e. START OF THE MODELS OF ELEMENTS IN THE LIBRARIES COMPLEX

3.1. Brief description of computational algorithm. Functions of the model of element in the composition of complex.

Here is given only brief information on to the computational algorithm of complex. For the more complete understanding the content of this document is recommended acquaintance by the detailed description of the utilized in PRADIS mathematical methods.

Mathematical model of the arbitrary technical object it is formed with the computational nucleus of complex PRADIS by the use of a node analysis (Fig. 3.1).

At the basis of this algorithm the formation and the solution lies system of equations, which reflect the laws of conservation in that or something different subject area. With the description of the technical object by a user is achieved the discreteness of space (i.e., the decomposition of object for the elements and the isolation from the the infinite quantity of degrees of freedom of the real object of some their finite number, which will be represented in the model). The equations of equilibrium are formed for each degree of freedom model. They are written relative to the variables, which conditionally it is possible to name flow (force, moment in the mechanics, expenditure in hydraulics, current in electronics). Complete system the equations of equilibrium for the model of the technical in question system it is called the system of topological equations, since it actually reflects the structure of the connections between the elements, entering this model.

State of each degree of freedom of model into each moment of time is characterized by a certain value of variable, which conditionally can be named potential (displacement, the angle turning, pressure, potential). Each of the flows, entering in the equation of equilibrium, in the general case depends on time and the values of potentials for several degrees of freedom of model. Equations, which make it possible to connect flow value for the given one moment of time with the appropriate values of potentials, they are called component.

Substitution of component equations into the system topological equations it brings in the general case to the system nonlinear differential equations. Use of the formulas numerical integration is allowed at each step integration to convert differential equations in nonlinear (algebraic and transcendent). Thus, for fulfilling each step of integration by the computational nucleus the system of nonlinear equations must be solved. It is solved by the iteration technique of Newton. It enters into the algorithm of Newton's method formation on each iteration of the system of the linear algebraic equations and its solution. Matrix of the coefficients of this system linear equations it is called the jacobian of system. This the quotients derivatives of the appropriate flow variables on by the corresponding potential variable (i.e., i- I is the line jacobian it corresponds to particular derivatives of the flows, entering

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in i- e equation, and j -1 column - by partial derivative on j -1 of potential variable). Partial derivatives are calculated with the values of potential variables, which correspond to the current approximation to the solution.

For the given values of potentials the model of the element it can determine the instantaneous values of flows and value of the quotients derivatives of flows on the potentials. Summing up of flows, the calculated by each of the models elements, it brings on the whole the case to a certain discrepancy (it appears because in comparison with the previous step of integration the state the analyzed system somewhat changed, and the value flow variables they are calculated for the values of the potential variables at the previous step of integration). Sense of the solution the system of nonlinear equations on the step of integration it consists of the selection of such values of the potential variables, which will be with the assigned accuracy to satisfy the equations of equilibrium.

Besides the summing up of flows on each iteration of the method Newton for obtaining the matrix of the coefficients of the system linear equations it is necessary to sum up also the jacobians all models of elements. By solution of the obtained system of equations increases in the instantaneous values of potential variables appear. The instantaneous values of potential variables are refined, and, if this is necessary and it is possible, new iteration is achieved.

From the aforesaid follow the functions of the model of element in the composition of complex PRADIS. It must in terms of the given values potential variables to determine the values of the flow variables and the value of particular derivatives of flows on to potentials (jacobian of element). Furthermore, it is always necessary to have in view, that in the general case in the limits of one step of the integration turning to each model occurs SEVERAL times (quantity such rotation it corresponds to a quantity of iterations of the method Newton).

The model of element is characterized by the certain quantity the degrees of freedom (or branches), with which it is connected from the the external by medium - by other elements, included in the description of object. Such degrees of freedom are called EXTERNAL. Furthermore, some degrees of freedom can be used for the the internal the needs of model - for example, the description of the displacement of internal units, the potentials of the internal points, in no way connected with others by the system elements, degrees of freedom, which are used for the integration of flow variable and such other degrees of freedom the models of element are called INTERNAL.

The process of integration for the time begins from the first step (NSTEP=1). For the initialization (installation of initial values) some utilized by the model variables, which it is necessary to conduct before beginning integration, there is a concept zero step (NSTEP=0).

The model of element can at the zero step of integration to establish the initial values:

- potential variables for those degrees of freedom, with which is connected the model;

- the elements of the state vector (NEW, OLD) and working vector the models (WRK), which DO NOT DEPEND ON THE PARAMETERS OF MODEL.

3.2. Structure of the operator SUBROUTINE of the model element.

Is examined below the model of mechanical element as most representative of the possible cases. Where this it is necessary, are made reservations relative to models from others subject areas.

In the most general case the operator SUBROUTINE of the model element it appears as follows:

```
SUBROUTINE MODEL (the I, Y, X1,…, XN, PAR, NEW, OLD, WRK)

REAL * of 8 I (1), of Y (1), X1 (1),… XN (1)
REAL * OF 8 NEW (1), OF OLD (1), OF WRK (1)
```

Here MODEL - name of the model of element. It is assigned according to the rules language FORTRAN (1-6 capital letters of the Latin alphabet or numbers). For the models of elements, which will have its graphic means on to silence, it is necessary to consider the rules the formation of the name of graphic means.

The I - vector of forces (moments) for the element. Size vector it corresponds to the total quantity the degrees of freedom of the model of element (quantity external degrees of freedom + the quantity internal degrees of freedom). In the models of another physical nature this is the vector of the electrical currents, heat fluxes, expenditures. Model element it must determine the amount of the forces (moments), that act FROM THE SIDE OF SYSTEM [NA] ELEMENT (in electronics - currents, which flow in element). Forces in this massif must to be located in that order, in which the corresponding degrees of freedom of element will be to be transferred with the description of the topology in the input language of complex.

Y - jacobian of the model of element. Dimensionality of the jacobian - Y (N * N, e), where N - quantity of the degrees freedom taking into account internal units. Structure jacobian it is depicted to [ris].3.2. It is necessary to note that in the general case the model of the element it must determine with each turning to it ALL elements of jacobian (since this massif it is used by all remaining models, participating in the calculation). In some the cases (key parameters of passport ADR and IGN; information about the key parameters of the passport of model - see below) it is possible to free model from responsibility for filling of the separate the sections of jacobian.

X 1- XN - massifs of potential variables. On the whole the case a quantity of such massifs corresponds to a quantity of degrees of freedom of element. It is assumed that in the beginning the list potential variables are located external degree of freedom, at the end - internal. If are not assigned the parameters of passport ADR and/or IGN (see further), then the elements of these massifs they correspond

X1 (1) - to displacement over the first degree freedom (in electronics - to integral on the time from the potential, in to hydraulics - integral of pressure, etc);

X1 (2) - speed according to the first degree of the freedom (to potential, to pressure);

X1 (e) - to acceleration according to the first degree of the freedom (by first time derivative of potential, pressure);

XN (1… e) - to displacement, speed and to acceleration on N -1 of degree of freedom.

ATTENTION! User is not on no account must to change the values of potential variables inside the model afterward the zero step of integration! IT IS NOT MUST.

PAR (M) - the massif of the parameters of model (parameters they are transferred to subprogram from the text the description of the structure of object). Quantity the parameters of the model of element it is determined it by passport. Model must not change the elements of this vector. If this massif in the program, which realizes the model of element, it is described by the usual method (for example, PAR (1)), that storage cell PAR (0) contains the quantity the parameters for this model. This can to be required in the case of the realization of the model element with the variable quantity the parameters. In that case storage cell PAR (0) contains the actual quantity the parameters, transferred to the model of the element with this call.

