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ASSESSMENT OF THRUST CHAMBER STABILITY MARGINS TO HIGH-FREQUENCY OSCILLATIONS BASED ON MATHEMATICAL MODELING OF COUPLED 'INJECTOR – ROCKET COMBUSTION CHAMBER' DYNAMIC SYSTEM

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High-frequency instability of a liquid-propellant rocket engine (LRE) during static firing tests is often accompanied by a significant increase in dynamic loads on the combustion chamber structure, often leading to a chamber destruction. This dynamic phenomenon can also be extremely dangerous for the dynamic strength of a liquid-propellant rocket engine. The calculation of acoustic combustion product oscillation parameters is important in the design and static firing tests of such rocket engines. The determination of the oscillation parameters (natural frequencies and stability margins such as oscillation decrement) is one of the problems solved in the LRE design period as part of the development of measures to ensure the engine stability.

The main aim of the paper is to develop a numerical approach to determining the parameters of acoustic oscillations of combustion products in liquid-propellant rocket engines combustion chambers taking into account the features of combustion space configuration and the variability of gaseous medium physical properties depending on the axial length of the chamber, acoustic impedance in critical throat and dissipation effects (damping experimental values) in the shell structure and the gas media in the chamber. The approach is based on mathematical modeling of the coupled 'chamber shell structure – gas' dynamic system by using the finite element method and the CAE (Computer Aided Engineering) system.

The developed approach testing and further analysis of the results for the RD 253 engine using nitrogen tetroxide and unsymmetrical dimethylhydrazine as a propellant pair were carried out. The dynamic system shapes and frequencies of longitudinal, tangential and radial modes are determined. The results of mathematical modeling of the dynamic system indicate a satisfactory agreement of the calculated decrements of the first longitudinal oscillation mode and third tangential oscillation mode with the experimental decrements obtained by hot-fire tests data. From system harmonic analysis of the thrust chamber, it follows that the dynamic pressure gain factor of the gas media in the chamber at the first longitudinal mode frequency is 1.6 times greater than the system dynamic gain in the tangential mode. At the same time, the oscillation decrement for the system tangential mode is 2 times smaller than that of the first longitudinal mode. This means that the thrust chamber tangential mode is more dangerous and can lead to rocket engine combustion instability.

The effect of the injector on the high-frequency stability of the combustion chamber and the possibility of partial suppression of combustion chamber thermoacoustic oscillations by adjusting the high-frequency dynamics of the injector are shown theoretically.

Key words: *liquid-propellant rocket engine, combustion chamber, high-frequency instability, oscillation frequencies, logarithmic decrements (oscillation decrements).*

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