300kW 급 가변속 PMSM의 냉각시스템 설계

Zhou Guangxu[1],이동희[1],안진우[1],안영주[2]
경성대학교[1] 부경대학교[2]

Design of Cooling System for Variable Speed 300kW PMSM

Zhou Guang-xu[1],Lee Dong-hee[1],Ahn Jin-woo[1],An Young-joo[2]
Kyungsung University[1], Pukyong National University[2]

Abstract - due to the modification of ventilation system for variable speed high efficiency PMSM, the ventilation structure is analyzed in this part. First, a cooling structure was proposed for the variable speed PMSM. Through the contrast result of whole stress and speed distribution in the cooling channel by fluid field, the fans setting fashion is confirmed. By the studying of cooling structure for improved PMSM, the position of the cooling hole in the rotor is optimized by the finite element method. At last, the thermal field distribution of the motor is calculated by FEM. The calculated thermal rise is in accord with measured value, which provides effective basement for the design and safety operation of PMSM.

1. Introduction

The permanent magnet motors using NdFeB magnets can operate over a wide temperature range. For this material, up to a well-defined temperature limit, the residual flux density and intrinsic coercively will linearly vary down or up as the temperature is increased or decreased. When the operating temperature of the magnet is increased above a critical designing temperature, not only the efficiency and motor performance decrease, but also it will result in irreversible demagnetization of the magnet. Once this happens, the flux density will present a non-linear recoil branch as the temperature is reduced. The critical designing temperature at which the irreversible demagnetization occurs depends both on the magnet properties, the operating load line of the magnetic circuitman the design of cooling system. The motor should be designed such that the normal operating temperature of permanent magnets to be below the critical designing temperature. In the following contents, section 2 introduces the main structure of the proposed cooling system. section 3 analyzes the cooling effect by FEA. sections 4 gives the experiment result.

2. Cooling System Analysis

2.1 The cooling structure

Because of their robustness and high efficiency, middle-capacity permanent magnet motors of several hundreds of kilowatts are used to drive important blowers and pumps applications such as water systems, power systems, and steel production plants. In particular, open-type motors, which take air into their interior, often chosen for economic reasons.

Middle-capacity open-type motors need large amounts of air for cooling as they produce large losses[1]-[3].so the cooling system is one of the indispensable part of motor, it depend on the motor structure and operation mode[4]. In this paper a cooling structure is proposed integrated the ventilation system of original induction motor. To keep the original symmetry structure of ventilation system, two axis flue fans is fixed at the bottom of motor. Fig.1 is the cooling system of variable speed PMSM.

The cooling system of variable speed PMSM includes the additional fans and composite ventilation system inside the motor. The additional fans are providing the enough wind quantity and pressure. The wind circuit inside the motor composed of radial and axis channels.

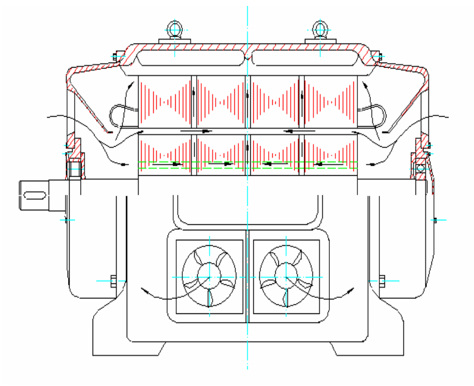

Fig.1 Cooling system of variable speed PMSM

Fig. 1 shows details of the air flow around the iron core. In the stator and rotor iron cores, there are radial paths of air. When a rotor rotates, axial fans and rotor radial air paths provide cooling air inside the motor. Air is blown onto the ends of the stator windings and onto the rotor iron core. Air to the rotor flows from rotor axial paths to rotor radial paths, air gap and stator radial paths, and then to the outside of the stator iron core.

2.2 Cooling holes position selection

The position of cooling holes in the rotor is important to the whole cooling system. If the holes were in the incorrect position, there is undesirable influence on the wind circuit and magnetic circuit. In this part, through analysis the flux distribution result and magnetic performance during different holes position, the appropriate location is confirmed.

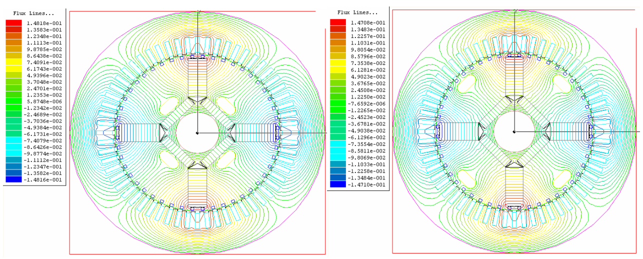

Fig.2 Field distributing when d=102 and 180 mm

Through the above electromagnetic field analysis, the magnetic parameters change with the different holes position is obtained.

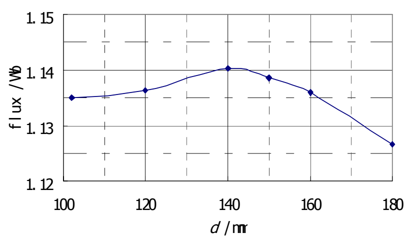

Fig.3 Influence of cooling hole position on flux

when the distance between cooling holes and axis is 140 mm, the above analysis results prove the design could obtain a more satisfied performance.

