A REVIEW ON PULSE DETONATION ENGINE

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Abstract: In this present paper, the design of Pulse Detonation Engine, it's various types, it's modified version, advantages and applications are discussed. Pulse Detonation Engine works on Humphrey cycle offering a great advantage and cost effectiveness over a conventional Brayton cycle. As the name suggests, it uses detonation of fuel to produce the thrust more effectively than any conventional engines. It holds the capability of running effectively up to speed of Mach 5.The present paper gives an overview of a Pulse Detonation Engine.

Keywords: Pulse Detonation Engine, Propulsion, Deflagration, PDE, DDT

Nomenclature

PDE	Pulse Detonation Engine
DDT	deflagration-to-detonation
FAM	fuel-air mixture
UAV	Unmanned Aerial Vehicles
UCAV	Unmanned Combat Aerial Vehicle

1. INTRODUCTION

Pulse Detonation Engine technology, which is advanced propulsion technology is able to seek considerable attention over a last era. The concept of Pulse Detonation Engine is attractive for both in-atmosphere and space flight. A technology that uses detonation of fuel, so that the thrust is efficiently produced than any current engine systems. It has no moving parts and still capable to run efficiently at Mach 5. It becomes easy to imagine a situation where aircrafts are crossing oceans at higher speeds and efficiencies or even space crafts launching with higher safety factors and lower costs. As it is seen in the Fig. 1 , the fuel and oxidizer gets mixed in a detonation chamber. And other significant features can be seen in the figure itself.

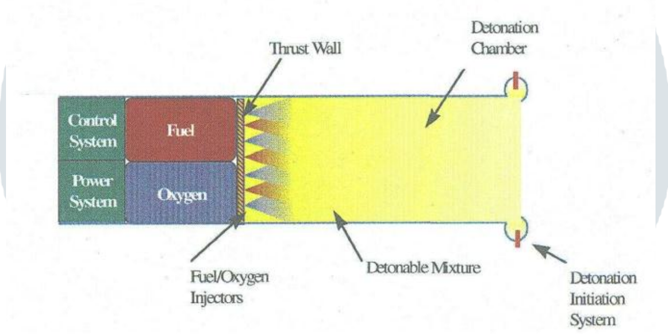

Fig. 1 : Schematics of main components of PDE[3].

It works on a Humphery cycle which is near constant volume operational cycle which provides higher thermodynamic efficiency than a conventional gas turbine cycles (Brayton Cycle). As we can see in Fig. 2 That Humphrey cycle covers larger area under the curve, which makes it more efficient as compared to Gas Turbine Engines.

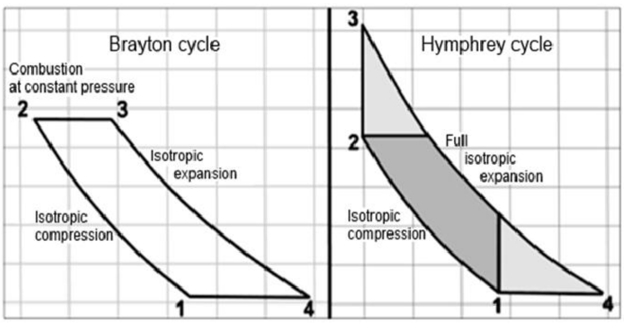

Fig. 2 : Comparison of Brayton and Humphrey cycles[12]

2. DESIGN

The mechanical simplicity adds a great benefit to the Pulse Detonation Engine. The less number of moving parts and its simplicity contributes to decrease the weight and cost as well[10].The schematic of a standard PDE can be seen in Fig. 3. The initiation system, other controls and injectors are in one compartment, also the detonation chamber and thrust wall are attached. Shmuel Eidelman[3] stated that an initiation device initiates the detonation at the open end of the detonation chamber and a planer shock develops which moves towards the thrust wall. When this wave hits the thrust wall, the thrust is produced and is continuously generated until the wave comes to the end of an engine.

