

Vibration and Noise Analysis of Permanent Magnet Synchronous Motor Based on Pole shape Optimization

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Abstract—In order to suppress the vibration and noise of the surface mounted permanent magnet synchronous motor (SPMSM), an analytical calculation model of electromagnetic force based on the optimized magnetic pole shape is proposed and verified by the finite element method. Secondly, the coupling simulation analysis of magnetic vibration and noise of SPMSM with magnetic pole optimization is carried out, and the magnetic pole optimization scheme with minimum vibration and noise value of the motor is obtained. Finally, the noise and sound pressure level of the motor during operation is obtained through vibration and noise experiment, which verifies that the optimized motor can effectively reduce the vibration and noise of the motor under the premise of ensuring the electromagnetic performance.

Index Terms—Electromagnetic force analytical calculation, Pole shape optimization, SPMSM, Vibration and noise analysis

I. INTRODUCTION

SPMSM has the advantages of simple structure, reliable operation and high efficiency, and has a good application prospect in many occasions. However, the harmonic content of SPMSM air-gap magnetic field is large, resulting in more obvious vibration and noise [1-3].

Therefore, the magnetic field analytical calculation model of SPMSM magnetic pole eccentricity structure is established to analyze the electromagnetic force of an 8-pole 36-slot SPMSM magnetic pole before and after optimization. The optimal magnetic pole structure is obtained by calculating the vibration amplitude of the motor, and the suppression effect of magnetic pole eccentricity on the vibration and noise of the motor is verified by finite element method and experiment

II. ELECTROMAGNETIC FORCE CALCULATION MODEL

Fig. 1 shows the finite element simulation model of the surface mounted permanent magnet synchronous motor. The permanent magnet adopts radial magnetization, the remanent magnetic density is $B_r=1.23\text{T}$, and the coercive force $H_c=-951000\text{A/m}$. The end thickness of the permanent magnet varies from 0.5mm to 4mm, and only the motor model with the end thickness of 2.5mm is shown in the Fig.1.

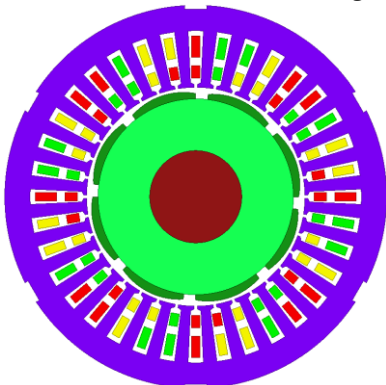


Fig. 1. Two-dimensional finite element model of motor.

The waveform comparison results of radial electromagnetic force density variation with position calculated based on analytical method and finite element simulation are shown in Fig. 2. The waveform of the two kinds of calculation results is in good agreement. The analytical calculation model can predict and calculate the radial electromagnetic force distribution of the motor quickly and accurately, so that the vibration and noise of the permanent magnet motor can be predicted and analyzed.

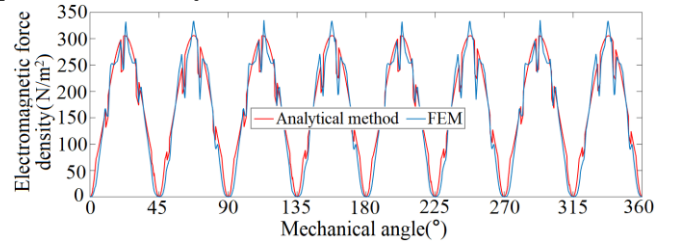


Fig. 2. Radial electromagnetic force density waveform comparison.

Fig. 3 shows the spectrum comparison diagram of radial electromagnetic force density with position based on analytical method and finite element simulation. It can be seen from the Fig. 3 that the harmonic content is greatly reduced after optimization, which indirectly indicates that the magnetic pole eccentric structure can effectively suppress the electromagnetic vibration and noise of the motor.

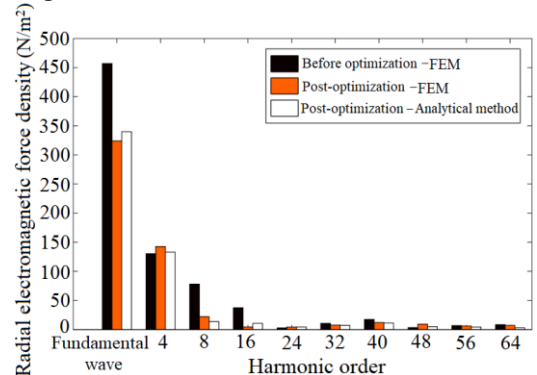


Fig. 3. Spectrum comparison diagram of radial electromagnetic force waveform.

III. RESULTS OF 3-D FEM

Under the condition that the motor running speed remains unchanged, the end thickness of permanent magnet is changed. Based on the finite element method, the vibration amplitude of the motor under no-load operation with magnetic pole eccentricity is simulated and analyzed. Fig. 4 shows the displacement amplitude spectrum distribution of different end thicknesses of permanent magnet under no-load operation.

