PERFORMANCE INSPECTION OF DOUBLE STATOR SINGLE ROTOR PERMANENT MAGNET MACHINE USING FINITE ELEMENT ANALYSIS

Saravanan. S
Department of Electrical and Electronics Engineering
AAA College of engineering and technology, Sivakasi, TamilNadu, India.
sarantajmahal@gmail.com

Marsaline Beno. M
Department of Electrical and Electronics Engineering
St.Xavier's Catholic College of Engineering, Nagercoil, Tamilnadu, India
marsaline_me@yahoo.com

Prabhu. S
Department of Electrical and Electronics Engineering
Arunai Engineering College, Tiruvannamalai, Tamilnadu, India
prabhutajmahal6@gmail.com

***Abstract* ─** *This paper predicts the performance of Double Stator Single Rotor Permanent Magnet Machine (DSSRPMM). Finite Element Analysis (FEA) has been carried out and it expands in three different aspects such as Magnetic field, Vibration and Thermal. The Magnetic Field analysis, Vibration Analysis and Thermal Analysis inferences the Torque ripple, Natural Frequencies and temperature distribution of the motor respectively.*

Key words: *Finite Element Analysis, Vibration Analysis, Magnetic Field Analysis and Thermal Analysis*

1. INTRODUCTION

In recent days, permanent magnet machines widely used in Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV) applications due to their salient features such as high efficiency, high power density, ease of control etc.,

The Switched Reluctance Motor has main disadvantages such as torque ripple, vibration and temperature rise due to doubly salient, Electromagnetic forces and Ohmic losses. [1-3].

This paper contributes the estimation of torque ripple, natural frequencies and temperature rise for Double Stator Single Rotor Permanent Magnet Machine (DSSRPMM). In 12/8 Switched Reluctance Motor, the permanent magnet is used in rotor to increase the power density of motor. This paper is organized in the following manner such as,

1. Introduction
2. Electromagnetic field analysis
3. Vibration analysis
4. Thermal analysis

2. Electromagnetic Field Analysis

The machine dimension is illustrated in the table 1 and the model is shown in Fig 1.

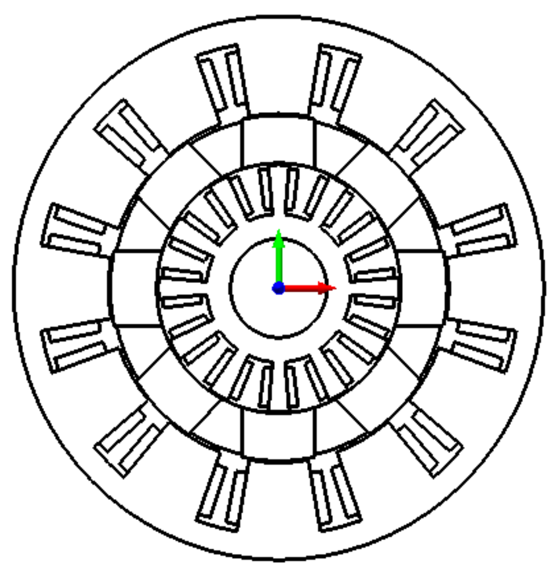

Fig. 1. 2D Sketch DSSRPMM

Table 1: Specifications of DSSRPMM

Specifications	Dimensions
Number of Inner stator poles	12
Number of Outer stator poles	12
Number of rotor poles	8
Inner stator diameter(mm)	50
Shaft diameter(mm)	20
Inner stator back iron(mm)	30
Inner stator airgap(mm)	0.3
Rotor diameter(mm)	35
Outer stator air gap(mm)	0.3
Outer stator back iron(mm)	47
Stator outer diameter(mm)	55
Stack length(mm)	55
Number of turns	300/phase
Rated torque (Nm)	5
Rated current(A)	5
Rated speed(rpm)	1000

The following assumptions are made to perform the electromagnetic field analysis.

1. Along the longitudinal direction the magnetic field distribution is constant.
2. The magnetic field outside the periphery is negligible.
3. The effects concerned with the end effect are ignored.

The distribution of Magnetic flux density in phase A is shown in Fig 2.

The step angle for the machine is given in the equation (1) and Torque ripple in equation (2).

$$Step\ angle = {}^{360}/_{(Q * N_r)} \qquad (1)$$

Where, Q is the number of poles, Nr is the number of rotor poles.

