Design and Simulation Analysis of 55kw 12/8 Switched Reluctance Motor for Air Compressor

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Abstract—The vibration and noise of switched reluctance motor are too large, which becomes an obstacle to the application of switched reluctance motor in air compressor. In this paper, a 55 kw 12/8 switched reluctance motor(SRM) for air compressor was designed, and static simulation analysis was carried out on the basis of finite element analysis software ANSOFTMAXWELL 2D, and the characteristic curve of the motor was obtained. The noise source of the SRM was analyzed, and the radial electromagnetic force was numerically calculated and obtained the air gap is the main structural parameter which affect the vibration of the motor. The air gap was parameterized and and the result provides the basis for optimization of motor parameters.

Keywords—air compressor; switched reluctance motor; radial force; parameter analysis; air gap

I. INTRODUCTION

Compressors are all kinds of general machinery and equipment, products with the technical progress from the piston compressor, twin screw compressor to today's single screw compressor. At present, the air compressor requires the motor to have high speed, strong starting torque, light weight, high efficiency and low noise [1]. Induction motor has simple structure, easy to manufacture, cheap, easy to operate, but the power factor is lagging behind, light load power factor is low, speed performance slightly worse. SRM is not only efficient, reliable, wide speed range, and excellent start-up, braking characteristics, but the SRM running vibration and noise is too large, which becomes a switched reluctance motor used in air pressure Machine an obstacle. In this paper, presented the use of SRM as a single screw air compressor drive motor, designed a 55 kw 12/8 SRM, and the characteristic curve of the motor is obtained. The noise source of the SRM is analyzed, and the radial electromagnetic force is numerically calculated and extracted to obtain the main structural parameters which affect the vibration of the motor, which provides the basis for the parameters optimization of the motor.

II. STRUCTURE AND PARAMETERS OF SWITCHED RELUCTANCE MOTOR

The asynchronous motors, for 37 kw single screw air compressor, rated speed of 2980 rpm, displacement 6 m3/min, speed performance is poor, low efficiency. Ideally, if the use of SRM as the drive motor, the same pressure, power up to 55 kw, speed increased to 6000 rpm, displacement can reach 12 m3/min, can greatly improve the efficiency of air compressor.
TABLE I. MAIN PARAMETERS OF THE MOTOR STRUCTURE

| Name                        | Data  | Name                        | Data  |
|-----------------------------|-------|-----------------------------|-------|
| Number of stator poles      | 12    | Number of rotor poles       | 8     |
| \( N_s \)                  |       | \( N_r \)                  |       |
| Rotor outside diameter      | 175   | Rotor inner diameter        | 60    |
| \( D_r \) (mm)              |       | \( D_{ri} \) (mm)          |       |
| Stator outer diameter       | 327   | Stator inner diameter       | 177   |
| \( D_s \) (mm)              |       | \( D_{si} \) (mm)          |       |
| Stator pole arc             | 12    | Rotor pole arc              | 18    |
| \( \theta_s \) (°)         |       | \( \theta_r \) (°)         |       |
| Stator yoke height          | 26    | Rotor yoke height           | 25    |
| \( h_s \) (mm)              |       | \( h_r \) (mm)             |       |
| Air gap \( g \) (mm)        | 1.0   | Winding turns \( T_{ph} \)  | 20    |
| Core length \( l \) (mm)    | 200   |                             |       |

III. ESTABLISHMENT AND SEGMENTATION OF FINITE ELEMENT MODEL

Compared with the traditional analytic method and the equivalent magnetic circuit method, the finite element method makes the solution of complex structure and complex boundary problem easy, and can calculate the nonlinear problem of switched reluctance motor [3].

In the ANSOFT software to establish a good motor model, the grid automatically split, split the effect shown in Figure 2 and Figure 3.

IV. FINITE ELEMENT SIMULATION OF SRM

The static electromagnetic properties of SRM include flux linkage characteristics, static torque characteristics, and inductive characteristics, which are closely related to motor design and are significant for verifying the correctness and accuracy of motor performance [5].

It can be seen from Figure 4 that when the rotor pole is close, the air gap is reduced and the magnetic field lines are connected together by the air gap, the rotor body and the stator yoke to form a closed loop. At this time, the magnetic field lines are in a bent state. Figure 5 shows the magnetic field distribution of the motor magnetic field when the single-phase winding is excited. As shown in Figure 6, it can be seen that Magnetic saturation has begun to occur at the portion where the stator and rotor are close to each other.
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and tangential magnetic force
m, 15% lower, and the maximum output
m, down by 10.5%.

110 N

FIGURE VI. TORQUE CHARACTERISTIC CURVE

Figure 6 is the SRM torque characteristic curve. In a half rotor pole distance, conducting the A-phase winding, when the rotor torque in the rotor rotation 22.5° mechanical angular position, as shown in Figure, the torque is 0, power generated will pull the rotor by the reluctance torque, when the rotor torque in the rotor rotation 45°mechanical angular position, the stator and rotor pole completely coincide, when the rotor turns through 45°, and conducting the A-phase winding, the rotor salient pole began to leave the stator salient pole, resulting in negative torque. So the commutation angle must be in the rotor salient pole from the stator salient pole, otherwise the rotor will produce negative torque, reduce the output torque.

V. PARAMETRIC SIMULATION ANALYSIS

Electromagnetic noise is the main noise of the switched reluctance motor, the effective suppression of electromagnetic noise can achieve the purpose of motor noise reduction [6]. The electromagnetic noise source from the switched reluctance motor stator, the rotor between the radial pulsating magnetic attraction.

The air gap is the main structural parameter that affects the ratio of radial magnetic force to tangential magnetic force of switched reluctance motor [7]. Based on the virtual displacement method to analyze the electromagnetic force of the switched reluctance motor, the ratio between the radial and tangential magnetic force of the switched reluctance motor is

\[ \delta = \frac{F_r}{F_t} = \frac{D_r \theta}{g}. \]  

\( D_r \) is the rotor outside diameter, \( \theta \) is the rotor position. It is concluded from the above formula that the ratio \( \delta \) between the radial magnetic force \( F_r \) and tangential magnetic force \( F_t \) of the switched reluctance motor is inversely proportional to the size of the air gap \( g \). Reduce \( \delta \) to help reduce vibration and noise reduction.

Keep the winding current constant, in a reasonable air gap range: 1.0 mm - 1.5 mm, air gap length of each increase of 0.1 mm, the stator by the radial magnetic force, the motor output torque calculation.

In order to reduce noise, air gap size selected 1.2 mm. In contrast, the radial magnetic force was reduced from 41.1 kN·m to 34.1 kN·m, 15% lower, and the maximum output torque decreased from 123 N·m to 110 N·m, down by 10.5%. Therefore, for different needs, in the optimization of the motor air gap, should consider the radial force and output torque [9].

VI. CONCLUSION

(1) A 55KW air compressor switched reluctance motor was designed. The motor was simulated by ANSOFT MAXWELL2D. The static characteristics of the motor were obtained.

(2) The finite element simulation software is used to simulate the air gap of the motor, and the accurate numerical solution of the change of the torque and the radial force is obtained by gradually changing the air gap size. The air gap parameter can effectively reduce the radial force.
(3) It is worth noting that the optimized structure reduces the radial force while reducing the average torque, which requires a trade off in the selection of the air gap. Which provides a basis for optimizing the motor parameters by using multi-objective intelligent algorithm.

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