Measurement of magnetic flux density on permanent magnet surfaces for IPM motor

T. Hosoi[1], R. Okamoto[1] , H. Matsui[1] , D. Miyata[1] , Y. Haseo[1] , N. Tanaka[2] , M. Inaba[2] , Y. Kamiya[2]
[1] NIPPON SOKEN,INC. , Nishio 445-0012 , Japan
[2] DENSO CORP. , Kariya 448-8661 , Japan

1. Introduction

The purpose of this study is to establish a technique on measuring magnetic flux density when an Interior Permanent Magnet (IPM) motor operates and to clarify higher-harmonic wave component causing a factor of generating an eddy current loss of permanent magnet.

The eddy current is generated inside of a permanent magnet by variable magnetic flux when the motor operates. This heating loss caused by the eddy current may become factors of degradation of conversion efficiency and thermal demagnetization.

2. Measuring technique

Fig.1 shows the structure of the measuring technique. It is constructed such that a signal amplification circuit is installed on the rotor, extracting amplified signals from a magnetic flux density sensor to the fixed side by a slip ring. The sensor is mounted on a magnet surface. The sensor measures AC component of magnetic flux density generating eddy current loss. Further, the magnet surface temperature is measured simultaneously using a thin film temperature sensor.

Fig.2 shows the construction of the mounted magnetic flux density sensor. For the search coil layer, patterning is conducted on the upper and lower surfaces of a flexible sheet of polyimide and the layer is electrically connected with a through hole. Both surfaces are covered with insulating layers, and the total thickness of the sensor is 74 μm.

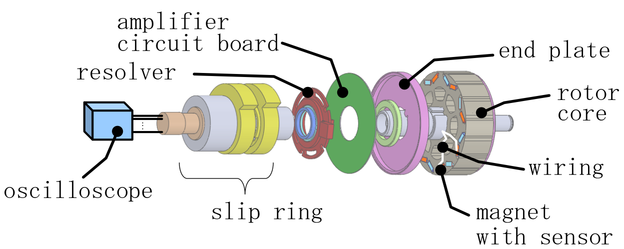

Fig. 1. Measurement setup

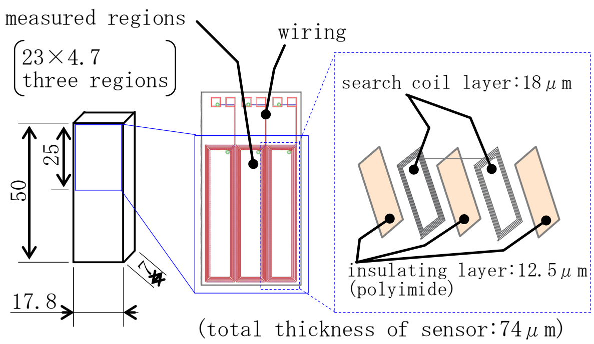

Fig. 2. Magnetic flux density sensor

3. Measurement result

Table.1 shows measuring conditions. The measurement of magnetic flux density of the magnet surface is conducted under PWM control by a general purpose inverter intended for the IPM motor with 4 pole pairs and 48 slots.

Fig 3 shows a time waveform for the measured magnetic flux density, and Fig 4 shows the frequency analysis results. Each component of the fundamental harmonics, slot harmonics and carrier harmonics of the magnetic flux density has been quantified. Assuming that the eddy current loss for the permanent magnet is proportional to the square of the magnetic flux density and the square of the frequency, it is estimated that the eddy current loss by the carrier second harmonic components (10800 Hz) accounts for an overwhelming 67% of the total.

Table. 1. Measurement conditions

rotation speed [rpm]	3000
torque [N・m]	40
carrier frequency [kHz]	5.4
inverter input voltage [V]	650
magnet temperature [℃]	39

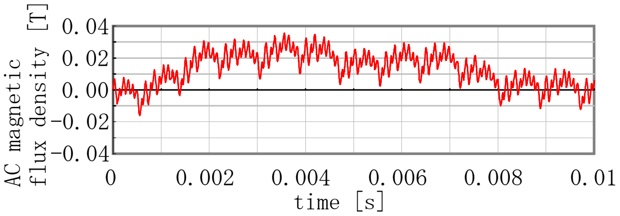

Fig. 3. Waveform of AC magnetic flux density

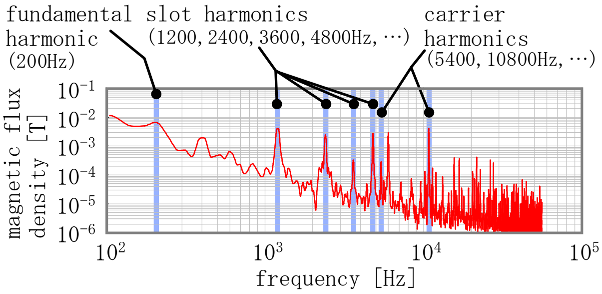

Fig. 4. Result of frequency analysis

4. Summary

We have established the technique for measuring magnetic flux density on magnet surfaces by using a magnetic flux density sensor when the motor operating. This technique enables us clarify higher-harmonic wave components of magnetic flux density as a factor in the generation of eddy current loss in permanent magnets.