

The Mechanism Study of Alternating Arc (AC) Magnetic Levitation Induction Motor

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ABSTRACT: Magnetic levitation (no bearings) motor by using magnetic force to make rotor suspend and drive realize its high or ultra high speed rotating. The stator's structure of traditional no bearing magnetic levitation motor is double winding which is polar logarithmic difference 1 of 2 sets of winding (torque winding and suspension winding) and embedded in the stator. Using two inverter respectively for the two sets of winding to go into the same frequency current in order to realize the suspension of the rotor and motor's driven, small carrying capacity of motor's structure, controlling complex system. This paper based on the traditional motor technology puts forward a kind of arc principle and respectively decorates two arc motors in horizontal and vertical direction symmetric to rotor according to the electromagnetic bearing suspension technology that is constituted the arc magnetic levitation induction motor. Establishing air-gap transformation regular between rotor and stator (air-gap length) motor is under the effect of interference. Based on the electromagnetic theory establishing distribution regular of the air-gap magnetic induction intensity. Virtual displacement principle is used to establish electromagnetism mathematical model and motor electromagnetism levitation. By the finite element analysis carrying on simulation research to the magnetic induction intensity, electric magnetic levitation force and distribution features of electromagnetic torque and so on.

KEYWORD: Alternating arc motor; Magnetic induction intensity; Levitation force features; Electromagnetic torque feature

1 INTRODUCTION

Magnetic levitation motor devotes the winding produced radial force in the electromagnetic bearing to overly on the motor stator's winding that is formed two different logarithmic rotating magnetic field in air-gap so as to produce torque and levitation force at the same time and realize the motor's driven and rotor's self-suspension[1]. Stator of magnetic levitation motor has double winding and single winding. At present, most of the magnetic levitation motor stator is double winding which is polar logarithmic difference 1 of 2 sets of winding (torque winding and suspension winding) and embedded in the stator. Using two inverter respectively for the two sets of winding to go into the same frequency current in order to realize the suspension of the rotor and motor's driven[1-2]. But bearing capacity of this kind of motor's structure is small and control system of that is complex. For this, put forward a new kind of alternating arc magnetic induction motor based on supporting and driving of the stator of 4 arc motor. It is same to the winding structure of traditional motor,

used to modify the balance of magnetic field produced by Arc motor stator's winding to produce levitation force realizing rotor's self-suspension. Compared to common double winding magnetic levitation motor, its structure is simple and the loss of motor's capacity factor is small[3]. This paper related to alternating arc magnetic levitation motor has studied rotating and suspension mechanism, establish mathematical model of system. By the finite element analysis and experiment method studying motor's suspension and rotating features.

2 THE MECHANISM OF ALTERNATING ARC MAGNETIC INDUCTION MOTOR

Ac arc magnetic induction motor's rotor is together supported to suspend and drive to rotate by 4 three mutually alternating arc motor. Arc motor based on traditional motor technology, which is rotated coil winding in wound arc stator and charged with electricity so that make rotor rotating. Analogy to traditional motor, divided to 3 phase, 2 phase or

single alternating motor (synchronism or asynchronous), straight motor, Dc motor, Stepper (reluctance) motor. Phase ac arc motor stator's winding creates a rotating magnetic field, to cut closed loop winding of rotor and produce induction current and potential, to achieve the rotor rotation.

Ac arc magnetic levitation induction motor is consisted by the stator, rotor, suspending and rotating detection system. Motor based on electromagnetic bearing suspension technology, on the traditional motor stator core, is wined two ac arc 3 phase motor winding symmetrical to rotor in horizontal and vertical direction. Under the comprehensive test control system, differentially modify current increment size of both sides arc motor in the same direction so as to change magnetic force size of rotor which is did by 2 arc motor and make the rotor always working in the direction of center equilibrium position of 2 arc motors. As shown in Figure 1 each set of three phase winding connection of type Y and current status in a certain time. 4 period of arc stator's windings respectively are sym-metrically arranged 2 circular arc in the x axis and the y axis. 3 phase stator winding of 4 period of arc motor which is paralleled to access three phase alternating current i_1, i_2, i_3 , respectively closed-loop controlling to current amplitude size of each set of arc motor stator winding, realizing the regulation of rotor's electromagnetic force, produce controllable electromagnetic levitation force. Its working principle of the rotor suspension is same to traditional electromagnetic bearing mechanism[4], under the effect of interference, the rotor is offset Δx along the x (right) direction in order to restore the rotor to center position (balance) of the stator. Under the effect of closed loop controlling system, the current of the arc motor stator winding on the left side of rotor increases Δi_{kx} ($k = 1, 2, 3$) into $i'_{kx} = i_k + \Delta i_{kx}$ ($k=1,2,3$), the rotor on the right side of the arc current of motor stator winding decreases ($k = 1, 2, 3$), the current of the arc motor stator winding on the right side of rotor decreases Δi_{kx} ($k = 1, 2, 3$) into $i_{kx} = i_k - \Delta i_{kx}$ ($k=1,2,3$). Figure 2 is 4 synthetic rotating magnetic flux produced by 4 period of arc motor winding.

