Influence of Shortened Nozzle Shape with a Bell-Shaped Tip on the Gas Flow Characteristics

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Abstract

Currently developers of nozzle for rocket engines are increasingly turning to unconventional configurations that differ from the classic Laval nozzle. For new rockets with strict dimensional restriction conditions (dense aircraft layouts), nozzles with a compressed contour of the supersonic part, close in configuration to the structural elements of the next rocket stage are of particular interest.

When the nozzle is shortened, wave thrust losses increase in it, which are caused by the appearance of low-intensity compression jumps and local separation zones in the nozzle. A relatively new direction in the design of supersonic nozzles is the creation of the so-called bell-shaped nozzle, which has, unlike the classic Laval nozzle, a larger entrance angle to the supersonic part of the nozzle. For Dual-Bell type nozzles with two bell-shaped sections, which are more effective in conditions of changing flight altitude, Computational Fluid Dynamics models (CFD) methods are preferred in calculations.

The paper investigated a shortened Laval nozzle with one spherical bell-shaped nozzle. The flow in the nozzle is characterized by the emergence of developed separation zones with compression jumps and significant velocity and pressure gradients. For turbulent flow modeling the equations of the turbulent model are added to the general set of equations describing the flow in the Laval nozzle. Unlike the Dual-Bell nozzle, its first section is a conical Laval nozzle, and the second section is bell-shaped. These nozzles can be used in the development of compacted aircraft layouts. At the same time, the operation advantages of this nozzle with a change in flight altitude are preserved. The influence of changing the both section lengths of the shortened nozzle with a tip, the angle of nozzle entrance, etc. on its characteristics is investigated. The calculations revealed new features of the gas flow in the nozzle, which are of not only scientific but also practical interest.