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SPACE STRUCTURAL-PARAMETRIC SYNTHESIS OF MULTI-DISCIPLINARY TECHNICAL COMPLEXES

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Abstract. The existing decomposition technology of cooperative developments of multidiscipline technical complexes (MTC) don't provide global optimality die to the imposiolity of solving the problem of developing principles of local project solutions made by a dreat number of specialists of different branches of science. This problem is supposed to be solved by means of controlling of real-time of MTC spacé structural-parametric synthesis in terms of hierarchically organized variety of assumed scheme-structural and technological solutions. The basis algorithm: 1) realization method for a variety of possible structural organizations of a complex technical system in the form of a network analyzer; 2) method combining synthesis combinatorial operations and parametric operations in search for short routes of the developed network analyzer.

The algorithm eliminates the necessity for parametric optimization in macroparameters of all possible structural realizations of a complex systemleaving the best variant optimization.

Key words: structure, synthesis, algorithm, combining operations, shortest routes, network, decomposition, compotion, generated, level, function.

One of the main difficulties in search for the structure of multidisciplinary technical complexes (MTC) is the impossibility of estimating real interaction of subsystems within a variety of possible design decisions, thus being one of the integrator effect forms. Therefore, in practice using the existing decomposition-composition technology of the MTC cooperative developments one should refuse the requirements of design decision global optimality limiting oneself by the achievement of practically acceptable results of the development (see Lazarev, 1986).

Problem stating. It is necessary to carry out a space structural parametric MTC synthesis (industrial truck) within a variety of possible structural organizations $G = (S, B)$ generated in the process of projecting by means of a computer (Fig. 1), where $S = \{S_{ij} \mid i \in I,\ j \in J\}$ network arcs corresponding to the data block elements realizing functional transformation (transfer) operations $\eta_{ij} \in \Theta$ of the energy (product, substance, information) flow; $B = \{b_k \mid k \in K\}$ – network nodes corresponding to different flow types generated while performing the above functional operations; $I,\ J,\ K$ – sets totally determining connections between the MTC elements within a variety of possible structural organizations.

Problem solving. The MTC is characterized by a greater number of constituent elements, by a variety of connection forms, by the inconsistency of the assumed quality indices, etc. Such complexes are designed by 2,3 and more (m)-level corporations of specialized design organizations (SDO). The key problem of a multilevel design decision optimization in the MTC development is the coordination of the assumed local decisions made by specialized design organizations. The coordination process of design decisions is carried out in this paper by means of synthesis operations of the MTC structure in realizing ascending and descending design strategies (Fig. 2) (see Telezhkin, 1989).

The MTC structure is synthesized by the algorithm combining operations having a structural nature which are connected with the tree formation Z of the shortest routes $z_\nu \in Z,\ \nu = 1, 2, \ldots, \mu$ of the flow transfer in the hierarchically organized network model $G = (S, B)$, as well as with search operations of the best parameters (denoting flow losses) of the above routes. In this algorithm the determination of the MTC structure variant is limited by the search of the shortest route $\{S_{t\gamma} - S_{\gamma\tau} - \cdots\} \in z_\nu \subset Z \subset G = (S, B),\ \nu = 1, 2, \ldots, \mu;\ \{t, \gamma, \tau\} \in I, J$ of the flow transfer from the fixed discharge node to another node of the network model, that of the source. For each arc (MTC elements) of this network the following estimates are made:

$$\begin{aligned}\Delta_{ij}(X) = \Delta_{ij}[X(\eta)] &= \Delta_{ij}[\gamma_1^{ij}(\eta), \ldots, \gamma_n^{ij}(\eta)] \\ &= \left|\det A_{ij}(X)\right| > 0;\ \{i, j\} \in I, J,\end{aligned} \tag{1}$$

