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Vibration Analysis of Switched Reluctance Motor with Exterior Rotor

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Abstract:
This paper deals about the vibration analysis of 6/3 switched reluctance motor with exterior rotor. The vibration analysis is carried for the 2-D FEA model developed in MagNet software, for this model vibration analysis is carried using ANSYS.

Key words: *Vibration, Switched Reluctance Motor (SRM), Exterior Rotor, ANSYS, Modal Analysis*

1. Introduction

Now days SRM drains lot of attention in the field of electric traction and other wide industrial applications. Due to its wide beneficial factors such as robust in construction, much durability, high power density, better efficiency and low power requirements hence it is adaptable to high speed and high temperature operations. However having lot of inherent advantage in its hand switched reluctance motor seriously suffer from (a) more acoustic noise (b) vibration (c) higher torque ripple (d) requirement of rotor position sensor for switching of SRM converter (e) non linearity in characterization of generated torque and winding inductance.

Torque in a switched reluctance motor is developed by means of interaction among the salient rotor and stator combination from electromagnetic excitation of stator and rotor poles, once a nominal value of phase current is established in the stator poles the rotor pole has tendency to align its position with stator pole at particular position on the instant. The force produced on the rotor to align itself to stator pole is due to the tangential and radial force produced in motor. Tangential force is responsible for the rotational torque of the motor, and the unbalanced radial force which is acting on the rotor is ready to cause the vibration. On the account of this radial force the deformation of stator is occurs.

2. Proposed Switched Reluctance Exterior Rotor Motor Design

In this proposed model, new winding topology implemented in order to obtain the flux reversal free stator. The fig.4 shows the proposed 6/3 Exterior Rotor SRM. The stator consists of two main poles and four auxiliary poles and the rotor consists of three poles.

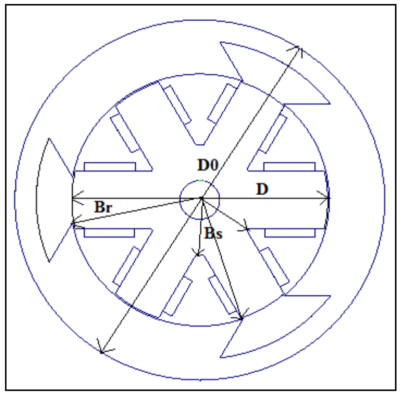

Figure 1: Wireframe Model of Switched Reluctance Exterior Rotor

Below Table 1 shows the machine dimensions of the proposed two phase 6/3 Exterior Rotor SRM topology

Power	250 Watts
Peak Voltage	48 Volt
Peak Current	8 Amps
No. of Phases	2
No. of stator poles	6
No. of Rotor poles	3
Stack length	50mm
Speed	1000rpm
Material	(M-43) Steel
Stator Pole Arc	62degree
Rotor Pole Arc	100 degree

Table 1: Machine Dimensions

3. Vibration Analysis

From the geometry of motor as mentioned above in the wireframe model, the natural vibration frequencies of switched reluctance motor exterior rotor is estimated using ANSYS.

3.1. Analytical Method

In analytical method the vibrational frequencies of switched reluctance motor is predicted by using the following equations

$$f_r = \frac{1}{2\pi}\sqrt{\frac{k_r}{m}} \qquad (1)$$

Where equivalent mass per m^2 is mentioned as m and equivalent spring co-efficient at the average yoke area on cylindrical surface is denoted by k_r, the value of m is find by using an equation given below,

$$m = \frac{M_y}{2\pi R_{y(avg)} L_{y(equ)}} \qquad (2)$$

By using the above equations natural resonance frequencies for the n^{th} order is calculated in analytical method

3.2. Boundary Condition for Vibration Analysis

The above figure shows 3-D meshed model of stator with assigned boundary conditions on two edges of shaft, the arrows at two edges of shaft denotes the boundary conditions. Boundary condition assigned to the shaft is zero because it is fixed one.

