The 2017 World Congress on
Advances in Nano, Bio, Robotics and Energy (ANBRE17)
28 August - 1 September, 2017, Ilsan(Seoul), Korea

Design of six-axis wireless wheel force transducer for simple installation and operation

*Hyobin Jeong[1], Jeasung Oh[2] and Jun-Ho Oh[3]

[1), 2), 3)] *Department of Mechanical Engineering, KAIST, Daejeon 34141, Korea*
[1)] *dhb111@kaist.ac.kr* [2)] *OJS9101@kaist.ac.kr* [3)] *jhoh@kaist.ac.kr*

ABSTRACT

In this paper, we propose effective design of 6-axis Wheel Force Transducer (WFT) using FEM analysis and suggest our own telemetry data acquisition device for heavy vehicles. By using our structure design, number of strain gages and manufacturing cost can be minimized. Our telemetry transmitter can convert analog signal to digital signal and transfer it through wireless communication. Telemetry receiver can convert wireless signal to analog signal again, so any kind of DAQ equipment is available for receiving our WFT sensor signal.

1. INTRODUCTION

Knowing force/torque exerted on the vehicle from the ground is critical for developing various vehicle control algorithms. In verification process of control algorithms such as ABS (Anti-Braking System) and TCS (Traction Control System), the force/torque data are very important elements. To investigate various phenomenon of the vehicle, WFT is widely used today. (Baffet (2009), Gobbi (2005))

In case of a commercialized WFT, however, its price is expensive and technical data are not available for general user. Therefore, many institutes are trying to develop low-cost and effective WFT. (Lin (2013), Meyer (2001)) However, Existing WFT designs utilize many strain gages and use slip-ring to transfer the signal from rotating part to fixed part, thereby increasing complexity of wiring and installation process. (Fig. 1)

[1)] Ph.D Candidate
[2)] Ph.D Candidate
[3)] Professor

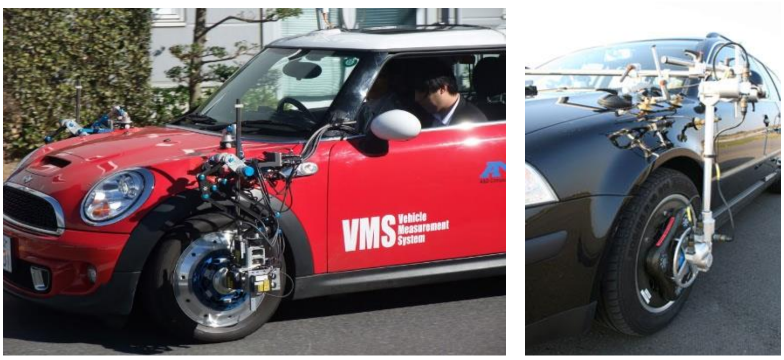

Fig. 1 Complex installation and wirings of commercialized WFT

2. Description of the WFT design and signal processing

Our target measuring capacity is ±5000kgf for each axis force, ±1000kgfm for each axis torque. Structure of WFT is Maltese Cross Element type and it has 4 beams between inner and outer structure (Fig. 2). To detect strain of the structure, we use 16 strain gages. Using 8 half-bridges, we get 8 strain signals which correspond to vertical banding and horizontal banding of each beam. These signal is transformed to 6 axis force/torque component by using decoupling matrix.

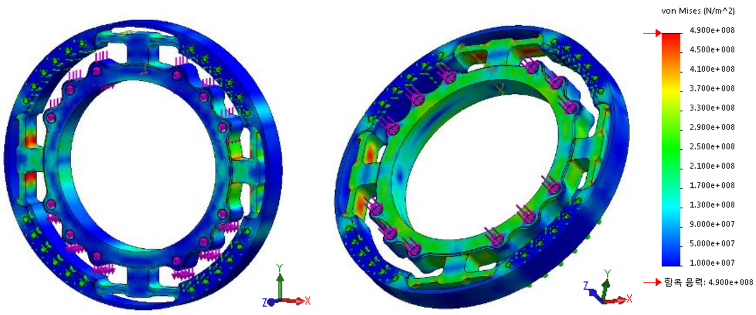

Fig. 2 FEM analysis of WFT structure

To obtain 6×8 decoupling matrix we get a sensor signal from 24 different configurations and compare with theoretical force/torque value and we used least square solution to calculate a decoupling matrix from experimental data.

$$H_{decouple} = FS^T (S\,S^T)^{-1}$$

$S : 8 \times N$ Measured strain value

$F : 6 \times N$ Exerted force/ torque value

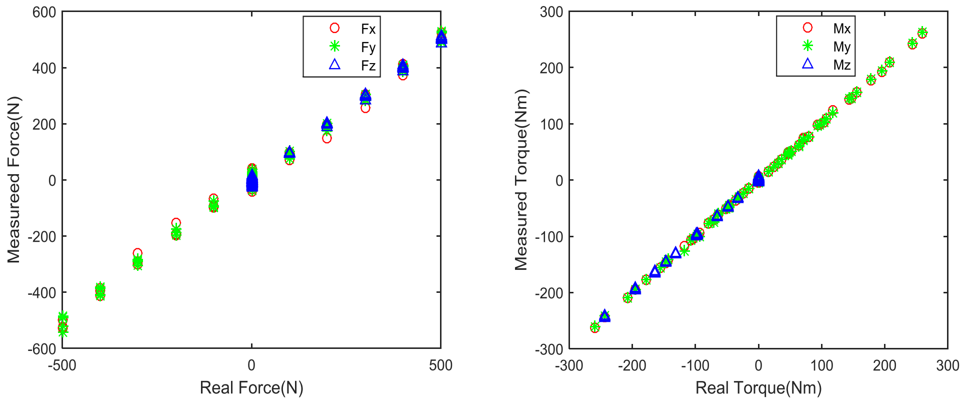

Fig. 3 WFT calibration data plot

Fig. 3 shows calibration data. X axis indicates real exerting force/torque value and Y axis indicates calculated force/torque by using decoupling matrix. Force calibration error is 1.9% (Force Error/Total capacity×100).

