UDC 621.454.2

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MATHEMATICAL SIMULATION OF DYNAMIC PROCESSES IN HYDRAULIC AND GAS PATHS AT THE START OF A LIQUID-PROPELLANT ROCKET ENGINE WITH GENERATOR GAS AFTER-BURNING

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One of the key problems in the design of liquid-propellant rocket engines (LPREs) is the assurance of a trouble-free LPRE start. LPRE bench tryout is highly expensive, and emergency situations may have grave consequences (including engine and bench equipment destruction), Because of this, one of the main tools that allow one to predict the LPRE dynamic characteristics and start-up operation features at the design and tryout stages is mathematical simulation. One of the most important and complex problems in LPRE start simulation is the description of LPRE gas–liquid volume filling, processes caused by pump cavitation, and the kinetics of propellant ignition and burn-out in the gas generator and the combustion chamber. This paper presents a modified mathematical model of cavitating pipe dynamics, which keeps its structure and operability over a wide cavitation number range and in mutual transitions between the cavitation and the cavitation-free pump operation, which is required for the numerical study of working processes in an LPRE at its start. An approach to the construction of a nonlinear mathematical model of LPRE hydraulic path filling is presented. The approach allows one, if necessary, to automatically change the scheme of partitioning the hydraulic path into finite hydraulic elements in the process of its filling at engine start. A scheme of approximate substitution of delay equations in the mathematical model of LPRE gas path dynamics is proposed. The scheme is constructed with account for the features of calculation of LPRE start transients, and it allows the simulation accuracy to be improved with the minimum of model complication. The operability of the mathematical models developed is demonstrated by the example of simulating the start of a sustainer LPRE with oxidizing generator gas after-burning. The results of this study may be used in the mathematical simulation of the start of modern LPREs.

Keywords: *liquid-propellant rocket engine, start, transient, cavitation, inducer-equipped centrifugal pump, gas generator, transfer function, frequency characteristics, lagging element.*

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Received on November 6, 2019,
in final form on November 20, 2019