Experimental Research on Continuous Detonation Engine

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Abstract

Continuous detonation engine(CDE) is a new conceptual engine model.It has fundamentally comparative advantages to the traditional engines in terms of thermal efficiency and impulse.The experiments and research on continuous detonation engine mainly focus on the feasibility of the preliminary verification on continuous detonation.The authors conduct the research and successfully verify the feasbility of continuous detonation via using independent design of ignition system and combustion chamber.

1 The research background and significance

This study object is Continuous Detonation Engine (CDE). The researching aim is to use a continuous rotation device detonating efficient combustion, which greatly improves the efficiency of present combustion engine, providing near-perfect driver for the Rockets and space vehicles and hypersonic flight.

1.1 Detonation and Deflagration

Since detonation is close to the isometric burning, the entropy increase is smaller than the traditional engines of isotonic combustion. It has a higher thermal efficiency. In the standard atmospheric condition, meeting the stoichiometric ratio of hydrogen / oxygen mixture, the compression ratio is 12, the detonation pressure ratio of thermal efficiency can be improved to 18% - 37% [1].

On propagation speed, rather than a few meters per second of deflagration waves, detonation waves can amount to thousands of metres per second . In previous pulse detonation engine's experimental study, the speed is about 2,700 meters per second.

Detonation engine's heat release quickly, and is more stable. Because of eliminating the need for compressor, turbine and other pressurized devices, simple structure makes the detonation engine have a smaller combustion chamber, and thrust-weight ratio can be greatly improved. .

1.2 Continuous Detonation Engine

Continuous detonation engine is also based on the principle of efficient detonation. The clever design will block detonation in the combustion chamber, preventing detonation being directly out of the engine .

Continuous detonation engine structure is typically a coaxial cylindrical cavity in the combustion chamber, along the axis of the fuel mixture injected into the head from the combustion chamber, detonation waves along the circumferential direction for the supersonic and even hypersonic propagation. In this process, the fuel mixture detonation instantaneous and dramatically boost, temperature, resulting in highly efficient refrigerant. Detonation of the fuel charge into the new continuous rotation of thelayers of mixed gas burns, the gas of high temperature high pressure is along the axial direction but can leave the combustion chamber. This method not only preserves the detonation combustion combustion efficiency, enhancing the continuity of the combustion,but for the use of continuous high temperature and pressure generated by gas providing the necessary conditions.[4].

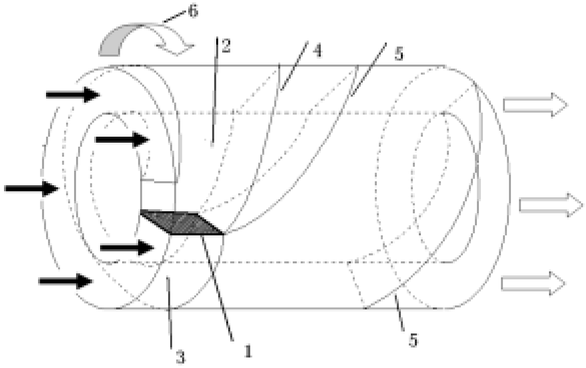

Figure 1. CDE transmission schemes

1-detonation wave, 2-burnt product, 3-fresh premixed gas, 4-slip line, 5-oblique shock wave, 6-detonation wave propagation direction.

Continuous detonation engine is a fundamental change to the existing engine combustion chamber, in essence, an innovative design, so it could mean a major leap in the development of power. Secondly, the design of the structure is very simple, not having the compressor and turbine. It reduces the complexity, improves reliability, and reduces cost .

2 Research methods

The experimental device consists of air-intake system, ignition system, control system and measurement system. The intake system includes hydrogen, oxygen, solenoid valves and one-way valve. Solenoid valves control the system by the single chip to control its on and off, in order to achieve the beginning and end of the inlet. Ignition system consists of the ignition coils and spark plugs, and ignition coils are controlled by the control system micro controller to achieve ignition. Control system consists of micro controller and circuit, and control of intake and ignition requirements at the time. Measurement system consists of the PCB pressure sensor and 702 MRD mobile data recorder. It is responsible for the experimental measurement of pressure in the combustion chamber.

2.1 Gas-intake system

Inlet pressure: hydrogen of 0.62MPa, oxygen of 0.82MPa. In this pressure condition the ratio of hydrogen and oxygen is approximately 2:1.

Control the solenoid switch: single chip microcomputer controlling system, will be in the third subclause and controlling system is also described.

2.2 ignition system

Ignition system consist of magnetic coupling coil and the spark plug. Taking the advantage of pre-detonation tube, the diameter is small, very small ignition energy to ignite hydrogen gas mixture, in a relatively short distance to form a detonation wave.

Controlling switch of spark plugs: use single chip control system, subsection 3 in the control system to elaborate. .

2.3 controlling system

Main function of each part:

Relay: the coupling through the optical digital circuit portion (control circuit) and post-level actuator (solenoid valves) isolation, and high power supply through the external control signals will increase with load capacity to drive the solenoid valve after the class.