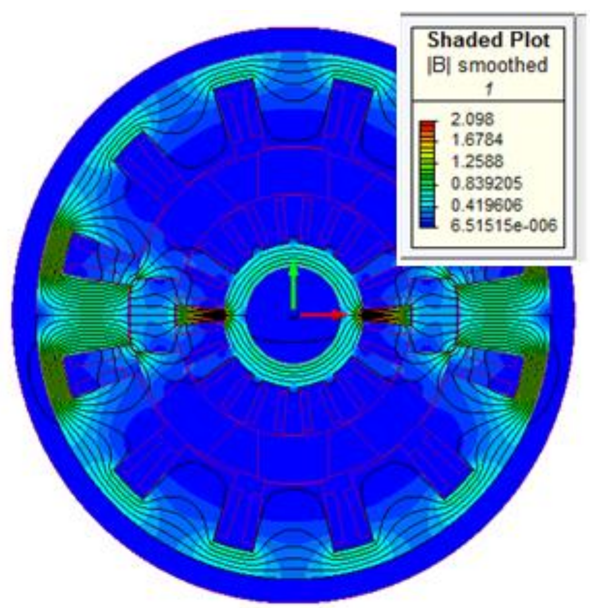

Fig. 2. Flux density distribution of Phase-A Excitation

$$Torque\ Ripple = \frac{(T_{max} - T_{min})}{T_{avg}} \quad (2)$$

Where, T_{max} = Maximum Torque, T_{min} = Minimum Torque, T_{avg} = Average Torque

From the fig 3, the obtained maximum torque is 5Nm and the minimum torque is 3Nm. So the torque ripple is estimated as 0.54Nm with an average torque of 3.673Nm. Electromagnetic analysis has been carried out using MagNET software.

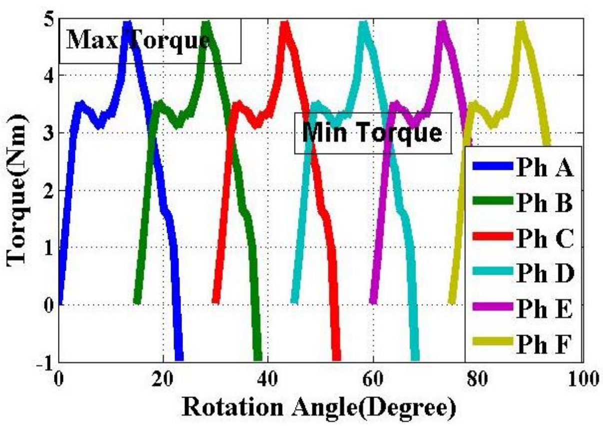

Fig. 3. Static Torque profile

3. VIBRATION ANALYSIS

The displacement at the base of the stator is fixed as zero for boundary condition. The material properties namely density, Young's modulus and Poisson's ratio is 7600Kg/m^3, 2e^{11} N/m^3 and 0.3 respectively for steel. In the case of copper the density is 8616Kg/m^3 [4, 5]. These are the parameters taken for the analysis.

The vibration analysis has been done for inner and outer stators. The number of poles in both inner and outer stator is 12. Vibration analysis has been carried out using ANSYS software.

a. Outer Stator

In outer stator, the vibration analysis has been carried out, Fig 4, Fig 5, Fig 6, Fig 7 and Fig 8 displays the nodal solution for modal (vibrating) frequencies with its corresponding displacement.

