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Vibration Analysis of Tapered Pole Linear Switched Reluctance Machine

N. C. Lenin[1], S. V. Arvind[2],
VIT University, Chennai, Tamilnadu, India

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ABSTRACT

The Vibration is one of the major problems in linear switched reluctance motors (LSRMs). This paper presents a detailed analysis of vibration in a two phase LSRM and proposes a new structure to reduce the effect. The experimental results of this paper prove that the proposed structure is well suited for conveyor application.

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Corresponding Author:

N. C. Lenin,
Department of Electrical and Electronics Engineering,
VIT University-Chennai Campus,
Chennai-600 127, Tamilnadu, India.
Email: lenin.nc@vit.ac.in

1. INTRODUCTION

Linear switched reluctance motors (LSRMs) with different machine configurations have been explored past in the literature [1]. LSRM has several drawbacks such as vibration and acoustic noise. Efforts to reduce or eliminate the torque ripple of the rotary switched reluctance motors (SRMs) are presented in literature [2]-[5]. In this paper a new stator structure is proposed to reduce the vibration.

When the frequency of the exciting force is close or equal to any of the natural frequencies of the machine, then resonance occur, which results in dangerous deformations and vibrations and a substantial increase in noise [6]-[8]. A modal study using ANSYS will cede the potential frequencies to be passing over for a noiseless operation of the motor. This paper provides a detailed 2D modal analysis by means of the ANSYS podium.

The organization of the paper is as follows: section 2 provides the LSRM specifications. Electromagnetic analysis of the conventional and the new stator geometry are explored in section 3, section 4 presents the modal analysis and comparison of the two sturctures. Experimental results from the prototype machine section 5. Conclusions are summarized in section 6.

2. LSRM MODEL

Figure 1 shows the two dimensional (2D) cross sectional view for the conventional LSRM. The LSRM has an active translator and a passive stator. It consists of six translator poles and 120 stator poles. Figure 2 shows the stator pole for the conventional structure whereas; Figure 3 shows the stator pole for the proposed structure. In the proposed structure, the poles are taperred by 1mm to 10mm in steps of 1mm for the purpose of optimization. Table 1 shows the physical dimensions of the LSRM prototype.

Table 1. Specifications of Prototype LSRM

Translator pole width=10mm	Translator pole height=25mm	Translator stack length=30mm
Translator back iron thickness=10 mm	No. of turns/phase = 40	Stator pole height=15 mm
Stator pole width=12mm	Stator slot width=30mm	Stator stack length=30 mm
Stator back iron thickness=12mm	Air gap length=3mm	Velocity=0.2m/s
Rated voltage=40 V	Rated current=4amps	Maximum force=3.2N
Translator slot width=20mm	Stator pole tapered values = 1 to 10 mm	Steel Type – M19

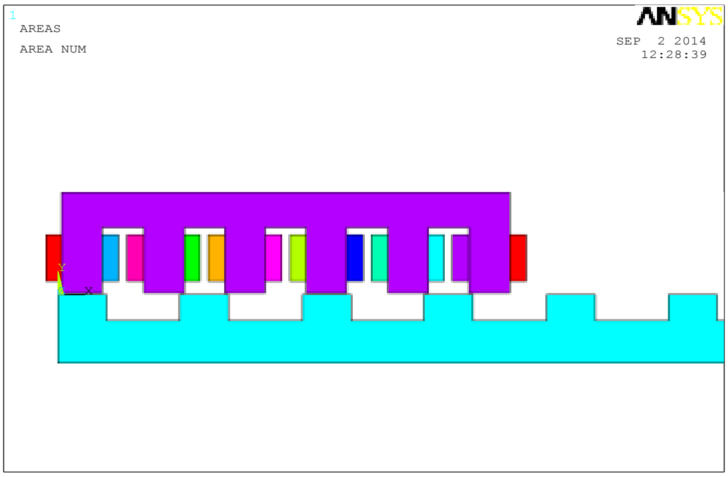


Figure 1. 2D cross sectional model of conventional LSRM

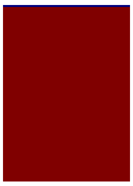


Figure 2. Conventional stator pole

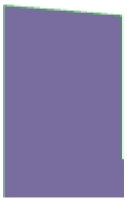


Figure 3. Proposed stator pole

3. FINITE ELEMENT ANALYSIS OF LSRM

The force and inductance profiles for the conventional and proposed LSRMs are depicted in Figure 4-7 respectively. The peak force obtained is 3.05N and the force ripple is 44.85% for the conventional LSRM whereas the peak force obtained in proposed LSRM is 3.32 N with the force ripple of 32.79%. The entire comparisons of the two structures are tabulated in Table 2.

