

Development of Ammonia/Hydrogen SI Engine

-Initial Performance of an Ammonia/Hydrogen PFI Engine and the Effects of Ignition Enhancement-

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This study investigates an ammonia/hydrogen co-combustion engine based on the concept of producing hydrogen from ammonia using a reformer. To reduce the reforming load and improve system efficiency, it is desirable to minimize the hydrogen fraction in the total fuel supply.

In our previous study, the hydrogen addition ratio required for stable combustion was investigated using an ammonia/hydrogen co-combustion engine equipped with hydrogen direct injection (DI) and ammonia port fuel injection (PFI). In addition, PFI spray models for hydrogen and ammonia were developed to facilitate the conversion of the engine from hydrogen DI to PFI.

In this study, a PFI engine was developed based on CAE predictions using the PFI spray models, and the minimum hydrogen addition ratio required for stable combustion was evaluated. Furthermore, the influence of ignition enhancement on reducing the required hydrogen addition ratio was investigated.

Figure 1 shows the minimum hydrogen addition ratio map for the DI engine, whereas Figure 2 presents the corresponding map for the PFI engine developed in this study. The conversion of the hydrogen fueling system from DI to PFI had little effect on the minimum hydrogen addition ratio at engine speeds below 2000 rpm and above 4800 rpm. In contrast, in the medium-speed range from 2400 rpm to 4400 rpm, the minimum hydrogen addition ratio was higher for the PFI engine than for the DI engine. Unlike the DI configuration, PFI does not allow hydrogen to be concentrated near the ignition source, thereby requiring a higher hydrogen addition ratio to achieve stable combustion.

These results indicate that the benefit of in-cylinder mixture distribution control for improving ignitability is limited in the PFI configuration. In particular, during engine start-up, the fuel reformer envisioned for future implementation has not yet reached its operating temperature, making it difficult to supply a sufficient amount of hydrogen. Therefore, the engine should be started under ammonia-only operation. To improve ignitability by other means, ignition enhancement was investigated. Figure 3 shows the effects of ignition energy and spark plug gap on combustion stability under ammonia-only operation at an IMEP of 350 kPa and an

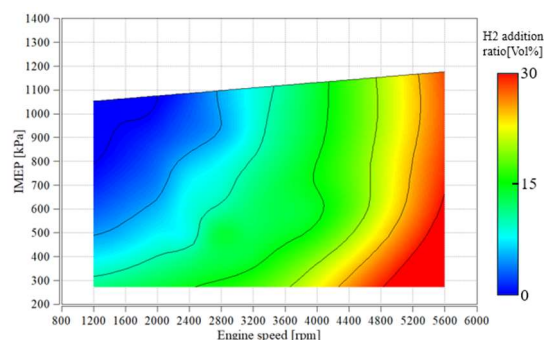


Fig.1 Minimum H₂ addition ratio in the DI engine

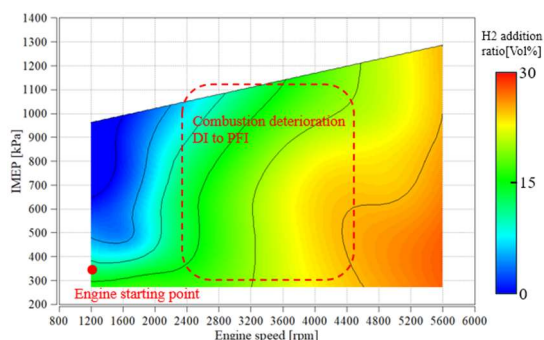


Fig.2 Minimum H₂ addition ratio in the PFI engine

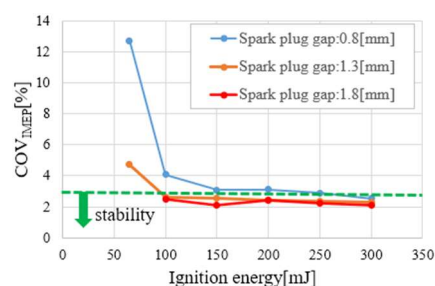


Fig.3 COV_{IMEP} vs. Ignition energy and Spark plug gap

engine speed of 1250 rpm, corresponding to engine start-up conditions. Although the evaluation was performed under these operating conditions, the engine was fully warmed up prior to testing. Increasing the ignition energy and spark plug gap reduced the occurrence of combustion cycles approaching misfire, thereby improving combustion stability and enabling stable ammonia-only operation.