NEW (L), the elements of the vector "of the state" of the model OLD (L) of element. Frequently in the course of computation it is required to accumulate any value or to establish the sign of the current state

object (for example, it is destroyed - it is not destroyed)
on
to the results of the current step of integration.
In this case is never known, how much
iterations during the solution of the system of the nonlinear
equations it will be made (i.e., it does appear
this turning to the model of element on the data
the step of integration by the latter, or not). For
such variables it is convenient to use the vector
“state”. With each sequential rotation
in the model for the I -1 variable of the state
is calculated the element of massif NEW (the I). In
the case, if step will be successfully completed,
working program itself will care about
to the sending of vector NEW into the vector OLD.
For example, the integration of any
the value, not directly connected with the determination
the vector of flow or jacobian, can
to occur thus:

```
….
IF (NSTEP .EQ.   0) OLD (1) = of 0.D0
….
C the instantaneous value of the work:
NEW (1) = OF OLD (1) + OF STEP * X1 (2)
….
```

In many respects the state vector of the model of the element
… for those,---> it agrees with with the similar object in [PA]6,
who with exception of the fact that he IN NO WAY influences
it worked directly on the process of integration and by the program
with [PA]6… of integration it is not used and not
it is modified (besides the the automatic
sending from NEW in OLD after the the successful
the completion of the step of integration). This vector
- private property of the model of element.
The length of state vector is determined
by the combination of the key parameters of the passport
the model of element STR and STP. If these
the key parameters determine the zero length
state vector, then is this vector
it is absent from the list of the formal parameters
the model of element.

WRK (K) - working massif for the model of element.
The developer of the model of element must have
in view, that in the analyzed technical
object can be present large
a quantity of similar elements. Therefore
it is necessary to ensure REPEATED insertion in
element at the step of integration. It is cannot in
tele- element to store any values,
if they can be others for others
the utilized similar elements. For
storage of these variables is used the massif
WRK. For each concrete call of the model
element is used its working massif
(these massifs as much, as the similar
the models of element it is present in the description
object). On the course of solution the element of the worker

vector it can be transmitted into the program
the calculation of output variables with the aid of
indicator W:. For example, W:Body (2) -
to transmit into the program of calculation by the output
by variable the second element of the working vector
the model of element with the identifier body.
The working vector of the model of element has
a constant part and variable part,
depending on a quantity of elements in the vector
the parameters of model. The overall length of accessible in
of the model of working vector it is determined
by the combination of the key parameters of passport WRK and
WRP. If these key parameters of the passport
the zero length of working vector is determined,
that this vector is absent from the list
the formal parameters of the model of element.

3.3. Passport of the model of element.

The passport of the model of element is located in the first lines
the program, which realizes the model of element in the columns from 2 through
72
inclusively. If it is not accommodated on one line, then for
transfer to the following line by the last symbol of the current line
must be comma.

The passport of the model of element begins with the keyword
MODEL. The name of the subprogram, which realizes the model goes after this,
element, and, after symbol ":", the list of the names of the key
the parameters of passport and their values - positive integers.
The name of the key parameter and its value are divided by the symbol
taking (=). Different key parameters in this list
they are separated from each other by commas.

In the passport of the model of element there can be such key
the parameters:

EXT - quantity of external degrees of freedom of the model
element (>0). This key parameter in
the passport of element it is required (it cannot be made
element with a zero quantity of the external degrees
freedom).

ENT - quantity of internal degrees of freedom of the model
element. If this key parameter
passport it is not assigned, then it is assumed ENT = 0;

PAR - determines a quantity of parameters for the elements
with a constant quantity of parameters. For
elements with a variable quantity of the parameters
- a smallest possible quantity of the parameters
for this element. If the key parameter
PAR is not assigned, a quantity of parameters of the element
1 are taken as equal to;

VPR - sign of the fact that the element has variable
a quantity of parameters. If VPR is not assigned or
it is equal to 0, it is considered that the element has
constant
a quantity of parameters. If VPR=1, then the element
has a variable quantity of parameters. With
this in the stage of the syntactic analysis
it is controlled, in order to the given quantity
the parameters of element there was not less than the key
the parameter PAR. Developer can require
from the translator of the additional control
quantity of parameters to the parity and
odd parity. If a quantity of parameters of the model
element must be odd, then
the key parameter VPR is assigned [ravynm] 11,
if even - that of 21;

STR - quantity of elements in the independent variable from
quantity of parameters of the part of state vector
the model of element (on silence = 0);

STP - determine, how many elements of the vector
state must correspond to each
to the parameter in the variable part of the vector
the parameters. This key parameter is useful in
the models of elements with the variable quantity
the parameters, when it is required for each
the parameter or the groups of the parameters to preserve
what or characteristic of state. For example,
the contact element, which simulates the contact
ellipsis with the broken line, is used the variable part
state vector for retaining flowing
the state of element in each of the the contact
points (is considered the fact that ellipsis can
to contact with that broken in several
points).
NOTE.
The overall length of state vector for each
element it is calculated from the dependence
STR +
(<[fakticheskoe] quantity of parameters # OF PAR) * STP

WRK - quantity of elements in the constant part
the working vector of model (on silence = 0).

WRP - determine, how many elements of the worker
vector must correspond to each
to the parameter in the variable part of the vector
the parameters. This key parameter is useful in
the models of elements with the variable quantity
the parameters, when it is required for each
the parameter or the groups of the parameters to preserve
the results of any single calculations.
The representative models, in passport of which
this key parameter is used -
contact section, the model of fist, tabular
the dependence of effort on the deformation, etc.

NOTE.
The overall length of the working vector, transferred of the model of element, it is calculated from the formula WRK +
(<[fakticheskoe] quantity of parameters # OF PAR) * WRP

ADR - this key parameter gives the possibility to change the rules of the call of the model of element. If is assigned ADR=2, then it is considered that the jacobian of the model "it is written relative to speeds". In this the case jacobian has a dimensionality Y (N * N, 2), with this Y (the I, 1) it corresponds to derivatives on to speeds, Y (the I, 2) - by acceleration derivative. Accordingly, the dimensionality of each of the vectors of potential variables it decreases by one. XJ (1) will correspond speed on J -1 of the degree of freedom, XJ (2) - to acceleration. ADR=3- the following step in this direction. Dimensionality of jacobian - Y (N * N, 1), all derivatives - on the accelerations, the dimensionality the vector of potential variables - also 1. XJ (1) (it is possible to also write simply XJ, without the indication of index) - acceleration on J -1 of the degree freedom. On silence ADR=1.

IGN - indication to the computational nucleus of the complex to ignore the appropriate fragments jacobian. IGN=2 speaks, that the elements jacobian Y (the I, 2) are zero (properties the models of element do not depend on speed), and this section of jacobian is not filled up with model. IGN=3 speaks, that they are zero the elements of jacobian Y (the I, e). IGN=23 speaks about that that the properties of the model of element depend only from the displacement. It is important to bear in mind that this key parameter does not influence the actual dimensionality of jacobian and it structure. Thus, for the model with IGN=2 in the jacobian the elements, which reflect as before be present, the dependence of efforts on the speed, they are simple they are considered zero and as the computational nucleus complex they are not analyzed

Possible combinations ADR and IGN:

ADR=1, IGN=0 - correspond "to complete" to the element, described in the division 3.1;

ADR=1, IGN=2- element possesses rigid and by inertia properties. With writing the model of this element it is not necessary to worry about the determination of the elements of jacobian, connected with the speed;

ADR=1, IGN=3- element with the rigid and the the viscous
by properties. It is not necessary to determine
the elements of jacobian, connected
by acceleration;

ADR=1, IGN=23- of purely rigid element. Not
it is necessary to determine the elements
jacobian, connected with the speed
and by acceleration;

ADR=2, IGN=0 - binding- inertia element. In
jacobian it is absent elements,
reflecting the dependence of forces on
displacements;

ADR=2, IGN=3- element with the viscous properties.
Elements of jacobian, which reflect
the dependence of forces on the displacements in
jacobian they be absent, A
the elements, which reflect the dependence
from the accelerations, to determine not
it is necessary;

ADR=3, IGN=0 - purely inertia element. In
jacobian there are no members,
reflecting the dependence of forces on
displacements and speeds.

On silence IGN=0.

It is important to note that one and the same program with different combinations ADR and IGN it can present different elements.

