講演番号 111

Measurement of Tire Contact Load Using a Strain-Sensing RFID Sensor Tag

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KEY WORDS: **Safety, Intelligent vehicle, Sensor technology**, RFID, Intelligent tire, Road contact load [C1]

Radio Frequency Identification (RFID) tags are widely used for product identification and condition monitoring, such as inventory management, because they can transmit information wirelessly without an external power supply. In recent years, RFID technology has been increasingly applied to measure temperature, humidity, and electrical conductivity. In the automotive field, developing intelligent tires capable of measuring contact load is essential for improving vehicle safety. While conventional sensors, such as strain gauges and accelerometers, require a continuous power supply, utilizing RFID technology allows for battery-less measurement of these parameters. Therefore, this study aims to conduct a fundamental investigation into measuring tire ground contact load by embedding a strain-sensing RFID tag—an RFID tag equipped with a semiconductor sensor capable of measuring strain—into the internal structure of a tire.

The RFID sensor tag consists of a strain-measuring IC, a printed circuit board (PCB), and two spring antennas. The IC performs strain measurement, signal digitization, and wireless communication, while the spring antennas handle signal transmission and power reception. Tensile testing confirmed that the sensor outputs the difference in strain between its two primary axes. As shown in Fig.1, the tag was embedded in the sidewall of a 235/55R19 tire, and an external antenna receiver was used to capture the strain signals wirelessly. A custom tire test bench, equipped with a two-degree-of-freedom closed-loop loading mechanism and a force plate, was utilized to evaluate the sensor's response (Fig.2).

The experimental results from Test 1 demonstrated that the sensor output varies approximately linearly with the vertical load (F_Z). Although the calibration coefficient varied depending on the tire's rotation angle, the coefficient of determination (R^2) remained high (over 0.98) at most angles, indicating that F_Z can be accurately calculated from the sensor's output. In Test 2, by decoupling the influence of F_Z, it was confirmed that the sensor output also shows an approximately linear relationship with respect to the longitudinal force (F_X) at various rotation angles. By calibrating these relationships in advance, it becomes highly feasible to measure the dynamic tire contact load during vehicle operation based on the sensor outputs. In conclusion, this study confirmed that the developed RFID sensor tag produces an almost linear output for both vertical and longitudinal loads acting on the tire, demonstrating its significant potential as a future battery-less sensor for measuring tire ground contact load.

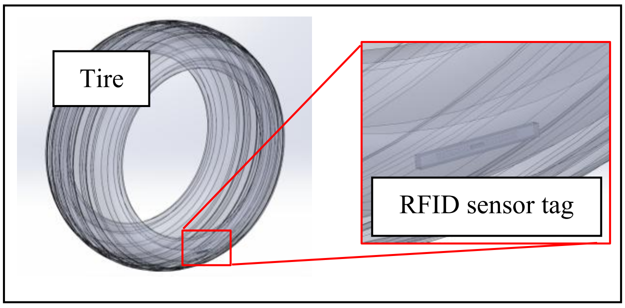

Fig.1 Sensor position in the tire

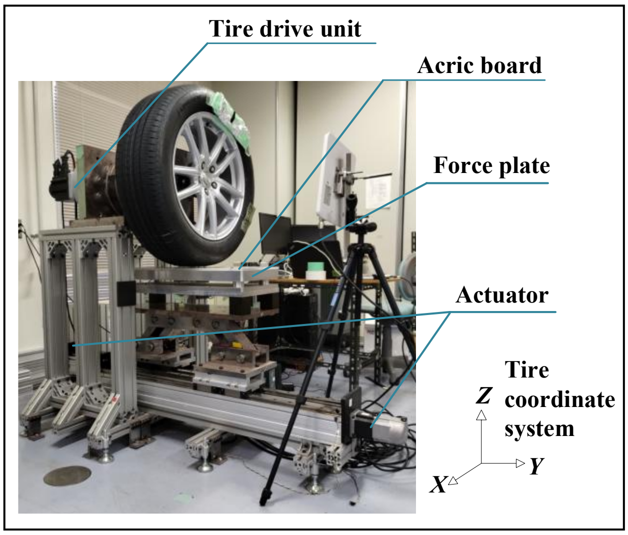

Fig.2 Tire test bench