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INFORMATION-CONTROLLING SYSTEM STRUCTURE SYNTHESIS OF OPERATION SUPPORT OF DIFFICULT TECHNICAL SYSTEMS

The system approach to formation of a functional-structural level of the information-controlling systems intended for support of operation of difficult technical systems on the expanded interval of an operational stage of their life cycle is offered.

Запропоновано системний підхід до формування функціонально-структурного рівня інформаційно-керуючих систем, призначених для супроводження експлуатації складних технічних систем на розширеному інтервалі експлуатаційного етапу їхнього життєвого циклу.

difficult technical system, energy, functional state, information-controlling system, technical state

Introduction

Difficult economic processes which flow in the economy of many countries of the world are reason of impossibility or they are not economic inexpediency of replacement of the morally old-fashioned difficult technical systems (DTS) on new. An objective necessity of the DTS use on the expanded interval of the operating stage of life cycle is consequenceof it.

The basic measures, directed on the increase of duration of DTS operation without conducting of labor-consuming repairs (capital) repairs, it is been:

– introduction of progressive, economic advantageous strategies of DTS operation, basis of which are conceptual principles of exploitation on the state;
– researches on determination of capabilities of increase of the set terms of operation and elements operation time of DTS;
– modernization of DTS with the purpose of efficiency indexes increase;
– creation information-controlling system (ICS), automatically deciding the tracking tasks of DTS exploitation.

ICS, on the functional and structural characteristics, must answer requirements:

– to have effective control contours of reliability, and also of the parameters of the functional and technical state| of DTS;
– to have an opportunity to carry out the forecast of change of technical and functional states of DTS;
– at formation of controlling influences to take into account the of long-life (slow) evolution processes of the technical and functional states of DTS on all of interval of the operating stage of their life cycle;
– to possess properties of flexible adaptation or invariance to the volumes changes of financing of the accompaniment system of DTS operation;
– to function continuously on all of interval of the operating stage of DTS life cycle;
– to provide the guaranteed controlling, allowing to arrive at the set indexes of functional efficiency of DTS.

Providing of effective work of ICS first of all depends on correctness and sufficiency structure of model kernel structure [1], which must include:

– integrated information models of DTS, reflecting their purpose;
– informative evolution models of the technical and functional states of DTS on all of interval of the operating stage of their life cycle;
– industrial and operating environment models.

The lacks of these models are their separation, passive and fragmentary character, inability to reflect the most general, fundamental laws of change of technical and functional state of DTS, in coordination with the of storage, operation and functional application of DTS [2].

Thus, there is a requirement in structure development of information-controlling systems of maintenance of DTS operating, based on single model formulation of dynamic evolutional processes, flowing on all of interval of the operating stage of life cycle of DTS.

Development of information-controlling system structure

With the formation purpose of the single approach to the synthesis of ICS for DTS, we shall consider dynamic processes formalization, flowing in the classic technical system.

The technical system dynamics equations, containing N of material points, look like [1]:

$$a_j w_j = F_j^{(e)} + F_j^{(i)} + R_j , \; (j = 1, 2, \dots N), \tag{1}$$

where

a_j are the masses;

w_j is an acceleration vector;

$F_j^{(e)}$ are external forces, describing interaction of technical system with an environment;

$F_j^{(i)}$ are internal forces;

R_j are reactions of connections, that forces activity of which on the system equivalently to the action of the considered connections.

With the purpose of obtaining of the closed equation system, we add to (1) connections equations:

$f_k(r_1, r_2, \dots r_N, t) = 0$ ($k = 1, 2, \dots N$),

where

r are the masses radius-vector a_j relative to the selected inertial system co-ordinates *Oxyz*.

In mechanics enter the concepts of the generalized co-ordinates *q* and generalized impulses *q*.

As the generalized co-ordinates we understand some mutually single-valued functions of co-ordinates of material points, determining at every time moment system location in space

For description of the behavior system in static or in a dynamics spaces can be considered:

− configurations space

$q = (q_1, q_2, \dots q_n)$;

− expanded configurations space

$q = (q_1, q_2, \dots q_n, t)$;

− states space

$u = (q_1, q_2, \dots q_n, \dot{q}_1, \dot{q}_2, \dots \dot{q}_n)$

or

$u = (q_1, q_2, \dots q_n, p_1, p_2, \dots p_n)$.