Example:

```
SUBROUTINE PROG (the I, Y, X1, X2, PAR,…)
REAL * of 8 I (1), Y (1), X1, X2, PAR (1), K
K = OF PAR (1)
I (1) = K * (the X 1- X2)
I (2) = K * (the X it is 2nd X1)
Y (1) = K
Y (2) = - K
Y (E) = - K
Y (4) = K
RETURN
END
```

If in the passport of this model is indicated ADR=1, IGN=23, then this is - the model of linearly elastic one cell, the connecting two bodies. If ADR=2, IGN=3, then this is - the model the linearly viscous one cell, which connects two bodies, if ADR=3, then this is inertia element. In the mechanics for the simulation of point inertia element this element it must stand by one “foot” on the earth. To the greatest degree it corresponds to electrical capacitance.

ATTENTION! As it follows of th information e given above, it is not possible to consider this program the model of element with similar the combinations of the key parameters ADR and IGN:

ADR=1, IGN=0,
ADR=1, IGN=2,
ADR=1, IGN=3,
ADR=2, IGN=0,

since it does not fill the corresponding sections of jacobian. I.e., during such combinations of the certified parameters IGN and ADR model is incorrect.

3.4. Reference information on the model of element.

The following divisions of the reference information are recommended on the model of the element:

1) the first line of reference information, which contains on the model);
2) the complete name of the model of element;
e) the field of application;
4) the description of the degrees of freedom of model;
shch) the description of the vector of the parameters;
') the description of those elements of working vector, which they can be useful for user.

3.5. Special features of the computational nucleus, to which it is necessary to focus attention with the development of the model element.

Besides this subsection about the special features of the development the model of element it is said also in the following subsection, on a example of the development of the concrete model of element.

3.5.1. Checking the parameters to the permissibility, the initial initializations of working vector and state vector.

The properties of the model of element are determined by its parameters. Therefore the developer of model must pay the special attention:

1) to testing the parameters of model to the permissibility;

2) to the calculation of various values, which use the value of the parameters of model. The most typical case - this

the single calculation of the elements of the working vector of model, depending on the parameters.

In the course of developing the model of element it is necessary to allow for the possibility of the sudden change of the parameters on the motion
integration. Here we are distracted from the consequences of this change the parameters for the current calculation (for example, the impact of the terrible force
it is possible to cause along the mechanical system, having thoroughly pressed the rod
to small hardness and then after increasing its hardness by several orders). As far as input language PRADIS is concerned, this it is ensured by the use of title of $REPLACE in combination with by the title of $RESTORE.

Therefore the developer of the model of element must to provide all necessary checkings of the parameters on permissibility and the necessary single calculations WITH EACH NEW CALL OF THE PROGRAM OF INTEGRATION.

It is necessary to emphasize here that the condition

```
IF (NSTEP .EQ.   0) and IF (NEWINT .EQ.  1)
```

they are not identical. The first of them is carried out only in the very beginning of calculation, at “zero step of integration”. The second with each new call of the program of integration. For example, this task for the calculation is carried out:

```
I RUN:
First stage of [integrirovanija]' SHTERM (END=1)
Second stage of [integrirovanija]' SHTERM (END=1.5)
Third stage of [integrirovanija]' SHTERM (END=2)
```

In this case condition IF (NEWINT .EQ. 1) will be on the course of computation to be carried out three times. Furthermore, it is carried out every time that user it starts the task for the already formed model, in which is present the title $RESTORE.

Thus, use in the model of element for the entrance into the block of the single calculations of the checking

```
IF (NEWINT .EQ.  1)
```

it insures from the troubles, connected with the the joint by the use of titles of $REPLACE and $RESTORE.

Diagnostics of the incorrect value of one or other parameter or another it is achieved by model itself and it must be accompanied by the installation the corresponding return code (see above description COMMON variable CODE. With the incorrect value of the parameter of the model element are assigned TO CODE=100). Obtaining this signal with the computational nucleus of complex PRADIS it leads to the the immediate to the curtailment of analysis with the delivery of the corresponding diagnostic communication into the file SYSPRINT.TXT.

A example of the fragment of the model of the element, where it is achieved checking the permissibility of value of one of the parameters.

```
        IF (NEWINT .EQ.  1)
     , THEN
                IF (PAR (1) .LT.  0.D0)
     , THEN
C
C the parameter PAR (1) with the new call
C of the program of integration has
C the inadmissible value.
                        IF (CODE .LT. 100)
     , THEN
                                 CODE = 100
                                 NAME = OF NAMEMD
                        END IF
C
C communication about the error and the emergency exit
C from the model of element.
                        ….
                        RETURN
                    ELSE
C
C the single calculation of the elements
C of working vector, which depend
C from PAR (1) and others single
C of the calculation:
                        WRK (1) = OF PAR (1) ** 2
                        ….
                END IF
        END IF
```

3.5.2. Special features of the models of elements, which assign initial conditions.

In the complex PRADIS is a group of models of elements, the intended for the task initial values of the potential variables (the initial velocities and initial displacements). This a operation can be accomplished ONLY AT THE ZERO STEP INTEGRATIONS. At the subsequent steps of integration model NOT It CAN CHANGE THE VALUES OF POTENTIAL VARIABLES, transferred, in it as the parameters. Such attempts will bring to to the unpredictable consequences. Furthermore, by the model of the element must be considered suddenly arrived to user thought in the course calculation to change the initial velocity (or initial displacement).

During the initialization of the initial values of the potential variables the model of element must itself worry about that, in order to it did not occur the contradictory installation of the values of the potential by variable. I.e., it is not possible to re-establish the value by potential by variable, already established another model. Diagnostics of this situation is accomplished by model itself and it must be accompanied by the installation of the corresponding value of the code

recovery (see above description COMMON variable CODE. With
to the contradictory installation of potential are assigned TO CODE=90). Obtaining
this signal with the computational nucleus of complex PRADIS it gives to
to the immediate curtailment of analysis with the delivery of appropriate
diagnostic communication into the file SYSPRINT.TXT.

A example of the fragment of the model of element, which has in the quality of the parameter is given the initial value of the speed of the first degree of freedom.

```
        IF (NEWINT .EQ.  1)
     , THEN
                V0 = PAR (1)
                IF (NSTEP .EQ.   0)
     , THEN
C of calculation at THE ZERO STEP
C OF THE INTEGRATION
                        IF (ABS (X1 (2) .GT. RLMIN .AND.
     , ABS (V0-X1 (2)) .GT. RLMIN)
     , THEN
                                 IF (CODE .LT. 90)
     , THEN
                                         CODE = 90
                                         NAME = OF NAMEMD
                                 END IF
C communication about the error and
C emergency exit from the model
C of element.
                                  ….
                                 RETURN
                             ELSE
                                 X1 (2) = V0
                                 WRK (1) = V0
                        END IF
                    ELSE
C
C of calculation with the new entrance into the program
C of integration, but NOT AT THE ZERO STEP
C OF INTEGRATION.
                        IF (WRK (1) .NE.   V0)
     , THEN
C
C the attempt to [pereustanovit]
C the initial velocity on the motion
C of calculation.
                                IF (CODE .LT. 100)
     , THEN
                                         CODE = 100
                                         NAME = OF NAMEMD
                                 END IF
C communication about the error and output from
C of program.
                                  ….
                                 RETURN
                        END IF
                END IF
        END IF
```

3.5.3. Calculation of the possibility of using different the diagrams of integration and the guarantee of the repeated insertion into the model of element.

As a result of the fact that PRADIS for the analysis of processes in time domain it can use different diagrams integration, the use of a step of integration (COMMON variable STEP) for determining of flows and calculation of the jacobian inside the model it is not desirable (if we speak frankly - that it is forbidden. Only exception - use of that flowing the step of integration for the approximation of time derivatives it is higher than the second order).

It is again necessary to focus attention of user to similar factors as REPEATED turning to the models of elements on each step of integration and the possible repeated entry one and the same model of element into the structure of the model of object (A means, and repeated turning to the models of elements within the limits one iteration of Newton's method). This leads to two important to the special features of programming of this type of the modules:

1) it is necessary to be careful with the operators of the type

ALFA = OF ALFA + OF DALFA,

since in the limits of one step of integration it the indeterminate quantity of times can be carried out. In similar or similar purposes is used the state vector of the model element (see the example, given above with the description of the vector the state of model).

