MEASUREMENT AND MODELLING OF CORE LOSSES OF SOFT MAGNETIC COMPOSITES UNDER 3D MAGNETIC EXCITATIONS IN ROTATING MOTORS

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Introduction

Soft magnetic composite (SMC) materials are especially suitable for construction of low cost high performance motors with three dimensional (3D) magnetic fields. The 3D finite element analysis (FEA) conducted in the design of a claw pole transverse flux motor (TFM) with an SMC core reveals very complicated **B** (flux density) loci in the core when the motor rotates. In order to understand and account for the effects of the patterns of **B** loci on motor parameters and performance such as core losses, a 3D magnetic property testing system was built for magnetic measurement on a cubic SMC sample. 3D rotational core loss models in SMC materials and rotating motors are developed and verified by the experimental results.

Claw Pole TFM with SMC Core

Fig.1 plots the layout and the magnetic field solution region of one pole pitch in one phase of an SMC claw pole TFM with a permanent magnet rotor of a flux-concentration structure. Fig.2 illustrates the **B** loci in the middle of (a) the stator yoke, (b) the claw pole, and (c) the flux-concentrating iron, respectively. While it is alternating in the stator yoke, the **B** locus in the claw pole is an ellipse with harmonics in a tiled plane, and a truly 3D irregular loop in the rotor iron. The effects of these **B** loci on the core losses in SMC core are quite different [1].

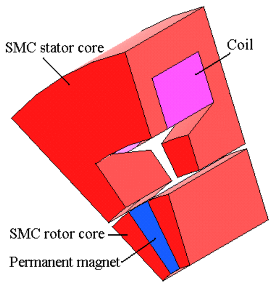

Fig.1 FEA solution region of a claw pole TFM

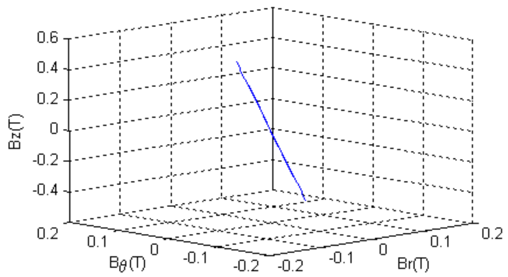

Fig.2(a) **B** locus in a typical element of stator yoke

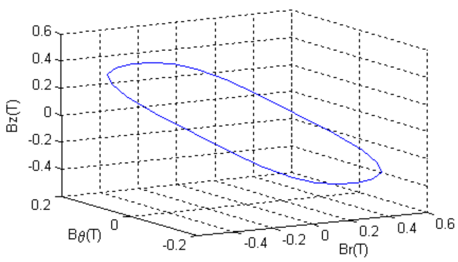

Fig.2(b) **B** locus in a typical element of claw pole

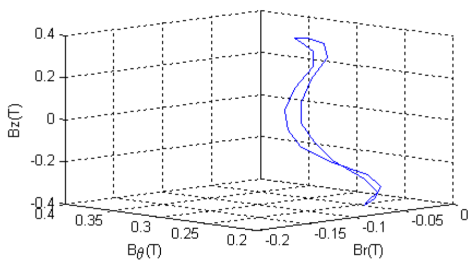

Fig.2(c) **B** locus in a typical element of rotor iron

3D Magnetic Property Measurement of SMC

Due to the rotation of magnetic domains, the **B** locus in a magnetic material is of 3D nature even under alternating or two-dimensional rotating magnetic excitations in a plane, no need to mention the 3D excitations in the claw pole TFM. Fig.3 illustrates the block diagram of the 3D magnetic testing system and the tester magnetic circuit [2]. Three groups of computer controlled excitation coils are used to generate various **B** patterns including the ones in real 3D space. Fig.4 shows the **B** and the corresponding **H** (field strength) loci measured in an SMC cubic sample when the three components of the **B** vector are controlled to be sinusoidal waveforms with amplitude 1 T at 50 Hz. Also shown are their projections.

