講演番号	099

Key Technology of Brand-New 1.5 L Three-Cylinder Engine for the Third-Generation Series Hybrid Powertrain

- (First Report) Development of Combustion Technologies -

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KEY WORDS:Spark ignition engine, Combustion analysis, Knock, Cycle-to-cycle variation [A1]

A new 1.5 L three-cylinder turbocharged engine dedicated to the third-generation series hybrid powertrain was developed to achieve both high thermal efficiency and high specific power. A maximum thermal efficiency of 42% and a maximum specific power of 77 kW/L under stoichiometric operation were achieved with a compression ratio of 13. The major challenge was suppression of knock in the high-load region while maintaining combustion speed and cycle stability.

To reduce end-gas temperature, three measures were applied. First, an early intake valve closing Miller cycle lowered the effective compression ratio and reduced end-gas temperature by approximately 24 K under equal volumetric-efficiency conditions. Second, a cold-spray valve seat contributed to end-gas temperature reduction through high thermal conductivity of the seat material, reduced interfacial thermal resistance between the seat and the cylinder head, and shorter distance between the combustion chamber and the water jacket. Third, a large-diameter turbocharger reduced turbine-inlet exhaust pressure, exhaust-gas temperature, and residual gas, resulting in an additional reduction of end-gas temperature.

For combustion improvement, the STARC concept was applied. The concept consists of a low-aspect-ratio combustion chamber and a strong in-cylinder flow concept that stabilizes the velocity near the spark plug. The low-aspect-ratio chamber shortened flame-propagation distance and improved combustion speed. In addition, intake-port geometry, larger valve included angle, center-mounted injector layout, and the cold-spray valve seat formed a continuous flow path from the intake port to the pent-roof surface, thereby reducing flow-energy loss and suppressing separation. These measures enabled strong tumble generation even under low-lift conditions.

To retain tumble until late compression, a small-bore, long-stroke layout and a rugby-ball-shaped piston crown were adopted. This geometry promoted formation of a strong tumble vortex with a straight vortex center and improved tumble retention. As a result, the tumble ratio during the compression stroke under E-IVC was restored to the level of the predecessor engine despite the shorter valve-opening duration.

Cycle-to-cycle variation was further reduced by stabilizing the flow near the spark plug. Hot-wire measurements showed a narrower distribution of local velocity near the spark plug than that of the conventional combustion system. Consequently, the number of knock-occurrence cycles was reduced even at the same mean combustion phasing, allowing more advanced combustion phasing at the same knock intensity. The combination of end-gas-temperature reduction, faster combustion, and reduced cycle-to-cycle variation enabled high knock resistance and high specific power in the new engine.

Table 1 Summary of major technologies and effects

Category	Technology	Main effect
End-gas temperature	E-IVC, cold-spray valve seat, large turbocharger	Reduced end-gas temperature
Combustion speed	Cold-spray valve seat, large turbocharger, low-aspect-ratio combustion chamber, enhanced in-cylinder flow	Enhancement of combusiton speed
Cycle-to-cycle combustion variation	Cold-spray valve seat, low-aspect-ratio combustion chamber, enhanced in-cylinder flow, reduction of velocity fluctuation near the spark plug	Reduction of cycle-to-cycle combusiton variation