Plastic Sensor Housings for Hall IC Torque Sensor

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Amid the growing demands for a lighter EPS system, we have developed a pinion type EPS (P-EPS) and a dual pinion type EPS (DP-EPS) plastic sensor housing for Hall IC torque sensors. We have achieved housings that have the capability to endure being installed in engine rooms. Moreover, when compared to the conventional aluminum sensor housing, we have lightened the weight of the housings; 148 g (which is 52% reduction) for P-EPS, and 81 g (which is 31% reduction) for DP-EPS.

***Key Words**: electric power steering, torque sensor, Hall IC, sensor housings, plastic, polyamide*

1. Introduction

As part of the improvements to automobile environment responsiveness, we are pursuing ever-increasing inquiries for electric power steering (EPS) system. JTEKT began[1] mass production of Hall IC torque sensors for column-type EPS (C-EPS) in 2006, as a torque sensor for the EPS system. In 2007 we started mass production for a waterproof specification Hall IC torque sensor for pinion-type EPS (P-EPS), and as such we currently support an EPS system corresponding to the needs of customers.

Nowadays there are also increasing demands for weight reduction within EPS systems. This has led to the development of plastic sensor housings for Hall IC torque sensors used in P-EPS and DP-EPS in particular, where weight reduction demands are intensifying. We will introduce this new technology below.

2. Explanation of Hall IC Torque Sensor Mechanism

2. 1 Explanation of Structure

The Hall IC torque sensor is structured from a board assembly and ring assembly mounted to the sensor housing, magnetic yoke assembly mounted to the pinion shaft, and a magnet mounted to the input shaft (**Fig. 1**).

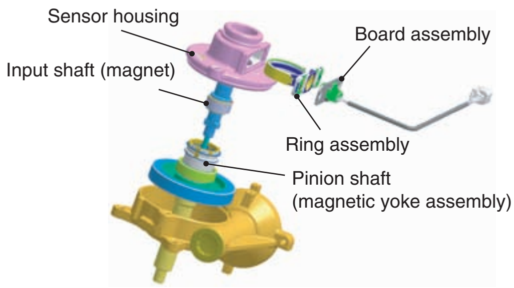


Fig. 1 Structure of Hall IC torque sensor

2. 2 Detection Principle

When steering is not being operated, the yoke core of the magnetic yoke assembly (tooth) short circuits the magnetic flux, and therefore the magnetic flux cannot be transmitted from the ring assembly (ring core) to the Hall IC.

When steering toque is inputted, the relative angle difference is generated for the magnet and magnetic yoke assembly connected with the torsion bar, and the magnetic flux of the magnet is transmitted to the ring assembly (ring core) from the magnetic yoke assembly (yoke core). Steering torque is detected when the magnetic flux proportionate to the twisted angle of the torsion bar is transmitted to the Hall IC in between the protruding part of the ring core[1) 2)]. Detection principle is shown in **Fig. 2**.

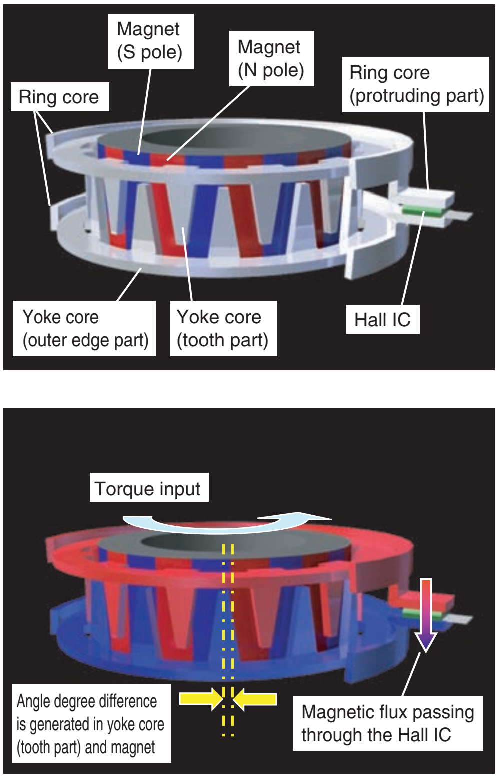


Fig. 2 Hall IC torque sensor detection principle

3. Plastic Sensor Housing

3. 1 Structural Changes

We have unified and created the conventional aluminum alloy sensor housing, and the ring assembly connected to it, in a resin mold. The board assembly was utilized as it is in present products. The structural changes from the conventional product are shown in **Fig. 3**.

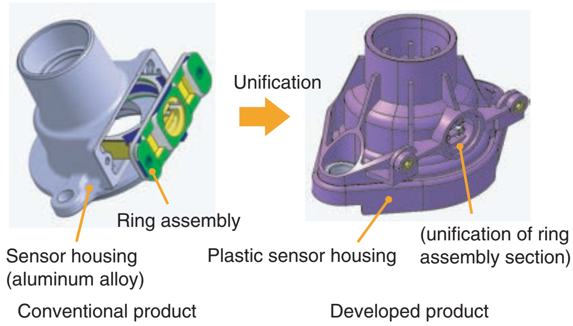


Fig. 3 Structure of sensor housing

3. 2 Demands for Environment-resistance

As the sensor housing is equipped to the engine room within a rough thermal environment outside of the automobile interior, heat resistance and waterproof ability must be taken into consideration. The environmental-resistance ability required for plastic sensor housings is shown in **Table 1**.

