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Development of High-Accuracy End-Gas Autoignition Prediction Model (Eighth Report)

- Expansion of Application Conditions for Ignition Delay Time Equations and Rediscussion of Error Correction Method -

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A high-accuracy knocking prediction model with low computational loads is necessary to develop thermal-efficiency improvement technologies for SI engines efficiently using computational techniques. In the previous reports, ignition delay time equations for a premium-gasoline surrogate fuel were developed to reproduce the temperature-, pressure-, equivalence ratio-, and EGR-dependences of ignition delay time produced using a detailed reaction mechanism. In the present report, the ignition delay time equations have been revised to be equations (1) to (5) for the expansion of those application conditions to 12 MPa.

$$\tau = B\{\tau_{1\_low} + A(\tau_{high} - \tau_{1\_low})\} \tag{1}$$

$$\tau_{1\_low} = 337\phi^{-0.53}(1-\mathrm{EGR})^{-0.52-0.18\phi} \times \exp\left\{7.1{p_0}^{0.052}\left(1000/T_0 - 2.02\right)\right\} \tag{2}$$

$$\tau_{high} = 1.20\times10^9\, {p_0}^{-1.8}\phi^{-1.0}(1-\mathrm{EGR})^a \times \exp\left\{(13.2-3.4\phi)\left(1000/T_0 - 2.71{p_0}^{-0.061}\right)\right\}$$
$$a = -0.22{p_0}^{0.11} - 1.40\times10^2\, {p_0}^{-0.43}\phi^{4.9} \tag{3}$$

$$A = 1 - 0.055^{\alpha}$$
$$\alpha = \exp\left\{-8.4(1-\mathrm{EGR})^{0.49}\left(1000/T_0 - b{p_0}^{c}\right)\right\}$$
$$b = 3.50 - 0.36\phi^{4.7} + d\mathrm{EGR}^{f}$$
$$c = -0.0767 + 0.0077\phi^{5.1} + e\mathrm{EGR}^{f} \tag{4}$$
$$d = 13.6 - 11.7\phi$$
$$e = -0.220 + 0.193\phi$$
$$f = 2.86 - 1.46\phi^{2.5}$$

$$B = 1 - 0.034^{\beta}$$
$$\beta = \exp\left\{11.9\left(1000/T_0 - 2.29{p_0}^{-0.059}\right)\right\} \tag{5}$$

Here, τ_{1_low} is cool-flame reaction induction time with low initial temperatures, τ_{high} is ignition delay time with high initial temperatures, T_0 and p_0 are initial temperature and pressure, ϕ is equivalence ratio, and EGR is egr rate in decimal. Also, error correction equations (6) and (7) have been developed for HCCI and end-gas autoignition, respectively, predicted using Livengood-Wu integral with the ignition delay time equations (1) to (5).

$$\theta_{ig} - \theta_{\mathrm{LWI}=1} = 0.295\left\{\left(\frac{1}{\tau_{deg}}\right)_{\mathrm{LWI}=1} - 0.01\right\}^{-0.58} \tag{6}$$

$$\theta_{ig} - \theta_{\mathrm{LWI}=1} = 0.134\left\{\left(\frac{1}{\tau_{deg}}\right)_{\mathrm{LWI}=1} - 0.02\right\}^{-1.2} \tag{7}$$

Here, θ_{ig} is ignition timing in crank angle degrees, $\theta_{\mathrm{LWI}=1}$ is timing in crank angle degrees predicted using Livengood-Wu integral, and τ_{deg} is ignition delay time in crank angle degrees. The error correction equations can be effective in cancelling prediction errors, as shown in Fig. 1.

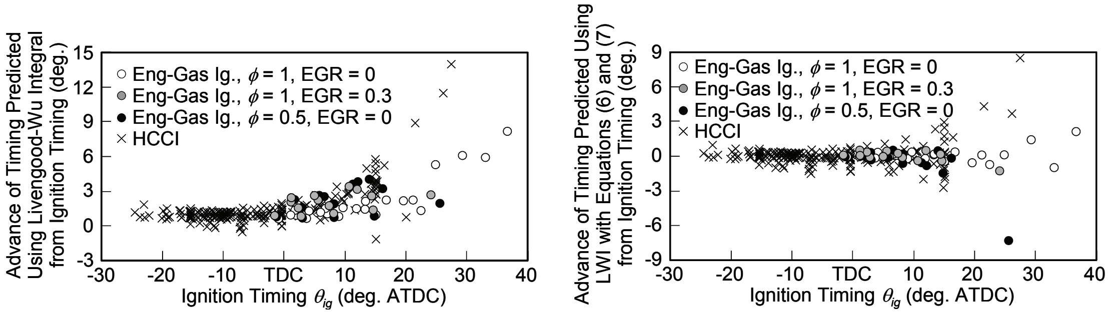

Fig. 1 Advances of Timing Predicted Using Livengood-Wu Integarl, from Ignition Timing Produced Using Detailed Reaction Mechanism