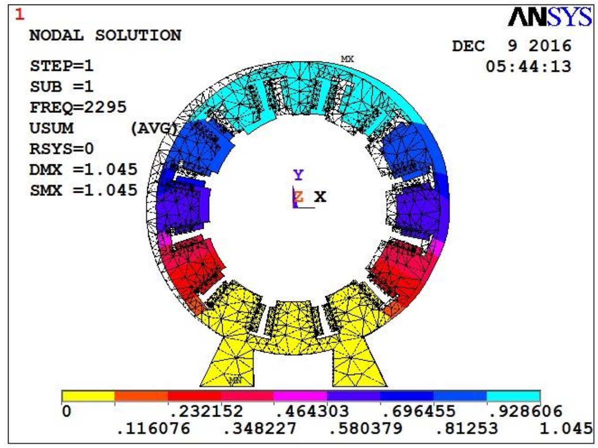

Fig. 4. Mode 1 at 2295Hz

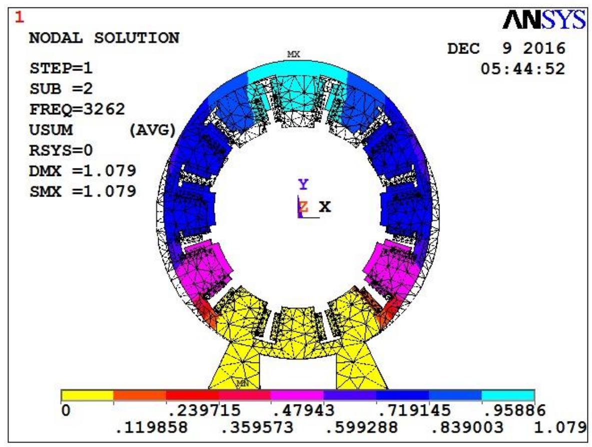

Fig. 5. Mode 2 at 3262Hz

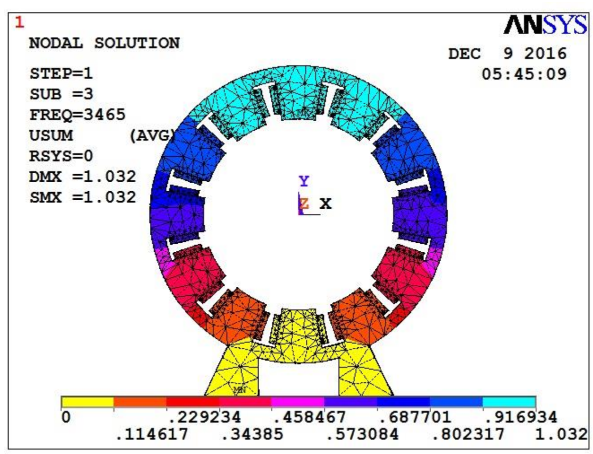

Fig. 6. Mode 3 at 3465Hz

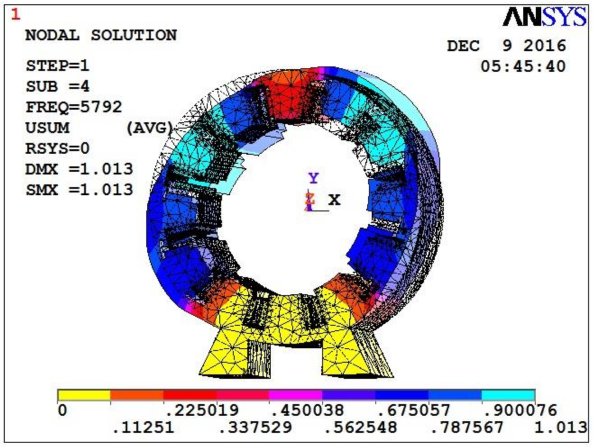

Fig. 7. Mode 4 at 5792Hz

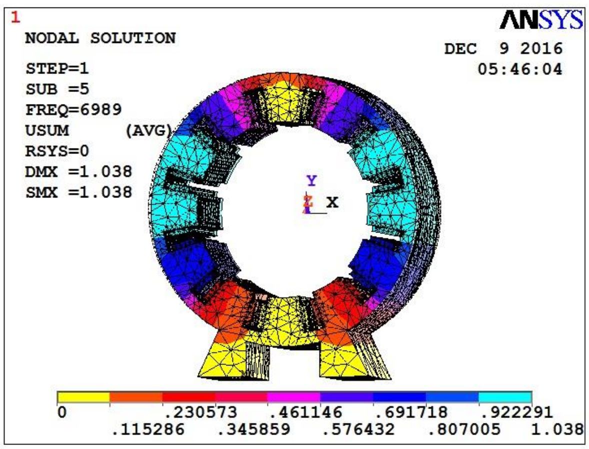

Fig. 8. Mode 5 at 6989Hz

The vibration analysis in outer stator carried out for the vibrating frequencies in mode 1 at 2295Hz, mode 2 at 3262Hz, mode 3 at 3465Hz, mode 4 at 5792Hz and mode 5 at 6989Hz.

The list of frequencies with maximum and minimum displacement in table 2 inferences that the modal frequency increases, the corresponding displacement also increases.

b. Inner Stator

The procedure and material properties remain same for both inner and outer stator the only differences is the boundary condition are said to fixed as zero at two of the shafts. Fig 9, Fig 10, Fig 11, Fig 12 and Fig 13 shows the nodal solution for modal frequencies with its corresponding displacement for the inner stator.

