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TURBINE ENGINE WITH DETONATION COMBUSTION CHAMBER IN INSTITUTE OF AVIATION

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Abstract

In Institute of Aviation from 2010 is realized a project POIG 2007-2014 "Turbine engine with detonation chamber." The main target is to develop a turbine engine using a rotating detonation effect in the process of combustion the fuel. This article presents the most important stages leading to achieve the goals. As a facility test, we have chosen a turbo shaft engine GTD-350 characterized by the location of combustion chamber, which is outside the engine. This feature has helped in modernization the combustion chamber to adjust it to the detonation combustion. Works over the project has been started from the attempts to obtain a rotating detonation in the combustion chamber with a diameter of 500 mm powered by hydrogen. These researches have allowed the team to master the method of detonation initiation and methods for identifying the process of spinning detonation. In the same time works over the kerosene injection on the visualization bench has been begun. On this bench, we have mainly evaluated the extent and location of the fuel stream and the quality of the spray. Simultaneously the program to simulate the injection and the process of spinning detonation in actual geometries of different combustion chambers has been created. The process of initiation the detonation is discussed in the article on the example of detonator using ammo tutorial. Researches about combustion detonation with simultaneously reinforcement the combustion chamber with hydrogen and liquid fuel JET-A1 has also been discussed in this article. Presented research results includes pressure fuel waveforms in supply manifold along with the measurements of combustion pressure correlated with Air-Fuel Equivalence Ratio – lambda. Currently we are working over the integration of the combustion chamber of the engine GTD-350.

Keywords: *turbine engine, rotating detonation, combustion*

1. Introduction

In 2010 during the realization the project POIG „ Turbine engine with detonation chamber" we have started researches over the phenomenon of rotation detonation. The main target of this project is to build and examine the technology demonstrator engine based on GTD-350. In the GTD-350 engine, combustion chamber is outside the system compressor – turbine, that is why the modifications of the chamber is much easier and we don't have to influence on the elements of the turbine.

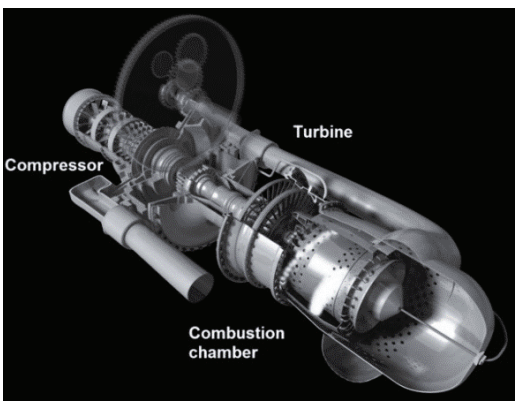

Fig. 1. Cross-section of the GTD-350 engine

Detonation combustion history dates back to the late nineteenth century, when works has been begun on the type of combustion:

- Works of Berthelot, Vieille, Marlland, Le Chatelier (1881).
- Chapman and Jouget theory of detonation.
- Pulse Detonation Engine made at the University of Michigan (J. A. Nicholls).
- First Continuously rotating detonation (Academy of Sciences in Novosibirsk).
- Patent on Rotation Detonation Engine (Tobita, Fujiwara, Wolański) issued in 2005.
- Work on Rotating Detonation in Warsaw University of Technology [1-3].
- 2010 Project POIG "Turbine engine with detonation combustion chamber," Institute of Aviation.

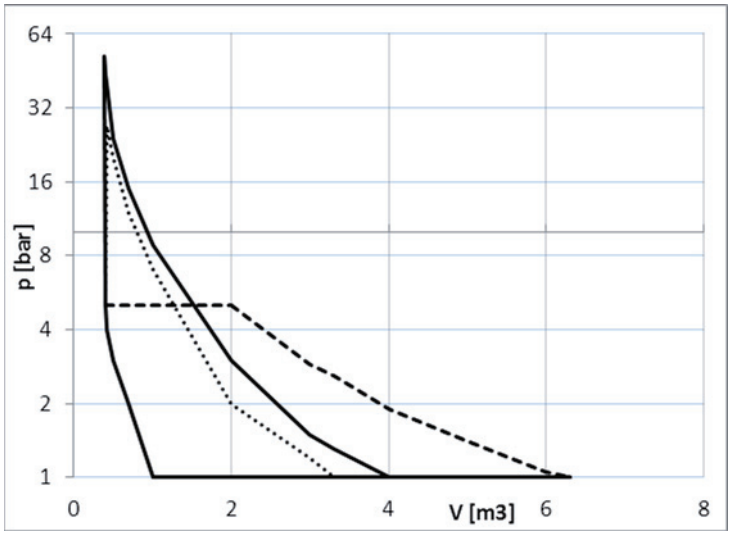

Fig. 2. Comparison of different ideal thermodynamic cycle: ---- isobaric (Brayton), ····· isochoric (Humphrey), ——— detonation (Fickett-Jacobs)

Applying a detonation combustion effect should increase efficiency by about 15%.