Solenoid valve: controlling the opening and closing of the airway to the inflatable chamber.
Magnetic coupling coil: Functions the same relay, on the one hand isolated digital and analog circuits, on the other hand increasing signal power to drive the spark plugs.

Spark Plug: The spark ignites the gas mixture.

Controlling circuit: the role of commander in the system to play, by adjusting the magnetic coupling coil relay and opening and closing timing, in order to achieve a different mode of ignition and detonation.

Controlling system uses single chip control circuit, features of which are summarized as follows:1) single chip with low power consumption and wide supply range, good anti-jamming;2) online download serial communication, debugging convenient, but also easy to keep the parameters

Experimental procedure: Open the inlet valves, open the ignition coil ignition, and three seconds off the solenoid valve to stop the intake. .

2.4 Measuring system

Measurement system uses PCB pressure sensor, and 702 MDR mobile data recorder which realizes data loading and ensures a high sampling frequency and sensor sensitivity.

3 Experimental results

During the experiment, a pressure sensor is fit in the combustor and when the detonation wave rotates across the pressure sensor, there will be a steep pressure increase and then a slow pressure decrease. The same change will happen when the next detonation wave comes. Thus, the condition goes in period.

According to the time interval and length between two close pressure signals, the detonation velocity can be calculated. This velocity proves to be of the detonation, comparing it (more than 2,000 meters per second)with the theoretical velocity of the detonation.

4 Experimental results and analysis

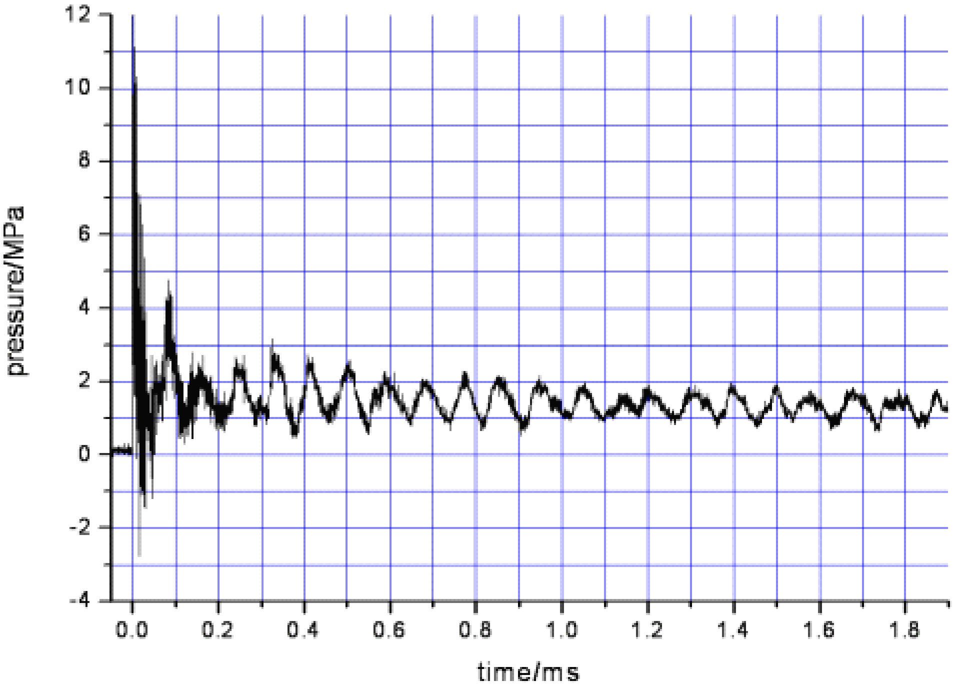

Figure 7 Experimental data diagram

As is shown in figure 7, when the pressure sensor feels the pressure changes, it will be triggered, while the data logger begins to record data. Because of the pre-detonation tube, the pressure of the first 0.1ms significantly increases, the peak about 11.1MPa. During 0.1 to1.8ms, the peak of the pressure is about 2MPa .In the process, the inlet pressure is relatively stable, and the combustion chamber of the detonation reaction is also relatively stable. The formation of a self-sustaining reaction is namely the experimental process of the desired continuous detonation. This process lasts about 20 cycles, known by the pressure sensor signal. The time interval and length between two close pressure signals are separately 0.09ms and 240mm. So the detonation velocity 2700m/s is gotten, which is close to the theoretical velocity of detonation. Pressure of each cycle is around 2MPa, in line with the relevant numerical results. .

5 Experimental Conclusions

Continuous detonation engine is a new idea of aeronautic propulsion, which goes by continuous inlet, one initiation, continuous rotation of the detonation, and continuous exhausting of combustion products. Following conclusions are gotten by experiment:

1 To Design a continuous detonation combustion chamber.

2 To design the intake system, ignition system, control system and measurement system.

3 To successfully achieve 20 cycles of continuous detonation, about 2ms, verifying the feasibility of continuous detonation..

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