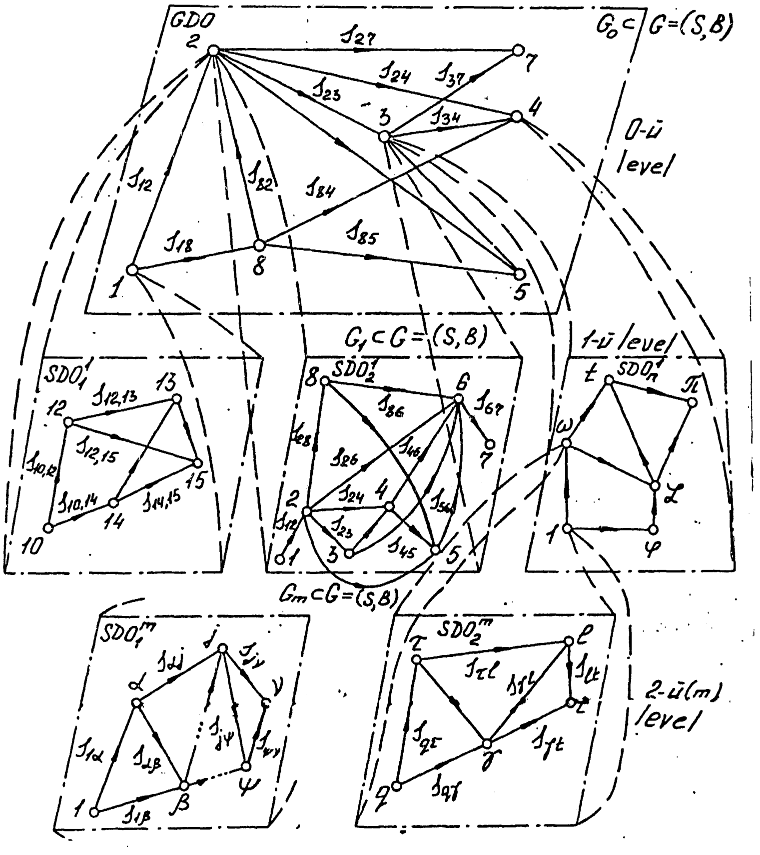

Fig. 1. Network model $G = (S, B)$ denoting a variety of possible variants of tractor design on account of different levels (echelons) of its details. ***First level:*** S_{12} – power unit; S_{18} – accumulator unit; S_{82} – constant speed electromechanical drive; S_{23} – force transmission; S_{34}, S_{24} – undercarriage; S_{25}, S_{35} – tool; S_{27}, S_{37} – auxiliary equipment; ***Second level:*** S_{12} – input unit; S_{24}, S_{34} – hydraulic pump; S_{23}, S_{26}, S_{56} – mechanical transmission; S_{46}, S_{45} – hydraulic motor; S_{36}, S_{25} – torque converter; S_{28} – generator; S_{86}, S_{85} – electric motor; S_{67} – output shaft.

