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COMPUTATION OF THE POGO SELF-OSCILLATION PARAMETERS IN THE DYNAMIC "PROPULSION – ROCKET STRUCTURE" SYSTEM BY USING A 3D STRUCTURAL MODEL

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A mathematical model describing the nonlinear dynamical interaction of a launch vehicle (LV) and its marching liquid-propellant engine in the active phase of the LV flight is developed on the basis of the finite-element discretization of the "propulsion – LV structure" self-oscillating system using three-dimensional and one-dimensional finite elements. An approach to the computation of the liquid-propellant launch vehicle self-oscillation parameters self-oscillations of the liquid launch vehicle under POGO instability is developed.

In the proposed approach, the rocket structure is considered as a complex multiply connected dissipative system "LV structure – liquid propellant in tanks" and is schematized by three-dimensional finite elements, which allows investigating the spatial vibrations of the LV structure and the liquid propellant in the tanks. Modeling of the low-frequency dynamics of the rocket engine pumps is performed on the basis of the theory of cavitation self-oscillations in pumping systems developed at the Institute of Technical Mechanics of the National Academy of Sciences of Ukraine and the State Space Agency of Ukraine (ITM of NASU and SSAU). The most significant nonlinearities in the numerical solution of the non-linear problem of liquid-propellant rocket POGO oscillations, namely, the nonlinearity of the dependence of the cavitation volume and the cavitation time constant on the pump operational parameters and the nonlinearity of the dependence of the LV structure oscillation decrements on the LV structure vibration amplitudes, were taken into account in the model of the system low-frequency dynamics.

Numerical modeling of POGO self-oscillations of a two-staged LV with a total mass of 165 tons and with a mass of 130 tons of the propellant in the first stage tanks is carried out. For the computation case of the resonant interaction of the LV structure and the liquid-propellant rocket engine (LPRE), the limiting cycle parameters of the dynamic "LPRE – LV structure" system are determined. It is shown that in the case of LV POGO self-oscillations the structural elements vibrate and the pressures and the flow rates in the liquid-propellant rocket engine oscillate at a frequency of 15.9 Hz, which is close to the natural frequency of the second mode of the structural longitudinal oscillations.

The scientific software developed may be used in the theoretical determination of the POGO self-oscillation parameters of prospective liquid-propellant rockets (including rockets whose structure has a complex spatial configuration) with respect to elastic longitudinal and transverse oscillations of the LV structure and in assessing dynamic loads on LV structures.

Keywords: *POGO instability, liquid-propellant rocket, self-oscillations, longitudinal structural vibrations, mathematical modeling, pump cavitation, low-frequency propulsion system dynamics, three-dimensional finite elements.*

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