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Numerical Research on New Variable Reluctance Sensor with Fixed Permanent Magnet for SMART Main Coolant Pump

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1. Introduction

Variable reluctance sensors (VRS) with permanent magnetic excitation do not need any external energy or supply based on Faraday's law of electromagnetic induction. For this reason, VRS with fixed permanent magnet is suitable for MCP rotational speed measurement. In order to achieve improved magnetic pickups due to wide air-gap, numerical magnetic field calculations for various kinds of magnetic pickups have been performed. As a result, we present the improvement design of MCP rotational speed sensor for SMART.

2. Methods and Results

In this section some of the numerical field calculations with finite element are described as well as the details of pickup coils[1].

2.1 Physical Principle and Construction

A permanent magnet produces a magnetic flux within a magnetic circuit of various shapes. Owing to changes of the length of an air gap within the circuit, the reluctance of the circuit and the magnetic flux will change. This change in flux induces a voltage V(t) in a pickup coil according to Faraday's law:

$$V(t) = -N \cdot \frac{d\phi}{dt} \tag{1}$$

Where N is number of coil windings, ϕ is magnetic flux through the coil, and t is time[2]. The output voltage thus depends on the change in flux with respect to time, i.e., the quicker the flux changes, the larger is the voltage. The construction of variable reluctance sensor depends on the application. In its simplest form, it consists of a permanent magnet in coil.

2.2 Proposed New Variable Reluctance Sensors

Some different forms of sensors are shown in Fig. 1, and Fig. 2. The choice of materials for and the shape of such sensors will mainly depend on the designer's experience in magnetism, since the mathematical treatment of the magnetic circuit is inaccurate in most cases. As many parameters are unknown or can be predicted only with difficulty, such as the operating points of both the magnet and the yoke on the hysteresis loop, the influence of small air gaps following mechanical mounting and the magnetic and mechanical tolerances of the impulse gear, calculations of the circuit with the reluctance model, for example, will lead to only rough approximations. In order to achieve improved magnetic pickups, the use of numerical field calculations with finite-element method with the aid of a computer is necessary

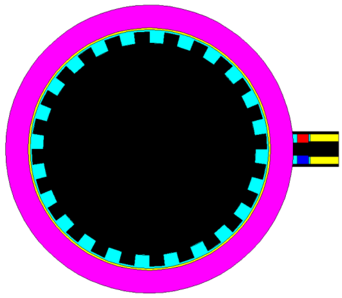

Figure 1. Sensor with Radially Magnetized Permanent Magnet.

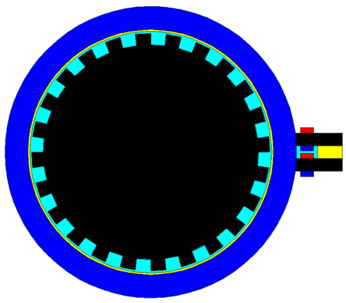

Figure 2. C-shaped Sensor.

2.3 Finite-Element Method Results

In recent year, the FEM has become widely accepted by the engineering professions as an extremely valuable method of analysis. Its application has enabled satisfactory solutions to be obtained for many problems which had been regarded as insoluble, and the amount of research effort currently being devoted to the FEM ensures a rapidly widening field of application. Especially the coupling of electrical circuit made it possible to calculate an induced current. Fig. 3 shows the coupled circuit of FEM model. A coupled circuit consists of two inductors and one resister. Where two inductors represent positive and negative pickup coils, and one 1,000kΩ resister represents output socket for calculating magneto-induced current.

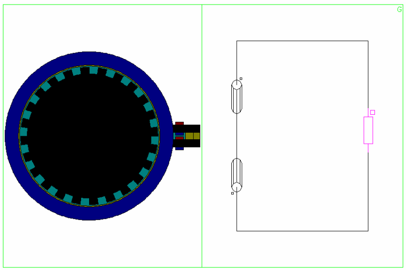

Figure 3. A Coupled Electrical Circuit to FEM Model.

A proposed new Fig. 1 model for such a computation is given in Fig. 4, where the exact course of the magnetic equi-flux of a sensor is shown.

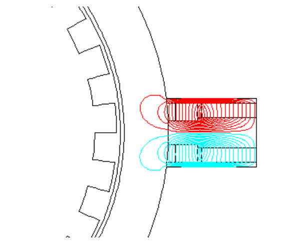

Figure 4. Equi-flux Lines Result of Sensor with Radially Magnetized Permanent Magnet.

A proposed new Fig. 2 model for such a computation is given in Fig. 5, where the exact course of the magnetic equi-flux of a sensor is shown.

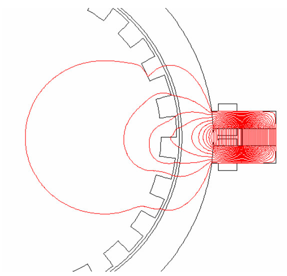

Figure 5. Equi-flux Lines Result of C-shaped Sensor.

Fig. 6 , and Fig. 7 show the calculated sinusoidal output signal from new proposed sensors, which are with radially magnetized permanent magnet and C-shaped, respectively

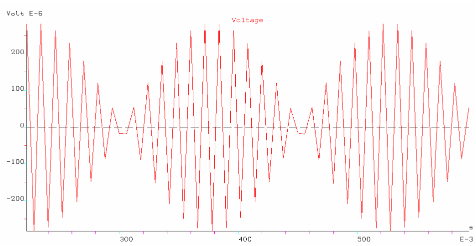

Figure 7. Induced Voltage Result of Sensor with Radially Magnetized Permanent Magnet.

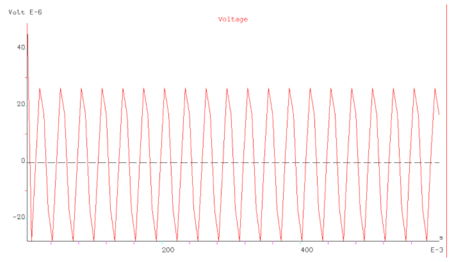

Figure 5. Induced Voltage Result of C-shaped Sensor.

3. Conclusion

The main FEM results from the new proposed variable reluctance sensors are as follows:

(1) A ferromagnetic yoke installation has the advantage of closing the magnetic circuit in order to increase the flux concentration within the circuit which will result in a higher output voltage.

(2) In order to calculate the induced voltage, a coupled circuit is introduced and shows a useful tool.

(3) A sensor with radially magnetized permanent magnet is more sensitive than C-shape sensor.

(4) Since the output voltage of the sensor depends on the varying magnetic flux, only movements above a certain minimum speed can be detected.

Acknowledgement

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REFERENCES

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[2] William H. Hayts, Jr., "Engineering Electromagnetics", McGRAW-HILL Book, 1989