Diagram of the process of spinning in a circularly symmetric detonation chamber is shown in Fig. 3.

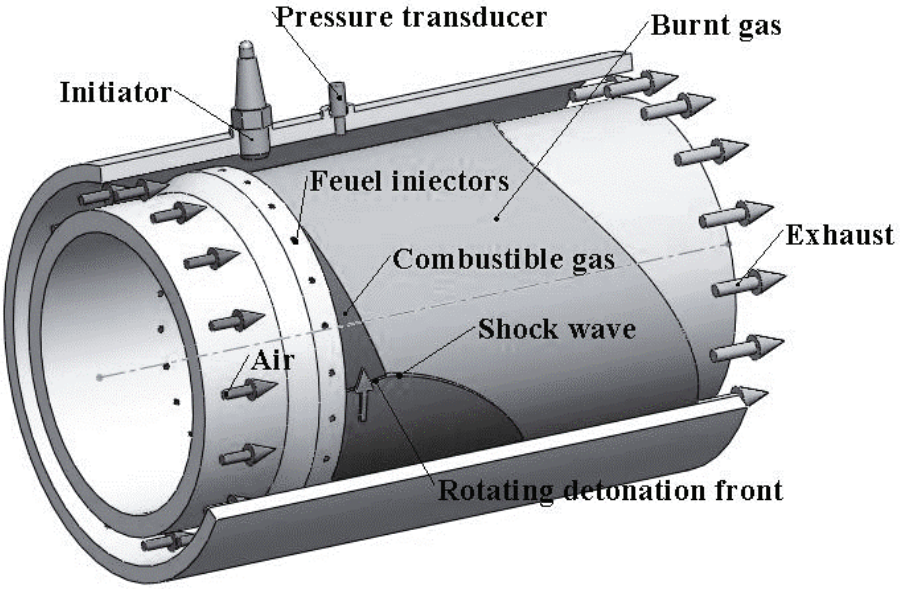

Fig. 3. Scheme of detonation combustion chamber

The air of critical parameters enters the chamber through a narrow gap where it mixes with the injected fuel by a number of injectors arranged symmetrically on the circumference of the chamber. The initiator is used to induce the detonation combustion. The necessary condition for the continuity of the rotating detonation is providing to the combustion chamber a new "batch" of detonative mix after the detonative wave front passes around the circumference of the combustion chamber. The pressure sensor installed on the chamber wall registers each crossing of the front of wave. The speed of the combustion flame for a deflagration is several tens of meters per second and for the detonation combustion is about 1500-1800 m/s. Determination of rotating speed of detonation wave; let us identify the combustion process.

2. Research results

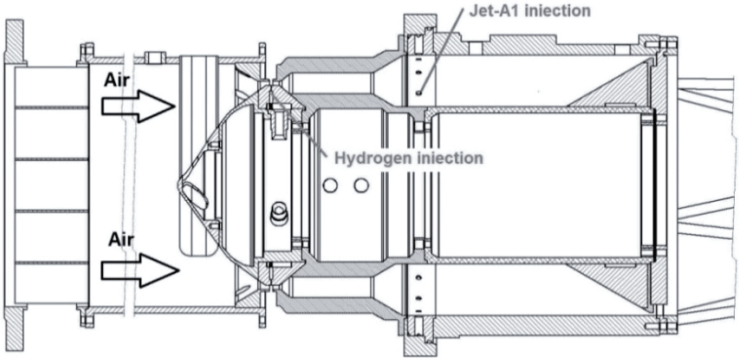

Fig. 4. Cross-section through the sample test chamber

The figure below shows us a research results, which were realized with supplying a combustion chamber with hydrogen ($Massflow_{air}$=0.5 kg/s, lambda = 1.15 using gas expansion to atmospheric pressure).