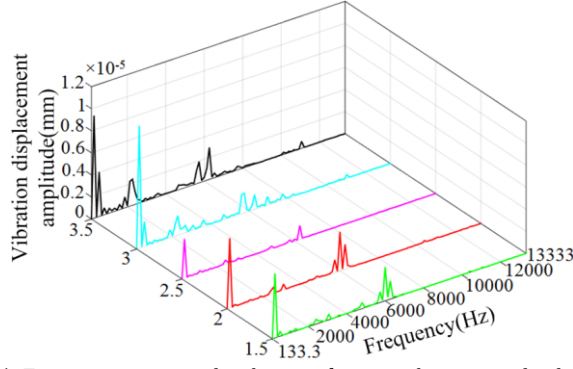


Fig. 4. Frequency spectrum distribution of motor vibration amplitude under magnetic pole optimization.

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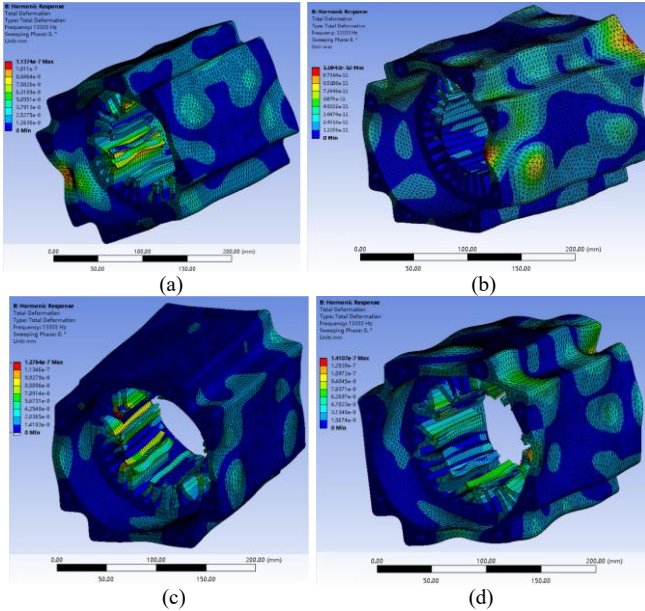


Fig. 5. The total deformation cloud of motor vibration under different end thicknesses of permanent magnet. (a) 2.0mm. (b) 2.5mm. (c) 3.0mm. (d) 3.5mm.

The total deformation cloud map of motor vibration with different end thicknesses of permanent magnets is shown in Fig. 5. It can be intuitively seen that when the end thickness of permanent magnet is 2.5mm, the stator deformation degree is the smallest, and the total vibration deformation is the smallest. It can be concluded that magnetic pole eccentricity

will reduce vibration and noise of permanent magnet motor under no-load operation.

IV. EXPERIMENTAL VERIFICATION

The motor test site is shown in Fig. 6. In the absence of a shock absorber, a rubber pad is placed under the motor to reduce the influence of the motor environment on the motor's natural vibration.

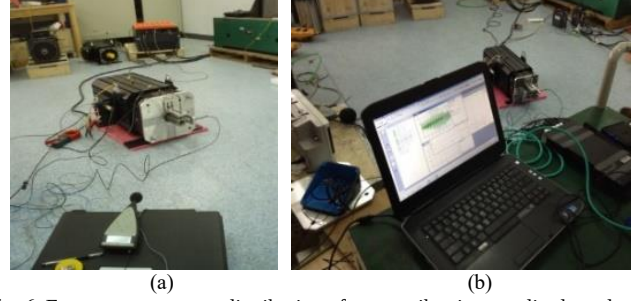


Fig. 6. Frequency spectrum distribution of motor vibration amplitude under magnetic pole optimization. (a) Test point distribution. (b) Test site.

During the experimental test, the motor maintained a speed of 2000r/min, and the frequency domain diagram of vibration and noise during no-load operation of the motor was measured, as shown in Fig. 7. The measured noise of the motor at the rated speed is 71.9dB, which is slightly higher than that obtained by the finite element simulation, because the actual operation of the motor is affected by many factors, and the finite element simulation is to simulate the vibration noise under the ideal state.

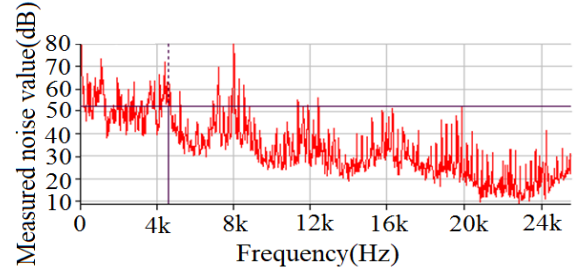


Fig. 7. Frequency domain diagram of motor measured noise.

V. CONCLUSION

The accuracy of the electromagnetic force calculation model is verified by experiments. The optimization of the magnetic pole shape can effectively reduce the radial electromagnetic force of the motor, and then restrain the vibration and noise of the motor.

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