom, depending on displacement (angle of rotation) by which is assigned effort.

Parameters

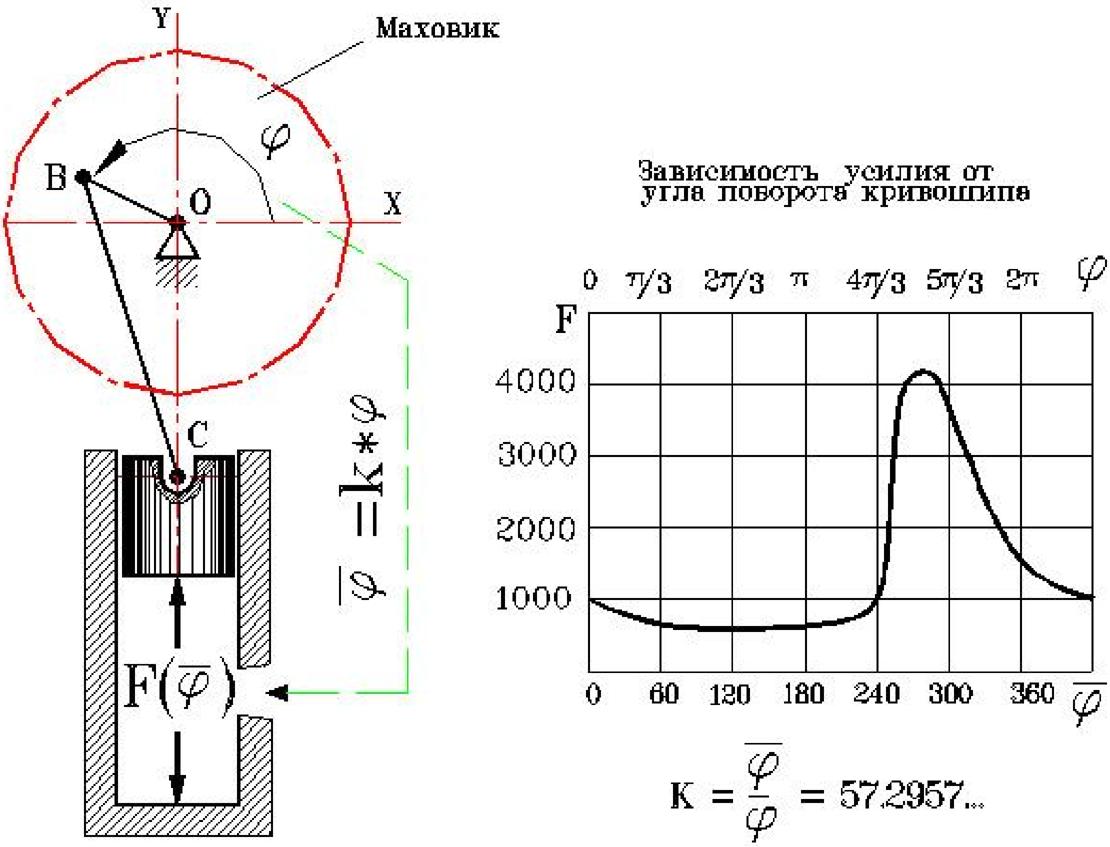
N in sequence	Description	Dimensionality	Range
1	Scaling coefficient for displacing the manager of degree of freedom		*- RLmax… +RLmax*
2	*S1* - the displacement, which determines the first point of the dependence of effort beyond the displacement	*m* or *[rad]**	*- RLmax… +RLmax*
3	*F1* - force (moment) for the displacement *S1*	*N* or *[N]*[m]*	*- RLmax… +Rlmax*
	…..		
2*i	*Si* - the displacement, which determines *i*-yu the point of the dependence of effort beyond the displacement	*m* or *[rad]**	Si_{-1} … *+RLmax*
2*i+1	*Fi* - force (moment) for the displacement *Si*	*N* or *[N]*[m]*	*- RLmax… +Rlmax*
	…..		
2*n	*Sn* - the displacement, which determines *n*-yu the point of the dependence of effort beyond the displacement	*m* or *[rad]**	Sn_{-1} … *+RLmax*
2*n+1	*Fn* - force (moment) for the displacement *Sn*	*N* or *[N]*[m]*	*- RLmax… +Rlmax*

*) the scaling coefficient is equal to 1, if the table of efforts is prescribed depending on the displacement, expressed before the system of units, accepted before the calculations PRADIS (before the system OF SI). In the case of using another system of units this value of the scaling coefficient is given, in order to transfer dimensionality PRADIS beside the user. Is given below the table of the values of the scaling coefficient before the dependence beyond the dimensionality of displacement, prescribed by user.

Table of the values of the scaling coefficient depending on the dimensionality of the displacement:

Dimensionality of displacement before the table of the efforts		Value of the scaling coefficient
Progressive	Angular	
m	*rad*	1
mm	-	1000
cm	-	100
-	*deg.*	180/p = 57.2957

<u>Example of use (SEE FIG. AS FAR AS FTABLS_2)</u>



FTABLS_2. **Use of an element FTABLS for the simulation of operating cycle before the internal combustion engine:**

$\overline{\varphi}$ - the angle of rotation, prescribed before the degrees;

φ - the angle of rotation, prescribed before the radians;
k - scale factor.

The dependence of the effort, which influences the piston of internal combustion engine, is prescribed depending on the angle of rotation of the crankshaft, expressed before the degrees. It is assumed that this table is obtained by the precomputation of working processes before the cylinder of engine and is recorded before the file FORSE.DAT in the following form:

```
 {angle of rotation    {effort}
 (deg)}
     2,                   25,
     3,                   25,
     8,                   100,
     9,                   140,
     10,                  150,
     12,                  147,
     18,                  127,
```

```
The origin coordinates:
crankshaft (point O)           -   0, 0
joint is the crank-connecting rod (point B)       -   0.02, - 0.1
joint is the connecting rod-piston (point C)      -   0,      - 0.5
```

Crank and connecting rod can be presented in the form the girder and pivotal elements, whose mass is evenly distributed along the length rod. Mass of the crank - 0.2 kgf, the mass of the connecting rod - 0.6 kg. the geometric moment of inertia down the bend of the cross section of the crank - 1.7e-6 [m]4, cross-sectional area 0.9e-4 [m]2. Cross-sectional area of the connecting rod - 0.7e-4 [m]2. Material of crank and connecting rod - steel.

Beyond the crankshaft is located the flywheel with the moment of the inertia of 0.933 [kg]*[m]2. The initial angular velocity of the flywheel (it corresponds to the initial velocities for all elements of mechanism) - 10 rad/s. Mass of the piston - 0.3 kg.

It is necessary to determine a change in the speed of rotation of flywheel about the time and to estimate the nonuniformity of its change.

Since the table of the dependence of effort beyond the angle of rotation is prescribed before the degrees, scale factor for the element FTABLS in this case will be 180/p = 57.2957… For the simulation of crank we will use a girder element, since the rotation down the flywheel is transferred as far as the angular coordinate. For the simulation of connecting rod it is sufficient pivotal element.

```
I DATA :
Cylinder = 57.2957,
I INCLUDE FORSE.DAT
Point O = 0, 0
Point B = 0.02, -0.10
Point C = 0.,   -0.5
Initial angular velocity = 10
X axis = 1
Axis Y = 2
```

```
    Material of crank = 0.2, 0.5, 1.7E-6,0.9E-4, 2.E11
    Material of connecting rod = 0.6, 0.5, 0.7E-4, 2.E11
    Mass of piston = 0.3
    J of flywheel = 0.933
    I FRAGMENT :
    # BASE: 1,2, 7
    # STRUCTURE:
    Flywheel 'M (3      ; J of flywheel)
    Crank 'BALKA (1 2 Oe 4 5 6; Point O, point B, the material of
crank)
    Connecting rod 'STRGN (4 5 7 8  ; Point B, point C, the material
of connecting rod)
    Piston 'M (8         ; Mass of piston)
    Cylinder 'FTABLS (8 1 Oe   ; Cylinder)
    {the determination of the initial angular velocity of crank}
    'VNKS (3 4 5 6 7 8; Point O, point B, point C, y axis, initial
angular velocity)
     OUTPUT:
    Angular velocity of shaft 'the V (3; 1)
    Shaft position deg 'the X (3; 57.295779579)
    Effort on the cylinder 'the X (the I: Cylinder 1; 1)
```

2.2.1.6.The source of mechanical force (moment), for which is assigned the tabular dependence of power factor beyond the rate (angular velocity) of the manager of degree of freedom FTABLV

Reflected properties

It assigns piecewise-the linear pulse of power action, depending on the rate of the manager of degree of freedom (FTABLV_1). Pulse is determined as far as an arbitrary quantity of points. For describing each point two parameters are used: 1 velocity of the manager of the degree of freedom, multiplied as far as the scaling coefficient; it is 2nd the corresponding to it amount of force. Points must be regulated on the growth of velocity.

Before the calculations Of pradis are used the values as far as dimensionality before the system OF SI. For convenience in the user before this model the possibility of the task of the table of efforts depending on the speed, expressed before another system of units, is realized. For this purpose before the list of the parameters of element the scaling coefficient is present. The scaling coefficient shifts the dimensionality OF PRADIS (*m/s* or *rad/it flogged*) beside the user. FOR EXAMPLE, the table of efforts is prescribed depending on the angular velocity of the manager of degree of freedom, expressed before [edenitsakh] [*deg/s*]. IN ORDER to get rid besides the conversion of the table of values, it is necessary to assign the value of the scaling coefficient, to the equal to 180π = 57.2957….

****

there is
no
figure

F *********
T *********
A ***
B
L
V
_
1
.

For the element must be prescribed an odd quantity of the parameters - the scaling coefficient and an even quantity of parameters, which determine the dependence of effort beyond the speed.

If the current rate of the manager of degree of freedom exceeds the scope of the tabular dependence of effort beyond the speed, then the current effort is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. FTABLV_1. In connection with this **two first** and **two last** points of the assigned table must not assign the different values of force for one and the same value of speed. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of force beyond the speed. Element recommends to the program of integration the decrease of the step of integration before the environment of the salient points of the prescribed dependence of effort beyond the speed.

Degrees of freedom

1 progressive or rotatory, on which acts the assigned effort or the moment;

it is 2nd the degree of freedom, beyond which the element "rests"; the effort of the opposite sign will act according to this degree of the freedom of element;

3- the controlling degree of freedom, depending on speed (angular velocity) by which is assigned effort.

Parameters

Number	Description	Dimensionality	Range
1	Scaling coefficient for the rate of the manager of degree of freedom		*- RLmax… +RLmax*
2	*V1* - the speed, which determines the first point of the dependence of effort beyond the speed	*m/s* or *rad/of [sek]**	*- RLmax… +RLmax*
3	*F1* - force (moment) for the speed *V1*	*N* or *[N]*[m]*	*- RLmax… +RLmax*
	…..		
2*i	*Vi* - the speed, which determines *i*-yu the point of the dependence of effort beyond the speed	*m/s* or *rad/flogged*	V_{i-1} … *+Rlmax*
2*i+1	*Fi* - force (moment) for the speed *Vi*	*N* or *[N]*[m]*	*- RLmax… +RLmax*
	…..		
2*n	*Vn* - the speed, which determines *n*-yu the point of the dependence of effort beyond the speed	*m/s* or *rad/flogged*	V_{n-1} … *+RLmax*
2*n+1	*Fn* - force (moment) for the speed *Vn*	*N* or *[N]*[m]*	*- RLmax… +Rlmax*

*) the scaling coefficient is equal to 1, if the table of efforts is prescribed depending on the speed, expressed before the system of units, accepted before the calculations PRADIS (before the system OF SI). In the case of using another system of units this value of the scaling coefficient is given, in order to transfer dimensionality PRADIS beside the user. Is given below the table of the values of the scaling coefficient before the dependence beyond the dimensionality of speed, prescribed by user.

Table of the values of the scaling coefficient depending on the dimensionality of the speed:

Dimensionality of the speed before the table of the efforts		Value of the scaling coefficient
Progressive	Angular	
m/s	*rad/flogged*	1
m/min	-	60
the km/h	-	3.6
-	*rad/min*	60
-	*rev./flogged*	1 (2p) = 0.1592
-	*rev./min*	30/p = 9.5493
-	*deg/s*	180/p = 57.2957
-	*deg/min*	10800/p = 3437.7

2.2.1.7.Source of the mechanical force (moment), which sinusoidally depends beyond the displacement (angle of rotation) FSINX

Reflected properties

Is assigned the pulse of power action, sinusoidally depending on displacement (angle of rotation). The amount of force is determined as far as the dependence:

$$F = Of\, fmax * \sin (X + XO)$$

, where *F* - the instantaneous value of the force;
Fmax - the amplitude value of the force;
X current displacement (angle of rotation);
XO - the initial value of displacement (angle of rotation).

Degrees of freedom

1 progressive (rotatory), on which acts the assigned power factor.

Parameters

Number	Description	Dimensionality	Range
1	Amplitude value of the power factor	*N* or *[N]*[m]*	*- RLmax… +Rlmax*
2	Initial displacement	*m* or *rad*	*- RLmax… +Rlmax*

2.2.1.8. Source of a constant effort, which simulates the action of the force of gravity FG

Reflected properties

Is assigned the constant value effort, which acts beyond the mass and the equal down the amount of gravitational force. The effort, generated by element, always acts before the negative reference direction.

Degrees of freedom

1 progressive, on which acts the assigned effort.

Parameters

Number	Description	Dimensionality	Range
1	The value of mass, beyond which acts gravitational force	*the kgf*	*0… +RLmax*

Example of the use

It is necessary to examine the motion of point inertia element of mass of 5[kg] under the action of gravitational force. Text of the description of object before the language *Of pradiSlang*:

```
I DATA:
  Mass = 5
I FRAGMENT :
        # BASE: 1
        # STRUCTURE:
              Body 'M (2; Mass)
              Gravitational force 'FG (2; Mass)
        # OUTPUT:
              Acceleration of body 'A (2; 1)
              Speed of body 'the V (2; 1)
              Displacement of body 'S (2; 1)
              Amount of gravitational force 'the X (the I:
        Gravitational force; 1)
….
```

2.2.2.Models of the elements, which assign the displacements of degrees of freedom

2.2.2.1.General information and recommendation up the assignment of the parameters

The models of the elements, which assign displacements, are as far as their nature elastic. This, actually, the bodies, moving about the prescribed law and which report to the degrees of freedom of object, with which they are connected, the corresponding displacements due to the elastic constraint. Therefore constant of proportionality between effort and deviation of displacement for these elements has a dimensionality of stiffness coefficient (*N/m* or *[N]*[m]/[rad]*).

It is piecewise for the ideal-of the linear dependence of displacement beyond the time of the acceleration curves it will be zero during entire process with exception of salient points (here acceleration are infinitely great). The graph of speeds is stepped with the constant velocity at the point of the elongation of each linear section and the instantaneous passage to another level of velocity in other linear section. When the model of the source of a difference in the displacements is used for accelerating the inert bodies, this serves after the source of the undesirable fluctuations, which distort the shape of pulse. An increase in the constant of proportionality between effort and deviation of displacement increases amplitude and frequency of the vibrations of the acceleration (let us note in this case that the precision of the adjustment of the prescribed law of variation in the displacement from the time grows because the amplitude of the fluctuations of displacements in this case it decreases).

With the assignment of the parameters of the model of element and key parameters of the program of integration in this case it is possible to be guided by the following considerations.

Fluctuations will appear before the points of rupture of the dependence of displacement beyond the time (at these moments of time sharply changes speed, that also serves after perturbation source). FOR EXAMPLE, for the trapeziform source STR0 velocity change upon transfer based on the gently sloping in the inclined section can be determined about the formula:

$$\Delta V = \frac{\Delta S}{\Delta t} \qquad (222.1)$$

, where ΔS - the difference between the prescribed initial displacement and the displacement, which corresponds to the gently sloping section of the pulse;

Δt - the time of front or trailing edge of pulse.

All reasonings will be analogous for the element STABL0. It is only necessary to consider that in this case disturbing velocity component - this is the difference between the speeds in two adjacent sections. For SSIN0 the value ΔV is designed as far as the formula:

$$\Delta V = 2\pi * \frac{A}{T} \cos\varphi_O \qquad (222.1.[a])$$

, where A - the amplitude of the assigned displacement;

φ_O - initial phase before the radians;

T - the period of sinusoid.

We are assigned by the value of the permissible absolute error in the adjustment of the law of variation in the displacement, let us say δ, before the meters or the radians, depending on that, translational or rotational degrees of freedom they are examined. Constant of proportionality K between the effort and the displacement can be tentatively determined about the dependence:

$$K = M * \left(\frac{\Delta V}{\delta}\right)^2 \qquad (222.2)$$

, where *it is m-th* the exemplary mass of the driven away body.

With an increase in the parameter *K* the duration of computations, as a rule, grows because of the forced need for tracking parasitic oscillations and splitting of the value of step down the value, which corresponds to the natural vibration frequency of spring pendulum with the mass *of M* and by rigidity *K*. taking into account the fact that these fluctuations are, as a rule, unessential from the point of view of the analyzed object, it is desirable "to crush them". For this we designate the parameter CONTROL of the program of integration, calculated about this tentative dependence:

$$\text{CONTROL} > \frac{T}{10} = \frac{\pi}{5} * \sqrt{\frac{M}{K}} \qquad (222.3)$$

, where *T* - the period of oscillations of spring pendulum with the mass *of M* and by rigidity *K*.

If the obtained value of the parameter CONTROL is too great for reasons of the accuracy of analysis of other transient processes before the system, then the parameter K should be designated, on the basis of dependence (222.3), after assigning the required value CONTROL. In this case the observance of the required precision of the adjustment of the law of displacements is guaranteed (since the requirements of precision on the dependence (222.2) satisfied the smaller values K).

With the value of constant of proportionality between effort and displacement of the order of 1e12 - 1e15 can arise problem with the convergence of the process of solving [SnLU]. With an increase in K they will be aggravated. It is in such cases necessary to increase the key parameter of the program of integration DABSI.

2.2.2.2.Source of the difference in the displacements, which is changed about the sinusoidal law SSIN0

Reflected properties

Is assigned the power action beyond the object, which supports displacement by means of one of the degrees of freedom relative to displacement by means of another, which is changed in the form of sinusoid (see Fig. 2.1.).

Degrees of freedom

1	progressive or rotatory, displacement by means of which is assigned;
it is 2nd	degree of freedom, relative to which is assigned the displacement by means of the first degree of freedom.

Parameters

Number	Description	Dimensionality	Range
1	Amplitude value of the difference of the displacements	*m* or *rad*	*- RLmax… +Rlmax*
2	Period of a change in the difference of the displacements	*it flogged*	*Smin… +Rlmax*
3	Initial phase	*deg.*	*- RLmax… +Rlmax*
4	Constant of proportionality between the deviation of a difference in the displacements from the given one and the effort, generated by the element	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE VALUE of the difference of displacements, which attempts to support the element	*m* or *rad*	
2	THE DIFFERENCE between the actual amount of the difference of displacements and	*m* or *rad*	

N in sequence	Description	Dimensionality	Range
	the value of the difference of displacements, which attempts to support the element		

Special situations

The model of element SSIN0 checks the correspondence of the prescribed initial level of a difference in the displacements, determined as far as the initial phase (on [ris].2.1), and an actual initial difference in the displacements between the degrees of freedom of element. If an actual initial difference in the displacements does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation is examined before the example given below.

Example of the use

Let us assume that user intends to assign the sinusoidal displacement of body with the mass of 5 kgf with the amplitude 1 or by the initial phase of 30 degrees. This means that the initial displacement according to this degree of freedom must compose half of amplitude. The precision of the adjustment of the law of displacement must be about 1 %.

After using the formula (312.1.[a]), let us find ΔV = 54.4 m/s based on the dependence (312.2): $K = 5 * (54.4/0.01)^2$ = of 1.48e8 [N/m]. The obtained value of stiffness coefficient determines the period of natural oscillations of system the body-the source of action of approximately 0.0015 Hz (CONTROL it is possible to assign 1e-4… 2e-4).

The correct text of the description of data and structure of object in this case can appear approximately thus:

```
I DATA :
        Amplitude of displacement = 1
   Period of oscillations = 0.1
   Initial phase = 30
   K = of 1.48e8
   Initial displacement = 0.5
   Mass of body = 5
I FRAGMENT :
   # BASE: 1
   # STRUCT:
      Source of action 'SSIN0 (2 1;
                                           Amplitude of displacements,
                                           Oscillatory period,
                                           Initial phase, K)
      Initial [peremeshchenie]'SN (2;
                                           Initial displacement)
      Body 'M (2;   Mass of body)
```

You will focus attention, that besides the source of a sinusoidal difference in the displacements is assigned the initial displacement according to the appropriate degree of the freedom of object. If the model of element SN was excluded based on the given description of structure, then the emergency interruption of the calculation will occur with prescribed initial data against the first step of integration: the initial displacement of the second degree of freedom they must be equal to 0.5, and the actual value of initial displacement will comprise in this case of 0.

On the basis of the assumptions, accepted with the calculation of rigidity, the key parameter of the program of integration CONTROL can be order 1.e-4. With the great significances CONTROL the certain possible increase in the expenditures for integration.

2.2.2.3.Source of a difference in the displacements, assigned tabular **STABL0**

Reflected properties

Is assigned the pulse of power action, which supports the difference of displacements between two degrees of freedom in accordance with the prescribed tabular dependence of displacement beyond the time. The shape of pulse it is piecewise-linear, is determined as far as an arbitrary quantity of points (Fig. 2.2). For describing each point two parameters are used: 1 moment of the time; it is 2nd the difference of displacements for this moment of time. One additional parameter assigns constant of proportionality between the deviation of relative displacement from the given one by user and as far as the effort, generated by element. Thus, for this element must be prescribed **an odd** quantity of parameters. The table of the dependence of displacement beyond the time must be regulated on the growth of time.

If the initial moment of time, prescribed before the table, exceeds the current model time, or the current model time left at the point of the time interval, at the point of elongation of which the table of displacements was defined, the instantaneous value of the assigned displacement is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. 2.2. In connection with this **two first** and **two last** points of table must be prescribed for distinguished moments of time. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of a difference in the displacements beyond the time.

Degrees of freedom

1 progressive or rotatory, displacement (angle of rotation) for which is assigned;

it is 2nd degree of freedom, relative to which is assigned the displacement by means of the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Constant of proportionality between the deviation of displacement and the effort, generated by the element	*N/m* or *[N]*[m]/[rad]*	*0... +RLmax*
2	*t1* - moment of time, which determines the first point of the dependence of a difference in the displacements beyond the time	*it flogged*	*0... +RLmax*
3	ΔS_1 required difference in the displacements at the moment of time *t1*	*m* or *rad*	*- RLmax... +RLmax*

.....

N in sequence	Description	Dimensionality	Range
2*i	*ti* - moment of time, which determines *i*-yu the point of the dependence of a difference in the displacements beyond the time	*it flogged*	ti_{-1} ... +*RLmax*
2*i+1	ΔS *it is i-th* the required difference in the displacements at the moment of time *ti*	*m* or *rad*	- *RLmax*... +*RLmax*
	…..		
2*n	*tn* - moment of time, which determines *n*-yu the point of the dependence of a difference in the displacements beyond the time	*it flogged*	tn_{-1} ... +*RLmax*
2*n+1	ΔS *it is n-th* the required difference in the displacements at the moment of time *tn*	*m* or *rad*	- *RLmax*... +*RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of the difference of displacements, which attempts to support the element	*m* or *rad*	
2	THE DIFFERENCE between the actual amount of the difference of displacements and the value of the difference of displacements, which attempts to support the element	*m* or *rad*	

Special situations

The model of element STABL0 checks the correspondence of the prescribed initial level of a difference in displacements and actual initial difference in the displacements between the degrees of freedom of element. Initial displacement can be defined as far as the extrapolation of the first of the prescribed sections of characteristic element as this shown down [ris].2.2. If an actual initial difference in the displacements does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation is examined before the example given below.

Example of the use

Let us assume that to user is required to assign the law of the displacement of body with the mass of 5 kgf, determined as far as the following table of the dependence of displacement beyond the time:

```
Moment  of  the Displacement
time
     1              0.5
     2              0.7
     3              0.1
```

The initial displacement of body, determined as far as this law, must comprise: 0.5 - (0.7 - 0.5)/(2-1) * (1 0) = 0.3. The correct text of the description of data and structure of object in this case can appear approximately thus:

```
I DATA :
   K = of 1.E3
   Table of a change in the displacement = 1, 0.5,
                                           2, 0.7,
                                           3, 0.1
   Initial displacement = 0.3
   Mass of body = 5
I FRAGMENT :
   # BASE: 1
   # STRUCT:
      Source of action 'STABL0 (2 1; K,
                              Table of displacement change)
      Initial [peremeshchenie]'SN (2; Initial displacement)
      Body 'M (2; Mass of body)
```

You will focus attention, that besides the source, which assigns the required law of variation in the displacements according to the second degree of freedom, is assigned also the initial displacement according to the appropriate degree of the freedom of object. If the model of element SN was excluded based on the given description of structure, then the emergency interruption of the calculation will occur with prescribed initial data against the first step of integration: the initial displacement of the second degree of freedom must be equal to 0.3, and the actual value of initial displacement will comprise in this case of 0.

2.2.2.4.Sources of the difference of displacements (angle of rotations), which is changed about the trapeziform law **STR0, STRC0**

Reflected properties

Is assigned the pulse of power action beyond the object, which supports the difference of displacements according to two degrees of freedom, that is changed about the trapeziform law (Fig. 2.3). Model STR0 adapts for the task of single, and STRC0 - the cyclically repetitive action.

Degrees of freedom

1	progressive or rotatory, displacement by means of which is assigned;
it is 2nd	degree of freedom, relative to which is assigned the displacement by means of the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Initial level of the difference of the displacements	*m* or *rad*	*- RLmax… +RLmax*
2	Level of the difference of displacements for the pulse apex	*m* or *rad*	*- RLmax… +RLmax*
3	Moment of the time of the beginning of an increase in the pulse	*it flogged*	*0… +Rlmax*
4	Duration of leading impulse front	*it flogged*	*0… +Rlmax*
5	Duration of pulse apex	*it flogged*	*0… +Rlmax*
6	Duration of trailing edge of pulse	*it flogged*	*0… +RLmax*
7 (only for STRC0)	Duration of the cycle	*it flogged*	*(PAR (4)+ PAR (5)+ PAR (6)) + (RLmin… Of rLmax)*
8	Constant of proportionality between the deviation of displacement and the effort, generated by the element	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE VALUE of the difference of displacements, which attempts to support the element	*m* or *rad*	
2	THE DIFFERENCE between the actual amount of the difference of displacements and the value of the difference of displacements, which attempts to support the element	*m* or *rad*	

Special situations

The models of elements STR0 and STRC0 check the correspondence of the prescribed initial level of a difference in displacements and actual initial difference in the displacements between the degrees of freedom of element. If an actual initial difference in the displacements does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation down the analogous situation, described before an example for the element STABL0.

2.2.3.Models of the elements, the given speed of degrees of freedom

2.2.3.1.General information and recommendation up the assignment of the parameters

The models of the elements, given speed, are as far as their nature viscous. This, actually, the bodies, which move with the given speed and which report to the degrees of freedom of object, with which they are connected, the corresponding speeds due to the viscous connection. Therefore constant of proportionality between effort and deviation of speed for these elements has a dimensionality of the coefficient of viscosity (*[N]*[sek]/[m]* or *[N]*[m]*[sek]/[rad]* - not to confuse with the kinematic and dynamic viscosities, which are been the characteristics of material).

The assignment of the value of constant of proportionality between the deviation of speed and the effort for these elements "is perceived" not as good as the assignment of stiffness coefficient for the elements, which assign displacement, or the mass for the elements, which assign accelerations. Therefore with the assignment of this coefficient it is possible to be oriented down to the following recommendations.

Let us examine the acceleration of massive body by the source of the constant velocity (this correctly for the gently sloping sections of elements VTR0, VTABL0 and so forth). Then in time $\delta\tau$ body acquires speed 95% of necessary, if constant of proportionality is approximately equal 3*M/dt, where *it is m-th* the mass of the body; 99% of speed at the point of the same time interval are collected with the constant of proportionality equal to (4.5… 5.0) of *M/dt.

If constant force resists motion, then so that there would be the possibility in principle to collect 95% of the given speed, it is necessary to designate the value of constant of proportionality more than 20*F/V0, where *V0* - given speed, *F* - opposing to motion force. For achievement 99% of speed this coefficient must be more than 100*F/V0.

2.2.3.2.Source of constant velocity according to one degree of freedom **VC0**

Reflected properties

Generates effort (moment), directed down to the maintenance for the prescribed degree of freedom of the object of the prescribed constant velocity.

Degrees of freedom

1 progressive or rotatory, the given value of speed on which is supported by element.

Parameters

N in sequence	Description	Dimensionality	Range
1	Velocity, assigned [elemetnom]	*m/s* or *rad/flogged*	*- RLmax… +RLmax*
2	Constant of proportionality between the deviation of speed and the effort, generated by the element	*[N]*[sek]/[m]* or *[N]*[m]*[s]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description of the parameter	Dimensionality	Range
1	The value of speed, which attempts to support the element	*m/s* or *rad/flogged*	
2	The difference between the actual velocity, and the value of speed, which attempts to support the element	*m/s* or *rad/flogged*	

Special situations

If the value of speed generated by element does not correspond to initial conditions, occurs the emergency interruption of calculation with the delivery of the corresponding communication about the contradictory installation of speeds. This situation and method of its elimination are analogous described before an example for the model of element VSIN0.

2.2.3.3.Source of the difference in the speeds, which is changed about the sinusoidal law VSIN0

Reflected properties

The power action beyond the object, which supports speed on one of the degrees of freedom relative to speed on another, that is changed in the form of the sinusoid (see [ris].2.1.) is assigned.

Degrees of freedom

1	progressive or rotatory, the speed, on which it is assigned;
it is 2nd	degree of freedom, relative to which is assigned the speed about the first degree of freedom.

Parameters

Number	Description	Dimensionality	Range
1	Amplitude value of the difference of the speeds	*m/s* or *rad/flogged*	*- RLmax… +Rlmax*
2	Period of a change in the difference of the speeds	*it flogged*	*Smin… +Rlmax*
3	Initial phase	*deg.*	*- RLmax… +Rlmax*
4	Constant of proportionality between the deviation of a difference in the speeds from the given one and the effort, generated by the element	*[N]*[sek]/[m]* or *[N]*[m]*[s]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description of the parameter	Dimensionality	Range
1	The value of speed, which attempts to support the element	*m/s* or *rad/flogged*	

N in sequen ce	Description of the parameter	Dimensionalit y	Range
2	The difference between the actual velocity, and the value of speed, which attempts to support the element	*m/s* or *rad/flogged*	

Special situations

The model of element VSIN0 checks the correspondence of the prescribed initial level of a difference in the speeds, determined as far as the initial phase (on Fig. 2.1.), and an actual initial difference in the speeds between the degrees of freedom of element. If an actual initial difference in the speeds does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation is examined before the example given below.

Example of the use

Let us assume that user intends to assign a change in the speed of body with the mass of 5 kgf with the amplitude 1 or by the initial phase of 30 degrees. This means that the initial velocity according to this degree of freedom must compose half of amplitude. The correct text of the description of data and structure of object in this case can appear approximately thus:

```
I DATA :
    Amplitude of speed = 1;
    Period of oscillations = 0.1
    Initial phase = 30; K = of 1.E3
    The initial velocity = 0.5
    Mass of body = 5
I FRAGMENT :
    # BASE: 1
    # STRUCT:
        Source of action 'VSIN0 (2 1; Amplitude of speed,
                          Oscillatory period,
                          Initial phase, K)
        Initial [peremeshchenie]'VN (2;   The initial velocity)
        Body 'M (2;  Mass of body)
```

You will focus attention, that besides the source of a sinusoidal difference in the speeds is assigned the initial velocity according to the appropriate degree of the freedom of object. If the model of element VN was excluded based on the given description of structure, then the emergency interruption of the calculation will occur with prescribed initial data against the first step of integration: the initial velocity according to the second degree of freedom must be equal to 0.5, and the actual value of the initial velocity will comprise in this case of 0.

2.2.3.4.Source of a difference in the speeds, assigned tabular VTABL0

Reflected properties

Are assigned the pulse of power action, the supporting difference of speeds between two degrees of freedom in accordance with the prescribed tabular dependence. The shape of pulse it is piecewise-linear, is determined as far as an arbitrary quantity of points (Fig. 2.2.). For describing each point two parameters are used: 1 moment of the time; it is 2nd the difference of speeds for this moment of time. One additional parameter assigns constant of proportionality between the deviation of speed and the effort, generated by element. Thus, for this element must be prescribed an odd quantity of parameters. The table of the dependence of speed beyond the time must be regulated on the growth of time.

If the initial moment of time, prescribed before the table, exceeds the current model time, or the current model time left at the point of the time interval, at the point of elongation of which the table of speeds was defined, the instantaneous value of the assigned speed is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. 2.2. In connection with this **two first** and **two last** points of characteristic must not have the identical value of time. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of a difference in the speeds beyond the time.

Degrees of freedom

1	progressive or rotatory, speed on which is assigned by the element;
it is 2nd	degree of freedom, relative to which is assigned the speed about the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Constant of proportionality between the deviation of speed and the effort, generated by the element	*N * of [sek]/[m]* or *[N]*[m]*[s]/[rad]*	*0… +RLmax*
2	*t1* - moment of time, which determines the first point of the dependence of a difference in the speeds beyond the time	*it flogged*	*0… RLmax*
3	$\Delta\varsigma_1$ - the required difference in the speeds at the moment of time *t1*	*m/s* or *rad/flogged*	*- Rlmax… +Rlmin*

…..

N in sequence	Description	Dimensionality	Range
2*i	*ti* - moment of time, which determines *i*-yu the point of the dependence of the difference of speeds beyond the time	*it flogged*	ti_{-1} ... +*RLmax*
2*i+1	Δςι - the required difference in the speeds at the moment of time *ti*	*m/s* or *rad/flogged*	- *Rlmax*... +*RLmax*
	…..		
2*n	*tn* - moment of time, which determines *n*-yu the point of the dependence of the difference of speeds beyond the time	*it flogged*	tn_{-1}... +*RLmax*
2*n+1	Δςν - the required difference in the speeds at the moment of time *tn*	*m/s* or *rad/flogged*	- *Rlmax*... +*RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of speed, which attempts to support the element	*m/s* or *rad/flogged*	
2	The difference between the actual amount of the difference of speeds and the value of the difference of speeds, which attempts to support the element	*m/s* or *rad/flogged*	

Special situations

The model of element VTABL0 checks the correspondence of the prescribed initial level of a difference in the speeds, determined as far as the initial phase (on Fig. 2.1.), and an actual initial difference in the speeds between the degrees of freedom of element. If an actual initial difference in the speeds does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation and method of its elimination are analogous described before an example for the element VSIN0.

2.2.3.5.Sources of the difference in the speeds, which is changed about the trapeziform law VTR0, VTRC0

Reflected properties

Is assigned the pulse of power action beyond the object, which supports the difference of speeds between two degrees of freedom of object changing about the trapeziform law. (Fig. 2.3). Model VTR0 adapts for the task of single, and VTRC0 - the cyclically repetitive action.

Degrees of freedom

1 progressive or rotatory, speed of which is assigned;

it is 2nd degree of freedom, relative to which is assigned the speed about the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Initial level of the difference of the speeds	*m/s* or *rad/flogged*	*- RLmax… +RLmax*
2	Level of the difference of [sokrostey] for the pulse apex	*m/s* or *rad/flogged*	*- RLmax… +RLmax*
3	Moment of the time of the beginning of an increase in the pulse	*it flogged*	*0… +Rlmax*
4	Duration of leading impulse front	*it flogged*	*0… +Rlmax*
5	Duration of pulse apex	*it flogged*	*0… +Rlmax*
6	Duration of trailing edge of pulse	*it flogged*	*0… +RLmax*
7 (only for VTRC0)	Duration of the cycle	*it flogged*	*(PAR (4)+ PAR (5)+ PAR (6)) + (RLmin… Of rLmax)*
8	Constant of proportionality between the deviation of speed and the effort, generated by the element	*[N]*[sek]/[m]* or *[N]*[m]*[s]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of speed, which attempts to support the element	*m/s* or *rad/flogged*	
2	The difference between the actual amount of [raznitsi] of speeds and the value of the difference of speeds, which attempts to support the element	*m/s* or *rad/flogged*	

Special situations

The models of elements VTR0 and VTRC0 check the correspondence of the prescribed initial level of a difference in speeds and actual initial difference in the speeds between the degrees of freedom of element. If an actual initial difference in the speeds does not correspond to the given one, occurs the emergency termination of calculation with the delivery of the corresponding communication about the error. This situation and method of its elimination are analogous described before an example for the element VSIN0.

2.2.4.Models of the elements, which assign the accelerations of degrees of freedom

2.2.4.1.General information

The models of the elements, which assign accelerations, are inertia. This, actually, the bodies, which move with the prescribed acceleration and which report to the degrees of freedom of object, with which they are connected, the corresponding accelerations due to the inertial coupling. Therefore constant of proportionality between effort and deviation of speed for these elements has a dimensionality of mass or moment of inertia (*kgf* or $kg*m^{2)}$. The greater the mass of connection, the more precise the element will reproduce the prescribed law of variation in the acceleration.

2.2.4.2.Source of uniform acceleration according to one degree of freedom AC

Reflected properties

Generates effort (moment), directed down to the maintenance for the prescribed degree of freedom of the object of the prescribed uniform acceleration.

Degrees of freedom

1 progressive or rotatory, the given value of acceleration on which is supported by element.

Parameters

N in sequence	Description	Dimensionality	Range
1	Value of acceleration, given by the element	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +RLmax*
2	Constant of proportionality between the deviation of acceleration and the effort, generated by the element	*kgf* or *[kg]*[m]2*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE VALUE of acceleration, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +RLmax*
2	THE DIFFERENCE between the actual amount of acceleration, and the value of acceleration, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	*0… +RLmax*

2.2.4.3.Source of the difference in the accelerations, which is changed about the sinusoidal law ASIN

Reflected properties

(see Fig. 2.1) assign the power action beyond the object, which supports acceleration on one of the degrees of freedom relative to acceleration on another, that is changed in the form of sinusoid.

Degrees of freedom

1 progressive or rotatory, acceleration on which is assigned;

it is 2nd degree of freedom, relative to which is assigned the acceleration about the first degree of the freedom

Note. If the second degree of freedom is fixed, then absolute acceleration about the first degree of freedom will be assigned by element.

Parameters

N in sequence	Description	Dimensionality	Range
1	Amplitude value of the difference of the accelerations	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +RLmax*
2	Period of a change in the difference of the accelerations	*it flogged*	*Smin… +Rlmax*
3	Initial phase	*deg.*	*- Rlmax… +Rlmax*
4	Constant of proportionality between the deviation of acceleration and the effort, generated by the element		

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of the difference of accelerations, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	

N in sequen ce	Description	Dimensionalit y	Range
2	The difference between the actual amount of the difference of accelerations, and the value of acceleration, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	

2.2.4.4.Source of a difference in the accelerations, assigned tabular **ATABL**

Reflected properties

Are assigned the pulse of power action, the supporting difference of accelerations between two degrees of freedom in accordance with the prescribed tabular dependence. The shape of pulse it is piecewise-linear, is determined as far as an arbitrary quantity of points (Fig. 2.2). For describing each point two parameters are used: 1 moment of the time; it is 2nd the difference of accelerations for this moment of time. One additional parameter assigns constant of proportionality between the deviation of acceleration and the effort, generated by element. Thus, for this element must be prescribed an odd quantity of parameters. The table, which assigns the dependence of acceleration beyond the time, must be regulated on the time.

If the initial moment of time, prescribed before the table, exceeds the current model time, or the current model time left at the point of the time interval, at the point of elongation of which the table of accelerations was defined, the instantaneous value of the assigned acceleration is defined as far as the extrapolation of extreme sections as this shown by broken line before Fig. 2.2. In connection with this **two first** and **two last** points of characteristic must not have the identical value of time. For the element must be prescribed not less than 2[kh] of the points of the tabular dependence of a difference in the accelerations beyond the time.

Degrees of freedom

1	progressive or rotatory, acceleration on which is assigned by the element;
it is 2nd	degree of freedom, relative to which it is assigned accelerations about the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Constant of proportionality between the deviation of acceleration and the effort, generated by the element	*kgf* or *[kg]*[m]2*	*0… +RLmax*
2	*t1* - moment of time, which determines the first point of the dependence of a difference in the accelerations beyond the time	*it flogged*	*0… +RLmax*
3	ΔA_1 - the required difference in the speeds at the moment of time *t1*	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +Rlmin*
	…..		
2*i	*ti* - moment of time, which determines *i*-yu	*it flogged*	t_{i-1} …

N in sequence	Description	Dimensionality	Range
	the point of the dependence of the difference of accelerations beyond the time		*+RLmax*
2*i+1	ΔAι - the required difference in the accelerations at the moment of time *ti*	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +RLmax*
	…..		
2*n	*tn* - moment of time, which determines *n*-yu the point of the dependence of the difference of accelerations beyond the time	*it flogged*	tn_{-1}… *+RLmax*
2*n+1	ΔAν - the required difference in the accelerations at the moment of time *tn*	*[m]/[sek]2* or *rad/of [sek]2*	*- Rlmax… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of the difference of accelerations, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	
2	THE DIFFERENCE between the actual amount of the difference of accelerations, and the value of acceleration, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	

2.2.4.5.Sources of the difference in the accelerations, which is changed about the trapeziform law ATR, ATRC

Reflected properties

Is assigned the pulse of power action beyond the object, which is changed about the trapeziform law (Fig. 2.3). Model ATR adapts for the task of single, and ATRC - the cyclically repetitive action.

Degrees of freedom

1	progressive or rotatory, acceleration of which is assigned;
it is 2nd	degree of freedom, relative to which is assigned the acceleration about the first degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Initial level of the difference of the accelerations	*[m]/[sek]2* or *rad/of [sek]2*	*- RLmax… +RLmax*
2	Level of the difference of accelerations for the pulse apex	*[m]/[sek]2* or *rad/of [sek]2*	*- RLmax… +RLmax*
3	Moment of the time of the beginning of an increase in the pulse	*it flogged*	*0… +Rlmax*
4	Duration of leading impulse front	*it flogged*	*0… +Rlmax*
5	Duration of pulse apex	*it flogged*	*0… +Rlmax*
6	Duration of trailing edge of pulse	*it flogged*	*0… +RLmax*
7 (only for ATRC)	Duration of the cycle	*it flogged*	*(PAR (4)+ PAR (5)+ PAR (6)) + (RLmin… Of rLmax)*
8	Constant of proportionality between the deviation of acceleration and the effort, generated by the element	*kgf* or *[kg]*[m]2*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The value of speed, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	
2	The difference between the actual amount of the difference of accelerations and the value of acceleration, which attempts to support the element	*[m]/[sek]2* or *rad/of [sek]2*	

2.2.5.Engines

2.2.5.1.General information

In the base library PRADIS are several models of elements, which make it possible to reproduce the prescribed dependence of the moving effort beyond the speed (motoring torque from the angular velocity). These elements are conditionally related to engines.

Elements DVLT and DVLU reproduce the mechanical characteristic of the engine in the form of inclined straight line before the coordinates $M = f\ (\omega)$. Element DVLT is controlled on the time, for the element DVLU is provide ford controlling degree of freedom. Can be used for the simulation the work of direct-current motors with the parallel excitation, and also for the simplified simulation of the work of asynchronous and synchronous motors in the working sections of mechanical characteristic.

With the aid of the element DVTBLU it is possible to simulate the mechanical characteristic of more intricate shape, which consists besides several straight portions. It is also supplied by the manager degree of freedom. An element can be used for the reproduction of the mechanical characteristic of direct-current motors with the series excitation, the internal combustion engines and the like

The specialized element DVAU is intended for the reproduction of the natural mechanical characteristic of induction motor.

For all engines as the initial data the moments of the inertia of moving elements must be assigned (rotor and the structural elements, connected for the sake of the rotor, for example, pulley). Furthermore, is provide ford the possibility of the task of the moment of the inertia of engine block (for those cases, when it is required the calculation of reactionary torque, fluctuations of engine block and its supports and so forth). If engine block is received after fixed, its moment of inertia can be assumed zero. The presence in models of elements DVLT, DVLU, DVAU and DVTBLU of the moments of the inertia of moving elements makes important the difference between the motoring torque and the moment on the output shaft of engine. By motoring torque is understood the moment, created inside the engine and which leads down the rotation of output shaft and moving elements connected for the sake of it. Since the part of the energy, which depends beyond the angular acceleration of the shaft of engine, is spent beyond the acceleration of rotor, moment on the output shaft of engine will be equal down motoring torque minus the part of the moment, which is spent beyond the acceleration of rotor. In the particular case, when idle engine pickup is examined, moment on the output shaft will be equal to 0.

```
I FRAGMENT :
   # BASE: 1
   # STRUCT:
      Engine 'DVLT (2 1;          Parameters of engine,
                                   Moment of the inertia of rotor, 0)
   # OUTPUT:
       Moment on the output shaft 'the X (the I: Engine (1); 1)
```

2.2.5.2.Model of the engine with the linear mechanical characteristic, which is included in the prescribed interval of time DVLT

Reflected properties

At the moment of the connection of engine down the system based on the side of engine begins to influence the moment, determined as far as the prescribed mechanical characteristic of engine ([ris].DVLU_1.[a].). If at the moment of launching the shaft of engine has not zero speed, then at this moment on system will begin to act not starting torque, but moment, determined as far as the current angular velocity. Its active effect on system ceases at the moment of [vyklyu]2[cheniya] of engine. The moments of the inertia of housing and shaft of engine are considered before element regardless of the fact, in what state (switch oned or switched off) the engine is.

Based on four shown before Fig. Of dVLU_1.[a]. characteristics two cannot be obtained for the actual engine, since they determine the unlimited increase in the revolutions of shaft. With a small change in the speed for the engine with this characteristic the moment on the shaft of engine grows before the same direction, which leads down a larger change in the angular velocity. Therefore for this model of element such characteristics, which are determined as far as starting torque and angular idling speed of different signs, are forbidden. The model of element DVLT can be used for the action not only beyond the rotatory, but also beyond the translational degrees of freedom of object. In this case it will realize the prescribed dependence of effort beyond the speed.

The dimensionality of the parameters of element, given before the table, are designed for the use of an engine for the task of rotary motion. If forward motion is assigned, then the dimensionality of the corresponding parameters must be changed.

Degrees of freedom

1	it corresponds to the shaft of the engine;
it is 2nd	it corresponds to engine block.

Parameters

N in sequence	Description	Dimensionality	Range
1	Starting torque of engine (moment on the shaft with the zero speed)	*[N]*[m]*	*- Rlmax… +RLmax*
2	Angular idling speed (ω)	*rad/flogged*	*- Rlmax… Smin, Smin… +Rlmax*

N in sequence	Description	Dimensionality	Range
3	*t1* - moment of time, in which is included the engine	*it flogged*	*0… +RLmax*
4	*t2* - moment of time, against which is switched off an engine	*it flogged*	*t1… +RLmax*
5	Moment of the inertia of the shaft of engine, including the inertia of all moving elements, connected for the sake of the shaft	*[kg]*[m]2*	*0… +RLmax*
6	Moment of the inertia of engine block	*[kg]*[m]2*	*0… +Rlmax*

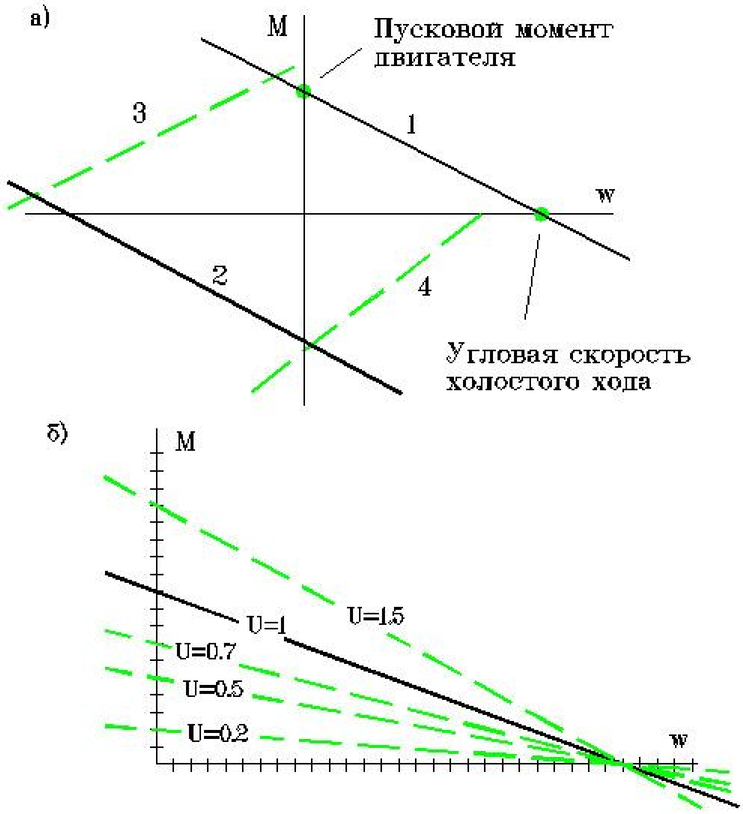
Working vector

N in sequence	Description	Dimensionality	Range
1	A relative drop in the angular velocity $(\omega_0 - \omega) / \omega_0$ (for the fixed shaft this value is equal to 1, for the idling speed - 0)		
2	Value of the relative moment $(Mmax - M)/Mmax$		

2.2.5.3.Model of the engine with the linear mechanical characteristic, controlled by potential DVLU

Reflected properties

Based on the side of engine on system acts the moment, which is obtained by the multiplication of the moment, undertaken based on the characteristic of engine ([ris].DVLU_1), down the potential of the manager of degree of freedom. This makes it possible to simulate not only engines with the purely rectilinear characteristic, but also engines, whose characteristic changes in the course of time (for example, launching direct-current motor with the parallel excitation). In this case it is necessary to consider that the controlling degree of freedom possesses single inertness. If the potential of the manager of degree of freedom less or is equal to 0, then engine is considered turned-off. Its active effect on system ceases against the cutoff of engine. For the engine control it is possible to use sources of kinematic actions of the type VC, VTABL0 and so forth



DVLU_1. Dependences of moment beyond the angular velocity for the element DVLU:

a) possible mechanical characteristics for different combinations of starting torque and idling speed. Characteristics 1 or 2 are permissible, 3 and 4 forbidden;

b) set of mechanical characteristics with the different values of the potential of the manager of degree of freedom. With U=1 is reproduced the prescribed mechanical characteristic.

The moments of the inertia of housing and shaft of engine are considered before the element regardless of the fact, in what state (switch oned or switched off) the engine is. Moment on the shaft of engine and angular velocity of shaft in no way influence the potential of the manager of unit. As for the model of element DVLT, starting torque and angular velocity for the data of element must be one sign.

The model of element DVLU can be used for the action not only beyond the rotatory, but also beyond the translational degrees of freedom of object. In this case it will realize the prescribed dependence of effort beyond the speed. The dimensionality of the parameters of element, given before the table, are designed for the use of an engine for the task of rotary motion. If forward motion is assigned, then the dimensionality of the corresponding parameters must be changed.

Degrees of freedom

1 it corresponds to the shaft of the engine;

it is 2nd it corresponds to engine block;

3- controlling degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	Starting torque of engine (moment on the shaft with the zero speed)	*[N]*[m]*	*- Rlmax… +RLmax*
2	Angular idling speed (ω)	*rad/flogged*	*- Rlmax… Smin, Smin… +Rlmax*
3	Moment of the inertia of the shaft of [dviatelya], including the inertia of all moving elements, connected for the sake of the shaft	*[kg]*[m]2*	*0… +RLmax*

N in sequence	Description	Dimensionality	Range
4	Moment of the inertia of the housing of [dvinatelya]	*[kg]*[m]2*	*0... +Rlmax*

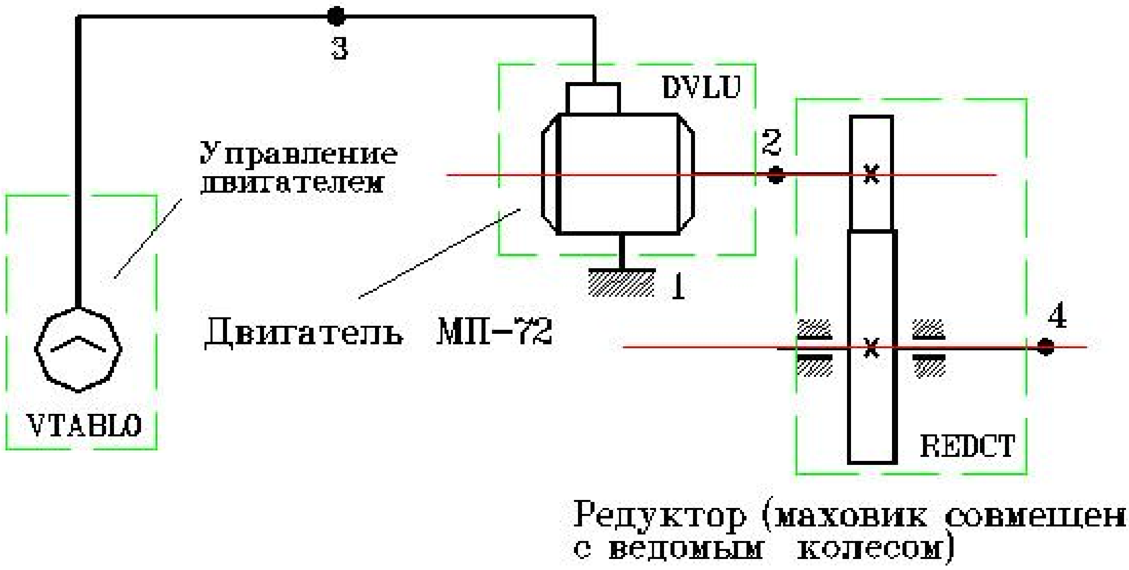
Working vector

N in sequence	Description	Dimensionality	Range
1	A relative drop in the angular velocity $(\omega_0 - \omega) / \omega_0$ (for the fixed shaft this value is equal to 1, for the idling speed - 0)		
2	Value of the relative moment $(Mmax - M)/Mmax$		

Example of the use

It is necessary to analyze the start of the drive of press. Into the composition of drive enters the flywheel with the moment of the inertia *Of j[m]* = 1080 kg*m [2.] for its acceleration it is used direct-current motor [MP]-72. Between the engine and the flywheel there is a transmission depressing revolutions, gear ratio of the transmission *of u=2.* transmission is calculated at the point of the nominal moment *Of m[n]* = of 1.5e3 Of [n]*[m]; its EFFICIENCY, including EFFICIENCY of the supports of flywheel and shaft of engine, η = 95%. Parameters of the engine: the power *W* = of 75 kW, nominal frequency *τηε* ω_n = of 54.5 rad/s. Engine is designed for the work before network 220 beside, the rated current 374 A, the certified resistance of the chain of the anchor - 0.0133 Ohm, the moment of the inertia of the anchor - 14 kg*m [2.] structure of the model of the process in question is depicted beyond Fig. DVLU_2.

