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Thermal Analysis Of 8/6 Switched Reluctance Motor Using Finite Element Method Under Steady State And Transient Conditions.

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Abstract: *Using Finite element method, a 2D steady state and transient thermal analysis performed in 8/6 switched reluctance motor is represented in this paper. With this, the heat distribution in diverse parts of the machine can be observed. A 2D steady state analysis is done to examine the maximum temperature rise for the extensive range of speed and load situations. The utmost temperature rise at various load conditions and time are predicted using the transient analysis. The temperature rise in the machine causes thermal stress and efficiency reduction. Hence the temperature of the machine must be maintained within the tolerable limits for secured operation. In electrical machines, the insulation life time varies inversely with the working temperature. Hence to improve the machine performance, its reliability and to maintain its long term stability of the machine, a thermal analysis is carried out under steady state and transient conditions by 2D Finite element analysis .*
Index Terms: *Core and copper loss, Switched reluctance machine, Steady State and Transient thermal analysis, Finite element method.*

I. Introduction

In recent times Switched reluctance motor plays a vital role in various industrial applications. This is due to their low cost manufacturing, robust performance and relatively simple control structure. It has an excellent attributes such as high torque density and high speed capabilities. Compared to other electrical machines, a 8/6 switched reluctance motor has low temperature rise capability for high speed range[1]. It has windings only in stator and rotor has no windings. With no winding in rotor the losses that occurred is reduced. Temperature rise of 8/6 switched reluctance motor is due to electromagnetic losses[2] that include core losses that occur in laminations and copper loss that occur in windings [3]. Hence by using a laminated sheet steel (SRM-M19) and a soft magnetic composite material in stator the temperature rise that predicted within the machine can be reduced[4].
The electromagnetic losses in a Switched reluctance motor causes temperature rise. These losses consists of core loss and copper loss. They are considered as a heat source in thermal analysis [5]. The core loss occur in both stator and rotor and the copper loss occur only in stator. The temperature rise in machine causes thermal stress[6] and reduction in efficiency which leads to machine damage[7].

II. Thermal Analysis Of Switched Reluctance Motor

Modern Thermal analysis can be carried out using various techniques such as
1. Experimental Method
2. Lumped parameter thermal model Method
3. Numerical Analysis Method

Experimental Method is suitable only for already designed machine. Based on its thermal behavior the cooling strategy can be decided. But the accuracy is less in case of complex structured machines.\In lumped thermal model thermal problem is solved using thermal networks similar to electrical circuits. The result shows only the overall heat distribution . But temperature inside the machine cannot be predicted.
Numerical method is one of the most promising technologies[8]. It involves numerical analysis computer programs by means of finite element method.

III. Types Of Numerical Methods

- Finite Element Method
- Boundary Element Method
- Finite Difference Method

In these different types of numerical methods Finite Element Method is the simplest method among all other numerical methods and has more accuracy. Therefore the thermal analysis was carried out under steady state and transient condition using Finite Element Method .

A. Finite Element Method

The Finite Element (FEM) is a numerical method which is used for solving field problems. It is a computational technique which is used to obtain approximate solutions of Boundary value problems which is also called as Field problems. In FEM it cuts a structure into several elements and then reconnects the elements at nodes. The nodes of those elements are hold together to form a partial differential equations (PDE).It reduces the partial differential equation system in to a system of algebraic equations that can be solved using linear algebraic techniques.

B. Geometrical Model Of Srm

The geometrical model of 8/6 SRM shown in fig.1 consists of Stator, Stator winding, rotor, Air gap and Shaft . A two dimensional (2D) model of 8/6 Switched Reluctance Motor is shown in fig.2 whose Specification are listed in the table 1.

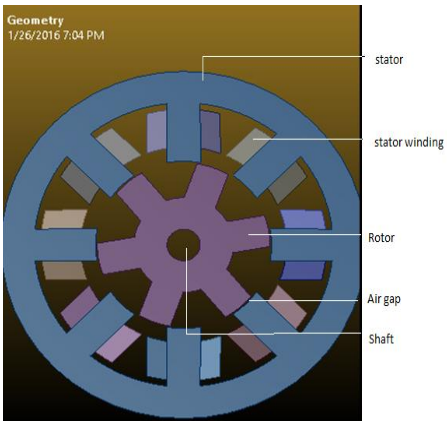


Figure1. Geometrical model of 8/6 SRM

TABLE I: THERMAL PAREMETERS

MATERIAL	THERMAL CONDUCTIVITY (W/MK)	DENSITY (Kg/m3)
Copper	380	8940
Steel(M19)	60	7850
Air	0.024	1.165

