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Pulse Detonation Engine - A Next Gen Propulsion

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Abstract: *Pulse detonation technology has the potential to revolutionise both in-atmosphere and space flight. Having an engine capable of running efficiently at Mach 5 will not only allow for faster, more efficient intercontinental travel, but will also change the way spacecrafts are launched. The preset paper discuss about the applications of Pulse detonation engines and different possible variants of the engine.*

Key words*: Pulse detonation, deflagration, detonation, DDT*

I. INTRODUCTION

The main differences between the PDE and the conventional internal combustion engine is that in the PDE the combustion chamber is open and no moving parts are used to compress the mixture before ignition and no shaft work is extracted. Instead the compression is an integral part of the detonation, and two of the main advantages of the PDE are the efficiency and simplicity which can be explained by the fact that the combustion occurs in detonative mode. The efficiency of the cycle can be explained by the high level of pre compression due to the strong shock wave in the detonation. Also, the simplicity of the device is a result of the fact that the shock wave responsible for this compression is an integral part of the detonation. PDE is similar to both the pulse-jet and the ram jet engine as no moving part is present in these engines. But in those two cases the mechanism behind the pre-compression is completely different. For the pulse-jet the pre-compression is a result of momentum effects of the gases, and is a part of the resonance effects of the engine. In the ramjet, pre-compression is obtained through the ram effects as the air is decelerated from supersonic to subsonic.

The major drawback with this concept is that the engine is ineffective for speeds lower than around M =2. The pulse detonation engine works on Humphrey cycle whereas gas turbines work on Brayton cycle. The cycles are as shown in the figure-1.

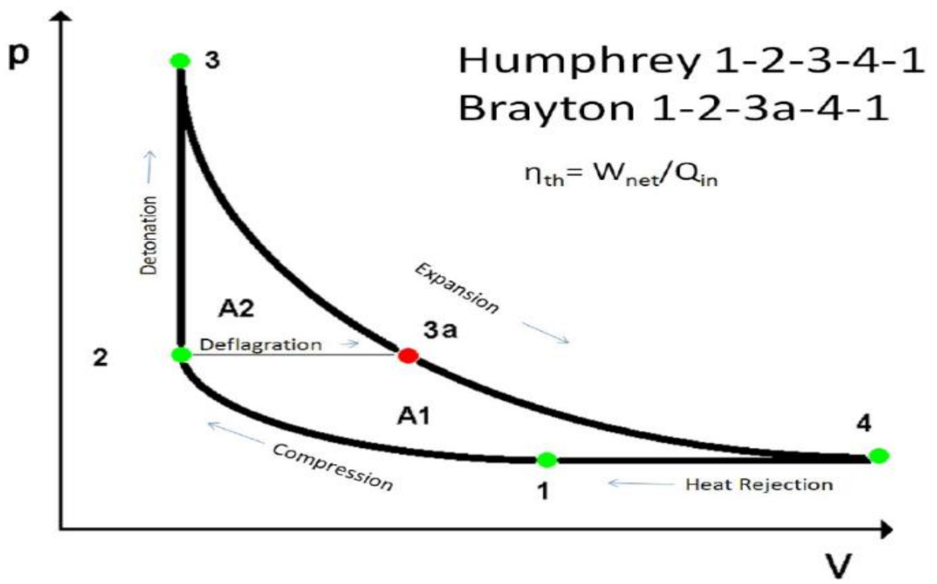

Figure-1 Comparison of Humphery and Brayton Cycle.

The Humphrey cycle gives more area under the PV curve. Making it more efficient engine as compared to Gas turbine Engines. The frontal area in case of pulse detonation engine will be very small thereby reducing drag to a large extent.

II. APPLICATIONS OF PULSE DETONATION ENGINES

Pulse detonation engine although in the development stage can have following applications.

2.1 Pulse Detonation Applications

The applications of pure PDEs are primarily military, as they are light, easy to manufacture, and have higher performance around Mach 1 than current engine technologies (Marshall Space Flight Center). This makes them an ideal form of propulsion for missiles, unmanned vehicles, and other small-scale applications (NASA Glenn Research Center 2004). The decrease in efficiency of PDEs at higher Mach numbers, the noise generated by them, and the advantages of using them in a hybrid combination, means that pure PDEs will likely not be used often for large-scale applications (Marshall Space Flight Center 200).