1) the calculation of the parameters of the natural mechanical characteristic of the engine (utilized dependences see application, [14]).



DVLU_2. The design diagram of the acceleration of drive by direct-current motor.

Nominal moment of the engine:

M[n] = P/ω_n = 75000/54.5 = of 1376 [*[N]*[m]*]

Nominal engine drag:

R[n] = U/Of i[ya] = 220/374 = 0.588 [*Ohm*]

Relative resistance of the chain of anchor and a relative drop in the frequency of the rotation of engine before the nominal rating:

R = Of r[ya]/Of r[n]* + 0.01 = 0.0326
S[n] = R*

(if specifications of engine would be not known, then determination *Of s[n]* based on the amalgamated dependence gives: *S[n] = R** = 0.3/$\sqrt{75}$ = 0.0346, that practically it would not introduce error beside further reasonings).

Angular idling speed and starting torque:

$\omega 0$ €= ω_n/(1-S_n) = 54.5/(1-0.0326) = 56.3 [*rad/flogged*]

M[pusk] = Of m[n] * ω_0/($\omega 0$ - ω_n) = 1376 /0.0326 = 4.22e4 [*Of [n]*[m]*]

2) the determination of the control characteristics of engine.

For constructing the control characteristics of engine let us assign the value of the peak moment, in reference down the nominal, *M1** = 2.5, and by three steps of starting resistor. Then the ratio of peak moment to that switching:

$L = (1/(0.0326*2.5))^{1/3} = 2.306$

This speaks, that with engine pickup the peak moments will compose 2.5 nominal, and switching - 2.5/2.306 = 1.08 nominal.

3) the selection of the parameters of the source of potential, controlling work engine.

Now let us select the required law of variation in the potential of the manager of degree of freedom. Against first stage of acceleration starting torque of engine, determined about the artificial characteristic, must be equal:

$M^{of [pi]1}$ = *M1 = Of m[n]* * 2.5 = 1376 * 2.5 = 3440 [*N/m*],

which is less than natural starting torque before

M^{P} $M^{of [pi]1}$ = of 4.22e4/of 3440 = 12.3 times.

Thus, against first stage of acceleration the potential of the manager of degree of freedom must be:

P1 = 1 12.3 = 0.081

Against each subsequent step the potential must be more before *L* of times:

P2 = P1 * L = 0.19

P3 = P2 * L = 0.44

Constant of proportionality between the deviation of potential and the flow (effort), generated by the manager element, for the engine of a series Of m[p] we determine with the use as far as electromagnetic time constant *T*:

$T = 0.05P + 0.17*\sqrt{P}$ = of $0.05*75 + 0.17*\sqrt{75}$ = 5.22 [*flogged*]
μ^{1} = 1 (*T* * P1) = 2.2
μ^{2} = 1 (*T* * P2) = 0.96
μ^{3} = 1 (*T* * P3) = 0.42
μ^{e} = 1/T = 0.19

After accepting coefficient *μ €= 2.2* > μ^{2}, μ^{3} μ^{e}, let us switch over to the idealized simulation of launching the engine (peak moments against the second and third steps of acceleration and upon transfer down the natural characteristic will be smoothed less than this will be in reality). Let us select the time of operation of each of the steps of starting resistor, after shaping the mathematical model of process and after making several trial calculations. For the beginning let us assume that the steps of resistor are disconnected every 10 seconds (before the text of task, given below, they are indicated the already selected values of the moments of turning off of starting resistors and the time intervals of their work). Engine is included in the moment of the time *t* = of 0.1 s.

4) other parameters.

For the simulation of reducing gear the model of transmission with the losses is used. For it: gear ratio is equal *to u* = 2; EFFICIENCY η = 0.95; nominal moment on drive wheel *Of m[n]* = 1 of 500 [N]*[m]. the rigidity of transmission, since it is not indicated in the task, let us select as far as sufficiently greater, for example, *k* = of 1e6 Of [n]*[m]/[rad]. the moment of the inertia of gear pinion, which is located beyond the shaft of engine, will accept less than the moment of the inertia of the flywheel proportionally of 4[oy] of the degree of gear ratio:

J[shesterni] = of 1080/24 = 67.5 [kg]*[m]2

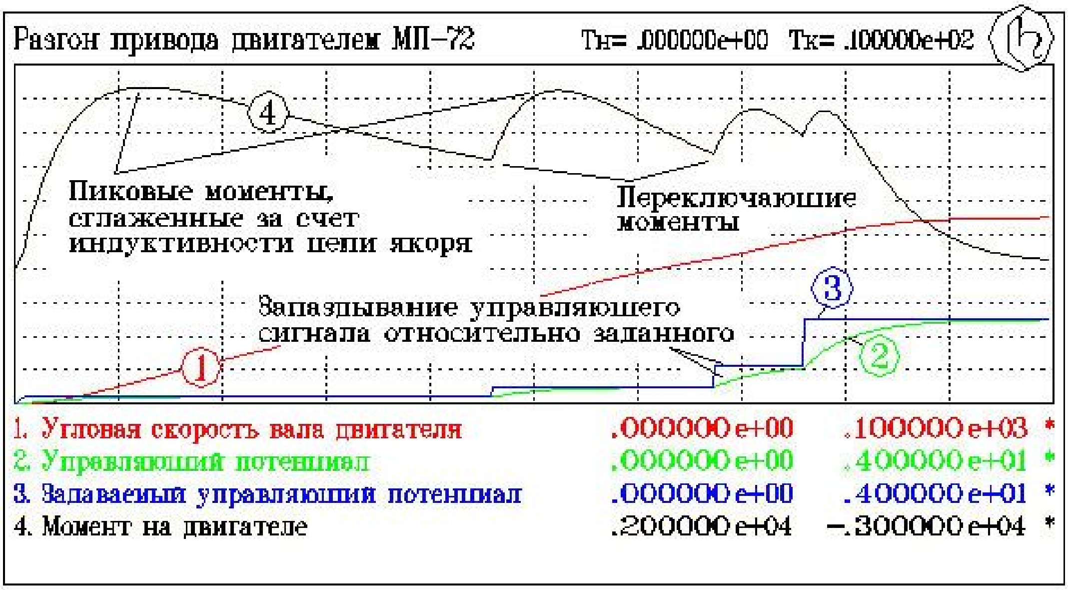
5) the results of the calculation interesting:
- the angular velocity of the shaft of the engine;
- moment on the engine;
- the actual value of the manager of the potential;
- the assigned value of the manager of the potential;
- relative reduction in the engine revolutions;
- the value of relative moment.

Taking into account of given reasonings and Fig. DVLU_2, we will obtain the following text of task before the language *Of pradiSLang*:

```
I DATA:
    Starting torque of the engine = of 4.22e4
    Angular idling speed = 56.3
    Moment of the inertia of anchor = 14
    Moment of the inertia of housing = 0
    Engine control = {0.19 e3,} 2.2,
```

```
            0, 0,
            0.1, 0.087, {1 step of acceleration}
            4.6, 0.087, {}
            4.6, 0.2, {2 step of acceleration}
            6.75, 0.2, {}
            6.75, 0.46, {3 step of acceleration}
            7.6, 0.46, {}
            7.6, 1.0, {natural}
            15.2, 1.0 {characteristics}
   Moment of the inertia of pulley = 67.5
   Moment of the inertia of flywheel = 1080
   Parameters of reducer = 2, 0.95, 1.5e3, 1.e6
I FRAGMENT :
   # BASE: 1
   # STRUCTURE :
      Engine 'DVLU (2 1 Oe; Starting torque of engine,
                 Angular idling speed,
                 Moment of the inertia of anchor,
                 Moment of the inertia of housing)
      Control element 'VTABL0 (3 1;                          Engine control)
      Reducer 'REDCT (2 4;                              Parameters of reducer,
                                                  Moment of the inertia of pulley,
                                                  Moment of the inertia of flywheel)
   # OUTPUT :
      Angular velocity of the shaft of engine 'the V (2; 1)
      Controlling potential 'the V (3; 1)
      Assigned manager of [potentsial]'X (W: Control element (1); 1)
      Moment on the engine 'the X (the I: Engine; 1)
      [Otnos].[snizhenie] of revolutions eng. 'THE X (W: Engine (1);
1)
      Value of relative moment 'the X (W: Engine (2); 1)
   #MAP:
I RUN:
   Engine pickup 'SHTERM (END=50, SMAX=0.1;
   Angular velocity of the shaft of engine = (0,100),
   Controlling potential = (0,1),
   Assigned manager of [potentsial]= (0,1),
   Moment on the engine = (0,5000),
   Value of relative moment = (0,0.01))
I PRINT:
   Results of calculation 'DISP (;
   Angular velocity of the shaft of engine,
   Controlling potential,
   Assigned controlling potential,
   Moment on the engine,
   Value of relative moment)
$ END
```

The results of calculations are given before Fig. DVLU_3.



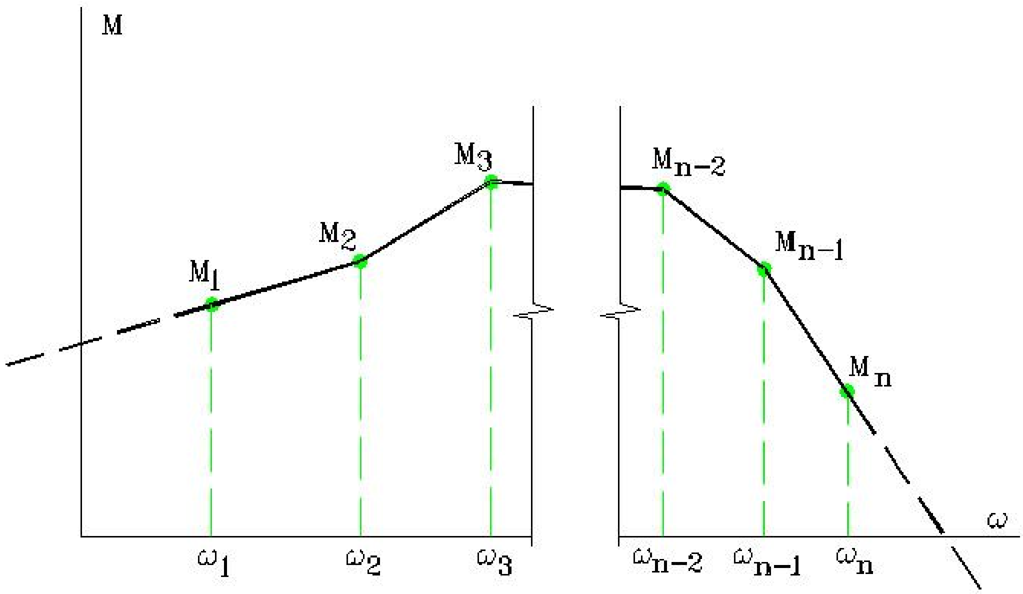
DVLU_3. Results of calculating the acceleration of drive.

2.2.5.4.The model of engine it is piecewise-by the linear mechanical characteristic, given tabular DVTBLU

<u>Reflected properties</u>

Based on the side of engine on system acts the moment, which is obtained by the multiplication of the moment, undertaken based on the characteristic of engine ([ris].DVTBLU_1), down the potential of the manager of degree of freedom.

<u>Rules of the task of the engine characteristic.</u>



DVTBLU_1. **Engine with the tabular assigned dependence of moment beyond the angular velocity. Each point of this dependence is assigned by the pair of the values of ωi - Mi. The first and last sections of characteristic must not be vertical (they they are used for the extrapolation of the values of moment as a result of the limits of the prescribed section of characteristic).**

1. points of the engine characteristic must be regulated on the growth of angular velocity $\omega_{\iota} =< \omega_{\iota+1}$. for the first two and two last points of characteristic must be satisfied condition ω_{ι}€<€$\omega_{\iota+1}$.
2. must be prescribed as the minimum two points of characteristic.

During control besides the work of engine with the aid of the potential of the manager of degree of freedom it is necessary to consider that the controlling degree of freedom possesses single inertness. If the potential of the manager of degree of freedom less or is equal to 0, then engine is considered turned-off. Its active effect on system ceases against the cutoff of engine. The moments of the inertia of housing and shaft of engine are considered before the elements regardless of the fact, in what state (switch oned or switched off) the engine is. Moment on the shaft of engine and angular velocity of shaft in no way influence the potential of the manager of unit.

The model of element DVTBLU can be used for the action not only beyond the rotatory, but also beyond the translational degrees of freedom of object. In this case it will realize the prescribed dependence of effort beyond the speed. The dimensionality of the parameters of element, given before the table, are designed for the use of an engine for the task of rotary motion. If forward motion is assigned, then the dimensionality of the corresponding parameters must be changed.

Degrees of freedom

1 it corresponds to the shaft of the engine;

it is 2nd it corresponds to engine block;

3- controlling degree of freedom.

Parameters

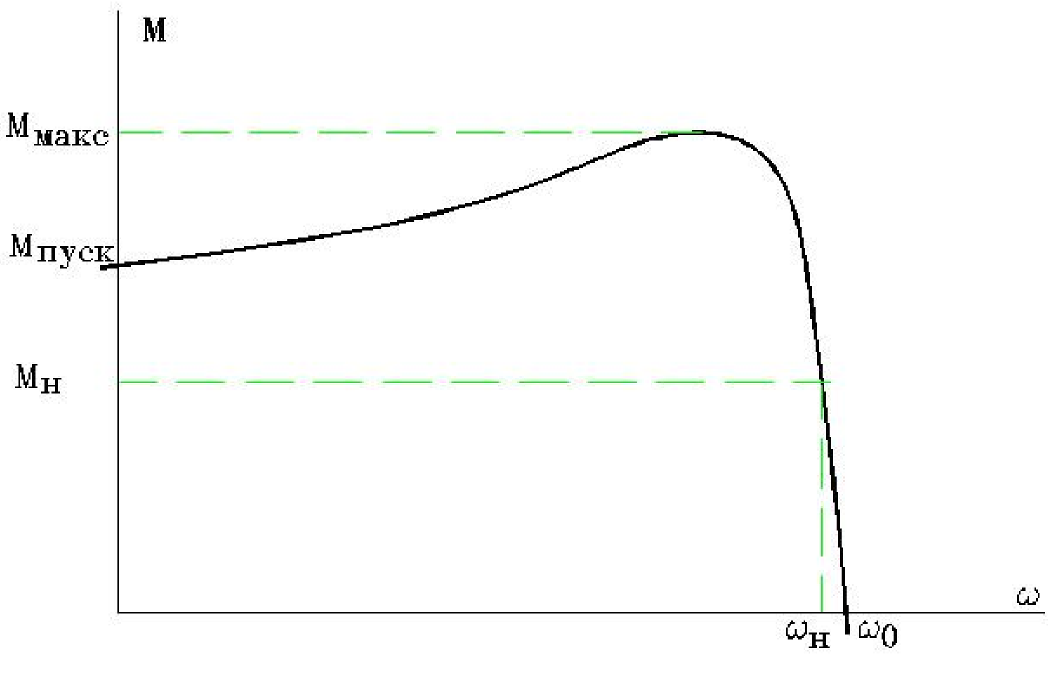
N in sequence	Description	Dimensionality	Range
1	Moment of the inertia of the shaft of engine, including the inertia of all moving elements, connected for the sake of the shaft	*[kg]*[m]2*	*0… +RLmax*
2	Moment of the inertia of engine block	*[kg]*[m]2*	*0… +Rlmax*
3	*ω1* - angular velocity for the first given point of the characteristic	*rad/flogged*	*0… +Rlmax*
4	*M1* - motoring torque on the shaft of engine at the first point	*[N]*[m]*	*- Rlmax… +RLmax*
	…..		
2*i+1	*ωι* - angular velocity for *i*-the oh given point of the characteristic	*rad/flogged*	$\omega_{\iota-1}$… *+Rlmax*
2*i+2	*Mi* - motoring torque on the shaft of engine before *i*-oh to the point	*[N]*[m]*	*- Rlmax… +RLmax*
	…..		
2*n+1	*ων* - angular velocity for *n*-the oh given point of the characteristic	*[N]*[m]*	$\omega_{\nu-1}$… *+Rlmax*
2*n+2	*Mn* - motoring torque on the shaft of engine before *n*-oh to the point	*[N]*[m]*	*- Rlmax… +RLmax*

2.2.5.5.Element, which reproduces the performance characteristic of induction motor, controlled by potential DVAU

Reflected properties

Based on the side of engine on system acts the moment, which is obtained by the multiplication of the moment, undertaken based on the characteristic of engine ([ris].DVAU_1), down the potential of the manager of degree of freedom. Are simulated engines with the synchronous number of revolutions of rotor 500… 3000 1/[min]. on the prescribed nominal angular velocity of shaft element automatically selects the nearest synchronous speed, which corresponds to this number of revolutions. If rated r is less than 500 1/[min], it is considered that the engine has synchronous number of revolutions 500. if rated r it exceeds 3000, overhangs communication about the incorrect parameter and calculation completes.

During control besides the work of engine with the aid of the potential of the manager of degree of freedom it is necessary to consider that the controlling degree of freedom possesses single inertness. If the potential of the manager of degree of freedom less or is equal to 0, then engine is considered turned-off. Its active effect on system ceases against the cutoff of engine. The moments of the inertia of housing and shaft of engine are considered before the element regardless of the fact, in what state (switch oned or switched off) the engine is. Moment on the shaft of engine and angular velocity of shaft in no way influence the potential of the manager of unit.



DVAU_1. Basic parameters, which assign the mechanical characteristic of the induction motor:

ω[n] - the nominal angular velocity of the engine;

M[n] - the nominal moment of engine (M[n]=[Rn]/of ω[n]);

Θ - the ratio of starting torque to the nominal (θ=[Mpusk]/[Mn]);

λ - the ratio of maximum moment to the nominal (λ=M[maks]/[Mn])

The model of element DVAU can be used for the action not only beyond the rotatory, but also beyond the translational degrees of freedom of object. In this case it will realize the prescribed dependence of effort beyond the speed. The dimensionality of the parameters of element, given before the table, are designed for the use of an engine for the task of rotary motion. If forward motion is assigned, then the dimensionality of the corresponding parameters must be changed.

Degrees of freedom

1	it corresponds to the shaft of the engine;
it is 2nd	it corresponds to engine block;
3-	controlling degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1	The nominal yield of the engine	*W*	*0... +Rlmax*
2	*ω[v]* - the nominal angular velocity of the shaft	*rad/flogged*	*- Rlmax... 314.2*
3	*ιτ ισ θ–τη* the ratio of starting torque to the nominal		*Smin... τηε λ*
4	Ratio of maximum moment to the nominal (*λ*)		*1.1... 4*
5	Moment of the inertia of the shaft of engine, including the inertia of all moving elements, connected for the sake of the shaft	*[kg]*[m]2*	*0... +RLmax*
6	Moment of the inertia of engine block	*[kg]*[m]2*	*0... +Rlmax*

Note. For the characteristics of the engines, which refer small of maximum moment to nominal (λ = 1.1… 2.5), $\theta = \lambda$ and very rigid characteristic (small nominal slips) usually [s] grow prettier by precision it is impossible to select the parameters of Closs's formula. In this case the communication overhangs:

```
DVAU:   For the given values of the parameters of engine it was impossible to select the appropriate mechanical characteristic
```

- and calculation completes emergency. The appearance of this communication is highly improbable for the production engines. However, if this communication appeared, it is usually sufficient very insignificantly (in the thousandths of percentage and less) to increase λ or to decrease θ.

Working vector

N in sequence	Description	Dimensionality	Range
1	A relative drop in the angular velocity $\left(\omega_0-\omega\right)/\,\omega_0$ (for the fixed shaft this value is equal to 1, for the idling speed - 0)		
2	Value of the relative moment *M/Of mmax*		

2.3.Three-dimensional elements

2.3.1.Models of the power actions

2.3.1.1.Element, which distributes constant pressure beyond the three-dimensional triangle FPRS3D

Reflected properties

Distributes uniform pressure along the units of three-dimensional triangle. It is assumed that the pressure of positive value is applied to the triangle based on the side of the external standard (effort, created by this pressure, it has a direction, opposite to the direction of external standard). External normal to the triangle is determined as far as vector product **AB x AC** (see Fig. OF FPRS3D_1). If points A, B and C are arranged in straight line (normal to the triangle and its area cannot be determined), overhangs communication about the error. If this situation appears on the course of computation, then the model of element establishes the requirement to decrease the step of integration.

The value of the effort applicable to the triangle is determined as far as the dependence:

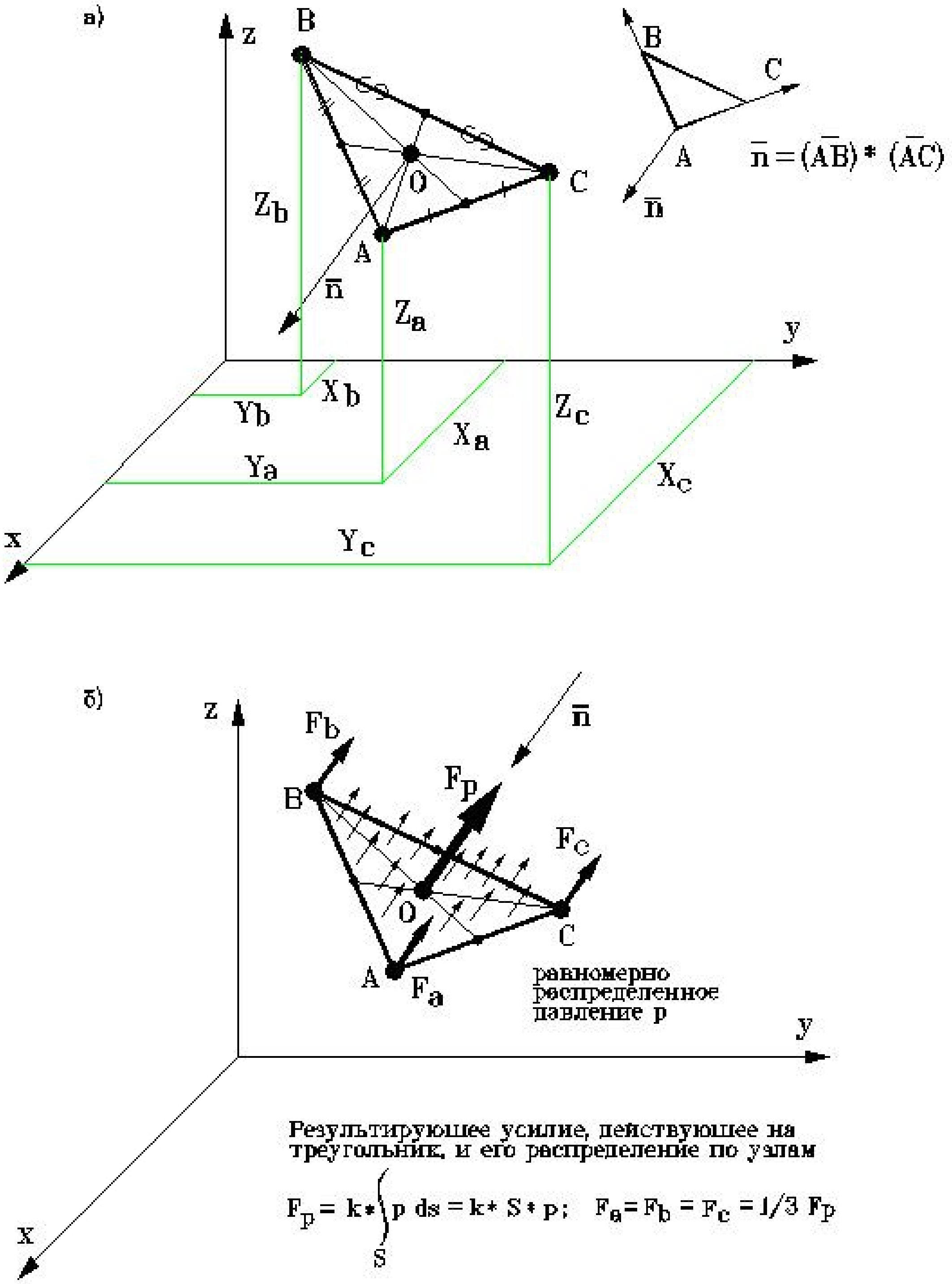
F[r] = of p*S*k

, where *F[r]* - the total quantity of the effort, which acts beyond the triangle;

p - the current pressure;

S - the current area of triangle, determined as far as the moving coordinates of points A, B and C;

it is k-th the value of the scaling coefficient. If coordinates are assigned before the meters, and pressures are counted before MPA, the value of coefficient *k* is taken after the equal of 1.e6. Negative values *k* can be used for changing the direction of the effective pressure.



FPRS3D_1. **Element, which distributes uniform pressure beyond the three-dimensional triangle**

a) the theoretical parameters, which determine the position of triangle before the space:

X[a], Y[a], Z[a] - the coordinate of point A;

Xb, Yb, Zb - the coordinate of point B;

Xc, Yc, Zc - the coordinate of point C;

it is n-th external normal to the plane of the triangle;

b) the total quantity of the acting beyond the triangle effort and the diversity of this effort on the units.

Degrees of freedom

1,2,3 - the progressive (respectively to the X, Y and Z) points A of the triangle;

4,5,6 - the progressive points B of the triangle;

7,8,9 - the progressive points C of the triangle;

10 it corresponds to degree of freedom, which assigns pressure.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of the point A of the triangle	*m*	*- Rlmax… +RLmax*
4,5,6	The origin coordinates of point [v] the triangle	*m*	*- Rlmax… +Rlmax*
7,8,9	The origin coordinates of point based on the triangle	*m*	*- Rlmax… +Rlmax*
10	Scaling coefficient for the conversion of pressure before the effort	*[N]/[Pa]* or *[N]/[MPa]*	*- Rlmax… +Rlmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	The total quantity of the applicable to the triangle effort	*N*	
2	Current area of the triangle	*[m]2*	
3,4,5	Direction cosines of external normal to the triangle (respectively to the axes of the X, Y and Z)		

3. The inertia elements

3.1.Introductory observations

Sluggishness - this is the property of any physical body to resist a change in the speed of motion. Its mass is the measure of the sluggishness of body. The mathematical model of technical system, formed for the sake of the means of program set PRADIS, possesses the finite number of degrees of freedom, after the measure of the sluggishness of motion for which serves the mass (for the translational degrees of freedom) or the moment of inertia (for the angular degrees of freedom).

Elements described in this chapter are intended for mapping of the inertia properties of the separate components technical of the systems with the one-dimensional, flat and spatial motion being simulated.

If we classify elements from the library of mechanical elements PRADIS about the sign of the presence of inertia properties, then it is possible to isolate three groups:

- THE ELEMENTS, which reflect only inertia properties of solid bodies (as far as them it is dedicated this head);
- THE ELEMENTS, which possess inertia properties together with mapping of other properties (for example, the elements of continuous environment);
- INERTIA-FREE elements (for example, connection).

To determine, does possess concrete element inertia properties, it is possible, first of all, according to its description before the division “reflected property”. Furthermore, the absence before the list of the parameters of the element of such values as mass, the moment of inertia or density, testifies that the element of [neinertsionen].

Before the majority of the cases inertia-free elements are used for the connection of the elements, which possess inertia. With this connection before the units, general for the inertia and inertia-free elements, the problems, connected for the sake of the absence of inertia properties, it does not appear. But if two inertia-free elements consecutively are connected, then, strictly speaking, to write down equation of motion according to the general degrees of the freedom in the absence of mass is impossible. Although, taking into account the finite quantity of the step of integration at the point of the time and with the condition of the presence of other, except sluggishness, properties of resistance to motion according to the degrees of freedom common for the combinable elements, the calculation of this system can be carried out. However, it will be, as a rule, complicated by the sufficiently fine pitch, caused “[dergannym]” nature of the accelerations of inertia-free units, which leads down the appropriate estimation of a local error in the integration. Therefore with the forming of the model of technical system it should be not disregarded the diagnostic communication, which inform about the absence of inertia properties on what-or to degrees of freedom, and to add according to these degrees of freedom the suitable inertia elements from those described in this chapter.

Reference data by means of volumes of bodies and density of some extended materials, masses of elements necessary for the computation, are given before the application. There it is possible to find the moments of inertia for the bodies of the simplest form.

3.2.1D Elements

3.2.1.1.One-dimensional inertia element M

Reflected properties

Inertia properties of solid body during the one-dimensional motion.

Degrees of freedom

1 progressive or rotatory, on which are assigned the inertia properties of body.

Parameters

N in sequence	Description	Dimensionality	Range
1	MASS (for forward motion) or the moment of inertia (for the rotary motion)	*kgf* or *[kg]*[m]2*	*0…* *+Rlmax*

Limitations on the use

The use of an element for the reflection of the inertia properties of body about the rotational degrees of freedom is possible only with the one-dimensional (twisting) or plane motion of solid body, when rotational axis does not change its angular position.

In the general case of three-dimensional rotation for the reflection of the inertia properties of body it is necessary to use three-dimensional inertia elements.

3.3.Two-dimensional elements

3.3.1.1.2D inertia element MD

Reflected properties

Inertia properties of solid body with the plane motion.

Degrees of freedom

1,2 - progressive of the center of the masses of body across the axes of the X, Y;

3- rotatory of the center of masses.

Note. The degrees of freedom of element are in the center of the masses of body.

Parameters

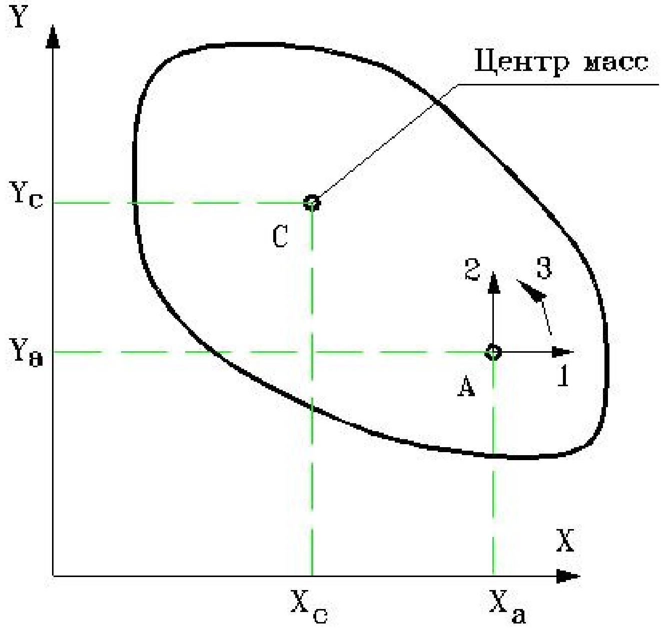
N in sequence	Description	Dimensionality	Range
1	THE MASS	*the kgf*	*0… +Rlmax*
2	Moment of inertia relative to rotational axis	*[kg]*[m]2*	*0… +Rlmax*

3.3.1.2.Flat inertia element with the displaced position of the center of masses MJ2E

Reflected properties

The inertia properties of solid body with the plane motion for the case, when the center of the masses of body and the point, with which are linked the degrees of freedom, do not coincide (Fig. MJ2E_1).

Explanations. The point, for the sake of which are connected the degrees of freedom of body, is designated here by point A, the center of the masses of the body - by point C.



MJ2E_1. Degrees of freedom and the parameters of flat inertia element with the displaced position of the center of masses.
Degrees of freedom:
1,2 - progressive points A across the axes of the X, Y;
3- rotatory of point a.
Parameters:
Xa, Ya - the origin coordinates of point A;
Xc, Yc - the origin coordinates of point [s] (center of masses).

Degrees of freedom

1,2 - progressive points A across the coordinate axes of the X, Y;

3- rotatory of point A.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	The origin coordinates of point A (XA; YA)	*m*	*-RLmax… +Rlmax*
3, 4	The origin coordinates of the center of masses (XC; YC)	*m*	*-RLmax… +Rlmax*
5	Mass of the body	*the kgf*	*0… +Rlmax*
6	Moment of inertia relative to the axis, passing through the center of the masses	*[kg]*[m]2*	*0… +Rlmax*

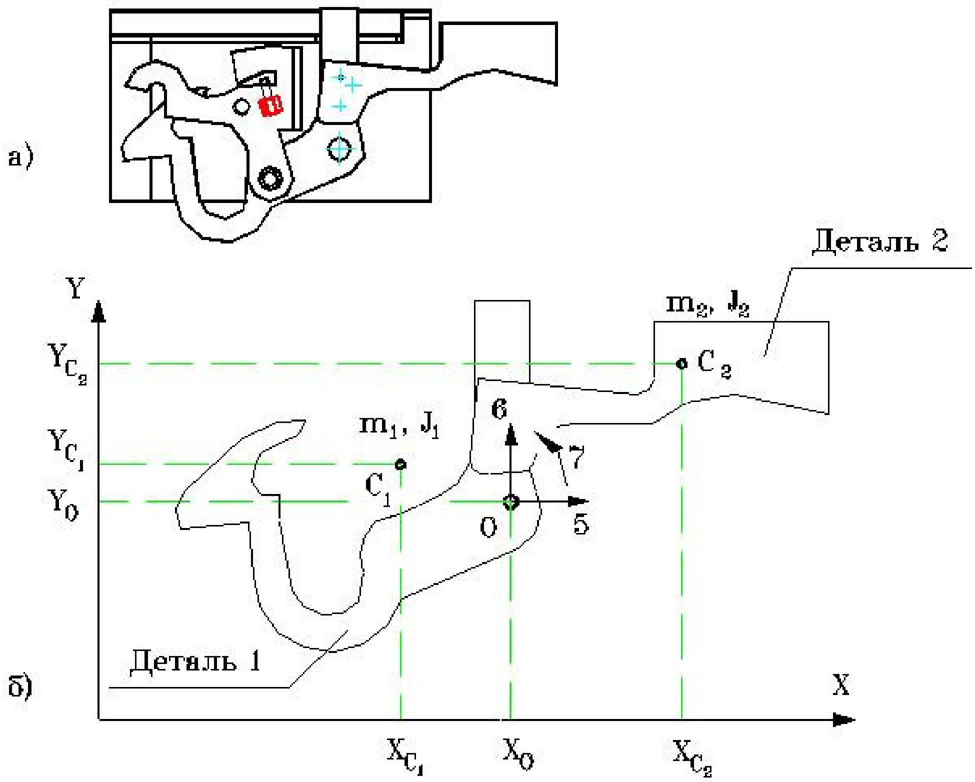
<u>Working vector</u>

N in sequence	Description	Dimensionality	Range
1,2	Displacements of the center of masses by means of the axes of the X, Y	*m*	

<u>Example of the use</u>

An example of the fragment of the description of task, before which for the reflection of inertial characteristics of one of the levers of automobile lock (Fig. MJ2E_2) is used the element MJ2E:

```
I DATA:

   Point O = 0. of e-3, 0. e-3
   Point C1 = -35. e-3, 18. e-3
   Point C2 = 32. of e-3, 27. e-3
   M1 = 22.e-3 ;   J1 = 1.8 e-3
   M2 = 16.e-3 ;   J2 = 0.85 e-3
                 ….
I FRAGMENT: Lock

# BASE:  1,2
# STRUCT:
     ….
       Component 1 'MJ2E (5 6 7; Point O, [Tochk] C1, M1, J1)
       Component 2 'MJ2E (5 6 7; Point O, [Tochk] C2, M2, J2)
```



MJ2E_2. **Example of the use of an element MJ2E for the reflection of the inertia properties of the moving elements of the automobile lock with the calculation of the behavior of lock under the action of the inertia loads:**
a) the construction of the lock;
b) the diagram, which elucidates the forming of inertia model of one of the levers of lock.

3.4.Three-dimensional elements

3.4.1.1.Three-dimensional inertia element, which reflects progressive component of the inertia properties of body M3D

Reflected properties

Progressive component of the inertia properties of solid body with the spatial motion. Element is recommended to use at the points, against which either there are no angular degrees of freedom or inertia properties according to the angular degrees of freedom are reflected by other elements.

Degrees of freedom

1,2, 3- the progressive across the coordinate axes X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1	THE MASS	*the kgf*	*0… +Rlmax*

3.4.1.2.Three-dimensional inertia element, which reflects the rotational component of the inertia properties of the spherical body of J30

Reflected properties

The rotational component of the inertia properties of spherical solid body with the spatial motion. Element is recommended to use at the points, against which either there are no translational degrees of freedom or inertia properties according to the translational degrees of freedom are reflected by other elements. Besides spherical body, the element can be used for the reflection of the inertia properties of any solid body, which has the identical moments of inertia relative to three principal central axes: cube, cylinder with the relationship of height to a radius H = of 1.73*R and others

Degrees of freedom

1,2, 3- the rotatory around the coordinate axes X, Y and Z.

Parameters

N in sequence	Description	Dimensionality	Range
1	Moment of the inertia of body relative to the axis, passing through the center of the masses	*[kg]*[m]2*	*0… +Rlmax*

Working vector

N in sequence	Description	Dimensionality	Range
1,2,3	angular accelerations across the axes of the X, Y, Z	*rad/of [sek]2*	
4,5,6	ANGULAR velocities across the axes of the X, Y, Z	*rad/flogged*	

3.4.1.3.Three-dimensional inertia element, which reflects the inertia properties of spherical body MJ30

Reflected properties

Inertia properties of spherical solid body with the spatial motion. Besides spherical body, the element can be used for the reflection of the inertia properties of any solid body, which has the identical moments of inertia relative to three principal central axes.

Element is the association of elements M3D and J3O.

Degrees of freedom

1,2, 3- the progressive across the coordinate axes X, Y, Z;

4, 5, 6 the rotatory around the coordinate axes X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1	Mass	*the kgf*	*0… +Rlmax*
2	Moment of the inertia of body relative to the axis, passing through the center of the masses	*[kg]*[m]2*	*0… +Rlmax*

Working vector

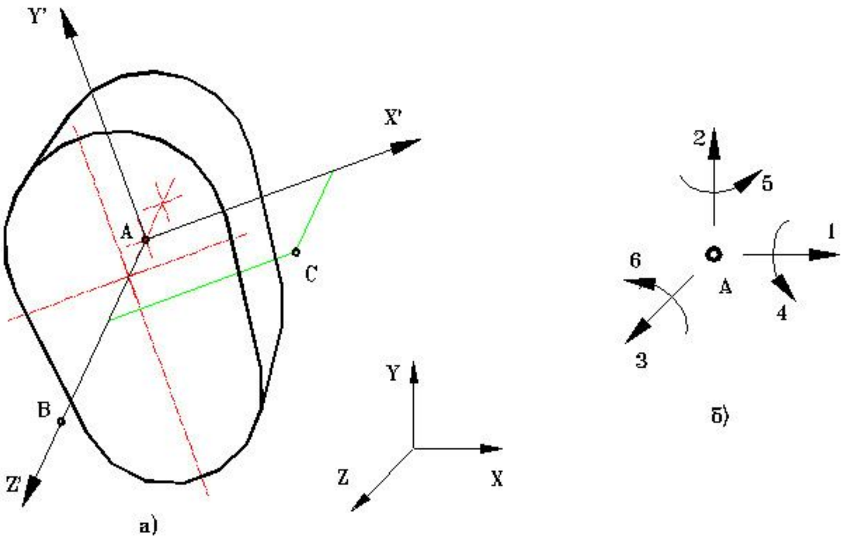
N in sequence	Description	Dimensionality	Range
1,2,3	angular accelerations across the axes of the X, Y, Z	*rad/of [sek]2*	
4,5,6	ANGULAR velocities across the axes of the X, Y, Z	*rad/flogged*	

3.4.1.4.Three-dimensional inertia element, which reflects the inertia properties of arbitrary solid body MJ3D

Reflected properties

Inertia properties of arbitrary solid body with the spatial motion. The degrees of freedom of element are in the center of the masses of body (Fig. MJ3D_1).

Note. The point, which coincides for the sake of the center of the masses of body, is designated here by point A. auxiliary point, together with the point A determining the initial position of the principal central axis of Z', is designated by point B. auxiliary point, together with the points A and B the determining plane of the arrangement of the principal central axis of X', is designated by point C. if point C it lies beyond the axis AB, then the moments of inertia relative to axes X' and Y' must be assigned by equal.



MJ3D_1. Parameters and the degree of freedom of the three-dimensional inertia element:

a) the parameters:
Xa, Ya, Za - the origin coordinates of the center of the masses;
Xb, Yb, Zb - the origin coordinates of the auxiliary point B, which lies beyond the principal central z axis';
Xc, Yc, Zc - the origin coordinates of the auxiliary point [s], which lies against the plane X' AZ'.
b) of degree of freedom:
1,2, 3- progressive of the center of masses across the axes of the X, Y, Z;
4, 5, 6 rotatory of the center of masses around the axes of the X, Y, Z.

Degrees of freedom

1,2, 3- progressive of the center of masses across the axes of the X, Y, Z;

4, 5, 6 rotatory of the center of masses around the axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2, 3	The origin coordinates of the center of masses (XA; YA; ZA)	*m*	*-RLmax… of +Rlmax*
4, 5, 6	The origin coordinates of auxiliary point B (XB; YB; ZB)	*m*	*-RLmax… of +Rlmax*
7, 8, 9	The origin coordinates of auxiliary point C (XC; YC; ZC)	*m*	*-RLmax… of +Rlmax*
10	Mass	*the kgf*	*0… +Rlmax*
11, 12, 13	Moments of inertia relative to the principal central axes of X', of Y', Z'	*[kg]*[m]2*	*0… +Rlmax*

Working vector

N in sequence	Description	Dimensionality	Range
1,2,3	angular accelerations across the axes of the X, Y, Z	*rad/of [sek]2*	
4,5,6	ANGULAR velocities across the axes of the X, Y, Z	*rad/flogged*	

Example of the use

Case of the regular precession of symmetrical solid body (astatic gyroscope). Solid body, which possesses the axial symmetry (ellipsoid of revolution) is fixed from the progressive displacements in the center of masses. Before the initial state the longitudinal axis of body lies in the plane of XY and is deflected from the [verikalnoy] y axis down a certain angle. To body is reported initial angular velocity ω_0, directed across the y axis. as a result body will begin to accomplish the inertial motion, which it is possible to represent (before the terms of the Euler angles) as the totality of spin around the axis of the symmetry of body and rotation (precession) of this axis around a certain three-dimensional axis, called axis of precession (Fig. MJ3D_2, a).

For the case in question there is a dependence, which links the angular velocities of precession and spin:

$$\omega_{SO\ ON} = \tau\eta\varepsilon\ \omega_{OF\ [SV]}*\ Of\ jz'/(Jz' - Jx')/cos\ (\theta),$$

, where $\tau\eta\varepsilon\ \omega_{SO\ ON}$ - the angular velocity of the precession;

$\omega[\sigma\varpi]$ - the angular velocity of the spin;

Jz' - the moment of the inertia of body relative to the axis of the symmetry;

Jx' - axial moment inertia (*Jx' = of Jy')*;

θ - the angle between the axis of the symmetry of body and the axis of precession.

The initial angular velocity, equal ω_0 and directed across the y axis, it is vector sum $\omega_{SO\ ON}$ ω_{SV}

The purpose of calculation is checking the correspondence of the results of the simulation of the given analytical dependence.

The structure of model includes three elements:

MJ3D - the inertness of solid body;

VWN3D - the element, which assigns the initial velocity of the rotation of point A (center of the masses of body) around the y axis;

SPCW3D - sensor, “hung up” on the degree of freedom of point A for the retention of the information, utilized before OVP COS3E.

Since solid body in question is symmetrical relative to its longitudinal axis of Z', that of the direction of principal axes X' and Y' it is possible clearly to not determine. Therefore before the parameters of element MJ3D auxiliary point C coincides for the sake of the point B, and the direction of the axes of X', Y' will be accepted on silence.

Before the division OUTPUT is called one program of the calculation output variable COS3E. It calculates 9 direction cosines of the axes of X', of Y', of Z', from which for the sake of necessary in this case they appear only three latter, which characterize current position of the longitudinal axis of the body of Z'.

```
I DATA:

    Point A = 0, 0, 0
   Point B = 0.2, 1, 0
   Axis Y = 0, 0, 0, 0, 1, 0
   M = 1
   Jx_ = 4; Jy_ = 4; Jz_ = 1
   W0 = 20

I FRAGMENT: Gyroscope

   # BASE : 1,2, 3

   # STRUCT:
      Body 'MJ3D (1 2 Oe 4 5 6; Point A, point B, point B, M, Jx_, Jy_, Jz_)
      Sensor 'SPCW3D (1 2 Oe 4 5 6; 1)
      The initial velocity 'VWN3D (1 2 Oe 4 5 6; Y axis,
                                                  Point A, W0)

   # OUT:
      Direction cosines 'COS3E (W: Sensor;
                                      Point A, point B, point B)

I RUN:
   Gyro precession 'NEWMARK (END=1)

I PRINT:
   Direction cosines of axis Z_ 'DISP (START=1.E-10, SCALE=1;
                                 Direction cosines (7),
                                 Direction cosines (8),
                                 Direction cosines (9))
```

```
$ END
```

The results of calculation are given before Fig. MJ3D_2, b. based on them is evident that the motion of axis Z' bears periodic nature. Full wave, i.e., 1 revolution around the axis of precession, axis Z' completed at the point of 1 s. thus, speed of the precession

$$\omega_{so\ on} = 1\ [r/s] = 6.28\ [rad/it\ flogged]$$

We determine the position of axis of precession. Direction cosines of axis Z':
- before extremely by right the position (t = 0 it flogged): 0.196, 0.981, 0;
- before the extremely left position (t = 0.5 it flogged): -0.913, 0.407, 0.

Thus, axis of precession lies in the plane of XY and is deflected from the y axis to the left on 27.3 deg.

Taking into account that the angle of the slope of axis Z' to the y axis before the initial position is equal to 11.3 deg., from the parallelogram of speeds (Fig. MJ3D_2, a) we find the angular velocity of the spin:

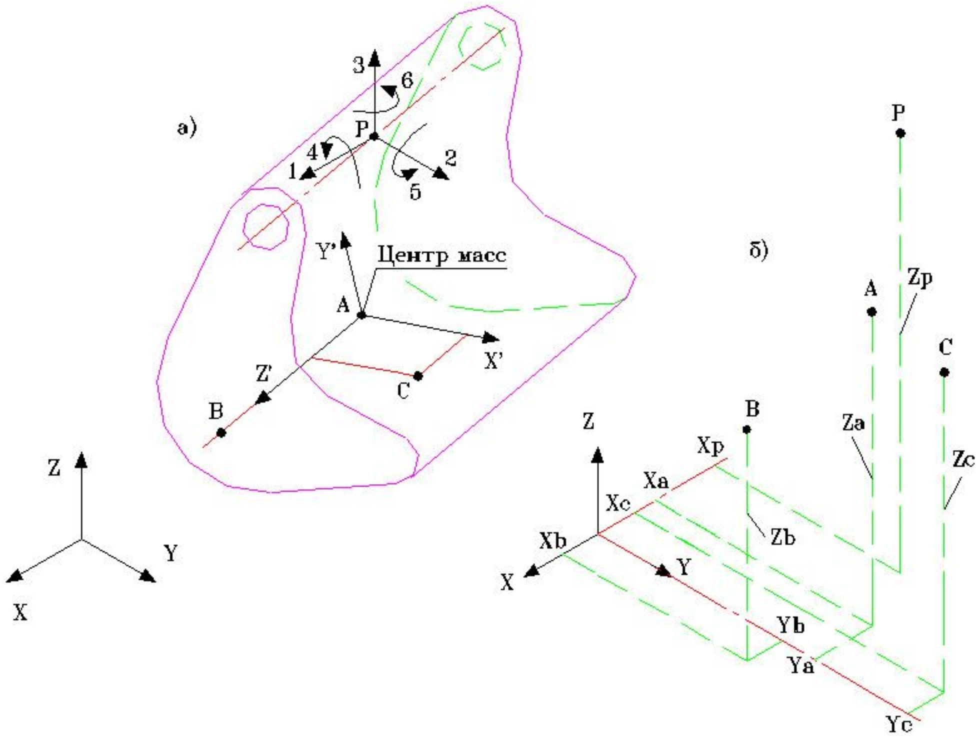
$$\omega_{so\ on} = 14.70\ [rad/it\ flogged]$$

After substituting the obtained results in the given above analytical relationship for the angular velocities of precession and spin, let us ascertain that it is satisfied identically.

3.4.1.5.Three-dimensional inertia element with the displaced position of the center of masses MJ3E

Reflected properties

Inertia properties of arbitrary solid body with the spatial motion. The center of masses can be displaced relative to the point, for the sake of which are connected the degrees of freedom of element (Fig. MJ3E_1).



MJ3E_1. Degrees of freedom and the parameters of inertia element with the mixed position of the center of the masses:
a) of degree of freedom and the direction of principal central inertia axes;
b) of the coordinate of points.

Note. The point, for the sake of which are connected the degrees of freedom of element, is designated here by point P. the center of the masses of body it is designated by point A. auxiliary point, together with the point A determining the initial position of the principal central axis of Z', is designated by point B. auxiliary point, together with the points A and B the determining plane of the arrangement of the principal central axis of X', is designated by point C. if point C it lies beyond the axis AB, then the moments of inertia relative to axes X' and Y' must be assigned by equal.

Degrees of freedom

1,2, 3- progressive points P across the axes of the X, Y, Z;

4, 5, 6 rotatory points P around the axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2, 3	The origin coordinates of point P (XP; YP; ZP)	*m*	*-RLmax… of +Rlmax*
4, 5, 6	The origin coordinates of the center of masses (XA; YA; ZA)	*m*	*-RLmax… of +Rlmax*
7, 8, 9	The origin coordinates of auxiliary point B (XB; YB; ZB)	*m*	*-RLmax… of +Rlmax*
10, 11, 12	The origin coordinates of auxiliary point C (XC; YC; ZC)	*m*	*-RLmax… of +Rlmax*
13	Mass	*the kgf*	*0… +Rlmax*
14, 15, 16	The moments of inertia relative to the principal central axes of X', of Y', of Z', of those having it began at point A	*[kg]*[m]2*	*0… +Rlmax*

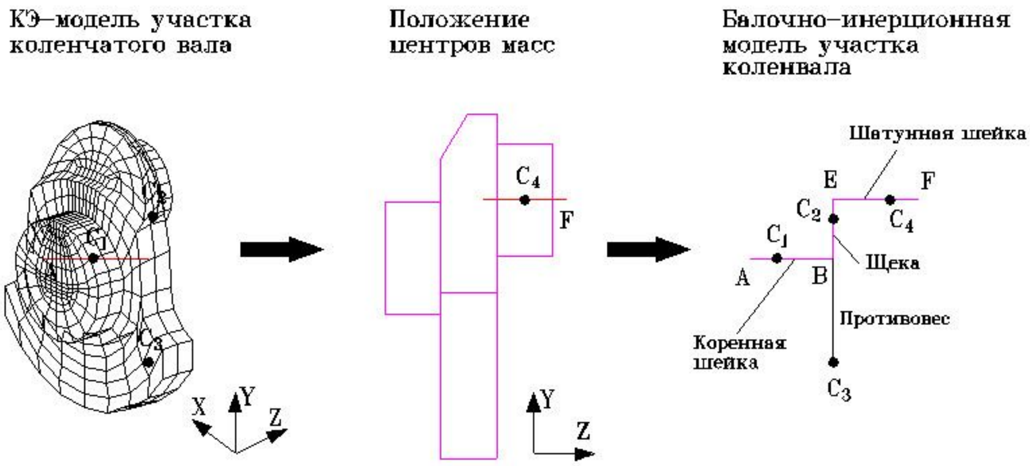
Working vector

N in sequence	Description	Dimensionality	Range
1,2, 3	the angular accelerations of body across the axes of the X, Y, Z	*rad/of [sek]2*	
4, 5, 6	THE ANGULAR velocities of body across the axes of the X, Y, Z	*rad/flogged*	
7, 8, 9	Displacements of the center of masses by means of the axes of the X, Y, Z	*m*	

Example of the use

It was used girder for the investigation of the loading of crankshaft before the process of its acceleration-the inertia model of crankshaft (Fig. MJ3E_2). The determination of the rigid and inertia parameters of this model was conducted with the aid of the finite-element model of the fragment of crankshaft. Rigidity of beams, i.e., the characteristics of their cross sections, were selected on the basis of the calculation of displacements by means of the finite-element model under the single influences. For the reflection of inertia properties inertia elements with the displaced position of the center of masses were used.

The fragment of shaft in question can be presented by that consisting of four parts: the main journal, cheek, crankpin and counterweight. The position of the center of masses was determined for each of these parts, and the inertia properties of each part were represented by separate element MJ3E. The description of structure is given below girder-the inertia model of one fragment of crankshaft.



MJ3E_2. The use of an element MJ3E during the construction is girder-the inertia model of crankshaft.

```
I DATA: [Koleno]_1
    {The coordinates of points}
    point A = 0, 0, 0
    point B = 0, 0, 22.7 e-3
    the point Of bx= 1, 0, 22.7 e-3
    point E = 0, 30.3 e-3, 22.7 e-3
    the point Of ex= 1, 30.3 e-3, 22.7 e-3
    point F = 0, 30.3 e-3, 44.5 e-3
            ….
I FRAGMENT: [Koleno]_1
    # BASE:  100
    # STRUCT:
       Rigidity of the main journal 'BAL3DK (1,2, 3, 4, 5, 6, 7, 8, 9,
                          10,11,12;
                          point A, point B, point Bx,
                          M. i. p. s. of the main journal Of ix_,
                          M. i. p. s. of the main journal Of iy_,
                          M. i. p. s. of the main journal Ik,
                          Area p. s. of the main journal,
                          Coeff.s of the shift of [koren]. neck on X_,
                          Coeff.s of the shift of [koren]. neck on Y_,
                          Young's modulus, Poisson ratio, 0)
       Rigidity of cheek 'BAL3DK (7, 8, 9, 10,11,12,
                          13,14,15, 16,17,18;
                          point B, point E, point Bx,
                          M. i. p. s. of the cheek Of ix_,
                          M. i. p. s. of the cheek Of iy_,
                          M. i. p. s. of cheek Ik,
                          Area p. s. of cheek,
                          Coeff.s of the shift of cheek on X_,
                          Coeff.s of the shift of cheek on Y_,
                          Young's modulus, Poisson ratio, 0)
       Rigidity of crankpin 'BAL3DK (13,14,15, 16,17,18, 19,20,21, 22,23,24;
                          point E, point F, point Ex,
```

```
                    M. i. p. s. of the crankpin Of ix_,
                    M. i. p. s. of the crankpin Of iy_,
                    M. i. p. s. of crankpin Ik,
                    Area p. s. of crankpin,
                    Coeff.s of shift connecting rod. neck on X_,
                    Coeff.s of shift connecting rod. neck on Y_,
                    Young's modulus, Poisson ratio, 0)
   Sluggishness of the main journal 'MJ3E (1,2, 3, 4, 5, 6;
                    point A,
                    point C1, point B, point Bx,
                    Mass of the main journal,
                    [GMI] X_ of the main journal,
                    [GMI] Y_ of the main journal,
                    [GMI] Z_ of the main journal)
   Sluggishness of counterweight 'MJ3E (7, 8, 9, 10,11,12;
                    point B,
                    point C3, point B, point Bx,
                    Mass of counterweight,
                    [GMI] X_ of counterweight,
                    [GMI] Y_ of counterweight,
                    [GMI] Z_ of counterweight)
   Sluggishness of cheek 'MJ3E (13,14,15, 16,17,18;
                    point E,
                    point C2, point B, point Bx,
                    Mass of cheek,
                    [GMI] X_ of cheek,
                    [GMI] Y_ of cheek,
                    [GMI] Z_ of cheek)
   Sluggishness of crankpin 'MJ3E (19,20,21, 22,23,24;
                    point F,
                    point C4, point E, point Ex,
                    Mass of crankpin,
                    [GMI] X_ of crankpin,
                    [GMI] Y_ of crankpin,
[GMI] Z_ of the crankpin
```

4. Connections

4.1.General information

For describing the models of elements, which assign the properties of connections before this division the following classification is conditionally accepted:

- the elements, which describe the dependence of force (moment) beyond the mutual displacement of the linked bodies (“rigid connections”);
- the elements, which describe the dependence of force (moment) beyond the relative speed of the motion of the linked bodies (“dissipative connections”);
- complex couplings.