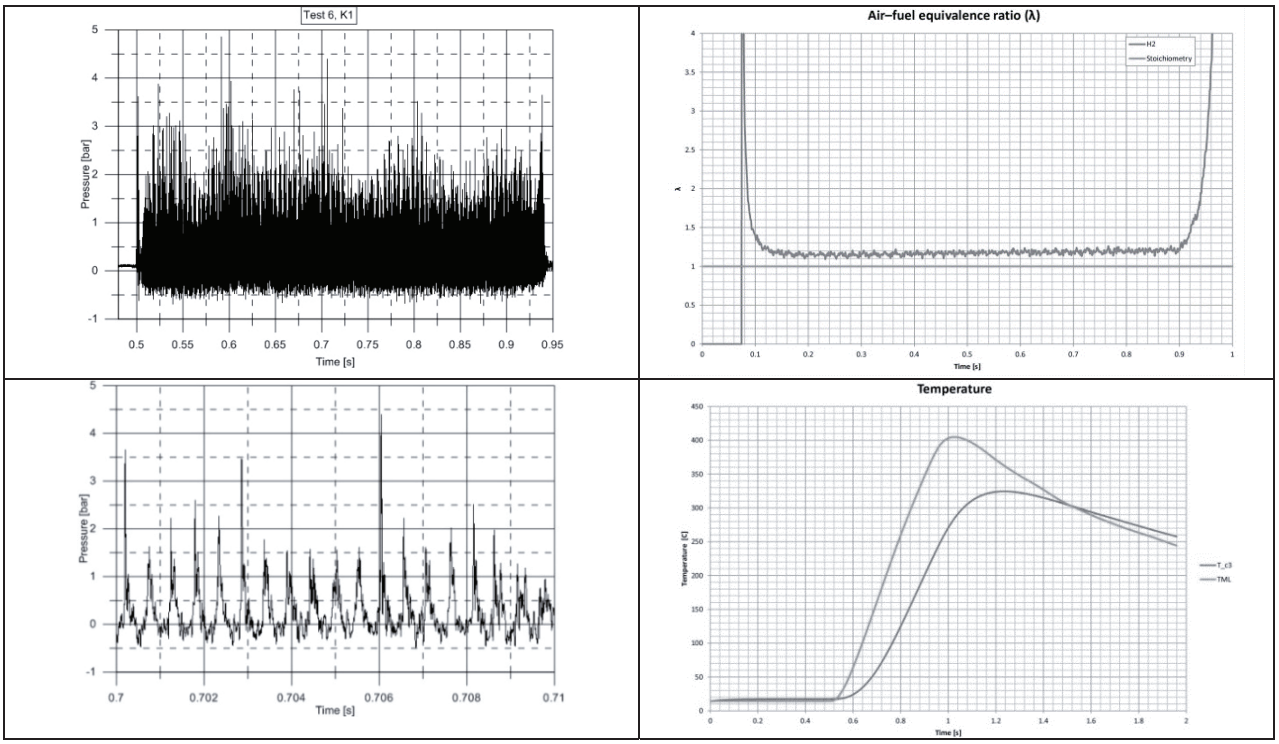

Fig. 5. Course of pressure and temperature of the gasses in detonation chamber (TML – temp. inside chamber, T_c3 temp. outside the chamber)

In the first phase of researches as the initiator of the process were used ammo tutorial. In subsequent researches were used gas and electric detonators using the spark plug engine jet F-15.

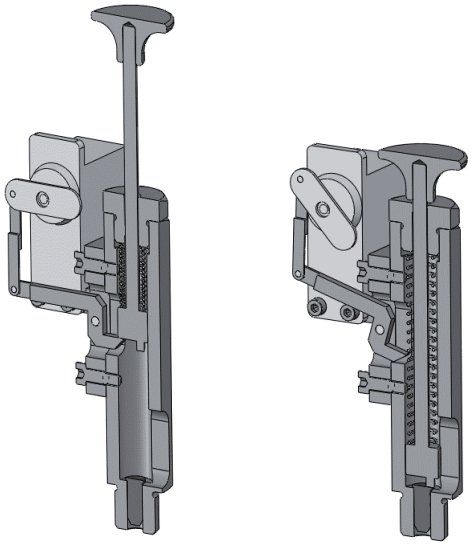

Fig. 6. Cross-section of a detonator using ammo tutorial

In parallel with the rotating detonation researches on hydrogen, work over the fuel injection JET-A1 was started. For this purpose were built a bench to visualize the injection of liquid fuel into the throat in a flow of warm air.