2.2 Hybrid Pulse Detonation Applications

Pulse detonation engines are well-suited for combination with turbofan and turbojet engines. This hybrid combination can be applied not only to produce faster aircraft, but also to make them more efficient and environmentally friendly. In a conventional turbofan engine, air travels into and around the combustion chamber. The air travelling around the chamber mixes with the exhaust from the combustion chamber to provide the thrust. In a hybrid pulse detonation engine, the bypass air enters pulse detonation tubes that surround the standard combustion chamber as shown in the figure-2. The tubes are then cyclically detonated; one detonates while the others fill with air or are primed with fuel. This combination promises to require simpler engine mechanisms and yield higher thrust with lower fuel consumption (NASA Glenn Research Center 2004; General Electric 2004).

Hybrid pulse detonation engines will allow commercial aircraft to be faster, more efficient, and more environmentally friendly. NASA is projecting that the intercity travel time will reduce significantly by the year 2007, and inter-continental travel time will also reduce significantly by 2022, thanks to this technology. In addition, they suggest that NOx emissions may decrease by up to 70% and 80% respectively in the same time periods (NASA Glenn Research Center 2004).

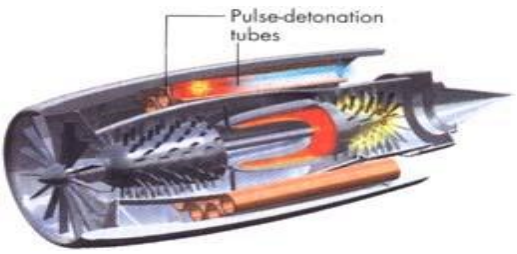

Figure 2: A PDE Hybrid Turbofan (right)

Similarly, hybrid PDEs can also be used in military applications. A large number of modern fighter jets employ afterburner-equipped low-bypass turbofan or turbojet engines. Although this process is an effective solution, it is not a fuel efficient solution. Hybrid PDEs will deliver the same thrust with less fuel consumption.

2.3 Pulse Detonation Rocket Engines (PDREs)

Similar to PDEs, PDREs produce thrust by cyclically detonating propellants within a detonation chamber and exhausting the combustion products through a nozzle. However, unlike PDEs PDREs must carry all of the oxidizer necessary to complete their specific missions onboard, and PDREs may have vacuum start and restart requirements for many applications. PDREs will incorporate propellant storage, feed, and injection system components; one or more detonation chambers ignition systems, detonation chamber/nozzle interface hardware, nozzles, and engine control system components. Similar to PDEs, numerous PDRE configurations may evolve depending upon engineering design solutions adopted to overcome technical challenges.

Once propellants are injected into PDRE detonation chambers, the fast-acting propellant injection valves close to seal the detonation chamber and detonation is initiated. The detonation wave passes through the detonation chamber at supersonic velocities, igniting the propellants and elevating the upstream pressure to several times (6-12 times) that of the initial fill pressure. Like conventional, steady combustion rocket engines, PRDEs require pressurization of the detonation chamber to obtain high performance. However, due to the high pressure ratios associated with detonation combustion, PDRE detonation chamber fill pressures are much lower than chamber pressures associated with conventional rocket engines.

PDREs can employ a variety of thermodynamic cycles to power turbo pumps, such as gas generator, staged combustion, or expander cycles, or incorporate pressurized feed systems. PDRE operating pressures may be on the order of 100-200 psia, as compared to several hundred psia for conventional open cycle engines and several thousand psia for conventional closed cycle engines.

The multiple-chamber PDRE concept shown in Figure-3 is provided by Pratt & Whitney Aero sciences. This concept includes six detonation chambers coupled to a common feed system and nozzle assembly. Operationally, the detonation chambers are fired in a phased manner allowing the feed system and manifolds to operate in a steady state manner. All of the detonation chamber combustion products are exhausted through the single common nozzle.