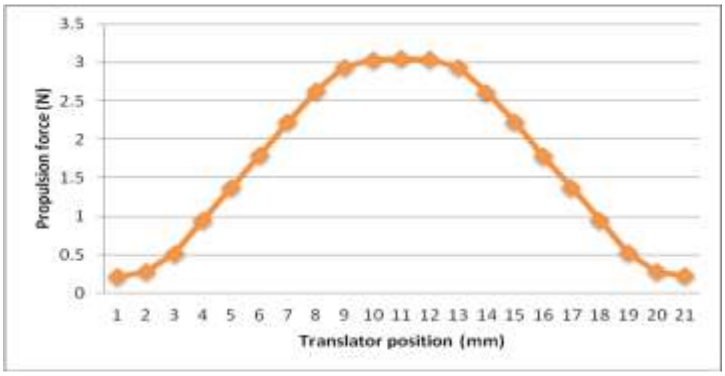


Figure 4. Propulsion force for the conventional stator

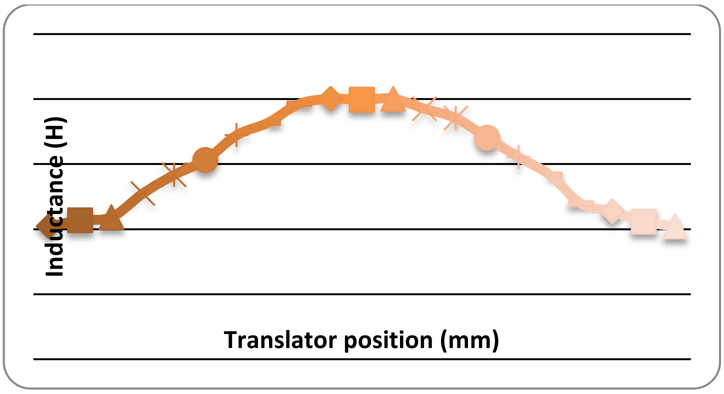


Figure 5. Inductance Profile for the conventional stator

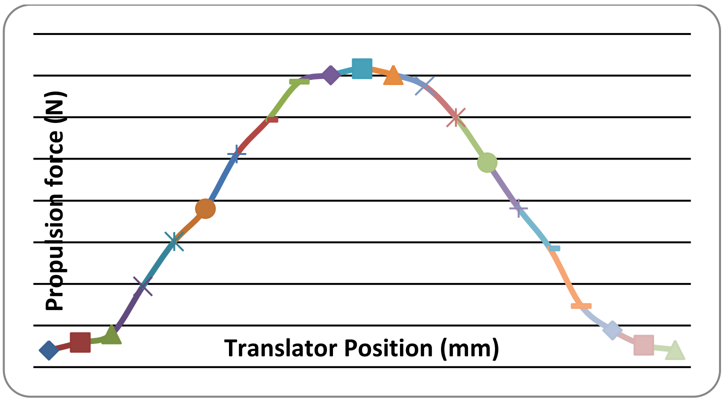


Figure 6. Propulsion force for the proposed stator

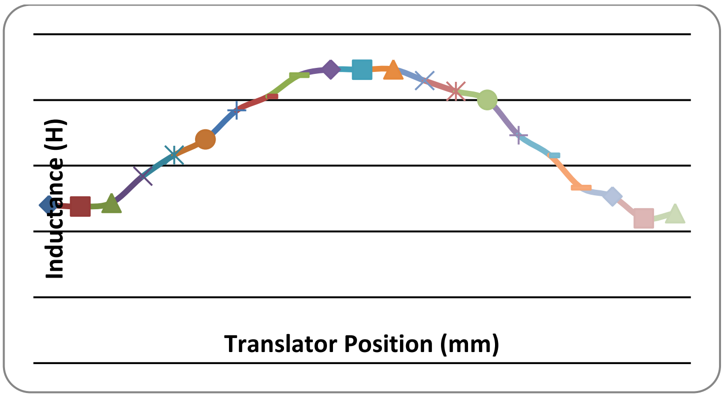


Figure 7. Inductance Profile for the proposed stator

Table 2.Summary of Comparison of the Two Structures

Type	Peak propulsion force (N)	Minimum propulsion force (N)	Average propulsion force (N)	Force ripple (%)	Inductance (H)	
					Aligned	Unaligned
Conventional Stator	3.05	1.83	2.72	44.85	0.0020	0.001
Stator with taper pole (4 mm)	3.52	2.5	3.11	32.79	0.0023	0.0012

4. MODAL ANALYSIS

Mode shapes are computed with the ANSYS finite element analysis platform. Initially the computed propulsion force and normal force are applied to the nodes of both the stator. The calculated mode shapes for the proposed structure is depicted in the Figure 8. The comparisons of the stator mode frequencies for the two structures are tabulated in Table 3. From Table 3, it is apparent that, the new stator structure considerably reduces the vibration effect of the LSRM.

