Liquid-Fueled Air-Breathing PDE Demonstrator

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In 1940 Zel'dovich has shown that detonative combustion is thermodynamically more efficient than constant-volume and constant-pressure combustion [1]. Two principle schemes of practical implementation of detonation cycle are possible. One applies a concept of fuel combustion in a stabilized detonation front. The other applies a concept of fuel combustion in repeatedly generated detonation waves traversing the combustion chamber [2]. The thermal efficiency of the ramjet cycle with such a repeated (pulse) process depends on the frequency of generation of detonation waves. The device implementing this cycle and referred to as a Pulse Detonation Engine (PDE) is the focus of this paper.

A lab-scale liquid-fueled air-breathing PDE demonstrator has been developed and tested using liquid *n*-hexane or *n*-heptane as fuel. The PDE comprises two combustion chambers: predetonator and main combustor. The predetonator is aimed at pulse detonation initiation in the heterogeneous fuel–air mixture and at transitioning the detonation to the main combustor (see Fig. 1). The predetonator is a tube equipped with the air-assist liquid-fuel atomizer, two electric dischargers, Shchelkin spiral, and tube coil. The atomizer provides entire flow rate through the predetonator. The first discharger repeatedly ignites the mixture in a continuous two-phase flow. Shchelkin spiral is used to accelerate the arising flame and generate a primary shock wave propagating at a velocity of about 900-1000 m/s. Tube coil is a new element, never used before for enhancing deflagration-to-detonation transition. Its compressive and expansive surfaces facilitate cumulating of flame-generated compression waves with the primary shock wave to virtually form a strong reactive shock or a detonation wave at the coil exit. The coil proved to be very efficient at low ignition energies. The second discharger is mounted at the exit of the tube coil and is activated in phase with the blast wave arrival at its position. Actually, the second discharger is used to ensure reliable detonation formation. The minimal attained rated energy of detonation initiation in the PDE was about 30 J at the discharge efficiency of about 20%.

The centrifugal air compressor and a standard automobile fuel injector provide the continuous two-phase flow in the main tube. To start the PDE in the multipulse detonation mode, the main tube is first operated on a continuous deflagration for a short time. The predetonator is activated after the tube wall attains the nominal temperature. Multipulse operation of the setup in the detonation mode was successfully demonstrated at the total fuel–air ratio close to stoichiometric. Thrust measurements have been performed using a pendulum technique. The maximum thrust measured was 30 N at a frequency of 4 Hz.

References

1. Zel'dovich Ya. B. J. Techn. Phys. 1940; 10(17): 1455-1461.
2. Roy G. D., Frolov S. M., Borisov A. A., Netzer D. W. Progr. Energy Comb. Sci. 2004; 30 (6): 545-672.

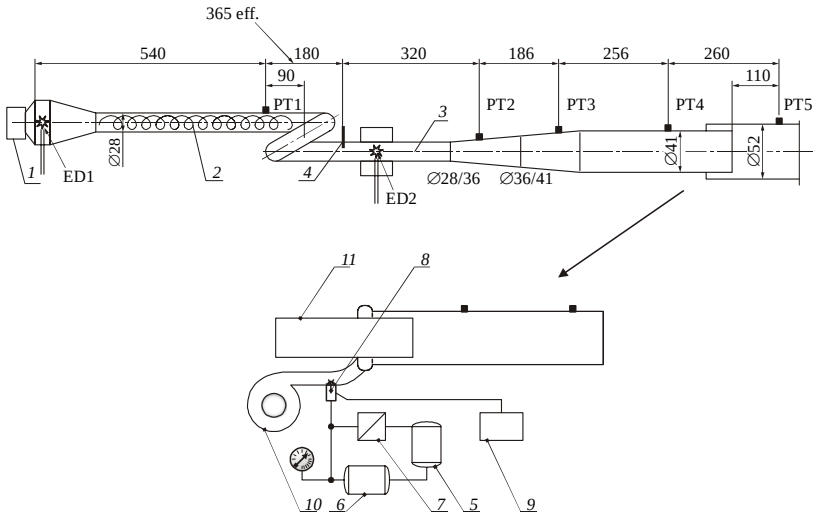

Fig. 1: Schematic of liquid-fueled air-breathing PDE demonstrator. 1 – air-assist atomizer, 2 – Shchelkin spiral, 3 – predetonator tube, 4 – discharge activation probe, 5 – fuel tank of main combustor, 6 – fuel pump of main combustor, 7 – fuel valve, 8 – fuel injector, 9 – fuel pulse modulator, 10 – centrifugal compressor, 11 - predetonator