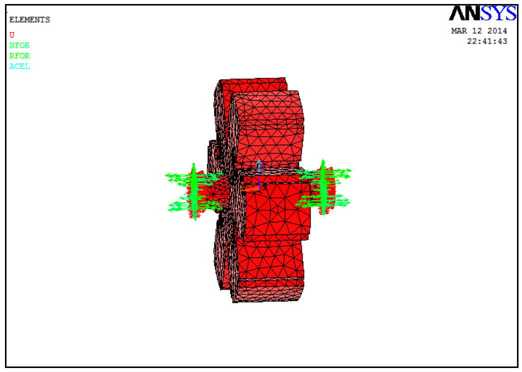

Figure 2: 3D Meshed Model with Boundary Condition

3.3. Static Vibration Analysis

In static analysis, the force is applied to the stator in a fixe position, the stator body is structurally stressed and elements in the body are displaced. The static FEA formula is based on the relation given below

- [X] [Y] = [Z]
- [X] is the stiffness matrix
- [Y] is the displacement vector
- [Z] is the force vector
- The resultant displacement vector is of the body is obtained by FEA using equation
- $[Y] = [X]^{-1} [Z]$

Static vibration analysis is used to predict the effect of steady state loading condition of motor, by ignoring inertia and a damping effect. It defines the oscillation and deformation of rotor under the gravitational pull.

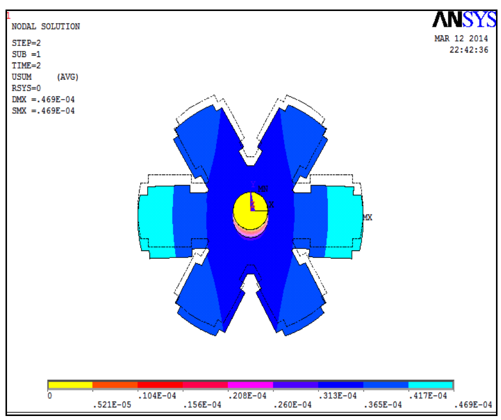

Figure 3: Static Vibration Due to Gravity

The vibration of stator under static condition is shown in figure-3, the dotted line shows deviation of stator from original position, maximum and minimum displacement of stator due to gravity is .49 micro meters.

3.4. Modal Analysis

The modal analysis is used to predict the time varying displacement, strain, stress and deformation due to force in stator of SRM, such that it denotes inertia and damping effects are considered.

The analysis type is defined as the modal analysis and the number of modes to be extracted is defined as 5 in the analysis. The result of the analysis option gives five mode frequencies and their corresponding displacement magnitude of modes.

The vibration equation for modal analysis is given by the below equation

[A]c + [B]c =0

Where , c is the modal displacement vector

[A] is the mass vector

The solution for free vibration will be obtained by the equation given below
{c(t)} = e^{f1t}{i};
Where, {i} Eigen vector corresponds to the mode shape of ith natural frequency. This equation leads to Eigen problem
The below table-2 shows about various modes and its corresponding frequencies, displacement of stator.

Modes	Frequency in Hz	Displacement in micro meters
1	19.175	.5166
2	69.908	.8083
3	72.436	.7948
4	80.868	.4788
5	81.104	.4713

Table 2: Modal Analyses

3.4.1. Mode-1 Vibration

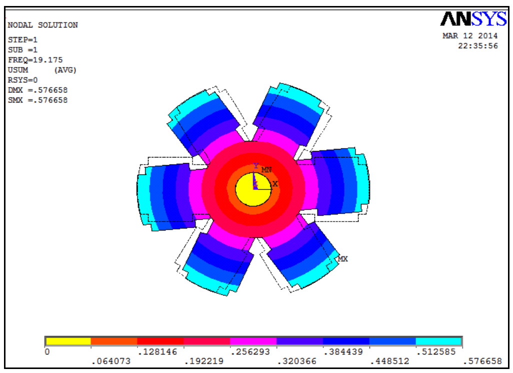

Figure 4: Mode-1 Vibration

The above figure-4 shows mode-1 vibration in modal analysis, the natural frequency of vibration is 19.175 hertz and displacement of stator is .5166 micro meters.

