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Development of in-tire inflation system for controlling tire dynamic characteristics

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Tire pressure significantly influences ground contact characteristics, cornering performance, wear, noise, vibration, and harshness (NVH), and rolling resistance. A numerical investigation of variations in longitudinal force, lateral force, and aligning torque at different tire pressures indicated that insufficient front- and rear-tire pressures can induce understeering and oversteering tendencies, respectively. Furthermore, changes in tire pressure can alter the stiffness of the tire sidewall, thereby modifying tire characteristics relevant to vehicle dynamic performance.

Conventional central tire inflation systems enable pressure control during driving; however, they require external compressors and rotary joints, which limit their application in passenger vehicles due to system complexity and cost. Therefore, there is an urgent need to develop a cost-effective system that enables tire-pressure control from within the vehicle.

To address this issue, this study proposes an In-Tire Inflation System (ITIS) that enables tire pressure adjustment using a flexible pressure tube installed inside the tire. The proposed system, shown in Fig. 1, consists of an in-tire pressure tube and an airflow circuit connecting the tire and the pressure tube. The tire and the in-tire pressure tube are independently pressurized using solenoid valves. By setting the pressure of the ITIS higher than that of the tire, air is transferred from the ITIS to the tire, resulting in an increase in tire pressure.

First, pressure increase tests using a prototype system confirmed that a pressure increase of up to approximately 50 kPa can be achieved without an external pneumatic source. The amount of pressure increase in the tire depends on the volume ratio between the tire and the in-tire pressure tube. In this prototype system, the pressure increase was approximately half of the pressure difference between the in-tire pressure tube and the tire.

Second, X-ray computed tomography (CT) was used to visualize the positional relationship between the pressure tube and the internal tire structure. Figure 2 shows a CT image of the ITIS. From the CT image, components such as the wheel, bead (including steel cords), sidewall, tread rubber (including belts), and the in-tire pressure tube can be clearly identified. One key finding is that the in-tire pressure tube comes into contact with the bead region when the pressure of the tube is higher than that of the tire. The results revealed that the contact condition between the in-tire pressure tube and the tire, particularly in the bead and sidewall regions, varies depending on the ITIS pressure state. Due to these differences in boundary conditions, even at the same tire pressure, the tire’s dynamic characteristics can change.

Finally, dynamic tests were conducted to investigate the effect of the contact condition between the in-tire pressure tube and the inner sidewall. Impact excitation tests under unloaded conditions showed a decrease in the first natural frequency when the pressure tube was in contact with the tire structure. These results indicate that the proposed ITIS has the potential to influence tire dynamic characteristics in addition to providing tire pressure control.

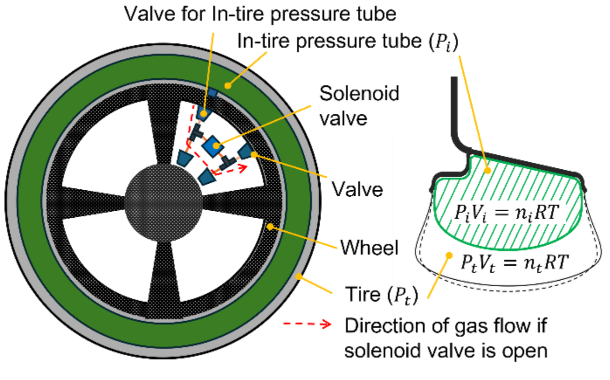

Fig.1 Illustration of proposed in-tire inflation system

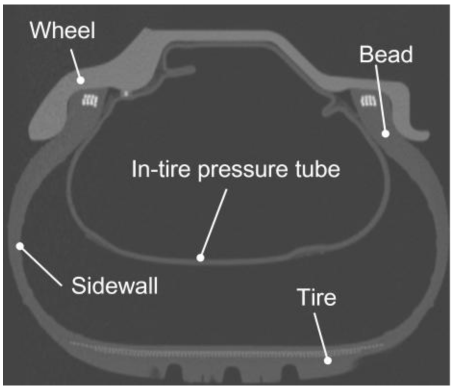

Fig.2 X-ray CT image under the tire pressure 180 kPa and in-tire pressure tube 280 kPa condition