SLAGGING OF NOZZLE THROAT IN A RAMJET GAS GENERATOR

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Abstract: The paper presents the results of experimental studies of the nozzle duct slagging process inside gas generator of a rocket ramjet during the deposition of condensed combustion products (CCP) on the nozzle walls, depending on the formulation factors, pressure and temperature of combustion products, as well as design factors. It is found that CCP deposited on the walls of the nozzle cover and nozzle inlet form a viscous film which can flow over the nozzle insert surface under the gasdynamic forces. The nozzle duct slagging process is of a threshold nature depending on the combustion products temperature. At temperatures lower 1500 K, the slagging process inside gas generator virtually vanishes. At temperatures exceeding 1520 K, the slagging intensity sharply increases, attains maximum at 1600–1800 K, and then starts decreasing.

Keywords: rocket ramjet engine; gas generator; solid propellant based on aluminum dodecaboride; condensed combustion products (CCP); nozzle slagging

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Figure Captions

Figure 1 Experimental time histories of pressure in the combustion chamber of gas generator at nozzle slagging

Figure 2 Characteristic points on the experimental pressure–time histories in the combustion chamber of gas generator

Figure 3 Dependence of slagging degree $\overline{P}$ on the total aluminum content in the propellant

Figure 4 Dependence of $\overline{P}$ on pressure in the combustion chamber of gas generator for AP-based propellants with the particle size of 10–12 (*1*), 15–20 (*2*), and 25–30 μm (*3*)

Figure 5 Dependence of $\overline{P}$ on pressure in the combustion chamber of gas generator for the propellants with different AP content (*1* — 10%; *2* — 14%; and *3* — 18%) and particle size: empty signs — 65 μm; and filled signs — 160 μm

Figure 6 Nozzle insert shapes: (*a*) normal shape insert; (*b*) "flush-type nozzle" insert; and (*c*) 2 nozzles with extended nozzle throat neck. Arrows show the gas flow direction

Figure 7 Experimental pressure–time histories in the combustion chamber of gas generator during tests with normal shape inserts (dashed curves) and "flush-type nozzle" inserts (solid curves): *1* — $P_{\max}/P_{\min} = 1.49$; *2* — 1.30; *3* — 1.47; *4* — 1.22; *5* — 1.77; *6* — 1.44; *7* — 1.74; and *8* — $P_{\max}/P_{\min} = 1.50$

Figure 8 Experimental pressure–time histories in the combustion chamber of gas generator during tests with one normal shape insert of Fig. 6*a* (solid curves) and two inserts of Fig. 6*c* (dashed curves): *1* — $P_{\max}/P_{\min} = 1.06$; *2* — 1.20; *3* — 1.57; and *4* — $P_{\max}/P_{\min} = 2.10$

Figure 9 Dependence of $\overline{P}$ on the characteristic length of combustion chamber of gas generator, number of nozzle holes, nozzle inlet angle, and nozzle cover shape: *1* — flat cover, 2 nozzles, $\alpha = 90^\circ$; *2* — flat cover, 1 nozzle, $\alpha = 45^\circ$; *3* — taper cover with point angle 90°, 1 nozzle, $\alpha = 30^\circ$; *4* — taper cover with point angle 60°, 1 nozzle, $\alpha = 30^\circ$; and *5* — taper cover with point angle 90°, 1 nozzle, $\alpha = 30^\circ$

Figure 10 "Crown" at the nozzle edge of gas generator ($\times 10$)

Figure 11 Dependence of $\overline{P}$ on the temperature of combustion products: signs — experiments; and dashed line — limit value envelope

Figure 12 Dependence of $\overline{P}$ on the coolant content in the propellant

Table Captions

Table 1 Geometric properties of nozzle inserts

Table 2 Operating parameters of gas generator

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