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Performance Comparison of Two Different Rotor Topologies of Line Start Permanent Magnet Synchronous Motors

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Abstract: The line start permanent magnet synchronous motor (LSPMSM), attracted a considerable attention in last two decades. Line start permanents magnet synchronous motor (LSPMSM) is hybrid motor, which exhibits the properties of both induction motor as well as synchronous motor. In this paper, two LSPMSM rotor configurations were proposed and designed. Their performances were investigated using FEA software. A complete model was developed with the objective of examining the behavior of the LSPMSM motor.

Keywords: Line start permanent magnet motor, design, performance, Finite element analysis

I. INTRODUCTION

The induction motor is the most widely used machine because of characteristics such as simple and rugged construction, low cost and minimum maintenance, high reliability and self-starting. But, this machine has some disadvantages compared with permanent magnet synchronous machines (PMSMs) such as lower efficiency, power density and power factor [1-2]. The low manufacturing cost and the robust structure of the induction motors are considered advantages, but in many constant-speed applications such as fans, pumps, and compressors, LSPMSMs are preferred [3]. Line-start permanent-magnet synchronous motors (LSPMSMS) are presented as substitutes for induction motors because of their higher efficiency and higher power factor. However, LSPMSMs have poor starting torque and synchronization because of braking torque caused by the permanent magnets, which decrease the total torque during start-up [4].Figure (1) shows the cross-sectional view of the LSPMSM. On the basis of placement of permanent magnets in rotor, six different types of rotors are available in literature. Figure (2) shows six different rotor configurations of LSPMSMS reported in literature.

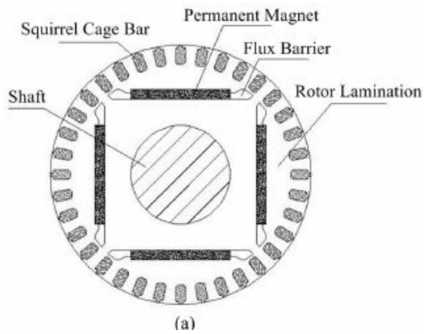

Fig. (1) - Cross-sectional view of rotor of LSPMSMs

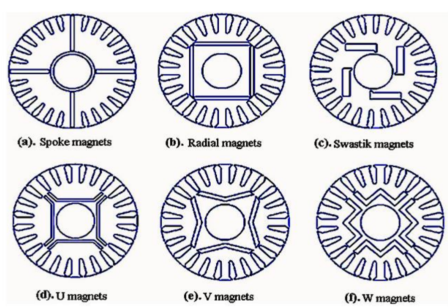

Fig. (2)- Six different rotor configurations of LSPMSMs

The rotor of LSPM motor has the permanent magnet below the squirrel-cage. The shape of magnet decides synchronous performance. The design of high performance motor should make compromise between a staring characteristic in the asynchronous operating region and the efficiency in the synchronous operating region. The rotor should be designed in such a way that it should fulfill both the requirements of successful start and synchronization of the motor on full load[5].

LSPMSM started as an induction motor directly from the main supply by damper bars placed on rotor. The LSPMSMs also has permanent magnets below the rotor cage in the rotor which pulls the motor into synchronism near synchronous speed. Once started, it continues to work as a permanent magnet synchronous motor in steady state[6-7]. In steady state, theoretically it will not have any rotor current, therefore, no rotor losses and as a result the efficiency will be higher as well as lower operating temperature than an induction motor of same size.

The aim of this study is to highlight the effect of some physical and geometrical parameters on the performance of the motors. In this work, main emphasis is on the 5 kW rating of LSPMSM which is widely used in many applications. Since analytical methods do not normally yield results with a high level of accuracy, therefore a comprehensive 2-D time-stepped finite element analysis (FEA) models are developed by the An soft Maxwell 2-D commercial software. These models are used to compute the performance of the LSPMSM.

II. DESIGN PROCEDURE AND ANALYSIS

For economic purpose, the stator of the LSPMSM is identical to that of induction motor of same power rating.Table-I shows different design parameters of two LSPMSMs under consideration.

