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Study of engine combustion in cold start in use of rich methanol blended fuel

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Introduction: In the global effort to achieve carbon-neutral society, the use of carbon-neutral fuels in internal combustion engines is very promising alongside vehicle electrification. Green methanol, in particular, is projected for increased production(1). However, methanol presents challenges for applications due to its low distillation point, high latent heat of vaporization, and low heating value. Previous studies on four-wheel vehicles have addressed characteristics such as air-excess ratio, fuel supply, ignition timing, and exhaust emissions. In contrast, motorcycle engines—designed for high speed and high output across a wide operating range—tend to exhibit combustion instability at low speeds. There are concerns that methanol-blended fuels further degrade cold-start performance and combustion stability. This report explores directions for addressing combustion challenges during cold-start and idling identified in previous work.

Experimental Methodology: Experiments were conducted using a motorcycle equipped with a 154 cm^3 single-cylinder, air-cooled, four-stroke engine. Three fuels were tested: 100% gasoline (M0), a 50/50 gasoline-methanol blend (M50), and 100% methanol (M100). Testing was conducted at four engine temperatures: 20°C (standard cold-start), 50°C (mid-warm-up), 80°C (fully warmed), and 7°C (simulated winter start). Combustion stability was evaluated using the Coefficient of Variation (COV) and the Lowest Normalized Value (LNV) of Indicated Mean Effective Pressure (IMEP) between the 51st and 150th cycles post-start. Fuel injection and ignition timing were controlled via a MoTeC M800 ECU.

Results and Discussion: In motorcycle engines, idling IMEP is naturally low (below 200 kPa). While advancing ignition timing (from 7° BTDC to 12° BTDC) was expected to improve combustion, it increased engine speed. To maintain the target 1800 rpm, the throttle had to be closed, reducing charging efficiency. This led to a longer combustion duration and, paradoxically, worse stability—especially at 20°C where misfires occurred. Methanol's high latent heat significantly impacts in-cylinder gas temperatures. Simulation data showed that at 20°C, the compression-end temperature for M100 is approximately 100°C lower than for gasoline. Enriching the mixture to lambda0.8 increased the latent heat of vaporization further, lowering the temperature and failing to improve stability at 20°C. This suggests that conventional enrichment strategies used for gasoline are ineffective for methanol at low temperatures. To promote vaporization, a glow plug-based "port heater" was installed on the intake port floor, as shown in Fig.1. At 7°C, the engine failed to start without heating but started successfully when the port was heated to 35°C. Both IMEP history were shown in Fig.2. For M50 and M100 at 20°C, port heating significantly improved COV and LNV. Emission analysis indicated that while heating reduced unburned methanol, it increased formaldehyde (HCHO) concentrations, particularly for M50 at 7°C.

Conclusion: Advanced ignition timing during idling does not necessarily improve methanol combustion because the required reduction in intake pressure offsets to keep idling speed. Enrichment of the mixture with high-concentration methanol lowers in-cylinder temperatures due to latent heat, contributing to instability. Heating the intake port floor effectively promotes vaporization and improves cold-start reliability, but further measures—such as increasing the effective compression ratio, miture improvement—are necessary for stable idling after cold start.

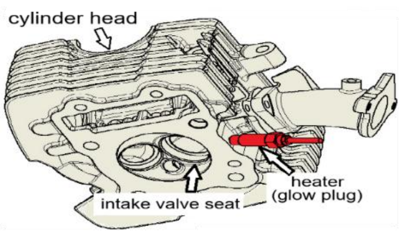
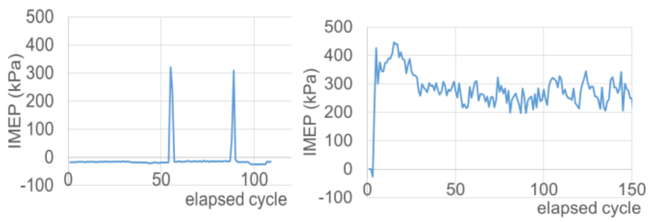


Fig.1 Illustration of Port-Heater Installation



a) w/o Port-Heater b) w/ Port-Heater

Fig.2 IMEP History in 7℃ Cold Start with M100

(1) Methanol Institute：Accelerating the Net-zero Transition：https://www.methanol.org/wp-content/uploads/2024/08/2024-AramcoMI-Joint-Report.pdf (2024).

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