Table 1 Demand for environment resistance

Item	Requirement
Temperature and relative humidity	Must be able to withstand the engine room environment
Oil and chemical resistance	Must have resistance to various types of oil, grease, and battery fluid, etc.
Airtightness	Must ensure the airtight ability required by P-EPS and DP-EPS

3. 3 Material Selection

A semi-aromatic polyamide was selected as the material of use, based on its superior characteristics within its environment of use, such as durability in high temperatures, strength, heat resistance, and chemical resistance. The resin utilized is the same as that for the primary molded part and secondary molded part described below in **Item 3. 4**. The characteristics of the material are shown in **Table 2**.

Table 2 Material property

Material		Present	Utilized	Reference	
		Aluminum alloy	Semi-aromatic polyamide	PBT	PA612
Tensile strength	[MPa]	228	190	114	168
Thermal expansion coefficient	[$\times 10^{-6}$]	21	20 (parallel) 50 (Transverse)	20 (parallel) 90 (Transverse)	17 (parallel) 113 (Transverse)
Melting point	[℃]	–	325	225	215
Density	[kg/m^3]	2.68×10^{-3}	1.44×10^{-3}	1.47×10^{-3}	1.32×10^{-3}

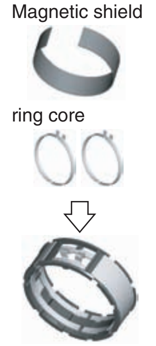
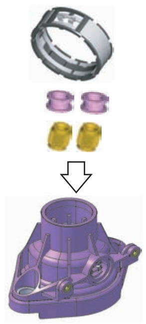
*Numbers are typical values

3. 4 Internal Composition

We have created a structure where we attach the magnetic shield and the ring core (a structural part of the ring assembly) to the primary molded part, and conducted an insert molding for this part to complete secondary molding (**Table 3**).

By adopting the secondary mold structure, we were able to secure position accuracy of the ring core, which influenced the ability of the torque sensor, using a relatively simple die structure.

Table 3 Composition of Plastic Sensor Housing

Process	Primary mold	Magnetic shield, ring core attachment	Secondary mold
Product shape		 Magnetic shield; ring core	

4. Topics in Development

4. 1 Waterproof Compatibility

Since primary molded part and secondary molded part are shaped from the same resin, immersion may occur due to capillary action from the boundary face when the boundary is exposed to the outer part. On the other hand, with the Hall IC torque sensor, it is necessary to continue the magnetic circuit by inserting the board assembly Hall IC part into the protruding part of the ring core, which is embedded in the primary molded part.

By providing the seal face which connects the board assembly and Hall IC to the secondary molded side, we have achieved the connecting of the Hall IC and ring core, without exposure of the primary molded part to the outer side to hinder waterproof ability (**Fig. 4**).

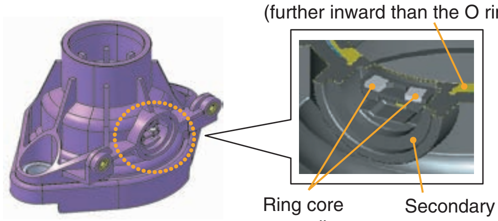


Fig. 4 Structure of Hall IC insertion part

4. 2 Dimension Accuracy and Cracks

Within the manufacturing of resin sensor housing, problems such as:

- Decrease in dimension accuracy due to mold shrinkage
- Crack after thermal shock test (welded part and magnetic shield edge part)

are anticipated to occur. Due to this, we reviewed countermeasures based on FEM analysis, etc. beforehand, and performed the following countermeasures during manufacturing.

- Optimization of gate position/rib position (**Fig. 5**)
- Internal bending of magnetic shield edge part (**Fig. 6**)

Through the results of the above countermeasures, we were able to satisfy the required dimension accuracy, strength and durability (**Table 4**).

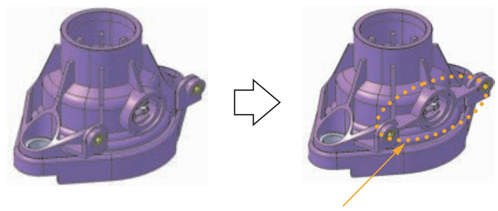


Fig. 5 Case example of rib addition

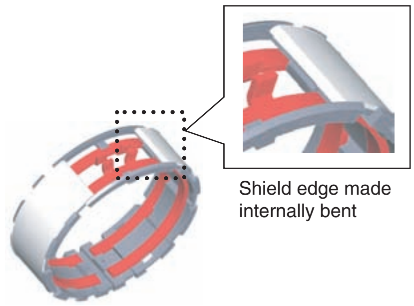


Fig. 6 Structure of magnetic shield

Table 4 Results of reliability test

No	Test Item	Result
1	High temperature storage test	○
2	Low temperature storage test	○
3	Thermal shock test	○
4	High temperature and high humidity test	○
5	Sea water acetic acid test (SWAAT)	○
6	Ice water test	○
7	High pressure washing test	○
8	Oil and chemical resistance test	○

5. Reduction in Mass

By unifying the shapes of the sensor housing and ring assembly, we have achieved weight reduction over the structure of the conventional product (**Item 3. 1**), as well as strength and durability (**Table 5**).

Table 5 Weight reduction of Development product for P-EPS and DP-EPS

	For P-EPS	For DP-EPS
Reduced mass	148 g (52% reduction)	81 g (31% reduction)

6. Conclusion

We have developed a plastic sensor housing for EPS, subsequently contributing to weight reduction in automobiles. We plan to promote continuous development for rising demands within these products.

References

1) Y. Nagahashi, A. Kawakubo, T. Tsujimoto, K. Kagei, J. Hasegawa, S. Kakutani: JTEKT ENGINEERING JOURNAL, no. 1003 (2007).
2) K. Hotta, T. Ishihara: JTEKT ENGINEERING JOURNAL, no. 1007 (2009).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