TABLE-I

DESIGN DATA OF THE PROPOSED LSPMSM			
		Machine A	Machine B
	Output power Voltage Number of poles Reference speed	5 kW 220 V 4 1500 RPM	5 kW 220 V 4 1500 RPM
Stator	Outer Diameter Inner Diameter Stack Length Steel type Number of Slots	130 mm 80 mm 90 mm Steel_1008 24	130 mm 80 mm 90 mm Steel_1008 24
Rotor	Outer diameter Inner diameter Number of slots Magnet Material Number of Slots	79.5 mm 30 mm 90 NdFe35 36	79.5 mm 30 mm 90 NdFe35 36

The present study motor of the 5 hp rating is taken, considering the fact that this rating is most widely used in the industrial sector in terms of volumes. It is estimated that one quarter of the installed pumps are driven by 5 hp rating motors. Structure of the rotor is one of effective part on performance of LSPMM. So, in LSPMSM only rotor configurations are altered to improve the steady state as well as transient characteristics. The LSPMSM has the same starting torque as compared to the induction motor but the average transient torque of the LSPMSMS is lower than the induction motor due to the braking torque of the permanent magnet.

Table (II) shows the rotor configurations and two dimensional (2-D) design models of rotors of two different rotors of Line Start Permanent Magnet Synchronous Motors studied in this article.

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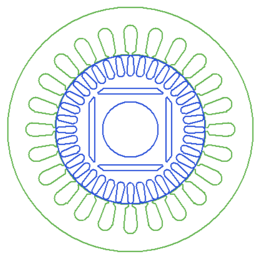
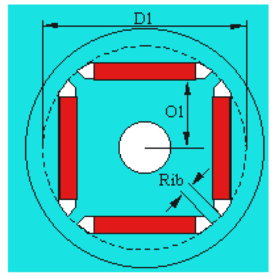
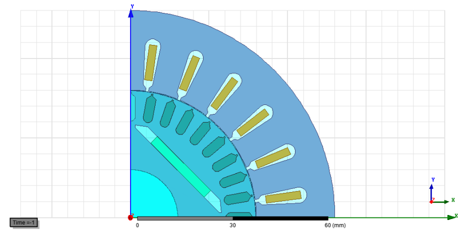
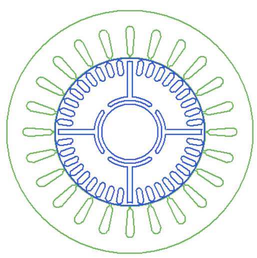
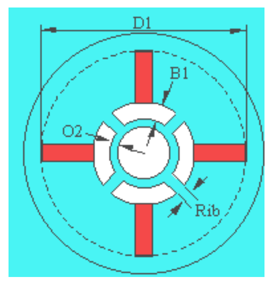
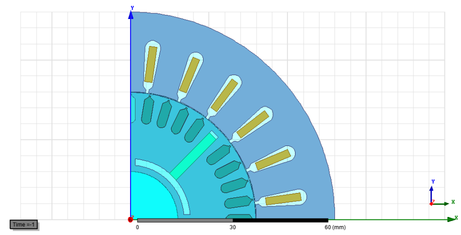
TABLE-II

Machine A			
Machine B			

A. Starting Torque

When the starting process of LSPMSM is studied, the total electromagnetic torque is the resultant of two torque components, asynchronous torque and magnet braking torque. Asynchronous torque is generated by the rotor cage winding and braking torque produced by the permanent magnets in the rotor of LSPMSM. Figure (3) shows the torque- speed characteristics of two different LSPMSM under consideration. Here, the starting torque for machine A is around 16 N-m while for machine B, it is around 18 N-m. So, machine B has more starting torque as compared to machine A. The starting torque can be improved by varying the cage winding of rotor.