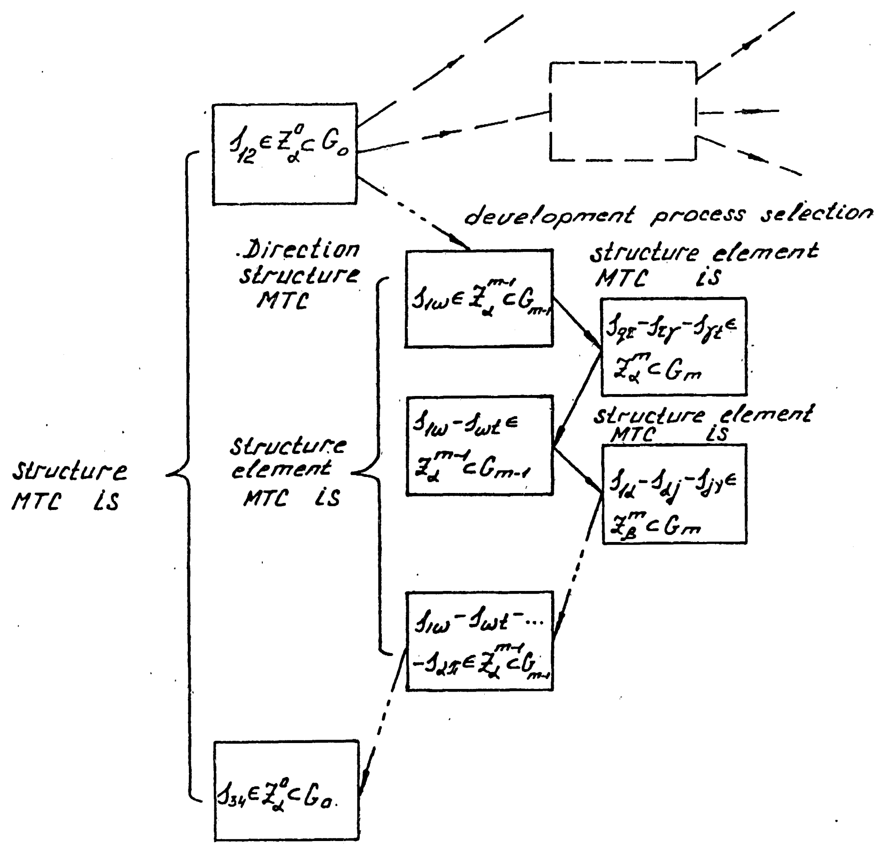

Fig. 2. Scheme of a decomposition-composition design of a multi-disciplinary technical complex within multi-level hierarchical design systems.

where $X = (x_1, \dots, x_n) \in \mathcal{X}$ inner parameters of the elements $S_{ij} \in G = (S, B)$; $\gamma_1^{ij}(\eta), \dots, \gamma_n^{ij}(\eta)$ – functions connecting inner parameters of the S_{ij} – element with its outer parameters $\eta = \eta_{ij} \in \Theta$; $A_{ij}(X) = DF_{ij}(X)/DX$ – Yakobi matrix; $F_{ij}(X) = (f_1^{ij}(X), \dots, f_l^{ij}(X), \dots, f_n^{ij}(X))$, $f_1^{ij}(X) \Rightarrow \min\limits_{X \in \mathcal{X}}, \dots, f_l^{ij}(X) \Rightarrow \min\limits_{X \in \mathcal{X}}, \dots, f_n^{ij}(X) \Rightarrow \min\limits_{X \in \mathcal{X}}$ – assumed (additive) quality indices (economical and reliable indices of a functional process) of the S_{ij} – element of the network $G = (S, B)$.

For each network are the usefulness (efficiency) functions are also realized:

$$\begin{aligned} U(\eta) &= U\left[F_\varphi(X), F_\psi(X), \dots\right] \\ &= U\left[F_\varphi\left[\gamma_1^\varphi(\eta), \gamma_2^\varphi(\eta), \dots\right], F_\psi\left[\gamma_1^\psi(\eta), \gamma_2^\psi(\eta), \dots\right], \dots\right]. \end{aligned}$$

These functions are used for the parametric optimization as they show individual expenses of each SDO in the form of dependences (non-linear in general) connecting the assumed quality indices with the outer parameters of the elements $S_\varphi, S_\psi, \dots \in z_\nu \subset Z \subset G = (S, B)$, $\nu = 1, 2, \dots, \mu$; $\{\varphi, \psi \dots\} = \{t\gamma,\ \gamma\tau, \dots\}$.

The direct search algorithm of both the combination of the MTC elements and outer parameters of these elements can be represented as an iterative process. The determination of the optimal route in the network $G = (S, B)$ can begin with the flow discharge.

Step 0. The equivalent transformation of arc estimates (1) entering the discharge is made. For this purpose the arc estimates $\Delta_{ij}(X)$ are reduced to min $\Delta_{ij}(X)$, i.e.,

$$\Delta_{ij}(X) = \Delta_{ij}(X) - \min_{X \in \mathcal{X}} \Delta_{ij}(X), \quad i \in I,\ j \in J. \tag{2}$$

Step 1. The arrangement of arc marks is carried out, the cost coefficients being $\Delta_{ij}(X) = 0$, $i \in I$, $j \in J$. The mark contains the numbers $N(j) = i$. Marking continues till at least one of the network routes $G = (S, B)$ reaches the flow source. The source being reached, synthesizing the algorithm is stopped. When further marking ($\Delta_{ij}(X) \neq 0$) is impossible, the transfer to another algorithm step is made.