2) storage of any values in those preserved (SAVE) local variables also it is possible to lead to number of problems because of that that one and the same model can be used in the structure object it is repeated. For example, in the description of any structure the model of rod can be present several times, in each of these models there can be different initial length. Then, if the developer of the model of element wants to preserve the initial length rod, he cannot simply calculate it and memorize in SAVE by variable because with the following entry into the model it it will be recalculated for another combination of the parameters - in the model of object the large quantity can be present rods. In this case the so-called worker is used the vector of the model of element. For each entry of the model of element in the model of object is started its unique copy of the worker vector.

For the calculation and storing the intermediate values the model of element can use a working vector and state vector.

3.5.4. Some other important special features the models of elements.

1) since zero step is not the valuable step integration, the calculation of the jacobian of element with NSTEP=0 it is possible not to carry out. However, flow variables it is recommended to calculate (they can fall into the file of results, into which on zero step is conducted the record of the initial state of the output variables).

2) the developer of the model of element must focus attention to the fact that the value of the efforts, generated by the model of element with the absence of external action, they must be equal to zero.

e) in the models of elements is done the large quantity intermediate calculations. Furthermore, frequently without the special expenditures it is possible to calculate these or other values, which can prove to be, useful as output variables (force and moments in the the local to the system of coordinates, stress, etc). Developer must to focus attention on this fact and to ensure the additional convenience to the user of its model. As a rule, the elements working vector, intended to the use as output variables, they must be located the in the beginning worker vector they must be described in HELP'[e] on the model.

3.6. Example of the development of the model of element.

3.6.1. Formulation of the problem.

Let us examine here the process of development and start in the composition of the complex PRADIS of the new model of element.

Let us assume that the task stands before the user systems analysis of two bodies, which accomplish plane motion. Each of the bodies is characterized by their mass and moment of the inertia relative to the center of gravity. The centers of gravity of two bodies are connected by the ideally elastic constraint, working in tension - compression. To to the second body is vertically downward applied force. Diagram of this system it is depicted in Fig. 3.3.

Let us assume that we did not reveal in the libraries of the complex no element, which makes it possible to realize the ideal elastic the connection between the bodies for the plane motion, and they are assured that this there is no element there actually (otherwise better to use the consultation of the knowing man). Results the decomposition of system to the elements are illustrated [ris].3.4. The following elements, necessary for the formation are isolated, the model:

- the point inertia element, which accomplishes the flat motion (MD, body 1, body 2);

the -source of constant force (F, force);

- the ideally elastic element, which moves in the plane and working in tension - compression (??? , Ideal elastic constraint).

Let us add as the necessary commentary that here is examined only hypothetical example for more detailed acquaintance with the inclusion in the composition of the complex of the model element. But if in your complex actually there is no similar the element (let us say, the elements of the group of rods), then can be they are assured that it is found in Adam's (i.e., completely naked) state.

Thus, the task of the development arose before us in entire increase the model of the element, which realizes the ideal elastic axial connection (i.e., power factors they act along the axis of element) for plane motion - i.e., the model of the spring of expansion-compression.

3.6.2. Basic dependences for the model of element and it the parameters.

As it follows from the information, given in this chapter, the model of the developed by us element in terms of the given values the displacements of the centers of the masses of two connected by it bodies it must to determine the amounts of the forces, with which THE SYSTEM ACTS ON ELEMENT and particular derivatives of forces on the displacements.

We intend to bring the matter to the creation of subprogram, realizing the model of this element. Therefore, for that, in order to it was easy to be dismantled with the text of program, it is below in all computations we will use designations of variables and the parameters, which subsequently will enter into the text of program.

The amount of the acting on the element axial force it is possible to determine from Hooke's law:

$$F = U * K \quad (3.1)$$

, where U - dilitational strain of element,
K - coefficient of elasticity,
F - axial tensile force.

The forces will act for each of the ends of spring, equal in the absolute value F and are mutually opposite directed. Given, necessary for their definition:

- the origin coordinates of the ends of spring (are assigned in the quality of the parameters of model). The origin coordinates point A let us designate XA0, YA0, points B - XB0, YB0;

- the displacement of spring over each of the degrees of freedom: X 1- displacement of point A from the initial position in the direction of the axis of the X, the X is 2nd the displacement of point A from initial position in the direction of y axis, X 3- the displacement of point B from the initial position in

the direction of axis the X, X 4- displacement of point B from initial position in the direction of y axis. by such by means, the model of element will have four degrees freedom;

- stiffness coefficient (is assigned as the parameter model).

The design diagram of spring and dependence for the determination the values of efforts, which act on the spring from the side of system on by each of the degrees of freedom, they are given in Fig. 3.5.

3.6.3. Jacobian of element.

At the basis of dependences for the power factors, obtained in the preceding point, lies Hooke's law. Developed element it does not possess inertia and viscosimetric properties. Therefore it is necessary and sufficient to calculate only that part of the jacobian element, which reflects the dependence of forces on the displacements. This massif of 16 elements (derivatives of each of four forces on to four displacements). The fact that derivatives of forces on to speeds and to accelerations they are equal to zero, let us reflect appropriate
by the determination of the elements of passport ADR and IGN.

Let us recall that THE QUOTIENTS are the components of jacobian derivatives of forces in terms of the appropriate potential variable (this it indicates, in particular, that dXi/of dX1=0). For the storage jacobian is utilized one-dimensional massif. Then first four the element of this massif - derivatives of the first force on to the corresponding displacements, the following four elements - derivatives of the second force, etc.

In the resultant expressions for the jacobians they are used the results of several intermediate computations:

```
1) dL/dX1 = (SQRT " XB-XA) ** 2+ (YB -Ya) ** 2))'=
                     = 2 * (XB-XA) * (XB-XA) '/2L
```

Taking into account that dXA/of dX1 = 1; dXB/of dX1 = 0, we will obtain:

```
    dL/dX1 = - (XB-XA)/L = - COS (ALFA)

    It is analogous

    dL/dX2 = - SIN (ALFA)
    dL/dX3 = - dL/dX1
    dL/dX4 = - dL/dX2

2) dCOS (ALFA)/dX1 = " XB-XA)/L) '=
                   = (- L - dL/dX1 * (XB-XA)) /L ** 2 =
                   = (- 1 + COS (ALFA) * OF COS (ALFA)) /L =
                   = - SIN (ALFA) ** 2/L
    dCOS (ALFA)/dX2 = (0 - dL/dX2 * (XB-XA))  /L ** 2 =
                   = SIN (ALFA) * COS (ALFA)/L
```

```
dSIN (ALFA)/dX1 = OF COS (ALFA) * OF SIN (ALFA)/L
dSIN (ALFA)/dX2 = - COS (ALFA) ** 2/L

dCOS (ALFA)/dX3 = - dCOS (ALFA)/of dX1
dCOS (ALFA)/dX4 = - dCOS (ALFA)/of dX2
dSIN (ALFA)/dX3 = - dSIN (ALFA)/of dX1
dSIN (ALFA)/dX3 = - dSIN (ALFA)/of dX1
```

Thus, the jacobian of the developed element it appears as follows:

```
Y (1) = of dF1/dX1 = - K * (dL/dX1 * OF COS (ALFA) +
                          + U * of dCOS (ALFA)/of dX1) =
                   = - K * (- COS (ALFA) ** IS 2ND
                          - U/L * OF SIN (ALFA) ** 2)) =
                   = - K * (- 1 + L0/L * OF SIN (ALFA) ** 2)

Y (2) = of dF1/dX2 = - K * (dL/dX2 * OF COS (ALFA) +
                          + U * of dCOS (ALFA)/of dX2) =
                   = - K * (- SIN (ALFA) * COS (ALFA) +
                          + U/L * OF SIN (ALFA * OF COS (ALFA) =
                   = K * (L0/L * OF SIN (ALFA) * COS (ALFA))
Y (E) = - Y (1)
Y (4) = - Y (2)

Y (shch) = of dF2/dX1 = - K * (dL/dX1 * OF SIN (ALFA) +
                          + U * of dSIN (ALFA)/of dX1) =
                   = K * (L0/L * OF SIN (ALFA) * COS (ALFA))
Y (') = of dF2/dX2 = - K * (- 1 + L0/L * OF COS (ALFA) ** 2)
Y (") = - Y (SHCH)
Y (8) = - Y (')
```

On the basis of the fact that F3 = - F1, and F4 = - F2, derivatives on the displacements from the third force they will be equal to corresponding by derivative of the first force with the opposite sign, A derivatives of the fourth force - by corresponding derivative of the second force. Furthermore, taking into account dependence for the determination the instantaneous length of spring, we have dFn/dX1=-dFn/of dX3, dFn/dX2=-dFn/of dX4.