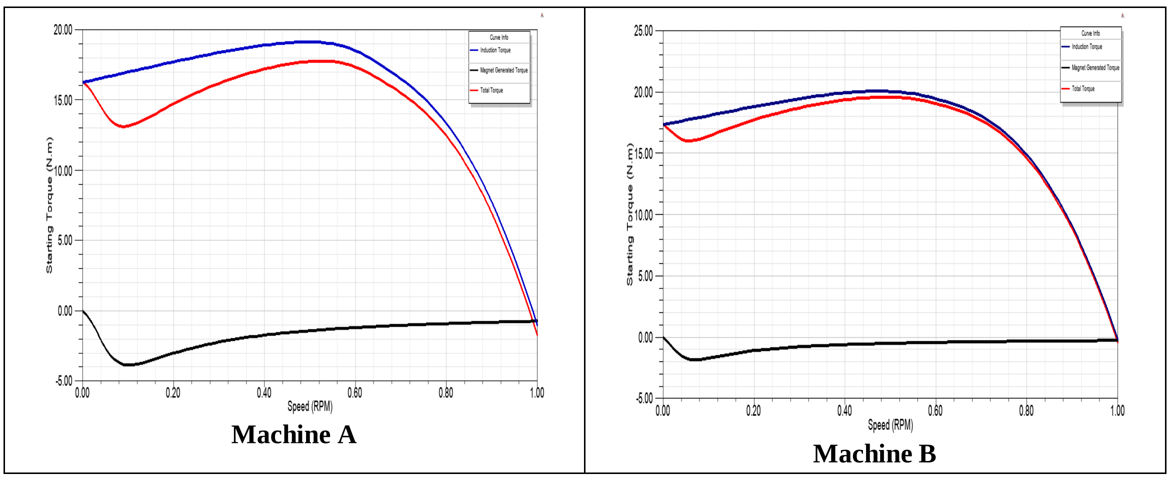


Fig. (3) - Torque- Speed characteristics of two different LSPMSMs

B. Power Factor

Induction motors, due to their inductive behavior, suffer from a low power factor, resulting in a reduction in the capacity of electricity distribution systems. LSPMSM can work with substantially higher power factor than induction motors. They even work in exact or close to unity power factor in many applications and working conditions. Figure (4) shows the power factor versus torque angle characteristics for two LSPMSMs.

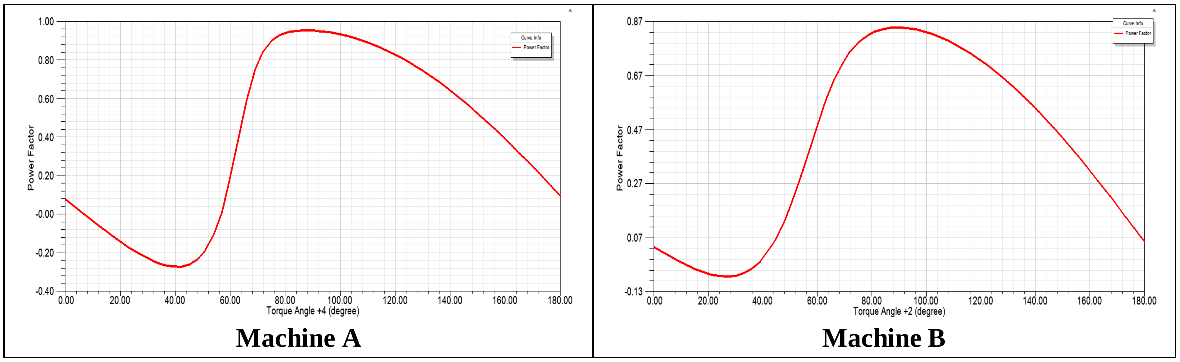


Fig. (4) – Power factor versus torque angle characteristics of two different LSPMSMs

Here, it is evident that for the power factor for machine A is 0.96 while for machine B, it is 0.86 which is very less as compared to machine A. So, in terms of power factor, machine A is superior over machine B.

C. Input Line Current

It is seen that almost 20% of the losses is dissipated in rotor cage. The rotor cage loss vanishes in LS-PMS motors except for the negligible harmonic portion. In addition, the ohmic-loss of stator in latter motors, which is the largest portion of the total motor loss, also reduces due to a significant reduction in magnetizing current and thus the input current amplitude of the motors. Figure (5) shows the input line current versus torque angle characteristics for two LSPMSMs.