In the general case the element can be used both for the task of the effort (or moment) of resistance to the build-up of relative speed or relative displacement and for the task of the moving effort (moment).

Before Fig. 4.1. are shown four characteristic examples to the relative dependence of effort beyond the mutual speed or the displacement of the linked bodies:

N 1 this is the characteristic of the usual viscous (or elastic) connection, when the damping factor μ depends on the speed (stiffness coefficient k it depends on displacement). Element generates the effort, directed down to the destruction of the difference between speeds or displacements of the linked bodies,;

NN 2,3 - the characteristics, which determine the initial effort (or moment) of interaction of those linked tel. The effort, generated by element, attempts to lead system beside the point, which corresponds to the zero value of the effort (indicated on the characteristics by pointers);

N 4 corresponds to the unstable characteristic of connection for the sake of the negative by the factors of damping and rigidity. Deviation from the position of equilibrium leads down an increase in the value of the effort, which increases this deviation.

For the simplest elements of the type K, SV3K, MU and so forth the task of generator characteristics is blocked with the analysis of the parameters of the model of element down the permissibility. For the elements of the type of the tabular dependence of force beyond the speed or the displacement the possibility to assign such characteristics is preserved; therefore in each specific case it is necessary to attentively analyze initial data of the decided task. If before the assigned table the sign of the relative speed or deformation does not coincide for the sake of the sign of effort (moment), this indicates of generator mode.

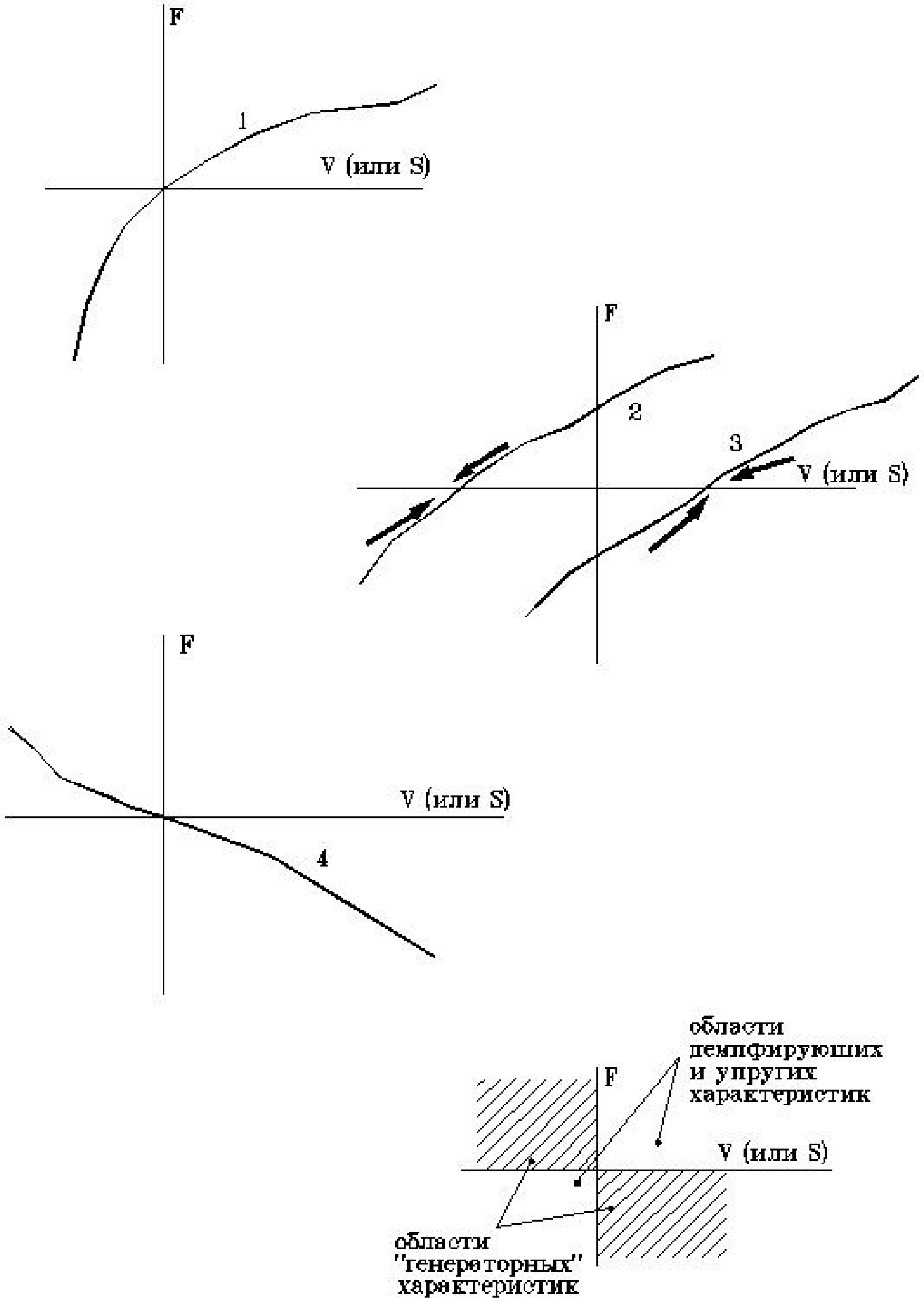


Fig. 4.1. **Different possible characteristics of the connections:**
1 characteristic, which assigns the usual damping or elastic element;
2, 3- the characteristic of the element, which assigns relative speed or relative displacement of those linked tel.
The steady value of speed (displacement) is indicated on the graphs by the pointers;
4 element with the negative damping (rigidity) and the point of unstable equilibrium with V=0.

4.2.One-dimensional connections

4.2.1.Rigid connections

4.2.1.1.Elastic constraint between two degrees of freedom K

Reflected properties

It serves for the task to the elastic constraint between two degrees of freedom ([ris].K_1). The dependence of effort F beyond the deformation of element is determined as far as Hooke's law:

$F = K *$ THE $\Delta\Xi$

, where F - the effort, which acts beyond the connection based on the side of the first body;
Stiffness coefficient *is k-th*;
$\Delta\Xi$ - the deformation of element.

Note. An element cannot be used for the binding of angular three-dimensional degrees of freedom.

Degrees of freedom

1 progressive or rotatory for the first linked body;

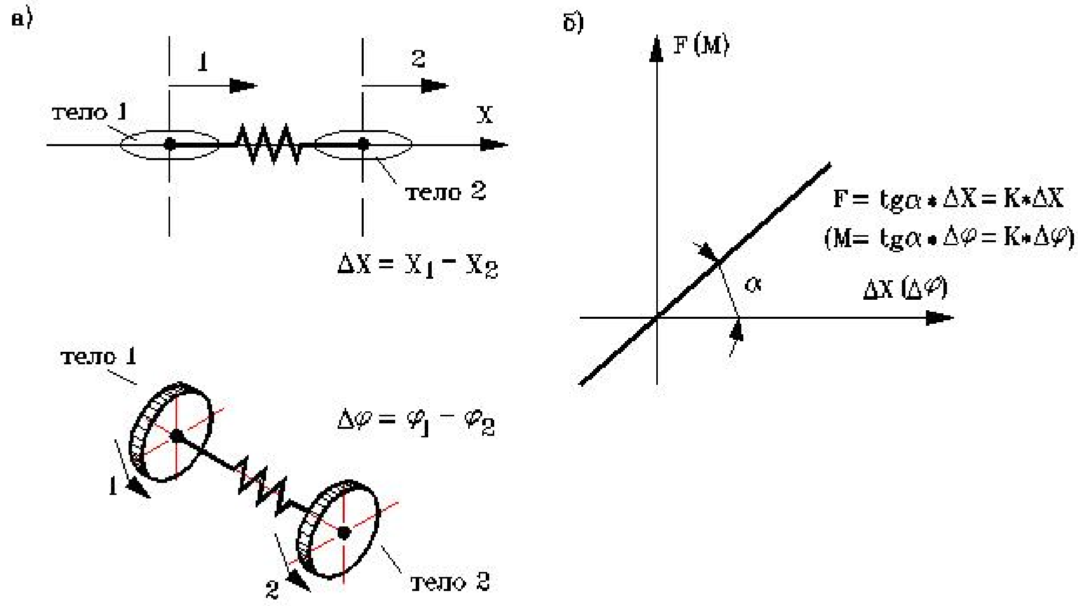
it is 2nd progressive or rotatory for the second linked body.

Parameters

N in sequence	Description	Dimensionality	Range
1	Stiffness coefficient	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE ENERGY, accumulated by the element	*George*	

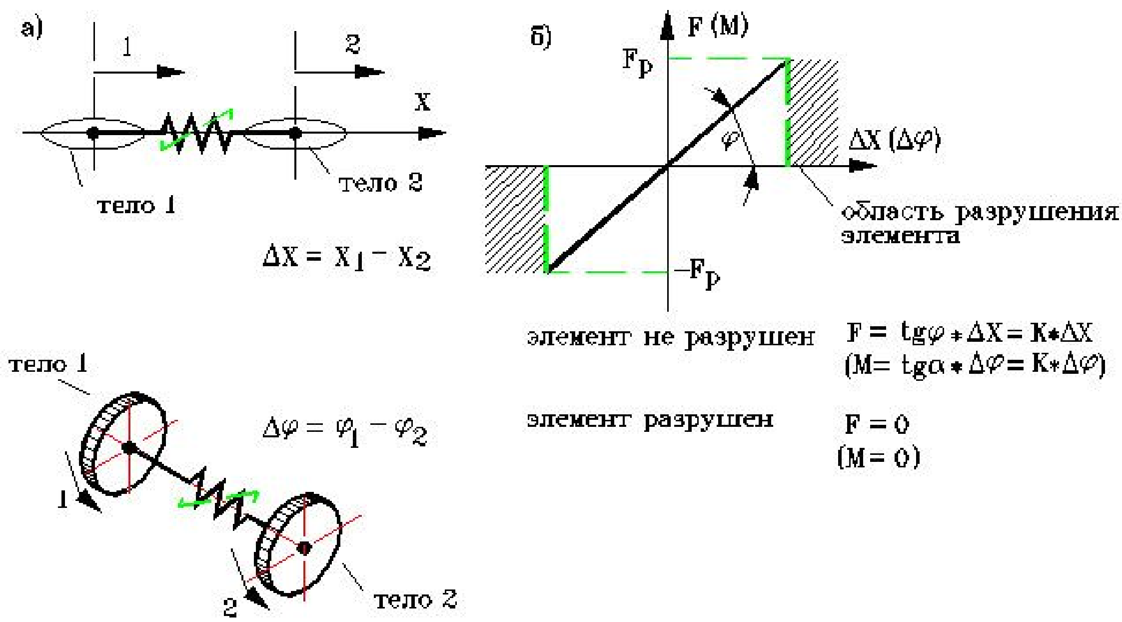


K_1. **Elastic constraint between two degrees of freedom.**
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔX (Δφ) - the deformation of element.
b) the dependence of effort (moment) beyond the deformation of connection.
To the stiffness coefficient of element.

4.2.1.2.Elastic constraint for the sake of brittle failure BRK

Reflected properties

It serves for the task to the elastic constraint between two bodies. At that moment when the absolute value of effort or moment attains the assigned magnitude, bond is broken (it is considered that the element is destroyed). The characteristic of connection is depicted beyond Fig. BRK_1.



BRK_1. **Elastic constraint c by brittle failure.**
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔX (Δφ) - the deformation of element.
b) the parameters:
To the stiffness coefficient of the element;
Fp - breaking stress.

Degrees of freedom

1 progressive or rotatory for the first linked body;

it is 2nd progressive or rotatory for the second linked body.

Parameters

N in sequence	Description	Dimensionality	Range
1	Stiffness coefficient	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*
2	The breaking stress	*N* or *[N]*[m]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE ENERGY, accumulated by the element	*George*	
2	THE SIGN of the destruction of element. If it is equal to 1, then element is not destroyed. If it is equal to 0 - element is destroyed		

4.2.1.3.Ideal elastic-plastic connection, the simplest element of dry friction KP

Reflected properties

The characteristic of element is depicted beyond Fig. KP_1. If deformation does not exceed the deformation of passage beside the plastic state, then the effort, generated by element, is subordinated down Hooke's law. If element passed beside the plastic state, then it generates the effort of constant, equal down the effort of the plastic deformation of element. You will focus attention on Fig. Of kP_1.[b]., that the line of unloading for the element is parallel to elastic line.

With the aid of the element KP it is possible to also simulate dry friction between the linked degrees of freedom, when the force of normal pressure beyond the contiguous surfaces and the coefficient of friction for the process being simulated can be accepted after constants. In this case the elastic section of characteristic is determined as far as the elastic deformations of contact layer before the direction of motion, which precede the moment of the beginning of slip. Section with the constant value of the force of interaction corresponds to the slippage of the first degree of freedom relative to the second with the frictional force:

*F[tr] = Of fmax = f * N*

, where *F[tr]* - the frictional force of the slip;
f - the coefficient of the friction;
It is n-th the normal clamping force.

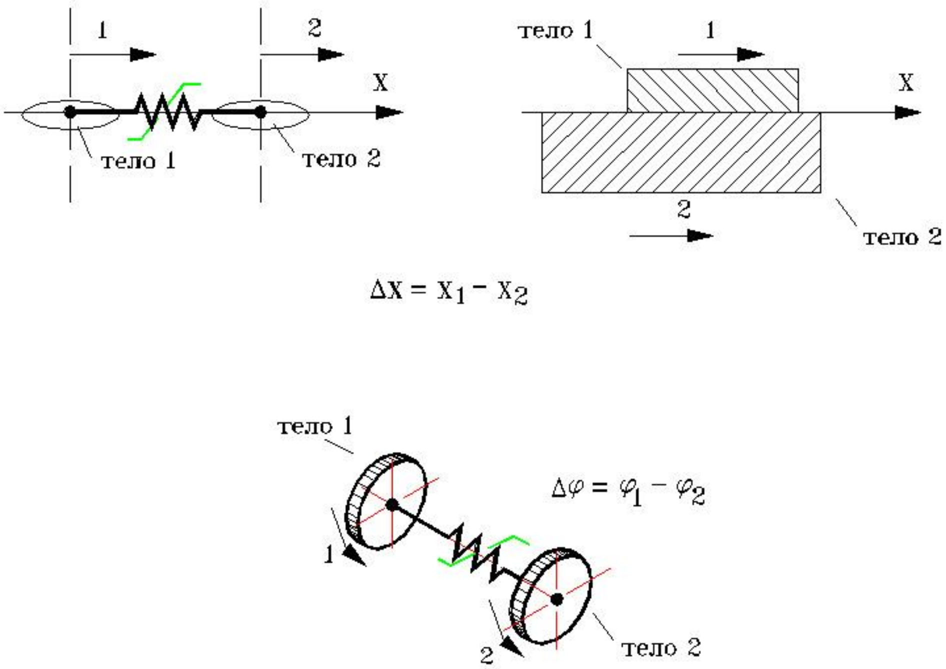
Degrees of freedom

1	progressive or rotatory for the first linked body;
it is 2nd	progressive or rotatory for the second linked body.

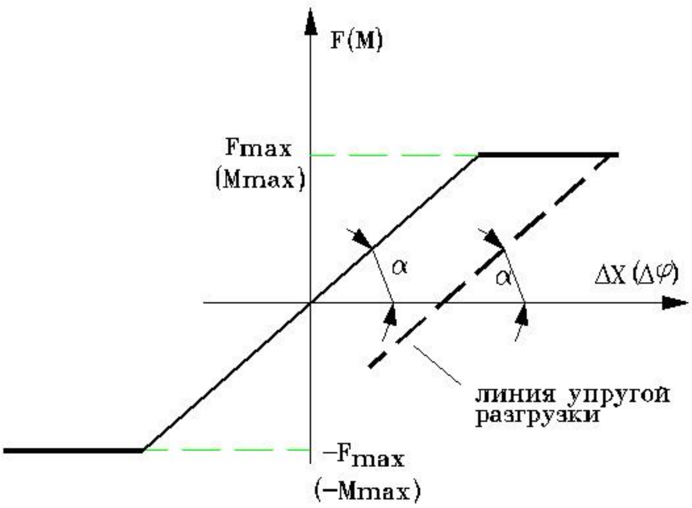
Parameters

N in sequence	Description	Dimensionality	Range
1	Stiffness coefficient	*N/m* or *[N]*[m]/[rad]*	*0... +RLmax*
2	Effort of plastic deformation (effort of friction)	*N* or *N/m*	*0... +RLmax*

а)



б)



KP_1. **Ideal elastic-plastic connection (ideal dry friction).**
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔX (Δφ) - the deformation of element.
b) the parameters:
To the stiffness coefficient of the element;
Fp - breaking stress.

4.2.1.4.Nonlinear elastic dimensionless spring KNL

Reflected properties

The characteristic of connection is depicted beyond Fig. KNL_1. The effort, generated by element, obeys the law:

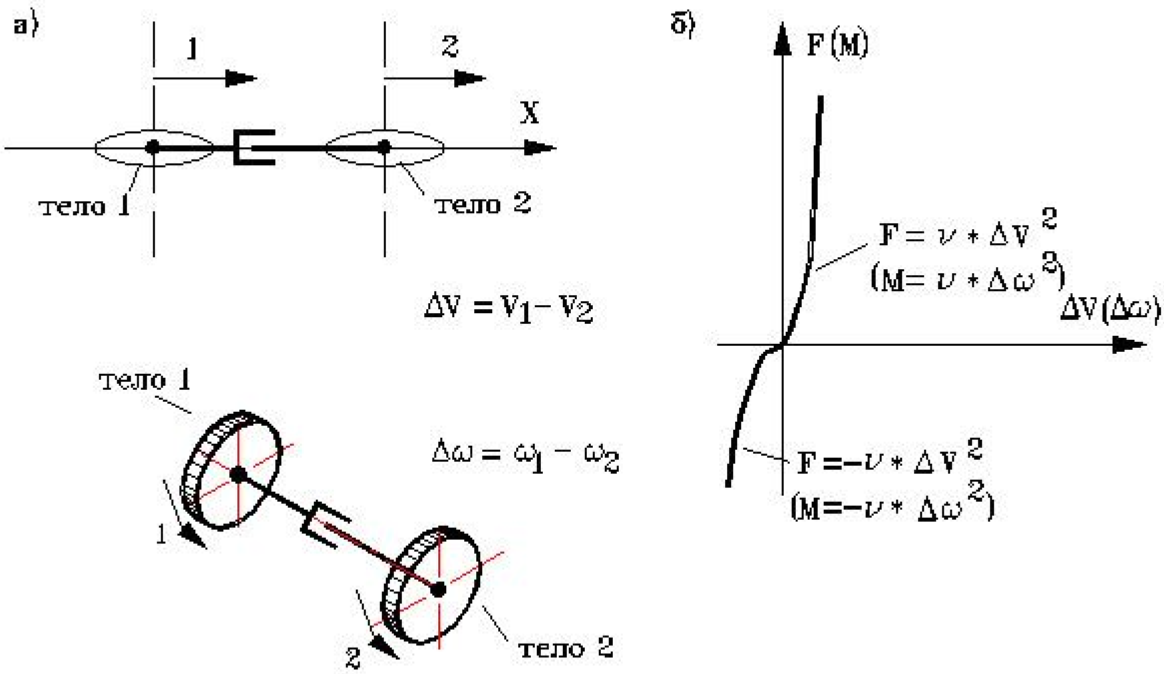
$F = C *$ THE $\Delta\Xi *$ OF THE I THE $\Delta\Xi$ OF THE I

, where C - constant of proportionality between the square of deformation and the effort; $\Delta\Xi$ - the deformation of element.

Degrees of freedom

1 progressive or rotatory for the first linked body;

it is 2nd progressive or rotatory for the second linked body.



KNL_1. Elastic constraint between two degrees of freedom for the sake of the quadratic dependence of effort beyond the deformation.
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔX ($\Delta\varphi$) - the deformation of element.
b) the parameters:
With constant of proportionality between the square of deformation and the effort.

Parameters

N in sequence	Description	Dimensionality	Range
1	Constant of proportionality between the square of deformation and the effort	*[N]/[m]2* or *[N]*[m]/[rad]2*	*0… +RLmax*

4.2.1.5.One-dimensional ratchet with the free forward stroke and the linear elastic resistance with the back stroke HRP

Reflected properties

The motion of the first body relative to the second before the positive direction of the axis of coordinates (forward stroke) occurs without difficulty. Connection prevents the negative motion of the first body relative to the second, i.e., to back stroke (Fig. HRP_1).

Elastic resisting force is determined as far as the dependence:

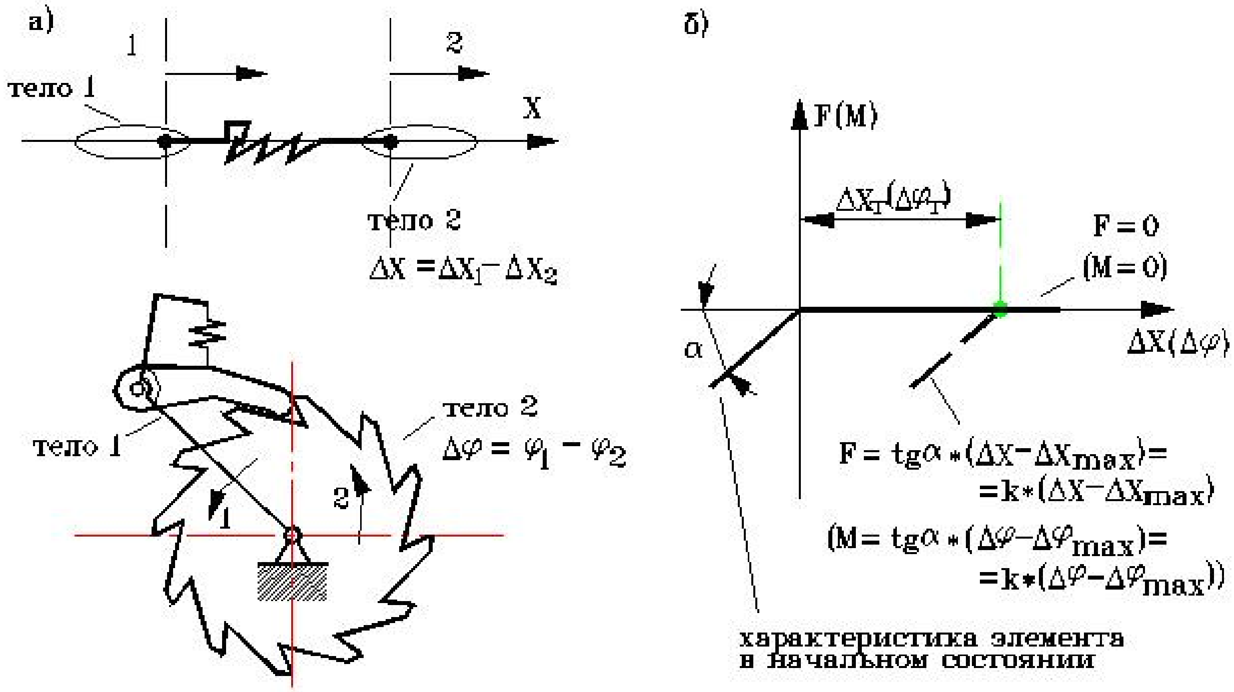
$$F = K * (\Delta\Xi - \Delta\Xi_{\ of\,max})$$

, where *IS K-TH* stiffness coefficient;

$\Delta\Xi_{\ of\,max}$ - the maximum deformation of the element reached;

$\Delta\Xi$ - the current deformation of element (ΔΞ =<ΔΞμαξ).

By deformation of element is understood the difference between the displacements of the first and second body.



HRP_1. One-dimensional ratchet.
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔX (Δφ) - the deformation of the element;
ΔXmax (Δφmax) - the maximum deformation of element reached.
b) the dependence of effort beyond the relative displacement of the first and the second tel. To the stiffness coefficient of element with the back stroke.

Degrees of freedom

1 progressive or rotatory for the first linked body;

it is 2nd progressive or rotatory for the second linked body.

Parameters

N in sequence	Description	Dimensionality	Range
1	Stiffness coefficient	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

4.2.2.Dissipative connections

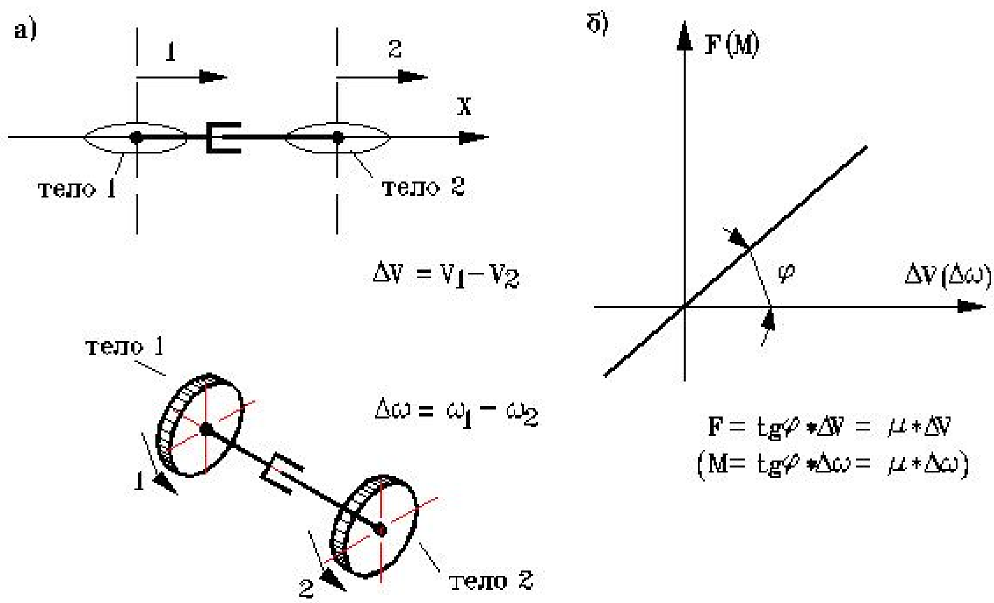
4.2.2.1.Linear one-dimensional liquid resistance OF MU

Reflected properties

It serves for the task to the ideal viscous connection between two bodies (Fig. MU_1). The value of the generated by element effort F is determined as far as the relationship:

$F = - \mu * \Delta\varsigma$

, where THE $\Delta\varsigma$ - the relative speed of the bodies;
$\tau\eta\varepsilon$ μ - the coefficient of viscosity.



MU_1. Viscous connection between the degrees of freedom.
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔV (Δω) - the rate of deformation of the element;
b) the dependence of effort beyond the deformation rate.
μ - the coefficient of the viscosity of element.

Degrees of freedom

1	progressive or rotatory for the first linked body;
it is 2nd	progressive or rotatory for the second linked body.

Parameters

N in sequence	Description	Dimensionality	Range
1	Coefficient of the viscosity	*[N]*[s]/[m]* or *[N]*[m]*[s]/[rad]*	*0… +RLmax*

4.2.2.2.Liquid resistance with the quadratic dependence beyond the speed MUNL

Reflected properties

The characteristic of the connection of element is depicted beyond Fig. MUNL_1. If deformation does not exceed the deformation of passage beside the plastic state, then the effort, generated by element, obeys the law:

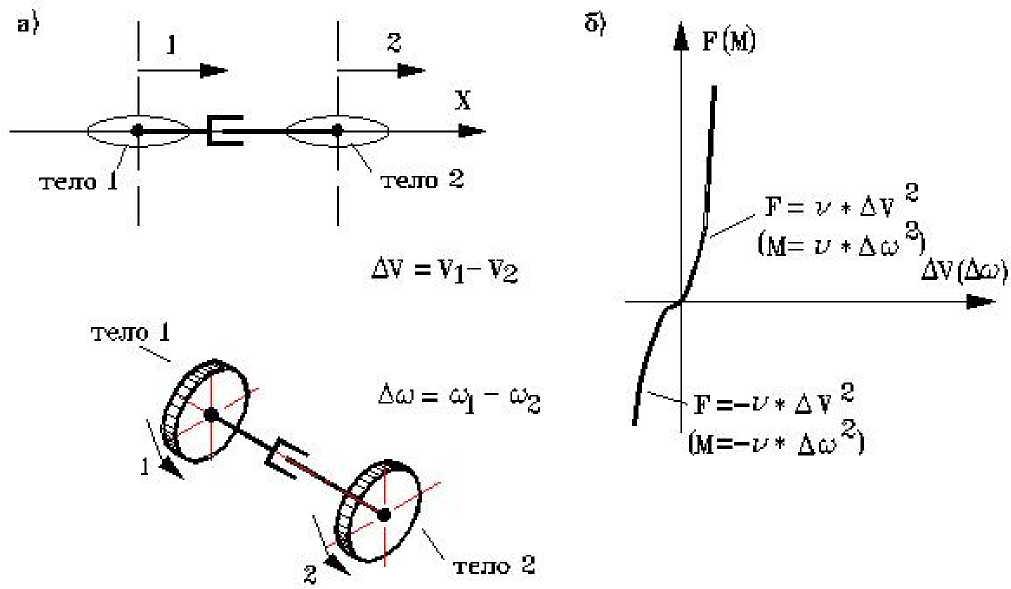
$F = \nu$ * THE Δς OF THE I THE Δς of the I

, where THE Δς - the relative speed of the bodies;
constant of proportionality between the square of relative speed and the effort *ισ ν–τη*.

Degrees of freedom

1 progressive or rotatory for the first linked body;

it is 2nd progressive or rotatory for the second linked body.



MUNL_1. Relation between two degrees of freedom for the sake of the quadratic dependence of effort beyond the deformation rate.
a) of degree of freedom and the deformation of the element:
1 translational (rotatory) degree of freedom of the first body;
it is 2nd the translational (rotatory) degree of freedom of the second body;
ΔV (Δω) - the rate of deformation of the element;
b) the dependence of effort beyond the deformation rate.
ν - constant of proportionality between effort and square of speed.

Parameters

N in sequence	Description	Dimensionality	Range
1	Constant of proportionality between the square of speed and the effort	*[N]* *([sek]/[m])* ^{2} or *[N]*[m]* * (it flogged/rad)* ^{2}	*0… +RLmax*

4.2.2.3.One-dimensional elastic constraint for the sake of the characteristic the deformation-effort, by assigned tabular SV1KT

Reflected properties

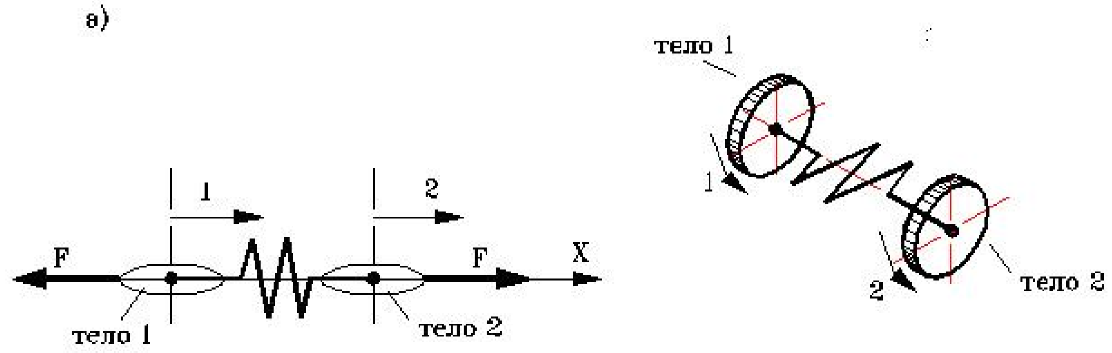
The elastic constraint between two bodies is assigned. The characteristic of connection is assigned in the form the table of values "the deformation - effort" (Fig. SV1KT_1).

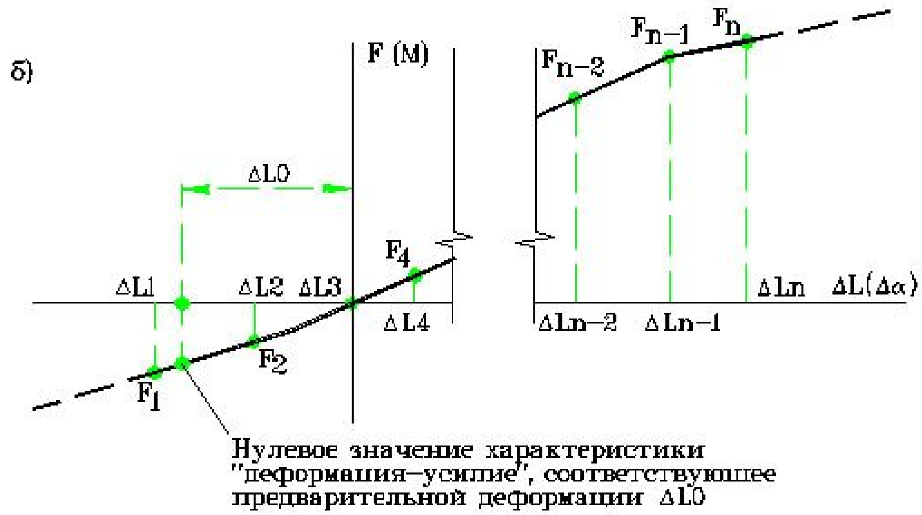
The rules, which must be observed with the task of the table:

1. points of the dependence of effort beyond the displacement must be regulated on the growth of deformation ($\delta\Lambda\iota =< \delta\Lambda\iota_{+1}$). For the first two and two last points must be satisfied the condition $\delta\Lambda\iota < \delta\Lambda\iota_{+1}$;
2. must be prescribed as the minimum two points of the dependence of effort beyond the displacement.

Degrees of freedom

1	progressive (rotatory) for the first linked body;
it is 2nd	progressive (rotatory) for the second linked body.





SV1KT_1. **One-dimensional connection, which realizes the tabular dependence of effort beyond the deformation.**
Adopted designations:
F - the effort, which acts beyond the combinable bodies based on the side of the connection;
ΔL - the deformation of element.
a) of the degree of freedom of the model:
1 displacement of the first body;
it is 2nd the displacement of the second body;
b) the tabular dependence of effort beyond the deformation. Each point of table is assigned by the pair of values "the deformation-effort". As a result of the limits of the interval of displacement L1-Ln the effort of connection is determined as far as the extrapolation of the extreme sections of characteristic.

Parameters

N in sequence	Description	Dimensionality	Range
1	Preliminary deformation of the element	*m*	*-RLmax… of +RLmax*
2	$\delta\Lambda_1$ - deformation for the first given point of the characteristic	*m*	*-RLmax… of +RLmax*
3	*F1* - the effort, which corresponds to deformation $\delta\Lambda_1$	*N*	*-RLmax… of +RLmax*
	…..		
2*i	τηε δΛι - deformation for *i*-y of the given point of the characteristic	*m*	dLi_{-1} … *+RLmax*
2*i+1	*Fi* - the effort, which corresponds to deformation τηε δΛι	*N*	*-RLmax… of +RLmax*
	…..		
2*n	τηε δΛν - deformation for *the n-th* given point of the characteristic	*m*	dLn_{-1} … *+RLmax*
2*n+1	*Fn* - the effort, which corresponds to deformation τηε δΛν	*N*	*-RLmax… of +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE AMOUNT of the deformation of the element	*m*	

4.2.2.4. One-dimensional viscous relation for the sake of the assigned tabular dependence of effort beyond the speed SV1MUT

Reflected properties

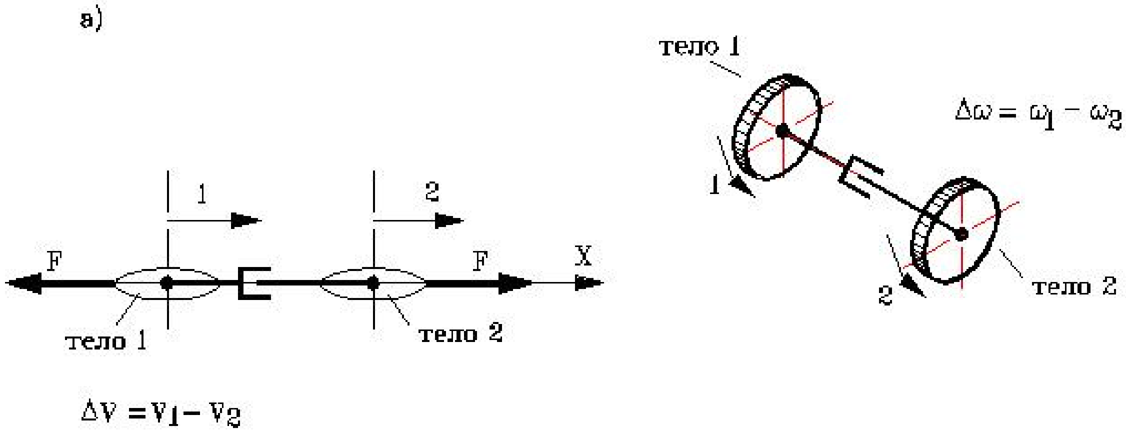
It serves for the task to the tabular dependence of the effort, which acts based on the side of the first body to the connection from the relative speed of the linked bodies $\Delta\varsigma = V1 - V2$ (Fig. SV1MUT_1). The effort, which acts based on the side of the second body to the connection, will be the same before the absolute value, but opposite on the sign.

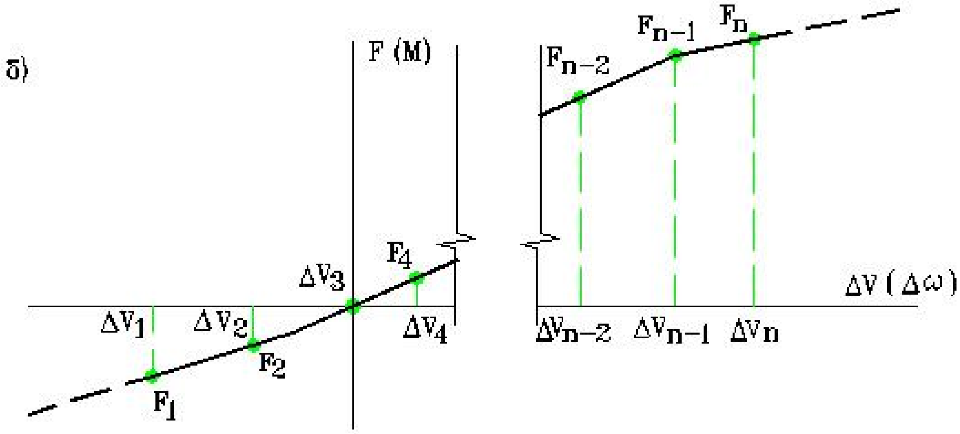
The rules, which must be observed with the task of the table:

1. points of the dependence of effort beyond the speed must be regulated on the growth of velocity ($Vi =< Vi+1$). For the first two and two last points must be satisfied the condition $Vi < Vi+1$;
2. must be prescribed as the minimum two points of the dependence of effort beyond the speed.

Degrees of freedom

1	progressive or rotatory for the first linked body;
it is 2nd	progressive or rotatory for the second linked body.





SV1MUT_1. One-dimensional connection, which realizes the tabular dependence of effort beyond the speed.
Adopted designations:
F - the effort, which acts beyond the combinable bodies based on the side of the connection;
ΔV - the speed of the first body relative to the second.
a) of the degree of freedom of the model:
1 displacement of the first body;
it is 2nd the displacement of the second body;
b) the tabular dependence of effort beyond the speed. Each point of table is assigned by the pair of values “the speed-effort”. As a result of the limits of the interval of displacement ΔV1- ΔVn the effort of connection is determined as far as the extrapolation of the extreme sections of characteristic.

Parameters

N in sequence	Description	Dimensionality	Range
1	$\Delta\varsigma_1$ - speed for the first given point of the characteristic	*m/s* or *rad/flogged*	*-RLmax… of +RLmax*
2	*F1* - the effort (moment), which corresponds to speed $\Delta\varsigma_1$	*N* or *[N]*[m]*	*-RLmax… of +RLmax*
	…..		
2*i-*1*	Δςι - speed for *i*-y of the given point of the characteristic	*m/s* or *rad/flogged*	$\Delta\varsigma_{(i-1)}$… *+RLmax*
2*i	*Fi* - the effort (moment), which corresponds to speed τηε Δςι	*N* or *[N]*[m]*	*-Rlmax… +RLmax*
	…..		
2*n-*1*	Δςν - speed for *the n-th* given point of the characteristic	*m/s* or *rad/flogged*	$\Delta\varsigma_{(n-1)}$… *+RLmax*
2*n	*Fn* - the effort (moment), which corresponds to speed τηε Δςν	*N* or *[N]*[m]*	*-Rlmax… +RLmax*

4.3.Two-dimensional elements

4.3.1.Rigid connections

4.3.1.1.Linear elastic dimensionless spring SV2K

Reflected properties

It serves for the task to the elastic constraint between two bodies, which move in the plane (Fig. SV2K_1). The value of the generated by element effort F is determined as far as Hooke's law:

$$F = - K * \text{THE } \Delta\Lambda$$

, where THE $\Delta\Lambda$ - the deformation of the element;
Stiffness coefficient *is k-th*.
Note. The initial length of element, determined as far as the prescribed origin coordinates of its ends, must be more than zero.

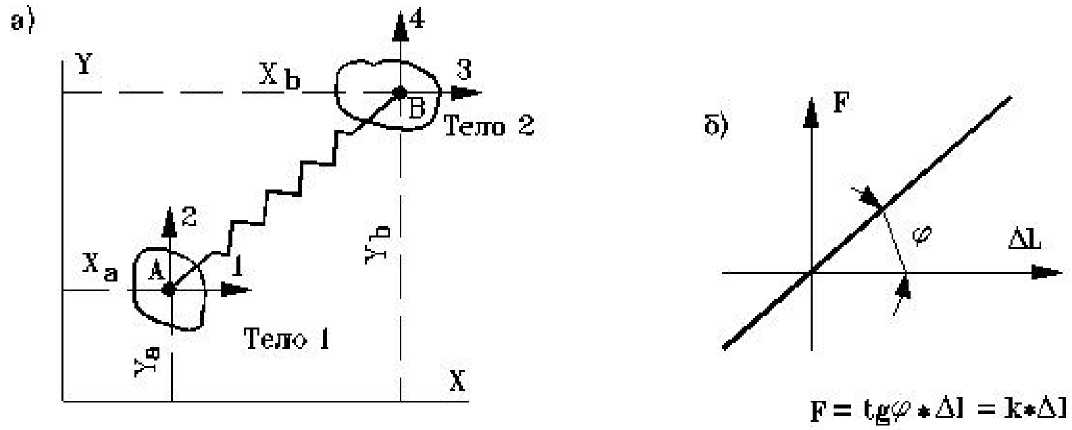
Degrees of freedom

1,2 - progressive for the first linked body on to x and y axes;

3,4 - progressive for the second linked body on to x and y axes.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	The origin coordinates of the first linked body (Xa, Ya)	*m*	*-RLmax… of +RLmax*
3,4	The origin coordinates of the second linked body (the X, Y)	*m*	*-RLmax… of +RLmax*
5	Stiffness coefficient	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

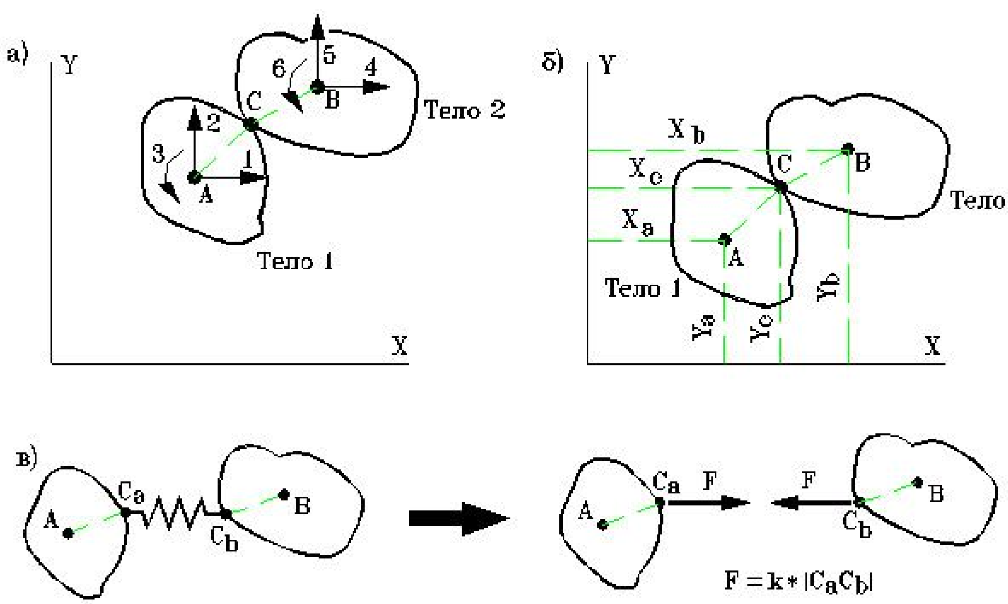


SV2K_1. **Linear ideally elastic two-dimensional connection, working in the tension-compression.**
a) of degree of freedom and the geometric parameters of the element:
1,2 - the motion of point A (1st body) on to x and y axes;
3, 4 motion of point B (2-GO of body) on to x and y axes;
Xa, Ya - the initial position of point A;
Xb, Yb - the initial position of point B;
b) the dependence of axial force beyond the relative displacement of the first and the second tel. To the stiffness coefficient of element.

4.3.1.2. The joint of two bodies, which accomplish plane motion SV2SHR_1

Reflected properties

It serves for the task to the ideal (without the clearances and the friction) joint between two bodies. The position of each of the bodies is described, correspondingly, by points A and B, which accomplish the plane motion (Fig. SV2SHR_1). In the general case the origin coordinates of the center of joint (point C) coincide neither for the sake of the point A nor for the sake of the point B.



SV2SHR_1. Two-dimensional ideally elastic joint.
a) of the degree of freedom of the element:
1,2, 3- progressive and rotatory of the point, which describes the motion of the first body (point a);
4, 5, 6 progressive and rotatory of the point, which describes the motion of the second body (point B);
b) the geometric parameters:
Xa, Ya - the initial position of point A;
Xb, Yb - the initial position of point B;
X[s], Y[s] - the initial position of point [s];
c) one of the possible positions of the connected by connection bodies in the course of motion and the force, which act in this case beyond the bodies. To the stiffness coefficient of joint.

Degrees of freedom

1,2 - progressive on to x and y axes of point A;

3- rotatory of point A;

4,5 - progressive on to x and y axes of point B;

6 rotatory of point B.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	The origin coordinates of point A (Xa, Ya)	*m*	*-RLmax… of +RLmax*
3, 4	The origin coordinates of point B (Xb, Yb)	*m*	*-RLmax… of +RLmax*
5, 6	The origin coordinates of the center of joint (Xc, Yc)	*m*	*-RLmax… of +RLmax*
7	Stiffness coefficient of joint down the tension-the compression	*N/m*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE CURRENT deformation of joint (distance between the points Ca and Cb before Fig. SV2SHR_1)	*m*	
2	THE VALUE of the effort, which acts based on the side of joint to the linked bodies	*N*	

4.4. Three-dimensional elements

4.4.1. Rigid connections

4.4.1.1. Elastic constraint between two points for the sake of the characteristic the deformation-effort, by assigned tabular SV3KT

Reflected properties

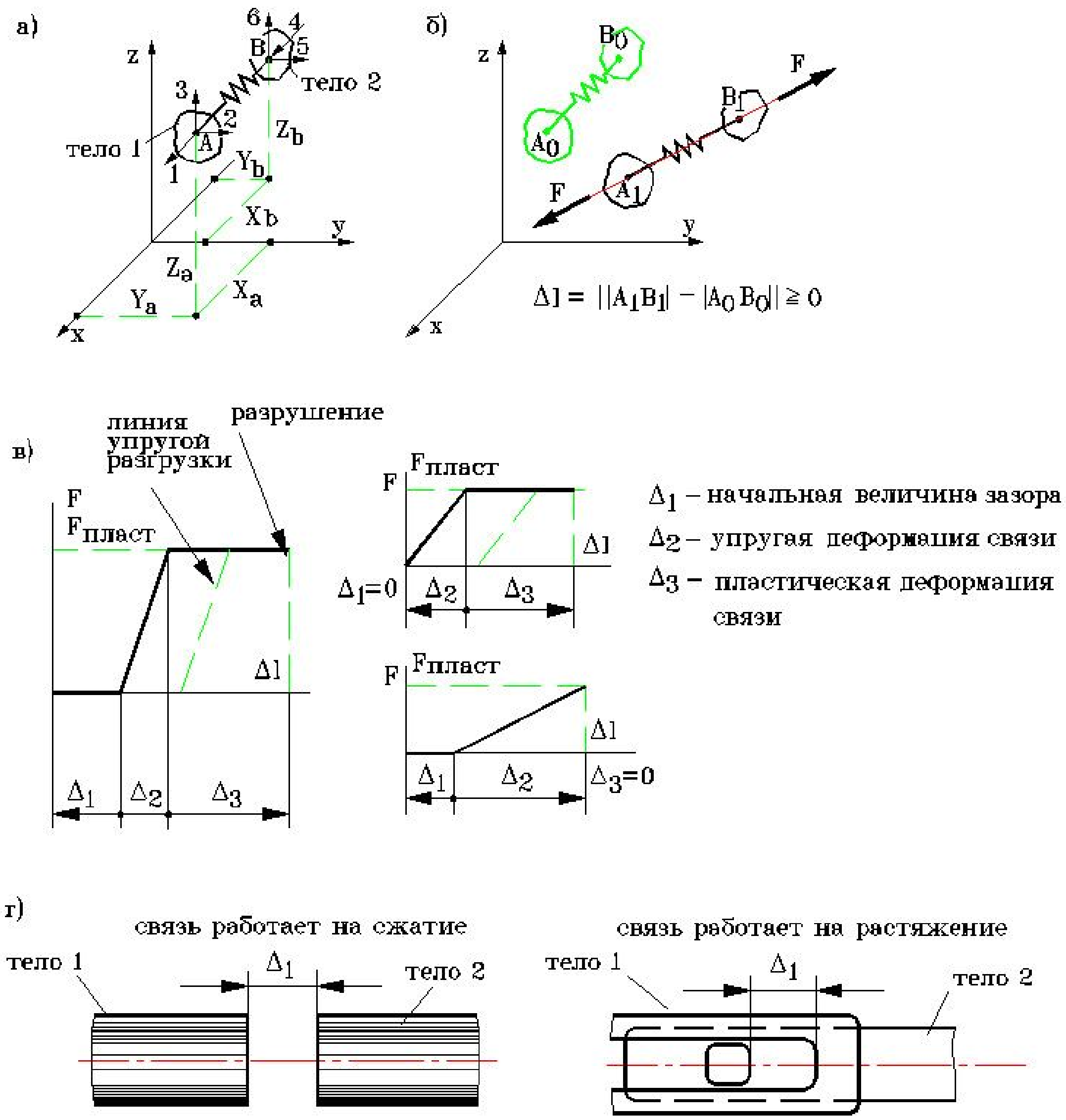
The elastic constraint (line of load it coincides for the sake of the line of unloading) is assigned between two bodies, which accomplish spatial motion. The deformation of element is defined as the difference between the instantaneous length and the length of element before the nondeformed state. The characteristic of connection is assigned in the form the table of values "the deformation - effort" (see Fig. SV3KT_1).

The rules, which must be observed with the task of the table:

1. points of the dependence of effort beyond the displacement must be regulated on the growth of deformation ($\delta\Lambda\iota$ =< $\delta\Lambda\iota_{+1)}$. For the first two and two last points must be satisfied the condition $\delta\Lambda\iota < \delta\Lambda\iota_{+1}$;
2. must be prescribed as the minimum two points of the dependence of effort beyond the displacement.

The parameter "length of element before the nondeformed state" makes it possible to assign elements with the preliminary deformations. If this parameter is more than zero, then the initial deformation of element is received equal down the difference between the initial length (it is determined as far as the origin coordinates of the ends of the element) and length of element before the nondeformed state. If the parameter less or is equal to 0, then it is considered that before the initial state the element is not deformed.

Note. The initial length of element, determined as far as the prescribed origin coordinates of its ends, must be more than zero.



SV3KT_1. **Three-dimensional connection, which realizes the tabular dependence of effort beyond the deformation.**

Adopted designations:

F - the effort, which acts beyond the connection based on the side of the combinable bodies;

Δl - the axial deformation of element.

a) of the degree of freedom of model and the parameters, which determine the initial arrangement of element before the space:

1,2, 3- the displacement of the first body by means of the axes of the X, Y, Z;

4, 5, 6 displacement of the second body by means of the axes of the X, Y, Z;

Xa, Ya, Za - the origin coordinates of point A;

Xb, Yb, Zb - the origin coordinates of point B.

b) the determination of the axial deformation of the element;

c) the tabular dependence of effort beyond the deformation. Each point of table is assigned by the pair of values “the deformation-effort”. As a result of the limits of the interval of the deformations Of δl1- Δln the effort of connection is determined as far as the extrapolation of the extreme sections of characteristic.

