Development of Torque Sensor Integrated with Plastic Sensor Housing

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Demands for energy saving in automobiles due to environmental concerns have led to the necessity of downsizing automotive parts. As such, there is a demand for lighter weight electric power steering (EPS). By integrating the torque sensor and torque sensor housing used in EPS, we have achieved a 20% reduction in the weight of the torque sensor housing assembly compared with the conventional type. This report highlights the results of the development of this product.

Key Words: *electric power steering, torque sensor, Hall IC, sensor housing, resin, integrate*

1. Introduction

From the perspective of reducing the burden placed on the environment, there has been an ongoing movement in the industry to make automobiles more energy-saving. As part of this, power steering systems are shifting from hydraulic power steering to electric power steering (EPS). Since 2006, JTEKT has mass produced the Hall IC torque sensor[1)] for use on column-type EPS as an EPS system torque sensor and has continuously engaged in the below initiatives.

· Mass production of the waterproof Hall IC torque sensor for use on pinion EPS since 2007[2)].
· In response to a strong demand in recent years to consider the environment, switched to mass production of plastic torque sensor housing instead of aluminum since 2013[3)].
· Most recently, development of an integrated production comprising the plastic torque sensor housing and torque sensor in response to a demand for further weight reduction[3)].

This paper will introduce the results of developing this product; the torque sensor integrated with plastic sensor housing.

2. Explanation of the Hall IC Torque Sensor Mechanism

2. 1 EPS System Structure

Figure 1 shows the structure of the EPS system. The key electrical components of an EPS system are the torque sensor, control unit and motor.

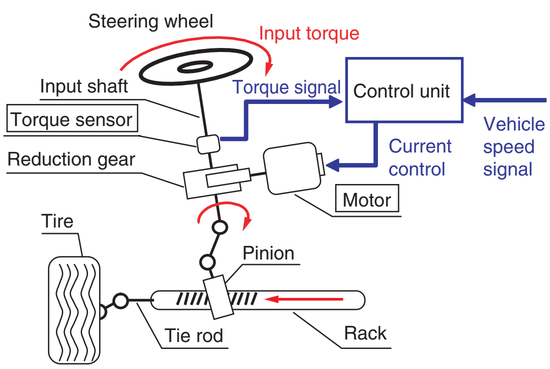

Fig. 1 Structure of EPS system

The steering force from the steering wheel is detected by the torque sensor and that torque signal is sent to the control unit. The control unit controls the amount of electrical current that flows through the motor in response to the torque signal and vehicle speed signal from the vehicle, and then assists steering by applying the appropriate assisting force[2)].

2. 2 Structure of the Hall IC Torque Sensor

The Hall IC torque sensor comprised of a ring core mounted on the sensor housing, a magnetic yoke assembly mounted on the pinion shaft and a magnet mounted on the input shaft (**Fig. 2**)[3).

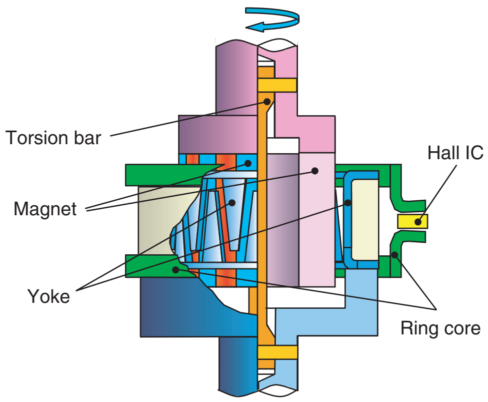

Fig. 2 Structure of Hall IC torque sensor

2. 3 Detection Principle of the Hall IC Torque Sensor

When the steering wheel is not being operated, the yoke core (teeth) of the magnetic yoke assembly short circuits the magnetic flux of the magnet, therefore magnetic flux is not transmitted from the ring assembly (ring core) to the Hall IC.

When steering torque is input, a relative angle difference emerges between the magnet and magnetic yoke assembly 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 proportional to the twisting angle of the torsion bar is transmitted to the Hall IC in between the protruding parts of the ring core. The detection principle is shown in **Fig. 3**[3).

3. Structure of the Integrated Plastic Sensor Housing

The conventional structure is to have the plastic torque sensor housing and the torque sensor separated, however in such a case, as **Fig. 4** shows, there was a need to use two bolts to assemble the housing portion comprising a ring core as the magnetic circuit and collar to mount the torque sensor integrated with a plastic mold to the torque sensor integrating a sensor for detecting a magnetic field from the ring core and plate for assembly. Meanwhile, in the case of the structure of the integrated plastic sensor housing developed on this occasion, as **Fig. 5** shows, the terminal combining a Hall IC and circuit is covered with a holder and the housing is molded based on this holder to integrate the housing with the torque sensor. As a result, the plate, collar and bolts have been eliminated.