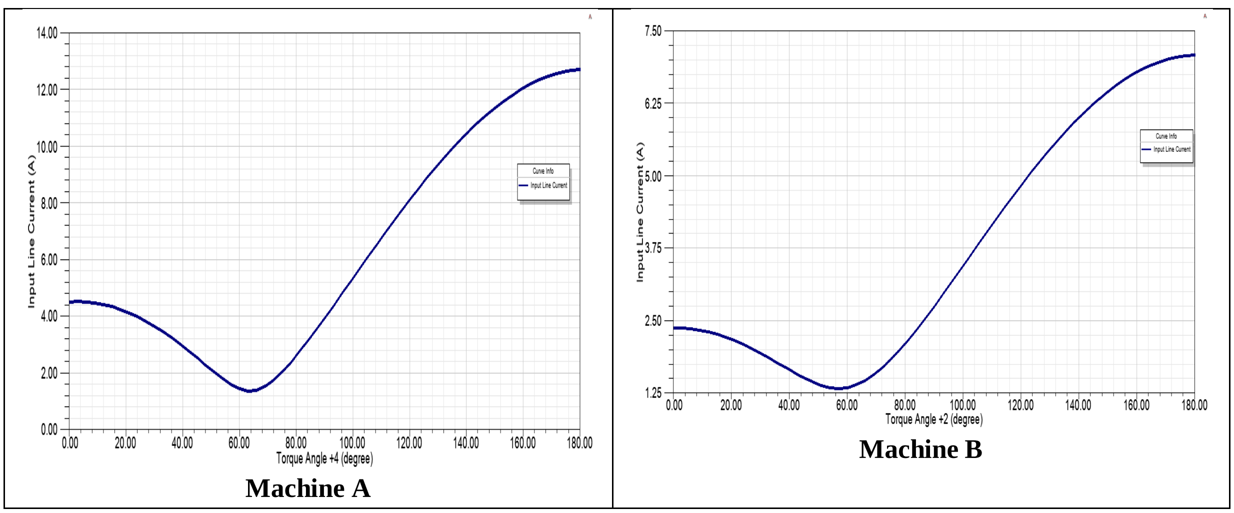


Fig. (5) **–** Input line current versus torque angle characteristics of two different LSPMSM

Here, it is evident that for the input line current for machine A is around 12.5 A while for machine B, it is around 7 A which is very less as compared to machine A. So, in terms of input line current, machine B is superior over machine A.

D. Efficiency

The standards observing efficiency of electric motors have become stricter over the time. The fulfillment of such a standard needs new technologies e.g. line start permanent magnet motors. The efficiency of these motors is much higher than induction motor of same dimensions. The efficiency of the motor can be increased by improvement in rotor cage and permanent magnets. Figure (6) shows efficiency versus torque angle characteristics of two different LSPMSMs. It is evident from characteristics that the efficiency of both the machines is same.

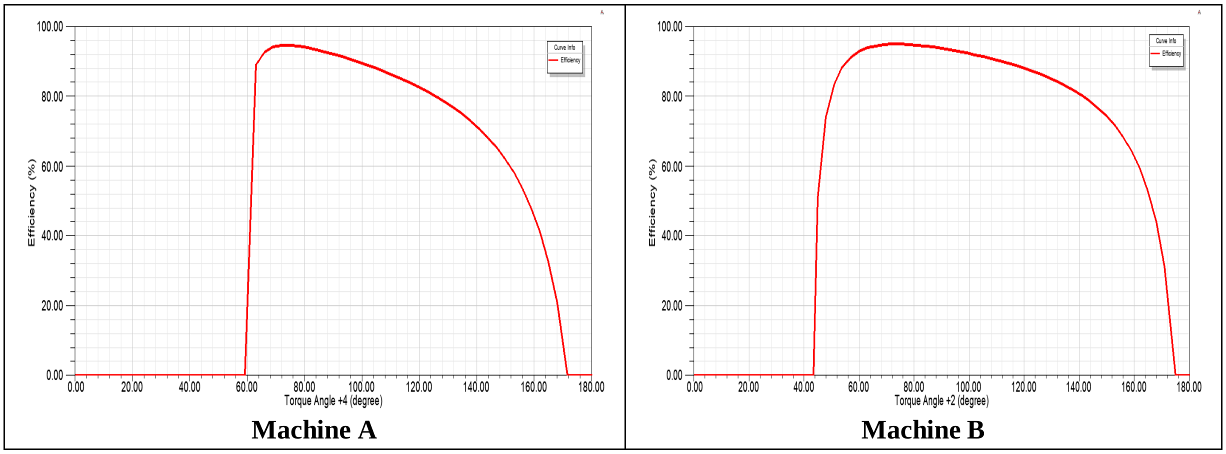


Fig. (6) – Efficiency versus torque angle characteristics of two different LSPMSM

E. Air Gap Power

Figure (7) shows air gap power versus torque angle characteristics of two different LSPMSMs. Here, the air gap power for machine A is around 2200 watts while for machine B, it is only 1200 watts. So, in terms of air gap power, machine A is superior over machine B.