Most complex and critical part of the work on the model element - obtaining its jacobian - it is completed.

3.6.4. Special situations.

By most important question during the guarantee of the computational of the reliability of the model of element appears a question of the identification of the special situations. Usually it is decomposed into two cases - diagnostics errors in the parameters of element and diagnostics of errors on the motion calculations (we assume that user as the authors, it is attempted not to obtain by interruptions “on the snout”, i.e., it avoids to divide into 0, to take the roots from the negative numbers and to accomplish other similar causing behavior).

1) the parameters of the model of th element e developed by us can to contain error in two cases - when they determine the element zero length or assigns negative hardness.

Strictly speaking, the zero initial length of element as the same is not error, since L0 in our computations nowhere it is present in the denominator. It is more serious the fact that if this element will not be deformed on however, the first iteration, then its length will as before remain zero. In the given dependences the instantaneous length is present in the denominators of the obtained expressions. I.e., this case must to be processed separately, with the use is special the obtained dependences. Taking into account that in that suppressing the majority of the cases these possibilities of element to be used not they will, accepted the solution forbid the zero initial length rod.

It is completely dangerous from the point of view of calculations the case of negative hardness. This element, after obtaining any, how conveniently small deformation, it will generate force, directed toward its increase. And how more will be deformation, those more there will be this force. Mechanical devices with similar it is not encountered by properties in the real life.

2) in the course of calculations there can be the only special situation - zero instantaneous length of element.

3.6.5. Selection of the name of the model of spring.

A question of the selection of the name of the model of element is important.
With the inclusion of the new model of element in the composition of complex PRADIS
it is necessary to bear in mind the following considerations:

1) the name of the model of element must be [mnemonichnym], i.e., as far as possible to reflect its designation. In this case it does not follow to forget, that the standard Of fORTRAN[a] allows in the name of the subprogram to use is not more ' of symbols.

2) the name of the model of element must make it possible to obtain from it the name of graphic means on silence (rule of the formation the names of the graphic means, which correspond to the model of element on to silence, see in the chapter shch of present management). If we have in view these rules, then in the model of element it is forbidden:

- if the name of the model of element contains 4 or shch of symbols, to use as the last symbol the number (because with the formation of the name of the graphic means po- silence the name of this model of the element it is reversed);

- if the name of the model of element contains ' of symbols, then it is not possible to use a number as shch of the symbol of the name (since before reversing of this name the latter symbol is rejected).

On the basis of the rules of the formation of the name of the graphic means, to all models of elements, five first symbols of the name which they coincide, corresponds on silence one and the same graphic means. This is done for guaranteeing the possibility the realization of the graphic means, which correspond to the groups of the similar elements. Therefore if you give the model of element name, so it is more similar to the name of the model of that already being present or future element, it is necessary to compulsorily take this fact into consideration.

e) the name of the model of element must not interesect the names other modules, included in the expansible libraries of the complex (their list can be obtained upon command ARM?). It is useful to obtain also from the assumed name of model the name of graphic means, which will correspond to this model of element po- silence (see Chapter shch), and to trace so that it also would not intersect by the names of the modules, included in the expansible libraries of complex.

4) the name of the model of element must not interesect the names the subprograms for the computational nucleus of complex. List the reserved names it is brought in appendix 2 to the the present to document.

shch) the name of the model of element must not interesect the names the COMMON- blocks, utilized by a computational nucleus of the complex: NOTAT, GRCONF, FLDSCR.

') as the name of model a element cannot be used the names Of v00 - V99.

For our example let us select the name of the model of element LINKD - LIN (=LIN) the [ejnyj] elastic (K) element, which accomplishes flat (D) motion. Subsequently to all models of the elements, whose names they will begin with symbols LINKD, it will be on silence to correspond one and the same graphic means - DKNIL. It name also does not interesect the reserved names computational nucleus and by the names, switch oned at present in the libraries of complex.

3.6.6. Passport of the model of element.

The developed element has four degrees of freedom (EXT=4). Parameters of element - origin coordinates of ends and stiffness coefficient (PAR=5). In order not to calculate initial the length of element on each iteration, with the first turning to of model let us memorize initial length in the first element of the worker vector. Furthermore, in the course of computation for those or others tasks it can be useful to calculate the instantaneous length of element and axial force. Let us memorize them, correspondingly, the secondly and the third the elements of working vector (i.e., WRK=3). Jacobian of the model element it is recorded relative to displacements (ADR=1) and does not depend from the speeds and the accelerations (IGN=23). Key parameters VPR, STP, WRP for this model are equal to 0; therefore in the passport of them it is possible not to assign.

3.6.7. Text of the model of element.

After accomplishing preparatory work, we approach directly to coding of the text of program. Necessary commentary to it:

1) the name of the model of element is better to memorize as the symbolic parameter, a value to which to assign in the beginning program (in immediate proximity from the operator SUBROUTINE). Then, with the development of elements with the the similar by the functions, when the text of model LINKD is taken as prototype, descends himself probability that developer he will forget to change the operators, which send the name of model into variable NAME in special situations. The error of this type appears sufficiently extended.

2) the initial length of coupling element (distance between it with ends) it is calculated with the first turning to the model of the element and it is memorized in WRK (1).

e) are only 4 elements of jacobian, which it is necessary to calculate. Rest are obtained, on the basis of considerations, that F (e) of =-F (1), of F (4) of =-F (2), of dFn/dX1=-dFn/of dX3,
dFn/dX2=-dFn/of dX4.

4) it is in certain cases convenient to cause the model of the element as “the submodel” from other models of elements - “supers-element”. Then it is undesirable to print from the submodel of communication about the incorrect parameters or emergency situations. It is convenient to attain the blocking of press by the resetting to zero
the number of device for the conclusion of diagnostic communications with the call of submodel from the super-element. For example:

```
        ….

        SYSOLD = OF SYSPRN
        SYSPRN = 0
        CALL LINKD (F, Y, X1, X2, X3, X4, PAR, WRK)
C
C not to forget to restore the value variable SYSPRN!
        SYSPRN = OF SYSOLD

        ….
```

In order to ensure this possibility, before by the press any diagnostic communication into the file of the communications is achieved checking variable SYSPRN to inequality zero.

