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FLIGHT DATA ANALYSIS OF THE EXPERIMENTAL ROCKET «VOLGA»

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Cargo arrangement is a set of geometrical bodies (objects) whose attitude is fixed relative the common coordinate system and meets specified requirements. In this work, cargo arrangement process definition means presence of a shell housing onboard equipment, different containers with food, propellant, etc. The given objects are to be arranged inside the cargo compartment with minimum labor expenditures. Task solution is to meet functional purposes of the transport spacecraft in case of cargo loading and unloading.

The narrow task of cargo arrangement in cargo compartments is to house specified set of equipment, units, and containers inside the given shell. Besides, functional purpose of a compartment included in a transport spacecraft, is stipulated by some specific requirements. The narrow task is easier to formalize, algorithmization methods and digital design can be applied for the task solution. Thus, cargo arrangement task in transport spacecraft compartments is to determine cargo coordinates in the compartment, and coordinates satisfying given requirements.

As practice of spacecraft operation shows, one of the most important requirement of cargo delivery is the requirement imposed by the center-of-gravity position of cargo sets. This requirement effects on overall center-of-gravity position of the STS. In some cases, in spite of mass shortage, it is necessary to install balance weight resulting in payload loss [1].

Consequently, STS center-of-gravity problem during cargo delivery is the task of geometric object arrangement optimization. STS compartments and cargoes shapes are complex surfaces, and they are described at least by the second-order equations. Optimum search area in such tasks is described by some nonconvex high order hypersurface, it is often multiply connected. It complicates optimum search and allows to find only rational solution [2; 3].

A set of demands is made to the transport spacecraft compartments; their fulfilment depends upon cargo arrangement. In particular, providing stability and controllability of a transport spacecraft imposes some restrictions on the center-of-gravity position and the magnitude of moments of inertia of compartments. Required compartment center-of-gravity coordinates and their permissible tolerance in axes, and requirements to compartment's moments of inertia have been determined.

Taking into account cargo inertia parameter, when STS delivers cargoes, the objective function can be represented as a total work (1) under restrictions (2–7).

In the general case, equation (1) characterizes cargo-handling work during loading, and in case of reset taking into account expenditures resulted from system's movement (and consequentially, cargoes), and also taking into account cargo replacement in case of contingencies during transportation. Restrictions on center-of-gravity position are established as inequality (2). Restrictions on moments of inertia for a transport spacecraft are established as equality of moments of inertia (3) relative to axes OX and OY (in Cartesian coordinate system OXУZ). Transport spacecraft flight features impose constraints on products of inertia looking like inequality (4).

$$
\begin{cases}
Z(u)=\sum_{i=1}^{n}\frac{p_0}{p_j}\left[m_i R_i(u_i)+\sum_{j\in J_i}^{n} m_j R_j(u_j)\right]+\sum_{i=1}^{n}\frac{\partial^2 J_i}{\partial t^2}; & (1)\\
\left|F(Y_Ц - Y_C)\right|-\delta_Ц \le 0 & (2)\\
\sum_{i=1}^{n}\left[m_i(y_i^2 - z_i^2)+(J_{zi}-J_{yi})\right]=0; & (3)\\
\left|\sum_{i=1}^{n} m_i x_i y_i\right|+\left|\sum_{i=1}^{n} m_i y_i z_i\right|+\left|\sum_{i=1}^{n} m_i z_i x_i\right| \le \in_j; & (4)\\
m_k=\sum_{i=1}^{n} C_i R_i^2 m_i; & (5)\\
(u_i,u_j)-R\le 0; & (6)\\
(u_i)-R\le 0. & (7)
\end{cases}
$$

Requirements for minimum mass of non-functional purpose, for example, for mounting hardware (cantilevers, beams, etc.) can be expressed by formula (5). Relation (6) allows to express restrictions on distance between cargoes in mathematical terms. Assembly restrictions on cargo arrangement require access to cargo fixing points. In some cases, cargo state is to be controlled, and sometimes even cargo replacement is necessary. To describe these restrictions, formalist approach of common arrangement schemes can be used; for example, to tie cargo arrangement to hatches and impose the appropriate requirements for cargo arrangement in the form of inequality (7).

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