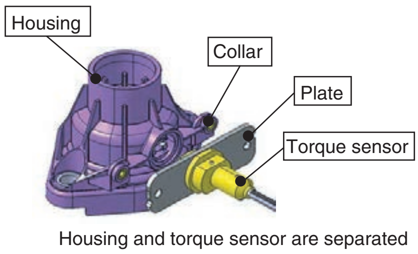

Fig. 4 Structure of conventional product

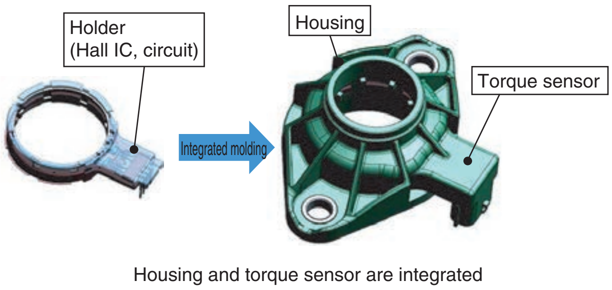

Fig. 5 Structure of developed product

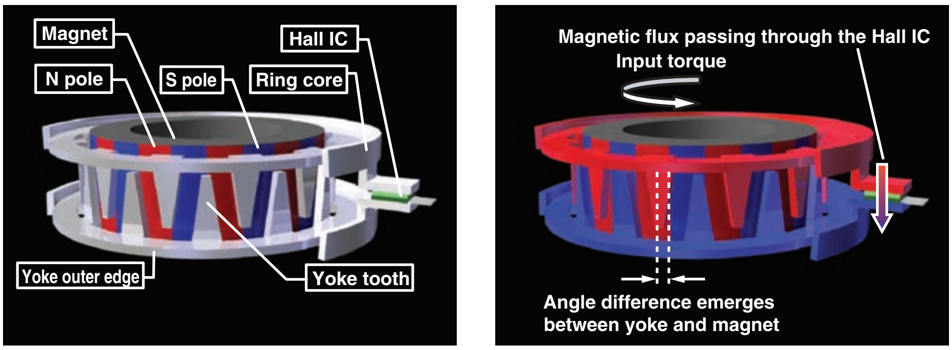

Fig. 3 Principle of detection in Hall IC torque sensor

4. Merits of Integration

By developing an integrated design and eliminating a number of parts, we succeeded in reducing the weight of this product. In addition, the following two merits were obtained.

①Reduction of the tolerance for the positions of the Hall IC and magnetic circuit due to the reduction of parts in the product. This makes it possible to supply a more stable magnetic flux to the Hall IC and improve torque sensor output accuracy.

②Conventionally, water resistance was secured by using an O ring to assemble the housing and torque sensor, however there was concern about the deterioration of the O ring. By integrating the housing and torque sensor, water resistance has been improved and semi-permanent water resistance has been secured (**Fig. 6**).

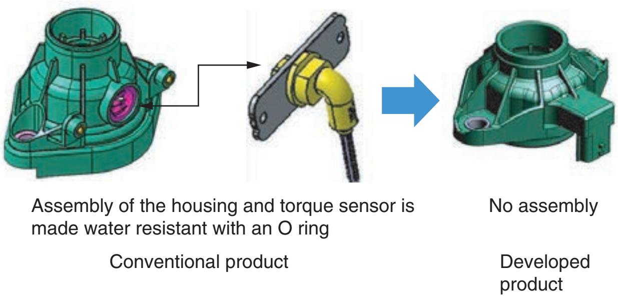

Fig. 6 Improved water resistance

5. Integration Issues and their Countermeasures

5. 1 Protection of Hall IC

The design of the developed product is such that the holder comprising of the Hall IC, etc. is molded together with the housing and, due to this, the Hall IC may be affected by the plastic forming pressure and forming temperature when the mold is created. The Hall IC has low resistance against external force, therefore the design must prevent the Hall IC from being subjected to pressure when the mold is being formed. Moreover, the forming temperature must also be below the temperature that the Hall IC can withstand. To resolve this, as shown in **Fig. 7**, the Hall IC was covered with a holder to prevent it from being affected by the pressure and temperature during integration molding. In specific terms, a rib was positioned around the periphery of the Hall IC storage area which had the effects of increasing rigidity and creating clearance with the Hall IC, thus avoiding contact with the Hall IC during mold forming.

