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# Development of an Intake Air Temperature Estimation Method for Transient Control of Diesel Engines (First Report)

## - Proposal of an Intake Air Temperature Estimation Formula for Steady-State Operation -

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In modern diesel engines, multi-stage fuel injection is used to meet emission regulations while suppressing combustion noise. However, during transient operation, the combustion chamber wall temperature has not yet reached its steady-state level. Heat transfer during the intake stroke lowers the in-cylinder gas temperature, increases ignition delay, and causes deviations from steady-state optimized combustion. Accurate estimation of the in-cylinder gas temperature at the start of compression ($T_{ivc}$) is therefore essential for transient control. Since $T_{ivc}$ cannot be measured directly, an onboard prediction method is required.

This study focuses on the initial temperature of the newly introduced gas excluding residual gas, defined as Tinit. Heat transfer during the intake stroke was modeled based on the Woschni correlation. As a result, $T_{init}$ was derived as a linear function of intake manifold gas temperature $T_{bin}$, coolant temperature $T_{water}$, and engine specific output $PkW$.

An experimental procedure was developed to inversely calculate Tinit from in-cylinder pressure and gas mass at the start of compression, and the model coefficients were identified. Under steady-state conditions, Tinit can be expressed as:

$$T_{init}=0.65T_{bin}+0.35T_{water}+0.7PkW+3.4$$

Figure 1 shows the correlation between the measured and calculated temperatures. A correlation coefficient of R = 0.91 was obtained over a wide range of cold-to-warm conditions, confirming the validity of the formulation.

To further verify the model, $T_{init}$ was applied as the initial condition in the zero-dimensional diesel cycle simulation UniDES, and pilot ignition timing was evaluated. Early pilot combustion is highly sensitive to gas temperature; thus ignition timing serves as an indicator of estimation accuracy. Figure 2 compares heat release rates under cold conditions (Tw = −10°C, Ta = −10°C) with three pilot injections followed by main and after injections. The calculated ignition timings agree well with the experiments.

These results demonstrate that the compression-start temperature can be represented by a first-order expression of three physically meaningful variables ($T_{bin}$, $T_{water}$, $PkW$), and that the proposed model is robust over a wide operating range, including cold conditions. The formulation provides a practical and physically interpretable foundation for future transient combustion control strategies.

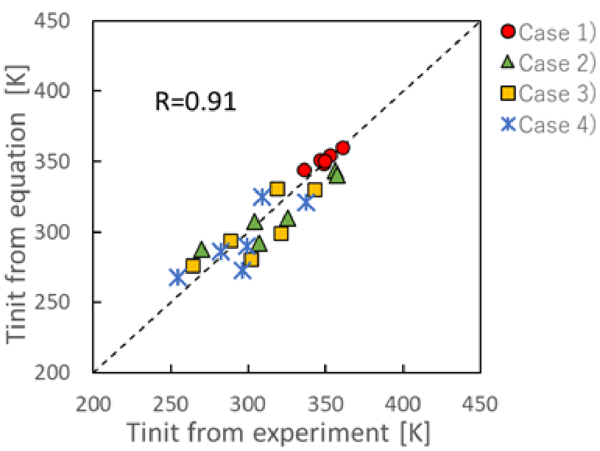


Fig.1 Correlation between Experimental Results and Formula of Initial Gas Temperatures

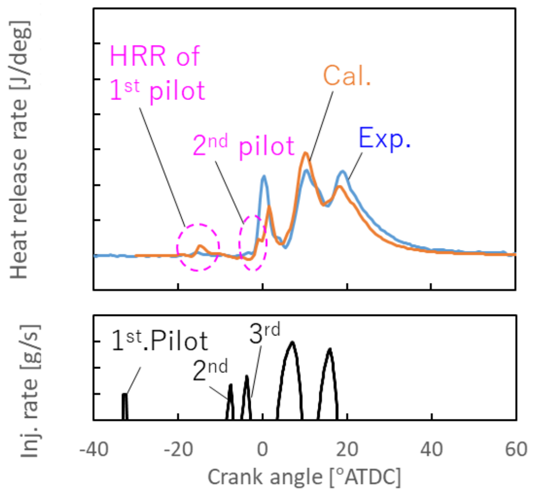


Fig.2 An Example of Calculation Results of Heat Release Rate (upper) and Fuel Injection Rate (lower)