In this study we developed a telemetry transmitter and receiver for data acquisition. Our transmitter contains a microprocessor to perform ADC (Analog to Digital Converting) and rotary encoder to measure wheel rotation. Telemetry receiver contains DAC (Digital to Analog Converting) module for analog sensor output. For wireless environment we use class 1 Blue Tooth module.

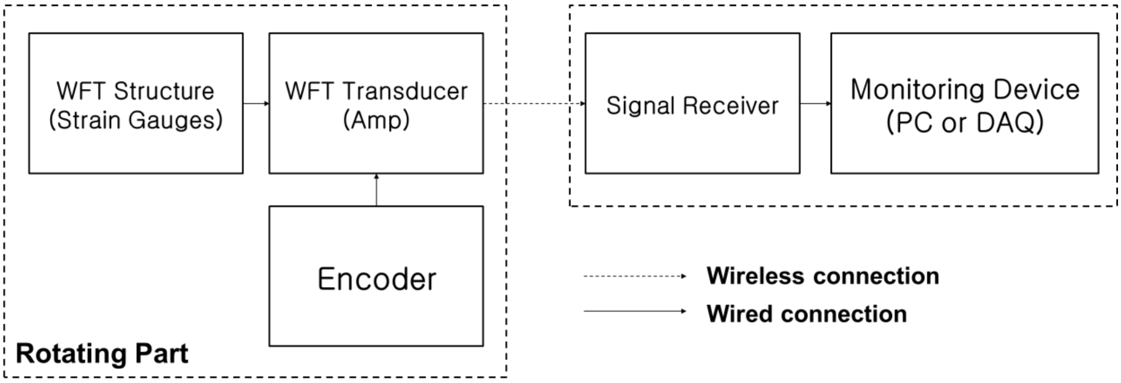

Fig. 4 WFT signal processing block diagram

Fig. 4 shows a signal processing block diagram of our telemetry device. First, strain gage signal is measured by ADC operation, and decoupling matrix and encoder value are used to convert it to force/torque elements in vehicle coordinate. These force/torque values are transferred via wireless communication. Telemetry receiver converts these signal to analog voltage for general DAQ equipment.

3. Experimental Results and Discussion

Proposed WFT in this study contains battery inside, so it is completely operational without any wirings. (Fig. 5) Therefore it is very convenient to install on the vehicle and easy to operate in the real field. (Fig. 6) Our proposed telemetry system does not require any signal post-processing such as calibration and coordinate transformation, so user can directly use the output signal from our telemetry receiver.

Fig. 5 Installation WFT on the vehicle and measuring wheel weight using scale

Fig. 6 Telemetry receiver and Transmitter

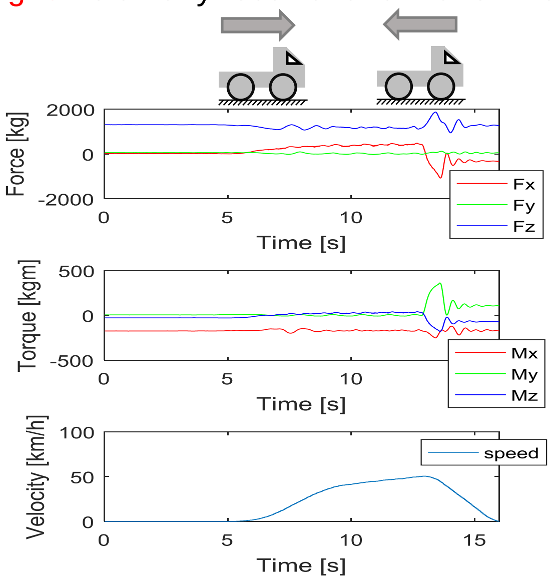

Fig. 7 Driving test of WFT with 2.5 ton truck. WFT is installed left-front wheel. Vehicle accelerate for 10s and brakes at 13s.

We measured sensor accuracy in static situation by putting the vehicle on the scale. We put left-front wheel on the scale and compare with WFT Fz value. Scale shows 1100kg and WFT shows 1150kg, so the error was 2.6%.

Fig. 7 shows driving test result. We can see 'Fz' and wheel axle moment 'My' are increase when the vehicle is braking

REFERENCES

Baffet, G., Charara, A., & Lechner, D. (2009) "Estimation of vehicle sideslip, tire force and wheel cornering stiffness", Control Engineering Practice, vol. 17, pp. 1255-1264

Gobbi, M., Mastinu, G., & Giorgetta, F. (2005) "Sensors for Measuring Forces and Moments With Application to Ground Vehicles Design and Engineering", ASME International Mechanical Engineering Congress and Exposition, pp. 161-168

Lin, G., Pang, H., Zhang, W., Wang, D., & Feng, L. (2013) "A self-decoupled three-axis force sensor for measuring the wheel force", Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 0954407013508278

Meyer, R. A., & Sharp, M. C. (2001) "Optimizing load transducer design using computer-based analytical tools", (No. 2001-01-0787). SAE Technical Paper