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Development of an Electronically Controlled On-demand Braking System

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Global warming has been taken up worldwide as an environmental problem, and government has declared that they will become carbon neutral by 2050, making the reduction of CO_2 emissions an essential theme. CO_2 emissions from automobiles are not small, and countermeasures are needed. In recent years, electric vehicles such as hybrid and battery electric vehicles have been rapidly expanding. In addition to the need to support regenerative coordinative braking technology, there is a demand for braking systems that can contribute to improved fuel efficiency by reducing the size and weight of braking systems. On the other hand, the market for autonomous driving vehicles expand rapidly, and the performance requirements for braking systems, such as the fail operation performance in case of system failure, tend to increase. From these backgrounds, we have developed a compact and advanced on-demand electronically controlled brake system (hereinafter referred to as ECB) that can realize the smooth blending of regenerative and friction braking for electric vehicles combined with the conventional ESC (Electronic stability control) unit to make a redundant brake system.

The ECB, which is the main pressure source, consists of a master cylinder, stroke simulator, power supply unit, linear solenoid valve for regulating pressure, pedal stroke sensor, hydraulic pressure sensors, and ECU. The power supply unit consists of a high-flow gear pump and brushless motor. A highly responsive brushless motor is used for normal brake operation, and an on-demand braking system is used to discharge the required amount of fluid from the pump when the driver requests braking. The linear solenoid valve regulates fluid discharged from the power supply unit, and realizes seamless hydraulic control while relieving the fluid. One is fed into the servo chamber behind the output piston of the master cylinder, which activates the output piston to supply fluid to the two wheel cylinders via ESC. The other is fed directly to the ESC without going through the master cylinder and supplies fluid to the remaining two wheel cylinders.

This paper describes the proposed ECB's miniaturization efforts. To achieve miniaturization, we approached the problem from the viewpoint of both overall length and body size. The former point is to secure a large effective fluid volume, which was achieved by adopting a single master cylinder and an oil channel configuration that directly sends fluid from the power supply. The effective fluid volume could be increased with the same overall length as that of the current ECB, and a substantially smaller size was achieved. For the latter, the target value was set to fit into the silhouette of a 9-inch booster applied to a compact vehicles. The key to achieving this goal is the size of the motor, particularly its axial length. One of the trade-offs of achieving this goal is the limitation of motor output torque, which in turn limits the generable pressure that can be output by the ECB.

As a countermeasure against the generable pressure limitation due to miniaturization, the ESC assisted control is developed to compensate for the pressure shortage by utilizing the pressurized redundant configuration. Because the fluid required for ESC pressurization is supplied from the ECB due to the system configuration, there was concern that the fluid required for ECB pressurization would be insufficient when simultaneous pressurization was performed, resulting in a pressure drop, and this control interference was an issue. In response to this, a countermeasure was implemented to supply the fluid necessary for ESC pressurization by increasing the ECB motor speed above normal. As shown in Figure 1, the pressure generated by ECB pressurization does not change even when ESC assisted control is performed, and it was confirmed that both systems of pressurization can be achieved and wheel cylinder pressure is increased above the pressure that can be generated by ECB.

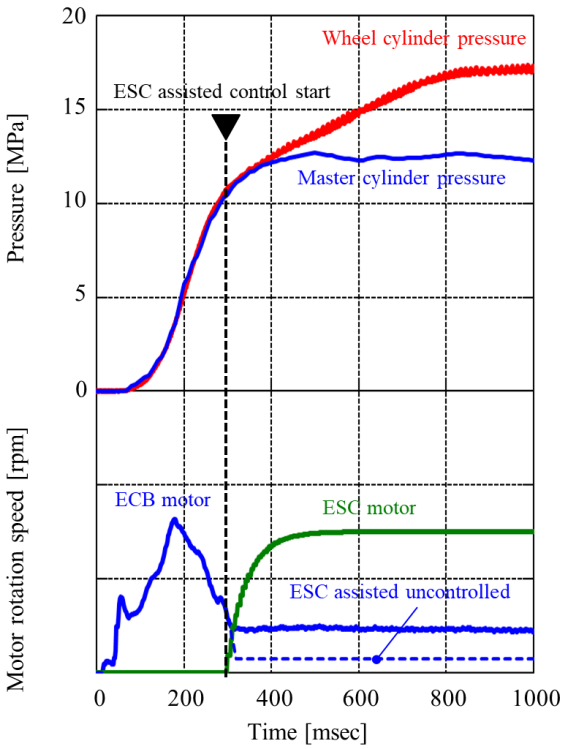

Fig.1 Experimental result of ESC assisted control