High-Resolution Steering Angle Sensor

1. INTRODUCTION

Recently, demands for the safety of vehicles are increasing in the field of automobiles, and the electronic stability control (ESC) system for vehicle attitudes which has been developed in response to such demands is expanding its applications. The ESC system stabilizes, when a vehicle begins to skid at the time of turning, the behavior of the vehicle instantly by automatic controlling of the brake and the engine output. Thus, the accuracy of the vehicle information such as speed, acceleration and steering angle is directly linked to the accuracy of vehicle control. For this reason, high precision and high reliability are required for the sensors that detect these vehicle information.

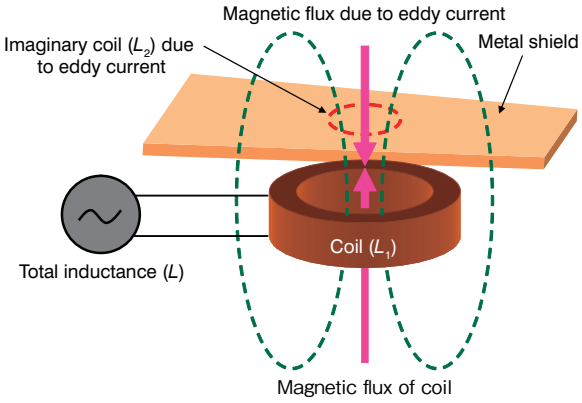
The product presented here is a steering angle sensor for the ESC system, and, to satisfy the above mentioned requirements, Furukawa Electric has developed a non-contact steering angle sensor of its proprietary design adopting an electromagnetic induction principle. See Figure 1.

Figure 1 Appearance of the developed product.

2. DETECTOR STRUCTURE

2.1 Basic Principle

The product developed here has adopted a detection principle of electromagnetic induction, in which a change in a coil inductance due to shielding of magnetic flux is detected. When a plate conductor is inserted in the region of magnetic flux generated by the coil, an eddy current will flow to shield the magnetic flux, so that by changing the shielding area of the plate conductor, a change in the coil inductance is caused as illustrated in Figure 2, and the steering angle can be detected from this inductance change.



$$L = L_1 - M \qquad M \propto L_2 = k\mu S/t$$

L, L_1, L_2 : total inductance, intrinsic inductance and mutual inductance of the coil and metal shield, respectively
k : Nagaoka's coefficient
μ, S, t : magnetic permeability, area and thickness of the metal shield, respectively.

Figure 2 Basic principle.

2.2 Detection Principle

Practical configuration of the product is such that a plate conductor of changing width is situated on the coil, and the plate conductor is fixed to a rotor that rotates in synchronization with the steering shaft. As the steering shaft rotates, the shielding area of the plate conductor for the magnetic flux generated by the coil changes, thus causing a change in the coil inductance that corresponds to the steering rotation angle. See Figure 3.

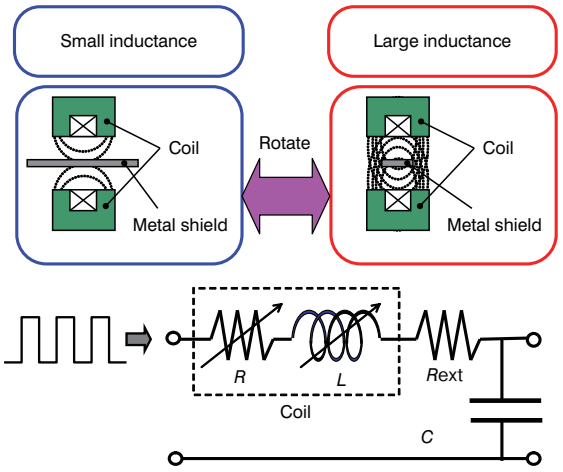


Figure 3 Detection principle.

3. FEATURES

3.1 High Resolution

In the conventional optical sensor of encoder type, its resolution improves as the slits on the rotator that interrupts the photodiode light beam increase in number. But, because the slit width must be decreased to increase the slit number in the tight space, there is a certain limit of resolution due to processing difficulties.

In contrast with this, the resolution of the product developed here can reach a level higher than 0.1° by improving the performance of signal processing which the total resolution depends on.

3.2 Low Hysteresis

The product has a structure such that the plate conductor is directly fixed on to the rotor that rotates in synchronization with the steering shaft, so that there exists no transmission loss of rotation signals to the sensing head, enabling steering angle detection of high precision and low hysteresis. See Figure 4.

For reference's sake, in the sensor adopting magnetoresistive (MR) elements it is necessary to acquire two types of signals with different periods to detect absolute steering angles. And, to change the signal period, rotation period of the permanent magnet for signal detection has to be changed usually using a gear. Moreover, the magnet has to be located on the center of a rotator that faces the MR element, and, because the steering shaft penetrates the rotor (i.e. rotator), the gear is linked with the rotor, and the magnet is located on the rotation center of the gear. Such a structure, however, tends to have a large hysteresis because a mechanical loss in rotation transmission is generated due to the gear.

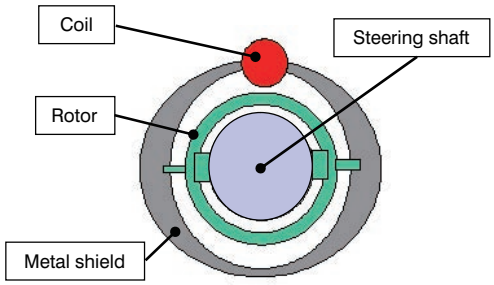


Figure 4 Structure of detector head.

3.3 Instantaneous Detection of Absolute Angles

Upon turning the ignition switch ON, the product instantaneously redetermines the absolute angle of the steering shaft, so that it is not necessary to store the value of steering angle to the electronic control unit (ECU) before turning the ignition switch OFF.

3.4 High Reliability

The product has high reliability due to its structure of noncontact type necessitating no mechanical contacts in the sensing head. The product has passed a severe rotational endurance test of five million rotations at 300 rpm in the heat cycle environments.

3.5 Self-Diagnosis Function

The product is provided with a variety of self-diagnosis functions as shown below, and in case an abnormality is detected by the sensor itself, the signal contaminated with possible errors is interrupted from outputting, and the sensor immediately shift to a warning mode. This function securely prevents malfunction of the host system.

1. Coil disconnection
2. Open/short of electric circuits
3. Outreaching the guaranteed temperature
4. Over-rotation due to deviations from the neutral position of rotation

4. PRODUCT SPECIFICATIONS

Table 1 shows the main specifications of the product.

Table 1 Product specifications.

Item		Specification
Operating temperature		−40～85 ℃
Rated operating voltage		5 V
Relative angular detection range		±750°
Absolute angular detection range		±225°
Angular resolution		1°
Angular hysteresis		within ±1°
Rotation speed limit		5 rps (1800°/s)
Current consumption		40 mA or less
Outer dimensions	(thickness)	18 mm
	(outer dia.)	65 mm
	(inner dia.)	25 mm
	(total length)	91 mm
Unit weight		77 g

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