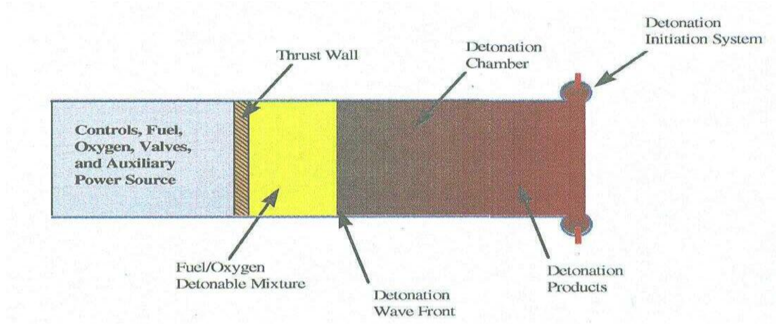

Fig. 3 : Simple geometry of PDE[3].

3. TYPES

3.1 Valved Concept

In this concept mechanical valves are used. Valves control the inward flow rate of fuel-air mixture(FAM) in to the detonation chamber, which ultimately prevents detonations from moving outwards from the chamber through the inlet. Also it provides the ample time for the proper mixing of fuel and air. In some PDE's valves also serves as thrust wall[7].

3.2 Valveless Concept

This is mechanically the simplest concept as there is a continuous flow of FAM to the detonation chamber without any involvement of valve. It simply works by an alteration between high and low pressure which occurs naturally[7].

3.3 Rotary *Concept*

This concept have a rotary valve system which includes a triangular rotor. The rotor have 3 working chambers. These chambers while moving in a circumferential direction passes through intake, compression, expansion and exhaust intervals to detonate the FAM which ultimately creates the detonation sequence[1].

3.4 Hybrid Concept

In this concept air enters pulse detonation tubes which surround the combustion chamber. The tubes are then cyclically detonated. When tube one detonates the other is filled with air. This combination promises to require simpler engine mechanisms and yield higher thrust with lower fuel consumption [10].

3.5 Multitube Concept

In this multitube concept, the operating frequency of the single pipe remains low, but by alternating pulses in different tubes the specific/desirable characteristics can be achieved. This concept also resolves the problem of vibration and the possibility of low frequency oscillations in the bottom area between the pipes[12].

4. DEFLAGRATION TO DETONATION

When the researchers faced the difficulty in starting of detonation, they came up with an idea to use deflagration-to-detonation (DDT). In this phenomenon the FAM undergoes a sudden transition from deflagration type of combustion to detonation type of combustion. For this, a device named Shchelkin spiral is used which guides the transition from deflagration to detonation. As we see in schematic of detonation tube with spiral (Fig. 4), the spiral creates a partial blockage of the tube, which shortens the distance along the detonation tube. Many different types of configurations like spiral length-to- diameter ratio and spiral blockage ratio were studied. In these studies shorter length configurations and highest blockage ratio were successful in achieving sustainable DDT[1].

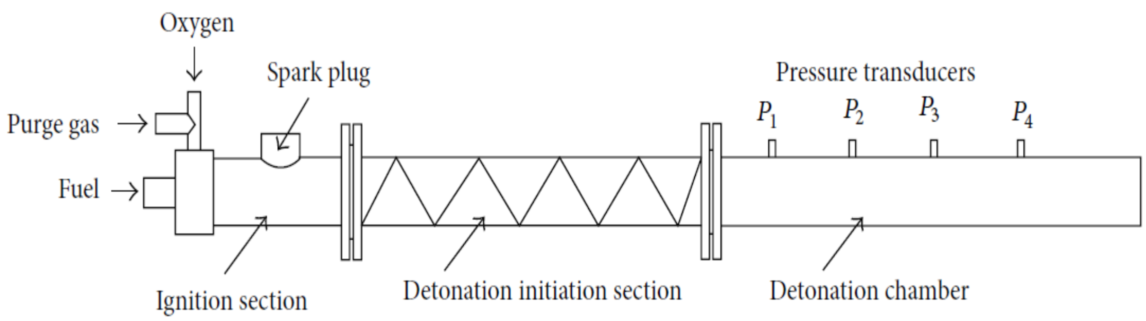

Fig. 4: Schematic of detonation tube with spiral[1].

