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Perspective

Advancements in Rotating Detonation Engine Technology: A Perspective

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ABSTRACT

This is a short survey of research conducted in Poland on development of the Rotating Detonation Engines (RDE). Basic research was conducted at the Institute of Heat Engineering of the Warsaw University of Technology (WUT) and then applied research at the Institute of Aviation (IoA) (since 2019 part of Lukasiewiewicz Network). The studies were also carried out in cooperation with international partners and led to develop many laboratory scale RDE and first World's rocket powered by RDE.

Keywords: Detonation; Continuously Rotating Detonation (CRD, RDE); Propulsion; Engine

ABOUT THE STUDY

Basic research

Polish research on CRD started at the WUT at the beginning of the 21st century. Initial studies were focused on understanding of the structure of the CRD. This research as well as the cooperation with Japan led to prepare patent on RDE [1] and unveil the 2D structure [2]. It was shown, that despite CRD wave is rotating, and the flow in the annular channel is basically axisymmetric with a small component of the rotating velocity, so there is only a small loss of thrust due to this component. Cooperation with the Institute of High Performance Computing (IHPC) Singapore resulted in presenting first 3D structure flow in the annular channel and RDE thrust calculation [3]. Those results and the experimental data were presented by Professor Wolanski at the P&W headquarters at East Hartford (2008) and to the P&W Rocketdyne at West Pam Beach. The research helped to explain not only in performance, but also stability of RDE. The conditions necessary to get stabile detonation were proposed and criteria for such stability were evaluated [4]. It is based on comparison of time necessary to supply sufficient amount of mixture to detonative chamber with the time of detonation wave rotation. This set of criteria well describes condition of the detonation wave stability and was later called "Wolanski wave stability criterion" [5]. Most of research on RDE results can be found in survey paper on RDE [6].

Applied research

2010 IoA research was devoted to studies on the gas turbine with detonative combustion chamber. Such engine was tested on Jet-A, with additions of gaseous hydrogen and on gaseous hydrogen-air mixture only [7]. The engine operating on gaseous hydrogen demonstrated 5%-7% higher thermal efficiency. Detailed description of this research has been provided by Wolanski P et al. [7-10]. Since it was hard to keep detonation stabile for the liquid fuel-air mixture with no hydrogen addition, a special fuel preparation system, connected to the detonation chamber was designed, built and tested [8,9]. In this case a very rich evaporated fuel-air mixture was injected into detonation chamber, where it was mixed with additional air. For those arrangements stabile CRD was achieved, however in all conducted experiments in this size of the chamber only single wave was measured, which means that those detonation is close to the margin. To obtain multi-headed detonation it will be necessary to use larger diameter chamber or a higher pressure of the mixture. Additional research concerned application of the CRD to the rocket engines and a combined cycle rocket-ramjet engine was conducted at the Institute [9]. The rocket RDE for different engines geometry was built and tested using gaseous as well as storable liquid propellants, manly propane and nitrous oxide. Best performance was achieved for cone shaped RDE. Such engine, after extensive testing was used to power World's first rocket, which made the flight under its own propulsion system (Figure 1) [10,11].

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Figure 1: Successful launch of the World's first rocket powered by RDE powered by liquid propellants.

CONCLUSIONS

The most important results of RDE research in Poland are:

- Evaluation of detailed 2D and 3D structure of the CRD for gaseous mixtures.
- Development of the theory of the stabile CRD as a function of mixture composition, rate of mixture supply and geometry of the chamber.
- Calculation and measurement of thrust and specific impulse of gaseous RDE.
- Possibility to obtain controlled CRD for liquid fuels-air mixtures demonstration.
- Developed and test of rocket and combine cycle RDE operating on gaseous as well as liquid storable propellants.
- World's first rocket launch, which made flight only on RDE supply by storable propellants.

That is only a short summary of the most important research carried out for understanding of the CRD as well as on application of that process to the propulsion system. The research made during last twenty years significant progress was made on understanding of the nature of rotating detonation as well as on benefits from its' application to the propulsion system. We hope that our effort, stimulated many research in this field and will result in development of more efficient and environmental friendly propulsion system.

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