Influence of Drive Current to Unbalanced-Magnetic-Pull in Spindle Motor

Chao BI, Nay Lin Htun Aung, Hla Nu Phyu, Quan JIANG, and Song LIN

Abstract-- Both symmetric and asymmetric armature windings are applied in the spindle motors used in hard disk drives. Consider the influence of the drive current in the windings, the analysis to the unbalanced-magnetic-pull (UMP) generated in the motor becomes more difficult. Besides the intrinsic and extrinsic components, the additional UMP can also induced by the current, and the UMP could thus be serious. This paper analyzes this phenomenon, and presents a model which can describe clearly the influence of the drive current to the UMP. For verifying the effectiveness of the analytic method proposed, several spindle motors are analyzed, and compared with the results obtained by using FE method. The comparing proves the effectiveness of the UMP model presented.

Index Terms—**acoustic noise, armature winding, drive current, magnetic field, spindle motor, unbalanced magnetic pull**

I. INTRODUCTION

The spindle motors used in hard disk drive (HDD) are 3-phase, and could use symmetric windings, or asymmetric windings in the motor. The motors are driven by BLDC drive mode, i.e., one electric drive cycle is formed by six steps, and every time only two phase winding have current. In normally, for the symmetric armature, the field produced by the current in the windings is always symmetric in the space, and the lowest order of the field harmonic in the space domain is same as the magnetic pole-pair of the moor. **Fig. 1** shows one example of the motor with symmetric windings. As the magnetic pole-pair of the spindle motors are not less than 3, the lowest order of the field harmonic produced by the symmetric winding is higher then one.

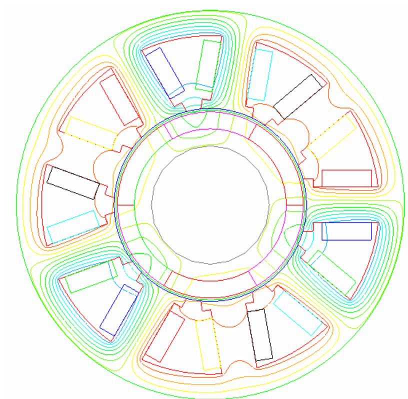

Fig. 1 the field produced by the armature windings in a 9-slot/3-pp spindle motor

However, some motors are using asymmetric windings, and the typical one is the motor with 9 stator slots and 4 magnetic pole-pairs, and **Fig. 2** shows its winding arrangement.

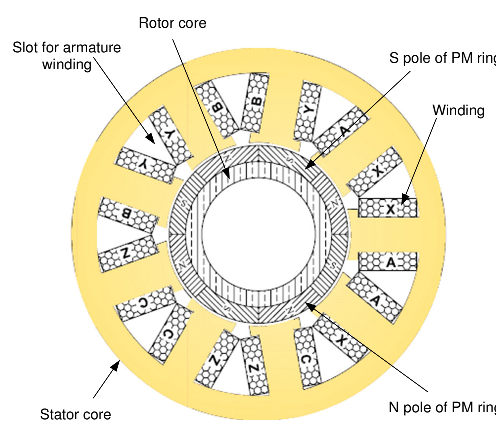

Fig. 2 EM structure of a 9-slot/4-pp spindle motor

The field produced by this kind of asymmetric windings is shown **Fig. 3**. It is clear, though the magnetic pole-pair of the motor is 4, but the lowest order of the field

Manuscript received August 9, 2006. This work was supported by Data Storage Institute

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harmonic in the space is one. The field produced by the winding is asymmetric in the space.