Other PDRE configurations are possible. PDRE designs and configurations are influenced by specific mission requirements and engineering solutions adopted to address fundamental technical and operability issues.

2.4 Pulse detonation wave engine

One option for a hypersonic vehicle might be four or six Pulse Detonation Wave Engines (PDWEs), fuelled with liquid methane. As air breathers, these PDWEs could theoretically propel a hypersonic aircraft towards Mach 10 at an altitude in excess of 180,000 feet.

The PDWE works by creating a liquid hydrogen detonation inside a specially designed chamber when the aircraft is traveling beyond the speed of sound [3]. When traveling at such speeds, a thrust wall is created in front of the aircraft. When the detonation takes place, the airplane's thrust wall is pushed forward. This process is continually repeated to propel the aircraft. From the ground the jet stream looks like "donuts-on-a-rope."Not much is known about Pulse Detonation Wave technology, but there have been quite a few reports and sightings of mysterious aircraft using propulsion technology unlike any heard or seen before. One of them is like……….

On February 25, 26, and 27, 1992, there were night-time sightings of an unknown aircraft with a "diamond-pattern" of lights at Beale Air Force Base, which was thought to be the Aurora aircraft. The aircraft had a distinctive engine noise, described as "a very, very low rumble, like air rushing through a big tube." On the night of February 26, what was thought to be a ground test of Aurora's propulsion systems took place. A series of

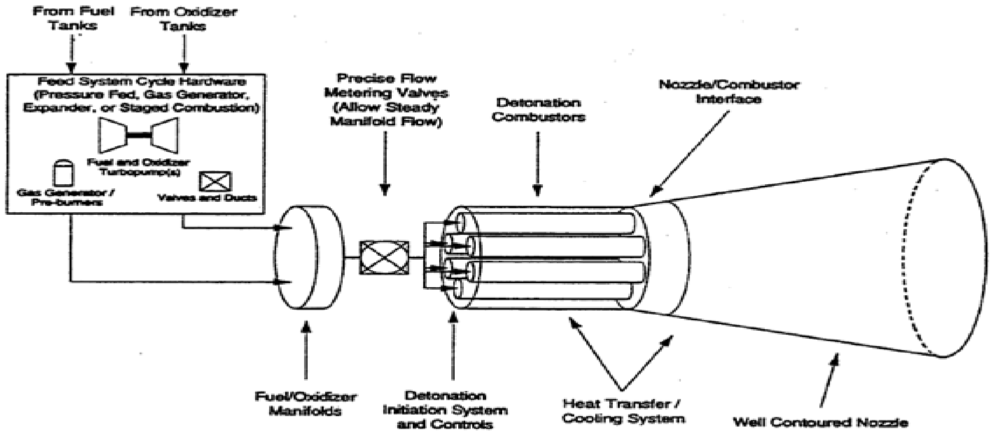

Figure 3Conceptual Pulse detonation rocket engine

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Booms" was heard and described as similar to "artillery fire" and "deep bass notes, not like sonic booms." It was thought these were "light-off" tests of the engines. It was speculated that the aircraft was using Pulse Detonation Wave Engines. The noise and low frequency would, it was said, be consistent with PDWE technology.

III. SPACE FLIGHT APPLICATIONS

While air breathing pulse detonation engines would not be able to operate in space, they may be used to reduce the cost and complexity of launching spacecraft. As PDEs do not require heavy and expensive pumps, they offer a viable alternative to current rocket engines. The decreased weight, along with better fuel consumption, would significantly reduce the cost of launching spacecraft. Using pulse detonation in combination with other propulsion sources could potentially decrease the cost of launching payloads into space.

IV. CONCLUSION

The Pulse detonation is a new technology, though the research started well in 1940. The pulse detonation engines have many advantages over the other engines for propulsive purposes and can be more reliable when developed fully. The main concern is the production of the shocks and noise. The other concern is the frequency of operation and the control of the temperature in the tube which lead to the material concerns. However there have been many excellent demonstrations of the engine all over the world. Pulse detonation engine is being seen as promising next generation propulsion system which will give aircrafts a clean configuration.

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