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A Study on Factors Affecting Water Evaporation from Emulsified Oil in a Hydrogen Engine

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Hydrogen internal combustion engines are promising for heavy-duty vehicles, but hydrogen combustion produces more water than diesel engines and may cause oil emulsification. It has been suggested that, in hydrogen engines, water repeatedly condenses and evaporates depending on oil temperature and operating conditions. In winter conditions, however, evaporation may be insufficient, and water can remain in the oil, degrading lubrication performance. Therefore, suppression of condensation and promotion of evaporation are required. In this study, the latter approach was investigated by unit tests focusing on humidity and container shape, and the contribution of each factor was evaluated using multiple regression analysis.

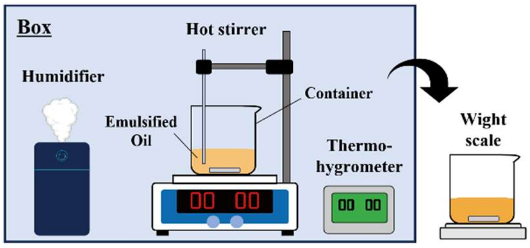


Fig.1 Schematic of Test System

Figure.1 shows the experimental setup used to evaluate water evaporation from emulsified oil. The test was conducted in a sealed chamber where temperature and humidity were controlled. Emulsified oil was heated and stirred at a constant temperature, and the evaporation amount was determined from the mass difference before and after the test. Multiple regression analysis was performed using evaporation amount as the dependent variable and oil temperature, time, bottom surface area, initial water content, humidity, and container shape as explanatory variables.

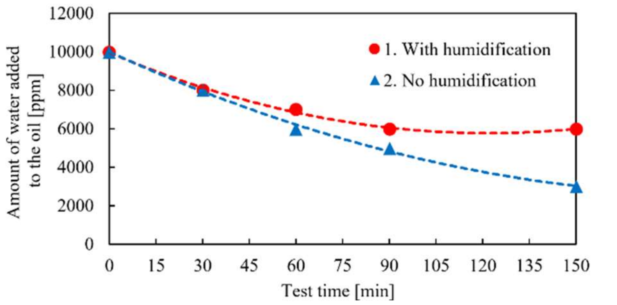
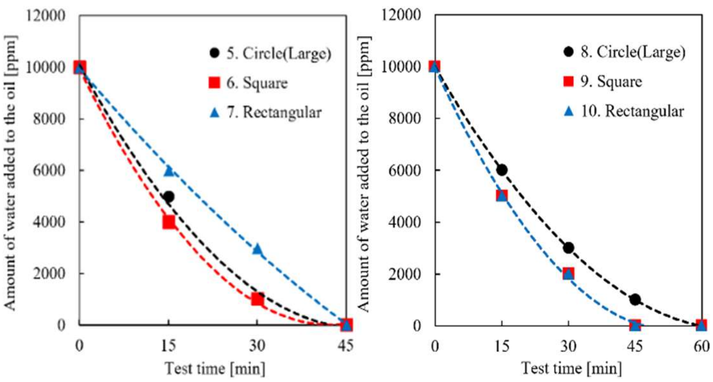


Fig.2 Effect of Humidity during the Test

Figure.2 shows the effect of humidity on water evaporation. Evaporation was suppressed under high humidity conditions due to increased vapor pressure, which reduces the diffusion of water vapor from the oil surface. This effect was mainly observed at low oil temperatures, while it became less significant at higher temperatures.

Figure.3 shows the effect of container shape on water evaporation. At low stirring speed, evaporation corresponded to the bottom surface area of the container. However, at higher stirring speed, this relationship changed due to increased surface disturbance, which affects the effective evaporation area.



(a) 200rpm (b) 350rpm

Fig.3 Effect of Container Shape on Water Evaporation

Table.1 shows the results of the multiple regression analysis. Oil temperature and time were the dominant factors governing water evaporation, followed by the bottom surface area of the container and initial water content. In contrast, humidity and container shape were not significant under all conditions, but their influence increased under low oil temperature conditions.

In conclusion, water evaporation from emulsified oil was mainly governed by oil temperature and time, while the effects of humidity and container shape became apparent under lower temperature conditions. These findings suggest that maintaining higher oil temperature is effective for promoting evaporation. The unit test results suggest applicability to real engines with further investigation.

Table1 Standardized Partial Regression Coefficient and p-value for each Explanatory Variable

Explanatory variable		Standardized partial regression coefficient β_i	p-value (<0.05)	
Ave. Oil Temp.	T_0	0.833	2.70×10^{-16}	○
Test time	t	0.619	3.60×10^{-11}	○
Static Liquid Surface Area	S	0.335	2.48×10^{-4}	○
Initial Water Content	W_0	0.273	1.19×10^{-4}	○
Rectangular	D_R	-0.140	6.00×10^{-2}	×
Square	D_S	-0.116	1.85×10^{-1}	×
Ave. Humidity	H	-0.0444	4.88×10^{-1}	×
Ave. Air Temp.	T_a	0.0312	6.23×10^{-1}	×