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WAVE STRUCTURE OF THE GAS FLOW IN A TRUNCATED NOZZLE WITH A LONG BELL-SHAPED TIP

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In recent years, more and more attention has been paid to nozzles with an unconventional profile, which differs from that of the classical streamline-profiled Laval nozzle. In such nozzles, the flow fields typically include interacting supersonic and subsonic flows, often with recirculation regions and a complex wave structure of the flow.

This work is concerned with a numerical study of the wave structure of the gas flow in a truncated supersonic nozzle with an elliptical bell-shaped tip whose length is long in comparison with the conical section upstream of the tip. The gas flow inside the nozzle and in the surrounding space was simulated using the ANSYS software package. The calculations were carried out in a non-stationary axisymmetric formulation based on the Reynolds-averaged Navier–Stokes equations closed with the use of the SST turbulence model with near-wall functions and a compressibility correction. In the calculations, the nozzle inlet pressure and the ambient pressure were varied. The correctness of the methodological approaches to the solution of the problem was confirmed in the authors' previous works.

The study showed the following. At low values of the nozzle inlet pressure (P_0 < 50 bar) and an ambient pressure of 1 bar, the tip wall exhibits a developed separation zone with a large-scale vortex and a small-scale one (near the tip exit). The first "barrel" of the outflowing gas shows a "saddle" low-intensity compression wave structure. In the case of a separated flow, the tip wall pressure in the separation zone is about 15% less than the ambient pressure. At P_0 > 100 bar, the tip wall pressure is nearly proportional to the nozzle inlet pressure. In the upper atmosphere, when going in a radial direction from the nozzle axis at the tip exit cross-section, the static pressure monotonically decreases, reaches a minimum, and then increases linearly to the its maximum value on the tip wall. In the case of a separated flow in the tip at a sea-level ambient pressure, the static pressure at the tip exit cross-section behaves in the same manner for inlet pressures P_0 > 50 bar. At P_0 = 50 bar, there exist two extrema: the pressure first deceases to its minimum value, then increases to its maximum value, and then decreases slightly to its value on the tip wall.

Keywords: *truncated supersonic nozzle, bell-shaped tip, static pressure distribution, nozzle thrust characteristic, ambient pressure.*

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