

# A study on the Combustion Characteristics of Methanol-Diesel Dual-Fuel Engine

Kei Morita<sup>1)</sup> Taiga Moriwaki<sup>1)</sup> Ryosuke Kogure<sup>2)</sup>

Takafumi Tanaka<sup>2)</sup> Tomohiro Koga<sup>3)</sup> Jin Kusaka<sup>1)</sup>

1) Waseda University, Graduate School of Creative Science and Engineering, Department of Modern Mechanical Engineering  
Room 226, Building 58, 3-4-1 Okubo, Shinjuku-ku, Tokyo, 169-8555, Japan

2) Mitsubishi Heavy Industries Engine & Turbocharger, Ltd.  
3000 Tana, Chuo-ku, Sagamihara-shi, Kanagawa, 252-5293, Japan

3) Mitsubishi Heavy Industries, Ltd.  
3-2-3 Marunouchi, Chiyoda-ku, Tokyo, 100-8332, Japan

**KEY WORDS:** Methanol, Dual fuel engine, Methanol energy ratio, 3D-CFD simulation [A1]

In recent years, environmental issues such as global warming have been accelerating and many countries are making various efforts to achieve carbon neutrality by 2050. Methanol has attracted attention as a low-carbon fuel that is relatively easy to synthesize and has good transport and storage properties due to its liquid state at room temperature and atmospheric pressure. Consequently, methanol-diesel dual-fuel engines (MDDF engines) are considered promising for use in ships. However, computational results have not been sufficiently validated against experimental data under a wide range of conditions. Therefore, it is essential to experimentally investigate combustion behavior and improve the accuracy of the numerical simulation.

In this study, visualization experiments were conducted using a rapid compression and expansion machine at an engine speed equivalent to 850 rpm and a constant total heat input energy of 4.31 kJ. The effects of methanol energy ratio, excess air ratio, and diesel injection timing on combustion characteristics were investigated through pressure and R.H.R. history analysis. The results at a diesel injection timing of -17.5 deg.ATDC showed that ignition delay time was prolonged and IMEP decreased as methanol energy ratio increased or excess air ratio decreased. Moreover, excessively advancing or retarding diesel injection timing resulted in misfire due to the lower cylinder temperature and degradation of diesel spray quality. Additionally, it was confirmed that advance limit of diesel injection timing was independent of excess air ratio and depended only on methanol energy ratio. A reaction mechanism was selected by comparing experimental measurements of laminar flame velocity and ignition delay time with values calculated using a detailed chemical reaction simulation. Two reaction mechanisms showed close agreement with experimental results, and Liu scheme<sup>(1)</sup> was chosen because it reproduced experimental results well in low temperature range of 750 to 900 K. Additionally, it consists of only 58 species and 182 reactions, which reduces the computational cost. A 3D-CFD model was developed by combining the SAGE model and G-equation models. The model was calibrated by adjusting two coefficients,  $b_1$  and  $b_3$ , in Pitsch's equation<sup>(2)</sup> for turbulent burning velocity, which is shown below. It was confirmed that the calibrated model reproduced not only the pressure and R.H.R history, but also the flame propagation from the combustion chamber to the external region. Furthermore, as methanol energy ratio increased, the combustion duration became longer, the thermal efficiency decreased, and exhaust loss and unburnt loss increased. However, the cooling loss decreased since the in-cylinder temperature was lower.

$$s_t = s_l \left( 1 - \frac{b_3^2 s_l \mu_t}{2 b_1 \mu u'} + \sqrt{\left( \frac{b_3^2 s_l \mu_t}{2 b_1 \mu u'} \right)^2 + \frac{b_3^2 \mu_t}{\mu}} \right)$$

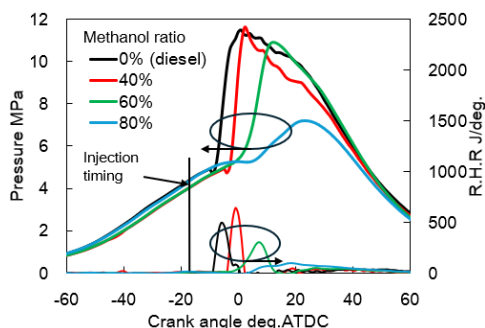


Fig. 1 Comparison of pressure and R.H.R history for varying methanol energy ratio (850 rpm,  $\lambda=2.0$ , total heat input=4.31kJ, diesel injection timing=-17.5 deg.ATDC)

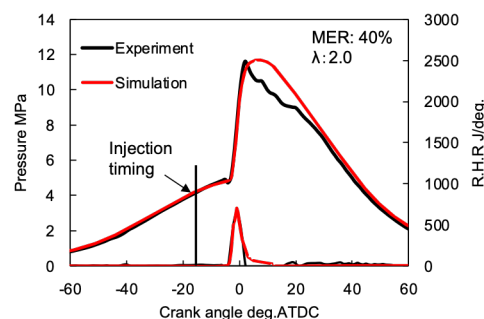


Fig. 2 Calculation validation against experimental data about pressure and R.H.R history (850 rpm, total heat input=4.31kJ, diesel injection timing=-17.5 deg.ATDC)

(1) Shuqi Liu, Ting Sun, Lei Zhou, Ming Jia, Wanhui Zhao, Haiqiao Wei : A new skeletal kinetic model for methanol/ n-heptane dual fuels under engine-like conditions, Energy, 263, 125648, 2023, doi: 10.1016/j.energy.2022.125648

(2) Pitsch, H., A G-equation Formulation for Large-Eddy Simulation of Premixed Turbulent Combustion, Center for Turbulence Research Annual Research Briefs, Stanford University Center for Turbulence Research, 2002.