Fig. 5: Photograph of experimental Shchelkin spiral[1].

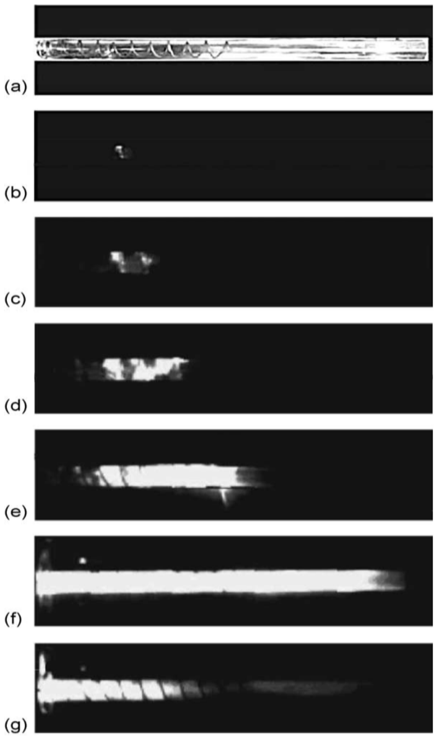

Figure 6 : High-speed digital imaging of DDT process with the Shchelkin spiral in polycarbonate tube[7].

The impact of Shchelkin spiral on DDT was studied using high speed digital imaging. As we see in Fig. 6 a transparent polycarbonate tube is used for the same. Events like formation of hotspot, micro-explosion ,DDT etc. can be observed. Pulse detonation devices using this enhanced DDT concept have been attracted much attention as they do not require energetic initiators like a predetonator[7].

As we see in Fig. 6, part (a) is a Still of polycarbonate tube with Shchelkin spiral, part (b) is when formation of hot spot starts, part (c) is when formation of multiple hot spots starts, in part (d) micro-explosion occurs, part (e) deflagration-to-detonation takes place, part (f) is of subsequent right running detonation and left running detonation, and part (g) is left running expansion wave during blow down process[7].

5. ADVANTAGES

Pulse Detonation Engine have a profound impulse, high efficiency and variable thrust. Also it can be fabricated at low cost. It offers a set of other advantages which are listed[3] below :

- Constant volume cycle increases the efficiency, thereby generating the direct thrust.
- As it has almost no moving parts, it eradicates the need of using complex turbines and compressors.
- As it operates on intermittent cycle, it offers a low thermal load.
- It offers a the convenience to independently generate every cycle and also the control over cycle frequency.
- Operational cycle is feasible for a wide range of conditions and different sizes.

6. APPLICATIONS

Despite of the fact that there are crucial uncertainties at component level which are supposed to overcome and provide a vast number of applications have been proposed by researchers [5]. Rocket-engine application have grabbed the attention over the last few decades because development of PDE have revolutionize space transportation technology, as such it provides efficient as well as low costing propulsion system. This may be used for interplanetary travel and also for earth-to-orbit launch vehicles[3]. In paper by Kailasanath[5] it is mentioned that PDEs are visualised as a low cost missiles for UAV and UCAV. Here they've paid attention on it's simplicity and it's potential to reduce the cost rather than it's high performance. The PDEs have a potential to operate over a wide range of conditions which can be exploited by human beings.

7. CONCLUSION

Pulse Detonation Engines are a promising alternatives to conventional gas turbine engines, pulse jet engines etc. provided they are developed fully. Also it is a reliable entity for propulsive purposes. The advantage of using PDE over other engines is it's drastic decrease in engine cost and increase in efficiency. Currently, Pulse Detonation Engine is visualised as next generation's engine for aircrafts. It is hoped that this review paper provides an overview and highlights of a Pulse Detonation Engine.

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