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Visualization and temperature variation for forced air cooling of electronic engine control unit (ECU)

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In recent years, the number of ECUs installed in automobiles has been increasing, but in order to improve the efficiency of vehicle development, we are proceeding with the consolidation and integration of functions of powertrain control ECUs agaist the background of higher performance semiconductors. As a result, ECUs procude more heat, and thermal requirement becomes severe. In the engine control ECU installed in the engine compartment, the thermal design may be performed assuming the air flow, and in the future, the thermal design that more efficiently uses the air flow will be required. Regarding cooling using airflow, the effect of vortices on the flat plate to promote heat transfer has been confirmed from previous studies. Therefore, in this paper, in order to enable thermal design considering the airflow and vortex around the engine ECU, the airflow around the engine ECU is visualized by changing yaw angles and wind speeds with and without the presence of votrex generators. The temperature change of the engine and the wind velocity and temperature near the surface are measured. The purpose of this study is to clarify the cooling effect of airflow and vortex generators. Utilization of airflow in the thermal design of engine ECUs is important for reducing the environmental load of automobiles and supporting multi-functionalization, and we believe that the importance will increase even if the electrification of automobiles is expected in the future.

In this experiment, the smoke generated by the smoke generator is flowed into a small wind tunnel (jet outlet size 150 x 150 mm), and the tracer is made to follow the flow field. A laser sheet is incident from the downstream side to visualize the 2D cross section of the jet. The central flow velocity at the wind tunnel exit was 1.05 m / s. A high-speed camera was used for recording. Visualization experiments were performed with yaw angles of 0° and 90° for the air flow. Vortex generators was created based on Torii et al. (1994). This vortex generator was installed on the upstream side of the engine ECU. 0.48 Ω resistors and RTV rubber adhesives were used to reproduce the heat generated by the engine ECU. Ten thermocouples were used to measure the internal temperature of the engine ECU, and they were attached to the inner surface of the upper surface. In experiments, using a large wind tunnel, the temperature was measured by changing the wind speed from 0.5 to 2.5 m / s in 0.5 m / s increments.

When the yaw angle was 0°, the flow on the upper surface of the engine ECU was separated near the trailing edge, and it was observed that no particular separation occurred on the lower surface. When the yaw angle is 90°, flow separation occurs from the vicinity of the leading edge on both the upper and lower surfaces. At a wind speed of 0.5 m/s, the presence or absence of a vortex generator had almost no effect on the temperature, but at 1.0 m/s, a temperature drop of about 3°C was confirmed. At a yaw angle of 90°, although a temperature drop of about 2°C was confirmed for both the vortex generator at a wind speed of 1 m/s, there was no difference between the vortex generator and the plate only. This is thought to be due to the large effect of flow separation. Comparing the cases of yaw angle 0° and 90°, the average temperature of yaw angle 0° where flow separation occurred near the trailing edge was about 5°C to 10°C lower. The engine ECU is installed in various orientations. Currently, assuming cooling by natural convection, the fin shape is such that the cooling effect is enhanced at a yaw angle of 90°, but it is difficult to obtain the cooling effect depending on the direction of the air flow.

Since the air cooling effect changes when the mainstream temperature changes, the air cooling promotion effect due to the change in wind speed is defined as follows.

(Air cooling promotion effect) = $(T_{0\,ave} - T_{x\,ave}) / (T_{0\,ave} - T_{\infty}) \times 100$ [%]

Here, $T_{0\,ave}$ [℃]: average temperature without vortex generator, $T_{x\,ave}$ [℃]: average temperature with installation, T_{∞} [℃]: mainstream temperature. The air-cooling promotion effect of the vortex generator at a yaw angle of 0 ° is about 8%, which is larger than the maximum of 4% for the plate alone. On the other hand, an air-cooling promotion effect of about 2-5% was confirmed even at a yaw angle of 90°, but there was no significant difference between the vortex generator and the plate alone.