Fig. 7. Visualization kerosene injection into the combustion chamber (Vair=100 m/s)

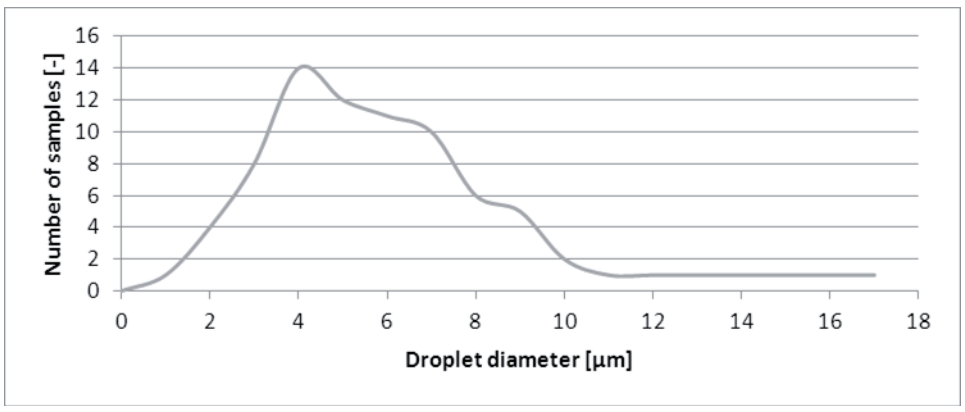

Fig. 8. The size distribution of droplets in the kerosene injection (height of channel 20 mm – inject. pinhole ϕ – 0.5 mm

Researches aimed to compare the quality of fuel atomization and designate the places in the combustion chamber of a rich composition of the mixture. For those purpose was also used software REFLOPS-2 and FLUENT.

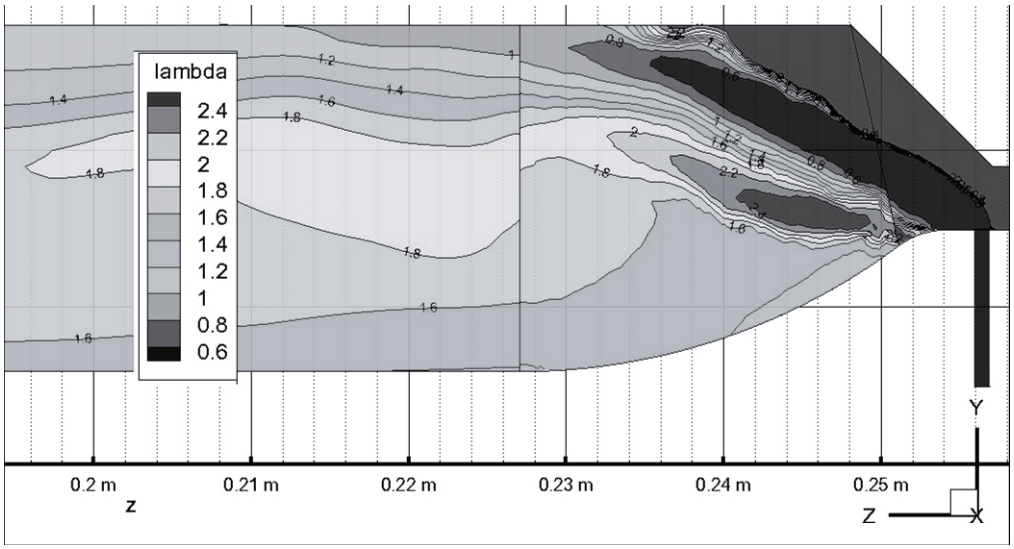

Fig. 9. The distribution λ coefficient with injection of hydrogen into the combustion chamber