The basic characteristic of a condition of system is energy.

General view of the equations of energy looks like:

− for potential energy

$$U = U(r_1, r_2, \dots r_n); \tag{2}$$

− for kinetic energy

$$T = \sum_{j=1}^{n} a_j \left| v_j \right|^2, \tag{3}$$

where

v_j is speed.

We will decompose equations (2) and (3) in the Maclaurin series and will get equations for kinetic and potential energies.

$$T = \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} a_{jk}\dot{q}_j\dot{q}_k; \tag{4}$$

$$U = \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} c_{jk}q_j q_k; \tag{5}$$

where

a_{jk} are inertia coefficients;

c_{jk} are quasi-elastic coefficients.

For the system with *n* generalized co-ordinates, expressions (4; 5) will become:

$$\begin{aligned} T = {} & \frac{1}{2}a_{11}\dot{q}_1^2 + \frac{1}{2}a_{22}\dot{q}_2^2 + \frac{1}{2}a_{33}\dot{q}_3^2 + \dots + \frac{1}{2}a_{nn}\dot{q}_n^2 + \\ & + \frac{1}{2}a_{12}\dot{q}_1\dot{q}_2 + \frac{1}{2}a_{23}\dot{q}_2\dot{q}_3 + \dots + \frac{1}{2}a_{n-1,n}\dot{q}_{n-1}\dot{q}_n, \end{aligned} \tag{6}$$

$$\begin{aligned} U = {} & \frac{1}{2}c_{11}q_1^2 + \frac{1}{2}c_{22}q_2^2 + \frac{1}{2}c_{33}q_3^2 + \dots + \frac{1}{2}c_{nn}q_n^2 + \\ & + \frac{1}{2}c_{12}q_1q_2 + \frac{1}{2}c_{23}q_2q_3 + \dots + \frac{1}{2}c_{n-1,n}q_{n-1}q_n. \end{aligned} \tag{7}$$

The canonical Hamiltonian differential equations system of kind [3] gives the most overall description of changes in time of the technical systems characteristics taking into account power components:

$$\frac{dq}{dt} = \frac{\partial H}{\partial p}; \ \frac{dp}{dt} = -\frac{\partial H}{\partial q} + Q, \tag{8}$$

where

Q_i are the generalized forces, working on the system;

$H = T + U$ are the Hamiltonian function, determining total energy of the system.

Generalized forces, included in expression, in general case can be represented in a kind:

$$Q(q_1, \dots, q_n; \dot{q}_1, \dots, \dot{q}_n) = -\frac{\partial F}{\partial \dot{q}} - G - \sum f, \tag{9}$$

where

F is dissipative Rayleigh function;

G are gyroscopic forces;

$\sum f$ are other forces, working on the system.

In order that dissipative forces determined energy dispersion in the system, it is necessary, that their virtual work almost in all of moving compatible with connections was negative. These forces can be entered in Hamiltonian equations by the use of the quadratic form of kind [3]:

$$F = \frac{1}{2}\sum_{j=1}^{n}\sum_{k=1}^{n} b_{jk}\dot{q}_j\dot{q}_k. \tag{10}$$

For the system with *n* generalized co-ordinates, expression (10) will be took the form:

$$\begin{aligned} F = {} & \frac{1}{2}b_{11}\dot{q}_1^2 + \frac{1}{2}b_{22}\dot{q}_2^2 + \frac{1}{2}b_{33}\dot{q}_3^2 + \dots + \frac{1}{2}b_{nn}\dot{q}_n^2 + \\ & + \frac{1}{2}b_{12}\dot{q}_1\dot{q}_2 + \frac{1}{2}b_{23}\dot{q}_2\dot{q}_3 + \dots + \frac{1}{2}b_{n-1,n}\dot{q}_{n-1}\dot{q}_n. \end{aligned} \tag{11}$$

Introduction of gyroscopic forces G to equations (11) is justified, if the system includes symmetric solid bodies rotating with permanent angular speeds. Work of these forces is always equal to the zero.