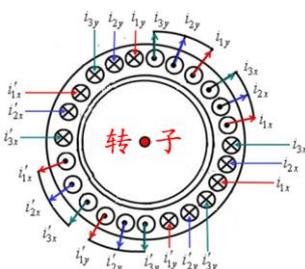


Figure 1. Principle diagram of electrifying magnetic flux.

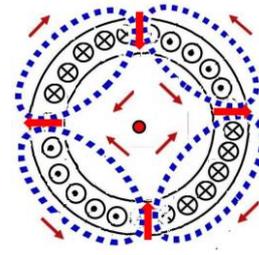


Figure 2. Rotating magnetic flux of ac arc magnetic motor levitation.

3 SUSPENSION AND ROTATING MODEL OF AC ARC MAGNETIC LEVITATION INDUCTION MOTOR

3.1 Change regulation of air-gap length between stator and rotor

If rotor is column, Figure 3 is schematic diagram when rotor happens to displacement, the air-gap length $\delta(\theta)$ between outer surface of rotor and inner surface of stator the stator can be expressed eccentric distance in the x and y directions. Supposing a unilateral average air-gap length $g_0 = R - r$, rotor offsets ρ along some (θ_0) direction. The Figure 3 shows $\rho \cos(\theta - \theta_0) + r + \delta(\theta) = R$, so the air gap length of any position in space is

$$\delta(\theta) = g_0 - (x \cos \theta + y \sin \theta) \quad (1)$$

In the formula, θ is the space vector Angle, x and y are the displacement when rotor along the x, y direction.

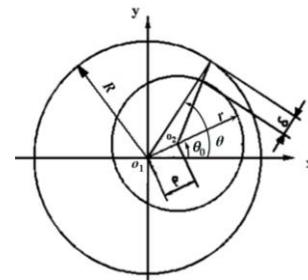


Figure 3. Eccentricity schematic magnetic diagram of rotor

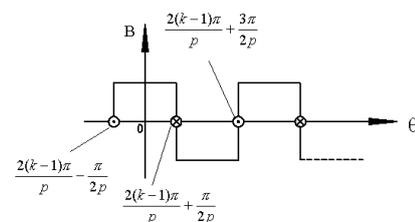


Figure 4. Distribution curve of induction intensity

3.2 Motor air-gap magnetic induction intensity distribution

According to the theory of magnetic field, under the action of alternating current $i(t)$, single-phase

winding of p pairs of magnetic pole, magnetic induction intensity of the rotating magnetic field in the circumference of air-gap effective length g is rectangular distribution[5], Figure 4 can gain the distribution of air-gap magnetic induction intensity

$$B(\theta, t) = \begin{cases} \frac{Ni(t)\mu_0}{2g} & \frac{2(k-1)\pi}{p} - \frac{\pi}{2p} \leq \theta < \frac{2(k-1)\pi}{p} + \frac{\pi}{2p} \\ -\frac{Ni(t)\mu_0}{2g} & \frac{2(k-1)\pi}{p} + \frac{\pi}{2p} \leq \theta \leq \frac{2(k-1)\pi}{p} + \frac{3\pi}{2p} \end{cases} \quad (3)$$

In the formula, k is natural Number; μ_0 is the permeability of magnetic field air, $\mu_0 = 4\pi \times 10^{-7}$ H/m; N is number of stator winding; g is the air-gap length between the stator and rotor.

$$B(\theta, t) = \left(\frac{NI\mu_0}{2g} \cdot \frac{4}{\pi} \right) \left(\cos p\theta - \frac{1}{3} \cos 3p\theta + \frac{1}{5} \cos 5p\theta + \dots \right) \cos \omega t \quad (4)$$

In the formula, I is current amplitude, ω is current frequency. Three phase winding of 4 period of circular arc stator is composed of three phase windings, and symmetrical distribution in the motor stator, each of single phase winding produces induction intensity of pulse vibration. The axis of three phase winding of all the motor stator winding composed, is successively separated electrical angle 120° in space, by the formula (4) after ignoring higher harmonic, the distribution of magnetic induction intensity of the fundamental wave in space is successively separated electrical angle 120° , by type (4) gaining

$$\begin{cases} B_A(\theta, t) = B_m \cos p\theta \cos \omega t \\ B_B(\theta, t) = B_m \cos(p\theta - 120^\circ) \cos(\omega t - 120^\circ) \\ B_C(\theta, t) = B_m \cos(p\theta - 240^\circ) \cos(\omega t - 240^\circ) \end{cases} \quad (5)$$

Among them, the magnetic induction intensity value is

$$B_m = \frac{2\mu_0 NI}{\pi g} \quad (6)$$

Its size is depends on the input current of winding and air-gap length. By type (5) calculating magnetic induction intensity of three-phase fundamental wave synthesis produced by all the three-phase winding magnetic potential in the stator's and rotor's magnetic field air-gap is

$$B_s(\theta, t) = B_m \cos(\omega t - p\theta) \quad (7)$$

In this formula, θ is tangential angle of reeling stator axis; p is magnetic field pole logarithmic produced by winding.

