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Mathematical model of the operation of a different-scale two-component low-thrust jet engine system

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The aim of this work is to modify a comprehensive mathematical model of a system of two-component low-thrust jet engines using the numerical method of characteristics in the propellant pipeline system with account for different sound speeds in the oxidizer and the fuel employing a unified method of pipeline discretization. This paper presents a unified approach to a numerical implementation of the method of characteristics for both fuel components and for regular computational cross-sections (internal for structural sections with constant geometrical and elastic parameters) and terminal cross-sections at the pipeline system inlets, the section joints, and the engine inlets for each propellant components. The approach accounts for the hydraulic resistances of the propellant injectors and electric propellant valves and the actual pressures in the engine combustion chambers. The performance of the mathematical model is illustrated by the example of the predesigning of a system of different-scale low-thrust engines to control the motion of a spacecraft relative to its center of mass in pitch, yaw, and roll and transfer the spacecraft to a new orbit (higher of lower) for maneuvering and docking with another spacecraft. The computed results show the possibility of determining the key hydraulic and gas-dynamic parameters of the system in transient conditions: the pressure and propellant component flow rate distribution at the inlet of any of the engines, the combustion chamber pressure and thrust characteristics of each engine, and the mutual effect of the engines on their thrust characteristics by the example of varying the flow areas of the propellant manifolds in the steady (continuous) and unsteady pulsed operation of all engines or some of them. The proposed mathematical model may be used in the computational justification of design parameters and operating conditions in the preparation of a draft proposal or in the predesign determination of an engine system configuration. Detailed information on the hydraulic and gas-dynamic performance parameters of an engine system is an important complement to the results of a ground tryout of both single engines and an engine system in conditions that simulate the flight environment.

Keywords: *low-thrust jet engine system, comprehensive mathematical model, numerical method of characteristics, computed results, thrust, propellant flow rate*

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