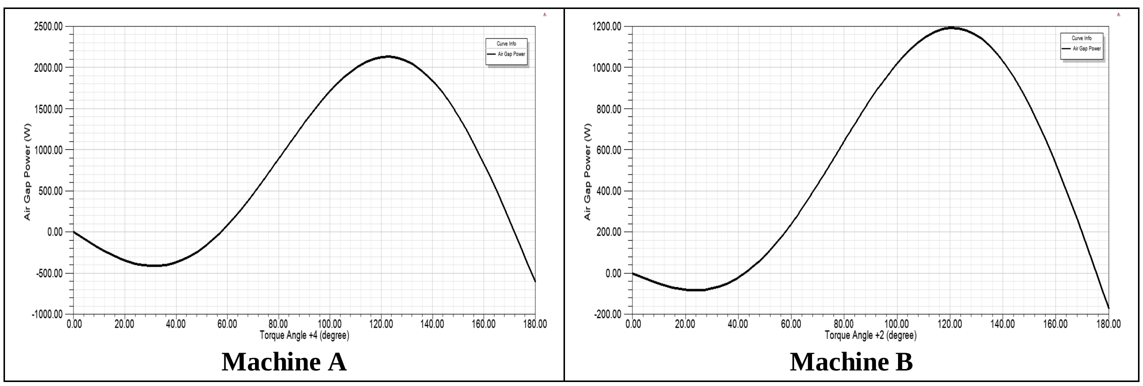


Fig. (7) – Air gap power versus torque angle characteristics of two different LSPMSM

F. Total Torque

The starting behavior of the LSPMSM is of considerable interest since it is to be started directly on line and has to overcome the magnet braking torque developed by permanent magnets during asynchronous operation of the machine. Figure (8) shows the torque-time characteristics of two different LSPMSMs.

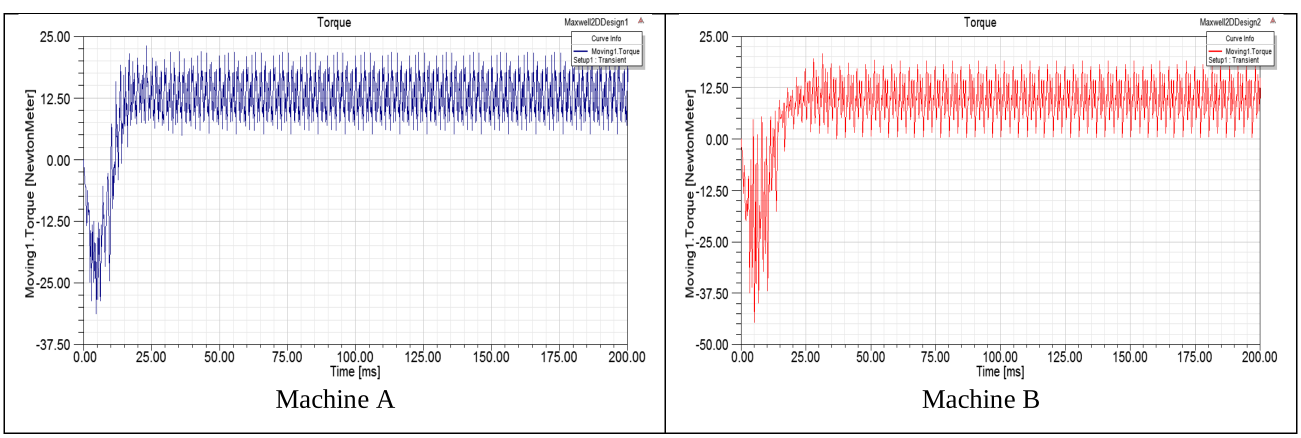


Fig. (8) –Starting torque versus time characteristics of two different LSPMSM

It is evident that starting torque response of machine A is much better than machine B. During transient period, the fluctuation of torque for machine A is smoother than machine B. On the basis of study of different parameters of two types of LSPMSMs, it can be concluded that machine A is superior than machine B.

III. CONCLUSION

In this paper, two LSPMSM rotor configurations were proposed and their performances were investigated. A complete model was developed with the objective of examining the behavior of the LSPMM motor. It can be seen that rotor play an important role in improving the performance of LSPMSM. By changing the magnet structure of rotor, performance can be changed. Hence, choosing the best structure for permanent magnets is a challenging task to get required characteristics of the motor.

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