Degrees of freedom

1,2,3 - progressive across the x axis, Y and Z of the first body;

4,5,6 - progressive across the x axis, Y and Z of the second body.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of the first linked body (Xa, Ya, Za)	*m*	*-RLmax… of +RLmax*
4,5,6	The origin coordinates of the second linked body (Xb, Yb, Zb)	*m*	*-RLmax… of +RLmax*
7	Length of element before the nondeformed state	*m*	*-RLmax… of +RLmax*
8	$\delta\Lambda_1$ - deformation for the first given point of the characteristic	*m*	*-RLmax… of +RLmax*
9	*F1* - the effort, which corresponds to deformation $\delta\Lambda_1$	*N*	*-RLmax… of +RLmax*
	…..		
2*i+6	τηε δΛι - deformation for *i*-y of the given point of the characteristic	*m*	τηε $\delta\Lambda\iota_{-1}$ … *+RLmax*
2*i+7	*Fi* - the effort, which corresponds to deformation τηε δΛι	*N*	*-RLmax… of +RLmax*
	…..		
2*n+6	τηε δΛν - deformation for *the n-th* given point of the characteristic	*m*	$\delta\Lambda\nu_{-1}$ … *+RLmax*
2*n+7	*Fn* - the effort, which corresponds to deformation τηε δΛν	*N*	*-RLmax… of +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE AMOUNT of the deformation of the element	*m*	

N in sequence	Description	Dimensionality	Range
2	AXIAL force before the element	*N*	

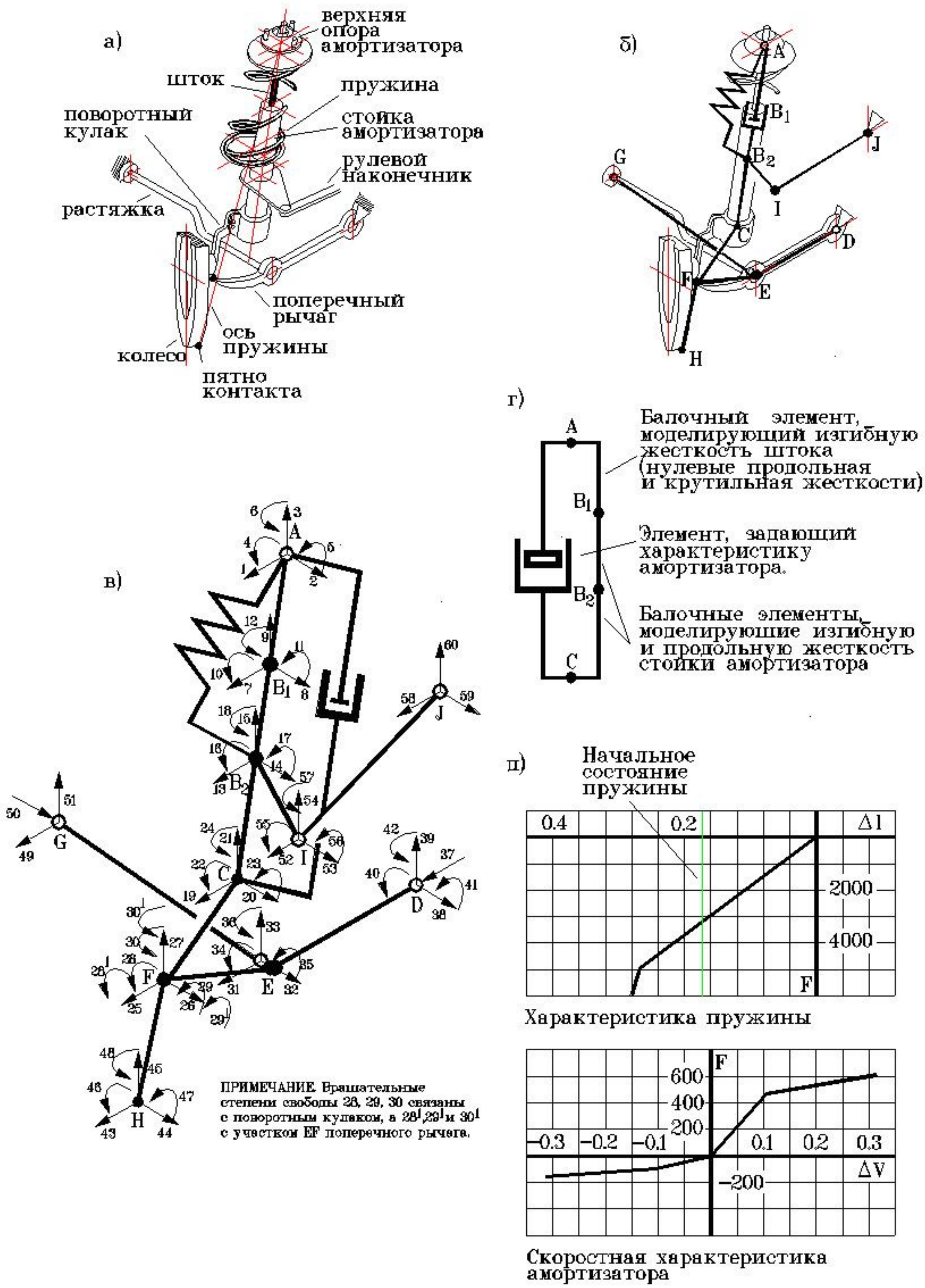
Example of the use

The problem of the transmission of effort based on the side of front suspension to the body of automobile before the places of fastening basic levers with different states of motion of automobile is solved. The design concept of suspension is given down [ris].SV3KT_2.[a]. the position of the characteristic points of suspension (Fig. Of sV3KT_2.[b].) before the system of coordinates of the automobile:

```
Point A = 0.014, -0.518 , 0.596 ;
Point Of b1= 0.0105, -0.5332, 0.4383;
Point Of b2= 0.0082, -0.5413, 0.3542;
Point C = 0.002, -0.566 , 0.098 ;
Point D = 0.060, -0.352 , -0.028 ;
Point E = 0.015, -0.587 , -0.047 ;
Point F = 0.000, -0.666 , -0.040 ;
Point G =-0.465, -0.352 , 0.007 ;
Point H =
Point of the I = 0.138, -0.560, 0.341 ;
Point J = 0.138, -0.025, 0.341 ;
```

Note. The model of suspension before the task in question is substantially simplified so that its text would become more visible. It is for this purpose accepted that the axis of spring coincides for the sake of the axis of shock absorber. The places of fastening the spring carrier and bracket of steering rod to the counter of shock absorber coincide (point B2). Stretching has rectilinear axis, the cross sections of all levers are symmetrical (orientation of cross section before the space it is indifferent). Load beyond the suspension based on the side of road is transferred through the girder element, which simulates the elastic properties of wheel. The pliability of joint is not considered. Material of all elements of the suspension - steel.

The telescope of shock absorber is represented before the model by the diagram, depicted separately beyond Fig. Of sV3KT_2.[g]. girder elements B1B2 and B2C are used for the simulation of the bending and longitudinal rigidity of the counter of shock absorber. Down the element B2C is closed the longitudinal force of spring AB (before the more detailed model of the suspension between the point B and the lower end of the spring they must be present the elements, which simulate spring carrier).



SV3KT_2. **Model of the front suspension of the passenger automobile:**
a) the design concept of the suspension;
b) the structure of design diagram and designation of the characteristic points;
c) the numeration of degrees of freedom;
d) the structure of the model of the telescopic hydro-shock absorber;
e) the characteristic of compression of spring and the speed characteristic of shock absorber.

For the simulation of the flexural rigidity of stock is used girder element AB1. The zero longitudinal rigidity of this element makes possible at the point of point A to move freely along the axis of shock absorber (line, which connects points B and C). The displacement of point A before the direction, perpendicular down the axis of shock absorber, will prevent the flexural rigidity of girders AB1 and B1B2. In this case automatically is considered a change of the flexural rigidity of girder element AB1 before the dependence beyond a change in its length. Since the stock can pivot around its axis, the torsional stiffness of girder AB1 is also received after zero.

For the simulation of compression spring is used the element SV3KT, and the dependence of effort before the shock absorber beyond the speed is simulated by element SV3MUT. The characteristic of spring and the speed characteristic of shock absorber are given down [ris].SV3KT_2.[d].

The decomposition of the model of suspension down the elements is shown before Fig. Of sV3KT_3.[a].

It is necessary to find the efforts, transferred down the body of automobile before the place of fastening stock under the vertical influence beyond the wheel in the form of sinusoid with different by amplitude and frequency.

Text of the description of the model:

```
I DATA:
                           {The parameters of materials}
   Modulus of elasticity of steel = of 2.E11
   Poisson ratio = 0.3
   Density of steel = 7800
               Steel = the modulus of elasticity of steel,
               Poisson ratio,
               Steel density
                          {The geometry of construction}
   Point A = 0.014, -0.518 , 0.596 {the upper point of stock}
   Point Of b1= 0.0105, -0.5332, 0.4383 {guard of rod}
   Point Of b2= 0.0082, -0.5413, 0.3542 {the lower end of the spring}
   Point C = 0.002, -0.566 , 0.098 {the bottom of counter}
   Point D = 0.060, -0.352 , -0.028   {fastening [pop].[rychaga]
                                                      to the body}
   Point E = 0.015, -0.587 , -0.047   {the connection of the stretching
                                            and transverse lever}
   Point F = 0.000, -0.666 , -0.040   {spherical bearing}
   Point G =-0.465, -0.352 , 0.007 {fastening stretching [k]
                                            to body}
   Point H = 0,      -0.739 , -0.250   {the area of contact}
   Point of the I = 0.138,  -0.560 , 0.341 {the end of the rotary
                                            lever}
   Point J = 0.138,  -0.025, 0.341 {the connection of the autopilot
                                            tip with the lath}
   Axis of joint D = 0.043, -0.349,  -0.027,
                     0.077, -0.355,  -0.029

          {The geometric moments of inertia and cross-sectional
                        area of the levers :

                    Jx, Jy, Jk, S}
     Section of stock = 1.15e-8, 1.15e-8, 0.00, 0.0 ;
     Section of counter = 1.40e-7, 1.40e-7, 2.8e-7, 5.50e-4;
```

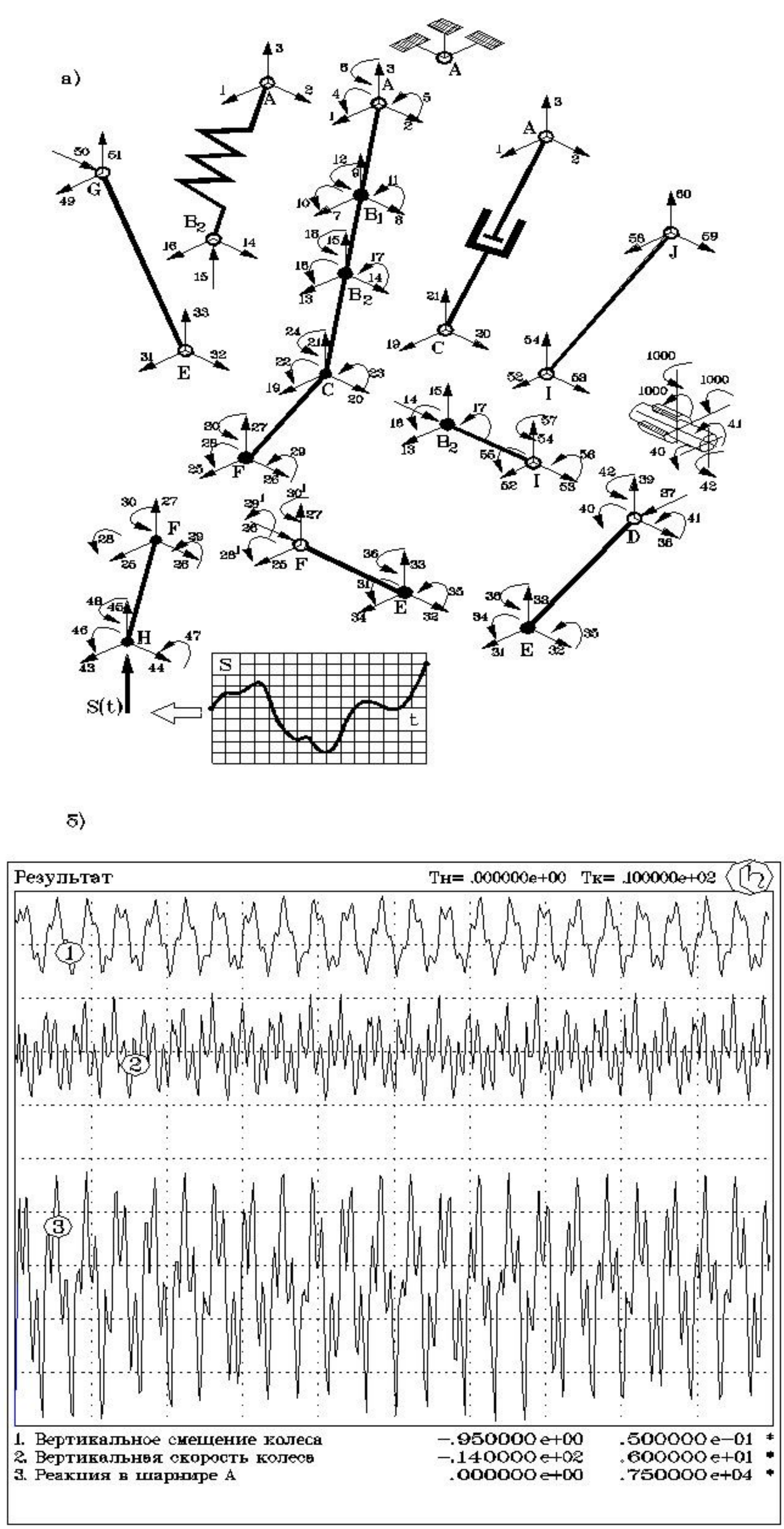
```
 Section of rotating holder =
            3.20e-8, 3.20e-8, 1.5e-8, 3.45e-4;
 Section of transverse lever =
            1.90e-8, 1.90e-8, 3.3e-8, 4.80e-4;
 Section of rolling cam =

            4.00e-8, 4.00e-8, 8.0e-8, 4.50e-4;
 Section of wheel =
                          3.00e-8, 3.00e-8, 6.0e-8, 4.00e-4;

       {The rigidity of joint the transverse lever - the body:

             Kl Kr Of k[i] Kk}
 Rigidity of joint D = 6.8 e5, 1.7 e6, 100, 100

   {The rigidity of body in the place of fastening stock to the body

             Kx Ky Kz}
 Rigidity of the body = of 1e5, 1e5, 1e5

           {The parameters of stretching and steering tip:

             Mass, lm, S, E}
Parameters of stretching = 1.4, 0.5, 4.15e-4, 2.e11
Parameters of the steering tip
           = 1.0, 0.5, 4.00e-4, 2.e11

          {The characteristic of spring and shock absorber}
Characteristic of spring =  -0.173,   - 3195,
               0, 0,
               1, 0
 Initial length of spring = 0.418;
 It [skorost]. nature. shock absorber =
               -0.314,   -  153,
               -0.105,   -   94,
               0, 0,
               0.105, 471,
               0.314, 612
Limitation of the motion of ring-off =
               0, 0,
               94.E-3, 0,
               95.E-3, 1.E4

                      {The concentrated masses}
Mass A = 0.1 ;      Moment of the inertia of joint A = 0.01;
Mass B2 = 0.1 ;      Mass D = 0. ;
Mass E = 0.21;      Mass F = 1.5;
Mass G = 0.  ;      Mass H = 5.3;
Mass of the I = 0.05;      Mass J = 0. ;

                      {Action beyond the wheel}

 Amplitude = 0.023; Period = 0.13; Phase = 0
 Amplitude 1= 0.071; Period 1= 0.43; Phase 1= 0
 Rigidity of the tire = of 1.E5;
```

```
 {The image of suspension beyond the shield in the course of computation}
  Parameters of image = 1.5, of 0, 0, 0,
                                  0.3, -1, 0,
                                  0.2, 0,
                                  0
  Diameter of spring = 0.35;   Quantity of turns = 4;
  Diameter of shock absorber = 0.15;
  Relative sizes = of 0.15, 0.7;
  Diameter of joint = 0.05;
  Dimensions of support = 0.1, 2, the diameter of the joint;
I FRAGMENT: Suspension
  # BASE:
       49, 50, 51, {fastening to the body of stretching}
       58, 59, 60, {fastening to the body of steering tip}
       1000
  # STRUCTURE:
                         {Hydro-shock absorber}
   Body 'KBASE (1 2 Oe;  Rigidity of body)
   Stock 'BAL3DJ (1 2 Oe 4 5 6 7 8 9 10 11 12;
                         Point A, [Tochk] B1, point A,
                         Section of stock, steel)
   Top of counter 'BAL3DJ (7 8 9 10 11 12 13 14 15 16 17 18;
                         Point Of b1, [Tochk] B2, [Tochk] B1,
                         Section of counter, steel)
   Bottom of counter 'BAL3DJ (13 14 15 16 17 18 19 20 21 22 23 24;
                         Point B2, point C, [Tochk] B2,
                         Section of counter, steel)
   Limitation of the output of [shtoka]'SV3KT (1 2 Oe 7 8 9;
                         Point A, [Tochk] B1, 0,
                         Limitation of the motion of ring-off)
   Shock absorber 'SV3MUT (1 2 Oe 19 20 21;
                         Point A, point C,
                         It [skorost]. nature. shock absorber)
   Spring 'SV3KT (1 2 Oe 13 14 15;
                         Point A, [Tochk] B2,
                         Initial length of spring,
                         Characteristic of spring)
   Rotating holder 'BAL3DJ (13 14 15 16 17 18 52 53 54 55 56 57;
                           Point B2, point I, [Tochk] B2,
                           Section of rotating holder,
                           Steel)
   Steering tip 'STERG (52 53 54 58 59 60;
                           Point of the I, point J,
                           Parameters of steering tip)
   [Poperech]. lever is section FE 'BAL3DJ (25 26 27 281 291 301 31 32 33
                                34 35 36;
                                    Point F, point E, point F,
                                    Section of transverse lever,
                                steel)
   [Poperech]. lever is section ED'BAL3DJ (31 32 33 34 35 36 37 38 39 40
                                41 42;
                                    Point E, point D, point E,
                                    Section of transverse lever,
                                steel)
```

```
        Joint of [poperechn].[rychag]_[kuzov] 'SH3CP (37 38 39 40 41 42
                                                    1000 1000 1000 1000 1000 1000;
                                              Axis of joint D,
                                              Rigidity of joint D)
                                              Stretching '
                                              STERG (31 32 33 49 50 51;
                                              Point E, point G,
                                              Parameters of stretching)
        Rolling cam 'BAL3DJ (19 20 21 22 23 24
                                              25 26 27 28 29 30;
                                              Point C, point F, point C,
                                              Section of rolling cam,
                                              Steel)
        Sheave 'BAL3DJ (25 26 27 28 29 30
                                              43 44 45 46 47 48;
                                              Point F, point H, point F,
                                              Section of wheel, steel)
        Action beyond the wheel 'SSIN0 (45 451;
                                              Amplitude 1, period 1, phase 1,
                                              Rigidity of tire)
                                           'SSIN0 (451 1000;
                                              Amplitude, period, phase,
                                              Rigidity of tire)
        Mass of the support A' OF M3D (1 2 Oe; Mass A)
        Inertia of the support A' OF J3O (4 5 6;
                                        Moment of the inertia of joint A)
        Mass B2 'M3D (13 14 15; Mass B2)
        Mass of the support D' OF M3D (37 38 39; Mass D)
        Mass of the joint E' OF M3D (31 32 33; Mass E)
        Mass of hub 'M3D (25 26 27; Mass F)
        Mass of the support G' OF M3D (49 50 51; Mass G)
        Mass of wheel 'M3D (43 44 45; Mass H)
        Mass of the joint I' OF M3D (52 53 54; Mass of the I)
        Mass of the support J' OF M3D (58 59 60; Mass J)
# OUTPUT :
    Reaction before the joint A 'ROUT (the I: Body (1),
                                       The I: Body (2),
                                       The I: Body (3); 1)
    Action beyond the suspension 'the X (the I: Action beyond the wheel; 1)
    Vertical displacement of wheel 'the X (45; 1)
    The vertical velocity of wheel 'the V (45; 1)
    Displacement of point Ex 'the X (31; 1)
    Displacement of point Ey 'the X (32; 1)
    Displacement of point Ez 'the X (33; 1)
#MAP:
I SHOW:
    Stock of shock absorber 'LAYER (stock ; Parameters of image)
    Counter of shock absorber 'LAYER (top counter,
                               Bottom of counter,
                               Rolling cam,
                               Mass B2 (POINT; Point B2,
                               Diameter of joint, 1);
                               Parameters of image)
    Transverse lever 'LAYER ([Poperech]. lever is section FE,
                               [Poperech]. lever is section ED,
                               Mass of joint E (POINT;
```

```
                                Point E,
                                Diameter of joint, 1);
                                Parameters of image)
   Stretching 'LAYER (stretching ;
                                Parameters of image)
   Rotary [kronshteyn]'LAYER (the rotating holder;
                                Parameters of image)
   Steering tip 'LAYER (steering tip;
                                Parameters of image)
   Spring 'LAYER (spring (PRUG;
                                Diameter of spring,
                                Quantity of turns);
                                Parameters of image)
   Shock absorber 'LAYER (shock absorber (AMORT;
                                Diameter of shock absorber,
                                Relative sizes);
                                Parameters of image)
   Wheel 'LAYER (sheave;
                                Parameters of image)
   Supports 'LAYER ((OPORAD;
                                Point A, the dimensions of support),
                                 (OPORAD;
                                Point D, the dimensions of support),
                                 (OPORAD;
                                Point G, the dimensions of support),
                                 (OPORAD;
                                Point J, the dimensions of support);
                                Parameters of image)
   Joint 'LAYER (mass of the joint of the I (POINT;
                                Point of the I,
                                Diameter of joint, 1),
                                Mass of joint E (POINT;
                                Point E,
                                Diameter of joint, 1);
                                Parameters of image)
I RUN:
   Fluctuations of suspension 'SHTERM (END=10, CONTROL=1.E-5, SCALE=1)
I PRINT :
   Result 'DISP (;
                                Vertical displacement of wheel,
                                The vertical velocity of wheel,
                                Reaction before the joint A,
                                Action beyond the suspension)
$ END
```

The results of calculating the effort, transferred down the body based on the side of suspension, are given before Fig. Of sV3KT_3.[b].



SV3KT_3. **a) the decomposition of the model of suspension down the elements;**
b) the results of calculating the effort, transferred down the body based on the side of suspension.

4.4.1.2.Controlled elastic constraint between two points for the sake of the characteristic the deformation-effort, by assigned tabular SV3KTU

Reflected properties

The elastic constraint (line of load it coincides for the sake of the line of unloading) is assigned between two bodies, which accomplish spatial motion. The deformation of element is defined as the difference between the instantaneous length and the length of element before the nondeformed state. The rating data of connection (characteristic of the connection of element if the potential of the manager of unit is equal 1) it is assigned in the form the table of values “the deformation - effort” (analogous for the sake of element SV3KT, see Fig. SV3KT_1). The rules, which must be observed with the task of the table:

1. points of the dependence of effort beyond the displacement must be regulated on the growth of deformation ($\delta\Lambda\iota$ =< $\delta\Lambda\iota_{+1}$). For the first two and two last points must be satisfied the condition $\delta\Lambda\iota < \delta\Lambda\iota_{+1}$;
2. must be prescribed as the minimum two points of the dependence of effort beyond the displacement.

The current effort, for the sake of which the connection acts on the combinable bodies, is determined as far as the work of the potential of the manager of unit down the nominal effort (it is obtained based on the characteristic of connection in accordance with the instantaneous value of deformation).

The parameter “length of element before the nondeformed state” makes it possible to assign elements with the preliminary deformations. If this parameter is more than zero, then the initial deformation of element is received equal down the difference between the initial length (it is determined as far as the origin coordinates of the ends of the element) and length of element before the nondeformed state. If this parameter less or is equal to 0, then it is considered that before the initial state the element is not deformed.

Basic applications of a model of element SV3KTU:

- Deformed before the initial state springs. For the simulation of this type of elements it is possible to use an element SV3KT. However, in this case at the initial moment of time the system being simulated will experience the impact, determined as far as the effort of the initial compression of spring. Using an element SV3KTU, it is possible to a considerable degree soften of this type impact, raising the potential (“speed”) of the manager of unit from zero to one due to one of the sources of control **besides speed** (VTR0, VTABL0 and so forth) not instantly, but at the point of a certain final time interval;
- Three-dimensional sources of the effort of various forms. In this case the characteristic of element independent from the displacement is assigned, and the source of the potential of the required form is joined down the controlling unit. The generatable effort will be directed along the axis of element.

Note. The initial length of element, determined as far as the prescribed origin coordinates of its ends, must be more than zero.

Degrees of freedom

1,2,3 - progressive across the x axis, Y and Z of the first body;

4,5,6 - progressive across the x axis, Y and Z of the second body;

7 controlling degree of freedom.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of the first linked body (Xa, Ya, Za)	*m*	*-RLmax… of +RLmax*
4,5,6	The origin coordinates of the second linked body (Xb, Yb, Zb)	*m*	*-RLmax… of +RLmax*
7	Length of element before the nondeformed state	*m*	*-RLmax… of +RLmax*
8	$\delta\Lambda_1$ - deformation for the first given point of the characteristic	*m*	*-RLmax… of +RLmax*
9	*F1* - the effort, which corresponds to deformation $\delta\Lambda_1$	*N*	*-RLmax… of +RLmax*
	…..		
2*i+6	τηε δΛι - deformation for *i*-y of the given point of the characteristic	*m*	$\delta\Lambda\iota_{-1}$ … *+RLmax*
2*i+7	*Fi* - the effort, which corresponds to deformation τηε δΛι	*N*	*-RLmax… of +RLmax*
	…..		
2*n+6	dLn - deformation for *the n-th* given point of the characteristic	*m*	$\delta\Lambda\nu_{-1}$ … *+RLmax*
2*n+7	*Fn* - the effort, which corresponds to deformation τηε δΛν	*N*	*-RLmax… of +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE AMOUNT of the deformation of the element	*m*	
2	AXIAL force before the element	*N*	

4.4.1.3.Connection between two bodies for the sake of the one-sided elastic-by plastic characteristic, by initial clearance and by destruction SV3UKP

Reflected properties

Is assigned the three-dimensional connection between two bodies, in the general case of characteristic (see Fig. SV3UKP_1):

- with the value of initial clearance between the surfaces of the linked bodies;
- by the section, which corresponds to the elastic deformation of the connection;
- by the section, which corresponds to the plastic deformation, when the effort of connection becomes maximum and it remains constant in the course of further increase in the deformation;
- by the maximum deformation, when element is destroyed.

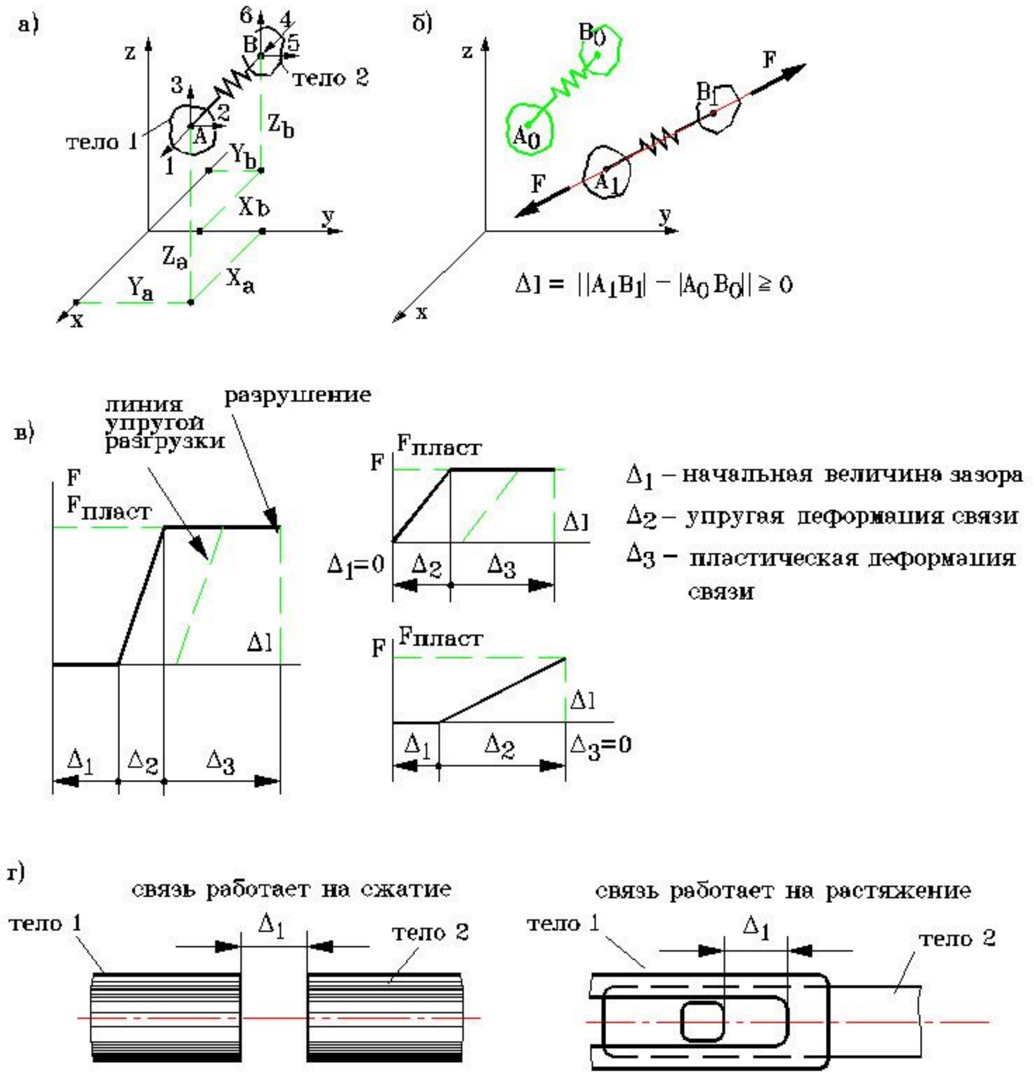
Connection is superimposed only on dilitational strain-the compression (element it is not possible to subject down bend or twisting). You will focus attention, that the line of unloading the element, which reached plastic deformations, is parallel to the elastic section of characteristic.

Note. The initial length of element, determined as far as the prescribed origin coordinates of its ends, must be more than zero.

Degrees of freedom

1,2,3 - progressive across the axes of the X, Y and Z of point A, which belongs to the first body;

4,5,6 - progressive across the axes of the X, Y and Z of point B, which belongs to the second body.



SV3UKP_1. **Elastic-plastic three-dimensional relation for the sake of clearance and possibility of destruction.**

Adopted designations:

F - the effort, which acts beyond the connection based on the side of the combinable bodies;

Δl - the axial deformation of element.

a) of the degree of freedom of model and the parameters, which determine the initial arrangement of element before the space:

1,2, 3- the displacement of the first body by means of the axes of the X, Y, Z;

4, 5, 6 displacement of the second body by means of the axes of the X, Y, Z;

Xa, Ya, Za - the origin coordinates of point A;

Xb, Yb, Zb - the origin coordinates of point B.

b) the determination of the axial deformation of the element;

c) the parameters, which determine the dependence of effort beyond the deformation.

Characteristic of element in the general case and special cases of characteristic (absence of initial clearance and the absence of the section of plastic deformations);

d) the parameter, which determines down the tension or for the compression works the connection;

the parameter is lower than 0 - connection works beyond the compression;

the parameter is more than 0 - connection works in tension;

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of the first linked body (Xa, Ya, Za)	*m*	*-RLmax… of +RLmax*
4,5,6	The origin coordinates of the second linked body (Xb, Yb, Zb)	*m*	*-RLmax… of +RLmax*
7	Value of effort, which determines passage beside the plastic state	*N*	*0… +RLmax*
8	Value of the initial clearance	*m*	*0… +RLmax*
9	Elastic displacement after [vyborki] of the clearance	*m*	*0… +RLmax*
10	Duration of the section of plastic deformation to the moment of the destruction	*m*	*0… +RLmax*
11	The sign, which indicates works element beyond tension (>0) or compression (<0). If this parameter is equal to 0, connection is considered the absentee	*m*	*-RLmax… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE AMOUNT of the deformation of the element	*m*	
2	AXIAL force before the element	*N*	

4.4.1.4. Linear elastic element, which fixes point according to three degrees of freedom KBASE

Reflected properties

Are set elastic limitations beyond the displacements of three-dimensional point according to three translational degrees of freedom. Its value of stiffness coefficient is assigned for each of the fastened degrees of freedom.

Degrees of freedom

1,2,3 - progressive across the x axis, Y and Z.

Parameters

N in sequence	Description	Dimensionality	Range
1	Rigidity of connection across the x axis	*H/[m]*	*0... +RLmax*
2	Rigidity of connection across the y axis	*H/[m]*	*0... +RLmax*
3	Rigidity of connection across the z axis	*H/[m]*	*0... +RLmax*

Working vector

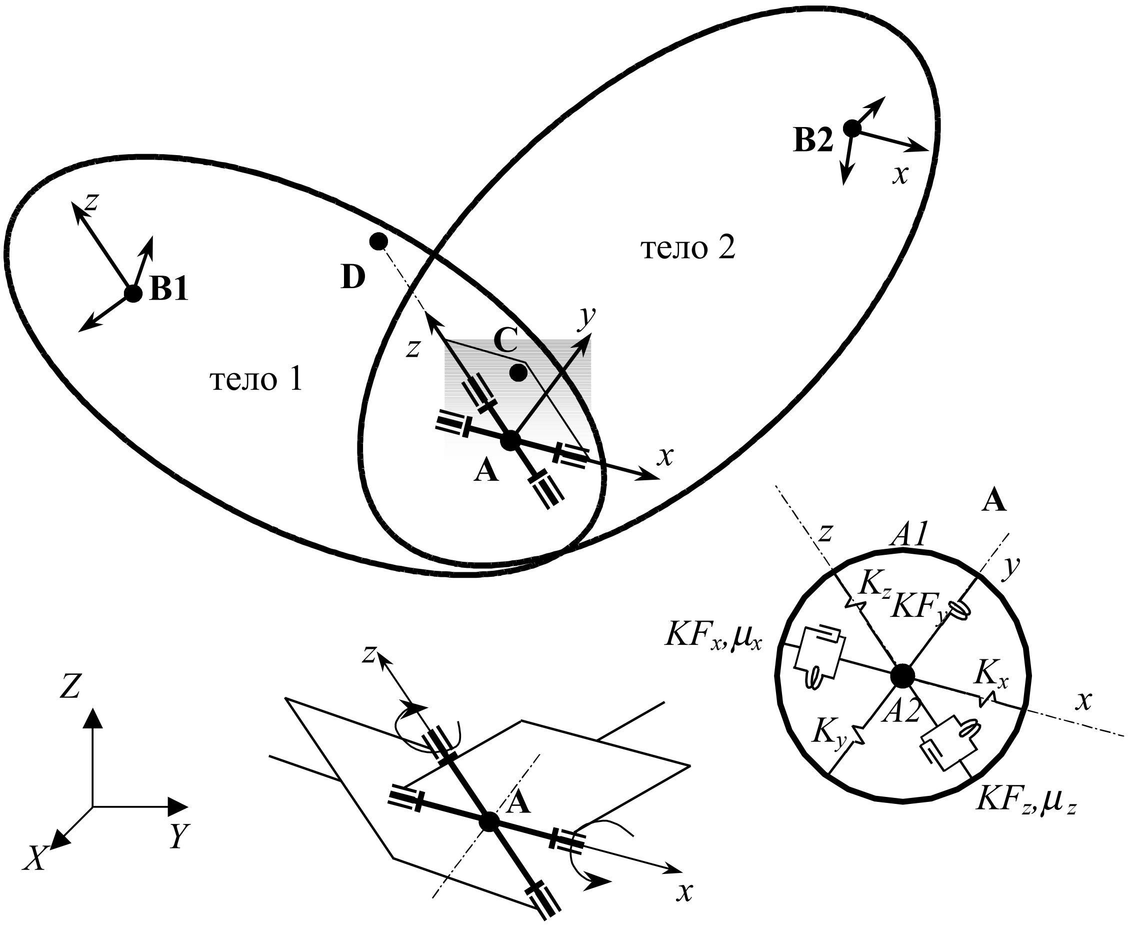
N in sequence	Description	Dimensionality	Range
1	THE ENERGY, accumulated by the element	*George*	
2	the overall reaction	*N*	
3	THE EXTENT of the absolute movement	*m*	

Example of the use

See an example from the division 4.4.1.1.

4.4.1.5.General-purpose joint UNVRS

Reflected properties



Model is intended for the reproduction of the properties of the connection of two absolutely rigid bodies of moving before the space is when permitted their relative rotation around two mutually perpendicular axes, each of which is rigidly connected for the sake of one of tel. Physically this connection is equivalent to the general-purpose joint (the universal joint of two bodies). Against the junction of bodies the elastic and viscous characteristics of connection during the rotation around the axes of the permitted turning are reproduced.

Two absolutely rigid bodies, whose spatial motion is determined as far as the displacements (progressive and angular) respectively of points B1 and B2, are connected by the connection, which resolves relative rotation around two mutually perpendicular z axis*, x.* Z axis is rigidly connected for the sake of body 1, x axis is rigidly connected for the sake of body 2. all the remaining relative displacements and rotations are forbidden. The current positions of axes *z, x* are completely determined as far as the angular position of those connected tel. The initial position of z axis is determined as far as the task of points A and D. point [s] together with the points A, D determines the initial position of the plane *Of axz* (plane of cross piece).

Communications center is located at point A. in the general case of point B1 and B2 can coincide for the sake of the point A. points B1 and B2 they can not be the centers of masses tel.

Interaction between the bodies at the point of connection is determined as far as the characteristics of connection, determined before the mobile local system of coordinates of the connection (ЛСКс) *Of axyz*. Local z axis is always parallel to the axis *z1* of the system of coordinates [LSK]1, connected for the sake of body 1. local x axis is always parallel to the axis *x2* of the system of coordinates [LSK]2, connected for the sake of body 2. current position of the y axis Of [lSKs] perpendicular down the plane of the arrangement of axes *z, x* (plane of the arrangement of the cross piece of universal joint). The origin of coordinates [LSK]1 and [LSK]2 is placed beside the points B1 and B2, and initial angular position coincides for the sake of the initial angular position Of [lSKs].

Interaction between the bodies at the point of connection is determined as far as the following characteristics of the connection:

- By rigidity of connection with the relative turning of bodies around the axes *z, x* of connection (by torsional stiffness of connection). The rigidity of connection is assigned by the table of the dependence of the elastic torque around the axis beyond the angle of rotation 1 of body relative 2-GO around this axis.
- By viscosities of connection during the relative rotation around the axes *z, x* (torsional viscosity). The viscosity of connection is assigned by the table of the dependence of the dissipative torque around the axis beyond the angular rate of rotation of the 1st body relative to 2-GO around this axis.

The exception (minimization) of relative displacements along all axes and rotation around the remained axis (y axis) is realized by the task:

- high rigidity before the axial directions (all rigidity we consider equal to each other) - *K=Kx=Ky=Kz*.
- high angular (torsional) rigidity around the y axis - *KFy*

<u>Degrees of freedom</u>

1,2, 3	Progressive points B1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Rotatory points B1 relative to the global coordinate axes of the X, Y, Z
7, 8, 9	Progressive points B2 before the direction of the global coordinate axes of the X, Y, Z.
10, 11, 12	Rotatory points B2 relative to the global coordinate axes of the X, Y, Z

<u>Parameters</u>

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point A	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D	*m*	*- Rlmax… +RLmax* With the agreement with the coordinates of

N in sequence	Description	Dimensionality	Range
			point The initial position of axis of communication coincides for the sake of the direction of the z axis of the conglobulation of the coordinates
13,14,15	the origin coordinates of point [s]	*m*	*- Rlmax… +RLmax* If it lies beyond the axis AD, then the initial position of axes x, y is determined as far as silence: by the turning of the conglobulation of coordinates around the axis, perpendicular down the plane of the arrangement of z axis, *z* to their combination.
16	Rigidity of connection with before the direction of any axis, passing through the point A (axis of the forbidden displacements)	*H/[m]*	*> 0* It is recommended for the sake of 108 - 1010.
17	Angular (torsional) rigidity of connection around the axis, perpendicular down the plane of the arrangement of cross piece (axis of the forbidden turning)	*H·[m]/[rad]*	*> 0* It is recommended for the sake of 105 - 107.
18	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
19…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the z axis.	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle

N in sequence	Description	Dimensionality	Range
	Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]		of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table it is 2nd the pairs of numbers, which determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the z axis. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table 3- of pair of numbers, that determine piecewise-the linear approximation of the dependence of	*rad/s, H·m*	Table must contain not less than 4-X of values

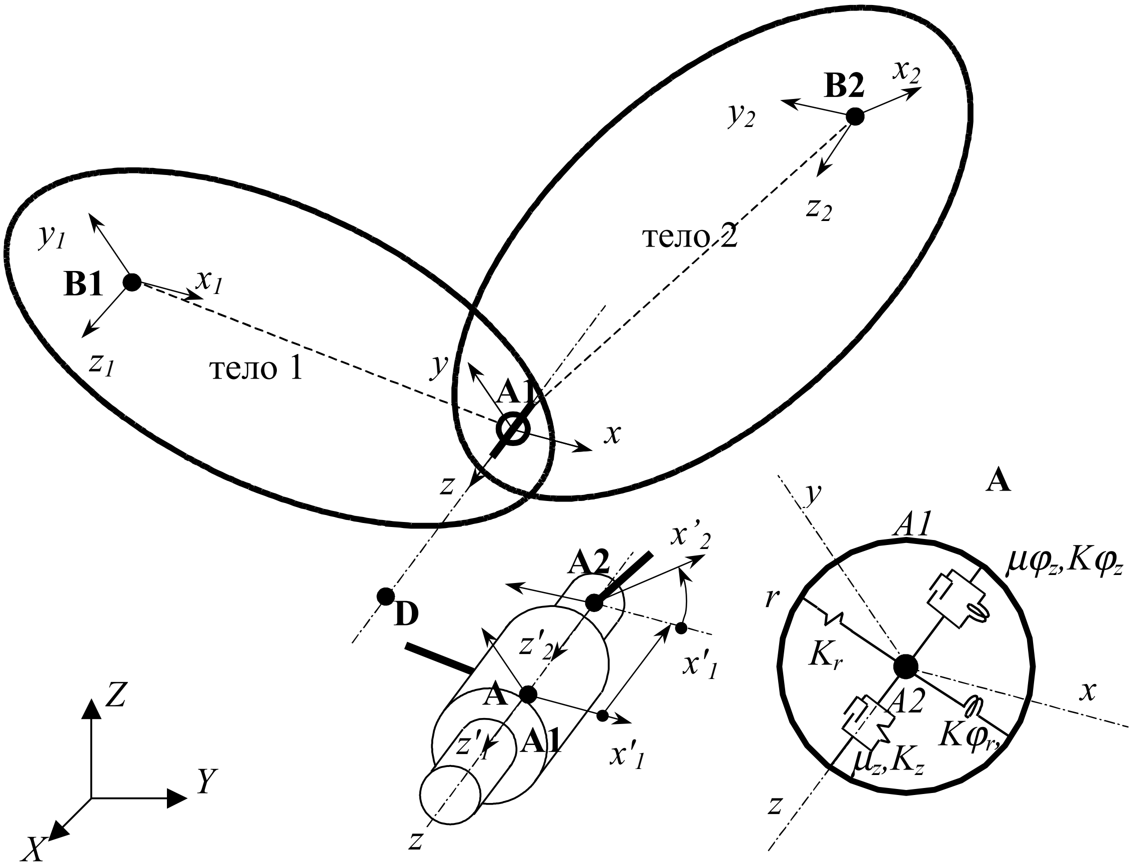
N in sequence	Description	Dimensionality	Range
	the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the x axis. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]		(2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table 4 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the x axis. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*

Working vector

N in sequence	Description	Dimensionality	Range
1	Complete axial deformation of the connection	*m*	
2	The angular strain of connection around the z axis	*rad*	
3	The angular strain of connection around the x axis	*rad*	
4	The angular strain of connection around the y axis	*rad*	
5	Angular velocity of relative rotation around the z axis	*rad/s*	
6	Angular velocity of relative rotation around the x axis	*rad/s*	
7	Complete axial elastic reaction of the connection	*N*	
8	Elastic moment of reacting the connection around the z axis.	*[N]Ч[m]*	
9	Elastic moment of reacting the connection around the x axis.	*[N]Ч[m]*	
10	Elastic moment of reacting the connection around the y axis.	*[N]Ч[m]*	
11	Dissipative torque around the z axis.	*[N]Ч[m]*	
12	Dissipative torque around the x axis.	*[N]Ч[m]*	
13, 14, 15	Angular velocities around the axes [GSK] for the 1st body	*rad/s*	
16, 17, 18	Angular velocities around the axes [GSK] for 2-GO of the body	*rad/s*	

4.4.1.6.Cylindrical connection of two bodies CYLDR

Reflected properties



Model is intended for the reproduction of the properties of the connection of two absolutely rigid bodies of moving before the space is when permitted relative displacement and rotation relative to a certain three-dimensional axis. Physically this connection is equivalent to cylindrical guides. Against the junction of bodies are reproduced the elastic and viscous characteristics of connection during the displacement lengthwise and the rotation around the axis of communication.

Two absolutely rigid bodies, whose spatial motion is determined as far as the displacements (progressive and angular) respectively of points B1 and B2, are connected by the connection, which resolves displacement lengthwise and rotation around the three-dimensional axis *z* (subsequently axis of communication). The relative rotation of bodies around the remaining axes is forbidden. The current position of z axis is completely determined as far as current angular position of both tel. The initial position of the z axis of connection is determined as far as the task of point D. the initial position of axes *x, y* computations does not influence and is assigned on silence.

The axis of maternal body (bushing) is connected for the sake of the point A1, the axis of the children's (rod) body - with the point A2, that belong to the first and second body respectively. They coincide at the initial moment of the time of point A1 and A2. In the general case of point B1 and B2 can coincide for the sake of the point A. the points B1 and B2 they can not be the centers of masses tel.

The origin of the coordinates of connection located at point A. the attitude of point A coincides for the sake of the geometric center of the bushing - by the point Of [a]1. Thus, the origin of the coordinates of connection is rigidly connected for the sake of body 1.

Interaction between the bodies at the point of connection is determined as far as the following characteristics of the connection:

- By rigidity of connection during the relative displacement of bodies along the axis of communication. The rigidity of connection is assigned by the table of the dependence of elastic force along the axis of communication beyond displacement 1 of body relative 2-GO before the direction of axis of communication.
- By viscosity of connection during the relative displacement of bodies along the axis. The viscosity of connection is assigned by the table of the dependence of dissipative force along the axis of communication beyond the speed of the displacement of the 1st body relative to 2-GO before the direction of axis of communication.
- By rigidity of connection with the relative turning of bodies around the axis of communication (by torsional stiffness of connection). The rigidity of connection is assigned by the table of the dependence of the elastic torque around the axis of communication beyond the angle of rotation 1 of body relative 2-GO around the axis of communication.
- By viscosity of connection during the relative rotation around the axis of communication (torsional viscosity). The viscosity of connection is assigned by the table of the dependence of the dissipative torque around the axis of communication beyond the angular rate of rotation of the 1st body relative to 2-GO around the axis of communication.

The exception (minimization) of relative displacements along other axes and rotations in the plane, perpendicular down axis of communication is realized by the task:

- high rigidity before the radial direction (in the plane, passing through the rotational axis)
- high flexural rigidity (in the plane, passing through the rotational axis).

Degrees of freedom

1,2, 3	Progressive points B1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Rotatory points B1 relative to the global coordinate axes of the X, Y, Z
7, 8, 9	Progressive points B2 before the direction of the global coordinate axes of the X, Y, Z.
10, 11, 12	Rotatory points B2 relative to the global coordinate axes of the X, Y, Z

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point A	*m*	*- Rlmax… +RLmax*

N in sequence	Description	Dimensionality	Range
10,11,12	the origin coordinates of point D	*m*	*- Rlmax… +RLmax* With the agreement with the coordinates of point The initial position of axis of communication coincides for the sake of the direction of the z axis of the conglobulation of the coordinates
13	Rigidity of connection before the radial direction (in the plane, passing through the axis of communication)	*H/[m]*	*> 0* It is recommended for the sake of 108 - 1010.
14	Angular (bending) rigidity of connection around the axis, perpendicular down the plane, passing through the axis of communication	*H·[m]/[rad]*	*> 0* It is recommended for the sake of 105 - 107.
15	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
16…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the dependence of elastic force beyond the displacement of the 1st body relative to 2-GO along the axis of communication. Before each pair of numbers: the first number - the displacement of the 1st body relative to 2-GO of [vdolosi] of connection [m] the second number - torque [N]	*m, H*	Table must contain not less than 4-X of values (2 pairs). The value of displacement must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of*

N in sequence	Description	Dimensionality	Range
			displacement the approximation must ensure the zero value of force.
…	Marker		*It is equal to the value of parameter 16*
…	Table it is 2nd the pairs of numbers, which determine piecewise-the linear approximation of the dependence of viscous force beyond the speed of the 1st body relative to 2-GO along the axis of communication. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*m/s, H*	Table must contain not less than 4-X of values (2 pairs). The value of speed must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of speed the approximation must ensure the zero value of force.*
…	Marker		It is equal to the value of parameter 16
…	Table 3- of pair of numbers, that determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the axis of relative rotation. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]	*rad, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of

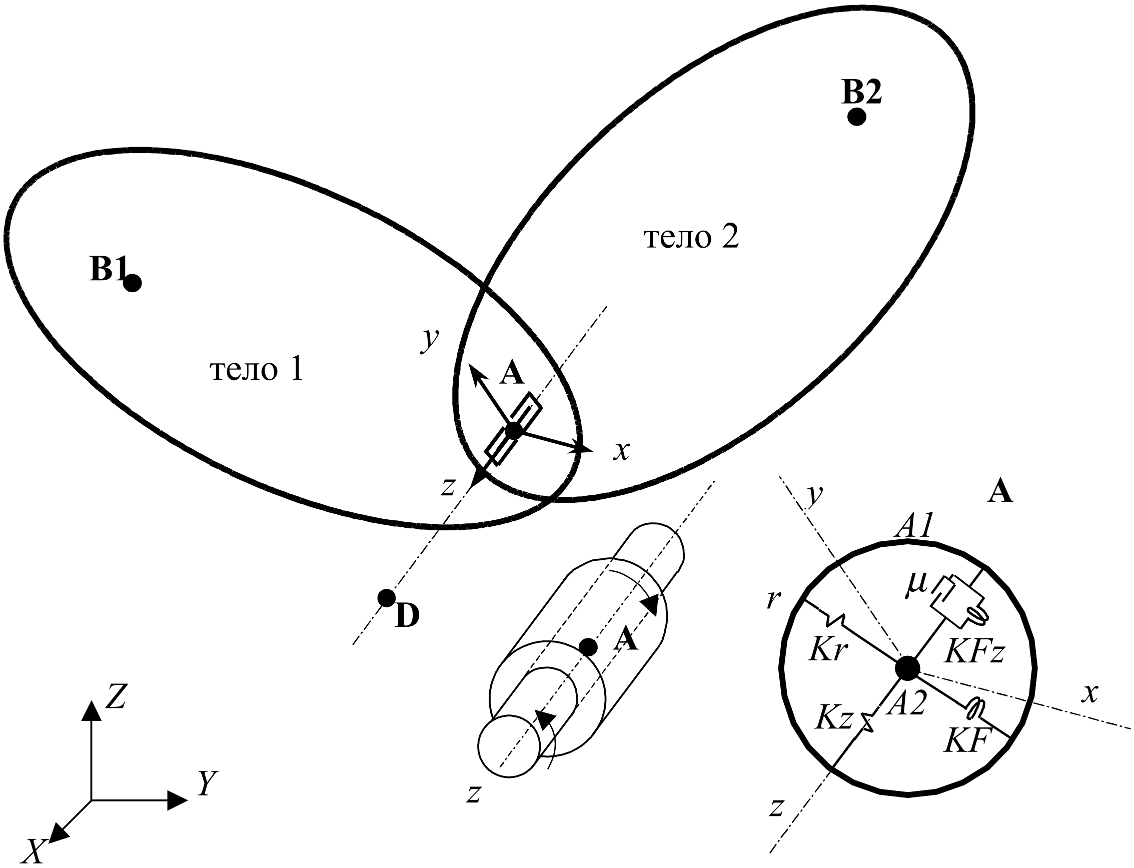
N in sequence	Description	Dimensionality	Range
			approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		It is equal to the value of parameter 16
…	Table 4 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the axis of relative rotation. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*

Working vector

N in sequence	Description	Dimensionality	Range
1	Axial deformation of the connection	*m*	
2	Radial deformation of the connection	*m*	
3	The angular strain of connection in the plane, passing through the axis	*rad*	
4	The angular strain of connection around the axis of communication	*rad*	
5	Speed of relative displacement along the axis	m/s	
6	Angular velocity of relative rotation around the axis	*rad/s*	
7	Axial reaction of the connection	*N*	
8	Radial reaction of the connection	*N*	
9	Elastic moment of reacting the connection in the plane, passing through the axis.	*[N]Ч[m]*	
10	Elastic moment of reacting the connection around the axis of communication.	*[N]Ч[m]*	
11	Dissipative force along the axis of communication	*N*	
12	Dissipative torque around the axis of communication	*[N]Ч[m]*	
13, 14, 15	Angular velocities around the axes [GSK] for the 1st body	*rad/s*	
16, 17, 18	Angular velocities around the axes [GSK] for 2-GO of the body	*rad/s*	

4.4.1.7.The swivel joint of two bodies ROT1

<u>Reflected properties</u>



Model is intended for the reproduction of the properties of the connection of two absolutely rigid bodies of moving before the space is when permitted their relative rotation around one, in the general case of mobile, coordinate axis. Physically this connection is equivalent to cylindrical bearing with the limitation of axial displacements. Against the junction of bodies the elastic and viscous characteristics of connection during the rotation around the axis of connection are reproduced.

Two absolutely rigid bodies, whose spatial motion is determined as far as the displacements (progressive and angular) respectively of points B1 and B2, are connected by the connection, which forbids rotation around two mutually perpendicular x axis*, y* and displacement along the third z axis (if necessary, displacement along the z axis can be resolved). The current position of z axis is completely determined as far as current angular position of both tel. The initial position of the z axis of connection is determined as far as the task of point D. the initial position of axes *x, y* computations does not influence and is assigned on silence.

Communications center is located at point A. in the general case of point B1 and B2 can coincide for the sake of the point A. points B1 and B2 they can not be the centers of masses tel.

Interaction between the bodies at the point of connection is determined as far as the following characteristics of the connection:

- By rigidity of connection with the relative turning of bodies around the axis of communication (by torsional stiffness of connection). The rigidity of connection is assigned by the table of the dependence of the elastic torque around the axis of communication beyond the angle of rotation 1 of body relative 2-GO around the axis of communication.
- By viscosity of connection during the relative rotation around the axis of communication (torsional viscosity). The viscosity of connection is assigned by

the table of the dependence of the dissipative torque around the axis of communication beyond the angular rate of rotation of the 1st body relative to 2-GO around the axis of communication.

