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Research on High Efficiency and Tribology of Direct Injection Hydrogen Engines

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1. Introduction

In recent years, research and development efforts has been actively undertaken to apply hydrogen to heavy-duty vehicles such as trucks and buses. On the other hand, hydrogen engines have some issues to be solved such as high cooling losses and an increase in nitrogen oxide (NOx) emissions under high-load operation. Such issues have been successfully mitigated without sacrificing thermal efficiency by applying a new combustion approach called the Plume Ignition and Combustion Concept (PCC) [1]. This study introduces the effect of PCC combustion concept on the thermal efficiency of direct injection hydrogen engines, and introduces the problem of hydrogen injector, which will be an issue in practical application.

2. Engine and experimental condition

Experiments were conducted using a single-cylinder test engine. This engine is a single-cylinder, 4-stroke engine with a bore of 108 mm and a stroke of 115 mm. Experiments were conducted at an engine speed of 1000 rpm, lubrication oil and coolant temperatures of 80 ± 2 °C under a wide-open throttle (WOT) condition without any intake air throttling at a hydrogen injection pressure of 10 MPa and with the ignition timing set at the minimum advance for the best torque (MBT) in each experiment.

3. Specifications of injector and nozzle used

The high-pressure hydrogen injector used for injecting fuel directly into the combustion chamber was driven by common rail hydraulic pressure and was developed independently at our university. The nozzle cap attached to the tip of the injector determined the hydrogen jet configuration and injection direction.

In the experiments, five nozzle holes were arranged in a straight line such that fuel was injected at injection angles of 15°, 25°and 35°with a jet spreading angle of 60°. A nozzle hole diameter of 0.6 mm was added to the main value of 1.0 mm to create four types of nozzle caps for evaluation.

4. Assessment of nozzle hole specifications simultaneous attaining improved thermal efficiency and reduced NOx formation

The relationships between the best thermal efficiency and NOx formation obtained with all the nozzle hole specifications evaluated in this study were summarized as shown in Fig. 1. Optimizing the injection angle and nozzle hole diameter achieved high thermal efficiency close to 49% and low NOx emissions at a single-digit ppm for the SOI timings selected.

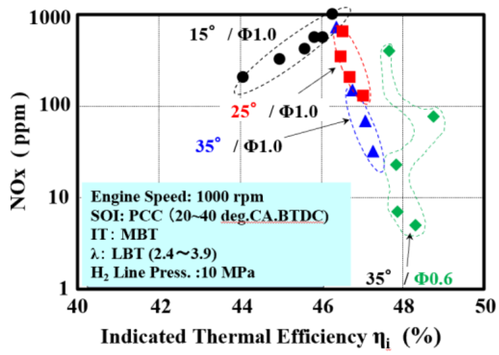

Fig.1 Thermal efficiency and NOx emission level achieved for all variation of injection angle

5. Abnormal combustion caused by the valve seat leakage of hydrogen injector

Hydrogen leakage from the valve seat of hydrogen injector causes abnormal combustion such as pre-ignition shown in Fig. 2. Therefore, the valve seat of a hydrogen injector must have high sealing performance to prevent hydrogen leakage and maintain sealing performance under severe conditions.

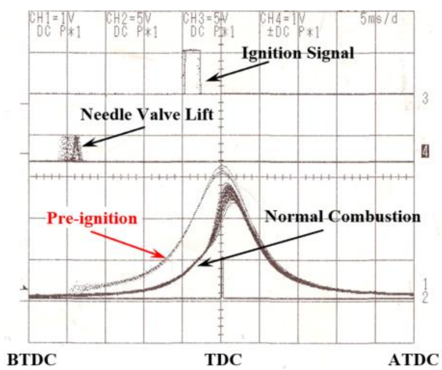

Fig.2 Indicator diagram to show pre-ignition combustion

Conclusions

The thermal efficiency and NOx emission of the direct injection hydrogen engine was greatly improved by the combustion improvement. On the other hand, there are many issues to be solved from a tribological viewpoint, such as the amount of hydrogen leakage from the valve seat of the hydrogen injector.

References

1) Y. Takagi, M. Oikawa, M. Sato, R. Kojiya, Y. Mihara, Near-zero emissions with high thermal efficiency realized by optimizing jet plume location relative to combustion chamber wall, jet geometry and injection timing in a direct-injection hydrogen engine, Int. J. of Hydrogen Energy, Vol. 44, No. 18, 5 April 2019, pp. 9456-9465.