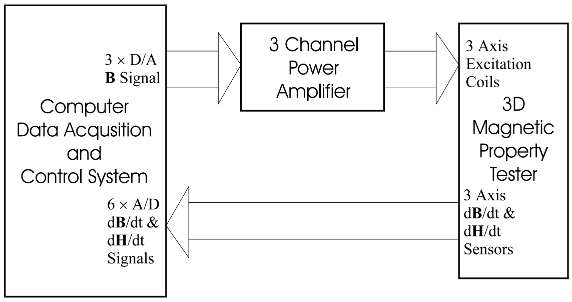

Fig.3(a) 3D magnetic property testing system

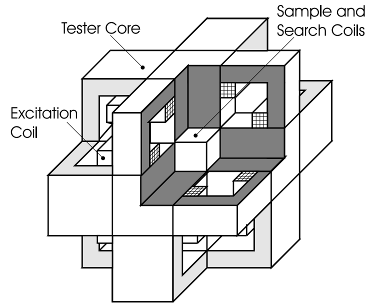

Fig.3(b) Cut away view of 3D tester

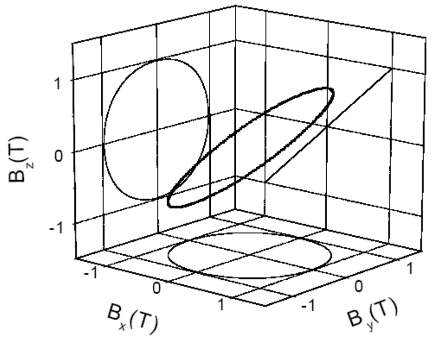

Fig.4(a) Loci of **B** vector

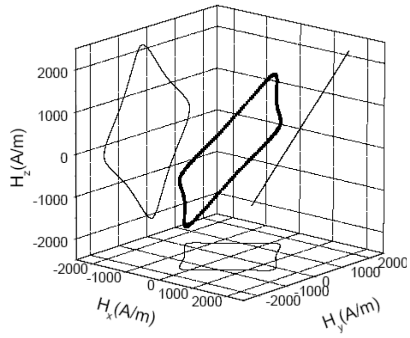

Fig.4(b) Loci of **H** vector

<u>Models of 3D Core Losses</u>

In an SMC sample, the alternating core loss $P_a=C_{ha}fB^h+C_{ea}(fB)^2+C_{aa}(fB)^{1.5}$, the core loss with circular rotating flux $P_r=P_{hr}+C_{er}(fB)^2+C_{ar}(fB)^{1.5}$, and the core loss with elliptical rotating flux $P_{er}=R_BP_r+(1-R_B)^2P_a$, where $\frac{P_{hr}}{f}=a_1\left[\frac{1/s}{(a_2+1/s)^2+a_3^2}-\frac{1/(2-s)}{[a_2+1/(2-s)]^2+a_3^2}\right]$, and $R_B=B_{min}/B_{maj}$.

In a rotating machine, the total core loss is the sum of the core losses in all elements, and in each element, the hysteresis loss $P_{th}=\Sigma[P_{rhk}R_{Bk}+(1-R_{Bk})^2P_{ahk}]$, the eddy current loss $P_{te}=C_e\Sigma(kf)^2(B_{kmaj}^2+B_{kmin}^2)$, and the anomalous loss $P_{ta}=\frac{C_{ar}}{(2\pi)^{3/2}}\frac{1}{T}\int_0^T\left[\left(\frac{dB_x(t)}{dt}\right)^2+\left(\frac{dB_y(t)}{dt}\right)^2+\left(\frac{dB_z(t)}{dt}\right)^2\right]^{3/4}dt$.

<u>Conclusion</u>

The complexity of the **B** loci in a claw pole TFM with SMC core has been studied by 3D FEA of magnetic field, revealing the direct need for study about the 3D magnetic property of SMC. The proposed models have been verified by the experimental results. More details of the 3D FEA of the motor field, 3D magnetic property measurement results on the cubic SMC sample, and the core loss prediction in the motor with real 3D flux density patterns will be presented in the full paper.

<u>References</u>

[1] Y.G. Guo, J.G. Zhu, J.J. Zhong, W. Wu, IEEE Trans. Magn. Vol. 39, p. 3199, (2003)
[2] J.G. Zhu, J.J. Zhong, Z.W. Lin, J.D. Sievert, IEEE Trans. Magn. Vol. 39, p. 3429, (2003)