Magnetic flux of inductive magnetic levitation motor stator winding rotates and cuts the armature

winding of rotor in space, producing inductive electromotive force and the current in the rotor. By alternating current in the rotor can produce spinning magnetic flux in the air gap all the same, its magnetic inductive intensity is

$$B_r(\theta, t) = \beta B_m \cos(\omega t - p\theta - \alpha) \quad (8)$$

In this formula, β is inductance coefficient of stator and rotor winding; α is phase difference between magnetic field and winding rotating magnetic field of rotor and stator (including rotor angular displacement). β 、 α each of them is decided by of rotor and stator structure and slip ratio of inducing magnetic levitation motor.

By the winding of stator and rotor produced total magnetic inductive intensity on the circumference of the air gap of are

$$B(\theta, t) = B_m (\cos(\omega t - p\theta) + \beta \cos(\omega t - p\theta - \alpha)) \quad (9)$$

Above the type, the distributive regulation of air-gap magnetic inductive intensity of inducing magnetic levitation motor is related to magnetic pole logarithm, tangential angle position around the axis of the stator, as well as the phase difference between the rotor and the stator rotating magnetic field produced by the winding of stator.

4 ANALYSIS OF FINITE ELEMENT SIMULATION OF AC ARC MAGNETIC LEVITATION INDUCTION MOTOR

Structure parameters of ac arc magnetic levitation induction motor have shown in table 1. By the parameters of table 1 building geometry model of magnetic levitation motor stator with rotor and mesh, Figure 5 is the air-gap enlargement chart. After the finite element calculation, can get the initial distribution of magnetic force lines, as shown in Figure 6.

Figure7 is distributive chart of magnetic flux density after running a spin cycle. Magnetic inductive intensity in the middle of the stator and rotor magnetic circuit with the air-gap distribute more uniform, magnetic flux density in the stator tooth is bigger, near the edge of rotor and outer of stator appear to magnetic leakage in a certain extent, but not obvious.

Figure8 is distributive chart of magnetic pole air-gap magnetic flux density produced by a set of circular motor winding. Due to the actual tooth slot, magnetic leakage and other factors for example edge effect, so the magnetic flux density is fluctuating, the average effect is fundamental with the cosine regulation distribution, equal to the theoretical value.

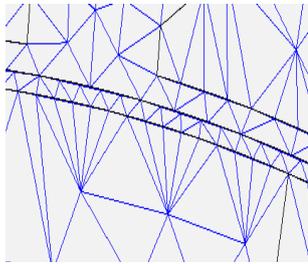


Figure 5

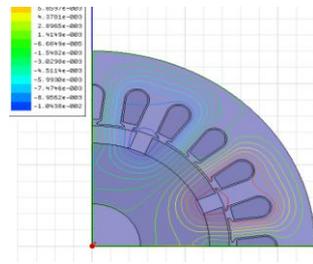


Figure 6

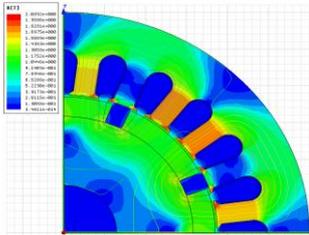


Figure 7

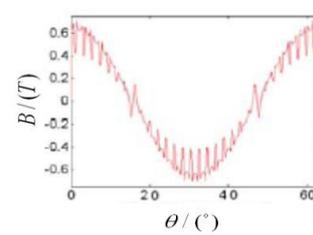


Figure 8

Table 1. Model parameters of ac arc magnetic levitation induction motor

Parameter name	Parameter values
Inner diameter of stator	64.5mm
Outer diameter of stator	75mm
Tooth width	14mm
Air-gap length	0.25mm
Axial length	20mm
Numbers of winding (A set of three phase winding)	130

5 THE CONCLUSION

1) This paper based on technology of the traditional motor is proposed principle of arc motor, according to the suspension mechanism of electromagnetic bearing, ac three phase-4 circular arc magnetic levitation motor is consisted by arc motor, analyzed the basic composition and working principle of the motor;

2) Setting up coordinates changing regulation and the and air-gap magnetic field distribution model of air-gap length of ac arc magnetic levitation induction motor;

3) Based on air-gap magnetic field distribution of ac arc magnetic levitation induction motor, the virtual displacement principle is used to establish the electromagnetic levitation force and electromagnetic torque model of motor;

4) By the finite element simulation analysis verifying air-gap magnetic induction intensity, electric-magnetic levitation force and electromagnetic torque distribution characteristics of ac arc magnetic levitation induction motor.

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