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MATHEMATICAL MODELLING 3D OSCILLATION OF LIQUID LAUNCH VEHICLE UPPER STAGE WITH CRUISE GIMBAL-MOUNTED ENGINE

Determinations of natural oscillation parameters of the launch vehicle upper stage is of important for the theoretical stability analysis of the launch vehicle upper stage relative to its elastic longitudinal and lateral oscillation. The modern launch vehicle upper stages represent the complex shell structure with the liquid and the upper stage engines have the thrust-vector control system for supporting and correcting stages motions. The thrust control is provided by liquid rocket cruise gimbal-mounted engines (LRCGME). Of practical interest is the analysis of the effect of LRCGME angular oscillation on the elastic oscillation parameters of the upper stage structure of the launch vehicle. The linear mathematical model for 3D oscillation of the launch vehicle upper stage with a sphero-conical configuration of the tank structure and with the LRCGME is developed to carry out this analysis. In developing the model the method of finite elements and means for the computer-aided design of CAE-systems are used to examine stage design features.

Based on the model developed, parameters of natural oscillation of the system of the structure of the upper stage with the LRCGME and liquid propellant in tanks are computed.

Its dominating modes due to angular oscillation of the liquid rocket engine, longitudinal and transversal oscillation of the stage structure (including longitudinal oscillation of the propellant compartment, spacecraft and liquid rocket engine) are measured.

It is shown that consideration of angular oscillation of the cruise engine can lead to a noticeable change of parameters of longitudinal oscillation of the system under consideration in the frequency range of variations in natural frequencies of the fluid oscillation in the engine feed system (30 Hz – 100 Hz).

These variations affect the selection of dominating longitudinal modes of the system, which are used for mathematical modelling longitudinal oscillation of liquid launch vehicles and the analysis of the longitudinal stability of their upper stages.

Keywords: liquid launch vehicle, upper stage, liquid rocket engine, gimbal, elastic longitudinal and transversal oscillation, angular oscillation, parameters of natural oscillation.

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