The exception (minimization) of relative displacements along any axes and rotations in the plane, perpendicular down axis of communication is realized by the task:

- high rigidity before the radial direction (in the plane, passing through the rotational axis)
- high rigidity before the axial direction (along the axis of communication).
- high flexural rigidity (in the plane, passing through the rotational axis).

In the case of the task to axial rigidity of the equal to zero model reproduces the cylindrical bearing without the limitation of the axial displacement of two bodies relative to each other.

Degrees of freedom

1,2, 3	Progressive points B1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Rotatory points B1 relative to the global coordinate axes of the X, Y, Z
7, 8, 9	Progressive points B2 before the direction of the global coordinate axes of the X, Y, Z.
10, 11, 12	Rotatory points B2 relative to the global coordinate axes of the X, Y, Z

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point A	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D	*m*	*- Rlmax… +RLmax* With the agreement with the coordinates of point The initial position of axis of communication coincides for the sake of the direction of the z axis of the conglobulation of the coordinates
13	Rigidity of connection before the radial direction (in the plane,	*H/[m]*	*> 0*

N in sequence	Description	Dimensionality	Range
	passing through the axis of communication)		It is recommended for the sake of 108 - 1010.
14	Angular (bending) rigidity of connection around the axis, perpendicular down the plane, passing through the axis of communication	*H·[m]/[rad]*	*> 0* It is recommended for the sake of 105 - 107.
15	Rigidity of connection before the axial direction (along the axis of communication)	*H/[m]*	*≥ 0* It is recommended for the sake of 108 - 1010. Three-dimensional cylindrical bearing without the limitation of the axial displacements realizes with the task to zero rigidity
16	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
17…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the axis of relative rotation. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 16*
…	Table it is 2nd the pairs of numbers, which determine piecewise-the	*rad/s, H·m*	Table must contain not less than 4-X of

N in sequence	Description	Dimensionality	Range
	linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the axis of relative rotation. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]		values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*

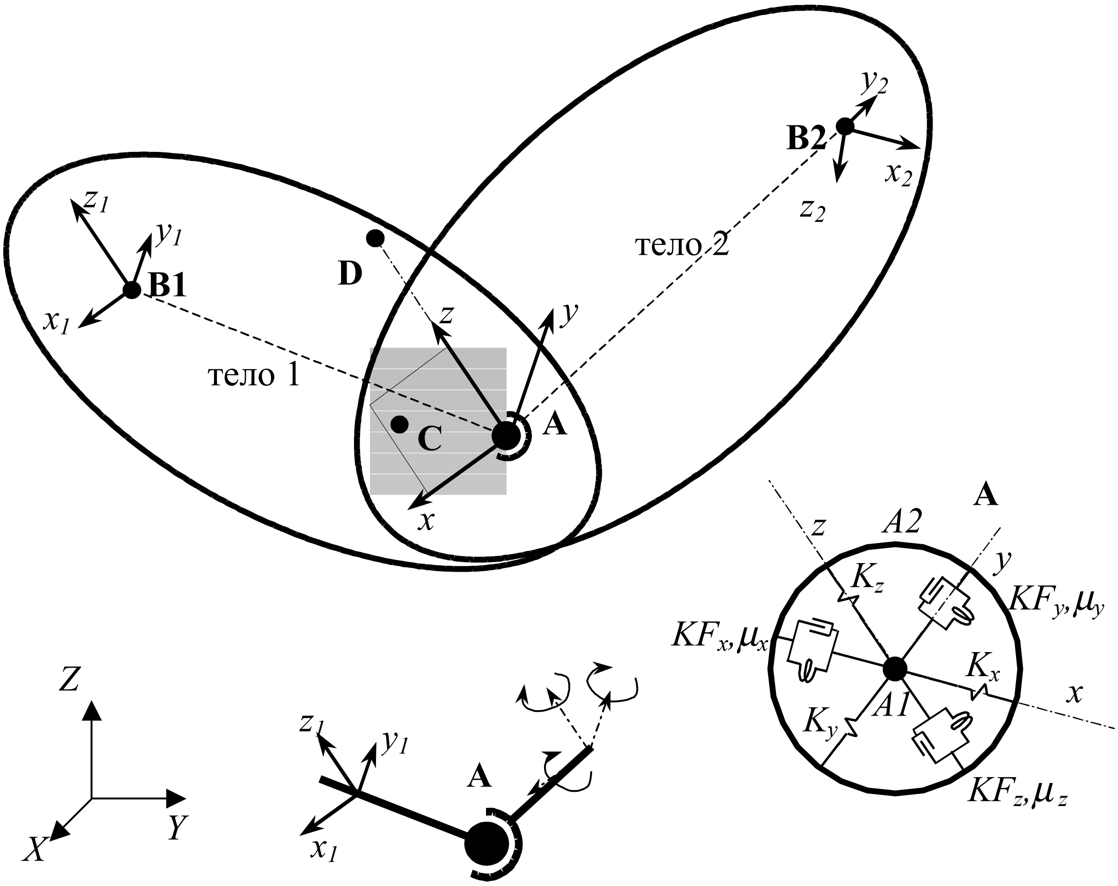
<u>Working vector</u>

N in sequence	Description	Dimensionality	Range
1	Axial deformation of the connection	*m*	
2	Radial deformation of the connection	*m*	
3	The angular strain of connection in the plane, passing through the axis	*rad*	
4	The angular strain of connection around the axis of communication	*rad*	
5	Angular velocity of relative rotation around the axis	*rad/s*	
6	Axial reaction of the connection	*N*	
7	Radial reaction of the connection	*N*	
8	Elastic moment of reacting the connection in the plane, passing through the axis.	*[N]Ч[m]*	
9	Elastic moment of reacting the connection around the axis of communication.	*[N]Ч[m]*	
10	Dissipative torque around the axis of communication	*[N]Ч[m]*	
11, 12, 13	Angular velocities around the axes [GSK] for the 1st body	*rad/s*	

N in sequence	Description	Dimensionality	Range
14, 15, 16	Angular velocities around the axes [GSK] for 2-GO of the body	*rad/s*	

4.4.1.8.Spherical joint ROT3

Reflected properties



Model is intended for the reproduction of the properties of the connection of two absolutely rigid bodies of moving before the space is when permitted the relative rotation of the second body around three mutually perpendicular axes, rigidly connected for the sake of the first. Physically this connection is equivalent to spherical joint. Against the junction of bodies the elastic and viscous characteristics of connection during the rotation around the axes of the permitted turning are reproduced.

Two absolutely rigid bodies, whose spatial motion is determined as far as the displacements (progressive and angular) respectively of points B1 and B2, are connected at point A by the connection, which resolves relative rotation 2-GO of body around three mutually perpendicular axes *x1, y1, z1*, which determine the attitude of the 1st body. The relative displacements of bodies at the point of connection A are forbidden. The current position of axes the systems of coordinates Of axyz are completely determined as far as the angular position of body 1 or in parallel to the system of coordinates Of b1x1y, *z1*. The initial position of z axis is determined as far as the task of points A and D. point [s] together with the points A, D determines the initial position of the plane *Of axz*.

In the general case of point B1 and B2 can coincide for the sake of the point A. the points B1 and B2 they can not be the centers of masses tel.

Interaction between the bodies at the point of connection is determined as far as the following characteristics of the connection:

- By rigidity of connection with the relative turning of bodies around the axes *x1, y1, z1* of the 1st body (by torsional stiffness of connection). The rigidity of connection is assigned by the table of the dependence of the elastic torque around the axis beyond the angle of rotation 1 of body relative 2-GO around this axis.

- By viscosities of connection during the relative rotation around the axes *x1, y1, z1* (torsional viscosity). The viscosity of connection is assigned by the table of the dependence of the dissipative torque around the axis beyond the angular rate of rotation of the 1st body relative to 2-GO around this axis.

The exception (minimization) of relative displacements along all axes and rotation around the remained axis (y axis) is realized by the task to high rigidity before the axial directions (all rigidity we consider equal to each other) - *K=Kx=Ky=Kz*.

<u>Degrees of freedom</u>

1,2, 3	Progressive points B1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Rotatory points B1 relative to the global coordinate axes of the X, Y, Z
7, 8, 9	Progressive points B2 before the direction of the global coordinate axes of the X, Y, Z.
10, 11, 12	Rotatory points B2 relative to the global coordinate axes of the X, Y, Z

<u>Parameters</u>

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point A	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D	*m*	*- Rlmax… +RLmax* With the agreement with the coordinates of point The initial position of axis of communication coincides for the sake of the direction of the z axis of the conglobulation of the coordinates
13,14,15	the origin coordinates of point [s]	*m*	*- Rlmax… +RLmax* If it lies beyond the axis AD, then the initial position of axes x, y is determined as far as silence: by the

N in sequence	Description	Dimensionality	Range
			turning of the conglobulation of coordinates around the axis, perpendicular down the plane of the arrangement of z axis, *z* to their combination.
16	Rigidity of connection before the direction of any axis, passing through the point A (axis of the forbidden displacements)	*H/[m]*	*> 0* It is recommended for the sake of 108 - 1010.
17	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
18	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the x axis. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table it is 2nd the pairs of numbers, which determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the x axis. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections*

N in sequence	Description	Dimensionality	Range
	2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]		*of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table 3- of pair of numbers, that determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the y axis. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table 4 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the y axis. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value*

N in sequence	Description	Dimensionality	Range
			of parameter 18
…	Table it is 5th the pairs of numbers, which determine piecewise-the linear approximation of the dependence of the elastic torque beyond the angle of rotation of the 1st body relative to 2-GO around the z axis. Before each pair of numbers: the first number - the angle of rotation of the 1st body relative to 2-GO around the axis of communication [radians] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angle of rotation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of moment.*
…	Marker		*It is equal to the value of parameter 18*
…	Table 6 of pair of numbers, that determine piecewise-the linear approximation of the dependence of the viscous torque beyond the angular velocity of the 1st body relative to 2-GO around the z axis. Before each pair of numbers: the first number - the angular velocity of the 1st body relative to 2-GO around the axis of communication [radians per second] the second number - the torque [Of [n]*[m]]	*rad/s, H·m*	Table must contain not less than 4-X of values (2 pairs). The value of angular velocity must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value of angular velocity the approximation must ensure the zero value of moment.*

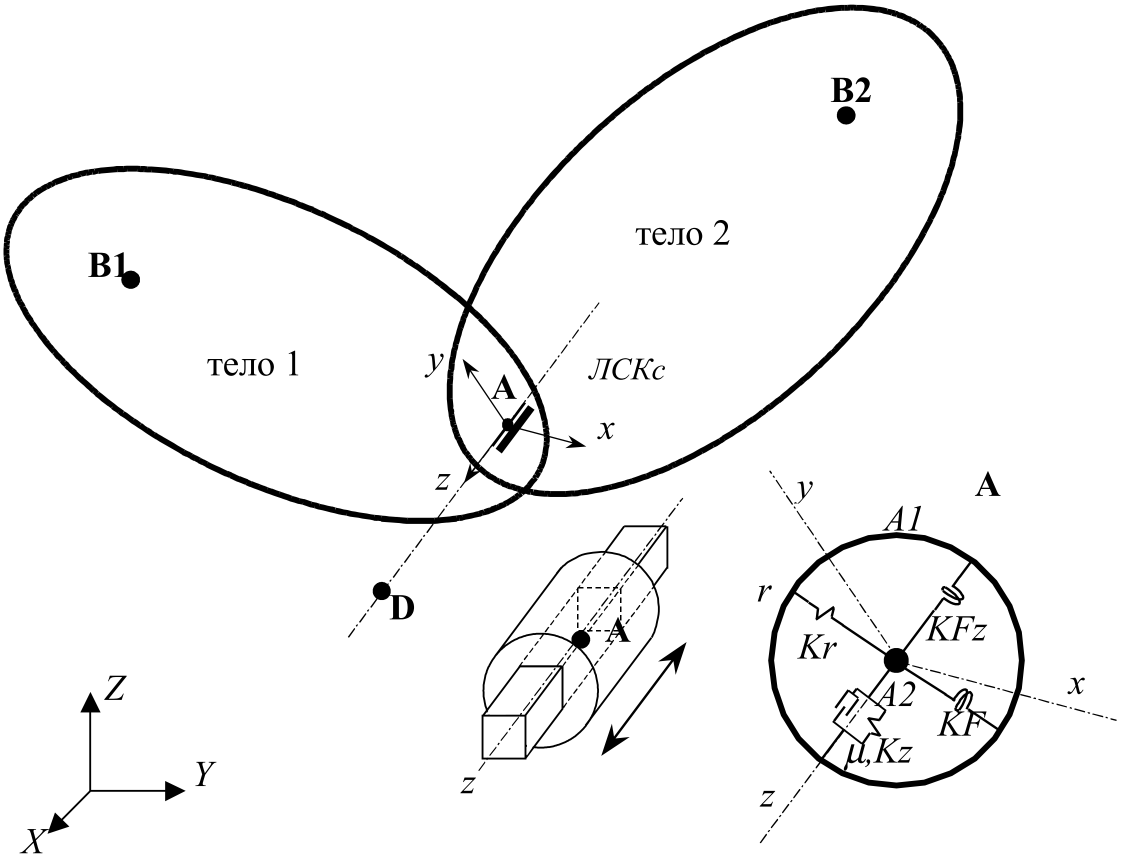
<u>Working vector</u>

N in sequence	Description	Dimensionality	Range
1	Complete axial deformation of the connection	*m*	
2	The angular strain of connection around the	*rad*	

N in sequence	Description	Dimensionality	Range
	x axis		
3	The angular strain of connection around the y axis	*rad*	
4	The angular strain of connection around the z axis	*rad*	
5	Angular velocity of relative rotation around the x axis	*rad/s*	
6	Angular velocity of relative rotation around the y axis	*rad/s*	
7	Angular velocity of relative rotation around the z axis	*rad/s*	
8	Complete axial elastic reaction of the connection	*N*	
9	Elastic moment of reacting the connection around the x axis.	*[N]Ч[m]*	
10	Elastic moment of reacting the connection around the y axis.	*[N]Ч[m]*	
11	Elastic moment of reacting the connection around the z axis.	*[N]Ч[m]*	
12	Dissipative torque around the x axis.	*[N]Ч[m]*	
13	Dissipative torque around the y axis.	*[N]Ч[m]*	
14	Dissipative torque around the z axis.	*[N]Ч[m]*	
15, 16, 17	Angular velocities around the axes [GSK] for the 1st body	*rad/s*	
18, 19, 20	Angular velocities around the axes [GSK] for 2-GO of the body	*rad/s*	

4.4.1.9.Movable connection of two bodies TRANS

Reflected properties



Model is intended for the reproduction of the properties of the connection of two absolutely rigid bodies of moving before the space is when permitted their relative displacement before direction of one, in the general case of mobile, coordinate axis. Physically this connection is equivalent to mobile guides of slip. Against the junction of bodies the elastic and viscous characteristics of connection with the displacement along the axis of connection are reproduced.

Two absolutely rigid bodies, whose spatial motion is determined as far as the displacements (progressive and angular) respectively of points B1 and B2, are connected by the connection, which forbids the relative rotation of bodies around any three mutually perpendicular axes of the local system of coordinates ([LSKs] before the figure) and displacement along the axes *x, y* of this coordinate system. Only relative displacement along the z axis of the local coordinate system is resolved. The current position of z axis is completely determined as far as current angular position of both tel. The initial position of the z axis of connection is determined as far as the task of point D. the initial position of axes *x, y* computations does not influence and is assigned on silence.

Communications center is located at point A. in the general case of point B1 and B2 can coincide for the sake of the point A. points B1 and B2 they can not be the centers of masses tel.

Interaction between the bodies at the point of connection is determined as far as the following characteristics of the connection:

- By rigidity of connection with the relative displacement of bodies along the axis of communication. The rigidity of connection is assigned by the table of the dependence of elastic force before the direction of axis of communication beyond displacement 1 of body relative 2-GO along the axis of communication.
- By viscosity of connection with the relative displacement along the axis of communication. The viscosity of connection is assigned by the table of the

dependence of dissipative force before the direction of axis of communication beyond the speed of the displacement of the 1st body relative to 2-GO along the axis of communication.

The exception (minimization) of relative rotations along any axes and displacements in the plane, passing through the axis of communication is realized by the task:

- high rigidity before the radial direction (in the plane, passing through the axis of communication)
- high flexural rigidity (in the plane, passing through the axis of communication).
- high torsional stiffness (around the axis of communication).

Degrees of freedom

1,2, 3 Progressive points B1 before the direction of the global coordinate axes of the X, Y, Z.

4, 5, 6 Rotatory points B1 relative to the global coordinate axes of the X, Y, Z

7, 8, 9 Progressive points B2 before the direction of the global coordinate axes of the X, Y, Z.

10, 11, 12 Rotatory points B2 relative to the global coordinate axes of the X, Y, Z

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point A	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D	*m*	*- Rlmax… +RLmax* With the agreement with the coordinates of point The initial position of axis of communication coincides for the sake of the direction of the z axis of the conglobulation of the coordinates
13	Rigidity of connection before the radial direction (in the plane, passing through the axis of communication)	*H/[m]*	*> 0* It is recommended for the sake of 108 - 1010.

N in sequence	Description	Dimensionalit y	Range
14	Angular (bending) rigidity of connection around the axis, perpendicular down the plane, passing through the axis of communication	*H·[m]/[rad]*	*> 0* It is recommended for the sake of 105 - 107.
15	Angular (torsional) rigidity of connection around the axis of communication	*H·[m]/[rad]*	*> 0* It is recommended for the sake of 105 - 107.
16	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
17…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the dependence of elastic force beyond the displacement of the 1st body relative to 2-GO along the axis of relative displacement. Before each pair of numbers: the first number - the displacement of the 1st body relative to 2-GO along the axis of communication [meters] the second number - force [newtons]	*m, H*	Table must contain not less than 4-X of values (2 pairs). Displacement value must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of angle the approximation must ensure the zero value of force.*
…	Marker		*It is equal to the value of parameter 16*
…	Table it is 2nd the pairs of numbers, which determine piecewise-the linear approximation of the dependence of viscous force beyond the speed of the 1st body relative to 2-GO along the axis of relative displacement. Before each pair of numbers: the first number - the speed of the 1st body relative to 2-GO along the axis of communication [meters per second]	*m/s, H*	Table must contain not less than 4-X of values (2 pairs). The value of speed must grow from the first pair to the latter. *It is not allowed the descending sections of approximation.* *With the zero value*

N in sequence	Description	Dimensionality	Range
	the second number - torque [newtons]		*of angular velocity the approximation must ensure the zero value of force.*

Working vector

N in sequence	Description	Dimensionality	Range
1	Axial deformation of the connection	*m*	
2	Radial deformation of the connection	*m*	
3	The angular strain of connection in the plane, passing through the axis	*rad*	
4	The angular strain of connection around the axis of communication	*rad*	
5	Speed of relative displacement along the axis of communication	m/s	
6	Axial reaction of the connection	*N*	
7	Radial reaction of the connection	*N*	
8	Elastic moment of reacting the connection in the plane, passing through the axis.	*[N]Ч[m]*	
9	Elastic moment of reacting the connection around the axis of communication.	*[N]Ч[m]*	
10	Dissipative force along the axis of communication	*N*	
11, 12, 13	Angular velocities around the axes [GSK] for the 1st body	*rad/s*	
14, 15, 16	Angular velocities around the axes [GSK] for 2-GO of the body	*rad/s*	

4.4.2.Dissipative connections

4.4.2.1.Viscous relation between two bodies for the sake of the dependence of effort beyond the rate of deformation of element, given tabular TO SV3MUT

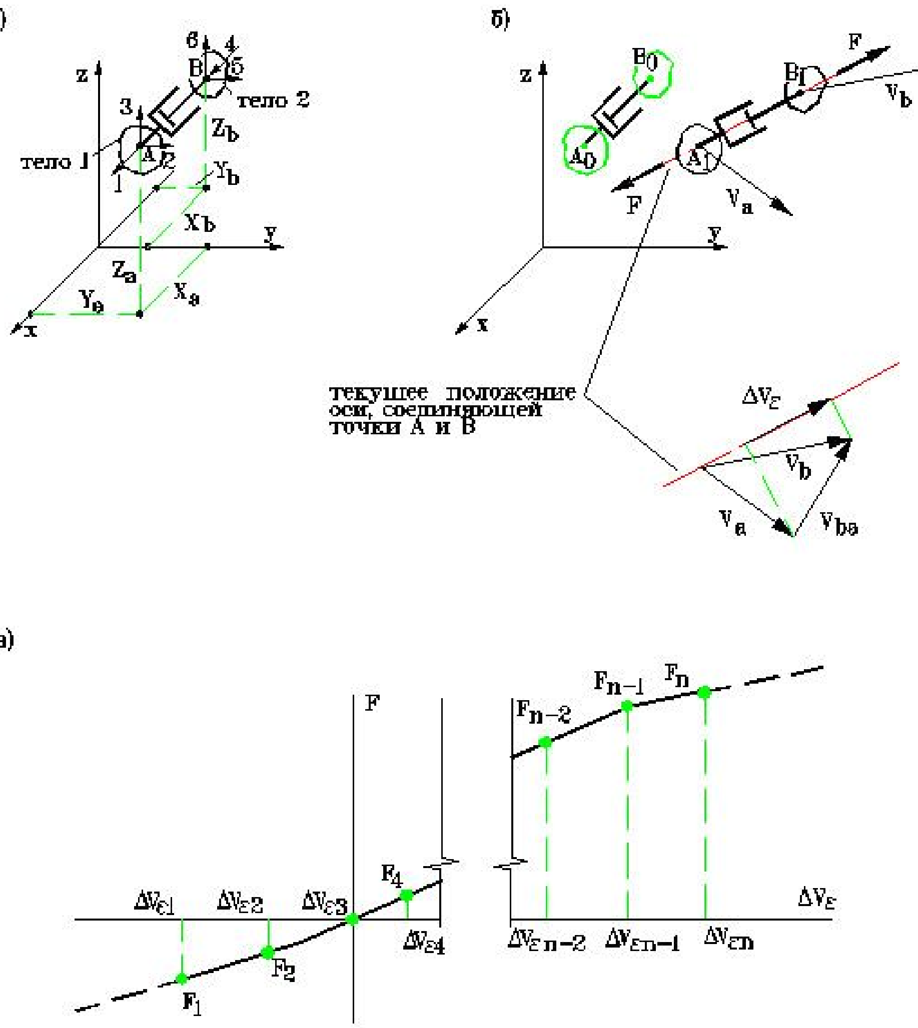
Reflected properties

The dependence of the effort, which affects between two bodies, is assigned beyond the rate of deformation of element. The deformation rate is defined as the projection of the relative speed of the linked points beyond the line, their connecting. The effort, generated by element, acts along the same line. The characteristic of connection is assigned in the form the table of values “the deformation rate - effort” (see Fig. SV3MUT_1).

The rules, which must be observed with the task of the table:

1. points of the dependence of effort beyond the speed must be regulated on the growth of velocity ($\delta\varsigma\iota =< \delta\varsigma\iota_{+1}$, the negative values of speeds correspond to the compression of element, positive - to tension). For the first two and two last points must be satisfied the condition $\delta\varsigma\iota < \delta\varsigma\iota_{+1}$;
2. must be prescribed as the minimum two points of the dependence of effort beyond the speed. This requirement is caused by the fact that if the real rate of deformation of element lies out of the prescribed range $\delta\varsigma_{1}... \delta\varsigma\nu$, the current effort is determined by the extrapolation of the extreme sections of characteristic.

Note. The initial length of element, determined as far as the prescribed origin coordinates of its ends, must be more than zero.



SV3MUT_1. **Three-dimensional connection, which realizes the tabular dependence of effort beyond the deformation rate.**

Adopted designations:

F - the effort, which acts beyond the connection based on the side of the combinable bodies;

ΔVε - the rate of deformation of element.

a) of the degree of freedom of element and the parameters, which determine the initial arrangement of element before the space:

1,2, 3- the displacement of the first body by means of the axes of the X, Y, Z;

4, 5, 6 displacement of the second body by means of the axes of the X, Y, Z;

Xa, Ya, Za - the origin coordinates of point A;

Xb, Yb, Zb - the origin coordinates of point B.

b) the diagram of the determination of the current rate of deformation of element and direction of the effective efforts before the dependence beyond the position of element before the space;

c) the tabular dependence of effort beyond the deformation rate.

Each point of table is assigned by the pair of values “the deformation rate-effort”

As a result of the limits of the interval of the velocities Of δVε1- ΔVεn the effort of connection is determined as far as the extrapolation of the extreme sections of characteristic.

Degrees of freedom

1,2,3 - progressive across the axes of the X, Y and Z of point A, which belongs to the first body;

4,5,6 - progressive across the axes of the X, Y and Z of point B, which belongs to the second body.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A (Xa, Ya, Za)	*m*	*-RLmax… of +RLmax*
4,5,6	The origin coordinates of point B (Xb, Yb, Zb)	*m*	*-RLmax… of +RLmax*
7	δς $_{1}$ - the deformation rate for the first given point of the characteristic	*m/s*	*-RLmax… of +RLmax*
8	*F1* - the effort, which corresponds to the deformation rate δς $_{1}$	*N*	*-RLmax… of +RLmax*
	…..		
2*i+5	τηε δςι - the deformation rate for *i*-y of the given point of the characteristic	*m/s*	δςι $_{-1}$ … +*RLmax*
2*i+6	*Fi* - the effort, which corresponds to the deformation rate τηε δςι	*N*	*-RLmax… of +RLmax*
	…..		
2*n+5	τηε δςν - the deformation rate for *the n-th* given point of the characteristic	*m/s*	δςν $_{-1}$ … +*RLmax*
2*n+6	*Fn* - the effort, which corresponds to the deformation rate τηε δςν	*N*	*-RLmax… of +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE VELOCITY of the deformation of the element	*m*	

N in sequence	Description	Dimensionality	Range
2	AXIAL force before the element	N	

Example of the use

See an example from the division 4.4.1.1.

4.5.Special connections

4.5.1.1.Elastic constraint, which makes it possible to transmit rotation between the one-dimensional (or flat) and three-dimensional elements around the prescribed three-dimensional axis SV13W

Reflected properties

It realizes elastic constraint via the rotation between two points M and N, the first of which belongs to one-dimensional (or flat) element and has one rotational degree of freedom around the assigned axis AB, the second - belongs to three-dimensional element and has three rotational degrees of freedom around the coordinate axes of the X, Y, Z. axis AB it can change its angular position. The angular displacement of axis AB is determined as far as the angular displacement of the point N, for the sake of which are connected the three-dimensional angular degrees of freedom of element.

Note. The position of the three-dimensional axis, around which is transferred the rotation, it is assigned by two points, designated here by points A and B (Fig. SV13W_1). At the point of the clockwise positive is accepted the direction from one point A to the next B. the point, which belongs to one-dimensional (or flat) element and the having one rotational degree of freedom, is designated by point M. the point, which belongs to three-dimensional element and which has three rotational degrees of freedom around the coordinate axes, it is designated by point N.

Degrees of freedom

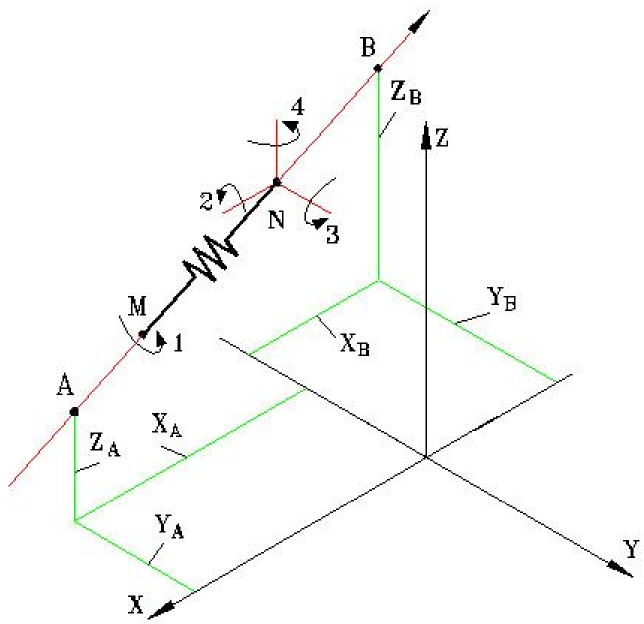
1 rotatory of point M around the axis AB;

2, 3, 4 rotatory points N around the coordinate axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A (XA, YA, ZA)	*m*	*-RLmax… of +RLmax*
4,5,6	The origin coordinates of point B (XB, YB, ZB)	*m*	*-RLmax… of +RLmax*
7	THE RIGIDITY of connection down twisting (*)	*N*m/rad*	*0… +RLmax*

*) with the strongly overstated values of rigidity down the twisting (> 1.e7) can be manifested the computational complexities, connected for the sake of the limitedness of the calculation grid of computer. One should designate the substantiated values of torsional rigidity, on the basis of the actual geometric dimensions and the modulus of elasticity of binder.



SV13W_1. Elastic constraint via the rotation between the point for the sake of the one-dimensional angular degree of freedom (point M) and the point with the three-dimensional angular degrees of freedom (point N).
Degrees of freedom of the element:
1 rotatory of point M around the axis AB;
2, 3, 4 rotatory points N around the coordinate axes of the X, Y, Z.
Parameters:
Xa, Ya, Za - the origin coordinates of point A;
Xb, Yb, Zb - the origin coordinates of point B.

Working vector

N in sequence	Description	Dimensionality	Range
1	TORSION ANGLE (difference between the turnings around the axis AB of point N and of point M)	*rad*	

Special situations

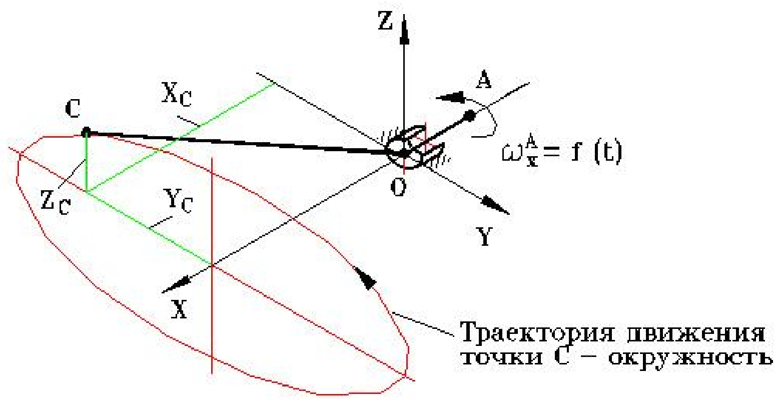
The enumeration of the situations, with which the current step of integration is considered lost and occurs the recovery at the beginning of step with the decrease of the value of the step:

1. at the point of the current step a change in the angular position of rotational axis is close down 180 degrees.
2. at the point of the current step increase in the angle of rotation of point N around the rotational axis exceeded 135 degrees.
3. against the current step is obtained the critical value of the normalizing factor, connected for the sake of the angular degrees of freedom of point N.

With the depletion of the possibility of dividing the step (if the current step - minimum), working program stops with the delivery of the corresponding diagnostic communication.

Example of the use

1. before Fig. SV13W_2 is given the example to the construction, which consists besides the section of the shaft AO, located along the x axis, the lever OC, rigidly connected with the shaft, and cylindrical joint, whose axis also coincides for the sake of the x axis. toward the end shaft it is applied the action, which determines the required dependence of angular rate of rotation beyond the time. In this case the rotary motion must be transmitted based on the one cell, which assigns the required characteristic of the angular rate of rotation of shaft (element VTR0) down the three-dimensional girder (element BAL3DJ), which simulates the motion of lever OC. Element SV13W reflects before this example the elastic properties of shaft AO for the twisting. The rigidity of connection is determined as far as the parameters of the section of the shaft: the length - 120 mm, the diameter - 20 mm (polar second moment of area Jp = 1.57e-8), the material - steel (modulus of rigidity Of g=0.79e11 pA).



SV13W_2. An example of the transmission of rotary motion based on the one-dimensional to the three-dimensional element for the case, when rotational axis barely changes its angular position.

Torsional stiffness of the shaft:

*G*Jr/L* = of 0.79e11 * 1.57e-8/0.12 = 1.03e4 [*Of h*[m]/[rad]*]

Inertness during the rotation (rolling-moment inertia of shaft):

*m*R2/2* = 0.29*0.012/2 = 1.45e-5 [*[kg]*[m]2*]

, where *m* = of 0.29 kgf - the mass of the section of shaft.

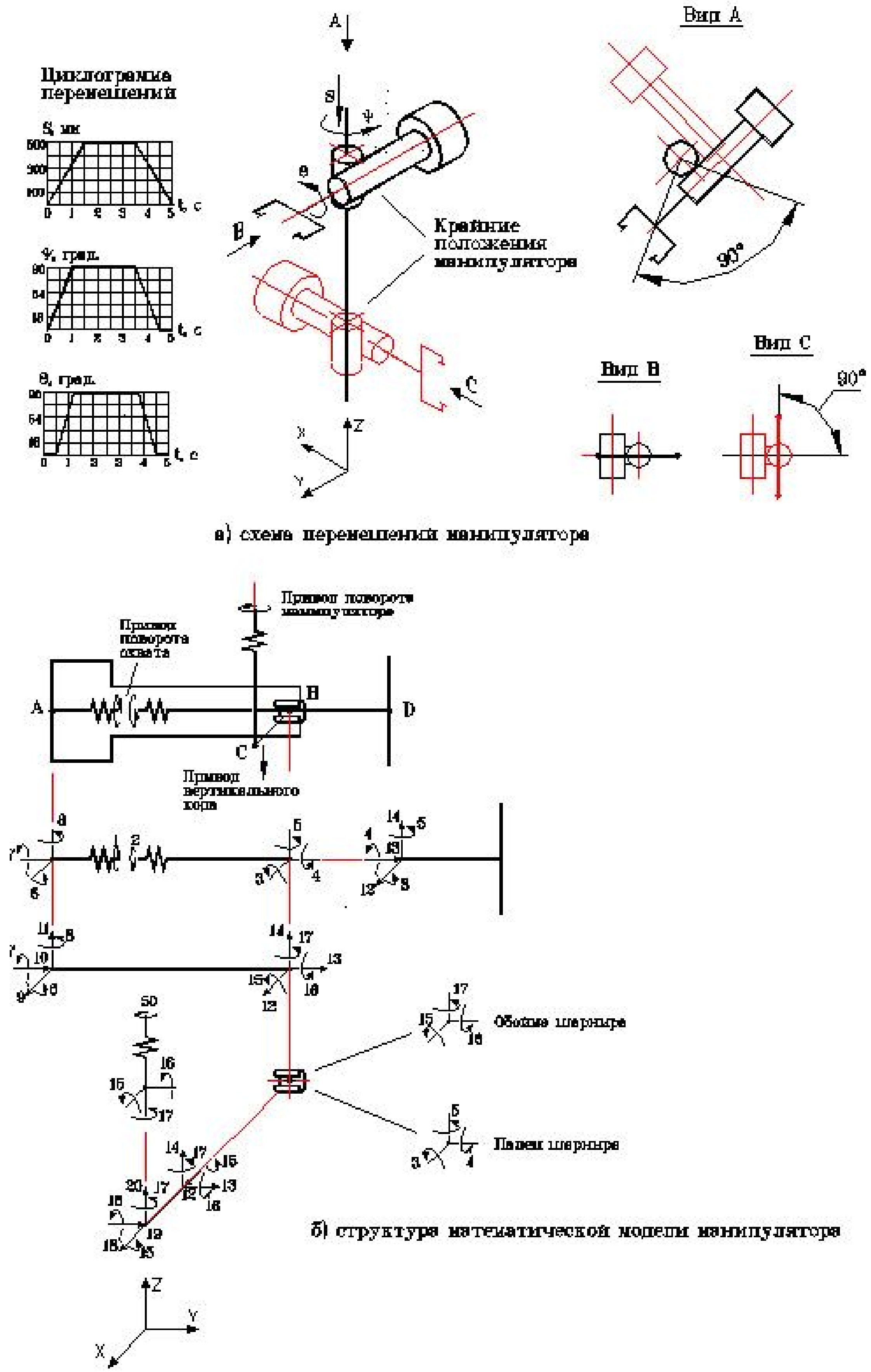
The geometric characteristics of the cross section of lever OC are determined the diameters of section, equal to 20 mm.

Text of task before the language *Of pradiSLang*:

```
I DATA:

    Point A = -100.e-3, 0, 0
    Point O = 0, 0, 0
    Point C = 400.e-3, -200.e-3, 70.e-3
    J = of 0.79 e-8
    Jk = 1.57 e-8
    S = of 3.14 e-4
```

```
    E = of 2.e11
    PO = 0.3
    RO = 7800

    Parameters of lever = J, J, Jk, S, E, PO, RO

    Torsional stiffness of shaft = 1.03 E4
    Moment of the inertia of the shaft = of 1.45 E-5
    The flexural rigidity of the joint = of 1.E4
    High-speed action = 0, 5, 0.2, 10, 10, 1.E8
    Form based on the side of axis X = 1.2, of 0, 0, 0.20,
                                 1, 0, 0.20, 0, 1, 0.20, 0
    Form based on the side of axis Z = 1.2, 0.20, 0, 0,
                                 0.20, 0, 1, 0.20, 1, 0, 0
I FRAGMENT:
    # BASE: 5,6,7, 100
    # STRUCT:
        Shaft AO 'SV13W (1, 2,3,4; Point A, point O,
                              Torsional stiffness of shaft)
                        'M (1; Moment of the inertia of shaft)
        Lever OC 'BAL3DJ (5,6,7, 2,3,4, 8,9,10, 11,12,13;
                              Point O, point C, point C,
                              Parameters of lever)
        Cylindrical joint 'SH3C (2,3,4, 100,100,100;
                                      Point A, point O,
                                      The flexural rigidity of joint)
        Action 'VTR0 (1 100; High-speed action)
    # OUT:
        Angular velocity of point A 'the V (1; 1)
        Angle of rotation of point A 'S (1; 1)
        Torsion angle between A and O 'the X (W: Shaft AO (1); 1)
        Shaft torque AO 'the X (F: Shaft AO (1); 1)
        Coordinates of point C 'KOORD3 (8,9,10; Point C)
I SHOW:
    Form based on the side of x axis 'LAYER (; Form based on the side of x
axis)
    Form based on the side of z axis 'LAYER (; Form based on the side of z
axis)
I RUN:
    Transmission of rotary motion 'SHTERM (END = 5)
I PRINT:
    Trajectory of the motion of point C 'DISP (FROM=1;
                                    Coordinates of point C (3),
                                    Coordinates of point C (2))
    Other results 'DISP (;
                                    Angular velocity of point A,
                                    Angle of rotation of point A,
                                    Torsion angle between A and O,
                                    Shaft torque AO)
     $ END
```

2. case of the transmission of rotation with a change in the angular position of rotational axis. Is examined the displacement of manipulator (Fig. SV13W_3), which consists of three together elapsing motions: vertical displacement downward, the turning of the group of manipulator in the horizontal plane, the turning of tongs relative to the longitudinal axis of housing.



SV13W_3. **Example of the transmission of rotary motion based on the one-dimensional to the three-dimensional elements with a change in the angular position of rotational axis with the simulation of the motions of manipulator.**

Before this model it is necessary to transmit rotation from two one-dimensional drives: the drive of the turning of housing and drive of the turning of tongs (drives they are simulated by elements STR0, which reproduce the required law of displacements). The turning of housing occurs relative to fixed vertical axis. Turning of the tongs - relative to the longitudinal axis of housing, which changes its position. The special feature of the construction of design diagram for the transmission of rotation from the drive of the turning of tongs is the use of two elements SV13W: one, as usual, transfers rotation from the shaft of engine to the tongs, and as far as the second - links engine block and group of manipulator. The need for the second element explains by the fact that the current position of the axis of the shaft of engine must be coordinated with the current position of the axis of engine block. Therefore fastening according to the angular degree of the freedom of engine block would be erroneous.

Before the process of calculation on shield is placed the conditional image of manipulator before three projections beyond the fixed coordinate system and the image of the turned tongs before the moving coordinate system, connected for the sake of moving housing.

Text of model before the language *Of pradiSLang*:

```
 I DATA:
Point O = 0, 0, 0
Point A =-125.e-3,  -416.e-3, 920.e-3
Point B =-125.e-3, 0.e-3, 920.e-3
Point C = 0, 0, 920.e-3
Point D =-125.e-3, 260.e-3, 920.e-3
Point E =-235.e-3, 260.e-3, 920.e-3
Point F = -15.e-3, 260.e-3, 920.e-3
k1 = 8.4e3
k2 = 4.6e4
k3 = 6.2e4
The flexural rigidity of the joint = of 1.e4
                     J1 = 8.7e-3;  J2 = 1.8e-2;  J3 = 0.17
Characteristic of [vertik]. [permeshcheniya] =
                     0, -0.50, 0, 1.5, 2, 1.5, 1.e6
Nature. the turning of housing =
                     0, 1.5708, 0, 1., 2.5, 1., 1.e6
Characteristic of the drive of tongs =
                     0, 1.5708, 0.5, 0.7, 2.6, 0.7, 1.e5
Steel = of 2.e11, 0.3, 7800
Parameters of housing = 2.e-7, 2.e-7, 4.e-7, 2.e-3, steel
Parameters of tongs = 1.e-8, 1.e-8, 2.e-8, 3.e-4, steel
Parameters of cross-beam = 1.e-7, 1.e-7, 1.e-7, 1.e-3, steel
Parameters of layer 1 = 2, of 0,-0.5, 0.2, 1,-0.5, 0.2, 0, 1, .2
Parameters of layer 2 = 2, -0.9, 0, 0.2, -0.9, 1, 0.2, -2, 0, .2
Parameters of layer 3 = 2, -0.9,-0.6, 0, -0.9,-0.6, 1, -2,-.6, 0
Size of window = 0.3
Color 1 = 14;  Color 2 = 4;  Color 3 = 1

I FRAGMENT: [Manipul]

   # BASE :  100, 15,16

   # STRUCT:
      Drive of the turning of tongs 'STR0 (1 2;
                                Characteristic of the drive of tongs)
                                 'M (1; J1); 'M (2; J2)
      Transmitting component to the tongs 'SV13W (2 Oe 4 5;
                                Point A, point B, k1)
      Transmitting component to the housing 'SV13W (1 6 7 8;
```

```
                              Point A, point B, k2)
    Group of manipulator 'BAL3DJ (9 10 11 6 7 8
                              12 13 14 15 16 17;
                              Point A, point B, point B,
                              Parameters of housing)
    Cylindrical joint 'SH3C (15 16 17 Oe 4 5;
                              Point A, point B,
                              The flexural rigidity of joint)
    [Skhvat]_[prodolnyy] section 'BAL3DJ (12 13 14 Oe 4 5
                              24 25 26 27 28 29;
                              Point B, point D, point D,
                              Parameters of tongs)
    [Skhvat]_[poperechnyy] section 1 'BAL3DJ (24 25 26 27 28 29
                              30 31 32 33 34 35;
                              Point D, point E, point E,
                              Parameters of tongs)
    [Skhvat]_[poperechnyy] section 2 'BAL3DJ (24 25 26 27 28 29
                              36 37 38  39 40 41;
                              Point D, point F, point F,
                              Parameters of tongs)
    Drive of the turning of manipulator 'STR0 (50 100;
                              Nature. the turning of housing)
    Transmitting component to the cross-beam 'SV13W (50 15 16 17;
                              Point O, point C, k3)
                                 'M (50; J3)
    Cross-beam 'BAL3DJ (18 19 20 15 16 17
                              12 13 14 15 16 17;
                              Point C, point B, point B,
                              Parameters of cross-beam)
    Drive is vertical. displacement 'STR0 (20 100;
                           Characteristic of [vertik]. [permeshcheniya])

  # OUT:
    Angle of rotation of tongs 'DX (2, 1; 1)
    Angle of rotation of housing 'S (50; 1)
    Vertical displacement 'S (20; 1)

I SHOW:

          {View of manipulator relative to fixed coordinate system}

                       {Based on the side of axis Y}

  Cross-beam 'LAYER (cross-beam;
                           Parameters of layer 2, color 1)
  Housing 'LAYER (group of the manipulator;
                           Parameters of layer 2, color 2)
  Tongs 'LAYER ([Skhvat]_[prodolnyy] section,
                           [Skhvat]_[poperechnyy] section 1,
                           [Skhvat]_[poperechnyy] section 2;
                           Parameters of layer 2, color 3)

                       {Based on the side of x axis}

  Cross-beam 'LAYER (cross-beam;
                           Parameters of layer 1, color 1)
  Housing 'LAYER (group of the manipulator;
                           Parameters of layer 1, color 2)
  Tongs 'LAYER ([Skhvat]_[prodolnyy] section,
                           [Skhvat]_[poperechnyy] section 1,
                           [Skhvat]_[poperechnyy] section 2;
                           Parameters of layer 1, color 3)

                       {Based on the side of axis Z}

  Cross-beam 'LAYER (cross-beam;
```

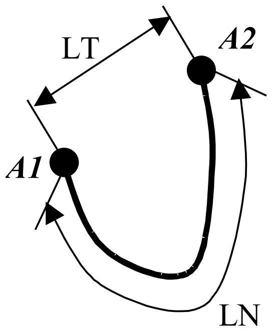
```
                              Parameters of layer 3, color 1)
   Housing 'LAYER (group of the manipulator;
                              Parameters of layer 3, color 2)
   Tongs 'LAYER ([Skhvat]_[prodolnyy] section,
                              [Skhvat]_[poperechnyy] section 1,
                              [Skhvat]_[poperechnyy] section 2;
                              Parameters of layer 3, color 3)

   {View of tongs beside [lokal].[sist].[koordinat], that moves together with
                                the housing}

   Cross-beam 'LAYER (cross-beam;
                              Size of window,
                              Point B, point D, point C, color 1;
                              12 13 14 24 25 26 18 19 20)
   Tongs 'LAYER ([Skhvat]_[poperechnyy] section 1,
                              [Skhvat]_[poperechnyy] section 2;
                              Size of window,
                              Point B, point D, point C, color 3;
                              12 13 14 24 25 26 18 19 20)
I RUN:

   Motion of manipulator 'SHTERM (END=5, ITR=7,
                                      CONTROL=1.E-3, SMAX=0.05)
I PRINT:

   Cyclogram of the motions of manipulator 'DISP ()
```

$ END

4.6.Threads

4.6.1.1.Elastic thread THREAD

Reflected properties



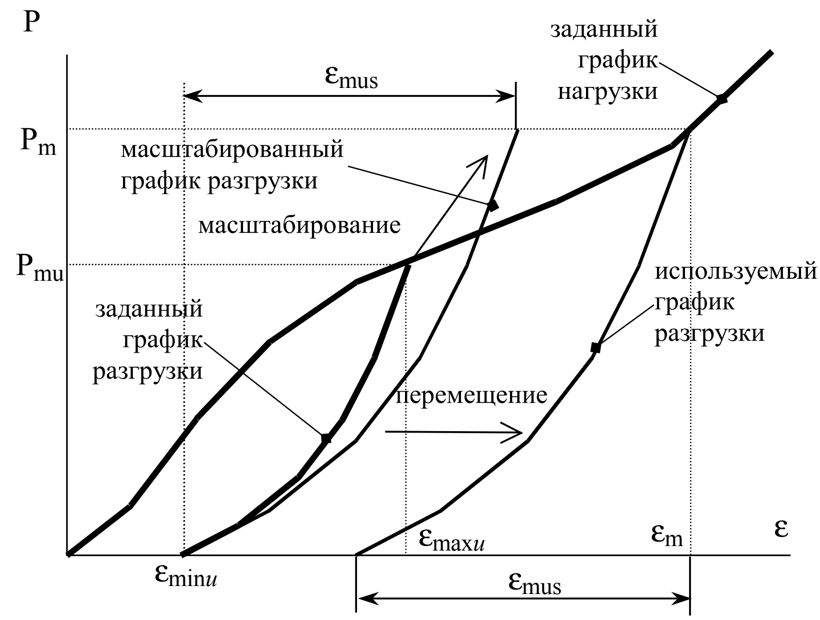


Fig. THREAD_1. **Fig. THREAD_2.**

Model is intended for the reproduction of the properties of elastic thread taking into account of hysteresis, inertia properties of the material of thread and its gravitational force. At extreme points the model can contact with other bodies and connections. Model does not reproduce the configuration of the thread between the extreme points before the loose state.

It can be used for the simulation of the segment of the belt of the safety of automobile in the sections between the places of fastening belt to the body. The sections of belt can be divided beside any quantity of segments, connected with each other. For the reproduction of the properties of the connection of the belt of safety for the sake of the ring and the coil, the study of the twisting of belt should be used other models.

Two points A1 and A2, capable of being moved before the space under the action of external forces, are connected together for the sake of elastic thread.

At the initial moment of time the thread can be in the loose state, in this case the origin coordinates of points A1 and A2 can coincide. Elastic force appears, if the current distance LT between the points A1 and A2 exceeds the length of thread before the loose state LN (see Fig. OF THREAD_1). Thread does not receive compressive load. The pretensioning of thread can be reproduced by the task of value LN smaller than LT0 (initial distance between the points).

The elastic properties of thread with the load and to unloading are prescribed as far as different tabular dependences before the coordinates “relative deformation” - “force”, which makes it possible to reproduce hysteresis.

The graph of unloading is scaled depending on the value of maximum force with the load reached and is shifted beside the point of the beginning of unloading (Fig. THREAD_2). The coefficient of scaling as far as both coordinates is designed as the ratio of a maximally achieved value of the force of load Pm to the maximum given value of force before the tabular dependence of the graph of unloading Pmu.

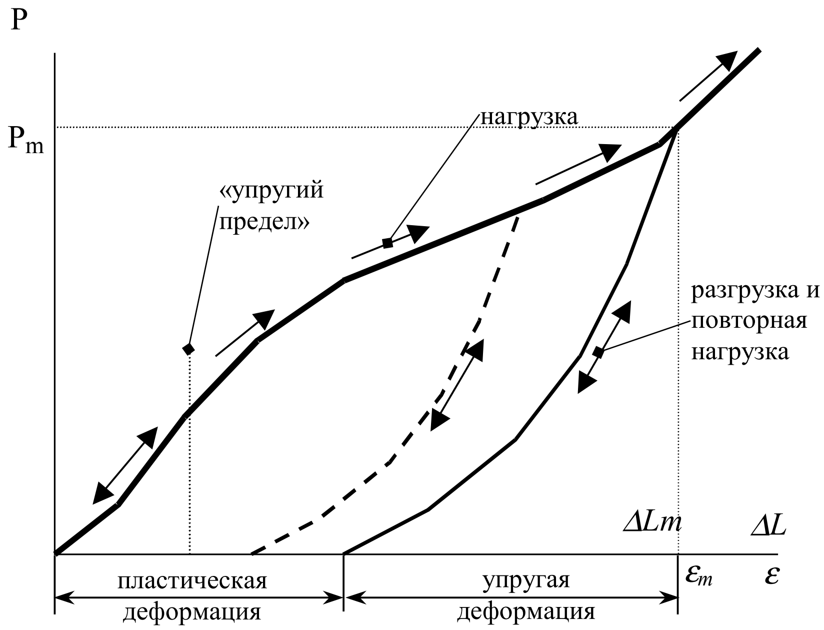


Fig. THREAD_3.

With the repeated loading before the initial stage (ε<εμ) elastic properties are reproduced first on the unloading branch of hysteresis loop before its intersection with the load branch. After reaching of deformation ε=εμ, to the corresponding point of the suppression of load and unloading branches (with ε>εμ), the elastic properties of thread subsequently are reproduced on the load branch.

The task to the maximum deformation ("elastic limit") is possible, around the reaching by which the load and unloading are reproduced according to the prescribed graph of load phase, thus, hysteresis it is absent.

The graphs of load and unloading must mutually correspond to each other:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.
2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.

Thread possesses inertia properties and is located before the gravitational field of the Earth.

Degrees of freedom

1,2, 3	Progressive points Of [a]1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Progressive points Of [a]2 before the direction of the global coordinate axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of the point Of [a]1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of the point	*m*	*- Rlmax… +RLmax*

N in sequence	Description	Dimensionality	Range
	Of [a]2		If the length of element before the nondeformed state (parameter 7) is equal to zero or negative, then the points Of [a]1 and [A]2 at the initial moment of time ***cannot*** coincide
7	Length of thread before the nondeformed state	*m*	*- Rlmax… +RLmax* With the negative or zero value of this parameter the initial length of thread is determined as far as the initial distance between the points Of [a]1 and [A]2
8	Sectional area of the thread	*[m]2*	*> 0*
9	Material density of the thread	*[kg]/[m]3*	*> 0*
10	Sign of the account of gravitational force	-	*- Rlmax… +RLmax* If the value of the parameter is equal to one, then model reproduces the force of gravity of element before the direction of global z axis.
11	Maximum relative deformation around the reaching by which unloading is produced according to the graph of load (“the elastic limit of relative deformation)	-	*≥ 0*
12	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
13…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread with the load.	-, *H*	Table must contain not less than 4-X of values (2 pairs). The value of deformation must

N in sequence	Description	Dimensionality	Range
	Before each pair of numbers: the first number - relative dilitational strain with the load the second number - the force [of N]		grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of displacement the approximation must ensure the zero value of force.* *Model ignores the branches of the graph of load with the negative deformations.*
…	Marker		*It is equal to the value of parameter 12*
…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread during the unloading. Before each pair of numbers: the first number - relative dilitational strain during the unloading the second number - the force [of N]	*m/s, H*	Table must contain not less than 4-X of values (2 pairs). The value of deformation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *The force, which corresponds to the minimum deformation of unloading must be equal to zero.*

NOTE:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.

2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.

3. during exceeding of maximum deformation, in comparison with the given one before the tables, force is designed by the extrapolation of the last section of graph.

Working vector

N in sequence	Description	Dimensionality	Range
1	Current distance between the points of the connection	*m*	
2	Current relative deformation of thread down the tension (with the compression it is equal to zero)		
3	Current absolute deformation of thread down the tension (with the compression it is equal to zero)	*m*	
4	Accumulated relative plastic deformation of the thread		
5	Accumulated absolute plastic deformation of the thread	*m*	
6	Elastic tensile strength of the thread	*N*	

Standard graphic means

In tension thread is depicted in the form the section OF THE WHITE color, which connects the end points of thread. Before the regime of dipping the thread is represented conditionally in the form by the broken line OF RED color. Salient point is located beyond the axis of parallel axis Z and passing through the middle of section. The value of [provisa] starts approximately to equal half of the difference between the initial and instantaneous length of thread taking into account the accumulated plastic deformation. Direction “of dipping” of the broken line - negative on the relation to the z axis. The plane of dipping is perpendicular down the plane of xOy.

