SIMULATION OF COMBUSTION OF HIGH-SPEED TRANSVERSE HYDROGEN JETS IN A RECTANGULAR DUCT USING THE IDDES APPROACH*

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Abstract: The results of the third stage of numerical simulation of the ONERA LAPCAT II experiment on high-speed hydrogen combustion in a model duct are described. At this stage, the calculations are carried out taking into account the duct wall roughness and the presence of glass on the side walls. A synthetic turbulence generator is also added at the duct entrance and the initial field is obtained in a preliminary RANS (Reynolds-averaged Navier–Stokes) simulation using the nonlinear shear stress transport (SST-NL) model causing the emergence of secondary flows in channel corners. The simulation results obtained using the SST-based improved delayed detached eddy simulation (SST-IDDES) approach are presented. It is shown that the account for glasses affects the structure of separation regions but has little effect on average flow parameters and pressure distribution along the duct. The nonlinear model and the synthetic turbulence generation have a significant impact on all flow parameters.

Keywords: supersonic combustion; roughness; heat transfer; numerical simulation; secondary flows

DOI: 10.30826/CE24170403 **EDN:** QHNKXD

Figure Captions

Figure 1 Model duct of the experimental setup ONERA LAERTE

Figure 2 Streamlines and isosurface of the zero longitudinal velocity component, RANS simulations: (*a*) without taking into account glass windows; and (*b*) taking into account glass windows

Figure 3 Structure of separation zones (flow is directed from left to right): (*a*) RANS simulation using the SST model; and (*b*) RANS simulation using the SST-NL model

Figure 4 Pressure distribution along the duct: ONERA experiments (*1*) and RANS simulations using the SST (roughness height (equivalent sand grain size) $h_s = 65$ μm) (*2*) and SST-NL models: *3* — $h_s = 65$ μm; *4* — 80; and *5* — $h_s = 85$ μm

Figure 5 The field of Mach number in the plane of symmetry in the vicinity of hydrogen jet: (*a*) IDDES simulation without STG from [6]; and (*b*) IDDES simulation with STG

Figure 6 The field of Mach number in the symmetry plane at successive time instants of the IDDES simulation: (*a*) $t = 0$ ms (initial field); (*b*) $t = 0.5$ ms; (*c*) 0.96; (*d*) 2.05; (*e*) 2.88; (*f*) 4; and (*g*) $t = 4.88$ ms

Figure 7 Pressure distribution along the duct: *1* — ONERA experiments; *2* — RANS simulation using the SST-NL model (initial field, $h_s = 80$ μm); and *3* and *4* — IDDES simulations ($h_s = 65$ μm) at two consecutive points in time (*3* — 2.88 ms and *4* – 4.88 ms)

Acknowledgments

The numerical studies described in the article are supported by the Ministry of Science and High Education of the Russian Federation (agreement No. 14.G39.31.0001 dated February 13, 2017). The authors also express their sincere gratitude to V. A. Sabelnikov for repeated discussions, proposed ideas, and invaluable comments.

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*The paper is based on the work that was presented at the 11th International Symposium on Nonequilibrium Processes, Plasma, Combustion, and Atmospheric Phenomena (NEPCAP), October 7–11, 2024, Sochi, Russia.

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Received July 15, 2024

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