THE FEATURES OF SPONTANEOUS CONDENSATION OF BORON OXIDE IN PLANE AND AXISYMMETRIC NOZZLES: NUMERICAL ANALYSIS

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Abstract: A model of spontaneous condensation of boron oxide vapors in chemically reacting gas mixtures based on the classical theory of nucleation and one-speed and one-temperature approximation for the equations of a two-phase mixture movement has been developed. The model takes into account the nucleation, condensation growth of droplets, their coagulation, and gas-phase chemical reactions. A numerical study of spontaneous condensation of boron oxide vapors in plane and axisymmetric nozzles has been performed. The condensation in flat nozzles with a small degree of expansion is shown to proceed according to a typical scenario: the formation of a condensation shock wave behind the nozzle throat and the condensation growth of droplets downstream after the jump. In the flat nozzles of similar geometry with the small expansion angle, the location of the condensation shock wave does not depend on the linear dimensions of the nozzle. An important feature of spontaneous condensation in nozzles with a small expansion angle is the equilibrium of vapor and condensate in the outlet section of the nozzle. Phase equilibrium is not achieved in nozzles with a high expansion angle. The higher the expansion angle of the nozzle supersonic part, the greater the deviation from equilibrium in nozzle.

Keywords: boron oxide; condensation; nucleation; nuzzle; modeling

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Figure Captions

Figure 1 Nozzle geometry

Figure 2 Equilibrium mass fractions of condensed boron oxide (*1*) and gaseous boron oxide (*2*) in different nozzle sections

Figure 3 The change in the supersaturation degrees (*a*) and in the mass fractions (*b*) of the condensed boron oxide in a flat nozzle with $\alpha = 30^\circ$ and $H_0 = 200$ mm

Figure 4 Temperature evolution along the plane of symmetry (*a*) and the nozzle wall (*b*) in geometrically similar nozzles, $\alpha = 30^\circ$: *1* — $H_1 = 400$ mm; *2* — 800; and *3* — $H_1 = 1600$ mm

Figure 5 Change in the Mach number along the plane of symmetry (*a*) and along the nozzle wall (*b*) in geometrically similar nozzles, $\alpha = 30^\circ$: *1* — $H_1 = 400$ mm; *2* — 800; and *3* — $H_1 = 600$ mm

Figure 6 Change in the Mach number along the plane of symmetry in the nozzles with the expansion angles of 15° (*a*) and 20° (*b*)

Figure 7 Change in the supersaturation degrees of the B_2O_3 vapors in the axisymmetric nozzles with the expansion angles of the supersonic part $\alpha = 15^\circ$ (*a*) and 30° (*b*); the diameters of the inlet parts of the nozzles $D = 400$ mm

Figure 8 Change in the mass fraction of condensed boron oxide along the height of the nozzles outlet sections with $\alpha = 15^\circ$ (*1*) and 30° (*2*): (*a*) $D = 400$ mm; and (*b*) $D = 1600$ mm

Figure 9 Field of Mach numbers in an axisymmetric nozzle: $D = 400$ mm and $\alpha = 30^\circ$

Table Caption

Chemical composition of combustion products at the nozzle inlet

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