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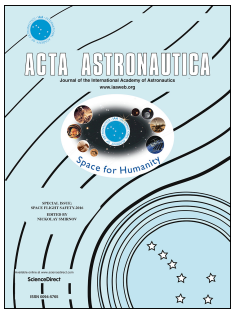

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Numerical investigations of hybrid rocket engines

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Abstract

Paper presents the results of numerical studies of hybrid rocket engines operating cycle including unsteady-state transition stage. A mathematical model is developed accounting for the peculiarities of diffusion combustion of fuel in the flow of oxidant, which is composed of oxygen-nitrogen mixture. Three dimensional unsteady-state simulations of chemically reacting gas mixture above thermochemically destructing surface are performed. The results show that the diffusion combustion brings to strongly non-uniform fuel mass regression rate in the flow direction. Diffusive deceleration of chemical reaction brings to the decrease of fuel regression rate in the longitudinal direction.

Key words: hybrid rocket, combustion, regression rate, solid fuel, supersonic

1. Introduction

In recent years the interest in hybrid rocket engines has increased and many efforts have been focused to study these engines [1-8]. The presence of a solid component makes it possible to significantly simplify the design, which makes the hybrid rocket engine one of the most promising, reliable and simple types of rocket engines. This type of engines is a combination of solid and liquid rocket ones. A hybrid rocket has fuel and oxidizer in different phases (generally solid fuel and either liquid or gaseous oxidizer).

The mathematical and numerical modeling of combustion process in solid fuel hybrid rocket engines is a specific section of physicochemical gas dynamics. The gaseous oxidant flows over the solid fuel surface, reacting with the pyrolysis gases close to the fuel-gas interface. In supersonic flows the combustion regimes are between the two basic modes: combustion and detonation. Therefore, in supersonic flows the stabilization of combustion is associated either with the detonation regimes, or with the supersonic flow braking to subsonic velocities and subsequent deflagration combustion. The stable operation of the scramjet is due to the re-initiation of the reaction in the inlet fuel mixture. This process is limited by the gasification of components and chemical kinetics.

The macrokinetics of combustion processes in engines includes not only the modeling of the chemical interactions (chains of chemical reactions), but also the processes of dispersing the condensed components, their heating and evaporation in the combustion chamber atmosphere, mixing of the fuel and oxidant as a result of diffusion and chemical reactions. In order to simulate chemical reactions, it is necessary to select the appropriate reduced mechanism, so that the accuracy of the description of chemical interactions is comparable with the accuracy of the description of other determining processes of gasification and mixture formation.

In recent years many numerical studies of the process were undertaken [3, 6, 8, 9, 11]. However, all the simulators rely heavily on the constant pyrolysis rate being the function of surface temperature thus disregarding the diffusive mixing and heat flux variation along the surface in the axial direction caused by the peculiarities of the flow inside combustion chamber. The aim of the present paper is to investigate numerically the process of combustible mixture