Equations system (8) is easily reduced to the canonical Cauchy form. By an exception p will take the equations system (8) to one second-order equation. For this purpose we will transform the second equation of the system (8) to the kind:

$$\frac{dp}{dt}+\frac{\partial H}{\partial q}-Q=0. \qquad (12)$$

Taking to account that $p=mv$, will represent the first term in the left part of equation (13):

$$\frac{dp}{dt}=\frac{d}{dt}(mv)=m\frac{d}{dt}\left(\frac{dq}{dt}\right)=m\frac{d}{dt}\left(\frac{\partial H}{\partial p}\right)=$$

$$=m\frac{d}{dt}\left(\frac{\partial H}{\partial(m\dot{q})}\right)=\frac{d}{dt}\left(\frac{\partial H}{\partial \dot{q}}\right),$$

where

m is mass.

Equation (12) will be by a kind:

$$\frac{d}{dt}\left(\frac{\partial(T+U)}{\partial \dot{q}}\right)+\frac{\partial(T+U)}{\partial q}+\frac{\partial F}{\partial \dot{q}}=-G-\sum f. \qquad (13)$$

We will put expressions (6), (7), (11) in (13) and after simple transformations will get:

$$A\ddot{q}+B\dot{q}+Cq=-G-\sum f. \qquad (14)$$

Equation (16) easily will be transformed in Cauchy form:

$$\ddot{q}=-\frac{1}{A}\left(B\dot{q}+Cq-G-\sum f\right). \qquad (15)$$

The generalized dynamic system (15) can be transformed to the type of the system of ordered equations of kind:

$$\sum_{k=1}^{n} e_{ik}q_k = f_i \ (k=1, 2, \ldots, n),$$

where

e_{ik} is a quadratic differential operator of kind:

$$e_{ik}=A_{ik}\frac{d^2}{dt^2}+B_{ik}\frac{d}{dt}+C_{ik}.$$

Equations (14) are the system of usual differential second-order equations. S expressions can be easily got and for the systems, based on other physical principles: electric, electromagnetic, electromechanics et cetera In case, expressions of coefficients A, B and C are accordingly dependences on kinetic, dissipative and potential energies coefficients.

At the same time, these coefficients are functions of the parameters of DTS elements that Hamiltonian equations (9) allow to connect together power and parametrical (informative) characteristics of evolutional processes, flowing in the technical system together.

The analysis of the equations system (14) shows that it can be as a structural fractal. As is known [4; 5], the basic fractals property is their structural invariance (self-similarity) at every level of DTS. Structural fractal of kind (14), for example, for the system with three degrees of freedom, it is possible to as a flow diagram, shown on fig. 1. However such representation does not give full understanding of evolutionary change processes of the technical and functional state, flowing in DTC.

For the elimination of this lack it is offered to expand state space, entering in the system model an additional level, reflecting power processes, flowing in DTS (fig. 2).