4.6.1.2.Overflow of the thread through the ring SRING

<u>Reflected properties</u>

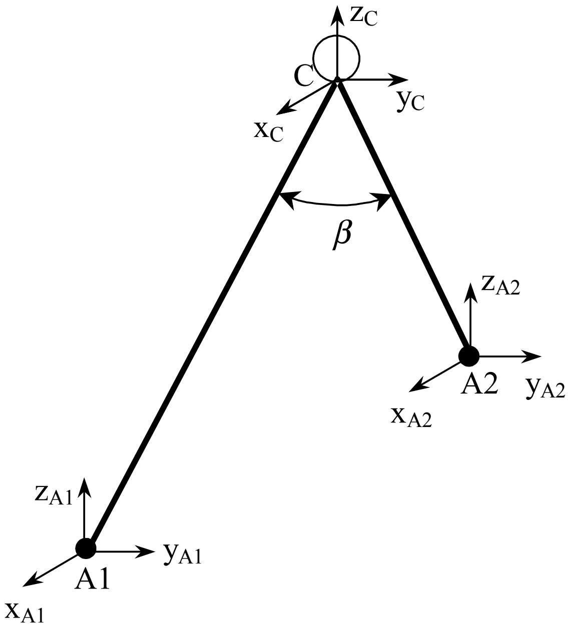


Fig. SRING_1.

Model is intended for the reproduction of the properties of the segment of elastic thread with its overflow through the ring. The initial length of segment is constant. Thread does not receive compressive load. Maximum frictional force is determined according to the law Euler. Model reproduces the frictional force of rest and the frictional force of slip. Model considers hysteresis and inertia properties of the material of thread, and also the force of gravity of thread. At extreme points the model can contact with other bodies and connections. Model does not reproduce the configuration of thread before the loose state.

Two points A1 and A2, capable of being moved before the space under the action of external forces, are connected together for the sake of the elastic thread, passed through the ring. Contact between the thread and the ring is accomplished at the point C, which also can be moved before the space. Contact between the ring and the thread cannot be extended.

The initial values of the lengths of the parts of the segment between the contact point with the ring c and the points of connection A1 and A2 (respectively *TO LCA1* and *LCA2*) must be such that against any moment of the time of calculation segment completely would not pass concerning the ring. Calculation in this case will be completed with the delivery of the diagnostic communication

The elastic properties of thread with the load and to unloading are prescribed as far as different tabular dependences before the coordinates “relative deformation” - “force”, which makes it possible to reproduce hysteresis.

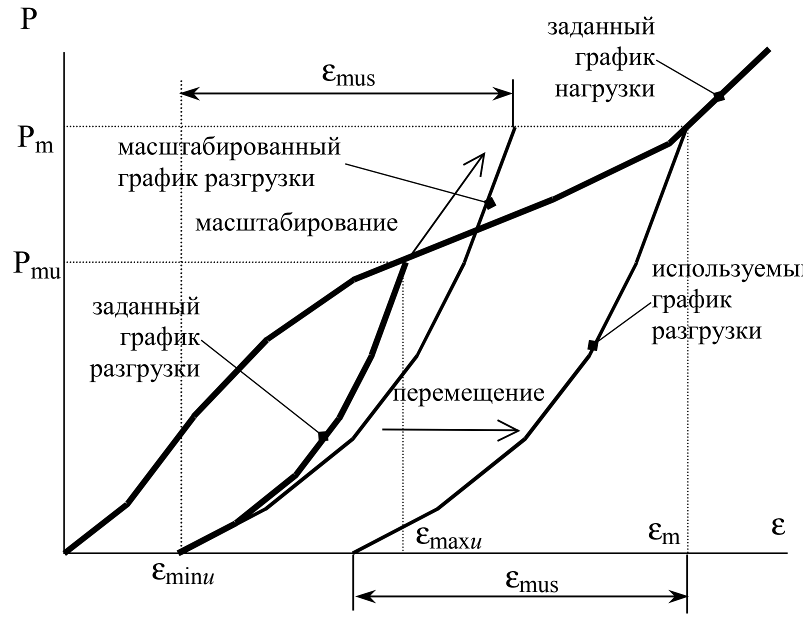


Fig. SRING_2.

The graph of unloading is scaled depending on the value of maximum force with the load reached and is shifted beside the point of the beginning of unloading (Fig. SRING_2). The coefficient of scaling as far as both coordinates is designed as the ratio of a maximally achieved value of the force of load Pm to the maximum given value of force before the tabular dependence of the graph of unloading Pmu.

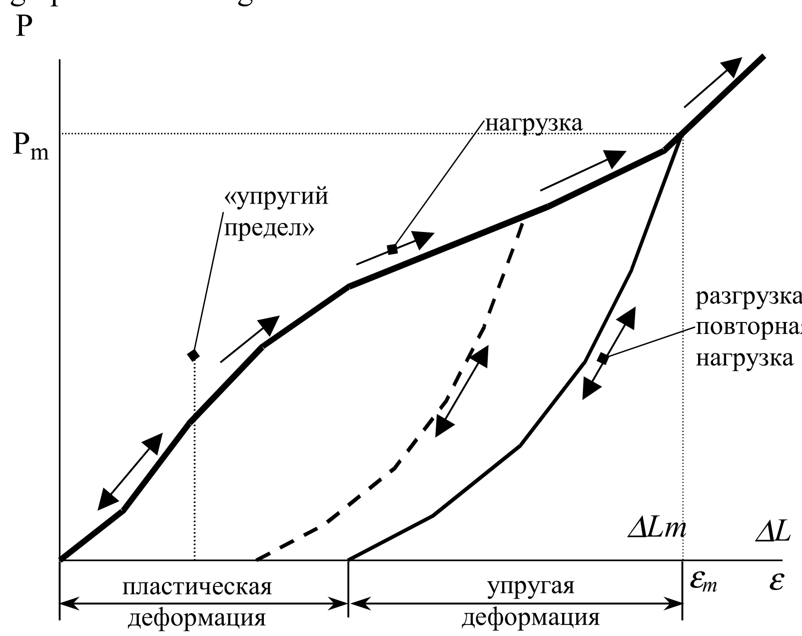


Fig. SRING_3.

With the repeated loading before the initial stage ($\varepsilon<\varepsilon\mu$) elastic properties are reproduced first on the unloading branch of hysteresis loop before its intersection with the load branch. After reaching of deformation $\varepsilon=\varepsilon\mu$, to the corresponding point of the suppression of load and unloading branches (with $\varepsilon>\varepsilon\mu$), the elastic properties of thread subsequently are reproduced on the load branch.

The task to the maximum deformation (“elastic limit”) is possible, around the reaching by which the load and unloading are reproduced according to the prescribed graph of load phase, thus, hysteresis it is absent.

The graphs of load and unloading must mutually correspond to each other:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.
2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.

Thread possesses inertia properties and is located before the gravitational field of the Earth.

Degrees of freedom

1,2, 3	Progressive points Of [a]1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Progressive points Of [a]2 before the direction of the global coordinate axes of the X, Y, Z.
7, 8, 9	Progressive points C before the direction of the global coordinate axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of the point Of [a]1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of the point Of [a]2	*m*	*- Rlmax… +RLmax* The points Of [a]1 and [A]2 at the initial moment of time ***can*** coincide. In this case the angle *τηε β* between the branches is equal to 0. point A1 and A2 are always considered located on the different sides rings.
7,8,9	the origin coordinates of point C	*m*	*- Rlmax… +RLmax* Point C must not coincide for the sake of the points A1 or A2. The initial lengths of sections CA1 and CA2 should be selected in such a way that before the process of calculation these lengths could not become negative.

N in sequence	Description	Dimensionality	Range
10	Coefficient of friction with the overflow of the thread through the ring	-	*> 0*
11	Length of thread before the nondeformed state	*m*	*- Rlmax… +RLmax* With the negative or zero value of this parameter the initial length of thread is determined as far as the sum of the initial distances between the point C and as far as the points Of [a]1 and [A]2
12	Sectional area of the thread	*[m]2*	*> 0*
13	Material density of the thread	*[kg]/[m]3*	*> 0*
14	Sign of the account of gravitational force	-	*- Rlmax… +RLmax* If the value of the parameter is equal to one, then model reproduces the force of gravity of element before the direction of global z axis.
15	Maximum relative deformation around the reaching by which unloading is produced according to the graph of load ("the elastic limit of relative deformation)	-	*≥ 0*
16	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
17…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread with the load. Before each pair of numbers: the first number - relative dilitational strain with the load	-, *H*	Table must contain not less than 4-X of values (2 pairs). The value of deformation must grow from the first pair to the latter. It is not allowed the descending sections of

N in sequence	Description	Dimensionality	Range
	the second number - the force [of N]		approximation. *With the zero value of displacement the approximation must ensure the zero value of force.* *Model ignores the branches of the graph of load with the negative deformations.*
…	Marker		*It is equal to the value of parameter 12*
…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread during the unloading. Before each pair of numbers: the first number - relative dilitational strain during the unloading the second number - the force [of N]	*m/s, H*	Table must contain not less than 4-X of values (2 pairs). The value of deformation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *The force, which corresponds to the minimum deformation of unloading must be equal to zero.*

NOTE:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.
2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.
3. during exceeding of maximum deformation, in comparison with the given one before the tables, force is designed by the extrapolation of the last section of graph.

Working vector

N in sequence	Description	*Dimensionality*	Range
1	Current distance between the points based on [A]1.	*m*	
2	Current distance between the points based on [A]2.	*m*	
3	The instantaneous length of thread.	*m*	
4	Current average relative deformation of thread down the tension (with the compression it is equal to zero)		
5	Current average absolute deformation of thread down the tension (with the compression it is equal to zero)	*m*	
6	Accumulated average relative plastic deformation of the thread		
7	Accumulated average absolute plastic deformation of the thread	*m*	
8	Average tensile strength of the thread	*N*	
9	Frictional force	*N*	
10	Elastic tensile strength of thread in the section between the points C and A1	*N*	
11	Elastic tensile strength of thread in the section between the points C and A2	*N*	

Standard graphic means

Graphic means on silence is two sections of white color, that connects points A1, and A2, when the thread is tightened. In the case of dipping branches the severings are converted beside those broken of red color, that connect these points, by length to the equal length of branch before the nondeformed state. Salient point is located beyond the axis of parallel axis Z and passing through the middle of section. The value of [provisa] starts approximately to equal half of the difference between the initial and instantaneous length of thread taking into account the accumulated plastic deformation. Direction “of dipping” of the broken line - negative on the relation to the z axis. The plane of dipping is perpendicular down the plane of xOy. With the flight the color of sections changes down the yellow.

4.6.1.3.Inertia coil **RETRTA**

<u>Reflected properties</u>

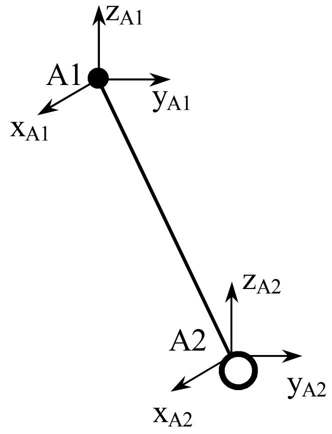


Fig. RETRTA_1.

Model is intended for the reproduction of the properties of the segment of the elastic thread of that connected with the inertia coil. Segment is concluded between the point Of [a]1 - by the point of connection to another segment of thread and by point A2 - by the entrance point of thread beside the inertia coil. The length of the segment of thread [A]1A2 is variable and depends on the properties of inertia coil and interaction of segment with other segments of thread at the point Of [a]1 and external bodies, on which is fixed the coil at point A2. The points Of [a]1 and A2 can accomplish arbitrary displacement before the space under the action of external forces.

Thread does not receive compressive load. The elastic properties of thread with the load and to unloading are prescribed as far as different tabular dependences before the coordinates “relative deformation” - “force”, which makes it possible to reproduce hysteresis. Model considers also the inertia properties of the material of thread, and also the force of gravity of thread. The length of the segment of thread against any moment of time must it is non-negative (point Of [a]1 with any conditions it cannot be pulled inside the coil). Calculation in this case ceases with the delivery of diagnostic communication. Model does not reproduce the configuration of thread before the loose state.

At the initial moment of time the segment of thread is considered tightened by the force, equal down the value of force with the zero racing before the table of the characteristic “[shpulevogo]” effect of coil (see below).

Coil reproduces the free racing of thread with a certain tensile stress and the process of cutoff, accompanied before the initial stage “[shpulevym]” effect. The beginning of the process of the cutoff of coil, accompanied by [shpulevym] effect, is characterized as far as exceeding the acceleration of the racing of the thread of a certain limiting value. The task of the delay of the wear and tear of coil with respect to the moment of the appearance of critical acceleration is possible. If before the period of the delay of start the acceleration of racing becomes less than the critical, then the wear and tear of coil does not occur. To the moment of operation of coil and before the process of the reproduction of [shpulevogo] effect the thread is considered as the absolutely elastic and hysteresis is not reproduced.

[Shpulevyy] effect consists before the dependence of the tensile stress of thread beyond the value of racing with the wear and tear of coil. This dependence is assigned by the table, which consists besides the pairs of numbers, the first of which is the value of the racing of thread after the wear and tear of coil, and the second - corresponding to this racing amount of the tensile stress of thread. The minimum value of force before the table is the amount of the tensile stress of thread before the stage of the free racing (see above). The maximum value of racing before the table corresponds to the moment of the complete cutoff of coil. If before the process of simulation racing with the wear and tear not of [dostignuv] of maximum value will begin to decrease and it will return to the zero value, then model will pass beside the regime of the reproduction of free racing.

[Shpulevyy] effect completes by the complete cutoff of coil, with which ceases both the racing of thread from the coil and its possible retraction inward. Model in this case begins to work as the segment of the thread of a constant initial length taking into account the occurred total racing.

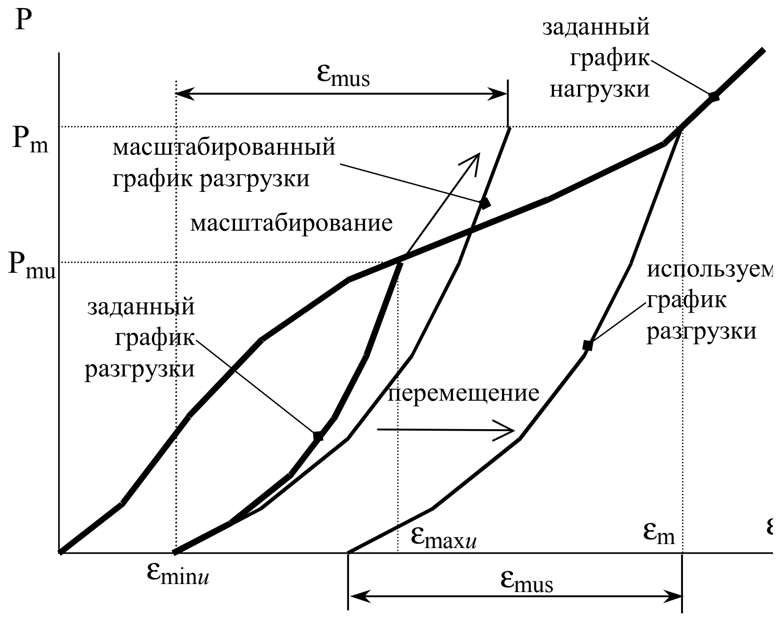


Fig. RETRTA_2.

The graph of unloading is scaled depending on the value of maximum force with the load reached and is shifted beside the point of the beginning of unloading (Fig. RETRTA_2). The coefficient of scaling as far as both coordinates is designed as the ratio of a maximally achieved value of the force of load Pm to the maximum given value of force before the tabular dependence of the graph of unloading Pmu.

With the repeated loading before the initial stage ($\varepsilon<\varepsilon\mu$) elastic properties are reproduced first on the unloading branch of hysteresis loop before its intersection with the load branch. After reaching of deformation $\varepsilon=\varepsilon\mu$, to the corresponding point of the suppression of load and unloading branches (with $\varepsilon>\varepsilon\mu$), the elastic properties of thread subsequently are reproduced on the load branch.

The task to the maximum deformation (“elastic limit”) is possible, around the reaching by which the load and unloading are reproduced according to the prescribed graph of load phase, thus, hysteresis it is absent.

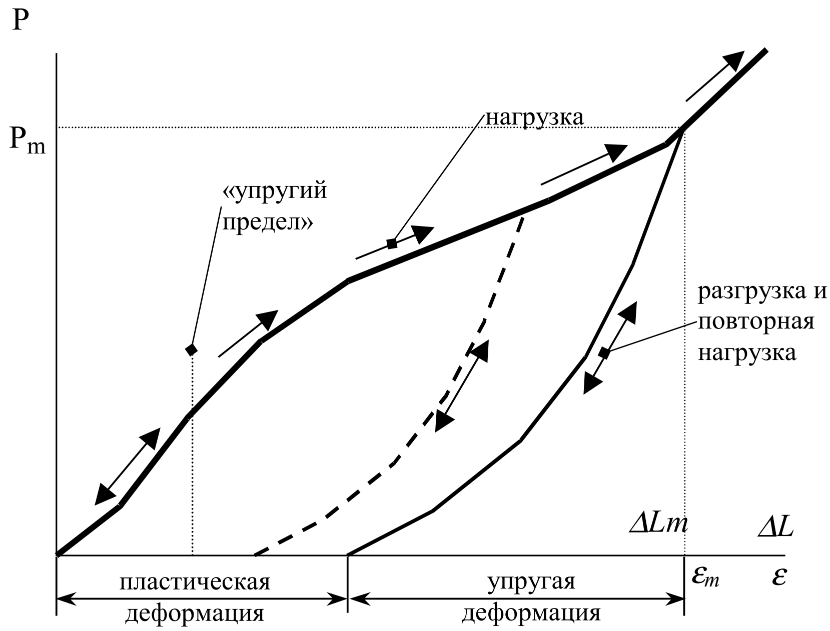


Fig. RETRTA_3.

The graphs of load and unloading must mutually correspond to each other:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.
2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.

<u>Degrees of freedom</u>

1,2, 3	Progressive points Of [a]1 before the direction of the global coordinate axes of the X, Y, Z.
4, 5, 6	Progressive points Of [a]2 before the direction of the global coordinate axes of the X, Y, Z.

<u>Parameters</u>

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of the point Of [a]1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point A2	*m*	*- Rlmax… +RLmax* The points Of [a]1 and A2 at the initial moment of time ***cannot*** coincide.
7	Critical acceleration of the racing of thread from the coil, which characterizes the moment of the beginning of the wear and tear	*[m]/c2*	*> 0*

N in sequence	Description	Dimensionality	Range
8	Delay time of the wear and tear	*[s]*	*≥ 0*
9	Sectional area of the thread	*[m]2*	*> 0*
10	Material density of the thread	*[kg]/[m]3*	*> 0*
11	Sign of the account of gravitational force	-	*- Rlmax… +RLmax* If the value of the parameter is equal to one, then model reproduces the force of gravity of element before the direction of global z axis.
12	Maximum relative deformation around the reaching by which unloading is produced according to the graph of load ("the elastic limit of relative deformation)	-	*≥ 0*
13	Marker (numerical value, which separates one table of values from another)		*- Rlmax… +RLmax*
14…	Table 1 of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread with the load after the cutoff of coil. Before each pair of numbers: the first number - relative dilitational strain with the load the second number - the force [of N]	*-, H*	Table must contain not less than 4-X of values (2 pairs). The value of deformation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *With the zero value of displacement the approximation must ensure the zero value of force.* *Model ignores the branches of the graph of load with the negative deformations.*
…	Marker		*It is equal to the value of parameter 13*
…	Table it is 2nd the pairs of numbers,	*-, H*	Table must contain

N in sequence	Description	Dimensionality	Range
	which determine piecewise-the linear approximation of the graph of the dependence of axial force beyond the relative deformation of thread during the unloading after the cutoff of coil. Before each pair of numbers: the first number - relative dilitational strain during the unloading the second number - the force [of N]		not less than 4-X of values (2 pairs). The value of deformation must grow from the first pair to the latter. It is not allowed the descending sections of approximation. *The force, which corresponds to the minimum deformation of unloading must be equal to zero.*
…	Marker		*It is equal to the value of parameter 13*
…	Table 3- of pair of numbers, that determine piecewise-the linear approximation of the graph of the dependence of the tensile stress of thread beyond the value of racing with the wear and tear of coil (characteristic "[shpulevogo]" effect). Before each pair of numbers: the first number - the value of racing [m] the second number - the force [of N]	*m, H*	Table must contain not less than 4-X of values (2 pairs). Retardation value must grow from the first pair to the latter. It is not allowed the descending sections of approximation. All values before the table must be non-negative. *The force, which corresponds to zero racing is taken after the equal down the tensile stress of thread with the free racing.* *The maximum value of racing before the table corresponds to the complete closing of the coil*

NOTE:

1. at any point of the graph of load after elastic limit plastic deformation after unloading must be positive.
2. plastic deformation (residual deformation after complete unloading) with an increase in the complete deformation of thread must monotonically increase.

3. during exceeding of maximum deformation, in comparison with the given one before the tables 1 or 2, force is designed by the extrapolation of the last section of graph.

Working vector

N in sequence	Description	Dimensionality	Range
1	Current distance between the points Of [a]1 and A2	*m*	
2	Current nondeformed length of the thread	*m*	
3	Current relative deformation of thread down the tension (with the compression it is equal to zero)		
4	Current absolute deformation of thread down the tension (with the compression it is equal to zero)	*m*	
5	Accumulated relative plastic deformation of the thread		
6	Accumulated absolute plastic deformation of the thread	*m*	
7	General racing of thread from the coil taking into account the deformation	*m*	
8	Racing of thread in the section of wear and tear taking into account the deformation	*m*	
9	Tensile stress of the thread	*N*	
10	Flag of the state of the thread 1 the free racing it is 2nd wear and tear with the [shpulevym] effect 3- closing coil the load of the thread 4 closing coil, unloading the thread it is 5th closing coil, dipping the thread		

Standard graphic means

Before the stage of racing the thread is reflected by the section of yellow before the stage of the wear and tear - dark-blue, tension after the wear and tear - white, unloading after the wear and tear - green. Before the regime of dipping thread is represented conditionally in the form by the broken line of red color the salient point it is located beyond the axis of parallel axis Z and passing through the middle of section. The value of [provisa] starts approximately to equal half of the difference between the initial and instantaneous length of thread taking into account the accumulated plastic deformation. Direction “of dipping” of the broken line - negative on the relation to the z axis.

5. Elements of the continuous environment

5.1.2D elements

5.1.1.Rod elements

5.1.1.1.Girder ideally elastic element with the small deformations BALKA

Reflected properties

Model of the two-dimensional rectilinear rod of constant section, capable elastic to be deformed via tension (compression), bend in the plane of its motion (see Fig. BY BALKA_1).

Girder element is capable to be moved and to occupy any position on the coordinate plane, determined as far as the linear and angular coordinates of its ends.

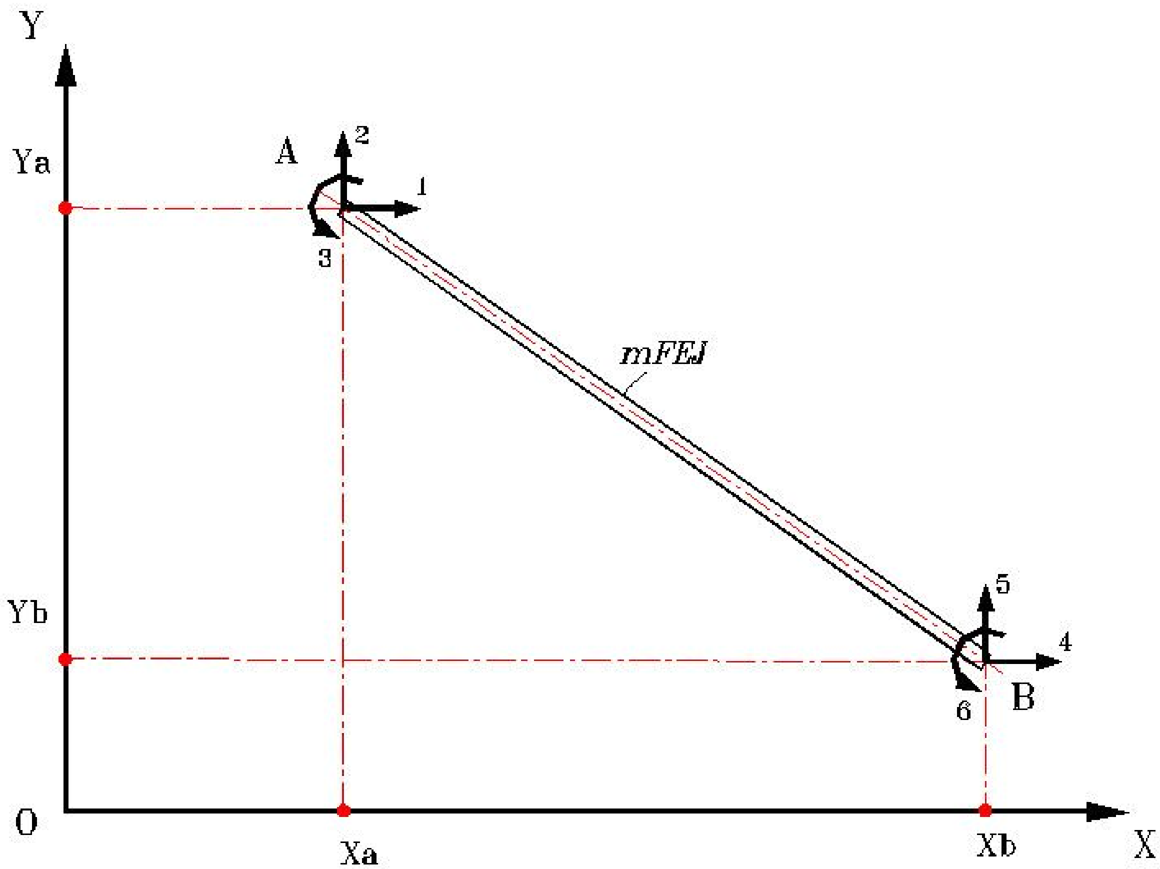
Degrees of freedom

1,2 - progressive points A across the axes OX, OY;

3- rotatory of point A;

4,5 - progressive points B across the axes OX, OY;

6 rotatory of point B.



BALKA_1. **Girder ideally elastic element with the small deformations.**
Degrees of freedom of the element:
1,2 - progressive points A across the axes OX, OY;
3- rotatory points A;
4, it is 5th progressive points B across the axes OX, OY;
6 rotatory of point B;
Xa, Ya - the origin coordinates of point A;
Xb, Yb - the origin coordinates of point B;
m - the mass of the girder;
J the geometric second moment of area of rod relative to the principal axis, perpendicular down the plane, in which moves the element;
F - cross-sectional area;
E - the modulus of elasticity of the material of rod.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	The origin coordinates of point A across the axes OX, OY	*m*	*-RLmax… +RLmax*
3,4	The origin coordinates of point B across the axes OX, OY	*m*	*-RLmax… +RLmax*
5	Mass of the girder	*m*	*0… +RLmax*
6	Ratio of the distance from the point A to the center of masses (before the direction from one point A to the next B) to the length of section AB		1/3… 2/3
7	GEOMETRIC moment of the inertia of the cross beam	*[m]4*	*0… L4*
8	Cross-sectional area	*[m]2*	*0… L2*
9	Modulus of elasticity of the material	*PA*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
6	AXIAL force before the rod	*N*	
7	TRANSVERSE before the rod	*N*	
11	the strain energy of the element	*George*	
12	POTENTIAL energy of the tension of the element	*George*	
13	POTENTIAL energy of the bend of the element	*George*	

Special situations

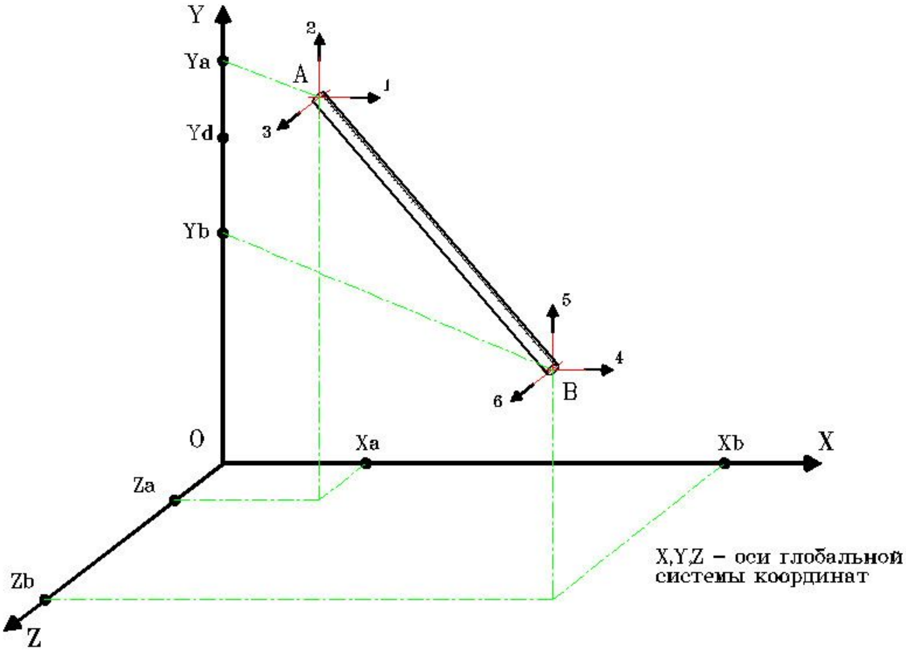
If in the course of computations the instantaneous length of element becomes equal to 0, emergency exit based on the model is accomplished.

5.2.Three-dimensional elements

5.2.1.Pivotal elements

5.2.1.1.It is extended-the compressible pivotal ideally elastic three-dimensional element STERG

Model of three-dimensional rectilinear rod (Fig. STERG_1), capable elastic to be deformed via tension (compression). Pivotal element is capable to be moved and to occupy any position before the three-dimensional space, which is determined as far as the moving coordinates of its ends.



STERG_1. Three-dimensional ideally elastic pivotal element.
Degrees of freedom of the element:
1,2, 3- progressive points A across the axes OX, OY, OZ;
4, 5, 6 progressive points B across the axes OX, OY, OZ;
Xa, Ya, Za - the origin coordinates of point A;
Xb, Yb, Zb - the origin coordinates of point B;

Degrees of freedom

1	progressive before the direction of the axis OX of the point A of the element;
it is 2nd	progressive before the direction of the axis OY of the point A of the element;
3-	progressive before the direction of the axis OZ of the point A of the element;
4	progressive before the direction of the axis OX of the point B of the element;
it is 5th	progressive before the direction of the axis OY of the point B of the element;
6	progressive before the direction of the axis OZ of the point B of element.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
4,5,6	The origin coordinates of point B across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
7	Mass of the rod	*the kgf*	*0… +RLmax*
8	RATIO OF THE DISTANCE from the point A to the center of masses (before the direction from one point A to the next B) to the length of section AB		1/3… 2/3
9	THE CROSS-SECTIONAL AREA of the element	*[m]2*	*0… +RLmax*
10	THE MODULUS of elasticity of the material of the rod	*PA*	*0… +RLmax*

Note. Initial length must be more than 0.

Working vector

N in sequence	Description	Dimensionality	Range
1	CURRENT [deformatsiya]*	*m*	*-RLmax…*

N in sequence	Description	Dimensionality	Range
2	CURRENT longitudinal [usilie]*	*N*	*+RLmax* *-RLmax… +RLmax*

*) note. Positive value corresponds to tension, negative - to compression.

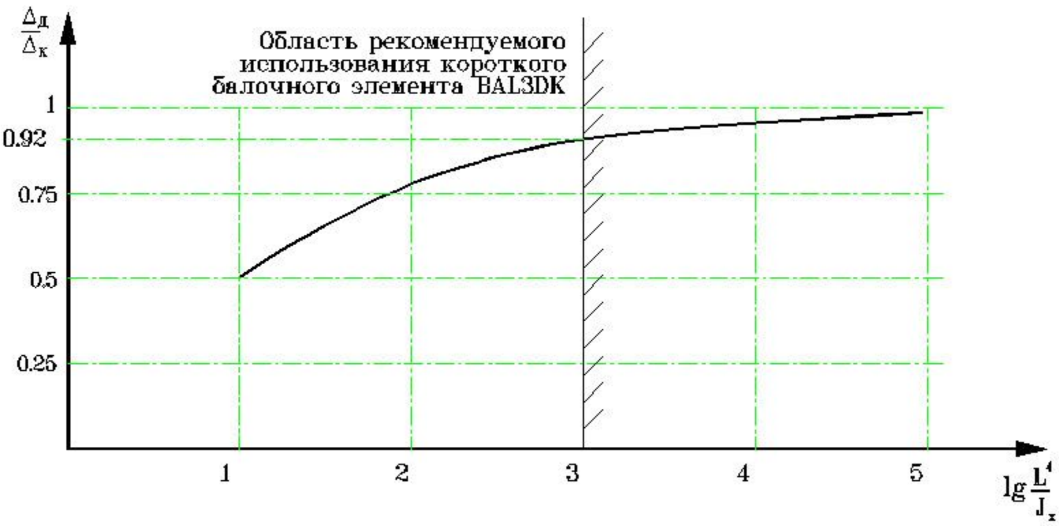
Special situations

If in the course of computations the instantaneous length of element becomes equal to 0, emergency exit based on the model is accomplished.

5.2.1.2. Three-dimensional elastic girder element with the task of the characteristics of the cross section in the form of the moments of inertia and sectional area BAL3DJ, BAL3DK

<u>Reflected properties</u>

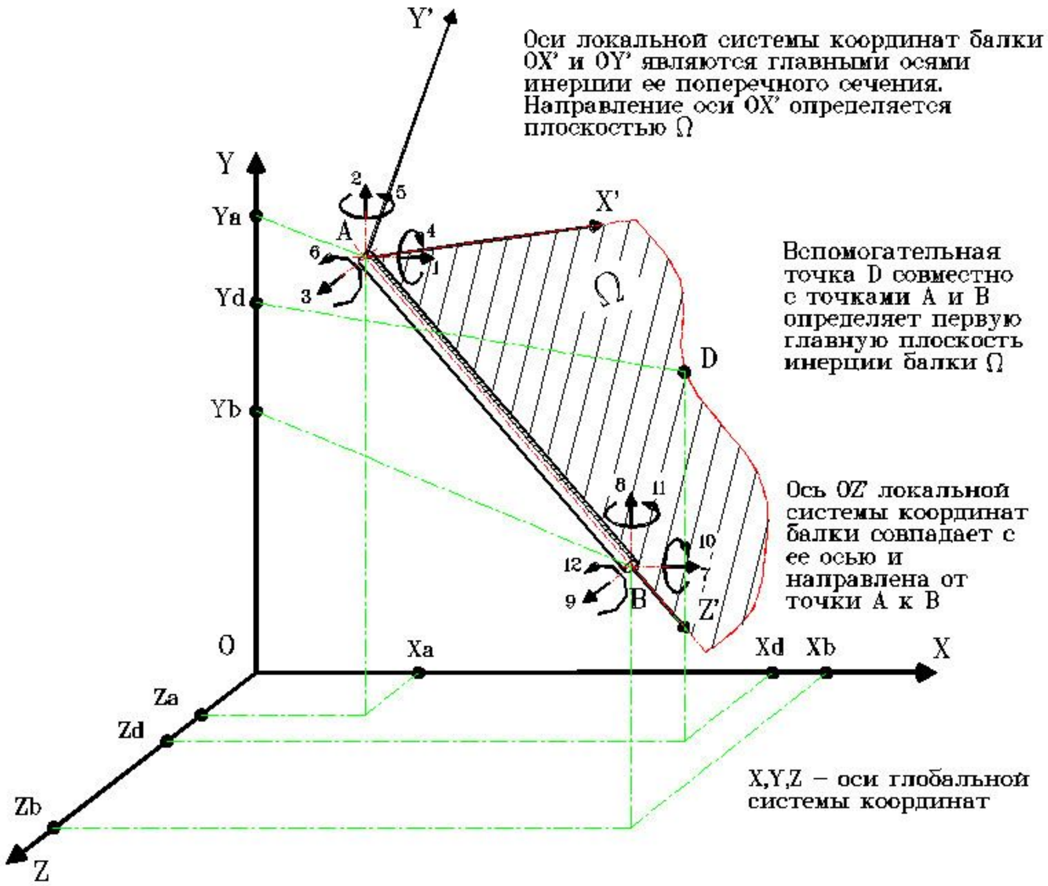
Model of the three-dimensional rectilinear girder element of a constant cross section, capable elastic to be deformed via tension (compression), bend in the planes of the principal axes of section and twisting around the longitudinal axis. Before the short girder element BAL3DK together with above named deformations are possible also the shearing strains. The following recommendations can be given on the selection of the type of girder element for the simulation of the tasks of mechanics. Before Fig. BAL3D_1 is led the curve of the influence of shift beyond the deformation of girder with the bend before the dependence beyond its length. Maximum sagging for a number of the lengths of the cantilever beam of round cross section under the effect of concentrated force against the free end was determined. Curve is built down the basis of the comparison of the results of calculating the girders BAL3DJ and BAL3DK. The shift, which accompanies bending strain, becomes significant when *L4* < 1000*JX (*L4* < 1000*JY). Therefore with the smaller values of the length of girder one should use an element BAL3DK.



BAL3D_1. Curve of the influence of shift beyond the deformation of girder with the bend and the dependences beyond its length.
Δ[d] - the maximum sagging of girder BAL3DJ;
Δ[k] - the maximum sagging of girder BAL3DK;
L the length of the girder;
Jx - the axial moment of the inertia of the cross section of girder.

Girder element is capable to be moved and to occupy any position before the three-dimensional space, which is determined as far as the moving coordinates of its ends.

The local system of coordinates ([LKS]) of girder is determined as follows (Fig. BAL3D_2). Axis OZ' [LKS] (axis of girder) is considered the ray, which emerges based on the point A towards to point [V]. [Vspomogatelnaya] point D determines the first principal plane of the inertia of girder.



BAL3D_2. **Three-dimensional elastic girder element.**
Determination of the axes of the local coordinate system.
Degrees of freedom of the element:
1,2, 3- progressive points A across the axes OX, OY, OZ;
4, 5, 6 -rotatory points A around the axes OX, OY, OZ;
7, 8, 9 progressive points B across the axes OX, OY, OZ;
10, 11, 12 -rotatory points B around the axes OX, OY, OZ;
Xa, Ya, Za - the origin coordinates of point A;
Xb, Yb, Zb - the origin coordinates of point B;
Xd, Yd, Zd - the coordinate of auxiliary point D;

Degrees of freedom

1,2,3 - progressive points A across the axes OX, OY, OZ;

4,5,6 - rotatory points A around the axes OX, OY, OZ;

7,8,9 - progressive points B across the axes OX, OY, OZ;

10,11,12 - rotatory points B around the axes OX, OY, OZ.

Parameters of element BAL3DJ

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
4,5,6	The origin coordinates of point B across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
7,8,9	The origin coordinates of auxiliary point D	*m*	*-RLmax… +RLmax*
10	THE MOMENT of the inertia of the cross section *Of jx'*	*[m]4*	*0… 10 * L4*
11	THE MOMENT of the inertia of the cross section OF J[U]'	*[m]4*	*0… 10 * L4*
12	THE MOMENT of inertia during twisting *Of j[kr]*	*[m]4*	*0… 10 * L4*
13	CROSS-SECTIONAL AREA	*[m]2*	*0… +RLmax*
14	THE MODULUS of elasticity of the material of the element	*PA*	*0… +RLmax*
15	POISSON RATIO		] *0… 0.5* [
16	material DENSITY	*[kg]/[m]3*	*0… +RLmax*

Note. If auxiliary point D, prescribed by user, lies beyond the axis Z' [LKS], then program establishes the position of the first principal plane of inertia on silence.

Parameters of element BAL3DK

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
4,5,6	The origin coordinates of point B across the axes OX, OY, OZ	*m*	*-RLmax… +RLmax*
7,8,9	The origin coordinates of auxiliary point D	*m*	*-RLmax… +RLmax*
10	THE MOMENT of the inertia of the cross section *Of jx'*	*[m]4*	*0… +RLmax*
11	THE MOMENT of the inertia of the cross section OF J[U]'	*[m]4*	*0… +RLmax*
12	THE MOMENT of inertia during twisting *Of j[kr]*	*[m]4*	*0… +RLmax*
13	CROSS-SECTIONAL AREA	*[m]2*	*0… +RLmax*
14	THE INFLUENCE COEFFICIENT of cross section beyond the shearing strain across the local axis X'		*0… +RLmax*
15	THE INFLUENCE COEFFICIENT of cross section beyond the shearing strain across the local axis Y'		*0… +RLmax*
16	THE MODULUS of elasticity of the material of the element	*PA*	*0… +RLmax*
17	POISSON RATIO		] *0… 0.5* [
18	material DENSITY	*[kg]/[m]3*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	TRANSVERSE at point A across the axis X'	*N*	
2	TRANSVERSE at point A across the axis Y'	*N*	
3	longitudinal force at point A	*N*	

N in sequence	Description	Dimensionality	Range
4	THE BENDING moment at point A relative to axis X'	*N*	
5	THE BENDING moment at point A relative to axis Y'	*N*	
6	torque at point A	*N*	
7	THE BENDING moment at point B relative to axis X'	*N*	
8	THE BENDING moment at point B relative to axis Y'	*N*	
9	torque at point B	*N*	
10	AXIAL dilitational strain-the compression		
11	TORSION ANGLE across the axis of the girder	*rad*	
12	BENDING deformation at point A relative to axis X'		
13	BENDING deformation at point A relative to axis Y'		
14	BENDING deformation at point B relative to axis X'		
15	BENDING deformation at point B relative to axis Y'		
16,17, 18	THE DIRECTION cosines of axis X' THE LCS of the girder		

Notes. Power factors and the deformation - before the local system of coordinates of girder (LCS). By bending deformation relative to axis X' or Y' LCS is understood the tangent of the angle of deflection of the projection of the elastic line of girder beyond the plane, perpendicular down the appropriate axis LCS, from the axis of girder.

<u>Special situations</u>

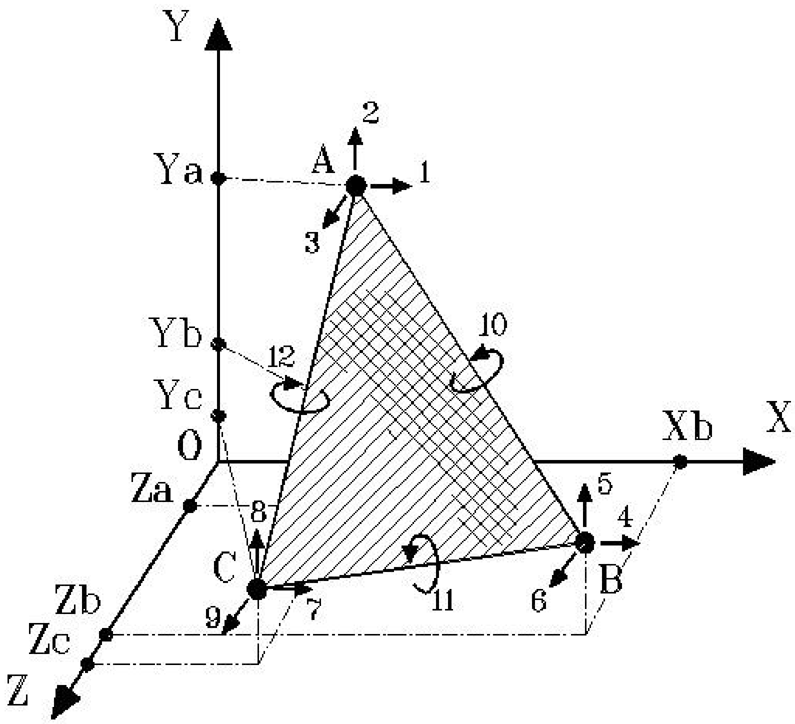
Almost all methods, characteristic for forward motion, remain valid and with the work with three external angular degrees of freedom of three-dimensional element BAK3DJ (BAL3DK). The operations of direct kinematic action with the aid of the sources of kinematic action, intended for the flat rotation, will be incorrect. To if necessary transmit rotation based on the one-dimensional or flat elements to the three-dimensional, it is necessary to use binders of the type of the section of the shaft (coupling element SV13W), which has against one end rotational degree of freedom, and on the second - three rotational degrees of freedom around the coordinate axes.

5.2.2.Plates

5.2.2.1.Three-dimensional triangular elastic plate, working in the tension-compression and bend PLSTU

Reflected properties

Triangular three-dimensional element with possibility of arbitrary displacement and small elastic dilitational strains-compression and bend. The model of three-dimensional triangular elastic plate is represented before Fig. PLSTU.



PLSTU_1. Three-dimensional triangular elastic plate.
Degrees of freedom of the element:
1,2, 3- progressive points A across the axes OX, OY, OZ;
4, 5, 6 progressive points B across the axes OX, OY, OZ;
7, 8, 9 progressive points C across the axes OX, OY, OZ;
10 rotatory of the middle of side AB;
11- rotatory of the middle of side BC;
12- rotatory of the middle of side CA;
Xa, Ya, Za - the origin coordinates of point A;
Xb, Yb, Zb - the origin coordinates of point B;
Xc, Yc, Zc - the origin coordinates of point C;

Degrees of freedom

1,2,3 - the progressive points A of element across the axes OX, OY, OZ;

4,5,6 - the progressive points B of element across the axes OX, OY, OZ;

7,8,9 - the progressive points C of element across the axes OX, OY, OZ;

10 rotatory of the middle of side AB;

11- rotatory of the middle of side BC;

12- rotatory of the middle of side CA;

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A across the axes [O]X, [O]Y, [O]Z	*m*	*-RLmax… +RLmax*
4,5,6	The origin coordinates of point B across the axes [O]X, [O]Y, [O]Z	*m*	*-RLmax… +RLmax*
7,8,9	The origin coordinates of point [s] across the axes [O]X, [O]Y, [O]Z	*m*	*-RLmax… +RLmax*
10	Thickness of the element	*m*	*0… +RLmax*
11	Modulus of elasticity of the material of [zlementa]	*PA*	*0… +RLmax*
12	Poisson ratio	-	*0… 0.5*
13	Material density	*[kg]/[m]3*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	SAGGING in the center of gravity of the plate	*m*	
2	THE [EKVIVALENTOE] stress beyond the lower surface of the plate	*PA*	
3	THE [EKVIVALENTOE] stress beyond the upper surface of the plate	*PA*	

N in sequence	Description	Dimensionality	Range
4	THE MAXIMUM equivalent stress	*PA*	
5	THE INDEX of [n].[s]. beyond the lower surface of the plate		
6	THE INDEX of [n].[s]. beyond the upper surface of the plate		
7, 8, 9	THE COMPONENT of stress tensor beyond the lower surface of plate before THE LCS		
10,11, 12	THE COMPONENT of stress tensor beyond the upper surface of plate before THE LCS		
13	SPECIFIC strain energy		
14	THE GENERAL strain energy of the plate	*George*	
15	THE GENERAL energy, transmitted to the plate	*George*	

Note. The thickness of plate must correspond to the dimensions of element. If the square of thickness exceeds the area of element, the value of thickness is counted inadmissibly to large.

Special situations

If in the course of computations the current area plate becomes close to zero, then emergency exit based on the model is accomplished.

6. Contact elements

6.1.1D Elements

6.1.1.1.The one cell, which reflects elastic contact interaction between two bodies and impeding the positive displacement of the first body relative to second UPRL

Reflected properties

Element serves for describing the contact two-body interaction, the motion of each of which is described by one degree of freedom. In the general case at the initial moment of time between the bodies is a clearance and effort before the contact is absent. The contact effort appearing after [vyborki] of clearance is proportional down the amount of the contact deformation:

$$F[upr] = K * " X1 - X2) - \delta),$$

, where *is k-th* the coefficient of the contact elasticity;
$\tau\eta\varepsilon$ δ - the initial clearance;
X1 - the displacement of the first body;
X2 - the displacement of the second body.

Before Fig. UPR_1. are shown design diagrams for the positive and negative gap lengths, and also dependence of the contact effort beyond the mutual displacement of bodies (X1 - X2) in these cases. With the use of an element UPRL it is necessary to consider that the relative position of the contacting bodies is defined **not as far as the coordinates** of bodies as before the majority of other contact elements, but by the order of the task of the degrees of freedom of these bodies before the description of the structure of fragment. Element always prevents **the positive** displacement of the first degree of freedom relative to the second.

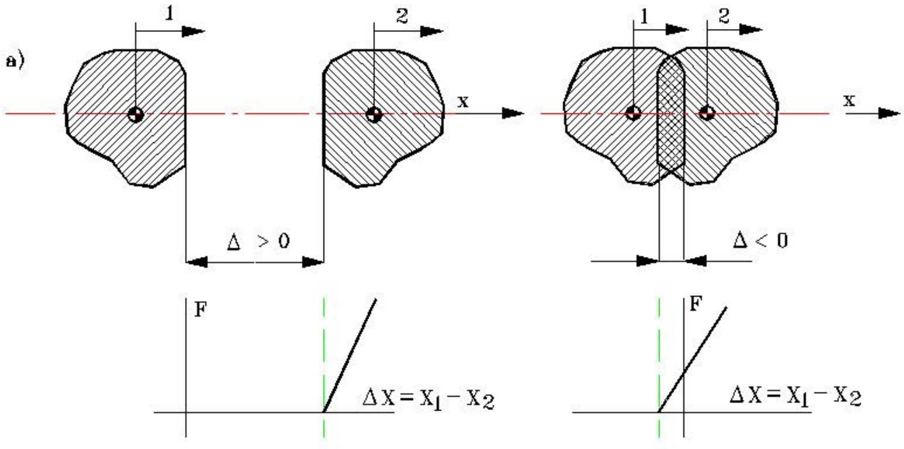


Fig. UPR_1. One-dimensional one-sided ideally elastic contact element UPRL. Are shown design diagrams for the cases of positive and negative initial clearance between the contacting bodies and efforts of interaction beyond the mutual displacement corresponding to dependence tel.

Some typical cases of applying the element (different cases of the relative initial arrangement of the contacting bodies with the one-dimensional and plane motion) are depicted beyond Fig. UPR_2.

<u>Degrees of freedom</u>

1 rotatory (progressive) of the first body;

it is 2nd rotatory (progressive) of the second body.

The design diagram of the process	Description of structure down *PradiSlang*

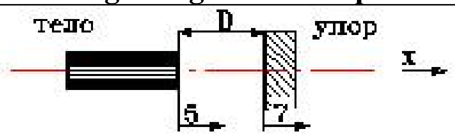
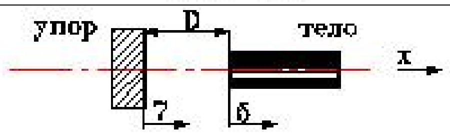
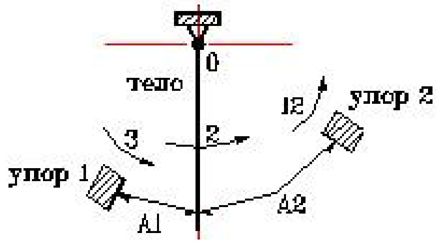
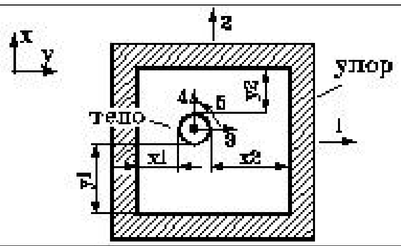

	
	
	


Fig. UPR_2.	**Some typical cases of applying the one-sided contact elements (based on the example of element UPRL).**

<u>Parameters</u>

N in sequence	Description	Dimensionality	Range
1	INITIAL gap length	*m* or *rad*	*- Rlmax… +RLmax*
2	THE CONTACT rigidity of the element	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE CURRENT gap length (negative value it corresponds to the introduction of the first body the secondly)	*m*	

6.1.1.2.One-dimensional contact element with the elastic-by plastic characteristic and by the possibility of destruction UPRC

Reflected properties

Element serves for describing the contact two-body interaction, the motion of each of which is described by one degree of freedom. In contrast to the element UPRL the characteristic of contact is elastic-by plastic (see Fig. UPR_3). If the deformation of element exceeds the amount of breaking strain, then element "is destroyed" (connection between the degrees of freedom it is lost). Subsequently the element is considered destroyed.

Element always prevents **the positive** displacement of the first degree of freedom relative to the second. The method of application of an element is analogous down the method of application of an element UPRL.

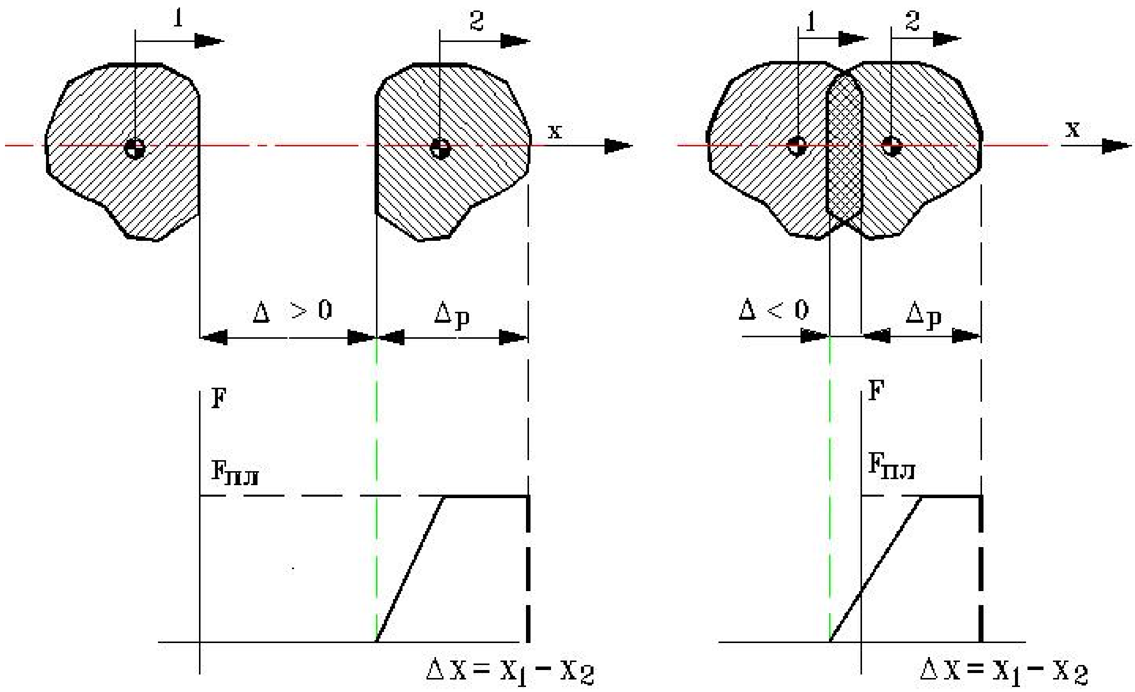


Fig. UPR_1. One-dimensional one-sided elastic-plastic contact element with the destruction.
Are shown design diagrams for the cases of positive and negative clearance between the contacting bodies and efforts of interaction beyond the mutual displacement corresponding to dependence tel.
Δp - the deformation, which destroys the element;
F[pl] - the effort of interaction, which corresponds to the output of element in the section of the plastic deformations

Degrees of freedom

1 rotatory (progressive) of the first body;

it is 2nd rotatory (progressive) of the second body.