shch) so that your model would not appear by white crow among other models, and the communication, issued by model, is good it lay down in SYSPRINT.TXT, it is necessary during the transmittal of communication always
to observe this size as in the given examples. And not to forget, that in the first message digit always goes the name model, which issues this communication.

```
C MODEL LINKD: EXT=4, PAR=5, WRK=3, ADR=1, IGN=23
C
C the date of the creation:                03/14/92 01:34 pm
C the date of the last correction: 07/21/94 01:43 am
C
C HELP ideal elastic axial connection for the plane motion
C HELP THE NAME:         Ideal elastic element for the case
C HELP of plane motion, which works on
C HELP expansion-compression.
C
C HELP THE FIELD OF APPLICATION: Mechanics.
C
C HELP OF DEGREE OF FREEDOM:
C HELP 1- is progressive in the direction of axis OX Vol. A of element;
C HELP is 2nd progressive in the direction of axis OY Vol. A of element;
C HELP 3- is progressive in the direction of axis OX Vol. B of element;
C HELP 4- is progressive in the direction of axis OY Vol. B of element.
C
C HELP THE PARAMETERS:
C HELP 1- initial abscissa of the point A of element;
C HELP is 2nd the initial ordinate of the point A of element;
C HELP 3- the initial abscissa of the point B of element;
C HELP 4- initial ordinate of the point B of element.
C HELP P R AND M E CH A N I e. of point A and B in the the initial
C HELP position must not coincide;
C HELP is 5th stiffness coefficient (>=0).
C
C HELP THE ELEMENTS OF THE WORKING VECTOR:
C HELP 1- initial length of element;
C HELP is 2nd the instantaneous length of element;
C HELP 3- the instantaneous value of axial force.
C HELP
C HELP THE SPECIAL SITUATIONS:
C HELP if in the course of calculations the instantaneous length of the element
C HELP becomes close to 0, the emergency exit is achieved
C HELP from the model.
C
        SUBROUTINE LINKD (F, Y, X1, X2, X3, X4, PAR, WRK)
C
C the name of the model
        CHARACTER * OF 8 NAMEMD
        PARAMETER (NAMEMD = "OF LINKD")
C
C the transferred parameters:
C
        REAL * OF 8 F (1), OF Y (1), OF PAR (1), OF WRK (1),
     , X1 (1), X2 (1), X3 (1), X4 (1)
C
C variables and the constant:
C
        REAL * OF 8 XA0, YA0, XB0, YB0,
     , XA, YA, XB, YB,
     , K, L0, L, U
        REAL * OF 8 SINAL, COSAL
C
C indeterminate COMMON - block:
C
```

```
        REAL * OF 8 TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND
        CHARACTER * OF 8 NAME
        INTEGER * OF 4 NSTEP, SYSPRN, NITER, ITR
        INTEGER * OF 2 CODE, NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C
C the unnamed COMMON- region
        COMMON TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND, NAME,
     , NSTEP, SYSPRN, NITER, ITR, CODE,
     , NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C
C the variables of the named COMMON- region/NOTAT/
        REAL * OF 8 RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC
C
C the named COMMON- region/NOTAT/
        COMMON/NOTAT/
     , RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC
C
C the initialization of the parameters and accumulated values:
C
C the hardness of element and its initial length
C
        XA0 = OF PAR (1)
        YA0 = OF PAR (2)
        XB0 = OF PAR (E)
        YB0 = OF PAR (4)
        K = OF PAR (SHCH)
C
        IF (NEWINT .EQ. 1)
     , THEN
C single calculations for each new
C of turning to the program of integration.
C
                L0 = DSQRT " XA0-XB0) ** 2 + (YA0-YB0) ** 2)
C
C checking the values of the parameters for the permissibility:
C
                IF (L0 .LE.  RLMIN .OR.
     .             K .LT.  0.D0)
     , THEN
C
C of =====> EXIT emergency exit from the model:
                      IF (CODE .LT. 100)
     , THEN
                            CODE = 100
                            NAME = OF NAMEMD
                      END IF
C press in SYSPRINT of communication about
C to error in the parameters:
                      IF (SYSPRN.GT.0)
     , THEN
```

```
                              IF (L0 .LE. RLMIN)
     , THEN
                                    WRITE (SYSPRN, 900) OF NAMEMD,
     , XA0, YA0,
     , XB0, YB0
                              END IF
                              IF (K .LT. 0.D0)
     , THEN
                                    WRITE (SYSPRN, 901) OF NAMEMD, K
                              END IF
                        END IF
                        RETURN
                  END IF
C the end of checking the permissibility of the parameters
                  WRK (1) = L0
C
          END IF
C the end of single calculations in the program.
C
C of calculation with each turning to the program
          L0 = WRK (1)
C
C The t[ekushchie] coordinates of the ends of the element:
          XA = X1 (1) + XA0
          YA = X2 (1) + YA0
          XB = X3 (1) + XB0
          YB = X4 (1) + YB0
C
C The t[ekushchaja] length:
          L = OF DSQRT " XA-XB) ** 2 + (YA- YB) ** 2)
C if length is close to 0, then emergency exit from the model
          IF (L .LE. RLMIN)
     , THEN
C
C of =====> EXIT emergency exit from the model:
                  IF (CODE .LT. 75),
                             THEN
                                 CODE = 75
                                 NAME = OF NAMEMD
                  END IF
                  IF (SYSPRN.GT.0)
     , THEN
                          WRITE (SYSPRN, 902) OF NAMEMD
                  END IF
                  RETURN
          END IF
C
C the direction cosines of the axis of the element
          COSAL = (XB-XA)/L
          SINAL = (YB -YA)/L
C
C the deformation of the rod:
          U = L - L0
C
C of effort along the coordinate axes:
          F (1) = - K * U * OF COSAL
          F (2) = - K * U * OF SINAL
```

```
        F (E) = - F (1)
        F (4) = - F (2)
C
C the calculation of the elements of the jacobian:
        Y (1) = - K * (- 1.D0 + L0/L * OF SINAL * OF SINAL)
        Y (2) = K * (L0/L * OF SINAL * OF COSAL)
        Y (E) = - Y (1)
        Y (4) = - Y (2)
C
        Y (shch) = K * (L0/L * OF SINAL * OF COSAL)
        Y (') = - K * (- 1.D0 + L0/L * OF COSAL * OF COSAL)
        Y (") = - Y (SHCH)
        Y (8) = - Y (')
C
        Y (9) = - Y (1)
        Y (10) = - Y (2)
        Y (11) = - Y (E)
        Y (12) = - Y (4)
C
        Y (13) = - Y (SHCH)
        Y (14) = - Y (')
        Y (15) = - Y (")
        Y (16) = - Y (8)
C
C the remained elements of working vector (the instantaneous length
C and axial force with its sign)
        WRK (2) = L
        WRK (E) = U * K
        RETURN
900 FORMAT (/T4, A8, ":",
     , T15, "error in the coordinates of element,"
     ,/T15, "leading to the zero length: "
     ,/T15, "the coordinate of point A =", 2 (G11.5, 2X),
     ,/T15, "the coordinate of point B =", 2 (G11.5, 2X))
901 FORMAT (/T4, A8, ":",
     , T15, "the erroneous task to the hardness:"
     ,/T15, "hardness =", G11.5)
902 FORMAT (/T4, A8, ":",
     , T15, "the length of element in the course of calculations is close to
0.")
        END
```

3.6.8. Autonomous testing of the model of element.

With very important stage in the development of the model of the element the autonomous testing of the developed model appears. From th information e given above becomes clear that most the complex and critical part of the program, which realizes the model element - this is its jacobian. Even for this simple model as in the dismantled example, its obtaining presents those determined difficulty. By the direct consequence of error with the calculation of the jacobian divergence during the solution of the system of nonlinear equations appears. At best, if error "insignificant", the program it will strongly crush the value of step and lose integrations a large quantity of steps. In the worse the -process of calculations it is simple it is broken.

Therefore the autonomous testing of the model of the element it is the necessary step in its development. As a rule, for this are written simple head program on FORTRAN[e], task by which - the initialization of the equivalent components COMMON- block, the introduction of the parameters of the model of element and the call of the model element with the specific values of displacements (speeds, accelerations). They are done after this, for each degree of freedom small increases in the displacements (speeds, accelerations), and the numerical values of the elements of jacobian are calculated. Calculated numerically values of jacobian are compared with those calculated by the model at the starting point. It is natural that they will be several to be distinguished. However, this difference for those correctly calculated jacobians 1) must be insignificant and 2) must decrease with the decrease of increase in the displacement (speed, acceleration).