II. 2D FINITE ELEMENT MODEL OF SRM

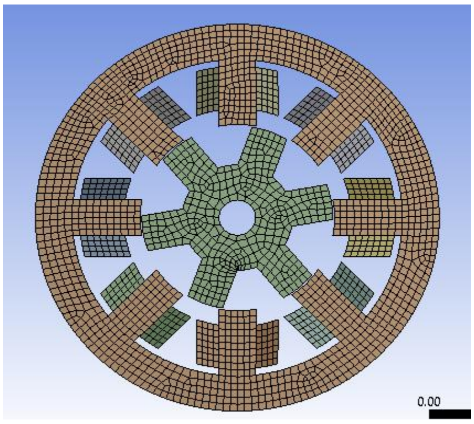


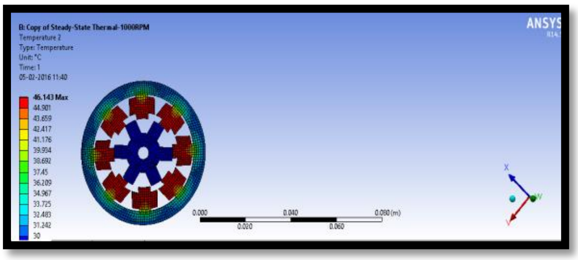
Figure2. 2D Finite Element model of SRM

Statistics	
Nodes	18186
Elements	2244
Mesh Metric	None

In Finite Element Analysis, to increase the accuracy the2D structure is divided into fine subdivisions. In 2D problems the elements used are triangles, rectangles, and quadrilaterals. In this the losses that calculated using finite element analysis is applied to the temperature analysis. The temperature rise within the machine is estimated using these results as a heat source. In this model plane 55 elements is used for analysis and it is used for the steady state and transient thermal analysis.

A.Steady State Thermal Analysis

In this the ambient temperature was set as 27°C to carry out a steady state analysis. Fig.3 shows that the maximum temperature of 46.143°C is obtained at 1000RPM. This occurs due to the higher copper loss in the internal coil. The copper loss depends on the current that pass through the coil. As the load increases the core loss will be greater than the copper loss. The model is simulated at various speeds and the results are tabulated in table II.In this steady state thermal analysis the maximum temperature of 46.641°C is obtained at 1500RPM. It is considered as an initial condition for the transient thermal analysis.



*S .Nithya[1], Steady state temperature distribution at 1000RPM

TABLE II : RESULT OF STEADY STATE THERMAL ANALYSIS

SPEED (RPM)	MAXIMUM TEMPERATURE(°C)
500	39.746
1000	46.143
1500	46.641
2000	39.789
2500	35.975

B.Transient Thermal Analysis

In this transient thermal analysis temperature varies with time. Temperature distribution after 1000 seconds is shown in fig.4.

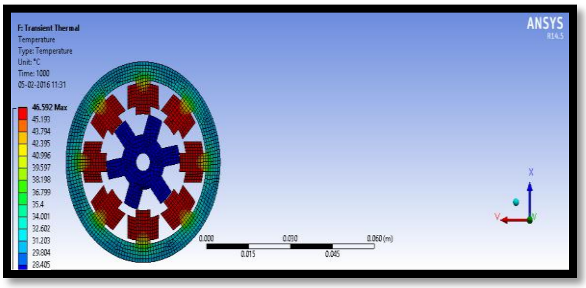


Fig.4 Temperature distribution after 1000 seconds.

In this transient thermal analysis time taken to reach steady state temperature has been calculated. Fig.5 shows how the temperature varies with time in a 8/6 SRM. Temperature of the winding at various time intervals are observed and listed in Table III. It shows that steady state temperature is reached after 1000seconds. Hence the heat distribution within the machine with respect to time can be calculated accurately using transient thermal analysis.

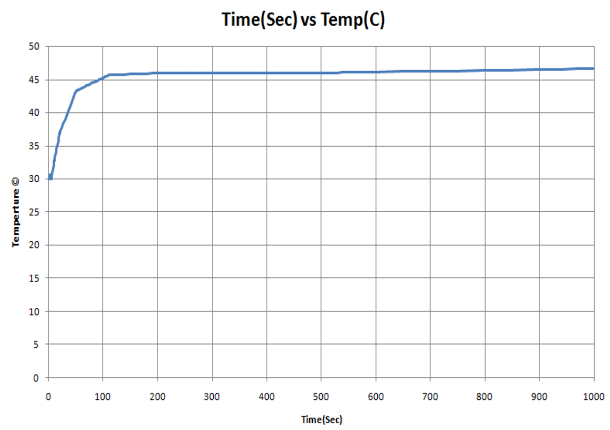


Fig.5 Temperature –Time curve

TABLE III : Results Of Transient Thermal Analysis

TIME (seconds)	MAXIMUM TEMPERATURE (ºC)
10	32.654
20	36.827
50	43.266
110	45.636
213	45.986
512	45.996
1000	46.592

IV. Conclusion

In electrical machine the temperature rise causes thermal stress and reduction in its efficiency. Hence the temperature of the machine must be maintained within the permissible limit for safety operation and its reliability. Therefore a 2D thermal analysis was carried out under steady state and transient condition using finite element method. It is observed that a maximum temperature of 46°C is obtained after 1000 seconds. Hence the temperature rise inside the machine has been analysed to maintain within its acceptable limits.

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