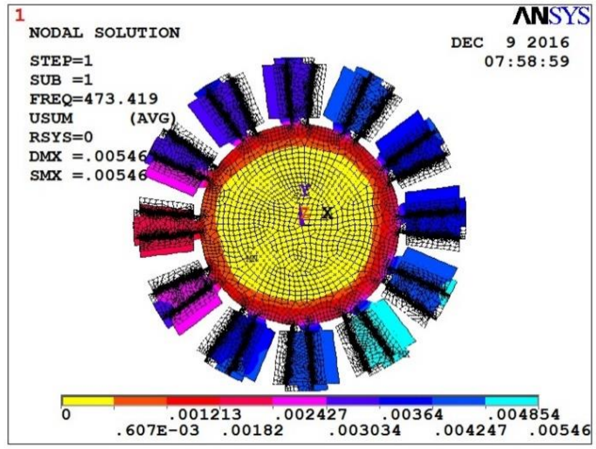

Fig. 9. Mode 1 at 473.419Hz

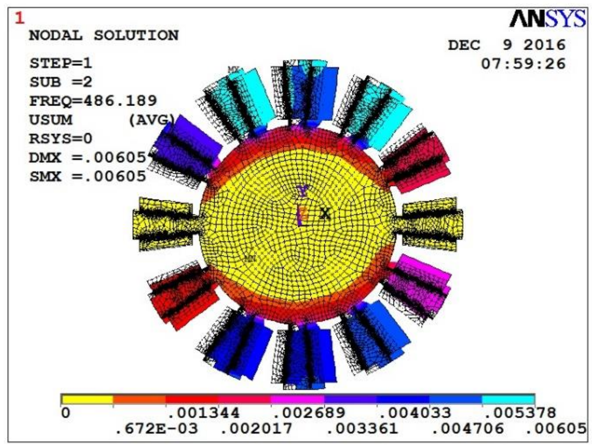

Fig. 10. Mode 2 at 486.189Hz

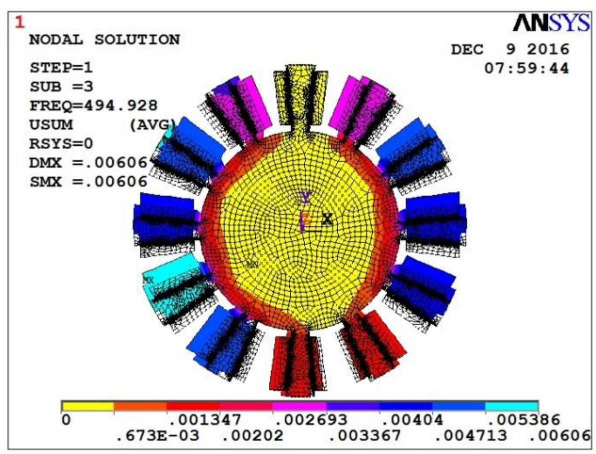

Fig. 11. Mode 3 at 494.928Hz

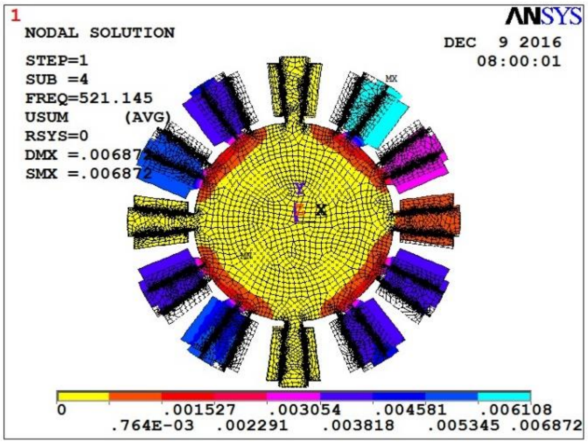

Fig. 12. Mode 4 at 521.145Hz

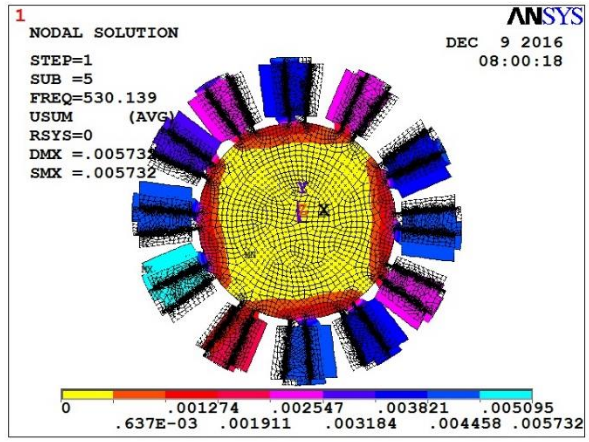

Fig. 13. Mode 5 at 530.139Hz

The vibration analysis in inner stator carried out for the vibrating frequencies in mode 1 at 473.419Hz, mode 2 at 486.189Hz, mode 3 at 494.928Hz, mode 4 at 521.145Hz and mode 5 at 530.139Hz.