Let us give a example of this program, used for testing the model of element LINKD:

```
        REAL * of 8 I (4), Of i1 (4), of Y (16,3), OF YTMP (16,3)
        REAL * of 8 X1s (e), X2 (e), X3 (e), X4 (e)
        REAL * OF 8 PAR (0:shch), WRK (e)

        REAL * of 8 DDX, Y1, Y2
        INTEGER * OF 4 NUM, LLL
C
C indeterminate COMMON - block:
C
        REAL * OF 8 TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND
        CHARACTER * OF 8 NAME
        INTEGER * OF 4 NSTEP, SYSPRN, NITER, ITR
        INTEGER * OF 2 CODE, NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C
C the unnamed COMMON- region
        COMMON TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND, NAME,
     , NSTEP, SYSPRN, NITER, ITR, CODE,
     , NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C
C the variables of the named COMMON- region/NOTAT/
        REAL * OF 8 RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC
C the named COMMON- region/NOTAT/
        COMMON/NOTAT/
     , RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC
C
C
C the initial initializations of the elements of the COMMON- blocks
C unnamed COMMON - block
        TIME = 0.   D0
        STEP = 0.   D0
        STEP01 = 0.   D0
        STEP02 = 0.   D0
        SMIN = 1.   D -10
```

```
        VAL001 = 0.   D0
        VAL002 = 0.   D0
        STEPMD = 0.01 D0
        TIMEND = 0.1 D0
        NAME = "
        NSTEP = 0
        SYSPRN of =10
        NITER = 0
        ITR = "
        CODE = 0
        NUMINT = 1
        NUMPRV = 1
        CODSTP = 1
        CODGRF = 0
        NEWINT = 1
        MINSTP = 1
C COMMON - region NOTAT
        PI = OF DACOS (- 1.D0)
        RLMIN = of 1.D-100
        MSHEPS= of 1.D-14
C
        OPEN (FILE= " OF SYSPRINT.TXT ", UNIT=SYSPRN)
C
20 CONTINUE
C the introduction of the parameters of the model of the element
        PAR (0) = shch.
        PRINT *, "XA0, YA0, XB0, YB0? "
        READ (SHCH, *) OF PAR (1), OF PAR (2), OF PAR (E), OF PAR (4)
        PRINT *, "K? "
        READ (SHCH, *) OF PAR (SHCH)
C the step of the numerical differentiation
        PRINT *, "DDX?"
        READ (SHCH, *) OF DDX
C
C the call of the model of element with NSTEP = 0, NEWINT=1
        CALL LINKD (the I, Y, X1, X2, X3, X4, PAR (1), WRK)
        IF (CODE .GT.  0)
     , THEN
                PRINT *, "error in the parameters, CODE=", CODE
                CODE = 0
                GO TO 20
        END IF
C
C we establish "first step of integration". NEWINT = 0.
        NSTEP = 1
        NITER = 1
        NEWINT = 0
C
50 CONTINUE
C the cycle of checking jacobian with the different values
C of the displacements
               PRINT *, "another point? (1- yes)"
               READ (SHCH, *) OF NUM
               IF (NUM .NE. 1) STOP
C the introduction of the values of the displacements
               PRINT *, "the values of displacements X1… X4?"
               READ (shch, *) Of x1 (1), X2 (1), X3 (1), X4 (1)
```

```
C the call of model with the given values of the displacements
               CALL LINKD (the I, Y, X1, X2, X3, X4, PAR (1), WRK)
C
C the printout of the vector of efforts.
               WRITE (', 799) (THE I (LLL), LLL=1,4)
               WRITE (SYSPRN, 799) (THE I (LLL), LLL=1,4)
C
100 CONTINUE
C the numerical checking of the jacobian
                    PRINT *, " introduce the number of unit”
                    READ (SHCH, *) OF NUM
C if NUM > 4, let us switch over to the following point
                    IF (NUM.GT.4) GO TO 50
C
C for the approximation of partial derivatives is utilized
C central differences.
                    IF (NUM.EQ.1) X1 (1) = X1 (1) - DDX
                    IF (NUM.EQ.2) X2 (1) = X2 (1) - DDX
                    IF (NUM.EQ.3) X3 (1) = X3 (1) - DDX
                    IF (NUM.EQ.4) X4 (1) = X4 (1) - DDX
                    CALL LINKD (the I, YTMP, X1, X2, X3, X4, PAR (1), WRK)
C
                    IF (NUM.EQ.1) X1 (1) = X1 (1) + OF DDX * 2
                    IF (NUM.EQ.2) X2 (1) = X2 (1) + OF DDX * 2
                    IF (NUM.EQ.3) X3 (1) = X3 (1) + OF DDX * 2
                    IF (NUM.EQ.4) X4 (1) = X4 (1) + OF DDX * 2
                    CALL LINKD (I1, YTMP, X1, X2, X3, X4, PAR (1), WRK)
C
                    WRITE (6,800) OF NUM
C
C the numerical determination of the elements of jacobian,
C the printout of the values of the elements of jacobian,
C of the obtained by model, and numerical values
C of jacobian.
                    DO OF 200 LLL=1,4
                      Y1 = (I1 (LLL) - the I (LLL))/DDX/2
                      Y2 = Y (4 * (LLL-1) of +NUM, 1)
C
C if Y1 is sufficiently great, we print
C relative difference, otherwise -
C absolute.
                      IF (ABS (Y1) .GT. SQRT (RLMIN))
     , THEN
                              WRITE (6,900) OF LLL, Y1, Y2,
     , (Y 1- Y2)/Y1 * 100.
                          ELSE
                              WRITE (6,900) OF LLL, Y1, Y2,
     , (Y 1- Y2)
                      END IF
200 CONTINUE
C
                    IF (NUM.EQ.1) X1 (1) = X1 (1) - DDX
                    IF (NUM.EQ.2) X2 (1) = X2 (1) - DDX
                    IF (NUM.EQ.3) X3 (1) = X3 (1) - DDX
                    IF (NUM.EQ.4) X4 (1) = X4 (1) - DDX
C
               GO TO 100
```

```
C
799 FORMAT (2X, "efforts at the assigned point:",
     ,/, 2X, "FAX=", D12.5,
     ,/, 2X, "FAY=", D12.5,
     ,/, 2X, "FBX=", D12.5,
     ,/, 2X, "FBY=", D12.5)
800 FORMAT (/1X, "force derivatives on", I2, "by the variable:",
     ,//10X, "numerical analytical difference"/)
900 FORMAT (1X, I3, 3d15.5)
C
        END
```

Autonomous testing, conducted with the use such programs, must be most complete. If it is not compulsory, then is very desirable to achieve:

1) testing the behavior of model in the special situations (with the corresponding task of the parameters of model or the determination displacements (speeds, accelerations);

2) and n and l and t and ch e to in yu checking the those calculated efforts with the assigned combination of the initial parameters and the values displacements (speeds, accelerations);

e) if the algorithm of model contains branchings, then entire the complex of checkings in such a way as to carry out the testing all parts of program at least one time.

Should be recognized as completely improbable outcome, with which in the course of autonomous testing it will not be found not one error (such is only for the simplest models). SEARCH FOR, YES [OBRJASHCHETE].

And still. Errors, found at the autonomous testing the models of element, bypass considerably cheaper than error, which appeared in the model of the element, when it became part the model of complex technical system. Then to find and to render harmless them it will be considerably more complexly.

3.6.9. Text of the model of technical system in the language PRADIS with the use of a element LINKD.

Thus, autonomous testing of the model of the element it is completed successfully. Now let us include it in the composition of the complex by the command

> ARM + OF LINKD

If everything is made correctly, the like to this command will be the objective module of the model of element is obtained. It will be included on in library CURRENT.LIB. Reference information on the model element it will be placed into the system catalog. From this point on,

it becomes accessible for the information on the model of element in the regime ON LINE (this must be COMPULSORILY VERIFIED!):

```
> ARM?          - into the general information on the libraries
                    complex it must fall
                    information about the designation of the module
                    LINKD;

> ARM? LINKD - complete information about the model
                    element LINKD.
```

Now the model of element can be tested in the composition complex. It seems to us, which not bad approach will be ALWAYS to receive the first starting of the developed module as TEST and to relate to them is so nagging and to the the autonomous to testing module. Are still better - the first tests for the developed element to make on those specially developed the models of technical systems. For example, for our case - this:

- the static deformation of spring by the force, directed along the axis;

- testing in the regime of spring pendulum with different initial angular positions of spring;

- testing in the regime of simple pendulum.