3.4.2. Mode-2 Vibraton

The below figure-5 shows mode-2 vibration in modal analysis, the natural frequency of vibration is 69.908 hertz and displacement of stator is .8083 micro meters

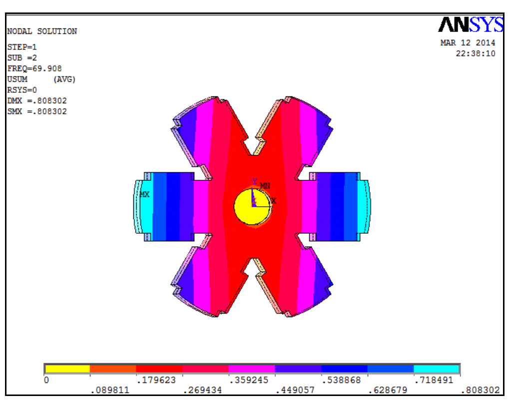

Figure 5: Mode-2 Vibraton

3.4.3. Mode-3 Vibration

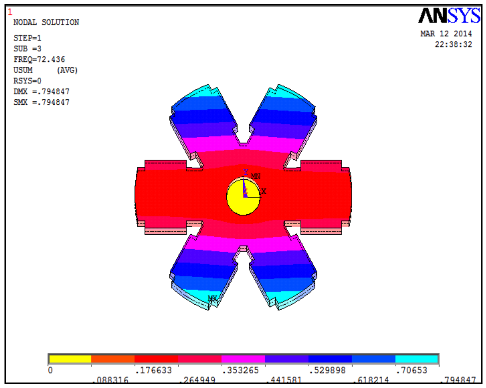

Figure 6: Mode-3 Vibration

The above figure-6 shows mode-3 vibration in modal analysis, the natural frequency of vibration is 72.436 hertz and displacement of stator is .7948 micro meters

3.4.4. Mode-4 Vibration

The below figure-7 shows mode-4 vibration in modal analysis, the natural frequency of vibration is 80.868 hertz and displacement of stator is .478micro meters

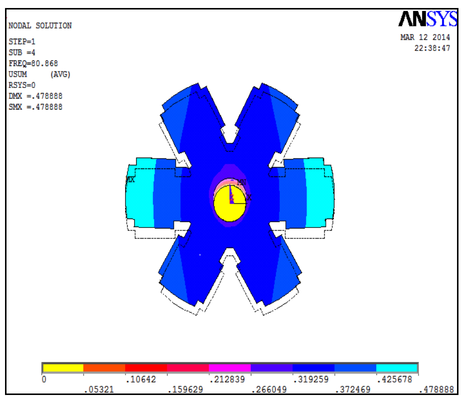

Figure 7: Mode-4 Vibration

3.4.5. Mode-5 Vibration

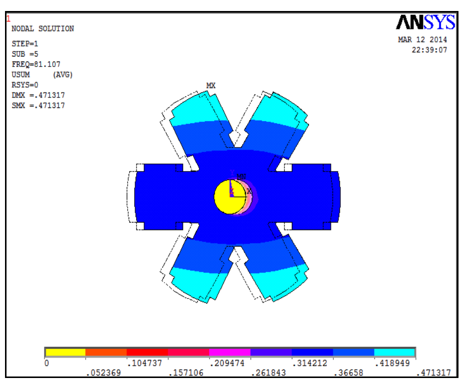

Figure 8: Mode-5 Vibration

The above figure-8 shows mode-5 vibration in modal analysis, the natural frequency of vibration is 81.107 hertz and displacement of stator is .4713 micro meters.

3.5. Vector Plot for Vibrational Analysis

The below figure-9 indicates vector plot of vibrational analysis on switched reluctance motor with exterior rotor , the arrows in an vector plot indicates direction of displacement of stator

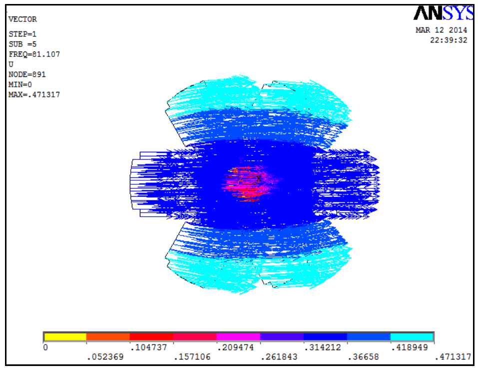

Figure 9: Vector Plot for Vibration

4. Conclusion

Thus , the vibration analysis is carried out for switched reluctance motor with exterior rotor in static and modal modes and its displacement of stator due to gravity and natural frequencies are predict. The future analysis for this work is carried out in thermal and vibrational with load.

5. References

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