Combustion of Hydrogen in Variable Compression Ratio Engine

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1. Introduction

As the global pursuit of sustainable energy solutions intensifies, the transition from conventional internal combustion engines to alternative fuels becomes imperative. Hydrogen, with its potential as a clean and efficient energy carrier, has garnered significant attention [1]. This study investigates the combustion characteristics of hydrogen in a variable compression ratio (VCR) engine.

2. Material and Methods

The study begins with a comprehensive overview of the properties and advantages of hydrogen as a fuel, emphasising its environmental benefits, high energy content, and combustion efficiency [2]. Next, it delves into the fundamentals of VCR technology and its potential for enhancing engine efficiency across a range of operating conditions. The study employed a modified Cooperative Fuel Research (CFR) engine, which incorporates both spark-ignition and homogeneous charge compression ignition (HCCI) technology to facilitate hydrogen combustion. The detailed experimental matrix and schematic of the experimental setup are illustrated in table 1 and figure 1, respectively.

Table 1. Experimental matrix and conditions.

Test type	Speed	Compression ratio	Intake temperature	Air fuel ratio	CA50	Others
SI	600 rpm	9 – 13	30 °C	1.0 – 4.0	MBT	Coolant temperature: 96±2 °C Oil temperature: 60±2 °C
HCCI		14 – 18	110 – 150 °C	2.0 – 5.0	3±1 CAD	

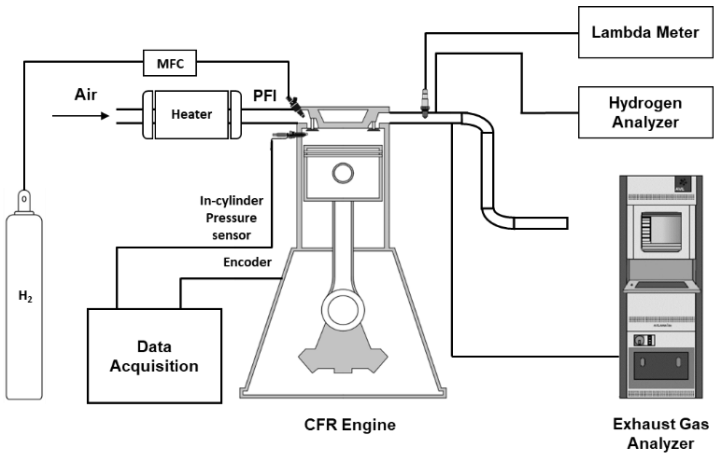

Figure 1. Schematic of the experimental setup.

3. Results and Discussion

In this section the detailed analyses of combustion stability, heat release characteristics, and emissions profiles are presented, shedding light on the complex interactions between compression ratio, combustion behaviour, and emissions in the SI and HCCI mode operating exclusively in the CR range of 9 to 18 will be discussed.

3.1. Spark Ignition

Under SI combustion the engine was operating with compression ratios of 9, 11, and 13. Key parameters such as ignition timing and air-fuel mixture were adjusted to explore their influence on combustion efficiency, emissions, and engine performance. The results indicate that hydrogen combustion in the SI mode exhibited distinct characteristics at different CR [2].

3.2. Homogeneous Charge Compression Ignition

Under HCCI combustion, the CFR engine was operated under a range of compression ratios from 14 – 18. HCCI mode results in higher thermal efficiency, improved combustion stability and negligible NOx emissions due to lean combustion [3].

Conclusion

In conclusion, this study investigated hydrogen combustion within a VCR engine, employing both SI and HCCI modes. The findings illuminated the influence of CR on overall efficiency, emissions, and performance. Lower compression ratios exhibited better emissions control in SI mode, while higher ratios improved thermal efficiency and power output. In the HCCI mode, higher thermal efficiency and lower emissions were achieved when compared to SI mode. These results highlight hydrogen's adaptability in VCR engines and provided the available range of operation is acceptable and can be made large enough for practical applications.

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