2.3 FEA analysis results

An analysis model is established is the FEA software. The basic equation of flow is the continuation (1) and the Navie-Stokes equation (2):

$$\frac{\partial ui}{\partial xi} = 0 \quad (1)$$

$$\frac{\partial ui}{\partial t} + ui\frac{\partial ui}{\partial xj} = -\frac{1}{\rho}\frac{\partial p}{\partial xi} + v\frac{\partial^2 ui}{\partial xj \partial xj} + Hi \quad (2)$$

Where, u is the flow velocity in m/s, i the subscript showing coordinate directions, x the coordinate value in meters, t the time in seconds, ρ the fluid density in kg/m3, p pressure in Pascal, and v the fluid kinetic viscosity coefficient in m2/s

In the Fig.4 Liquid route in the cooling channel, Fig.5 Speed distribution in the cooling channel, Fig.6 Whole stress in the cooling channels

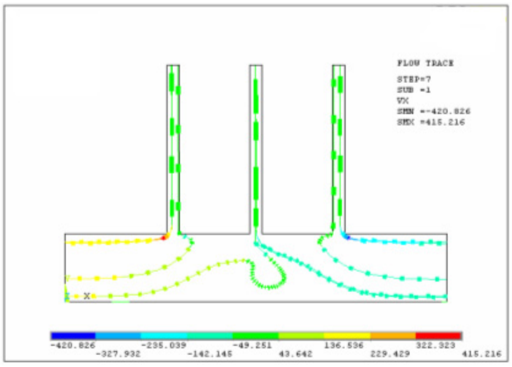

Fig.4 Liquid route in the cooling channel

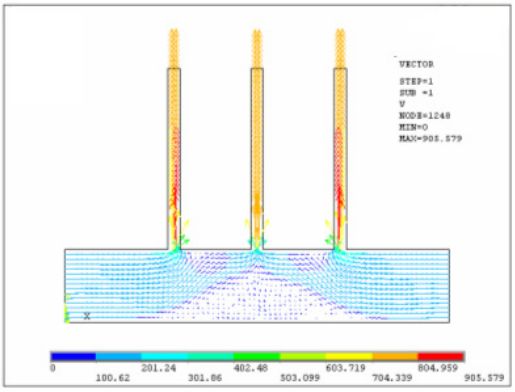

Fig.5 Speed distribution in the cooling channel

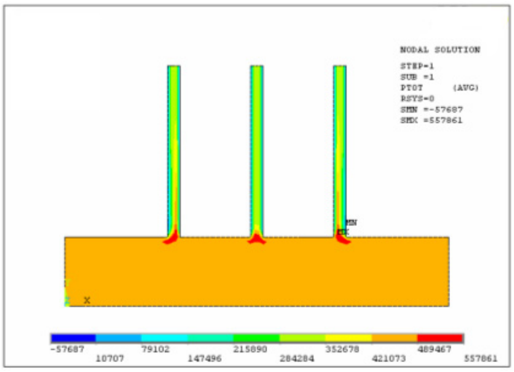

Fig.6 Whole stress in the cooling channels

The Speed and Whole stress simulation distribution results in the cooling channel prove the axis and radial channels work very well when the motor running.

3. Experiment results

To verify our proposed method, the temperatures distribution was measured of the 300 kW PMSM with coolant channels which was manufactured like above illumination. Fig.7 is axis temperature rise of different parts Table.1 is temperature rise distribution of the motor (the circumstance was 26℃).

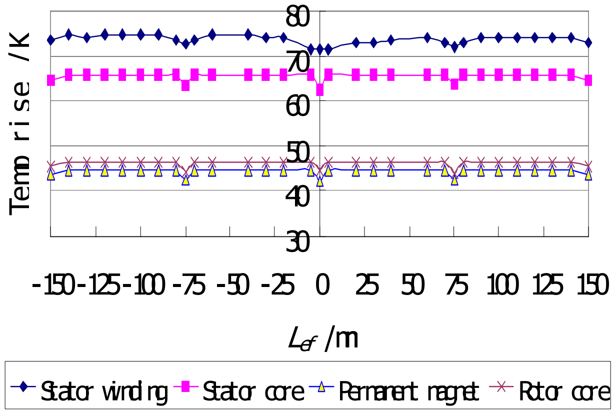

Fig.7 Axis temperature rise distribution of different parts

Table.1 Temperature rise distribution of the motor (26℃)

	Calculated	Measured	Error %
Housing /K	45.8	43.4	6.45
Stator core /K	61.2	65.6	-6.71
Stator winding /K	74.6	71.5	4.33
Rotor core /K	47.5	45.4	3.79
Permanent magnet /K	42.2	44.6	4.39
Shaft /K	42.5	39.8	6.78

Form the experiment results we can see that the maximum temperature rise is in the stator winding and the temperature rise of this part is up to 71.5K. The permanent magnet material working temperature is 70.6℃. The experiment result is matching with the calculated value. The method can provide a effective induction for the design and running of variable speed PMSM

4. Conclusion

This paper shows the simulations and experiments of ventilation system for variable speed high efficiency PMSM. the ventilation structure is analyzed in this part. according to the original induction motor structure, proposed a cooling structure for 300kW variable speed PMSM. Through the contrast result of whole stress and speed distribution in the cooling channel by fluid field, confirms the fan setting fashion. By the studying of cooling structure for improved PMSM, the position of the cooling hole in the rotor is optimized by the finite element method. At last, the thermal field distribution of the motor is given. The calculated temperature rise is in accord with measured value, this simulation provides effective basement for the design and safety operation of PMSM.

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