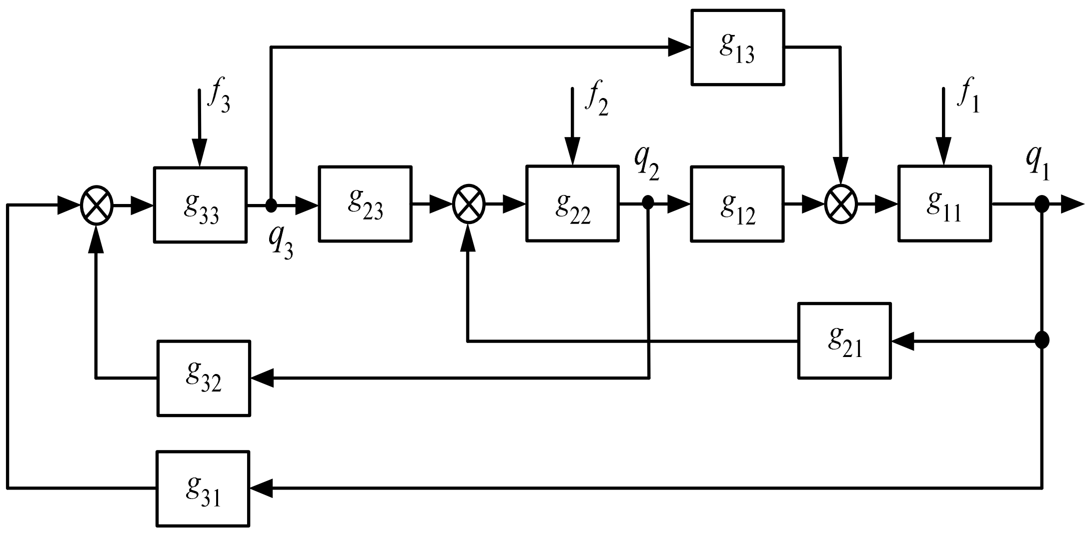

Fig. 1. Structural fractal with three degrees of freedom

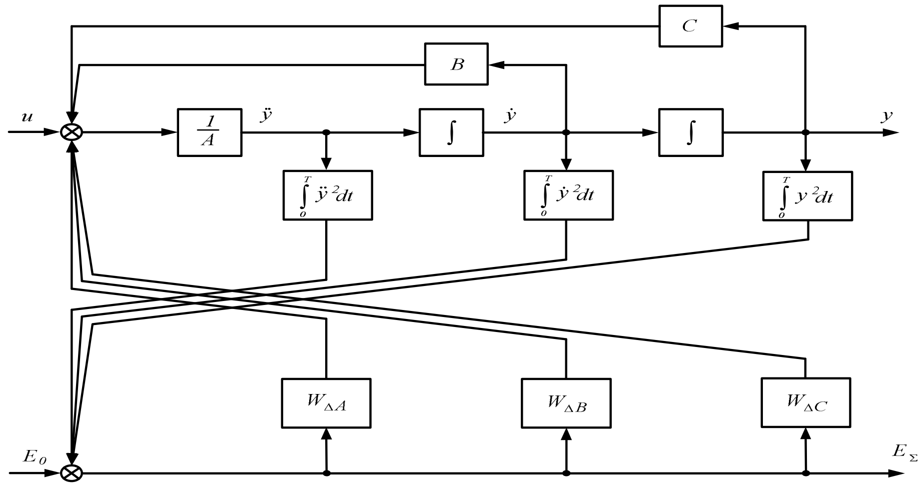

Fig. 2. Structural fractal with a power level

Power influences on DTS can be divided on revolting and directed on support of their purpose functioning. In the process of DTS exploitation these processes cause the change of their physical parameters. At the use of classic chart of representation of structural fractal (fig. 1), the physical parameters change corresponds the coefficients increments g_{ij} of DTS elements model.

Power level Addition results in structural fractal transformation in multipole, shown on fig. 2. Fig. 2 can be transformed to more compact kind. The stages of transformation are on fig. 3.

For DTS a power level can be represented as separate strata. Multidimensional vector of initial values of energy E_0 designed-in the DTS construction and vector of energy which is transformed in the DTS construction in the process of functioning by the operator $W_{E_0 y}$, go on its entrance. Total energy, producible DTS is the power strata return (fig. 4).

Power level introduction to the generalized dynamic DTS model allows to form the ICS structure, and also to define a role and place of controlling the technical and functional DTS state at its functioning on the complete interval of life cycle (fig. 5).

Conclusion

Thus, the got ICS structure consists of two parts – power and informative and contains four basic levels:

− level 1, including the ordered hierarchical models structure of dynamic modes of behavior of DTS component;

− energy transformation surveillance level 2 in the DTS functioning process;

− DTS parameters "virtual moving" level 3;

− DTS parameters "virtual moving" controlling level 4.

The ICS structure synthesized thus allows to decide the basic tasks of informative arrays synthesis, synthesis of transformation procedures of one arrays in other, of rational variants of separate parts and all ICS on the whole, formation of entrance and output information arrays in DTS and other.

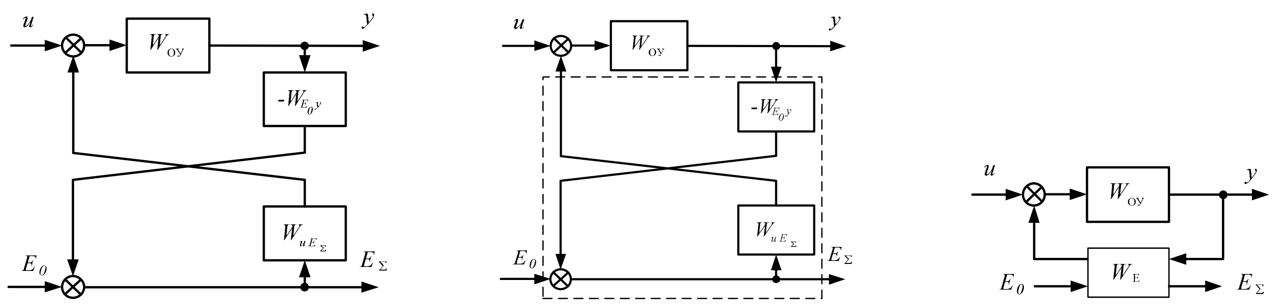

Fig. 3. Structural fractal graphic transformations:

W_{oy} is the operator, describing dynamic behavior of DTS;

$W_{E_0 y}$ is the transformation operator of energy in the process of DTS functioning;

$Wu_{E\Sigma}$ is the "virtual moving" operator of DTS parameters

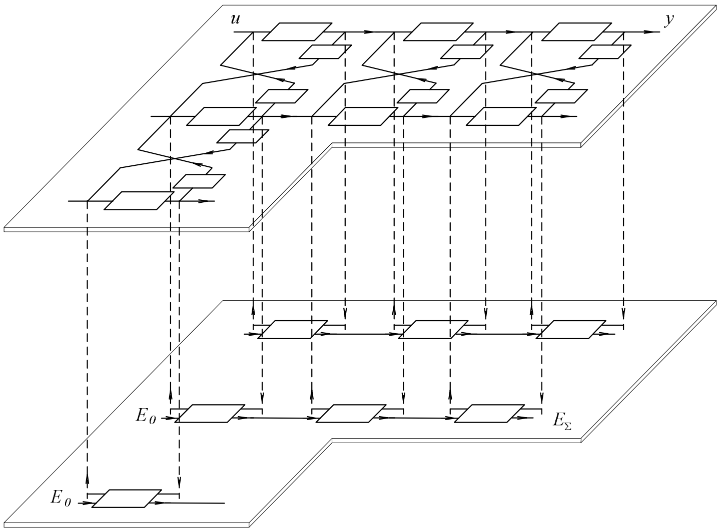

Fig. 4. Multidimensional structural fractal with the selected power level

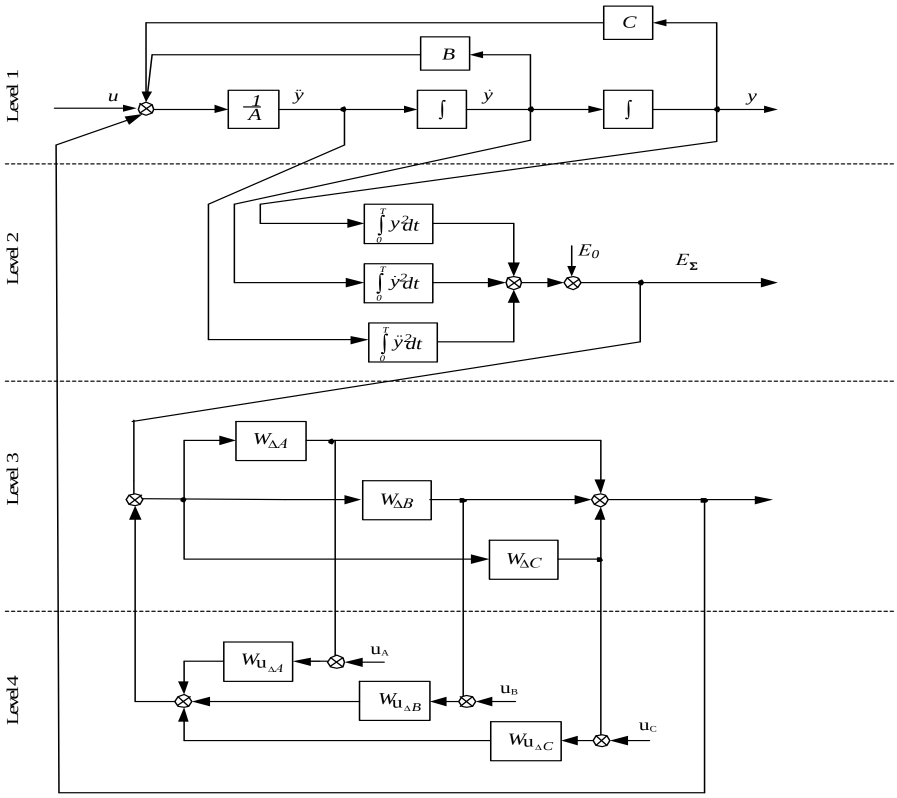

Fig. 5. ICS structural representation

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