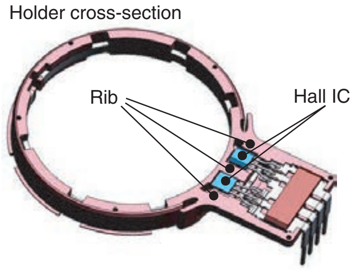

Fig. 7 Hall IC preservation countermeasure

5. 2 Prevention of the Cracks that Form in the Housing

The magnetic shield (steel) and housing plastic (PA6T/6I), which pass through a process of insert molding, have differing linear expansion coefficients, therefore when the temperature changes during the hot and cold shock tests, the edge of the magnetic shield is subjected to excessive stress, causing cracks to form. One of the limitations on molding conditions from the perspective of protecting Hall IC, as mentioned in **5. 1** above, included these cracks that form in housing, as shown in **Fig. 8**, which were discovered from the initial development stage when conducting these tests. As a countermeasure, the portion where stress becomes concentrated was covered with a holder and the design was changed to prevent plastic flowing inside the housing during integration mold formation to prevent plastic from contacting the edge of the magnetic shield during molding, thus preventing concentration of stress. This countermeasure made it possible to prevent cracks.

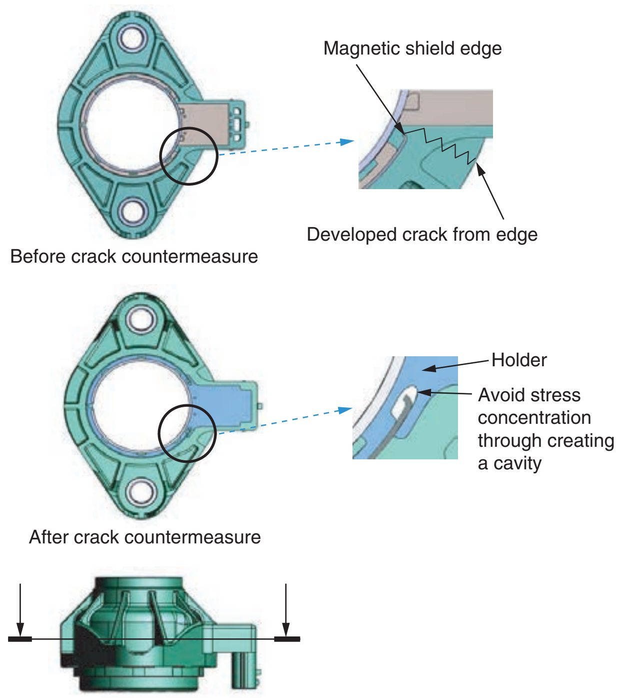

Fig. 8 Countermeasures against cracking

5. 3 Securing Dimensional Accuracy

An FEM analysis elucidated that dimensional accuracy drops as a result of shrinkage after the product is molded due to a high number of parts that are integrated together through molding. To resolve this, we optimized the rib position and molding conditions, thus securing dimensional accuracy (**Fig. 9**).

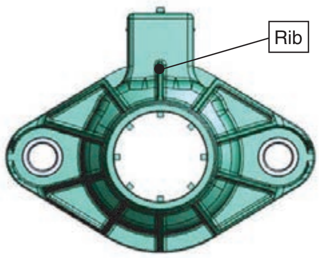

Fig. 9 Rib position

6. Development Results

6. 1 Weight Reduction

By integrating the plastic sensor housing and torque sensor, weight was reduced by 20%.

6. 2 Protection of the Hall IC Portion After Molding the Housing

A Hall IC with the worst dimensional accuracy was used to mold the product using molding conditions such as molding pressure and temperature below their respective upper limits then a cross-section was observed to confirm whether or not the protruding parts of the ring core were making contact with the Hall IC. As a result, it was confirmed that there was no contact, therefore there were no problems.

6. 3 Results of Reliability Tests

Table 1 shows the results of the major reliability tests performed. It was confirmed that there were no problems for all reliability evaluations.

Table 1 Reliability check results

Test item	Result
High temperature storage test	OK
Low temperature storage test	OK
Thermal shock test	OK
High temperature and high humidity test	OK
Vibration test	OK
Shock test	OK

7. Conclusion

This initiative involved the development of a torque sensor integrated with a plastic sensor housing for EPS systems.

Through doing so, we further reduced the weight of vehicles and improved vehicle reliability. Moving forward, we will promote the horizontal deployment of this product, advance this technology and develop products which are lightweight and reliable, more than ever.

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