KEROSENE-FUELED TURBOJET AFTERBURNER OPERATING ON DETONATIVE COMBUSTION

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The objective of the work summarized in this paper is to develop, fabricate, and test the continuous-detonation afterburner (CDA) for the commercially available small-size TJ100S-125 turbojet engine [1]. The TJ100 turbojet engine is equipped with a single-stage centrifugal compressor and axial turbine, operates on the standard aviation kerosene TS-1 (Russian analog of Jet-A), and possesses the maximum thrust of about 1250 N. To keep the gas temperature ahead of the turbine at a sufficiently low level ($\sim$1200 °C at most), the overall air-to-fuel equivalence ratio in the turbojet is quite high (attains the value of 4.0 to 6.0), i. e., a large amount of hot compressed air expels to the atmosphere together with combustion products. The motivation of our research is to explore the possibility of afterburning this air in the mixture with additionally injected kerosene by mounting the CDA downstream from the turbojet turbine.

The CDA is designed based on multivariant parametric three-dimensional numerical simulations fulfilled at the ICP using the computational technology reported elsewhere [2] and is fabricated at the ICP. The influence of the CDA on turbojet operation due to back-

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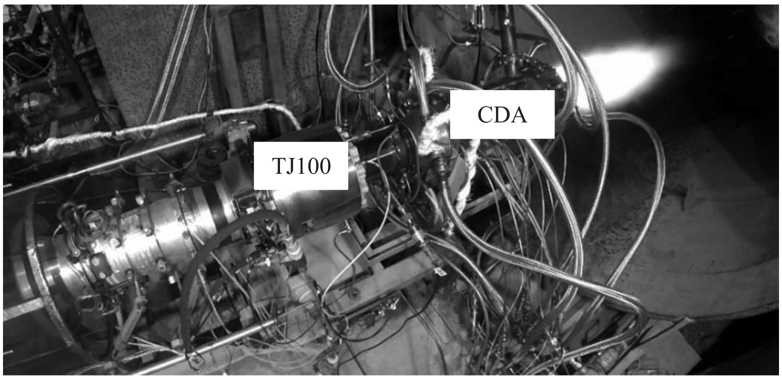

Figure 1 Test rig with TJ100–CDA assembly during firing

pressure rise is minimized using the choking throat at the CDA inlet with the cross-section area equal to that of the standard turbojet nozzle. The CDA is a kerosene-fueled annular axisymmetric combustor 200 mm in the outer diameter and 800 mm long equipped with an exhaust nozzle. Kerosene is injected to the CDA through 240 radial holes 0.15 mm in diameter evenly distributed at the outer and inner walls of the annulus at a distance of 10 mm downstream from the CDA inlet throat. Exhaust converging nozzles 100, 120, 140, and 150 mm in the exit diameter are used. For the optional compensation of the air oxygen depleted in the turbojet combustor, the CDA is equipped with the oxygen supply system allowing the increase of the oxygen mass fraction at the CDA inlet to a level of 23%. The inner and outer walls as well as the supporting pylons and the exhaust nozzle of the CDA are water cooled. The TJ100S-125–CDA assembly is installed at the thrust measuring table and is fired in different operation modes of the turbojet. The maximum duration of test fires with the activated CDA is 10 s. The data acquisition system includes thermocouples, low- and high-frequency pressure gauges, ionization probes, load cell, mass-flow meters, video cameras, microphones, etc. Figure 1 shows the photograph of the assembly in operation.

In the test fires, three modes of CDA operation are registered: continuous spinning detonation (CSD), longitudinally pulsating detonation (LPD), and constant pressure combustion (CPC). The charac-

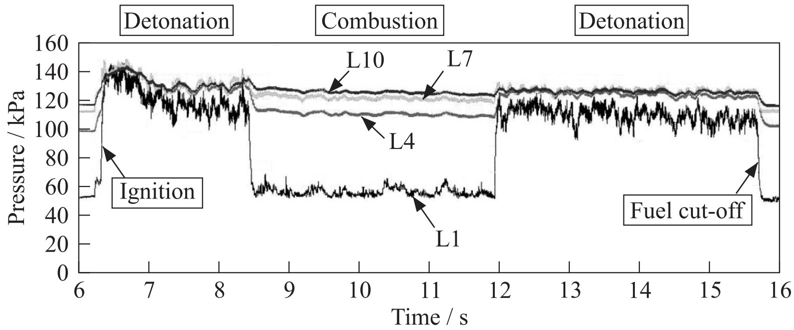

Figure 2 Static pressure records in the CDA during one of the test fires with CSD–CPC–CSD mode transition

teristic frequencies of the LPD and CSD operation modes vary around 0.2–0.4 and 1.0–1.5 kHz, respectively. The mean heat fluxes to the CDA walls estimated based on the measurements of the cooling water temperature are ∼0.50 and 0.86 MW/m^2 for the LPD and CSD operation modes, respectively. During the operation of the TJ100–CDA assembly, the overall air-to-fuel equivalence ratio tended to 0.6–1.8.

Considerable improvement of the CDA thrust performance as compared to that of a conventional deflagration-based afterburner is registered. This improvement is explained by a significant increase in the mean static pressure in the flow region occupied by the rotating or pulsating detonation. As an example, Fig. 2 shows the static pressure records in the CDA during one of the test fires, in which a temporal LPD–CPC–LPD transition is registered. The pressure sensors are located at distances 50 (L1), 170 (L4), 290 (L7), and 410 mm (L10) downstream from the CDA inlet throat. It is seen that in the near-limit LPD mode, the main pressure rise is detected by sensors L1 and L4, whereas sensors L7 and L10 show insignificant pressure variation during LPD–CPC and CPC–LPD transitions. The excessive pressure detected by sensors L1 and L4 creates an additional force on the CDA internal surfaces and significantly increases the total TJ100–CDA assembly thrust. The fact that the static pressure at the end of the CDA (sensor L10) is nearly the same for both LPD and CPC modes indicates that the combustion completeness in both modes is nearly the same.

The measured excessive thrust created by the CDA and the measured values of fuel and air mass flow rates allow estimating the values of the specific fuel consumption, specific thrust, and thrust boosting coefficient for the CDA and comparing these values with those estimated for the conventional large-scale turbojet afterburners with the same in-chamber pressure level. As compared to a conventional turbojet afterburner, the specific fuel consumption in the CDA is lower by about 30%, while the specific thrust and the thrust boosting coefficient are higher by at least 30%. These numbers indicate a great potential of the CDA for perspective air-breathing propulsion.

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