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Study of Boundary Conditions in CFD Analysis of Brake Disc

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Brakes in automobiles function to control the movement of the vehicle by converting its kinetic energy into thermal energy. During driving, a huge amount of energy must be converted, resulting in an extremely large amount of heat being absorbed by the brake disc, brake pads, and brake caliper. This issue is particularly pronounced when potential energy is converted into kinetic energy, such as when descending a mountain pass, or in motorsports, where repeated acceleration and deceleration cause frequent increases and absorption of kinetic energy, leading to significant temperature rises. To mitigate these temperature increases, the cooling performance has been improved by designing ventilated disc shapes. In brake system design, the thermal capacity (mass) and cooling performance of the brake disc are estimated to determine the optimal shape to suppress temperature rise. However, since brake discs are generally installed inside the wheel, their cooling is considered to be strongly influenced by the vehicle body and suspension components. In other words, even with the same disc shape, it is difficult to estimate cooling performance during actual driving when either the vehicle or the disc shape changes significantly.

In recent years, improving vehicle fuel efficiency and electric power consumption has become important for environmental reasons, and thus the weight reduction of brake components is increasingly required. To achieve further weight reduction, it is necessary to accurately estimate and design based on actual usage conditions. The purpose of this development is to accurately grasp the airflow around the brakes when mounted on the vehicle and to reproduce it precisely in CAE analysis, thereby achieving reliable temperature estimation and improved cooling performance. In conventional methods, simplified initial temperature values were used, which led to a significant discrepancy between analysis results and actual vehicles when the shape or cooling performance changed greatly. Furthermore, since the cooling performance of the brake disc increases in direct proportion to the airflow passing through the ventilated part, it is extremely important to determine the amount of passing airflow. However, this airflow varies due to external factors (vehicle shape) and internal factors (brake disc shape). Conventional methods estimate external factors based on past actual vehicle data, so they cannot account for changes when the vehicle side is modified. As a result, it becomes difficult to estimate cooling performance when installed on actual vehicles.

In this study, the implemented method forms the initial temperature distribution by simulating braking and applying heat input, instead of using fixed initial temperature values as in conventional methods, thereby providing a continuous temperature distribution within the brake disc through thermal conduction. The analysis was conducted under two conditions: with and without a brake duct.

In the case with a brake duct, actual vehicle measurements showed that the inlet airflow speed of the brake duct was proportional to the driving speed. Under this condition, the temperature change in the analysis closely matched that in the actual vehicle(Fig. 1).

In the case without a brake duct, the discharge airflow speed at the outer circumference of the brake disc was measured by rotating only the axle to understand the phenomenon. The measurement results showed a tendency for the airflow speed to decrease when the wheel was mounted. This tendency could not be reproduced in an analysis model consisting only of the brake disc and wheel, but it was reproduced when a shielding plate was added to the inner circumference side of the brake disc.

From this result, it is considered that the decrease in airflow speed when the wheel is mounted is due to the presence of intake resistance, causing the pressure on the inner circumference side of the brake disc to be lower than the surrounding pressure. As a result, the pressure at the outer circumference of the brake disc becomes higher, and the work of the disc is consumed in increasing the static pressure, therefore preventing the airflow speed.

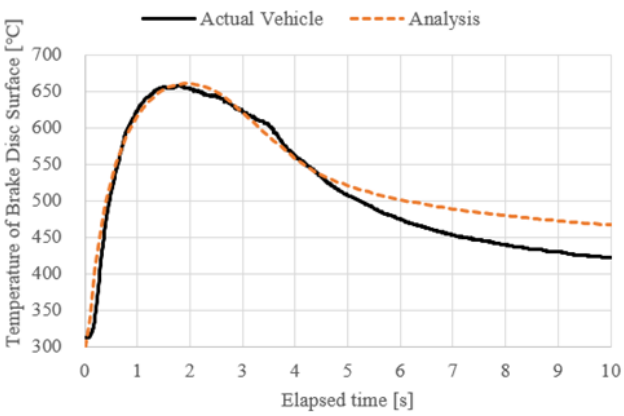

Fig.1 Temperature Change with Brake Duct