Step 2. The selection of outer parameters $\eta \in \Theta$ of the elements $S_{ij} \in G = (S, B)$ belonging to the tree Z of the shortest routes $z_1 = \{S_{tl} - S_{l\tau}\} \in Z$, $z_2 = \{S_{t\gamma} - S_{\gamma\tau}\} \in Z, \dots,$ $z_\mu = \{S_{t\gamma} - S_{\gamma g}\} \in Z$ – subvariants of the MTC structure (Fig. 1, second level). The best values of these route outer parameters are determined by the relationship of "cost" characteristics of each route interacting elements. At each route all elements having their own aims should provide optimal search decision for all tree routes Z. The determination of optimal values of flow losses $\Theta_1 = \{\eta_{tl}, \eta_{l\tau}\}$, $\Theta_2 =$

$\{\eta_{t\gamma}, \eta_{\gamma T}\}, \dots, \Theta_\mu = \{\eta_{t\gamma}, \eta_{\gamma q}\}$ of the routes $Z = \{z_1, \dots, z_\nu, \dots, z_\mu\}$ is carried out in the following way. For each element (of a subsystem) of the set $G = (S, B)$ the efficiency functions (functions of individual SDO expenses) are defined:

$$U^\alpha_{\varphi\psi}[\eta(X)] = \sum_{\varphi} \Phi^\alpha_{\varphi\psi}[\widehat{f}^\varphi_1(X), \dots, \widehat{f}^\varphi_n(X), \widehat{f}^\psi_1(X), \dots, \widehat{f}^\psi_n(X)]$$
$$- \sum_{\psi} \Phi^\beta_{\varphi\psi}[\widehat{f}^\varphi_1(X), \dots, \widehat{f}^\varphi_n(X), \widehat{f}^\psi_1(X), \dots, \widehat{f}^\psi_n(X)], \quad (3)$$

where $\Phi^\psi_{\varphi,\psi}(\cdot)$ – subjective usefulness of the SDO_α design branch (the efficiency function of the S_φ – element) denoting the effective coordination according to the assumed (normalized $\widehat{f}_i(X)$) quality indices $F_\varphi(X), F_\psi(X)$ of the MTC elements (of subsystems) at their mutual redistribution. The function for the SDO_β $\Phi^\beta_{\varphi\psi}(\cdot)$ is defined in a similar way. As each MTC element is designed by the corporations (SDO_α, SDO_β), these characteristics denote the subjective "usefulness" of the assumed decisions by individual designers.

The function (3) enables to determine the "cost" of the agreed balance according to the assumed quality indices (limited usefulness of the agreement according to the SDO) by the following relationship:

$$\frac{\partial U^\alpha_{\varphi\psi}}{\partial x^\varphi_i} \Big/ \frac{\partial U^\alpha_{\varphi\psi}}{\partial x^\psi_j} = \pi^\alpha_{ij}, \quad i, j = \overline{1, n}. \quad (4)$$

Optimal values (according to the SDO_α) of outer parameters $z_\nu \in Z$ of the MTC structure variant can be found by solving the following system of algebraic equations (non-linear in general).

$$\sum_{i=1}^{n} D''_i(\eta)\pi^\alpha_{ij} = D'_j(\eta), \quad j = \overline{1, n}, \quad (5)$$

where $D'_j(\eta) = \widehat{f}^\alpha_j(X)$, $j = \overline{1, n}$; $D''_i(\eta) = \Delta\widehat{f}^\alpha_i(X)$, $i = \overline{1, n}$. Calculated values of quality indices enable to determine outer parameters $\eta_\varphi, \eta_\psi \in \Theta_\alpha$ of the elements in calculations according to the SDO_α. Parameters $\eta_\varphi, \eta_\psi \in \Theta_\beta$ for the SDO_β are determined similarly.

The parameters determined are coordinated by the Head Design Organization (HDO) by means of the algorithm used for the determination of the Kemeni median. Optimal outer parameters of the tree Z are determined similarly. Then correlation of the element estimates (1) of the routes $z_1, z_2, \dots, z_\mu \in Z$ is performed as well as the equivalent transformation of their estimates. After that it becomes possible to mark the network top (Step 1).

Conclusion. The approach suggested enables to make the coordination of local design decisions by solving the problem of searching optimal variant of a space structural-parametric organization in the newly developed technical complex models.

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