Analysis of Magnet Field Degradation on PM Motor Vibration

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Abstract —In this paper, the effect of magnet field degradation on vibration of the permanent magnet motor is analyzed. Combination of 2D and 3D FEM is carried out to identify the electromagnetic vibration sources. Vibration signals are analyzed by electromagnetic-vibration coupled analysis. Results are useful in optimal motor design for PM machine to minimize vibration and to detect the magnet field degradation failure in online and offline monitoring.

I. Introduction

Generally, a permanent magnet (PM) degrades its strength and stability mainly due to high operating temperature and strong adverse magnetic field produced by the high short-circuits currents in PM machines [1]. Other factors include aging, corrosion, oxidation, exposed in radiation, metallurgical changes in magnet material and manufacturing defects such as chipping, cracking can cause partial or total field degradation on permanent magnet. Either partial or total magnet field degradation leads to unbalanced magnetic field distribution of the motor. The unbalance magnetic field provokes the magnetic-force harmonics which induce noise and vibration in the machine [2]. In this paper, the effect of magnet field degradation on vibration due to the electromagnetic vibration sources such as unbalance magnetic force (UMF), cogging torque and torque ripple are analyzed. Combination of 2D and 3D FEM is carried out to identify the electromagnetic vibration sources. Vibration signals are analyzed by electromagnetic-vibration coupled analysis.

II. Magnet Field Degradation Model

PM field degradation on outer rotor type brushless permanent magnet DC (PM-BLDC) motor with NdFeB magnets (energy product of 10MGOe) is used as a working example. Motor geometry is show in Fig.1. Electromagnetic field simulation is conducted considering 5% and 25% uniform field degradation on all poles of the magnet and partial field degradation on two adjacent magnet poles (North and South Poles).

III. Electromagnetic-Vibration Coupled Analysis

Noise and vibration in PM machines can be classified into aerodynamic, mechanical and electromagnetic based on its sources [3]. Electromagnetic source is dominating in low and medium power rage machines. In this work, 2D FEM is used to calculate the electromagnetic vibration sources such as unbalance magnetic force (UMF), cogging torque and torque ripple. 2D results are used in 3D electromagnetic-vibration coupled analysis to analyze the motor vibration.

A. *Calculation of electromagnetic vibration sources*

PM field degradation induces unbalance magnetic field especially while partial field degradation set on. In that condition, radial field provokes unbalance magnetic force (UMF). Results show that UMFs are weaker while field degradation level is higher in uniform field degradation. Spectrum analysis shows that extra harmonics add on in partial field degradation as shown in Fig. 4. UMF can use as a failure signal to detect PM field degradation in PM motor.

Cogging torque due to slotted stator structure and rotor magnet can cause start-up problem and greatly effect to the running torque fluctuation and motor vibration. Cogging torque analysis shows that higher uniform PM field degradation gives lower cogging toque. Partial field degradation gives spike in cogging torque especially when motor rotates under affected PM segments as shown Fig. 3. Magnet degradation can detect by cogging torque harmonics spectrum as show in Fig. 5.

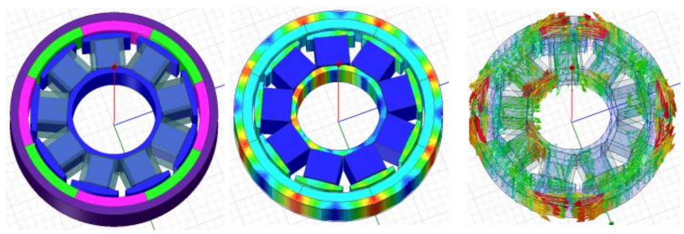

Fig.1 (a) Motor structure (b) Flux density distribution (c) Magnetic vector field plot

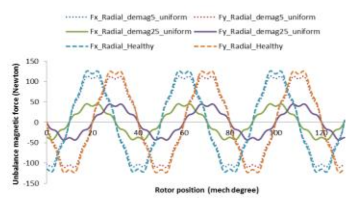

Fig. 2 Unbalance magnetic force under uniform field degradation

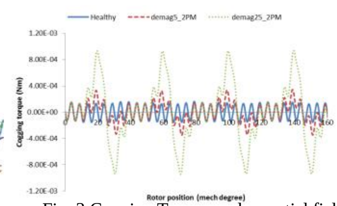

Fig. 3 Cogging Torque under partial field degradation

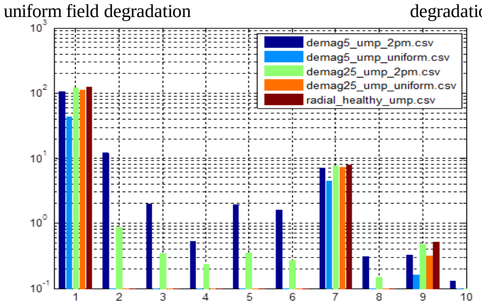

Fig. 4 Spectrum analysis result of unbalance magnetic force

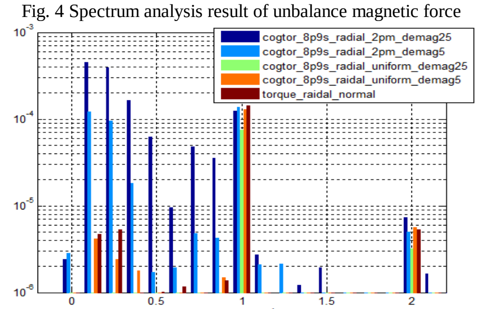

Fig. 5 Spectrum analysis result of cogging torque

B. Vibration Analysis

Radial vibration of the motor structure is usually the most important type of vibration. Fig. 6 shows deformation of the motor using the UMF under 25% partial field degradation. Detailed analysis for cogging torque, torque ripple and UMF in uniform and partial field degradation will be discussed in extended full paper.

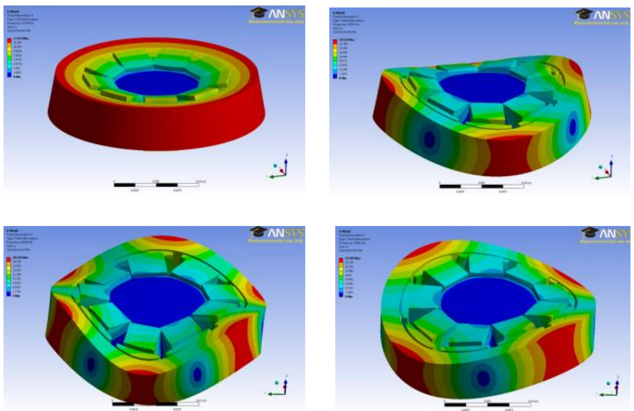

Fig .6 Deformation of the motor structure under 25% partial magnet field degradation

IV. Conclusions

The effect of magnet field degradation on vibration due to the electromagnetic vibration sources is analyzed. Vibration signals are analyzed by electromagnetic-vibration coupled analysis. Analysis results are useful in optimal motor design for PM machine to minimize vibration and to detect the magnet degradation failure.

V. References

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