Parameters

N in sequence	Description	Dimensionality	Range
1	INITIAL gap length (Δ)	*m* or *rad*	*- Rlmax…* *+RLmax*
2	THE CONTACT rigidity of the element	*N/m* or *[N]*[m]/[rad]*	*0...* *+RLmax*
3	THE EFFORT of the passage of element beside the plastic state	*N* or *[N]*[m]*	*0...* *+RLmax*
4	the breaking strain of element (Δπ)	*m* or *rad*	*0...* *+RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE CURRENT gap length - the distance between the nondeformed surfaces of the contacting bodies (negative value it corresponds to the introduction of the first body the secondly)	*m* or *rad*	

6.2.Two-dimensional elements

6.2.1.1.Element, which describes contact interaction of point with the circle KNTO

Reflected properties

Element serves for describing contact interaction of point (before Fig. KNTO_1 - point C) with the circle. The motion of circle in the plane is assigned by the progressive displacements of its center (before Fig. KNTO_1 - point O). Contact effort proportional down the radial deformation of element and directed along the radius, which connects center of circle with the point C. frictional force before the contact is not considered.

Some typical cases of applying the element (different cases of the relative initial arrangement of the contacting bodies with the one-dimensional and plane motion) are depicted beyond Fig. UPR_2.

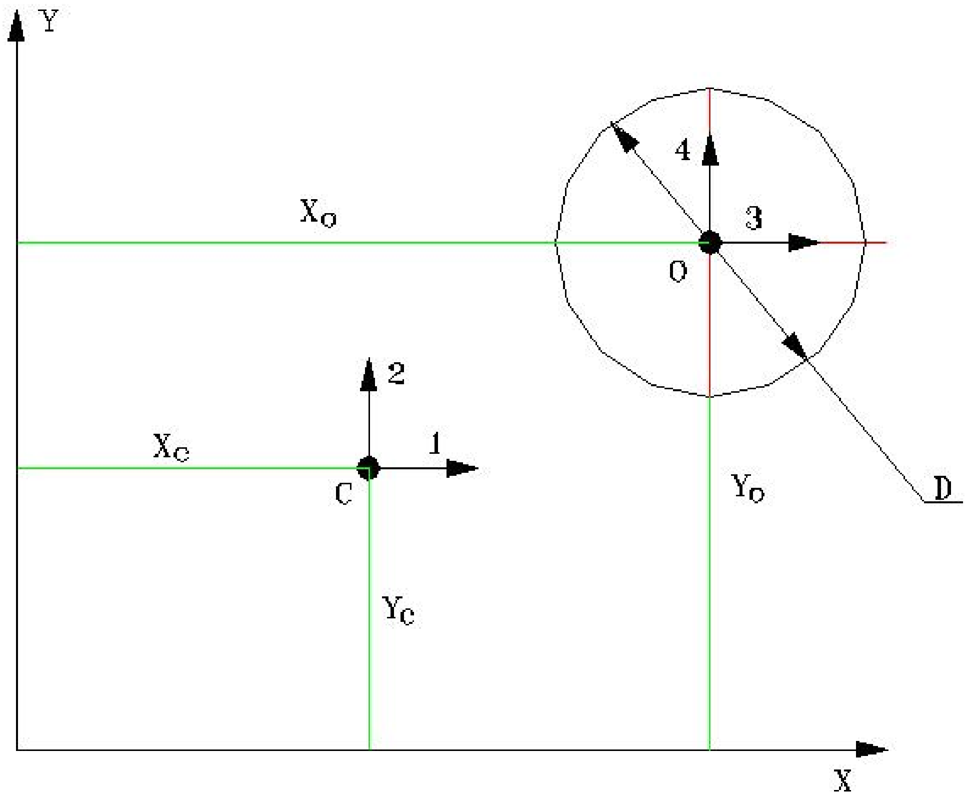


Fig. KNTO_1. Geometric parameters and the degree of freedom of contact element "point with the circle":
Xc, Yc - the origin coordinates of the contact point;
Xo, Yo - the origin coordinates of the center of the contact circle;
D - the diameter of contact circle.

Degrees of freedom

1 progressive of point C across the x axis;

it is 2nd progressive of point C across the y axis;

3- progressive of point O across the x axis;

4 progressive of point O across the y axis.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	the origin coordinates of point C (Xc, Yc)	*m*	*- Rlmax… +RLmax*
3,4	the origin coordinates of point O (Xo, Yo)	*m*	*- Rlmax… +RLmax*
5	THE DIAMETER of contact circle (D)	*m*	*- Rlmax… +RLmax*
6	THE RIGIDITY of the contact	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE CURRENT gap length (negative value it corresponds to the introduction of the first body the secondly)	*m*	
2	THE INSTANTANEOUS value of the contact effort	*N*	

6.2.1.2.The element, which describes contact interaction of point with the flat line, whose contour consists of the sequence N of sections KONT

Reflected properties

Contact interaction of the point, which moves in the plane, and a certain flat body, whose boundary is represented by the totality N of sections. The motion of contact boundary is determined as far as the displacement of the rigidly connected for the sake of it point O, which has two degrees of freedom of progressive displacement and one rotational degrees of freedom. With the description of contact line as bilateral, is limited the displacement of point C beside both sides along the normal to the line of contact (it is simulated motion on the guide). With the description of one-sided line of contact the coordinates of the sections, which compose line of contact, are assigned before such sequence that during the motion along the contact line contact region would remain to the left. Contact line must consist as the minimum of one section. The point C, contact with which is tracked, it possesses two degrees of freedom of forward motion ([ris].KONT_1).

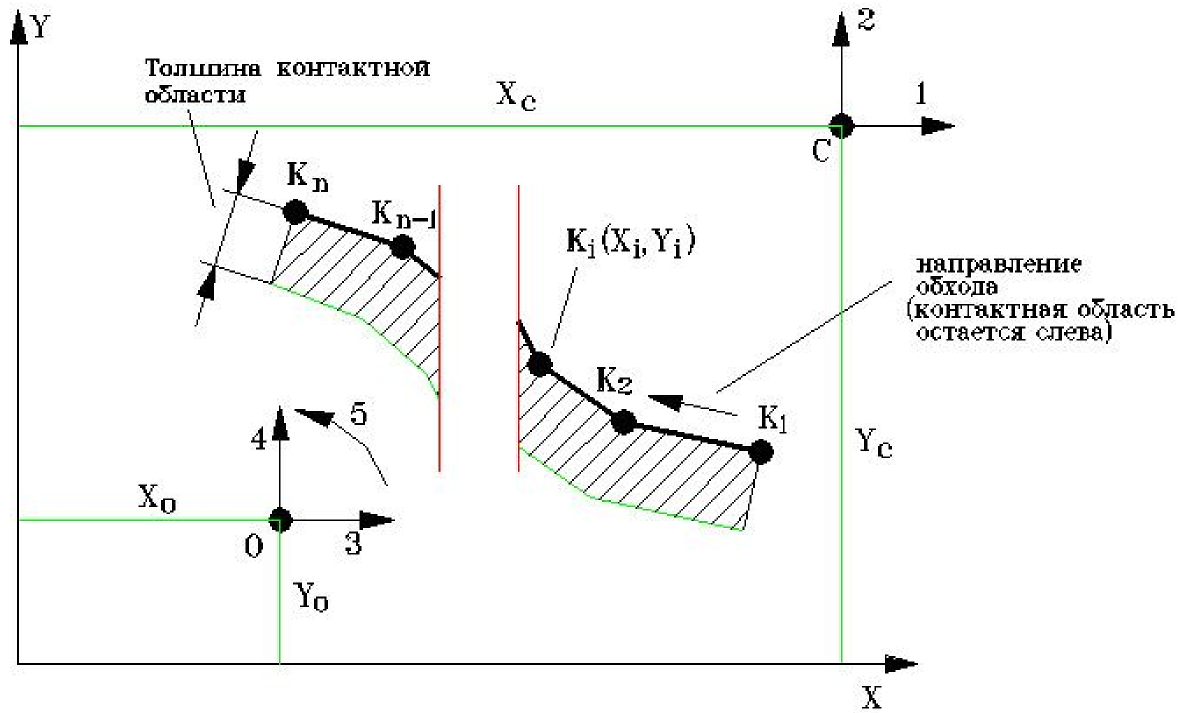


Fig. KONT_1. Geometric parameters and the degree of freedom of contact element "point with the broken line":
Xc, Yc - the origin coordinates of the contacting point (point [s]);
Xo, Yo - the origin coordinates of the point, with the motion by which the coupled motion of contact section (point [o]);
Xi, Yi - origin coordinates i-oh the point of the contact contour;
1,2 - the displacement of the contacting point;
3, 4, it is 5th the displacement of the point, for the sake of which is connected contact section.

With the appearance of contact the force of contact interaction has normal and tangential components. Normal component is proportional down the value “of the penetration” of point C inside the contact region. Constant of proportionality is determined as far as the assigned normal rigidity of contact. Tangential component simulates the dry friction of slip before the contact area.

The zones of influence of the adjacent sections, which compose contact line, are divided as far as the bisector of the angle, formed by these sections (Fig. Of kONT_2.[a].). If point C will cross this bisector already in the course of contact, the direction of contact effort will change and it will be determined as far as that section, before the zone of influence of which is located contact point against the given moment. So that the zone of influence of each of the adjacent sections of contact line would not be too small, the angle between the adjacent sections before this element must be not less than 60 degrees.

Is the important parameter with the description of element the thickness of the contact region (region, being located before which, contact point it is considered interacting the contact section). With the assignment of the value of this parameter it is desirable to avoid two extremes. Too small a thickness of contact region can lead down “jumping” of the contact point through the contact region.

Unjustifiably great thickness of contact region can lead down the formation of the being overlapped zones of influence of contact sections, and in certain cases - to the formation of the zones, in which contact point will be pulled inside the contact region (Fig. Of kONT_2.[b].).

If contact point is located before the zone of influence of two and more than sections, contact effort will be determined as far as section with the smaller number (by section, whose coordinate with the description of element they are prescribed earlier).

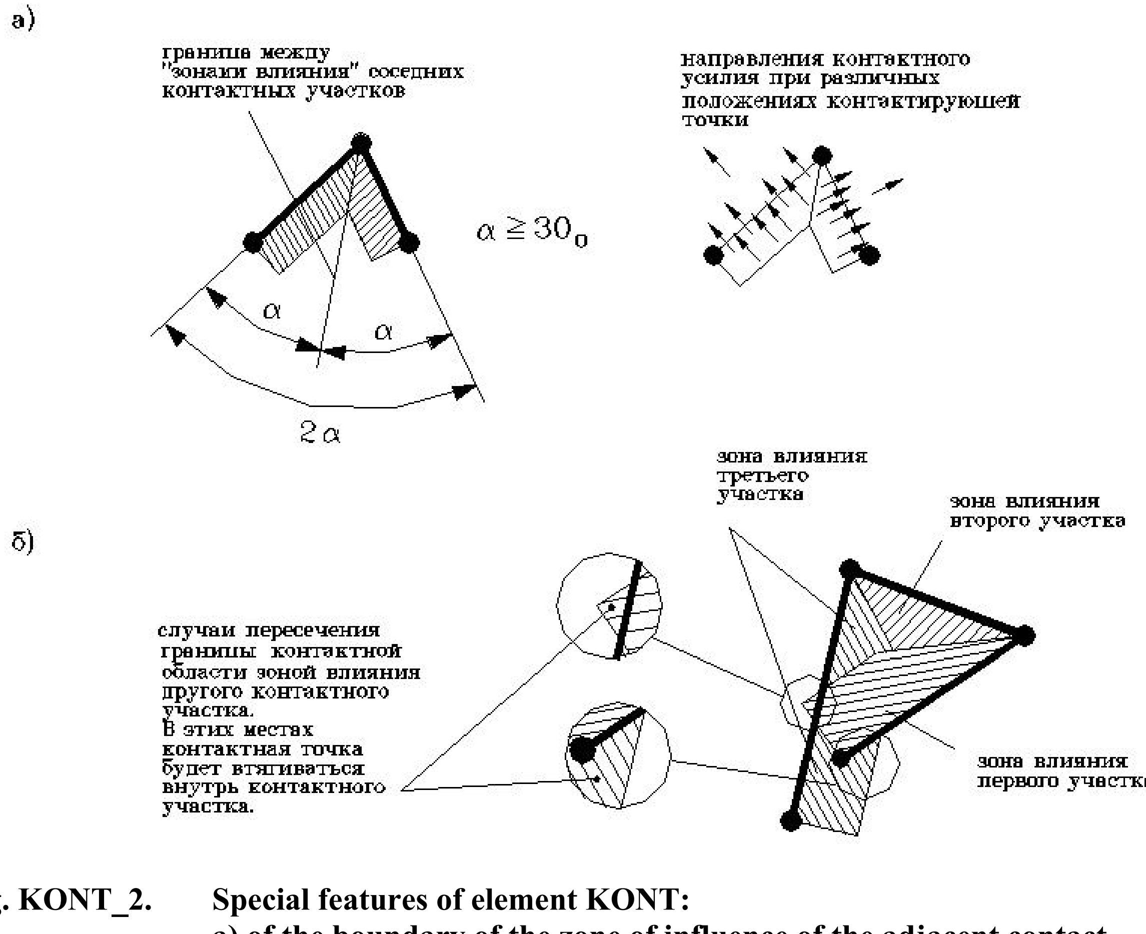


Fig. KONT_2. **Special features of element KONT:**
a) of the boundary of the zone of influence of the adjacent contact sections;
b) the case of the self-intersection of the element (zone of influence of one of the sections it intersects the boundary of contact region).

Degrees of freedom

1 progressive of point C across the axis OX;

it is 2nd progressive of point C across the axis OY;

3- progressive of point O across the axis OX;

4 progressive of point O across the axis OY;

it is 5th rotatory of point O.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	the origin coordinates of point C across the axes OX, OY	*m*	*- Rlmax… +RLmax*
3,4	the origin coordinates of point O across the axes OX, OY	*m*	*- Rlmax… +RLmax*
5	THE THICKNESS of the contact region	*m*	*0… +RLmax*
6	Normal rigidity of the contact	*N/m* or *[N]*[m]/[rad]*	*0… +RLmax*
7	THE FRICTIONAL DRAG COEFFICIENT		*0… +RLmax*
8	THE SIGN of the one-sided or bilateral contact		1 or 2
9,10	origin coordinates 1-y of the point of contact line across the axes OX, OY	*m*	*- Rlmax… +RLmax*
	….:.		
2*i+7, 2*i+8	origin coordinates *i*-y of the point of contact line across the axes OX, OY (*i* =1, *N+1*, where *it is n-th* a quantity of sections of broken line)	*m*	*- Rlmax… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
2*i-1	THE NORMAL reaction, which acts on *i*-y the section of broken line based on the side of point [s]	*N*	
2*i	THE FRICTIONAL FORCE, which acts on *i*-y the section of broken line based on the side of point [s] (*i* =1, *N*, where *it is n-th* a quantity of sections)	*N*	
3	Rate of point [s] across the line of contact	*m/s*	

Notes:

1) the reaction (normal and frictional force), which acts in the contact section based on the side of point C, and the rate of point C across the line of contact IS DERIVED;

2) AT THE POINT OF the positive directions for the elements of working vector start the directions of the axes of the local coordinate system, connected for the sake of the contact area. The positive direction of the axis of the X local coordinate system coincides for the sake of the direction of the circuit of contact section. Y axis is directed inside the contact region (if element is one-sided);

3) IN THE ABSENCE contact against current time all elements of working vector are reduced to zero.

6.2.1.3.The element, which describes contact interaction of ellipsis with the flat line, whose contour consists of the sequence N of sections KN2EL

Reflected properties

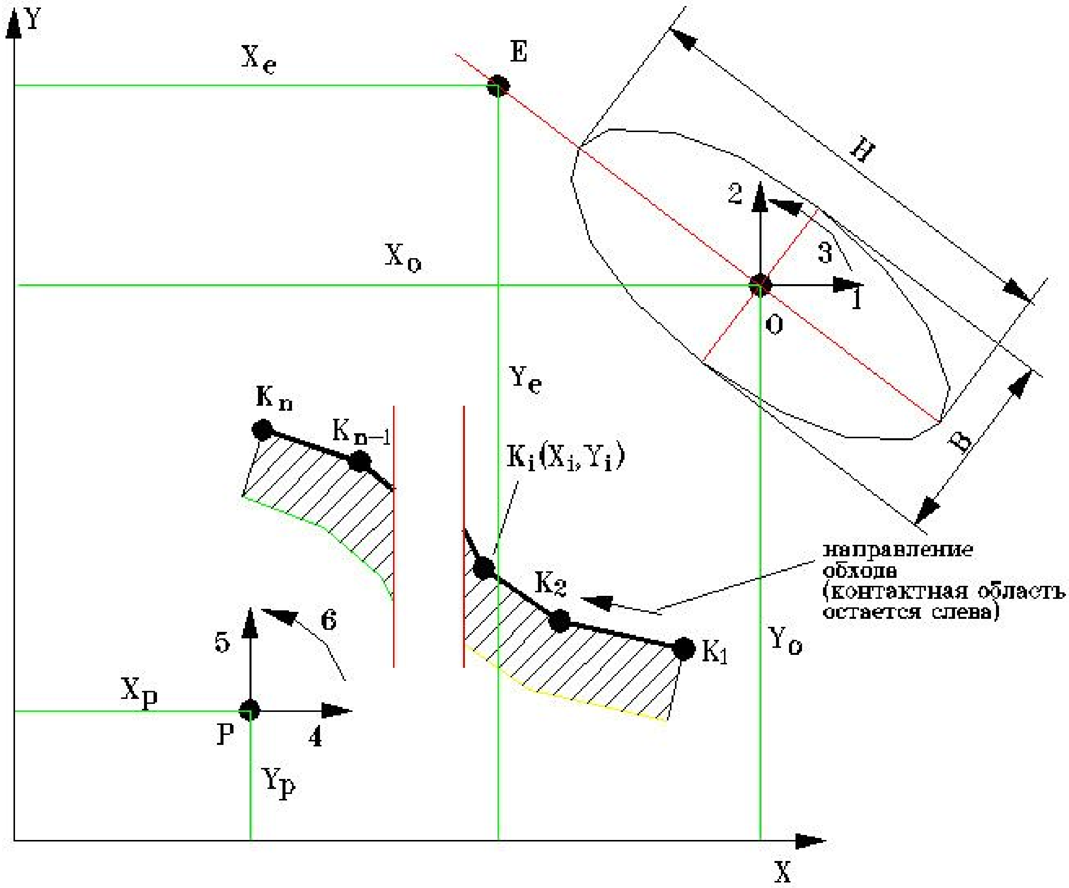


Fig. KN2EL_1. Geometric parameters and the degree of freedom of contact element “ellipsis with the broken line”:
Xo, Yo - the origin coordinates of the center of ellipsis (point [o]);
Xe, Ye - the coordinate of point, which determines the initial position of the first principal axis of ellipsis (point E);
H - the value of the axis of ellipsis, whose direction is determined as far as points O and E;
B - the value of the second axis of the ellipsis;
Xp, Yp - the origin coordinates of the point, with the motion by which the coupled motion of contact contour (point P);
Xi, Yi - origin coordinates i-oh the point of the contact contour;
1,2, 3- of displacement and the turning of the center of the ellipsis;
4, 5, 6 displacement of the point, for the sake of which is connected contact section.

Contact interaction of the ellipsis, which moves in the plane, and a certain flat body, whose boundary is represented by the totality N of sections. The motion of contact boundary is determined as far as the displacement of the rigidly connected for the sake of it point P, which has two degrees of freedom of progressive displacement and one rotational degrees of freedom. With the description the lines of contact of the coordinate of sections are assigned before such sequence that during the motion along the line of contact contact region would remain to the left. Contact section must consist as the minimum of one section. The initial position of ellipsis is determined as far as the origin coordinates of center and auxiliary point E, which is arranged beyond the transverse. Its motion is described by three degrees of freedom, connected for the sake of its center ([ris].KN2EL_1).

With the appearance of contact the force of contact interaction has normal and tangential components. Normal component is determined as far as the contact dependences of Hertz (contact of plane with the cylinder). In this case the rigidity of element is defined as far as both the given module of the elasticity of the contacting bodies and as far as thickness of element, i.e., as far as size of element before the direction, perpendicular down the plane of motion. Tangential component simulates the dry friction of slip before the contact area.

Degrees of freedom

1	progressive of point O across the axis OX;
it is 2nd	progressive of point O across the axis OY;
it is 5th	rotatory of point O;
4	progressive of point P across the axis OX;
it is 5th	progressive of point P across the axis OY;
6	rotatory of point P.

Parameters

N in sequence	Description	Dimensionality	Range
1,2	the origin coordinates of point O across the axes OX, OY	*m*	*- Rlmax… +RLmax*
3,4	the origin coordinates of point E across the axes OX, OY	*m*	*- Rlmax… +RLmax*
5,6	LENGTHS of the first and second axes of ellipsis (H and B)	*m*	*0… +RLmax*
7	THE THICKNESS of the contact region	*m*	*0… +RLmax*
8	Given modulus of elasticity of the contacting bodies		*0… +RLmax*
9	THE FRICTIONAL DRAG COEFFICIENT		*0… +RLmax*

N in sequence	Description	Dimensionality	Range
10,11	The origin coordinates of point R across the axes OX, OY	*m*	- *Rlmax…* +*RLmax*
12,13	origin coordinates 1-y of the point of contact line across the axes OX, OY	*m*	- *Rlmax…* +*RLmax*
	…..		
2*i+10 of 2*i+11	origin coordinates *i*-y of the point of contact line across the axes OX, OY (*i* =1, *N+1*, where *it is n-th* a quantity of sections)	*m*	- *Rlmax…* +*RLmax*

<u>Working vector</u>

N in sequence	Description	Dimensionality	Range
2*i-1	THE NORMAL reaction before the contact area, which acts on *i*-y the section of broken line based on [strony] of the ellipsis	*N*	
2*i	THE FRICTIONAL FORCE, which acts before the contact area on *i*-y the section of broken line based on the side of ellipsis (*i=1*, *N*; *It is n-th* a quantity of sections of broken line)	*N*	

Notes:

1. is derived the reaction (normal and frictional force), which acts based on the side of ellipsis in the contact section of broken line.

2. at the point of the positive directions for the elements of working vector start the directions of the axes of the local coordinate system, connected for the sake of the contact area. The positive direction of the axis of the X' local coordinate system coincides for the sake of the direction of the circuit of contact section. Y axis' is directed inside the contact region (if element is one-sided).

3. in the absence contact against current time all elements of working vector are reduced to zero.

6.3.Three-dimensional elements

6.3.1.1.Element, which describes contact interaction of cylinder with the point KNCLT

Reflected properties

Contact interaction of cylinder and point, that accomplish arbitrary motion before the space ([ris].KNCLT_1). The point, with which is tracked the contact of cylinder, is designated by point C. the attitude of the axis of cylinder it is assigned by two points: O and P ([ris].KNCLT_1.[a].). The position of the cylindrical section of possible contact along the axis OP is assigned by the fixed bias of the lower edge of cylinder relative to point O. displacement it is considered positive, if it is directed from O down to P.

Element can be used for describing the contact of two types ([ris].KNCLT_1.[b].) - external (when the cylinder - the surface of shaft) and internal (when the cylinder - the surface of opening).

If the nontrivial value of the coefficient of friction is prescribed, then is considered the frictional force, which acts before the contact along the generatrix of cylinder. Element does not consider the possible rotations of cylinder around its axis and, correspondingly, force component of friction, that affects in the transverse (perpendicular axis of cylinder) plane.

Degrees of freedom

1,2, 3- progressive points C across the axes of the X, Y, Z;

4, 5, 6 progressive points O across the axes of the X, Y, Z;

7, 8, 9 progressive points P across the axes of the X, Y, Z.

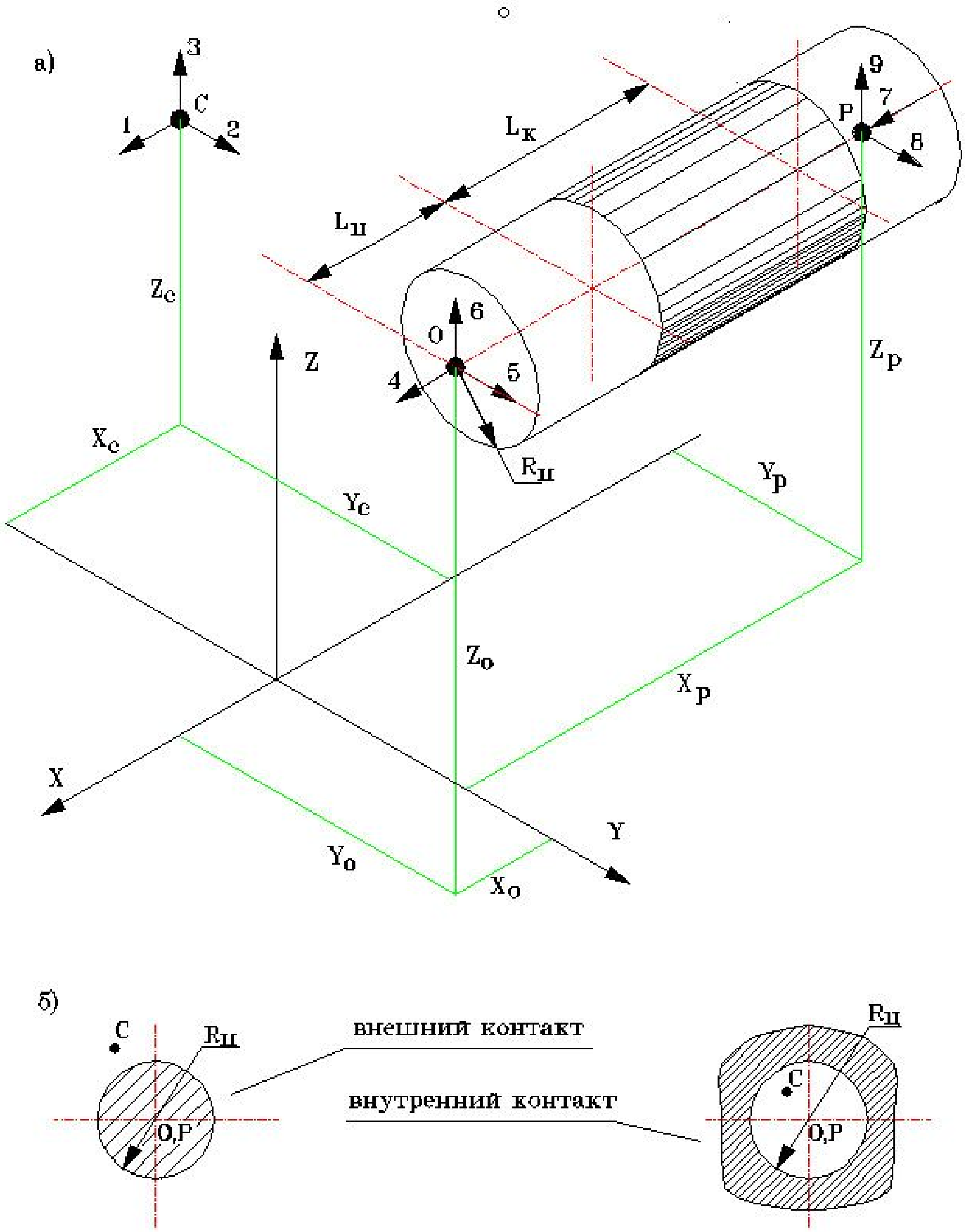


Fig. KNCLT_1. **Contact element "the cylinder-point". The position of the axis of cylinder before the space is determined as far as points O and P.**
a) geometric parameters and degree of freedom:
X[s], Y[s], Zc - the origin coordinates of point [s];
X[o], Y[o], Z[o] - the origin coordinates of point [o];
Xp, Yp, Zp - the origin coordinates of point P;
R - a radius of the contact cylinder;
L[ts] - distance from the point [o] to the edge of the cylinder;
L[k] - the length of the contact surface;
1,2, 3- of the degree of freedom of point [s];
4, 5, 6 degree of freedom of point O;
7, 8, 9 degree of freedom of point P;
b) the use of an element for describing the external and internal communication.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point C across the axes OX, OY, OZ	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point O across the axes OX, OY, OZ	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point P across the axes OX, OY, OZ	*m*	*- Rlmax… +RLmax*
10	A RADIUS of the cylindrical surface	*m*	*0… +RLmax*
11	THE LENGTH of the cylindrical section of contact (L[k])	*m*	*0… +RLmax*
12	THE AXIAL shift of the edge of contact cylinder relative to point O	*m*	*0… +RLmax*
13	THE NORMAL rigidity of the contact	*N/m*	*0… +RLmax*
14	THE FRICTIONAL DRAG COEFFICIENT		*0… +RLmax*
15	THE TYPE of the contact: external (>=0); internal (<0)		*- Rlmax… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	NORMAL effort down the cylinder against the contact point	*N*	
2	THE FRICTIONAL FORCE, which acts beyond the cylinder against the contact point	*N*	
3	THE SPEED of the motion of point C relative to cylinder before the contact	*m/s*	

Notes:

1. axial displacement of cylinder is connected for the sake of the displacement of point O and is not connected for the sake of the displacement of point P;
2. static friction is not considered;
3. is possible the account only of sliding friction and only along the generatrix of the cylinder;
4. if before the initial state or before the process of calculation points C, O, P prove to be on one straight line - the effort of contact it will be zero;
5. elements of working vector are filled up only with the presence of contact, otherwise they initialize by zero. The signs of the elements of working vector are determined as far as sign projections beyond the axis of this local system of coordinates of OX'Y', before which axis OX' it is directed across the axis of cylinder from [t].O to [t].P, and axis OY' - it is perpendicular down the axis of cylinder in the plane OPC, down the side of the arrangement of point C;
6. in the absence contact model accomplishes a forecast of the value of step on the condition of the possible entrance beside the contact against the next step.

6.3.1.2.Element, which describes contact interaction of sphere with the point KNSFT

Reflected properties

Contact interaction of sphere and point, that accomplish arbitrary motion before the space ([ris].KNSFT_1). The point, with which is tracked the contact of sphere, is designated by point C. the center of the sphere - point O ([ris].KNCLT_1.[a].)

Element can be used for describing the contact of two types ([ris].KNSFT_1.[b].) - external (when the sphere - the surface of sphere) and internal (when the sphere - the surface of spherical cavity).

Element does not consider the possible rotations of sphere and the frictional force, which acts before the contact area.

Degrees of freedom

1,2, 3- the progressive points C, with which are tracked the contact of sphere, across the x axis, Y, Z;

4, 5, 6 progressive of the center of sphere (point O) across the axes of the X, Y, Z.

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point C across the axes OX, OY, OZ	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point O across the axes OX, OY, OZ	*m*	*- Rlmax… +RLmax*
7	A RADIUS of the sphere	*m*	*0… +RLmax*
8	THE NORMAL rigidity of the contact	*N/m*	*0… +RLmax*
9	THE TYPE of the contact: external (>=0); the internalizations (<=0)		*- Rlmax… +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE NORMAL effort, which acts beyond the point [s] in the place of contact with the sphere	N	
2	“THE PENETRATION” of point C inside the contact region (amount of contact deformation)		
3	THE CURRENT distance between the points O and C	m	

Notes:

1. signs of the 1st and 2-GO of the elements of working vector they correspond to the signs of projections beyond the axis, directed along a radius from the center of sphere down to the contact point;

2. if before the initial state or before the process of calculating the point C and O they coincide - the efforts of contact at this moment will not be;

3. in the absence contact model accomplishes a forecast of the value of step on the condition of possible contact against the next step.

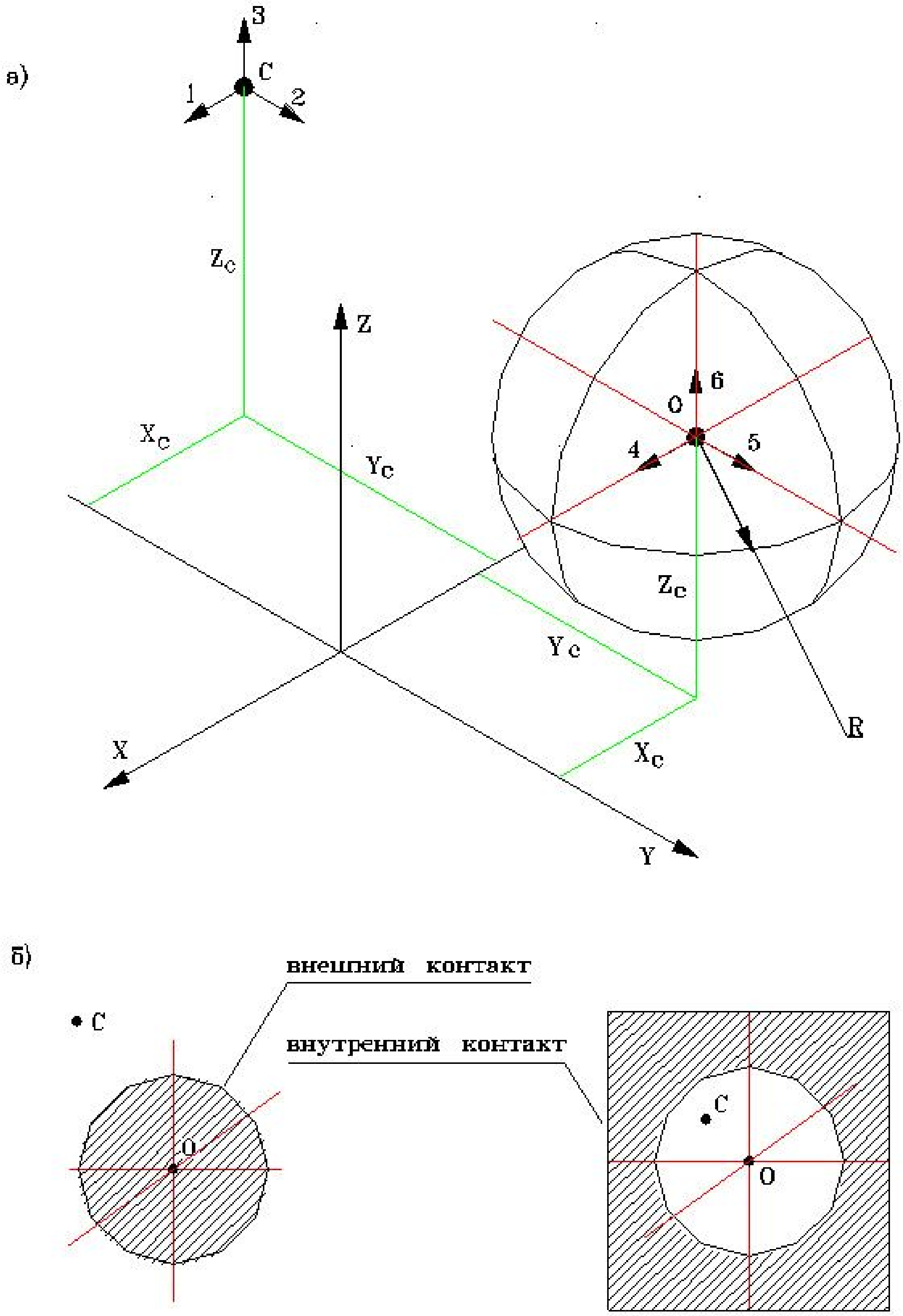


Fig. KNSFT_1. **Contact element “sphere with the point”.**
a) geometric parameters and degree of freedom:
X[s], Y[s], Zc - the origin coordinates of point [s];
X[o], Y[o], Z[o] - the origin coordinates of point [o];
R - a radius of the contact sphere;
1,2, 3- of the degree of freedom of point [s];
4, 5, 6 degree of freedom of point O;
b) the use of an element for describing the external and internal communication.

6.3.1.3.Element, which describes contact interaction of point with the fragment of plane, which has the form of parallelogram KN3TP

Reflected properties

Contact interaction of the point, which moves before the space, and the flat body, which has the form of parallelogram. The positions of point T1 and body T2 are determined as far as the appropriate potential variables: three translational degrees of freedom determine the position of point, three progressive and three rotatory - the position of the fragment of plane.

Initial position of the bodies of [zadaetsya] by the parameters: for the point are indicated its origin coordinates (coordinate of point A1); for the fragment of plane are indicated the origin coordinates of points A2, B2, C2 and D2 (point B2, C2, D2 also determine the form of parallelogram). Pole of the rotation of the fragment of the plane - this is point A2 (Fig. KN3TP.1).

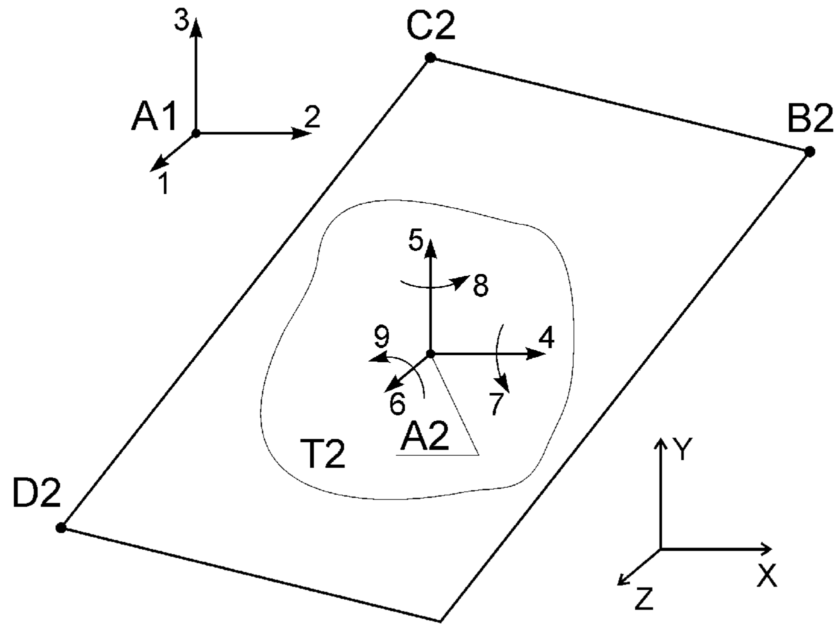


Fig. KN3TP_1. Parameters and the degree of freedom of contact element the point - the fragment of the plane:
Parameters:
XA1, YA1, ZA1 - the origin coordinates of point A1
XA2, YA2, ZA2 - the origin coordinates of point A2
XB2, YB2, ZB2 - the origin coordinates of point B2
XC2, YC2, ZC2 - the origin coordinates of point C2
XD2, YD2, ZD2 - the origin coordinates of point D2
Degrees of freedom:
1,2, 3- progressive points A1 across the axes of the X, Y, Z
4, 5, 6 progressive points A2 across the axes of the X, Y, Z
7, 8, 9 rotatory bodies T2 around the axes of the X, Y, Z

With the appearance of contact the force of contact interaction has normal and tangential components. The amounts of these forces are determined as far as contact deformation and speed of point relative to the fragment of plane, and also as far as selected model of the description of the forces of contact interaction and as far as set of the parameters. For greater detail, see before Section 6.4 (model of the description of the forces of contact interaction). Contact deformation is defined as the depth of penetration of point beside the half-space, limited as far as the fragment of plane.

Degrees of freedom

1,2, 3- progressive points A1 across the axes of the X, Y, Z;

4, 5, 6 progressive points A2 across the axes of the X, Y, Z;

7, 8, 9 rotatory bodies T2 across the axes of the X, Y, Z;

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point A1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point A2	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point C2	*m*	*- Rlmax… +RLmax*
13,14,15	the origin coordinates of point D2	*m*	*- Rlmax… +RLmax*
16,…	Parameters of the model of the forces		

Working vector

N in sequence	Description	Dimensionality	Range
1	Sign of the presence of contact (0 - no, 1 there is)		0 or 1
2	Amount of the contact deformation	*m*	
3	Projection of relative of speed beyond the standard	*m/s*	
4	Module of the projection of relative of speed beyond the plane of the flat fragment	*m/s*	
5	Force of normal reaction against the contact point	*N*	
6	FRICTIONAL FORCE against the contact	*N*	

N in sequence	Description	Dimensionality	Range
	point (module)		

Notes:

1) it is considered that the normal to the plane is directed down that side, with which was located the point throughout the beginning of contact.

2) IN THE ABSENCE contact against current time all elements of working vector are reduced to zero.

6.3.1.4. Element, which describes contact interaction of ellipsoid with the fragment of plane, which has the form of parallelogram KN3EP

Reflected properties

Contact interaction of two surfaces, rigidly connected for the sake of the absolute solids T1 and T2. The contact surface of the first body is three-axis ellipsoid, or, is more accurate - the surface of degree $p > 1$, described before the canonical (main) basis by the equation

$$\left|\frac{x_1}{R_1}\right|^p + \left|\frac{x_2}{R_2}\right|^p + \left|\frac{x_3}{R_3}\right|^p = 1$$

(x_1, x_2, x_3 - coordinate relative to main basis, R_1, R_2, R_3 - semiaxis). The contact surface of the second body is considered the fragment of plane, which has the form of parallelogram. The positions of bodies T1 and T2 are determined as far as the appropriate potential variables: three translational and three rotational degrees of freedom determine the position of each of tel.

Initial position of contact surfaces, and also poles of the rotation of bodies, [zadaetsya] by the parameters (Fig. KN3EP.1, 2): for the body T1 are indicated the origin coordinates of points A1 (pole of the rotation of body T1), By b1 (center of ellipsoid), C1 (point, which lies beyond the third principal axis of ellipsoid), D1 (point, which lies against the plane of the first and third principal axes); for the fragment of plane are indicated the origin coordinates of points A2 (pole of the rotation of body T2), B2, C2 and D2 (point B2, C2, D2 determine the form of parallelogram). The form of ellipsoid is determined as far as the task of its three semiaxes and degree.

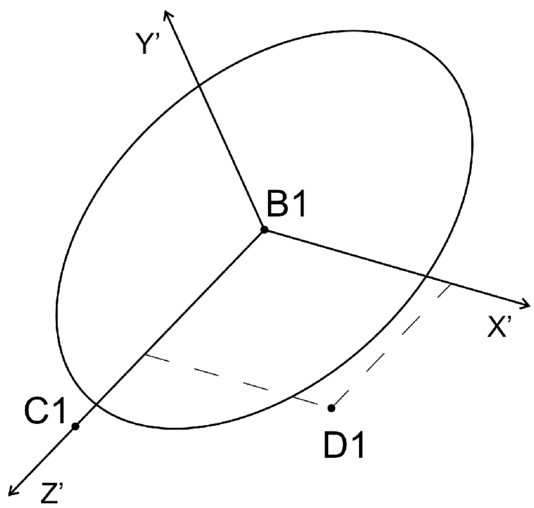


Fig. KN3EP_1. Parameters of the attitude of ellipsoid before the contact element the ellipsoid - the fragment of the plane:
XB1, YB1, ZB1 - the origin coordinates of point B1 (center of ellipsoid)
XC1, YC1, ZC1 - the origin coordinates of point C1 (this point it lies beyond the z axis' THE LCS of ellipsoid)
XD1, YD1, ZD1 - the origin coordinates of point D1 (this point it lies in plane X' Z' THE LCS of ellipsoid)

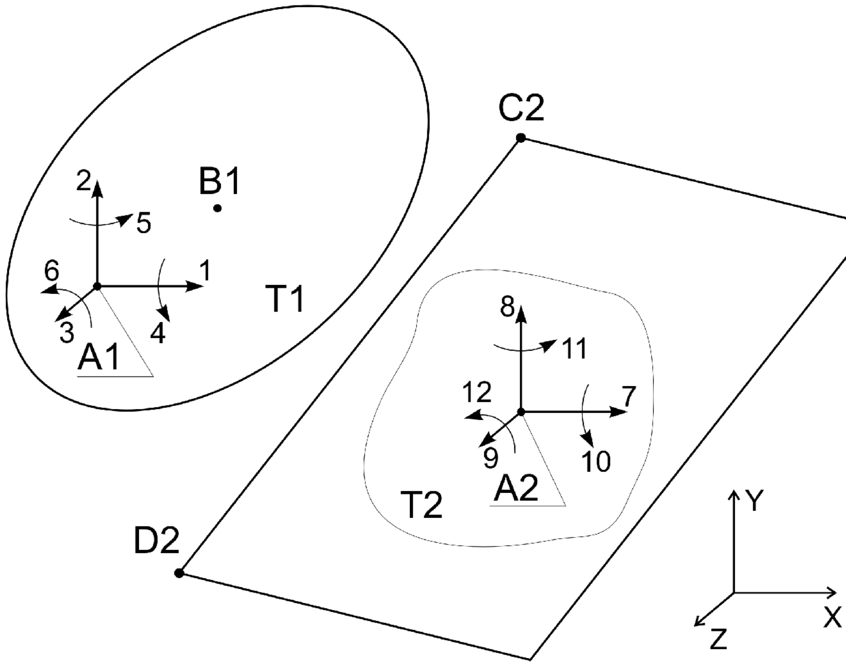


Fig. KN3EP_2. **Parameters and the degree of freedom of contact element the ellipsoid - the fragment of the plane:**

Parameters:

XA1, YA1, ZA1 - the origin coordinates of point A1 (pole of the rotation of body T1)

R1, R2, R3 - the semiaxis of the ellipsoid

P - the degree of the ellipsoid

XA2, YA2, ZA2 - the origin coordinates of point A2

XB2, YB2, ZB2 - the origin coordinates of point B2

XC2, YC2, ZC2 - the origin coordinates of point C2

XD2, YD2, ZD2 - the origin coordinates of the point D2 of degree of freedom:

1,2, 3- progressive points A1 across the axes of the X, Y, Z

4, 5, 6 rotatory bodies T1 around the axes of the X, Y, Z

7, 8, 9 progressive points A2 across the axes of the X, Y, Z

10, 11, 12- rotatory bodies T2 around the axes of the X, Y, Z

With the appearance of contact the force of contact interaction has normal and tangential components. The amounts of these forces are determined as far as normal contact deformation and relative speed of bodies before the contact point, and also as far as selected model of the description of the forces of contact interaction and as far as set of the parameters. For greater detail, see before Section 6.4 (model of the description of the forces of contact interaction). Normal contact deformation is defined as the greatest depth of penetration of the surface of ellipsoid beside the half-space, limited as far as the fragment of plane, if contact occurs not On the Border parallelogram. The determination of contact deformation more complex, but sense remains with the contact with the boundary of parallelogram (details see before the description of mathematical model).

Degrees of freedom

1,2, 3- progressive points A1 across the axes of the X, Y, Z;

4, 5, 6 rotatory bodies T1 across the axes of the X, Y, Z;

7, 8, 9 progressive points A2 across the axes of the X, Y, Z;

10, 11, 12- rotatory bodies T2 across the axes of the X, Y, Z;

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point A1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point C1	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D1	*m*	*- Rlmax… +RLmax*
13,14,15	Semiaxes R1, R2, R3	*m*	*Rlmin… RLmax*
16	DEGREE of ellipsoid, P	*m*	*>1*
17,18,19	the origin coordinates of point A2	*m*	*- Rlmax… +RLmax*
20,21,22	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
23,24,25	the origin coordinates of point C2	*m*	*- Rlmax… +RLmax*
26,27,28	the origin coordinates of point D2	*m*	*- Rlmax… +RLmax*
29,…	Parameters of the model of the forces		

Working vector

N in sequence	Description	Dimensionality	Range
1	Sign of the presence of contact (0 - no, 1 there is)		0 or 1
2	Amount of the contact deformation	*m*	
3	Projection of relative of speed beyond the standard	*m/s*	
4	Modulus of the tangential component of the relative speed	*m/s*	
5	Force of normal reaction against the contact point	*N*	
6	THE FORCE of tangential reaction against the contact point (module)	*N*	

Notes:

1) it is considered that the normal is directed from one body T1 to the next T2. During the presence of contact point inside the parallelogram the standard is perpendicular down plane, and the surface of the ellipsoid; during the presence of the contact point On the Border of parallelogram, but inside its side, the standard is perpendicular down this side and surface of the ellipsoid; during the presence of contact point in the apex of parallelogram the standard is perpendicular down the surface of ellipsoid.

2) IN THE ABSENCE contact against current time all elements of working vector are reduced to zero.

3) use in KN3EP for the body T1 of the contact surfaces of any degree, different from the two, requires more labor-consuming computational operations.

4) with the use of surfaces of the degree higher than two it is necessary to have in mind that some elements of the jacobian of flow variables can it goes to infinity, if contact point occurs on one of the coordinate planes of the coordinate system, connected for the sake of the ellipsoid.

6.3.1.5.Element, which describes contact interaction of ellipsoid with the ellipsoid KN3EE

Reflected properties

Contact interaction of two surfaces, rigidly connected for the sake of the absolute solids T1 and T2. Each contact surface is three-axis ellipsoid, or, is more accurate - the surface of degree $p_i > 1$ ($i = 1, 2$), described before the canonical (main) basis by the equation

$$\left|\frac{x_1^{(i)}}{R_{i,1}}\right|^{p_i} + \left|\frac{x_2^{(i)}}{R_{i,2}}\right|^{p_i} + \left|\frac{x_3^{(i)}}{R_{i,3}}\right|^{p_i} = 1, \qquad i = 1, 2$$

($x_1^{(i)}, x_2^{(i)}, x_3^{(i)}$ - coordinate relative to main basis *i*-GO of ellipsoid, $R_{i,1}, R_{i,2}, R_{i,3}$ - semiaxis *i*-GO of ellipsoid). The positions of bodies T1 and T2 are determined as far as the appropriate potential variables: three translational and three rotational degrees of freedom determine the position of each of tel.

Initial position of contact surfaces, and also poles of the rotation of bodies, [zadaetsya] by the parameters (Fig. KN3EE.1, 2): for the body T1 are indicated the origin coordinates of points A1 (pole of the rotation of body T1), By b1 (center of ellipsoid), C1 (point, which lies beyond the third principal axis of ellipsoid), D1 (point, which lies against the plane of the first and third principal axes); for the body T2 are indicated the analogous values - the coordinate of points A2, B2, C2, D2.

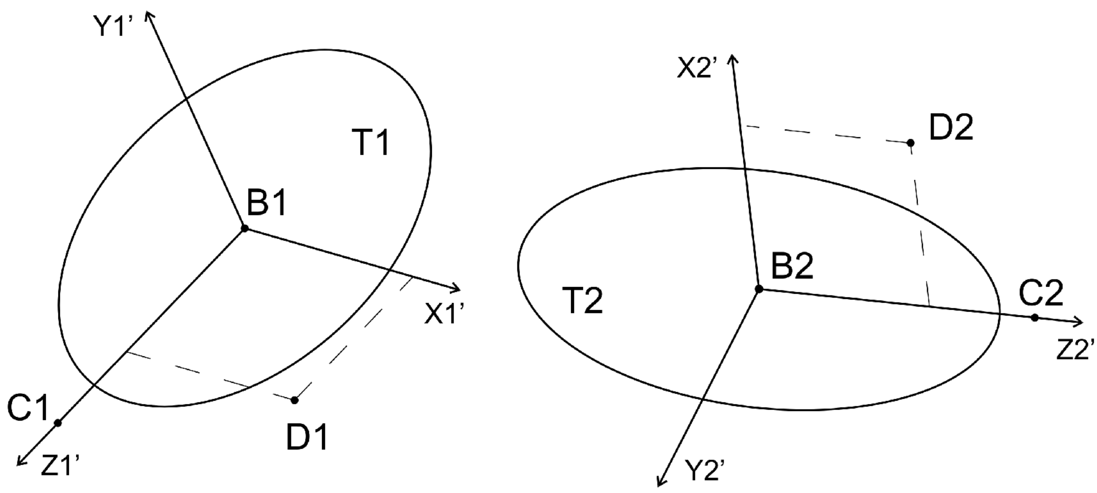


Fig. KN3EE_1. Parameters of the attitude of ellipsoids before the contact element the ellipsoid - the ellipsoid:
XB1, YB1, ZB1 - the origin coordinates of point B1 (center of the first ellipsoid)
XC1, YC1, ZC1 - the origin coordinates of point C1 (this point it lies beyond the axis Z1' THE LCS of the first ellipsoid)
XD1, YD1, ZD1 - the origin coordinates of point D1 (this point it lies in plane X1' Z1' THE LCS of the first ellipsoid)
XB2, YB2, ZB2 - the origin coordinates of point B2 (center of the second ellipsoid)
XC2, YC2, ZC2 - the origin coordinates of point C2 (this point it lies beyond the axis Z2' THE LCS of the second ellipsoid)
XD2, YD2, ZD2 - the origin coordinates of point D2 (this point it lies in plane X2' Z2' THE LCS of the second ellipsoid)

With the appearance of contact the force of contact interaction has normal and tangential components. The amounts of these forces are determined as far as normal contact deformation and relative speed of bodies before the contact point, and also as far as selected model of the description of the forces of contact interaction and as far as set of the parameters. For greater detail, see before Section 6.4 (model of the description of the forces of contact interaction). Normal contact deformation is defined as the greatest depth of the interpenetration of ellipsoids.

