

Fuel Injection Optimization Based on Combustion Chamber Wall Temperature Estimation

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Background

Frequent ISS(Idle Stop System) activation is required in HEV applications to maintain combustion stability, and additional fuel injection is typically required during restart. In production engine control systems, the required fuel correction is primarily determined based on coolant temperature and engine stop duration. However, experimental results indicate that the required fuel injection quantity varies even under identical coolant temperature conditions, because in-cylinder thermal conditions differ depending on the preceding driving history.

Method

To investigate the relationship between combustion chamber wall temperature and combustion characteristics during engine restart, a thermocouple-equipped test engine with 57 temperature measurement points installed in one cylinder was mounted in a vehicle. The correlations among coolant temperature, combustion chamber wall temperature, and air-fuel ratio behavior during engine restart were investigated under various driving histories. To evaluate the feasibility of production implementation, a wall temperature estimation model was developed using only signals available in the production ECU, without requiring additional temperature sensors.

Results

As shown in Fig.1, coolant temperature exhibited a correlation coefficient of 0.76 with peak air-fuel ratio enrichment during engine restart. In contrast, combustion chamber wall temperature showed a substantially stronger correlation, with a coefficient of 0.95, as shown in Fig.2.

Although the coolant temperature was identical, combustion chamber wall temperature varied significantly depending on the preceding driving history. These results indicate that coolant temperature alone does not sufficiently reflect the thermal conditions near the combustion chamber during engine restart.

The potential reduction in the fuel injection quantity corresponding to differences in combustion chamber wall temperature was estimated to be approximately 1.0% per °C. These results suggest that a portion of the additional fuel injection currently applied during engine restart to accommodate worst-case thermal conditions could be reduced when combustion chamber wall temperature information is available.

Furthermore, the combustion chamber wall temperature estimation model based on existing ECU signals successfully reproduced the temporal variations in combustion chamber wall temperature.

Conclusions

Combustion chamber wall temperature can be considered a more suitable indicator for engine restart fuel correction than engine coolant temperature, owing to its stronger correlation with air-fuel ratio behavior during restart. These findings suggest that excessive fuel injection during engine restart can be reduced while maintaining combustion stability, demonstrating the feasibility of applying the proposed approach to production engines.

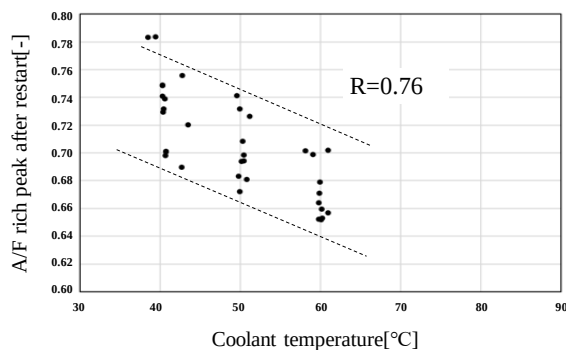


Fig.1 Coolant temperature vs. A/F rich peak after restart

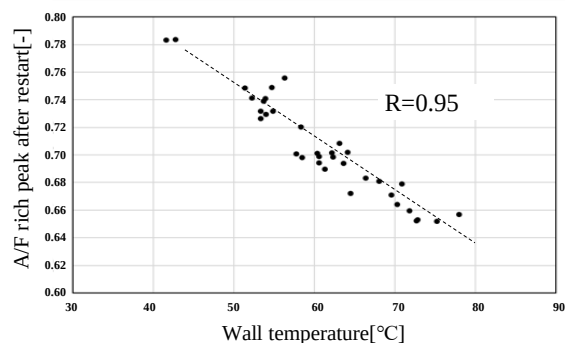


Fig.2 Wall temperature vs. A/F rich peak after restart