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Study on Improving the Accuracy of Stroke Sensors for Steer-by-Wire EPS

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This study investigates methods to enhance the accuracy of stroke sensors used in steer-by-wire electric power steering (EPS) systems. As automotive electrification and automation progress, steer-by-wire technology enables the replacement of mechanical steering shafts with electrical cables, contributing to vehicle weight reduction and design flexibility. To meet the demand for precise wheel angle control, we are developing a stroke sensor capable of directly detecting the position of the rack shaft with a target accuracy of 0.1%FS over a 200 mm stroke.

An inductive position sensor was selected for its robustness against external magnetic fields. Figure 1 illustrates its application in EPS: a metal target is fixed to the rack shaft, and the sensor is mounted parallel to it. However, accuracy degradation occurs due to nonuniformity in magnetic flux density caused by surrounding conductive materials such as housings and rack shafts. This leads to distortion in the sensor's output signal.

To address this, two countermeasures were proposed. The first method involves optimizing the shape of the receiving coils to match the actual magnetic flux distribution. Using electromagnetic simulations, we designed coil geometries that compensate for nonuniformity in magnetic flux density, thereby restoring ideal signal waveforms. The second method applies harmonic correction by adding specific frequency components to the coil design to suppress unwanted harmonics generated by eddy currents in the target area.

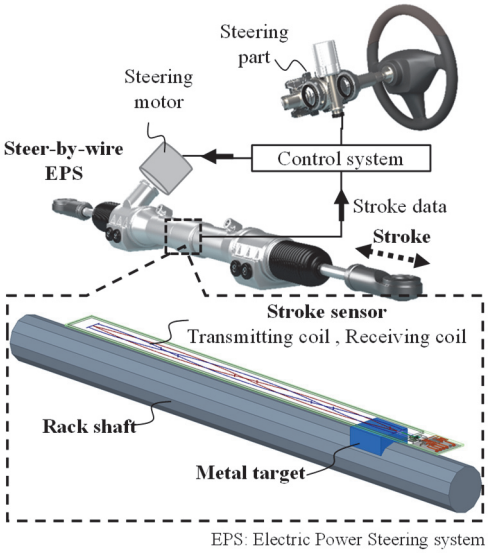
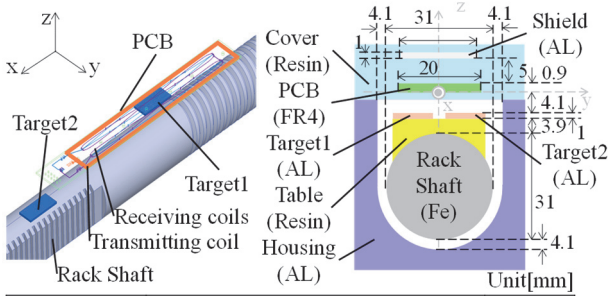


Fig.1 Application image of the Stroke sensor to EPS

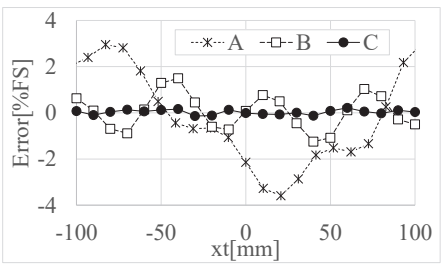
Figure 2 shows the simulation model used to validate these approaches, and Figure 3 shows the comparison of detection errors. Three conditions were compared: A (standard sinusoidal coils), B (optimized coils), and C (optimized coils with harmonic correction). Simulation results revealed that detection error was reduced from 3.60%FS in condition A to 1.50%FS in B, and further to 0.22%FS in C, confirming the effectiveness of the proposed methods.

In conclusion, by optimizing the coil design to the magnetic environment and applying harmonic correction, the accuracy of inductive stroke sensors for steer-by-wire EPS can be significantly improved. Future work will focus on further refinement and product development.



	Dimensions	Material
PCB	T=0.9mm, 4 layers	FR4
Transmitting coil	135x18mm,2turns, L&S=100um, T=18um	Copper
Receiving coils	115 x 11.8mm, L&S=100um, T=18um	Copper
Targets	23 x 8 x 1(T)mm, 4.1mm from PCB	Aluminum

Fig.2 Simulation model



Condition	Optimization of the receiving coils	Harmonic compensation shape	Max (|Error|) [%FS]
A			3.60
B	✓		1.50
C	✓	✓	0.22

Fig.3 Comparison of detection errors