Table 2 compares the modal frequencies and displacement for both inner and outer stator inferences the high displacement at mode 4 for inner stator and at mode 5 for outer stator.

Table 2. Modal Frequencies with displacement

Mode	Frequency(Hz)		Displacement(mm)	
	Outer	Inner	Outer	Inner
1	2295	473.419	1.045	0.005
2	3262	486.189	1.079	0.00605
3	3465	494.928	1.032	0.00606
4	5792	521.145	1.013	0.0068
5	6989	530.139	1.038	0.00573

4. THERMAL ANALYSIS

Thermal analysis is used to predict the heat distribution inside the motor. The ohmic losses is converted into heat generation as equation3 which act as input to the thermal analysis. [6],[7]

$$Heat\ Generation = \frac{Ohmic\ Losses}{Surface\ Area} \quad (3)$$

The boundary condition is applied to be as 30^0C. The maximum amount of heat dissipated inside the machine is 33.2^0C.

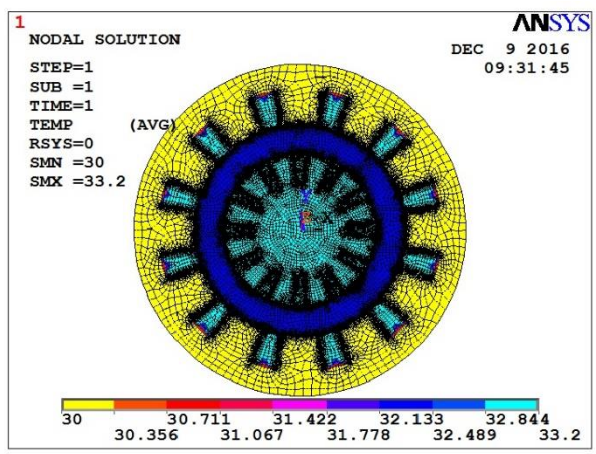

Fig. 14. Temperature distribution

5. CONCLUSION

This paper gives out the wide essential needs of finite element analysis both in electrical and mechanical aspects. The Double Stator Single Rotor Permanent Magnet Machine (DSSRPMM) has been investigated using Finite Element Analysis. Electromagnetic field analysis, Vibration analysis and Thermal analysis are carried out in the machine. The results has been furnished. The future scope of this research work is to undergo the transient and prototype model to estimate the efficiency of the machine.

REFERENCES

1. Krishnan, R., *Prof. Joachim Holtz Everlasting Contributions in Power Electronics and Electric Motor Drives*. In: IEEE Industrial Electronics Magazine, June 2011, p. 4–5.
2. Siadatan, A., & Afjei, E., *A Stepped Two-Phase Configuration for Switched-Reluctance Motor with High Starting Torque*, In: Majlesi Journal of Electrical Engineering, 2010, Vol.4, Issue.1, p. 51–57.
3. Lenin, N. C., & Arumugam, R. *Analysis and Experimental Verification of a Linear Switched Reluctance Motor Having Special Pole Shape*, In: Majlesi Journal of Electrical Engineering, 2010, Vol.4, Issue.2, p. 1–7.
4. Lin, C., & Fahimi, B. *Prediction of Radial Vibration in Switched Reluctance Machines*, In: IEEE Transactions on Energy Conversion, 2013, Vol. 28, Issue.4, p.1072–1081.
5. T. S. R., Gan, C., Wu, J., Shen, M., Yang, S., Hu, Y., & Cao, W. *Investigation of Skewing Effects on the Vibration Reduction of Motors*, In: IEEE Transactions on Magnetics, 2015, Vol.9464, Issue. c, p. 1–9.
6. Huai, Y., Melnik, R. V. N., & Thogersen, P. B. *Computational analysis of temperature rise phenomena in electric induction motors*. Applied Thermal Engineering, 2003, Vol.23, Issue.7, p. 779–795.
7. Wichert, T. *Design and construction modifications of switched reluctance machines*, In: Ph.D. Thesis, 2008, Institute of Electrical Machines, Warsaw University of Technology, Warsaw.