Analysis of rotor vibration characteristics of surface mounted permanent magnet synchronous motor under air gap eccentricity fault

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Introduction

Motor air gap refers to the gap between stator and rotor. Due to manufacturing, assembly, operation and other reasons, the motor air gap will be uneven in the circumferential direction, resulting in a long air gap on one side and a short air gap on the other side, which is called air gap eccentricity [1]. It has been proved that the air gap eccentricity fault will have a great impact on the operation of rotating machinery. The unbalanced magnetic tension will cause the system to vibrate, and in serious cases, it may cause the rotor stator to rub [2]. A small amount of air gap eccentricity will not have a great impact on the normal operation of the motor [3], but when the eccentricity reaches 10% of the radial air gap value, it is considered that the fault standard is reached [4], and human intervention is required to maintain the vibration stability of the shafting and protect the bearing and winding insulation from damage [5]. Therefore, it is very important to study the influence of unbalanced magnetic pull on the vibration of rotor system, whether it is for the unit design or condition maintenance. Through numerical calculation and finite element simulation, the effects of pole pairs, eccentricity and eccentricity angle of the motor on the vibration characteristics of the rotor under the action of unbalanced magnetic tension can be obtained,

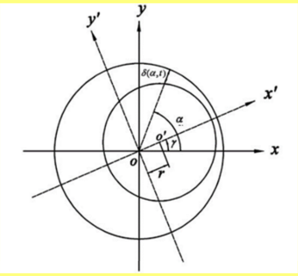

Fig. 1. Air gap under eccentric rotor of motor.

Numerical analysis

The Jeffcott model is adopted for the rotor. It is assumed that the shaft section of the rotor has no mass, the central disc has a concentrated mass of m, a stiffness coefficient of k, and a damping coefficient of c. the gyro effect of the rotor is ignored. The rotor dynamics equation is established and solved by Newmark-β method. By comparing different relative eccentricities(ε =0.05, 0.1 and 0.2), eccentric angles(γ =0°, 45° and 90°) and pole pairs of motor(p=1,2,3 and more than 3), the time domain diagram, frequency spectrum diagram and shaft center trajectory diagram of the rotor are obtained. Due to space reasons, only the influence of motor pole pairs and eccentric angle(γ =0°) on rotor vibration characteristics is shown here.

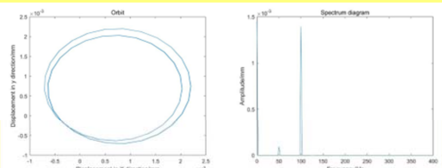

Fig. 2a. When $p = 1$, Orbit and Spectrum diagram

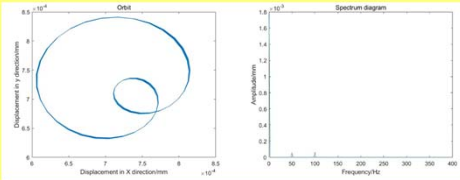

Fig. 2b. When $p = 2$, Orbit and Spectrum diagram

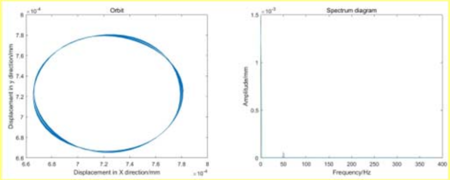

Fig. 2c. When $p = 3$, Orbit and Spectrum diagram

Fig. 2 depicts that with the increase of the pole number of the motor, the amplitude of the double frequency of the unbalanced magnetic pull decreases continuously, the axis trajectory tends to a stable state, and the vibration stability of the rotor system also improves.

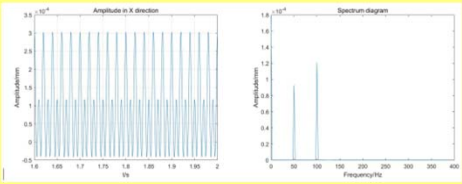

Fig. 3a. When$\gamma = 0°$, Time domain diagram and frequency domain diagram in X direction

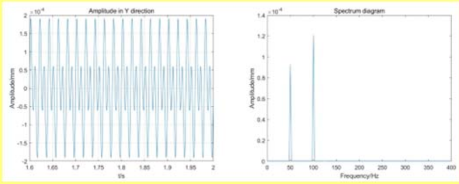

Fig. 3b. When$\gamma = 0°$, Time domain diagram and frequency domain diagram in X direction

Fig. 3 depicts that The amplitude of the second harmonic generation is roughly the same in the X direction and Y direction, while the zero frequency component disappears in the Y direction and only the second harmonic generation component exists.

Finite element simulation

Using ANSYS Maxwell finite element software, the model of permanent magnet synchronous motor is established, and the unbalanced magnetic pull of the motor under different eccentricity is calculated respectively.

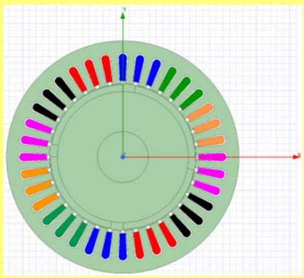

Fig. 4. Two dimensional model of permanent magnet synchronous motor

Through Maxwell software, the rotor is translated by 0.05, 0.1 and 0.2mm along the positive direction of the x-axis To simulate the case when $\gamma = 0°$, and the rotor rotation axis is also translated by the same distance along the x-axis, the time-domain waveform of unbalanced magnetic tension in normal state with static eccentricity of 5%, 10% and 20% can be obtained

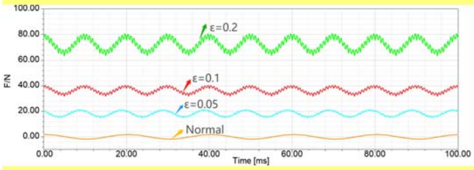

Fig. 5. Time domain waveform of unbalanced magnetic pull in X direction

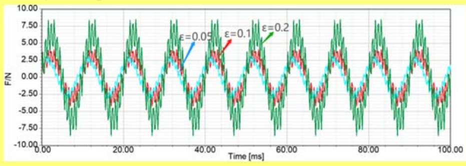

Fig. 6. Time domain waveform of unbalanced magnetic pull in X direction

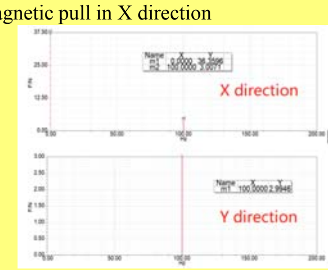

Fig. 7. when $\varepsilon = 0.1$, X-direction and Y-direction unbalanced magnetic pull spectrum

With the increase of relative eccentricity, the amplitude of unbalanced magnetic pull also increases ,as shown in Fig.5 and Fig.6. There are zero frequency and double frequency components in the X direction, while there are only zero frequency components in the Y direction, which verifies the correctness of the numerical analysis as shown in Fig.7

Conclusions

The main conclusions drawn from all these work are:

-With the increase of eccentricity, the unbalanced magnetic pull also increases

-When the number of motor poles is less than 3, increasing the number of motor poles can reduce the unbalanced magnetic tension

-The unbalanced magnetic pull shows double frequency and zero frequency components, and the derection of join force points to the minimum air gip;

-The static eccentric angle will affect the component of the unbalanced magnetic pull

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