論 文 の 要 旨

題 目　Experimental Study on Diesel Spray Combustion and Wall Heat Transfer by Means of Rapid Compression and Expansion Machine
（急速圧縮膨張装置を用いたディーゼル噴霧燃焼と壁面熱流束に関する実験的研究）

ファン　チェンユアン
氏 名 范　程遠（FAN　Chengyuan）

Internal combustion engines operate at high-pressure and high-temperature conditions where there is a particularly strong need to improve the understanding of combustion phenomenon inside. Substantial amount of fuel energy input is lost in combustion process. These heat losses, which mainly due to the heat transfer between the impinging spray flame, piston cavity, and the cylinder wall, accounting for the thermal efficiency reduction and engine performance deterioration.

One of the key factors in reducing heat loss is to precisely control the combustion process, which is a very complicated condition and significantly affected by the spray/wall interaction, mixture formation, flame development, etc. In addition, the potential of spray/wall interaction when applying multiple injections for highly premixed combustion could have impacts on engine performance resulting from the fuel injection events are going to target the squish region and cylinder liner which most likely lead to the locally rich mixture and deposit formation on crevices, and therefore show the potential to deteriorate the combustion performance.

To further understanding the complicated spray and combustion processes, improving the combustion efficiency, and reducing emission exhausts, this study investigated the cohesive correlation and mechanism between diesel spray/flame characteristic and heat transfer upon spray and combustion processes in a diesel engine-like condition. Accordingly, a series of experiments were conducted under double and triple injection strategies, while the results as per single injection strategy with a fixed injection timing was taken for comparison. Highly premixed condition was achieved followed by the main injection closer to top dead center, while the early injections such as the pilot injection and the pre-injection were involved to promote the mixture formation and uniform mixture distribution. Consequently, the effect of injection pressure, injection pulse, and injection timing on spray and combustion processes were studied.

This study was performed in a rapid compression and expansion machine with a two-dimensional piston cavity installed inside. Several optical diagnostics were applied to facilitate the deep observation on ambient air flow motion, spray development, mixture formation, and mixture distribution in combustion cylinder from later side view. Meanwhile, various types of high accuracy and high response sensors were used to effectively capture and analyze the combustion information, such as the combustion pressure, apparent heat release rate, soot temperature, and KL factor. Furthermore, the dynamic heat flux on the typical locations of piston cavity and cylinder wall was also studied simultaneously in spray and combustion process to clarify the cohesive correlation and mechanism between diesel spray/flame and heat transfer.

This study aims to investigate the effect of multiple injection strategy on spray and combustion characteristics in a rapid compression and expansion machine under diesel engine-like conditions to further clarify the correlation between spray/wall interaction, combustion, and heat transfer. The specific objectives of this study are shown as follows:

1. Clarify the ambient air motions under motoring condition in a two-dimensional piston cavity.
2. Observe the effect of double injection strategy on spray/wall interaction, mixture formation for non-reaction condition.
3. Observe the effect of double injection strategy on spray/wall interaction, mixture formation, and combustion characteristic for reaction condition.
4. Analyze the effect of double injection strategy on flame temperature and soot generation.
5. Investigate the triple injection strategy on spray/wall interaction, mixture formation, and combustion characteristic.
6. Clarify the correlation between impinging spray flame and heat transfer characteristics under triple injection strategy.
7. Explain the combined effect to find the optimum level for decreasing heat loss in a combustion diesel engine-like condition.

In this study, a two-dimensional piston cavity, designed as the cross section of a reentrant piston, was installed in cylinder to facilitate the observation from the lateral side in a rapid compression and expansion machine. Spray and flame information were recorded by a high-speed color video camera, and the shadow method was adopted in motoring and double injection experiments to clearly capture the ambient air motion, spray/wall interaction, mixture formation, and flame development. Diffused back-illumination method was applied for the observation on spray impingement, autoignition, and flame development. Two-color pyrometry was used to analyze the flame temperature and soot distribution in the cylinder. In addition, heat flux information was supported by thin film thermocouple heat fluxes which were installed in the several important locations of piston cavity and chamber body. In-cylinder pressure, piston movement were recorded by pressure transducer and laser sensor, separately.