

A Study on Waste Heat Recovery Efficiency Using Thermoelectric Modules in Hydrogen Engines

Itsuki Motomiya¹⁾ Ryosuke Ichimura¹⁾ Satofumi Maruyama¹⁾ Koichi Nishibe¹⁾ Akemi Ito¹⁾
 Koji Kikuhara²⁾ Miyuki Usui³⁾ Yuma Osawa¹⁾

1) Tokyo City University
 1-28-1 Tamadutumi, Setagaya, Tokyo, 158-8557, Japan (E-mail: itsuki207nbr@gmail.com)

2) Waseda University.
 3-4-1 Okubo, Shinjyuku, Tokyo, 169-8555, Japan

3) RIKEN NPR City University
 8-1 sanbanyo, Chiyodaku, Tokyo, 102-8202, Japan

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Hydrogen engines could be a promising option for achieving Japan's goal of carbon neutrality by 2050, owing to their low implementation cost and durability based on established engine technology. Improving efficiency is essential, and exhaust heat recovery is an effective approach. In port-injection hydrogen engines, a high air-fuel ratio (λ) results in relatively low exhaust temperatures, enabling the use of thermoelectric module suitable for low-temperature operation. Another option is installing the thermoelectric modules in the oil-pan, where temperature change is moderate and stable power generation is expected.

On-road tests were conducted using a hydrogen-powered small truck with a 3 L engine. Temperatures were measured at eight locations as shown in Fig. 1. Thermocouples were directly attached at red-circled points, while at yellow-circled points, thermoelectric devices were installed and temperatures were measured on their outer surfaces, which was the cold side of the modules. Tests were conducted over three days, with approximately one hour of operation per day.

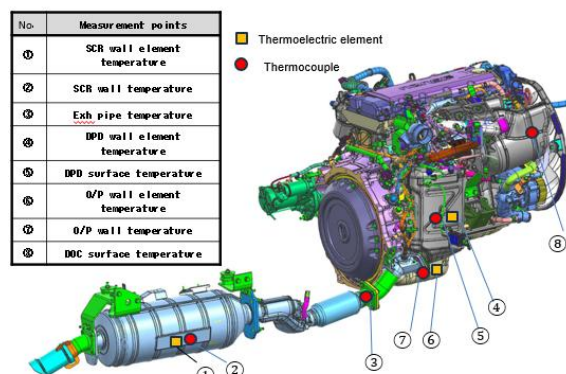


Fig.1 Measurement Point

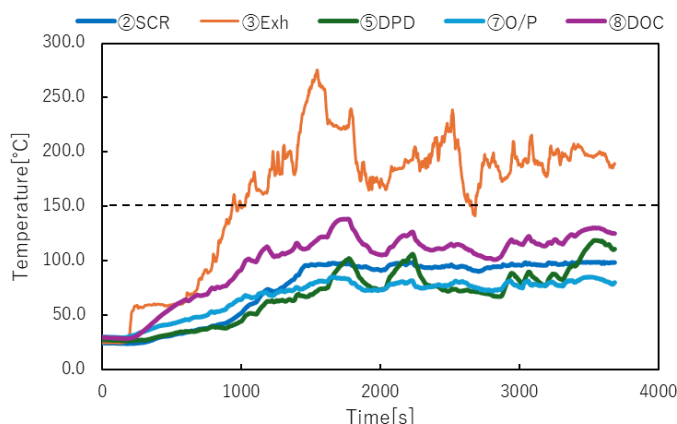
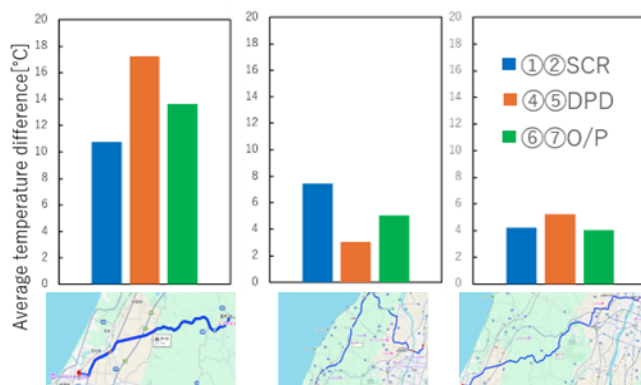


Fig.2 Engine Temperature Measurement Results

Fig. 3 shows the temperature difference between the hot side and cold side of the modules. SCR locations ① and ② exhibited the largest temperature differences under 24 °C and 5 °C, but not at 8 °C, suggesting a strong dependence on operating conditions. It was suggested that the Thermoelectric modules should be installed on SCR in the case of the tested engine

Fig. 2 shows that all locations remained below 150 °C except for the exhaust pipe ③, despite variations in operating and ambient conditions, indicating suitability for Bi₂Te₃ thermoelectric modules.



(a) Outside 24°C (b) Outside 5°C (c) Outside 8°C

Fig.3 Time Averaged Temperature Difference