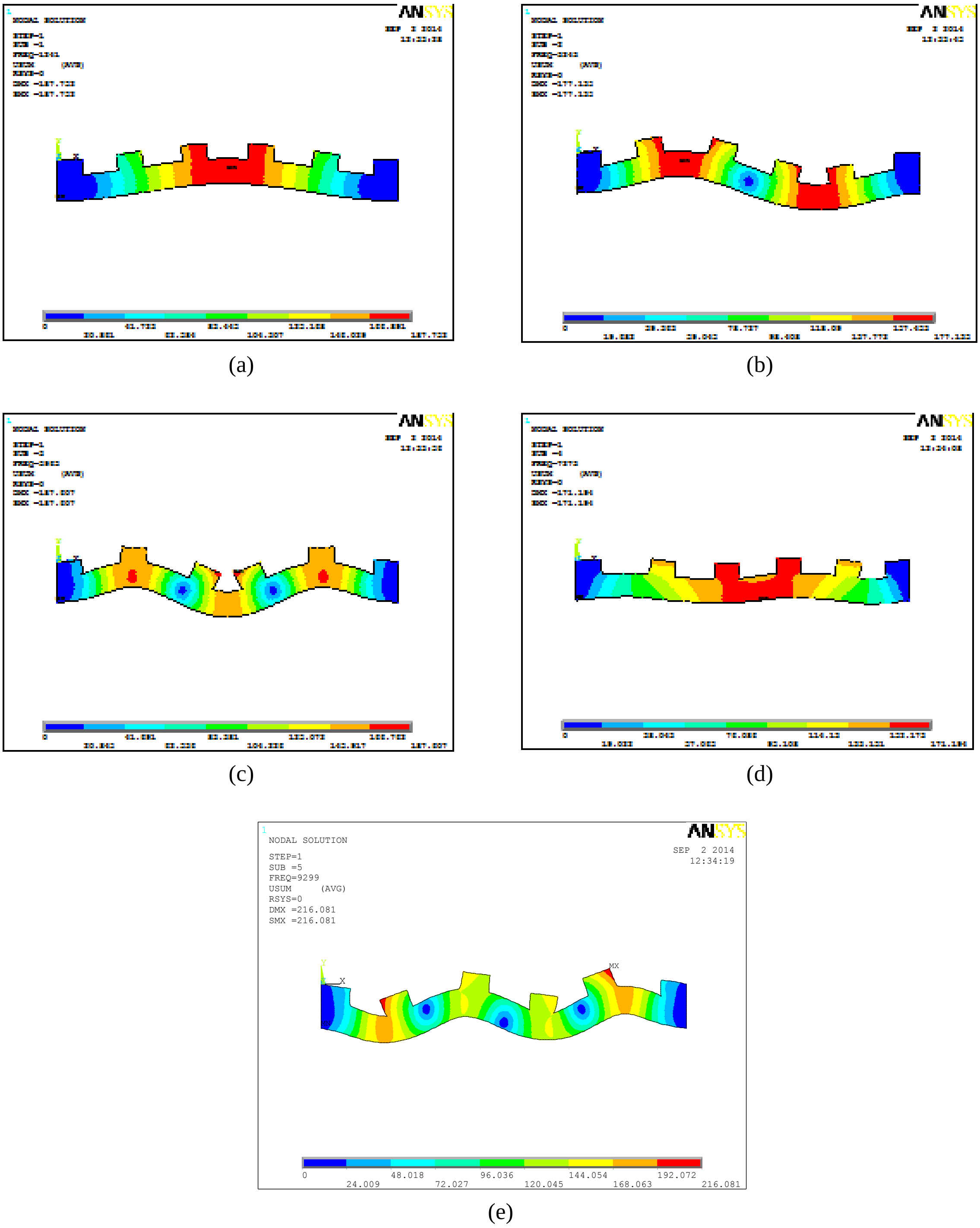


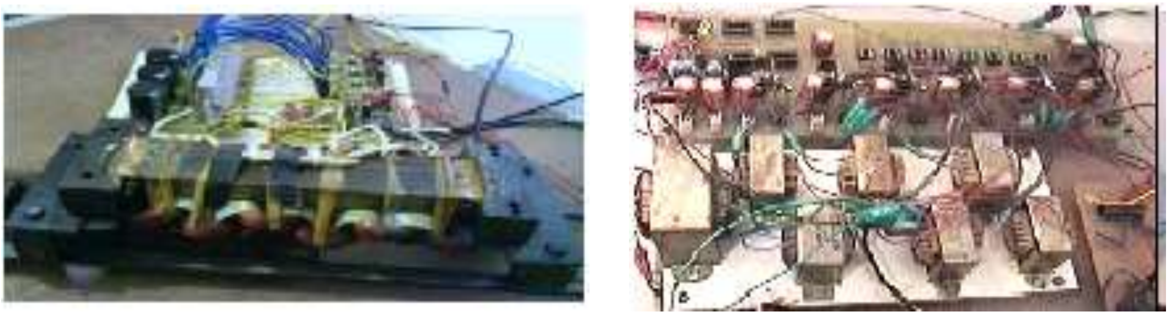
Figure 8. Mode shapes for the proposed stator

Table 3.Mode frequencies for the both structures

Mode no.	Frequencies (Hz)	
	Conventional	Stator with Tapered poles
1	1425	1241
2	3589	3243
3	7125	5965
4	8459	7273
5	11245	9299

5. EXPERIMENTAL RESULTS

Figure 9 shows the experimental setup for the prototype LSRM used as a material carrying vehicle in the laboratory. The experimental road is 0.5 m long and translator weight is 2.7 kg. The vibration modes are captured using accelarameters fixed on the stator surface shown in Figure 10.



(a) (b)

Figure 9. Experimental setup of (a) LSRM and converter (b) Driver circuit

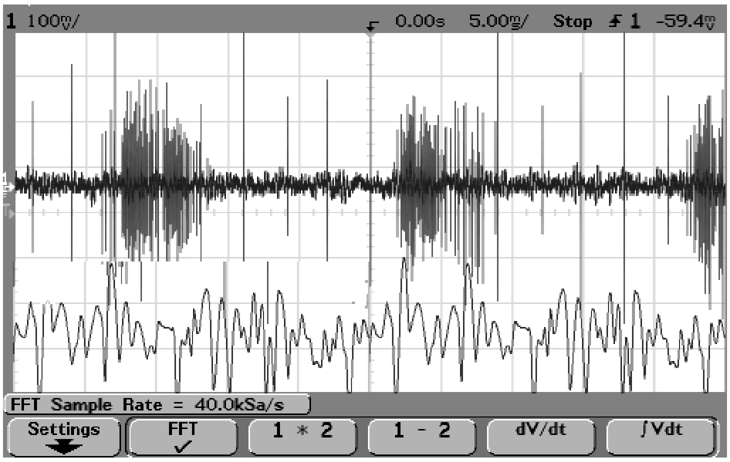


Figure 10. Acceleration on stator surface and its spectrum

6. CONCLUSION

Modification of the stator geometry by the provision of tapered poles has been presented in this paper. A 0.5m long LSRM prototype has been constructed. Force and inductance profile has been obtained by using FEA. There is a fine concurrence among measurement results and FEA values. The proposed structure reduces the force ripple by approximately 27% compared to the conventional machine. The vibration frequencies envisaged due to the normal forces nearly matches with the vibrations produced on the stator side. It is observed from the experimental results that, the spectrum contains a set of frequencies. The magnitude of the vibration is high at 9299 Hz (nearer to the fifth mode) on the stator surface of the LSRM.

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BIOGRAPHIES OF AUTHORS

N. C. Lenin (SM'2016) completed his PhD in Anna University, India in the year 2012. He has published 25 international journals and more than 30 international conferences. Currently he is working as Associate professor in the School of Electrical Engineering in VIT University, Chennai, India. His areas of interest are Design of Electrical Machines and Finite Element Analysis.

S.V.Arvind completed his Master's degree in Manufacturing Engineerign at Madras Institute of Technology (MIT), Anna University, India in the year 2016. Currently he is working as Junior Research Fellow in the School of Electrical Engineering in VIT University, Chennai, India. His areas of interest are Thermal, Vibration and Acoustic Noise studies in Switched Reluctance, Permanent Magnet and Synchronous Reluctance Electrical machines through Numerical Analysis.