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Thermal efficiency improvement of a diesel engine by High-heels heat release rate profile

-Engine experimental results and analysis by utilizing multiple-injector system-

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To improve thermal efficiency of reciprocating ICEs, degree of constant volume combustion has to increase theoretically. However, further increase in degree of constant volume combustion from current condition is not only a difficult problem for engines having constraint on peak cylinder pressure especially under high load conditions, but also a major cause of increased heat loss. Therefore, this study has proposed a novel High-heels heat release rate (HRR) profile. This HRR profile aims improvement in indicated thermal efficiency with simultaneous reduction of heat loss around TDC by the form of isobaric combustion followed by the steep increase HRR to suppress the deterioration of degree of constant volume combustion.

This study utilized a multiple-injector system as a tool of controlling HRR profile. Automotive diesel engines are generally equipped one injector, whereas this system has two more injectors mounted in the periphery of cylinder opposite each other. Nozzle orifice directions were designed not to interfere each other even though three injectors are simultaneously injected.

Engine performance comparison was carried out between ‘Conventional’ combustion with a single injection and ‘High-heels-like’ combustion aiming to achieve ideal High-heels HRR by utilizing multiple-injector system. Injection sequences for High-heels-like HRR are composed of side injection only with the low injection rate injectors in the initial combustion phase and simultaneous injections with all injectors in the late part of combustion phase.

Figure 1 compares in-cylinder pressure and apparent heat release rate history for Conventional and High-heels-like combustion with three different isobaric combustion durations. Figure 2 shows the comparison of heat balance analysis results for them organized by 50% mass fraction burnt timing (CA50) on the horizontal axis. The results confirmed simultaneous improvement in heat loss and indicated thermal efficiency with High-heels-like combustion except for the longest isobaric combustion condition.

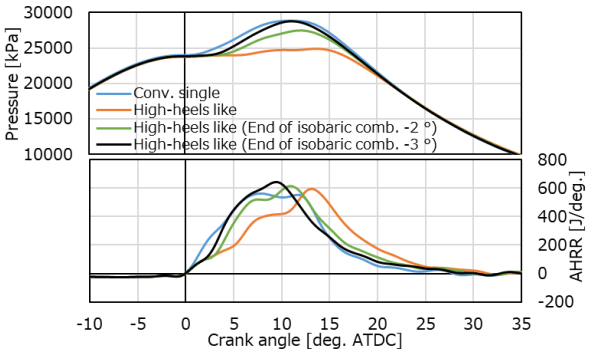

Fig. 1 Comparison of in-cylinder pressure and AHRR

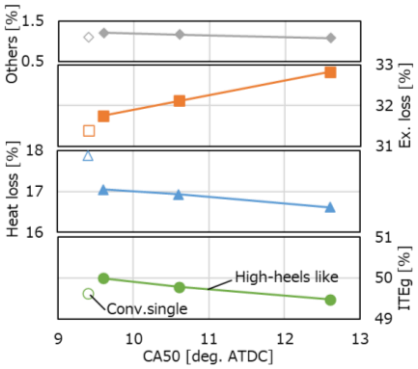

Fig. 2 Comparison of results of heat balance analysis

To clarify the cause of thermal efficiency improvement, heat loss during combustion duration is derived from the subtraction integrated apparent heat release from input heat energy. The result indicated that heat loss reduction during combustion duration with High-heels-like combustion was suggested. To identify the cause of heat loss reduction during combustion duration, in-cylinder flame observation with a bottom view transparent engine and numerical simulation of the combustion phenomena with 3-D CFD software: CONVERGE were carried out. By analyzing flame observation test results with two-color method, a simple quantitative estimate of radiative heat transfer was tried. As the result, radiative heat transfer was reduced with High-heels-like combustion. The reduction could be mainly caused by the reduction of duration, when the space occupancy of luminous flame was high. This phenomenon was occurred with the injection sequence, starting with the side injectors with smaller number of orifice than the center injector, and relatively higher injection quantity of them. As the factor which strongly affects convective heat transfer, time integration of wall area, where flame was contacted, was calculated. The result also confirmed the reduction of time integration with High-heels-like combustion, since the direction of side injector orifices are harder to contact to the side wall of the cavity than that of the center injector.

In conclusion, simultaneous improvement in heat loss and indicated thermal efficiency was achieved with HRR control closer to the ideal High-heels HRR by utilizing the multiple-injector system. However, the contribution which stems from the multiple-injector system itself should be included in the improvement, and this is difficult to separate from the contribution with optimized HRR profile. As the future work, the comparison of engine performance for various HRR profiles with the same multiple-injector system will be planned to identify the effect of HRR profile optimization.