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Development about Film-Heat-Transfer model by carrying out Multi-Phase Flow Calculation

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For the development of engines aiming to conform to Euro 7, engine combustion CFD needs to accurately predict not only fuel consumption and output, but also the amount of harmful gas emissions. The behavior of the liquid film near the wall of the combustion chamber has a great influence on the emission of harmful gases. Normally, in engine combustion CFD, in order to reduce the computational load, models such as atomization, wall adhesion, and vaporization are applied to droplets simplified by DDM to predict combustion. Among them, many studies have been attempted on fuel atomization and wall adhesion behavior. On the other hand, there is little knowledge about vaporization of fuel that adheres to the wall. In order to accurately predict the film temperature, which greatly affects the vaporization of the film adhering to the wall, a new film heat transfer model was developed

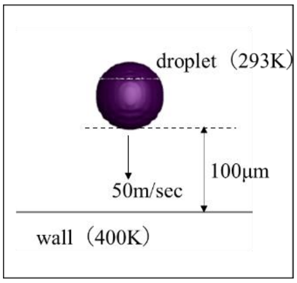

Fig.1 View of the numerical analysis

The film temperature T_{film} is expressed by the following equation using the contact area between the wall and the film A_{film}, the heat flux q_{wall}, the mass of the film m_{film}, and the specific heat $c_{p,film}$. The superscript n indicates the time passage.

$$\left(T_{film}^{n+1} - T_{film}^{n}\right) = A_{film}^{n} q_{wall}^{n} \left(t^{n+1} - t^{n}\right) / m_{film} c_{p,film}^{n} \quad (1)$$

The physical quantities representing film heat transfer are A_{film}, q_{wall}, and T_{film}. It is difficult to obtain these from measurements for the liquid film. Therefore, multiphase flow numerical analysis was carried out for the wall impact phenomenon of droplets. And the mechanism of film heat transfer was clarified and a model was developed by analyzing the obtained results.

Table 2 Verification condition of model formula

Name	Case1	Case2	Case3	Case4
Component	iC_8H_{18}	←	←	$iC_{16}H_{34}$
Velocity[m/s]	50.0	10.0	50.0	←
Diameter[μm]	50.0	←	100.0	50.0
Viscosity[kg/m-s]	4.56e-4	←	←	2.94e-3

Figure 1 shows a conceptual diagram of the numerical analysis performed in this report. A droplet with a diameter of 50 μm was placed 100 μm above the wall and collided perpendicularly with the wall.

2 model formulas were constructed from the results of multiphase flow numerical analysis.

$$A_{film}^{n+1} = \pi\left\{r^{n} + 40.0\frac{m_{film} l_{film}^{n} u^{n}}{\mu A_{film}^{n}}\left(1 - \exp\left(0.018\frac{\mu A_{film}^{n}}{m_{film} l_{film}^{n}}\left(t^{n+1} - t^{n}\right)\right)\right)\right\}^{2} \quad (2)$$

$$q_{wall} = 1.5 Pr^{1/2} Re^{1/3} \frac{\lambda}{l_{film}}\left(T_{film} - T_{wall}\right) \quad (3)$$

A Model equation (2) is constructed by incorporating the viscous stress inside the liquid film into the equation of motion that expresses the shape change of the liquid film. A model equation (3) was constructed by assuming that the heat transfer between the liquid film and the wall surface is convective heat transfer. A new film temperature prediction formula (liquid film heat transfer model) was obtained from model formulas (2), (3) and (1).

Additional multiphase flow numerical analysis were performed under the 4 conditions shown in Table 2, and the prediction accuracy of the liquid film temperature by the new film heat transfer model was verified.The result is shown in figure 2. For the reference, the result of predicting the film temperature by heat conduction is also described. It was confirmed that the new film heat transfer model can predict the liquid film temperature obtained by multiphase flow numerical analysis with higher accuracy than the heat conduction model.

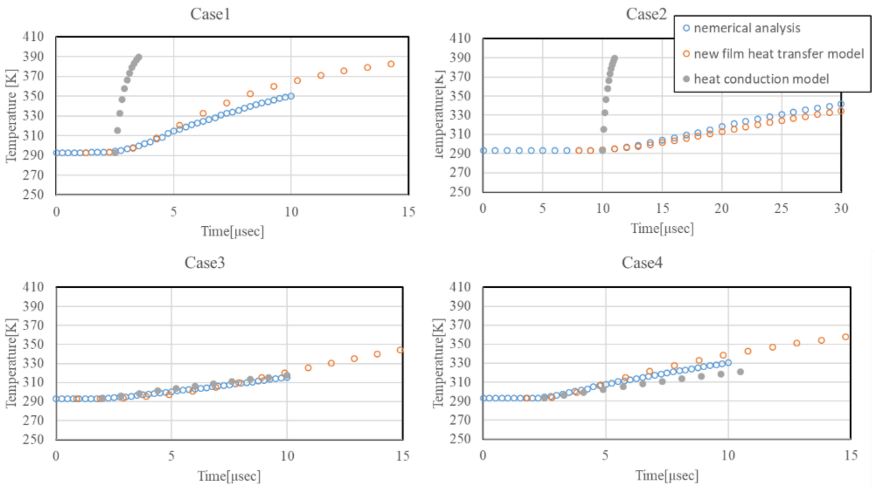

Fig.2 inspection results of new film heat transfer model