

## State of the art in the theoretical study of the high-frequency stability of working processes in liquid-propellant rocket combustion chambers

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In the tryout of liquid-propellant rocket engines (LPREs), the parameters that govern working processes in the LPRE systems (the pressure, the flow velocity, the gas and liquid temperature, the turbopump speed, etc.) exhibit low- and high-frequency oscillations. High-frequency oscillations in a combustion chamber, which are potentially dangerous to the LPR operational reliability and integrity, are the least understood. The most important tool in the study and development of measures aimed at their elimination in the flight of liquid-propellant launch vehicles is a mathematical simulation of high-frequency processes in a combustion chamber.

This paper overviews recent publications and analyzes the state of the art in the numerical study of high-frequency dynamic processes in LPRE combustion chambers with the aim to assess the possibility of using the available numerical methods to simulate the above-mentioned processes in the problem of theoretical prediction of LPRE high-frequency stability and the combustion chamber pressure and flow rate oscillation amplitudes. Consideration is given to the currently adopted mechanisms of high-amplitude oscillations in the LPRE systems involving the dynamic interaction of physical and chemical processes in the mixing and combustion zone in conditions of periodical heat removal under the action of acoustic oscillations and turbulence in the flow and combustion of the propellant components and combustion products.

The analysis conducted shows that the methods of mathematical simulation of high-frequency acoustic oscillations in an LPRE can be divided into three basic groups: methods for the calculation of the acoustic oscillation parameters in cylindrical chambers based on analytical mathematical models of a relatively low order with the use of the Bessel functions, methods for the study of thermoacoustic phenomena using approaches of computational fluid dynamics, and hybrid methods, in which combustion dynamics is calculated separately from the combustion product acoustic oscillation parameters. The main results obtained in the framework of the above-mentioned groups are overviewed. The advantages and drawbacks of the numerical study of combustion product thermoacoustic oscillations in LPRE chambers are analyzed.

**Keywords:** *liquid-propellant rocket engine, combustion chamber, self-oscillations, high-frequency thermoacoustic instability, vibration combustion, Crocco mechanism, CFD methods of gas dynamics.*

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