In-cylinder Hydrogen Mixture Formation with Schlieren Observation Investigation of In-Cylinder Hydrogen Mixture Formation by In-Cylinder Schlieren Observation in Hydrogen Direct Injection Engine

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While countries around the world are making long-term efforts to reduce greenhouse gas emissions, Japan declared "carbon neutrality by 2050" in 2020, and aims to reduce greenhouse gas emissions by 46% from fiscal 2013 as the target for fiscal 2030, and aims to achieve carbon neutrality by 2050. Hydrogen engines are attracting increasing attention as a future powertrain in the automotive field because conventional engine components can be diverted. In particular, hydrogen direct injection engines, which inject hydrogen directly into the cylinder, are attracting attention in order to achieve higher output and efficiency. In a hydrogen direct injection engine, the generation of backfire can be suppressed by injecting high-pressure hydrogen during the compression stroke , but it is known that the formation of air-fuel mixture in the cylinder becomes difficult, which greatly affects engine performance. Therefore, it is important to understand the mixing phenomenon of hydrogen in the cylinder in detail. Hydrogen mixture formation in the cylinder by CAE has been reported . However, the validity of the results obtained by CAE is limited to the jet model of the injector alone, and it is desirable to obtain detailed information on the flow in the cylinder formed by the engine and the diffusion of hydrogen due to pressure changes. A optical engine test using a glass cylinder is a method to observe the air-fuel mixture formation in an actual engine cylinder. However, unlike liquid fuel, it is difficult to directly visualize the behavior in the engine cylinder in gas fuel. The schlieren method is used for gas visualization. The Schlieren method can visualize the density gradient of the heterogeneous state in space and is the most suitable method for understanding the mixed state of hydrogen. A hydrogen injector has been used to monitor the mixing state of air and hydrogen by schlieren observation in a constant volume vessel. However, it is very difficult to visualize the hydrogen mixture formation process in the glass cylinder of the optical engine by the Schlieren method, which utilizes the parallelism of the light, because the incident light is refracted in a complicated manner by the lens effect. In order to overcome the problem of refraction of light in a glass cylinder, various devices have been devised and schlieren photography in the cylinder has been performed. However, this phenomenon is different from the actual phenomenon, such as the unique cylinder shape due to the incidence of parallel light into the cylinder. Furthermore, it has been difficult to take schlieren images in the cylinder due to the complexity of the apparatus. In this study, in a optical engine using a glass cylinder, we fabricated a special lens that allows parallel light to enter the cylinder. By installing the special lens at the front and rear of the cylinder, we visualized the hydrogen gas mixture formation process during engine operation using schlieren photography and grasped the diffusion of hydrogen jet.

In the manufacture of special lenses, it is necessary to finish the machining accuracy of each lens with high precision in order to expand the observation range in the cylinder. In order to realize a wide range of internal photographing, it is important to manufacture a cylinder liner and a large aspherical cylindrical lens with high precision optical performance. In the schlieren image inside the cylinder taken by the manufactured lens group, it can be confirmed that the lattice shape installed inside is clearly observed without distortion. (Fig.1)

Hydrogen jet diffusion in the air flow during engine operation was successfully observed by incorporating the fabricated special lens into the optical engine. The behavior of the hydrogen jet changes depending on the specification of the hydrogen direct injection injector (with or without a chip cap), and the change of the hydrogen diffusion behavior in the engine cylinder was observed by this visualization system.(Fig.2)

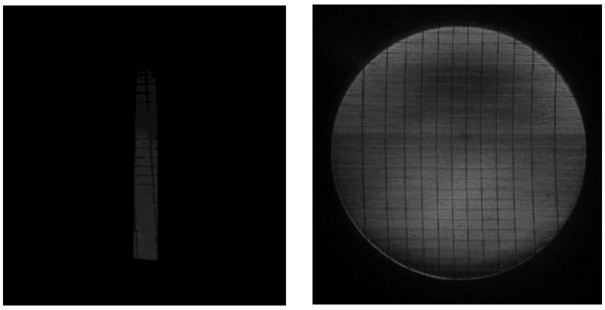

Fig.1 Result of Schlieren with Quartz glass cylinder lens （Left: Liner lens only, Right: with In-cylinder Schlieren

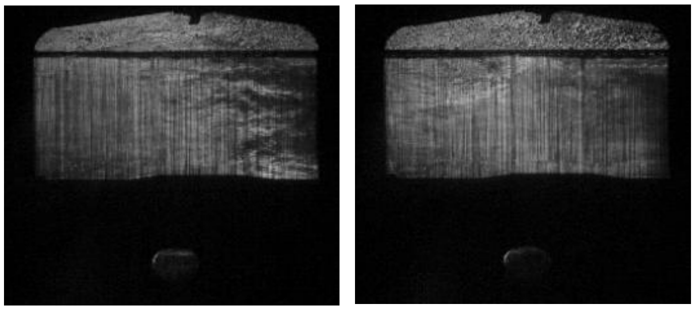

Fig.2 Result of Schlieren experiments at injection pressure of 41 barA, at 130 [deg.BTDC] （Left: With injector cap attached, Right: