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A Numerical Approach for Accurate Prediction of Magnetic Field in Permanent Magnet Motors.

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I.INTRODUCTION

To support very dense data storage on recording disks, the spindle motor is to provide high precision rotation with minimal jitter in speed and minimal departure from perfect rotation. In designing such motors, accurate prediction of the magnetic air gap field is essential for analysis of cogging effect and validation of design choices [1]. The radial and tangential components of airgap field in PM motors were derived by pervious works [2,3] to allow magnetic forces to be speedily computed. The analytical solutions for instantaneous air gap magnetic field in PM motors were discussed by various researchers [3-5], using the relative permeance function. However, the relative permeance function only accounts for the peak value of flux reduction in the slot center. Therefore, whilst the prediction of the radial forces is usually of satisfactory accuracy, the tangential flux density derived was not accurate especially in the area of magnet pole transition passing over slot opening. As a result, the prediction of cogging effect can be very poor for some pole and slot number combinations. Fig.1 shows the comparison of the flux density predication between FEM calculation and previous analytical solution. It is observed that the radial field component of the existing analytical solution has good accuracy. However the tangential field component is not so satisfactory, especially over the region when the magnet transition is close to slot opening. Such inaccuracy is the main cause of inaccuracy in cogging torque calculation.

In this paper detailed analysis of the tangential force due to pole transition passing over slot opening is given. It is shown that such component predominantly contributes to cogging effect. A practical approach based on a combination of numerical and analytical methods is introduced for accurate prediction of the magnetic field and cogging effect.

II.MAGNETIC FIELD IN PM MOTORS

As the accuracy of the air gap field has a strong impact on the prediction of the cogging effect. We focus our attention on the accurate prediction of magnetic field in slot opening regions. The governing Laplace equations for the air gap field can be solved analytically if the boundary condition at the slot opening is known,which can be defined as

$\Phi g|stator=\Phi stator(1)$

where Φstator is the scalar potential distribution on stator surface in slotted PM motor.

A numerical approach is then introduced to obtain scalar potential at the circumferential boundary of the stator, including the slot opening. The variation in the scalar potential due to existence of slot is denoted as Φi (i=1,2,…m,m is the slot number). Itcan be expanded to Fourier series,

$\Phi i=\Sigma akcos(km\theta)+ bksin(km\theta)(2)$

It will be noted that the geometric model of the pole transition over slot model is much simpler than the PM motor and the Fourier coefficients are well represented by second order polynomial of the above geometric parameters. Therefore, the computing power of personal computers is sufficient for the above numerical experimentation tasks. An explicit expression of the magnetic field can then be obtained in the form of Fourier series by solving the governing equations with usual boundary conditions.

The fitted model for the scalar potential over the slot opening is valid over a wide range of settings of design parameters, such as the magnet thickness, airgap length, and slot opening.

Fig. 3 shows the computed tangential flux density and it is in good agreement with the FEM results. The resultant cogging torque calculated by Maxwell stress tensor method agrees well with FEM simulation too.The analytical results is also with good accordance to the experimental results.

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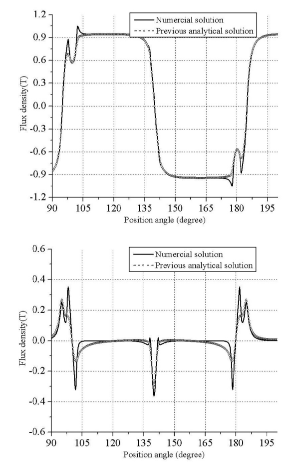

Fig 1 Comparison of flux density

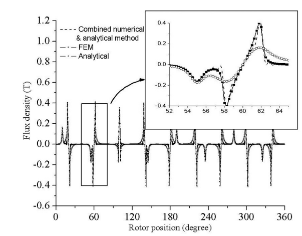

Fig.2 Comparison of tangential flux density over slot opening

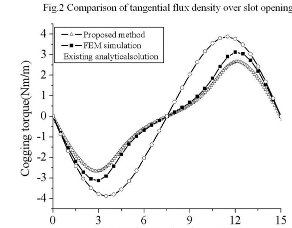

Fig.3 Comparison of cogging torque calculation in an 8-pole/6-slot motor