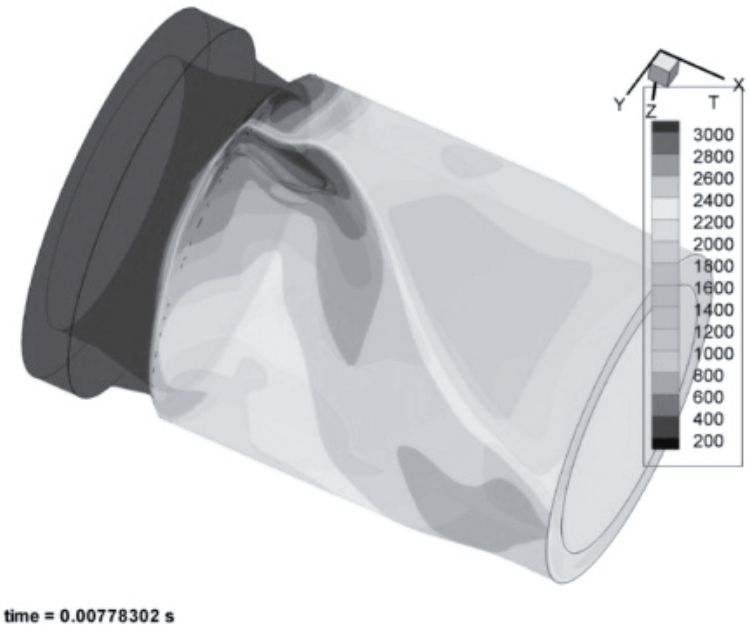

Fig. 10. The simulation of the temperature distribution in the combustion chamber during the rotating detonation

Studies of the combustion chambers are realized on the bench with parameters:

- airflow 2.5 kg/s,
- temperature up to 200°C,
- supplying with hydrogen and kerosene up to 6 MPa.

We have tested several variants of the combustion chamber (various shapes of the chamber) to find a solution for stable detonation flow parameters occurring in motor GTD-350. We were set different values of lambda (air fuel ratio) fuel mixture for different values of flow rate and backpressure for the chamber, simulating the conditions of the compressor and turbine engine GTD-350. Below are shown the research results with supplying chamber with kerosene with an additional injection of hydrogen.

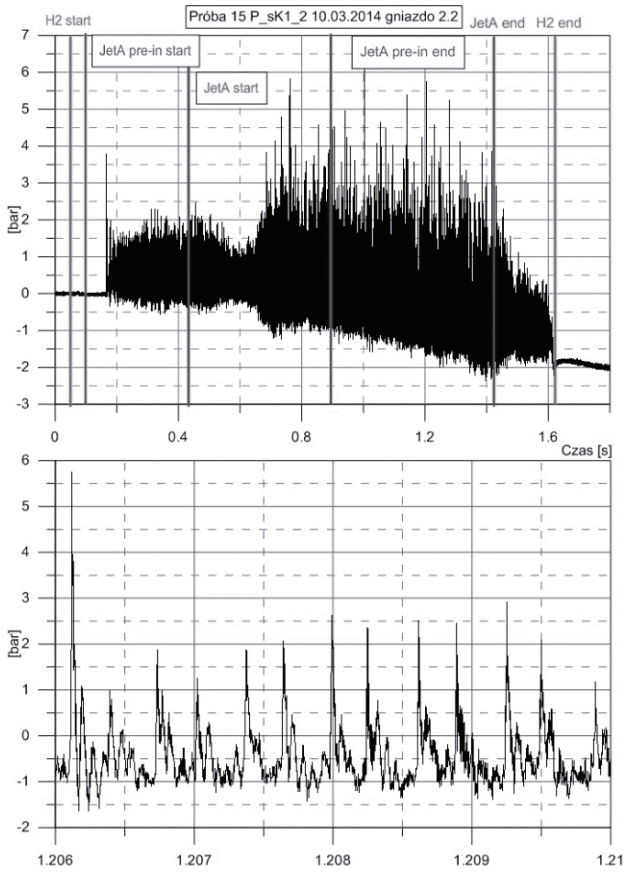

Fig. 11. Course of the pressure in the combustion chamber during the supplying by hydrogen and kerosene

The illustrated graph shows a significant amplitude increase of the pressure after the addition of kerosene. The spinning detonation occurred only in the presence of hydrogen.

3. Summary

- In the article are shown the main aspects of the project "A turbine engine of the detonation chamber".
- A rotating detonation phenomenon were discussed and a method for its identification.
- Were presented examples of computer simulation of the injection and the course of the detonation.
- On selected examples we have shown research results.
- As a result of the work were achieved an effect of spinning detonation in the combustion chamber matched to GTD-350.
- Were started testing engine GTD-350 equipped with a detonation combustion chamber to get 4 seconds of engine working.

References

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