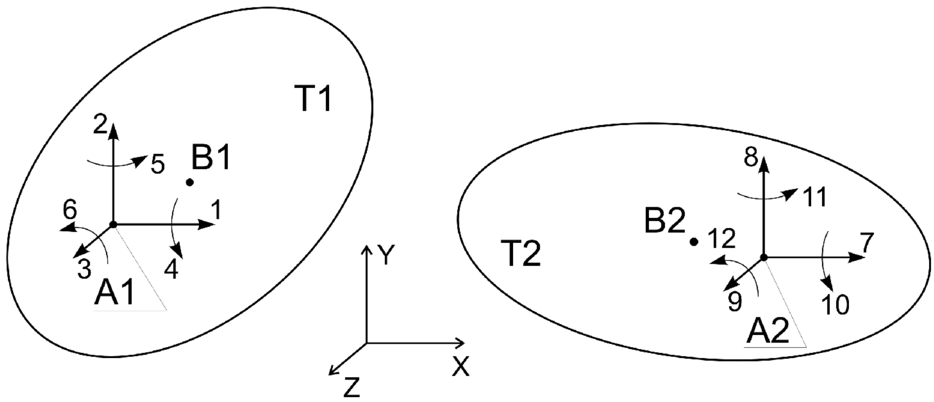


Fig. KN3EE_2. **Parameters and the degree of freedom of contact element the ellipsoid - the ellipsoid:**
Parameters:
XA1, YA1, ZA1 - the origin coordinates of point A1 (pole of the rotation of body T1)
R11, R12, R13 - the semiaxis of the first ellipsoid
P1 - the degree of the first ellipsoid
XA2, YA2, ZA2 - the origin coordinates of point A2 (pole of the rotation of body T2)
R21, R22, R23 - the semiaxis of the second ellipsoid
P2 - the degree of the second ellipsoid
Degrees of freedom:
1,2, 3- progressive points A1 across the axes of the X, Y, Z
4, 5, 6 rotatory bodies T1 around the axes of the X, Y, Z
7, 8, 9 progressive points A2 across the axes of the X, Y, Z
10, 11, 12- rotatory bodies T2 around the axes of the X, Y, Z

Degrees of freedom

1,2, 3- progressive points A1 across the axes of the X, Y, Z;

4, 5, 6 rotatory bodies T1 across the axes of the X, Y, Z;

7, 8, 9 progressive points A2 across the axes of the X, Y, Z;

10, 11, 12- rotatory bodies T2 across the axes of the X, Y, Z;

Parameters

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point A1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point C1	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D1	*m*	*- Rlmax… +RLmax*
13,14,15	Semiaxes Of r11, R12, R13	*m*	*Rlmin… RLmax*
16	DEGREE of the first ellipsoid, P1	*m*	*>1*
17,18,19	the origin coordinates of point A2	*m*	*- Rlmax… +RLmax*
20,21,22	the origin coordinates of point B2	*m*	*- Rlmax… +RLmax*
23,24,25	the origin coordinates of point C2	*m*	*- Rlmax… +RLmax*
26,27,28	the origin coordinates of point D2	*m*	*- Rlmax… +RLmax*
29,30,31	Semiaxes Of r21, R22, R23	*m*	*Rlmin… RLmax*
32	DEGREE of the second ellipsoid, P2	*m*	*>1*
33,…	Parameters of the model of the forces		

Working vector

N in sequence	Description	Dimensionality	Range
1	Sign of the presence of contact (0 - no, 1 there is)		0 or 1
2	Amount of the contact deformation	*m*	

N in sequence	Description	Dimensionality	Range
3	Projection of relative of speed beyond the standard	*m/s*	
4	Modulus of the tangential component of the relative speed	*m/s*	
5	Force of normal reaction against the contact point	*N*	
6	THE FORCE of tangential reaction against the contact point (module)	*N*	

Notes:

1) it is considered that the normal is directed from one body T1 to the next T2.

2) IN THE ABSENCE contact against current time all elements of working vector are reduced to zero.

3) before the present version of element KN3EE for the body T1 it is necessary that degrees of the contact surfaces Of p1 and P2 would not exceed the two; otherwise the search algorithm of contact point works unstably. Before the following version of element this problem will be solved.

6.3.1.6.Element, which describes contact interaction of two facet surfaces KN3FF

Reflected properties

Contact interaction of two facet surfaces, M1 and M2, rigidly connected for the sake of the absolute solids T1 and T2. Each contact surface is assigned by the grid, which consists besides the triangular faces. With the task of grid separately are indicated the coordinates of units, and separately - the troikas of the numbers of units, which determine the faces of the grid (in this case the number of the first unit it is considered equal down one). The positions of bodies T1 and T2 are determined as far as the appropriate potential variables: three translational and three rotational degrees of freedom determine the position of each of tel.

Initial position of contact surfaces, and also of poles of the rotation of bodies, [zadaetsya] by the parameters (Fig. KN3FF.1): for the body T1 are indicated the origin coordinates of points A1 (pole of the rotation of body T1), B1 (beginning LCS, before whom it is prescribed facet surface), C1 (point, which lies beyond the axis O' Z' LCS), D1 (point, which lies against the plane X' O' Z' LCS, but not beyond the axis O' Z'); for the body T2 are indicated the analogous values - the coordinate of points A2, B2, C2, D2.

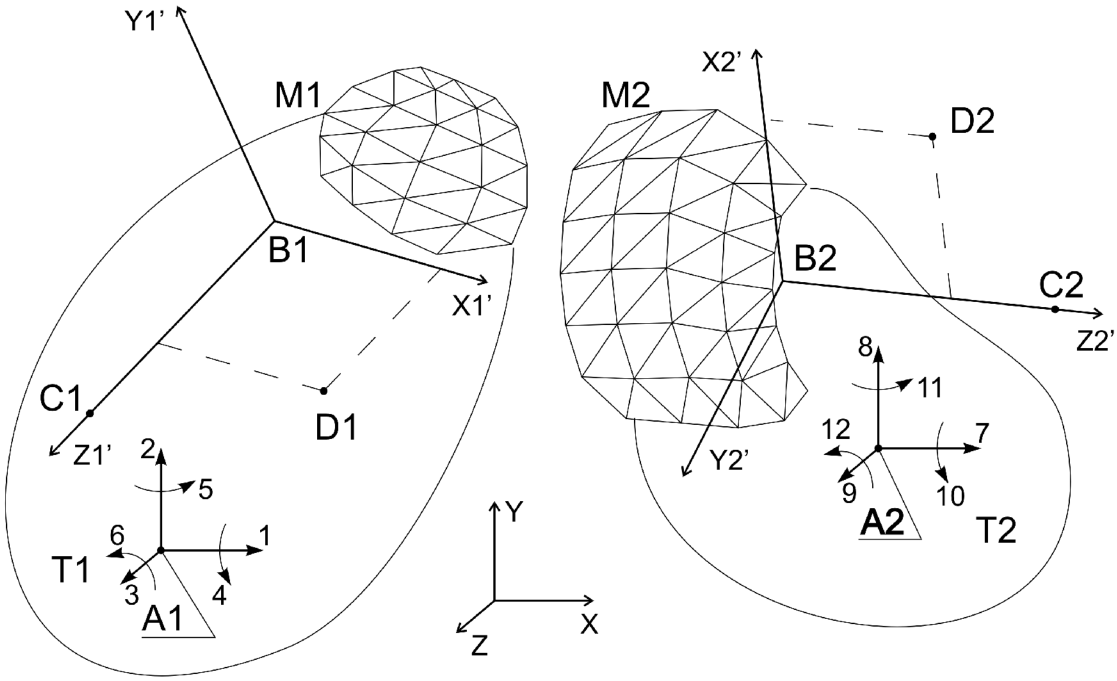


Fig. KN3FF_1. Degrees of freedom and the parameters of attitude before the contact element the facet - the facet

With the appearance of contact the force of contact interaction has normal and tangential components. The amounts of these forces are determined as far as normal contact deformation and relative speed of bodies before the contact point, and also as far as selected model of the description of the forces of contact interaction and as far as set of the parameters. For greater detail, see before Section 6.4 (model of the description of the forces of contact interaction). Normal contact deformation is defined as the greatest depth of the interpenetration of surfaces. Contact points there can be several, but not more than 20.

Degrees of freedom

1,2, 3- progressive points A1 across the axes of the X, Y, Z;

4, 5, 6 rotatory bodies T1 across the axes of the X, Y, Z;

7, 8, 9 progressive points A2 across the axes of the X, Y, Z;

10, 11, 12- rotatory bodies T2 across the axes of the X, Y, Z;

Parameters

N in sequence	Description	Dimensionality	Range
1… n1	Parameters of the geometry of surface, connected for the sake of the body T1		
n1+1… of n1+n2	Parameters of the geometry of surface, connected for the sake of the body T2		
n1+n2+1…	Parameters of the model of the forces		

The first two blocks before this table have one and the same structure and consist of n1 and n2 the parameters respectively; this structure is described before the following table (before it the number of the parameter it is counted off relative to the beginning of block). Third block - the description of the model of power interaction, standard for all elements KN3XX (see Section 6.4).

Parameters of the geometry of surface, connected for the sake of the body T (I) (I of =1,2)

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A (i)		- *Rlmax*… +*RLmax*
4,5,6	The origin coordinates of point B (i)		- *Rlmax*… +*RLmax*
7,8,9	The origin coordinates of point C (i)		- *Rlmax*… +*RLmax*
10,11,12	The origin coordinates of point D (i)		- *Rlmax*… +*RLmax*
13	Quantity of mesh points M (i) (nr (i))		
14	Quantity of faces of grid M (i) (nf (i))		
15… 14+3*nr (i)	Coordinates of mesh points M (i)	*m*	- *Rlmax*… +*RLmax*
15+3*nr (i)… n (i) = 14+3*nr (i) + of 3*nf (i)	Circuits of the faces of grid M (i) (troika of the numbers of the units, which correspond to the faces; 1-y unit has a number 1)		1… nr (i)

Observation. Facet surface must satisfy the following requirements of the algebraic nature:

- the connectedness: from any face it is possible to pass to any another, intersecting the edges;
- “simplicity of surface”: each edge belongs not more than to two faces;
- the matched orientation of the faces: the common edge of two faces bypasses before the descriptions of these faces before the different directions;
- the simple connectivity: it is allowed not more than one connected component of the boundary (line, which consists besides the edges, each of which belongs only to one face);
- “simplicity of boundary”: each unit of boundary belongs to the exactly two edges of boundary.

Furthermore, before the grid there must not be of the edges of zero length.

Working vector

N in sequence	Description	Dimensionality	Range
1	Quantity of contact points		0… 20
2-12	Information on 1-y to contact point		
13-23	Information on 2-y to contact point		
…	…		
211-221	Information on 20-y to contact point		

Here block of information about each of the contact points contains the following values.

Block of information on the contact point

1,2,3	Radius-vector of contact point	*m*	
4,5,6	Standard against the contact point		
7	Amount of the contact deformation	*m*	
8	Projection of relative of speed beyond the standard	*m/s*	
9	Modulus of the tangential component of the relative speed	*m/s*	
10	Force of normal reaction against the contact point	*N*	
11	THE FORCE of tangential reaction against the contact point (module)	*N*	

Notes:
TODO

6.3.1.7.Element, which describes contact interaction of ellipsoid with the facet surface KN3EF

Reflected properties

Contact interaction of ellipsoid and facet surface, rigidly connected for the sake of the absolute solids T1 and T2. The positions of bodies T1 and T2 are determined as far as the appropriate potential variables: three translational and three rotational degrees of freedom determine the position of each of tel.

For the sake of the body T1 is connected the surface "of ellipsoid" - the surface of degree $p > 1$, described before the canonical (main) basis by the equation

$$\left|\frac{x_1}{R_1}\right|^p + \left|\frac{x_2}{R_2}\right|^p + \left|\frac{x_3}{R_3}\right|^p = 1$$

(x_1, x_2, x_3 - coordinate relative to the main basis of ellipsoid, R_1, R_2, R_3 - the semiaxis of ellipsoid).

The second contact surface is assigned by the grid M2, which consists besides the triangular faces. With the task of grid separately are indicated the coordinates of units, and separately - the troikas of the numbers of units, which determine the faces of the grid (in this case the number of the first unit it is considered equal down one).

Initial position of contact surfaces, and also poles of the rotation of bodies, [zadaetsya] by the parameters (Fig. KN3EF.1). For the body T1 are indicated the origin coordinates of points A1 (pole of the rotation of body T1), By b1 (center of ellipsoid), C1 (point, which lies beyond the third principal axis of ellipsoid), D1 (point, which lies against the plane of the first and third principal axes). For the body T2 are indicated the analogous values - the coordinate of points A2 (pole of the rotation of body T2), B2 (beginning LCS, before which it is prescribed facet surface), C2 (point, which lies beyond the axis O' Z' LCS), D2 (point, which lies against the plane X' O' Z' LCS, but not beyond the axis O' Z').

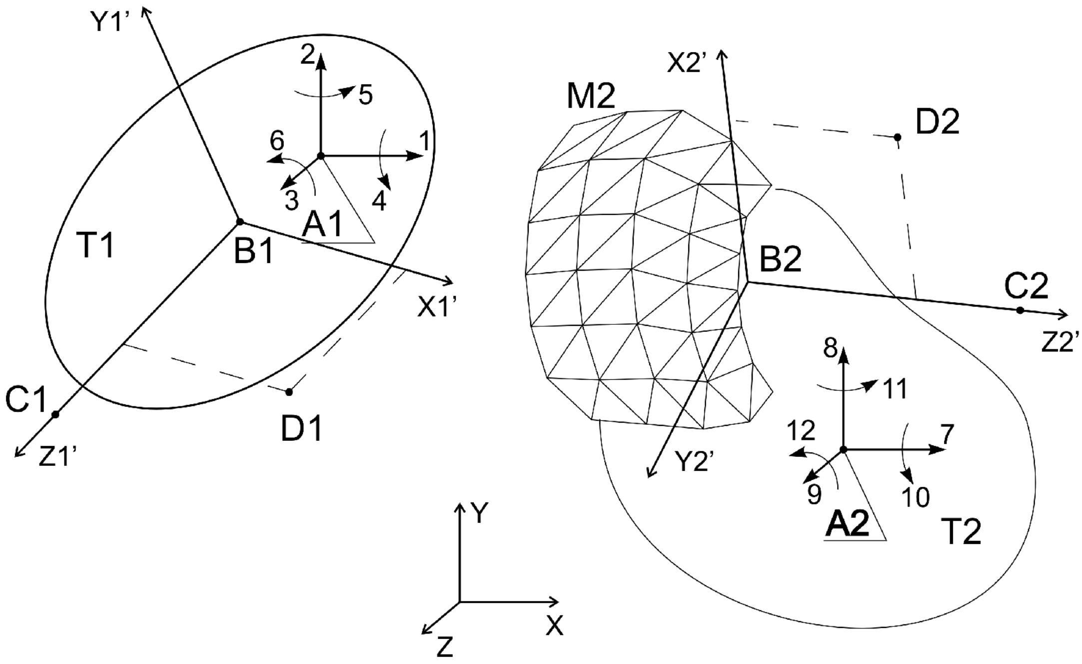


Fig. KN3EF_1. Degrees of freedom and the parameters of attitude before the contact element the facet - facet.

With the appearance of contact the force of contact interaction has normal and tangential components. The amounts of these forces are determined as far as normal contact deformation and relative speed of bodies before the contact point, and also as far as selected model of the description of the forces of contact interaction and as far as set of the parameters. For greater detail, see before Section 6.4 (model of the description of the forces of contact interaction). Normal contact deformation is defined as the greatest depth of the interpenetration of surfaces. Contact points there can be several, but not more than 20.

<u>Degrees of freedom</u>

1,2, 3-	progressive points A1 across the axes of the X, Y, Z;
4, 5, 6	rotatory bodies T1 across the axes of the X, Y, Z;
7, 8, 9	progressive points A2 across the axes of the X, Y, Z;
10, 11, 12-	rotatory bodies T2 across the axes of the X, Y, Z;

Parameters

N in sequence	Description	Dimensionality	Range
1… n1	Parameters of the geometry of the ellipsoid, connected for the sake of the body T1		
n1+1… of n1+n2	Parameters of the geometry of the facet surface, connected for the sake of the body T2		
n1+n2+1…	Parameters of the model of the forces		

The first block before this table determines the geometry of the ellipsoid; it consists of n1=16 of the parameters, enumerated before table "the parameters of ellipsoid". The second block n2 of the parameters, its structure is described before the table "the parameters of facet surface" (before it the number of the parameter it is counted off relative to the beginning of block). Third block - the description of the model of power interaction, standard for all elements KN3XX (see Section 6.4).

Parameters of the ellipsoid

N in sequence	Description	Dimensionality	Range
1,2,3	the origin coordinates of point A1	*m*	*- Rlmax… +RLmax*
4,5,6	the origin coordinates of point B1	*m*	*- Rlmax… +RLmax*
7,8,9	the origin coordinates of point C1	*m*	*- Rlmax… +RLmax*
10,11,12	the origin coordinates of point D1	*m*	*- Rlmax… +RLmax*
13,14,15	Semiaxes R1, R2, R3	*m*	*Rlmin… RLmax*
16	DEGREE of ellipsoid, p	*m*	*>1*

Parameters of the facet surface

N in sequence	Description	Dimensionality	Range
1,2,3	The origin coordinates of point A2		- *Rlmax*… +*RLmax*
4,5,6	The origin coordinates of point B2		- *Rlmax*… +*RLmax*
7,8,9	The origin coordinates of point C2		- *Rlmax*… +*RLmax*
10,11,12	The origin coordinates of point D2		- *Rlmax*… +*RLmax*
13	Quantity of mesh points M2 (nr2)		
14	Quantity of faces of grid M2 (nf2)		
15… 14+3*nr2	Coordinates of mesh points M2	*m*	- *Rlmax*… +*RLmax*
15+3*nr2… n2 = 14+3*nr2 + of 3*nf2	Circuits of the faces of grid M2 (troika of the numbers of the units, which correspond to the faces; 1-y unit has a number 1)		1… nr2

Observation. Facet surface must satisfy the following requirements of the algebraic nature:

- the connectedness: from any face it is possible to pass to any another, intersecting the edges;
- "simplicity of surface": each edge belongs not more than to two faces;
- the matched orientation of the faces: the common edge of two faces bypasses before the descriptions of these faces before the different directions;
- the simple connectivity: it is allowed not more than one connected component of the boundary (line, which consists besides the edges, each of which belongs only to one face);
- "simplicity of boundary": each unit of boundary belongs to the exactly two edges of boundary.

Furthermore, before the grid there must not be of the edges of zero length.

Working vector

N in sequence	Description	Dimensionality	Range
1	Quantity of contact points		0… 20
2-12	Information on 1-y to contact point		
13-23	Information on 2-y to contact point		
…	…		
211-221	Information on 20-y to contact point		

Here block of information about each of the contact points contains the following values.

Block of information on the contact point

1,2,3	Radius-vector of contact point	*m*	
4,5,6	Standard against the contact point		
7	Amount of the contact deformation	*m*	
8	Projection of relative of speed beyond the standard	*m/s*	
9	Modulus of the tangential component of the relative speed	*m/s*	
10	Force of normal reaction against the contact point	*N*	
11	THE FORCE of tangential reaction against the contact point (module)	*N*	

Notes:
TODO

6.4.Application: the model of the forces of contact interaction

Before all three-dimensional contact elements KN3?? power interaction is simulated uniform: the same models of power interaction are applicable to the different elements. Therefore the description of the models of power interaction (or, briefly, the models of forces) is assembled before this separate division.

With each element KN3?? for the sake of one or several models of forces can be connected. The description of the models of forces before the element follows its basic parameters. The description of each model begins based on the number of the model - its identifier; the values of the parameters of the model of forces are described after identifier. Such blocks, which consist besides the identifier of the model and following above it parameters, there can be several (not less than one and not more 12), before the description of element they simply follow each other.

Let us transfer the models of forces, realized against the present moment.

1. model of the elastic normal force, which linearly depends beyond the deformation

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 1)		
2	Contact rigidity	*N/m*	*Rlmin… RLmax*

OBSERVATIONS:

This model of forces with the description of element must be mentioned before the models of the tangential forces

2. model of viscous normal force, linearly depending beyond the speed deformation

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 2)		
2	Contact viscosity	*N of [s]/[m]*	*0… RLmax*

3. model of the elastic normal force, which arbitrarily depends beyond the deformation. Bending characteristic must be determined as far as the parameters of model.

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 3)		
2,…, 2+2*N1	The bending characteristic, [opredelennaya] as it is piecewise-the linear dependence of force beyond the deformation; here N1 - the number of units before the bending characteristic. It is necessary to assign not less than two points; moreover the first point must be (0,0). Characteristic is assigned in the form the set of pairs (x, f (x)); moreover x must strictly grow; completing zero must go after the last point of characteristic.	*m, N*	*x: 0… RLmax, y: Rlmin… RLmax*

OBSERVATIONS:

This model of forces with the description of element must be mentioned before the models of tangential forces.

4. model of the viscous normal force, which arbitrarily depends beyond the deformation. Viscous characteristic must be determined as far as the parameters of model.

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 4)		
2,…, 2+2*N1	The viscous characteristic, [opredelennaya] as it is piecewise-the linear dependence of force beyond the deformation rate; here N1 - the number of units before the bending characteristic. It is necessary to assign not less than two points; moreover the first point must be (0,0). Characteristic is assigned in the form the set of pairs (x, f (x)); moreover x must strictly grow; completing zero must go after the last point of characteristic.	*m/s, N*	*x: 0… RLmax, y: Rlmin… RLmax*

5. model of tangential frictional force. It realizes the frictional force, which acts in the tangential plane before the direction, opposite down the tangential projection of relative of speed, before the value proportional down elastic component of normal reaction and down the coefficient of the friction; the coefficient of friction, f, is considered constant.

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 11)		
2	the coefficient of the dry friction		*0… RLmax*

OBSERVATIONS:

This model of forces with the description of element must be mentioned after the models of the normal forces

6. model of tangential frictional force. It realizes the frictional force, which acts in the tangential plane before the direction, opposite down the tangential projection of relative of speed (VTR), on the value proportional down elastic component of normal reaction (QNE) and the coefficient of the friction; the coefficient of friction, f, in turn, depends on module VTR as follows: with |VTR| < v0 linearly changes from 0 to f0; with |VTR| >= v0 it is constant and equal to f0. f0 and v0 - the parameters of model.

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 12)		
2	f0, the limiting value of the coefficient of the friction		*0… RLmax*
3	v0, the speed, with which the coefficient of friction it reaches f0		*RLmin… RLmax*

OBSERVATIONS:

This model of forces with the description of element must be mentioned after the models of the normal forces

7. model of tangential frictional force. It realizes the frictional force, which acts in the tangential plane before the direction, opposite down the tangential projection of relative of speed (VTR), before the value proportional down the module of the relative speed |VTR| and to the coefficient of the viscous friction; the coefficient of viscous friction, b, is considered constant.

Parameters

N in sequence	Description	Dimensionality	Range
1	IDENTIFIER (always 13)		
2	the coefficient of the viscous friction	*N of [s]/[m]*	*0… RLmax*

7. Transmissions

7.1.1D elements

7.1.1.1.Transmission with the losses of moment (force) before the dependence beyond prescribed efficiency REDCT

Reflected properties

It serves for the translation of motion between two [stepnyami] of freedom with the given value of gear ratio. The typical cases of applying the element are depicted in the figure Of rEDCT_1.[a]. as can be seen from of this figure, degree of freedom of those linked [elemetom] of bodies can be both the rotatory and progressive. The connection between the speeds according to these degrees of freedom is assigned by the dependence:

$$\omega_1 + u * \omega_2 = 0$$

, where u - prescribed gear ratio;

$\omega_{\tau\eta\varepsilon\ 1}$ - the speed of the motion of the leading component;

$\omega_{\tau\eta\varepsilon\ 2}$ - the speed of the motion of slave component.

Element does not reproduce the phenomenon of slippage, which can occur before the real transmissions of the type of friction or belt. Losses before the transmission are determined as far as the fixed time of the friction (by effort of friction), whose value is determined as far as prescribed efficiency and nominal moment (nominal effort) of the transmission:

$$M^{TR} = M^{Nome} * \tau\eta\varepsilon\ \eta$$

, where *By m[nom]* - the nominal moment (effort), applied to the first degree of the freedom;

$\tau\eta\varepsilon\ \eta$ - TRANSMISSION EFFICIENCY with the nominal moment (effort).

Since the value of the moment (effort) of friction does not depend on load, the nature of a change transmission efficiency before the dependence beyond the moment (effort) applied to the first degree of freedom changes according to the law, shown before Fig. Of rEDCT_1.[b].

Element does not reproduce the phenomenon of self-braking (irreversibility of transmission), which is characteristic for such real transmissions as wave, spiral with the appropriate angle of the slope of helix and other

а)

Тип передачи	Передаточное отношение	
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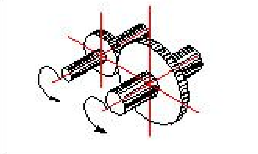
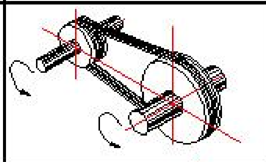
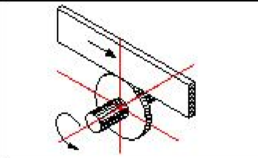
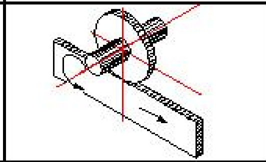
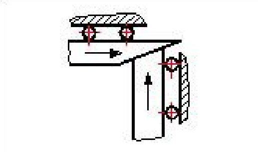
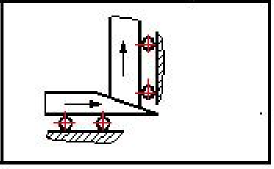
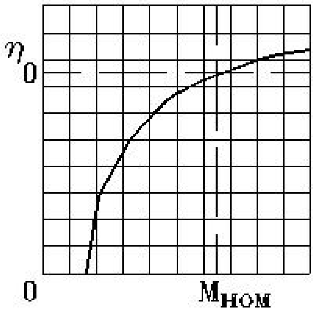
вращательное звено – вращательное звено		
вращательное звено – поступательное звено		
поступательное звено – поступательное звено		

б)



REDCT_1 Model of transmission with the losses:
a) the typical cases of application the elements;
b) the dependence of efficiency beyond the load.

<u>Degrees of freedom of the element</u>

1 rotatory (progressive) of the first body;

it is 2n d rotatory (progressive) of the second body.

Parameters

N in sequence	Description	Dimensionality	Range
1	GEAR ratio		*- Rlmax… 0* [] *0… +RLmax*
2	EFFICIENCY with the nominal moment (effort)	*m*	*0… 1*
3	NOMINAL moment (effort) for the first degree of the freedom	*[N]*[m]* or *N*	] *0… +RLmax*
4	THE RIGIDITY of transmission, led down input component (*)	*N*m/rad* or *N/m*	] *0… +RLmax*
5	THE MOMENT of inertia (mass) about the first degree	*[kg]*[m]2* or *the kgf*	] *0… +RLmax*
6	THE MOMENT of inertia (mass) according to the second degree of the freedom	*[kg]*[m]2* or *the kgf*	] *0… +RLmax*

*) the physical sense of this parameter: the amount of the deformation of element about the first degree of freedom under the action of the applied to it single moment (effort) with the fixed second degree of freedom. The dimensionality of the parameter is determined as far as the fact, the first degree of the freedom of element is rotatory or progressive.

7.1.1.2.Differential with the fixed time of friction and the rigid kinematic constraint between the output [poluosevymi] gears DIFMC

Reflected properties

It serves for distributing the torque between the input and output components and guaranteeing their rotation with the different angular velocities. Examples of the functional diagrams of differentials are given before Fig. DIFMC_1.

If the leading component (housing) revolves with the angular velocity ω_{D}, and leftist and right the [poluosevye] gears - with the angular velocities $\omega_{1\,op}$ ω_{2}, the relationship between the angular velocities ω_{D}, $\omega_{1\,op}$ ω_{2} is assigned by expression [20]:

$$\omega_{\tau\eta\varepsilon\,1} + of\,u[d] * \omega_{2} = (1 + u[d]) * \omega_{D}$$

, where *u[d]* - internal gear ratio of differential.

Internal gear ratio of differential can be defined as the relation of a quantity of teeth on the slave [poluosevykh] gears:

$$u[d] = z2/z1$$

Down [ris].DIFMC_1.[a]. is given the example to the construction of symmetrical (*u[d]* = 1), while down [ris].DIFMC_1.[b]. - asymmetrical differential.

The friction moment acts between the output semiaxes of differential. Its value is determined as far as the dependence [19]:

$$M^{TR} = K^{B} * M^{Nome}$$

, where K^{B} the coefficient of blocking (0… 1);

By m[nom] - the nominal moment of differential.

If before what-that moment of time one of the semiaxes becomes “running in”, and what-first “delaying”, then motoring torque is redistributed between the semiaxes taking into account moment of frictions [20]. If “running in” - the first semiaxis, then moments *M1* and *M2* are calculated based on the relationships :

$$M1 = (M^{D}\ M^{TR})/(1 + u[d])$$

$$M2 = (u[d] * M^{D} + M^{TR})/(1 + u[d])$$

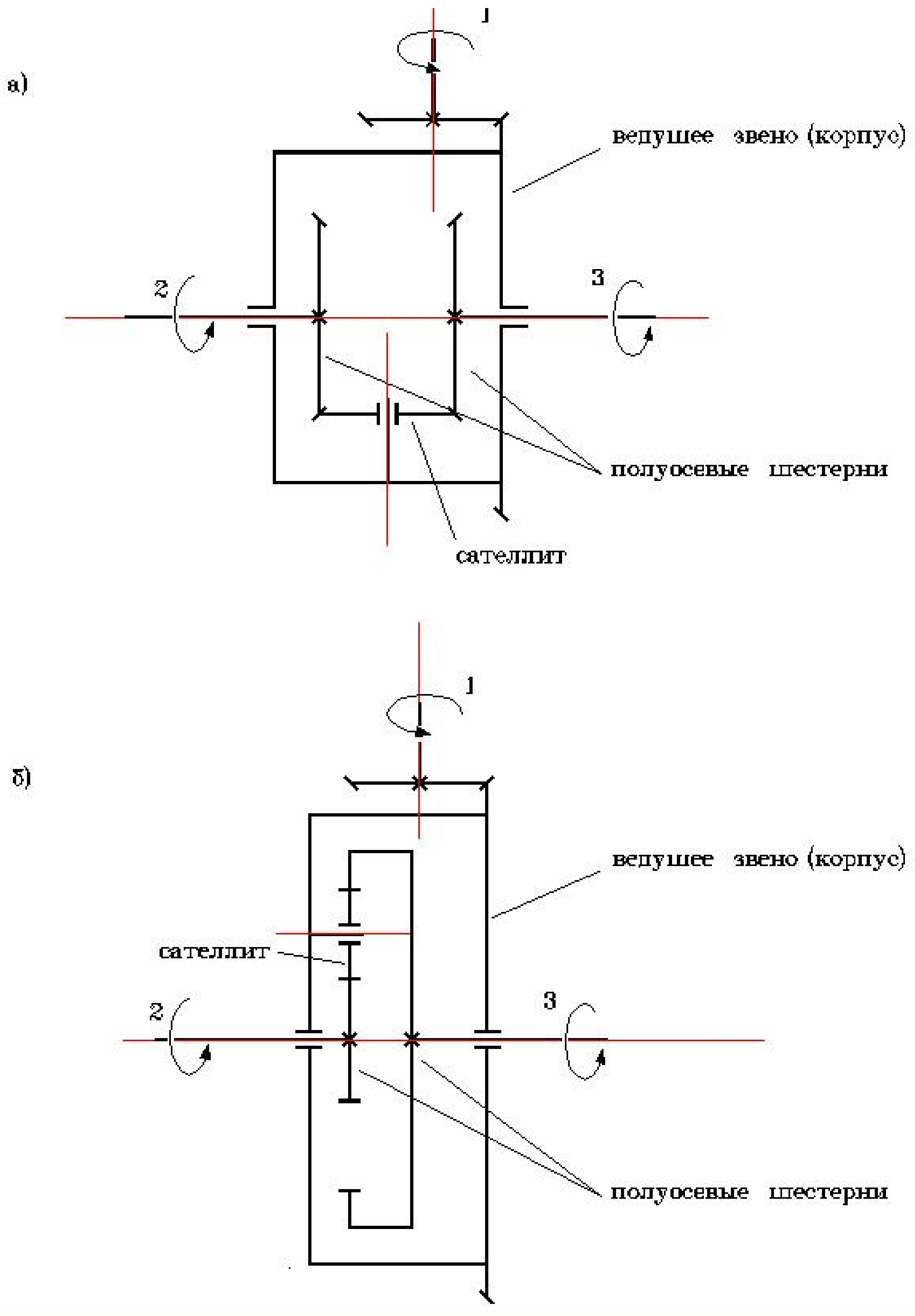
, if “running in” becomes the second semiaxis, then these relationships change intermittently:

$$M1 = (M^{D} + M^{TR})/(1 + u[d])$$

$$M2 = (u[d] * M^{D}\ M^{TR})/(1 + u[d])$$

, where *M1*, *M2* - moments on the output semiaxes;

M^{D} motoring torque.



DIFMC_1 **Examples of the design concepts of differential and degree of freedom of the model of the element:**
1 angle of rotation of the leading component;
2, 3- the angle of rotations of the first and second [poluosevykh] gears;
a) the symmetrical differential;
b) asymmetrical differential.

Degrees of freedom of the element

1 rotatory of the input component;

it is 2nd rotatory of the first [poluosevoy] gear;

3- rotatory of the second [poluosevoy] gear.

Parameters

N in sequence	Description	Dimensionality	Range
1	THE COEFFICIENT of the blocking		*0... 1*
2	THE INTERNAL gear ratio		] *0... +RLmax*
3	THE NOMINAL input moment	*[N]*[m]* or *N*	] *0... +RLmax*
4	THE RIGIDITY of transmission, led down input component (*)	*N*m/rad* or *N/m*	] *0... +RLmax*

*) the physical sense of this parameter : the amount of the angular strain of input component under the action of the applied to it single moment with the fixed semiaxes.

Working vector

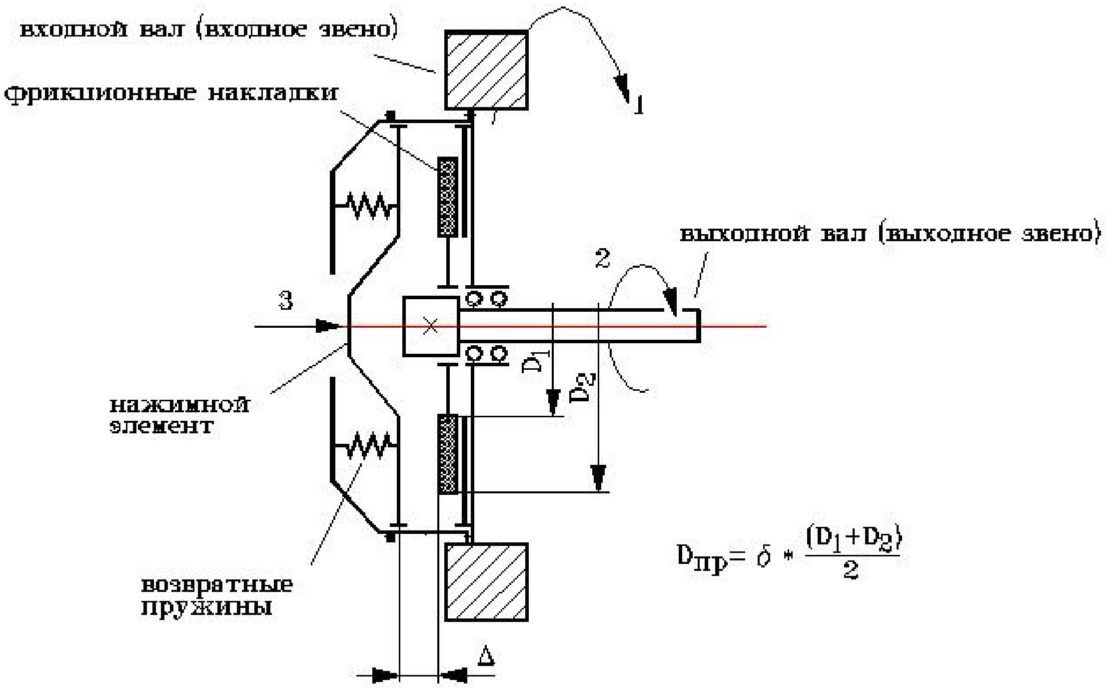
N in sequence	Description	Dimensionality	Range
1	THE INSTANTANEOUS value of friction moment	*[N]*[m]*	
2	THE INSTANTANEOUS value of the coefficient of blocking (K = of the I (M_{TR} M OF [VKH].[ZVENA]) I)		

7.1.1.3.Friction main clutch MUFTA

Reflected properties

It serves for the translation of motion based on the input to the output component due to the friction. The design concept of typical main clutch is given before Fig. MUFTA_1.

Before the initial state the clutch is switched off (half-coupling they are extended). The external effort, which influences the pressure element, causes its displacement before the axial direction. After overcoming of clearance occurs the joining of half-couplings, which causes the clamp of friction elements and the transmission of the torque between the half-couplings.



MUFTA_1 Examples of the design concept of friction clutch.
The friction moment, developed as far as clutch, is determined as far as the coefficient of friction and as far as the given diameter of the friction lining Of d[pr].
Δ - the free motion of the pressure element;
δ - reduction coefficient, depending on quantity and the shape of surface of friction.

The maximum value of the transferred torque is determined as far as the expression:

$$M^{\text{OF MAX}} = \mu * D_{\text{SO ON}}/2 * N$$

, where μ - the coefficient of the friction;

$D_{\text{SO ON}}$ - the given diameter of the friction lining. Is defined as the work of the mean diameter down the coefficient δ, that considers a quantity and the form of the elements of friction. For the single-disk clutch with two annular rubbing surfaces $\delta = 2$;

It is n-th the force of clamping of the friction lining.

Degrees of freedom

1 rotatory of the first half-coupling;

it is 2nd rotatory of the second half-coupling;

3- progressive of pressure element.

Parameters

N in sequence	Description	Dimensionality	Range
1	THE RIGIDITY of the return springs	*N/m*	] *0... +RLmax*
2	THE AXIAL contact rigidity of the half-couplings	*N/m*	] *0... +RLmax*
3	THE SHIFT contact rigidity of the half-couplings	*N*m/rad*	] *0... +RLmax*
4	THE FREE motion of the pressure element	*m*	*0... +RLmax*
5	THE GIVEN diameter of the friction lining	*m*	] *0... +RLmax*
6	THE MOMENT of the inertia of the first half-coupling	*[kg]*[m]2*	*0... +RLmax*
7	THE MOMENT of the inertia of the second half-coupling	*[kg]*[m]2*	*0... +RLmax*
8	THE MASS of the pressure element	*the kgf*	*0... +RLmax*

Working vector

N in sequence	Description	Dimensionality	Range
1	THE FORCE of clamping of friction clutch plates	*N*	
2	THE EFFORT of the return springs	*N*	

8. SPECIAL ELEMENTS

8.1.1D elements

8.1.1.The instrumentation

8.1.1.1.Single-channel accelerometer with the built-in filter of low frequency AKSEL

Reflected properties

It serves for the frequency filtration of the graph of the acceleration of physical point, obtained by calculated or experimental way.

The internal structure of filter is depicted beyond Fig. Of aKSEL_1.[a]. entering the entrance of filter signal penetrates the oscillatory circuit *it is k-th m1* - μ_1. Destination of this contour - to ensure minimum signal distortions in frequency range 0… *Fh*, where *Fh* - the frequency, numerically equal down the class of the filtration of channel. After this, the signal penetrates viscously-inertia filter $\mu_{\tau\eta\varepsilon 2}$€ *m2*, that ensures fulfilling requirements at the point of the filter at frequencies, that exceed the band edge of transmission *Fn*.

The model of element can be used for processing of the results of impact tests and corresponds to the requirements of standard ISO 6487-80 ("the technology of measurement before the tests at the point of collision. Equipment. ").

Static it is amplitude-the frequency characteristic of filter is depicted down [ris].DAKSEL_1.[b]. before the same figure it is shaded the zone, [dopukaemaya] for AChKh for the sake of the requirements of standard ISO 6487-80.

Its phase shift occurs with the passage of the signal concerning the filter. By requirements of standard ISO 6487-80 are established limitations beyond the difference before the phase displacement between frequency 0.03 *Fh* and *Fh*. It must not exceed value 1 (10Fh). For four of those determined as far as this standard of the classes of filtration the model of element gives the following results on the phase shift at frequencies of 0.03Fh and *Fh*:

Class of the frequency	Phase displacement (*ms*)		Difference before the phase displacement (*ms*)	
the channel	the frequency of 0.03Fh	frequency *Fh*	the calculation	requirement ISO 6487-80
60	3.48	3.52	0.04	1.67
180	1.16	1.18	0.02	0.56
600	0.34	0.36	0.02	0.17
1000	0.22	0.22	0.00	0.10

Degrees of freedom

1	progressive, acceleration of which is measured;
it is 2nd	progressive of sensing element of accelerometer.

Parameters

N in sequence	Description	Dimensionality	Range
1	Class of the frequency of the channel of filtration *Fh*	*Hertz*	*0… +RLmax*
2	Band edge of transmission *Fn*	*Hertz*	*Fh… +RLmax*
3	The initial velocity of the sensor	*m/s*	*-RLmax… +RLmax*

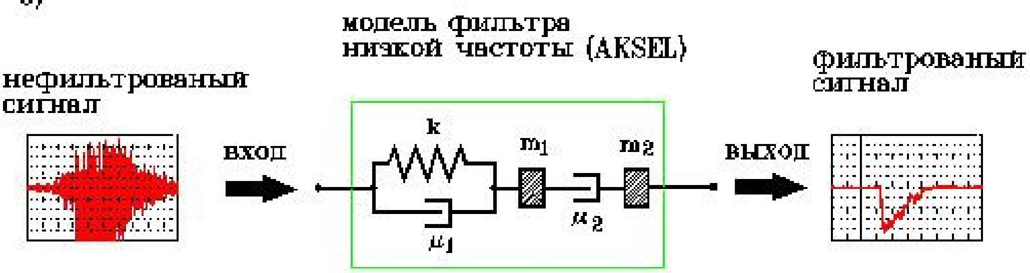
Notes:

1. standard classes of the channels of the filtration, provide ford by standard ISO 6487-80 : 60 Hertz (band edge of transmission 100 Hertz), 180 (300), 600 (1000), 1000 (1650).

2. element can be used for measuring the acceleration of degree of freedom, which has the nontrivial initial velocity. The parameter "the initial velocity of sensor" is provide ford for this case, since the element has internal degree of freedom.

3. internal mass of element is 0.001 g.

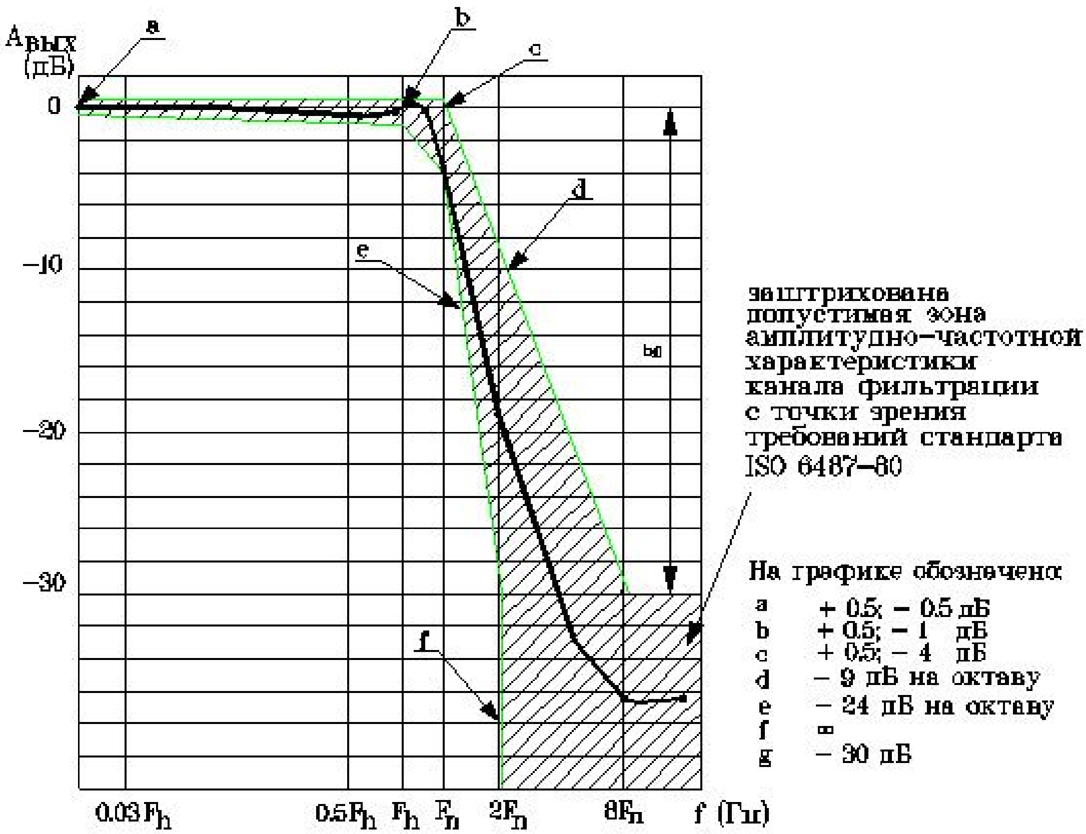
а)



ПРИМЕЧАНИЕ

1. $m_1 + m_2 = m_{екс} < 0.001$ г
2. Параметры колебательного контура k и μ_1 подбираются из условия минимального искажения сигнала на частоте F_h
3. Характеристика демпфера μ_2 определяется требованиями к фильтру на частотах, превышающих границу полосы пропускания F_n

б)



AKSEL_1 **Filter of low frequency for the channel of the measurement of the accelerations:**
a) the schematic diagram of the filter;
b) is amplitude-the frequency characteristic of filter.
Fh - the class of the frequency of channel (Hz);
Fn - the band edge of transmission (Hz).

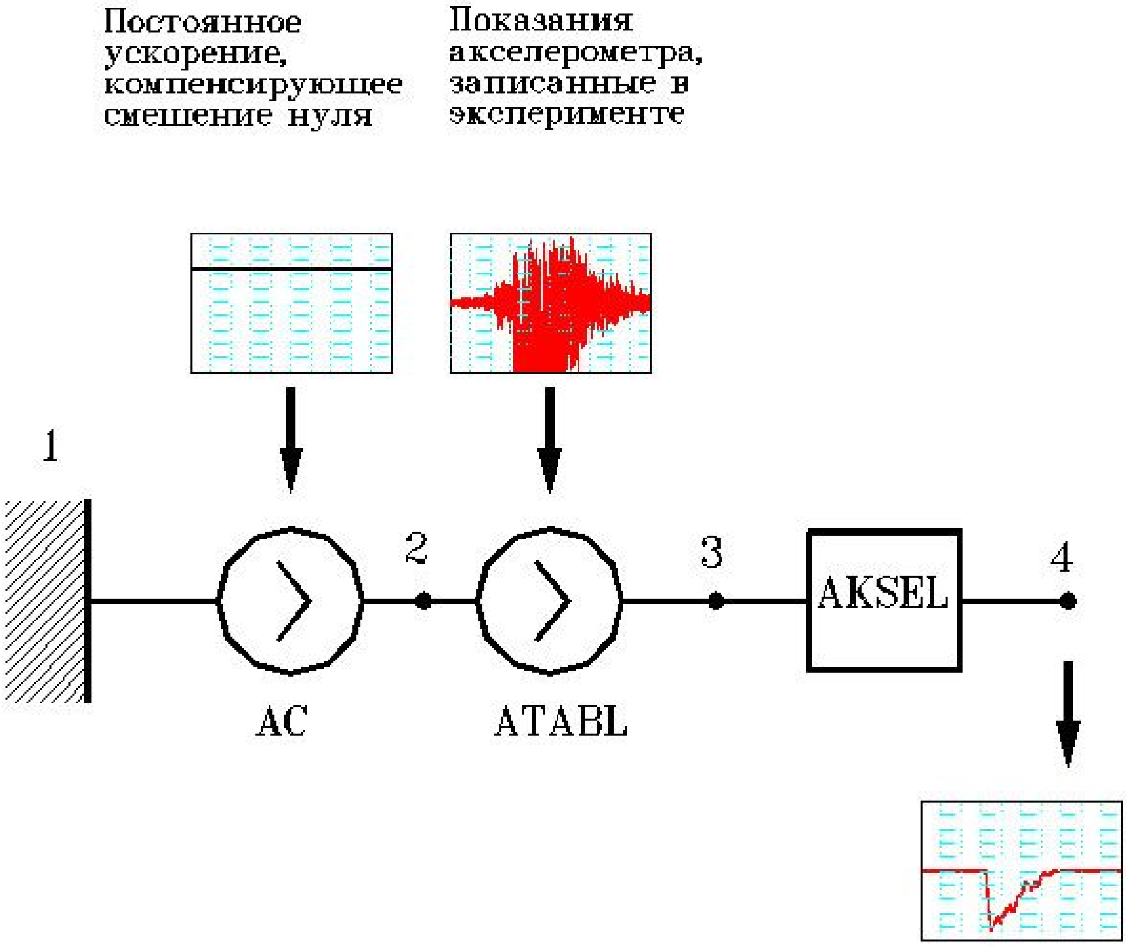
Example of the use

There is a file, which contains the data, obtained before the experiment, past a change in the acceleration from the time. The fragment of this file appears as follows:

```
{time} {acceleration}
0.000000, 0.,
0.004778, 0.499847,
0.004875, 0.397838,
0.004973, 0.295829,
0.005070, 0.193820,
0.005168,    -0.010198,
   ….
```

It is necessary to filter out the graph of accelerations with the use of a filter, which has the class of the frequency of the channel of filtration 60 Hz. after this necessary to obtain the dependence of speed and displacement beyond the time and to reconstruct the dependences of speed and acceleration beyond the time before the dependence of the same values based on the displacement.

For the solution of problem it is proposed to use the filtering channel, whose schematic is depicted beyond Fig. AKSEL_2.



AKSEL_2 Structure of the mathematical model of the device of the filtration of the oscillogram of accelerations, obtained before the experiment.

Designation of the network elements:

AC - the compensating source of acceleration (for the destruction of an inaccuracy in the installation of the zero line of the graph of accelerations);

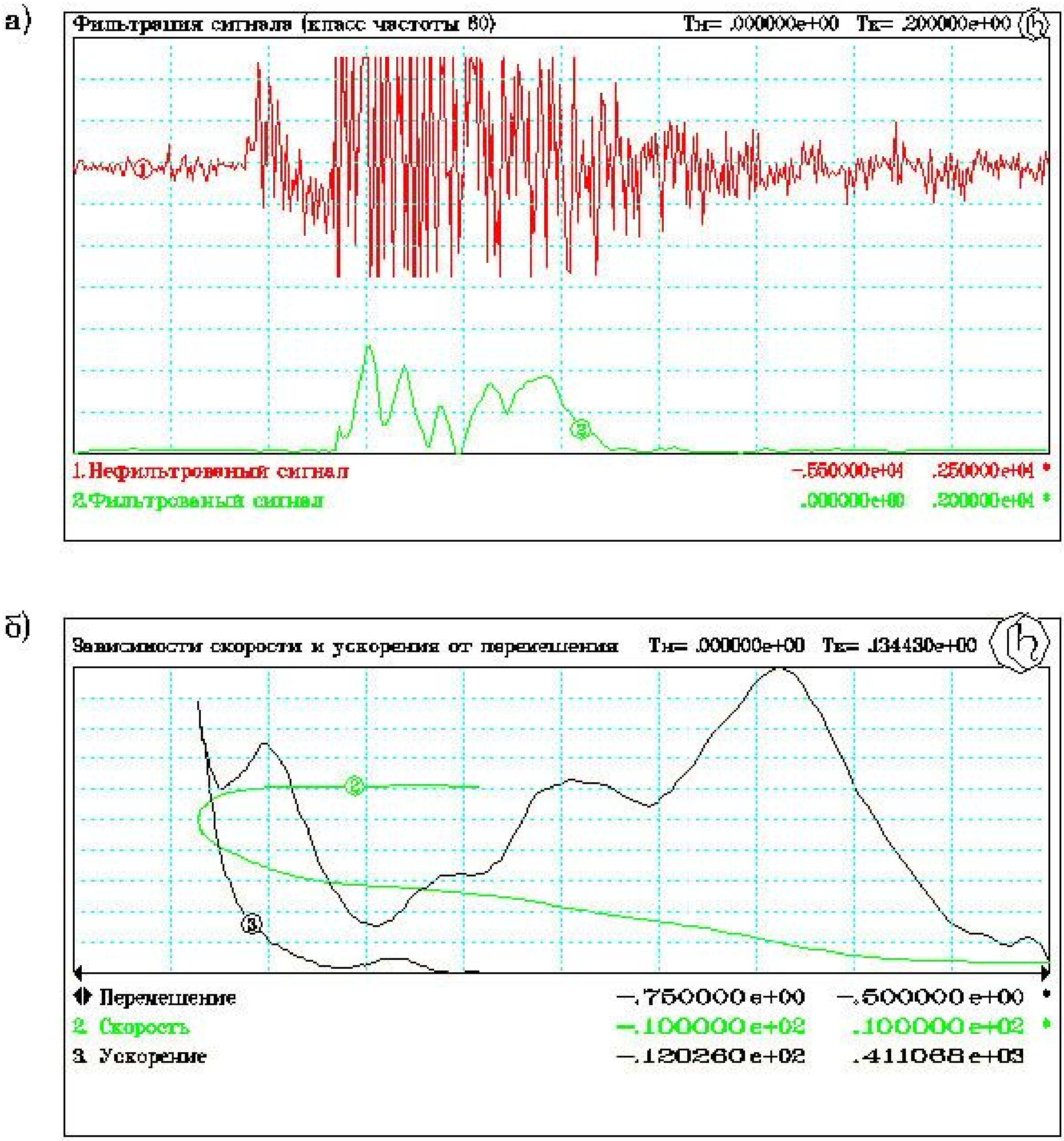
ATABL - the source of the tabular dependence of acceleration beyond the time, reproducing is the dependence of accelerations beyond the time, obtained before the experiment;

AKSEL - accelerometer with the built-in channel of filtration.

Text of task at the point of *PradiSLang*:

```
I DATA:
   Table of retardings =
     I INCLUDE: TEST.DAT
   The initial velocity = 5.0
   Compensating acceleration = 0
   Class of filtration = 60
   Band edge of transmission = 100
I FRAGMENT :
   # BASE : 1
   # STRUCT :
      Acceleration with the tests 'ATABL (3 2;
                               Table of retardings)
      Acceleration const 'AC (2;
                               Compensating acceleration, 100)
      Filtering channel 'AKSEL (3 4;
                               Class of filtration,
                               Band edge of transmission,
                               The initial velocity)
   # OUTPUT:
      Acceleration 'X (3 "; 1) {the values of [nefiltrovanykh]}
      Speed "X (3″; 1) {kinematic indices}
      Displacement 'the X (3 ; 1)
      Acceleration F 'X (4 "; 1) {the values of [filtrovanykh]}
      Speed F "X (4″; 1) {kinematic indices}
      Displacement F 'the X (4 ; 1)
I RUN:
   Calculation 'NEWMARK (END=0.3, SCALE=1;
                   Acceleration, acceleration F,
                   Speed, speed F)
I PRINT:
   Filter 60 Hz 'ACAD (;
                               Acceleration = (-5500, 2500),
                               Acceleration F = (0, 2000))
   The V and A from S 'ACAD (FROM=1;
                               Displacement F = (-0.75, -0.5),
                               Speed F = (-100, 100),
                               Acceleration F)
    $END
```

An example of the results of filtration and the obtained dependence of the acceleration and the speeds beyond the displacement are given before Fig. AKSEL_3.



AKSEL_3. **Example of processing the results of the experiment:**
a) the initial and filtered dependence of acceleration beyond the time;
b) the reconstructed dependences of acceleration and speed beyond the displacement.