Each test, as far as possible, it must be accompanied BY ANALYTICAL checking of results. Generally, quality and the effectiveness of test can be estimated as far as its possible analytical checking.

It will be the final stage of the development of the model of element the stage of testing in the composition of the model of the required technical system (in this case - Fig. 3.3). The text is given below this model in the language PRADIS:

```
        I DATA:
        Center of gravity of body 1 = 1, 1
        Center of gravity of body 2 = 2, 2
        Mass and the moment of the inertia of body 1 = 1, 0.1
        Mass and the moment of the inertia of body 1 = 2, 0.1
        Hardness of connection = shch E3
        Force = of 1.E3
        I FRAGMENT:
# BASE: "
# STRUCTURE:

    Body 1 'MD (1 2 Oe; Mass and the moment of the inertia of body 1)
    Body 2 'MD (4 shch '; Mass and the moment of the inertia of body 2)
    Connection 'LINKD (1 2 4 shch; Center of gravity of body 1,
                            Center of gravity of body 2,
                            Hardness of connection)
    Force 'F (shch; Force)

# OUTPUT:
    Displacement of body 2X 'the X (4; 1)
```

```
Displacement of body 2Y 'the X (shch; 1)
Bond length 'the X (W:Connection (2); 1)
Effort of [deformatsii]'X (W:Connection (e); 1)

    I RUN:
    Calculation 'SHTERM (END=1)

    I PRINT:
    Results of calculation 'DISP ()

    I END
```

3.7. One additional example to the model of element.

As one additional simple example let us give the text the model of the point inertia element, the center of masses of which and the point of application do not coincide (degrees of freedom they have certain eccentricity relative to the center of masses). This a example is characteristic fact that the power factors here depend on displacements, speeds and accelerations (i.e., jacobian has all three constituting).

Since the element has e of degree of freedom (two progressive and one rotatory), then must be determined e of the power of factor (two forces according to the translational degrees of the freedom and moment on the rotatory). Size of jacobian - e * e * e = 27 elements.

A little in more detail about the structure of jacobian. This massif in FORTRAN to program can be described differently:

1) as one-dimensional massif (REAL * of 8 Y (1));

2) as the two-dimensional massif, where the second index it corresponds to speeds (2) derived on displacements (1), and to accelerations (e) (REAL * of 8 Y (16,1));

e) as the three-dimensional massif, where the first index

it corresponds to the number of the potential, on which they differentiate, the second index - number of power factor, last index - as in the second case (REAL * of 8 Y (3,3,1))

In Fig. 3.6.- 3.8. are given the layout diagrams the elements of jacobian for all its three possible methods description.

Text of the model of point inertia element by the displaced center of gravity, that accomplishes plane motion, it is given below.

```
C
C MODEL MEKS: EXT=3, PAR=3, ADR=1, IGN=0
C
C the date of the creation:                01/21/92 08:34 am
C the date of the last correction: 10/08/93 10:18 am
C
C HELP point inertia element with eccentricity
C HELP THE NAME:             Point inertia element
C HELP by eccentricity.
C
C HELP THE FIELD OF APPLICATION: Mechanics.
C HELP OF DEGREE OF FREEDOM:
C HELP 1- progressive along the x axis;
C HELP is 2nd progressive along the y axis;
C HELP 3- is rotatory.
C HELP THE PARAMETERS:
C HELP 1- value of the mass (M >= 0);
C HELP is 2nd eccentricity of the mass (R >= 0);
C HELP 3- the initial angle between the axis OH and the radius-vector,
C HELP connecting center of rotation with the center of mass (deg).
C
        SUBROUTINE MEKS (the I, Y, X1, X2, X3, PAR)
C of the constant of this program:
        CHARACTER * OF 8 NAMEMD
        PARAMETER (NAMEMD = "OF MEKS")
C
C the transferred parameters:
        REAL * OF 8 I (1), OF Y (9,1)
        REAL * of 8 X1s (1), X2 (1), X3 (1),
     , PAR (1)
C variables and the parameters of the program
        REAL * OF 8 M, R, ALFA, J,
     , FI, EPS, W, AX, AY,
     , COS FI, SIN FI
C
C the variables of the unnamed COMMON- region
        REAL * OF 8 TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND
        CHARACTER * OF 8 NAME
        INTEGER * OF 4 NSTEP, SYSPRN, NITER, ITR
        INTEGER * OF 2 CODE, NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C the variables of the named COMMON- region/NOTAT/
        REAL * OF 8 RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC

C the unnamed COMMON- region
        COMMON TIME, STEP, STEP01, STEP02, SMIN,
     , VAL001, VAL002, STEPMD, TIMEND, NAME,
     , NSTEP, SYSPRN, NITER, ITR, CODE,
     , NUMINT, NUMPRV, CODSTP, CODGRF,
     , NEWINT, MINSTP
C the named COMMON- region
        COMMON/NOTAT/
     , RLMAX, RLMIN, INTMAX, MSHEPS,
     , PI, REZA, REZB, REZC
C
```

```
C the initialization of the parameters of the program:
        M = OF PAR (1)
        R = OF PAR (2)
        ALFA = OF PAR (E) * PI/180
C single calculations in the program:
         IF (NEWINT .EQ. 1)
     , THEN
C checking the values of the parameters for the permissibility:
                IF (M .LT. 0.0 .AND.
     .               R .LT. 0.0)
     , THEN
C
                         IF (CODE .LT. 100)
     , THEN
                                  CODE = 100
                                  NAME = OF NAMEMD
                         END IF
C
C press in SYSPRINT of the incorrect vector
C of the parameters:
                         IF (SYSPRN.GT.0)
     , THEN
                                 WRITE (SYSPRN, 900) OF NAMEMD, M, R
                         END IF
C of ===> EXIT emergency exit from the model:
                         RETURN
                END IF
C the end of actions on checking of the parameters on
C permissibility.
        END IF
C the end of single calculations in the program.
C
C some auxiliary values
        AX = X1 (e)
        AY = X2 (e)
        FI = X3 (1) + ALFA
        W = X3 (2)
        EPS = X3 (e)
        J = M * R* R
        COS FI = OF DCOS (FI)
        SIN FI = OF DSIN (FI)
C
C of the value of forces and moments:
        I (1) = (- W * W * R* COS FI - EPS * R* SIN FI + AX) * M
        I (2) = (- W * W * R* SIN FI + OF EPS * R* COS FI + AY) * M
        I (E) = EPS * J
C
C the conductance matrix of the element
        Y (1, 1) = 0.
        Y (2, 1) = 0.
        Y (e, 1) = M * (W * W * R* SIN FI - EPS * R* COS FI)
        Y (4, 1) = 0.
        Y (shch, 1) = 0.
        Y (', 1) = M * (- W * W * R* COS FI - EPS * R* SIN FI)
        Y (", 1) = 0.
        Y (8, 1) = 0.
        Y (9, 1) = 0.
```

```
C
        Y (1, 2) = 0.
        Y (2, 2) = 0.
        Y (e, 2) = - 2.D0 * W * R* M * OF COS FI
        Y (4, 2) = 0.
        Y (shch, 2) = 0.
        Y (', 2) = - 2.D0 * W * R* M * OF SIN FI
        Y (", 2) = 0.
        Y (8, 2) = 0.
        Y (9, 2) = 0.
C
        Y (1, E) = M
        Y (2, e) = 0.
        Y (e, e) = - R* M * OF SIN FI
        Y (4, e) = 0.
        Y (SHCH, E) = M
        Y (', e) = R* M * OF COS FI
        Y (", e) = 0.
        Y (8, e) = 0.
        Y (9, E) = J
C
        RETURN
900 FORMAT (/T4, A8, “:”,
     , T15, “error in the task of the parameters:”
     ,/T15, “mass =”, G11.5,
     ,/T15, “eccentricity =”, G11.5)
        END
```