OPTICAL CHARACTERIZATION OF ATOMIZATION AND COMBUSTION OF LIQUID FUEL BEHIND THE FLAME TUBE HEAD OF A MODEL COMBUSTION CHAMBER FOR A GAS TURBINE ENGINE

O. G. Chelebyan[1], A. Yu. Vasiliev[1], A. A. Sviridenkov[1], A. A. Loginova[1], V. D. Kobtsev[1], D. N. Kozlov[1,2], S. A. Kostritsa[1], V. V. Smirnov[1,2], and V. I. Fabelinsky[2]

[1]P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation

[2]A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 38 Vavilov Str., Moscow 119991, Russian Federation

Abstract: At a test rig for investigation of the processes of a liquid fuel atomization and mixing with air by flame tube heads of model combustion chambers and of combustion in the flow of fuel–air mixture, certain characteristics of kerosene spray and of the kerosene–air mixture combustion have been determined employing optical diagnostic techniques. A model combustion chamber installed at the rig was a single-burner sector with a pneumatic atomizer in the flame tube head. By using the particle shadow velocimetry technique, spatial distributions of average droplet dimensions, axial velocities, and volume flux densities have been measured in the flow axial section, which prove the efficiency of the test atomizer in formation of finely dispersed kerosene–air mixture flow with a stable structure enabling a steady combustion process. Employing coherent anti-Stokes Raman scattering during combustion of the mixture, gas temperature distributions have been measured in the flame section and the possibilities have been demonstrated to define, in a certain point of the flow, both statistical characteristics of "instantaneous" temperature fluctuations and relatively slow variations of temperature mean values during the combustion process. The optical techniques employed in this study provide complementary data characterizing operation of combustion chambers. These data can be used for verification of numerical models both of liquid fuel atomization and evaporation in a flow, which accompany fuel–air mixture formation, and of combustion process of the mixture and its optimization.

Keywords: combustion; gas turbine engine combustion chamber; liquid fuel atomization; flame tube head; pneumatic atomizer module; optical diagnostics; laser diagnostics; particle shadow velocimetry; fuel droplet diameter measurements; coherent anti-Stokes light scattering; nonintrusive flame thermometry

DOI: 10.30826/CE20130108

Figure Captions

Figure 1 Schematic of a particle shadow velocimetry system

Figure 2 Diagram of the coherent anti-Stokes scattering process employing Raman-resonant transitions between the rotational levels of the ground ($v = 0$) and the excited ($v = 1$) vibrational states of N_2 molecules in the flame at broadband Stokes optical pumping

Figure 3 Schematic of the CARS spectrometer

Figure 4 Transverse distributions of Sauter diameter D_{32} of the atomized kerosene droplets (*a*) and of their average axial velocity U (*b*) in the axial cross section of the mixture flow: *1* — $\alpha = 0.9$; *2* — 1.0; and *3* — $\alpha = 1.5$. The connecting lines are drawn for better perception

Figure 5 A photograph of the flame at the exit of the flame tube ($\alpha \approx 1.3$)

Figure 6 Experimental (*1*) and calculated (*2*) rovibrational CARS-spectra of N_2 molecules and their difference (*3*); $T = 1685$ K

Figure 7 Experimentally-defined (from CARS-spectra) gas temperature distributions about 1 mm away from the edge of the flame tube in the axial cross section of the flow at different air-to-fuel equivalence ratios α: *1* — 0.9; *2* — 1.0; and *3* — 1.5. The connecting lines are drawn for better perception

Figure 8 Temporal variation of temperatures in a particular spatial point at the flow axis ~ 1 mm away from the edge of the flame tube at $\alpha = 1$; $T_{tc} = 1448$ K

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Received December 11, 2019

Contributors

Chelebyan Oganes G. (b. 1988) — Candidate of Science in technology, head of a sector, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; ogchelebyan@ciam.ru

Vasiliev Alexander Yu. (b. 1977) — Candidate of Science in technology, department deputy director, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; ayvasilev@ciam.ru

Sviridenkov Alexander A. (b. 1942) — senior researcher, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; aasviridenkov@ciam.ru

Loginova Anna A. (b. 1993) — engineer, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; aaloginova@ciam.ru

Kobtsev Vitaly D. (b. 1989) — junior researcher, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; vdk@ciam.ru

Kozlov Dmitry N. (b. 1954) — Candidate of Science in physics and mathematics, senior researcher, A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 38 Vavilov Str., Moscow 119991, Russian Federation; dnk@kapella.gpi.ru

Kostritsa Sergey A. (b. 1956) — acting head of sector, P. I. Baranov Central Institute of Aviation Motors, 2 Aviamotornaya Str., Moscow 111116 Russian Federation; sakostritsa@ciam.ru

Smirnov Valery V. (b. 1944) — Doctor of Science in physics and mathematics, professor, head of department, A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 38 Vavilov Str., Moscow 119991, Russian Federation; vvs@kapella.gpi.ru

Fabelinsky Victor I. (b. 1953) — Candidate of Science in physics and mathematics, senior research scientist, A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, 38 Vavilov Str., Moscow 119991, Russian Federation; vif@kapella.gpi.ru