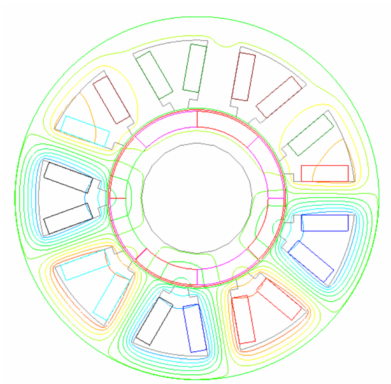

Fig. 3 the field produced by the armature windings in a 9-slot/4-pp spindle motor

II. UMP Induced by the Drive Current

The magnetic-circuit analysis method is used to analyze the magnetic field of the PMSM. In the airgap of the motor, the magnetic-motive-force (MMF) generated by the PM ring on the rotor can be described by,

$$\begin{aligned} F_R(\theta) &= \sum_{n=1} F_{R2n-1} Sin[(2n-1)p(\theta+\alpha)] \\ &= \sum_{n=1} F_{R2n-1} Sin[(2n-1)p(\theta+\Omega t)] \end{aligned}, \qquad (1)$$

where, θ is the rotor position, p is the pole-pair of the PM ring, α is the position difference to a static reference point. The UMP produced by the rotor magnet can be expressed as

$$P_x(\alpha,\delta) = P_{Ix}(\alpha) + P_{Ex}(\alpha,\delta), \qquad (2)$$

where, the substrate *I* means the intrinsic and *E* means extrinsic.

As the order of fundamental field harmonic produced by the drive current could be one, the MMF of the drive current can be expressed as

$$\begin{aligned} F_C(\theta,) &= \sum_{n=1} F_{cn} Sin[n\theta + (-1)^n \alpha] \\ &= \sum_{n=1} F_{cn} Sin[n\theta + (-1)^n \Omega t] \end{aligned}. \qquad (3)$$

The UMP produced in the motor can be expressed as

$$\begin{cases} P_x(\alpha,\delta) = \dfrac{v_0 hR}{2} \displaystyle\int_0^{2\pi} \{[F_R(\theta,\alpha) + F_c(\theta,\alpha)] \Lambda_e(\theta,\alpha,\delta)\}^2 \cdot Cos(\theta) d\theta, \\ P_y(\alpha,\delta) = \dfrac{v_0 hR}{2} \displaystyle\int_0^{2\pi} \{[F_R(\theta,\alpha) + F_c(\theta,\alpha)] \Lambda_e(\theta,\alpha,\delta)\}^2 \cdot Sin(\theta) d\theta \end{cases} \qquad (4)$$

Analysis shows that, the existence of the low order field harmonics is also one source inducing the UMP, and the UMP of the spindle motors with asymmetric windings are more sensitive to the drive current than the symmetric one, and **Fig. 4** and **Fig. 5** show the UMP variation of the 9-slot/4-pp motor with and without drive current.

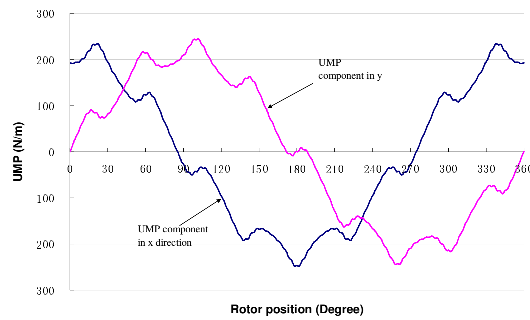

Fig. 4 the UMP produced in the 9-slot/4-pp spindle motor without drive current (eccentricity is 0.05 mm)

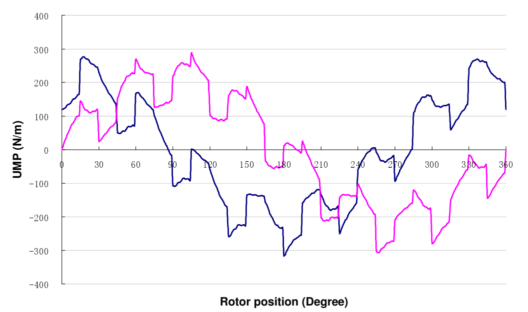

Fig. 5 the UMP produced in the 9-slot/4-pp spindle motor with rated drive current (eccentricity is 0.05 mm)

III. Conclusion

The drive current is also the source of UMP in the spindle motor operation, and it may induce serious UMP if the EM structure of the motor is not suitable. The paper presents an effective method for analyzing this kind of UMP, and introduces also some measures to reduce the UMP induced by the drive current.

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