INFLUENCE OF HEAT EXCHANGE CONDITIONS AND CHEMICAL KINETICS ON THE FLOW STRUCTURE IN THE ONERA LAPCAT II MODEL COMBUSTOR

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Abstract: The results of the initial stage of numerical simulation of the ONERA LAPCAT II experiment on hydrogen combustion in a model high-speed combustion chamber are described. Calculations were carried out using two models of chemical kinetics. Simulation of the flow in the fire heater with the aim to obtain boundary conditions at the entrance to the combustor is described. The physical analysis of the flow structure obtained in the calculations of the model chamber, is provided. The effect of heat transfer on the duct walls is investigated. The results of the calculations are compared with the experimental and calculated data from ONERA. Satisfactory agreement between the calculated results of TsAGI and ONERA is obtained; however, both differ considerably from the experiment. Various reasons of this descrepancy will be examined by further calculations in TsAGI.

Keywords: supersonic combustion; heat transfer; kinetic scheme; numerical simulation; experimental validation

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Figure Captions

Figure 1 Duct geometry and block structure of the computational mesh for calculations of the heater and Laval nozzle (*a*) and of the combustion chamber (*b*): arrows — fuel supply; grey color — cross section of the Laval nozzle connection with the combustion chamber ($x = 0.065$ m); *1* — heater; *2* — Laval nozzle; *3* — buffer section of constant cross section with velocity no-slip walls; *4* — expanding buffer section with velocity slip walls; *5* — section of constant cross section; *6* — section with 2 degree expansion; *7* — section with 6 degree expansion; *8* — section with 2 degree expansion; and *9* — expanding buffer section with velocity slip walls. Half of the duct is shown (to the right of the longitudinal vertical plane of symmetry)

Figure 2 Calculated flowfields in the heater: field and isolines of the stagnation temperature (*a*); and field and isolines of the OH mass fraction in the calculation with 7 reactions (*b*) and with 19 reactions (*c*)

Figure 3 Longitudinal distributions of the OH mass fraction in the calculations of the heater: *1* — 7 reactions, duct symmetry axis; *2* — 19 reactions, duct symmetry axis; *3* — 7 reactions, heater wall; and *4* — 19 reactions, heater wall

Figure 4 Field and isolines of temperature at the combustion chamber compartment $0.18 \le x \le 0.58$ m: (*a*) 7 reactions, heat-insulated walls; (*b*) 7 reactions, $T_w = 716$ K; and (*c*) 19 reactions, $T_w = 716$ K. The lower wall of the chamber, the longitudinal horizontal plane of symmetry, and cross sections $x = 0.24$, 0.29, 0.34, 0.39, 0.44, 0.49, and 0.54 m are shown. Black color shows isosurfaces with the mass fraction of H_2 is 0.028

Figure 5 Fields and isolines of Mach number at the combustion chamber compartment $0.18 \le x \le 0.58$ m: (*a*) 7 reactions, heat-insulated walls; (*b*) 7 reactions, $T_w = 716$ K; and (*c*) 19 reactions, $T_w = 716$ K. The lower wall of the chamber, the longitudinal horizontal plane of symmetry, and cross sections $x = 0.24$, 0.29, 0.34, 0.39, 0.44, 0.49, and 0.54 m are shown. Black color shows isosurfaces with the mass fraction of H_2 is 0.028

Figure 6 Static pressure distribution along the duct upper wall: (*a*) influence of heat exchange conditions on the walls of the duct, (*b*) influence of the kinetic scheme; *1* — ONERA experiment, without fuel supply; *2* — ONERA experiment, with fuel supply; *3*–*6* — TSAGI calculations (*3* — 7 reactions, heat-insulated walls; *4* — 7 reactions, $T_w = 1000$ K; *5* — 7 reactions, $T_w = 716$ K; and *6* — 19 reactions, $T_w = 716$ K); and *7* — ONERA calculation, 19 reactions, $T_w = 716$ K

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