

New disc type switched reluctance motor for high torque density

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Abstract

A new disc type switched reluctance motor (DSRM) structure for high torque density is presented. The new motor has a double sided stator structure that provides higher torque and less acoustic noise than classical switched reluctance motors (SRMs) of small sizes. The motor is based on linear switched reluctance motors. The results of the analytical and numerical analysis are given to evaluate the effectiveness of the motor structure, and experimental noise measurement data are presented. In the numerical analysis, due to the highly nonlinear nature of the motor, finite element analysis is employed. A prototype 6/4 DSRM and a classical SRM are built and tested for experimental studies. The obtained test and simulation results show that the DSRM has a higher torque and less acoustic noise performance.

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1. Introduction

There has been widespread interest in SRM drives in recent years. The numerous advantages of the SRM make it an attractive solution for many industrial applications. Some advantages of the SRMs are robust construction, low cost in mass production, reduced maintenance requirements, fault tolerance, high efficiency, rugged behavior and large torque output over very wide speed range [1–10]. However, the available literature seems to concentrate on the rotary switched reluctance motor (RSRM), leaving the linear version of the SRM largely unexplored. The linear switched reluctance motors (LSRM) retains the desirable attributes of the RSRM. LSRMs are the attractive alternative to other linear motors due to the lack of windings on either the stator or rotor structure. Furthermore, the windings are concentrated rather than distributed, making them ideal for low cost manufacturing and maintenance. This paper presents a new disc type double sided stator SRM (DSRM) based on the LSRM, and it can be called a disc SRM.

The DSRM has a double sided structure with three phases. Because of the double sided structure, the torque of the DSRM is higher than the torque of the motor with single sided structure and the classical SRM. In addition, the size of the motor is smaller than the classical SRMs, because the LSRM has a disc type.

This paper contains an illustration of the proposed motor design and analysis procedures for a prototype motor. The analysis procedure of the motor is realized with the use of analytical analysis and FEA prior to construction of the prototype motor. The analytical methods use simplifying physical assumptions, but they are not very accurate for calculating the magnetic characteristics of the SRMs. Most of the limitations of the analytical techniques can be overcome by using numerical methods, such as FEA [11–14], which provide accurate results but usually require tremendous computational effort and numerical procedures. The results of these techniques are presented and compared.

The organization of the paper is as follows. Section 2 gives the topology of the proposed DSRM, and its basic operation principles are described in detail. Section 3 covers the analytical and FEA calculations of the characteristics of the motor. Section 4 gives a comparison of the

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results of the analytical method and FEA and the data of the experimental noise measurements. Section 5 presents the conclusions of this study and interpretations about the proposed DSRM structure.

2. Description of the proposed DSRM

Fig. 1 shows the cross-section of one side of the stator structure on the proposed double sided disc type LSRM with three phases. Because the motor is based on a 6/4 SRM structure, the energization sequence $A_1 - A'_1$, $B_1 - B'_1$, $C_1 - C'_1$, $A_1 - A'_1 \dots$ makes the rotor move in

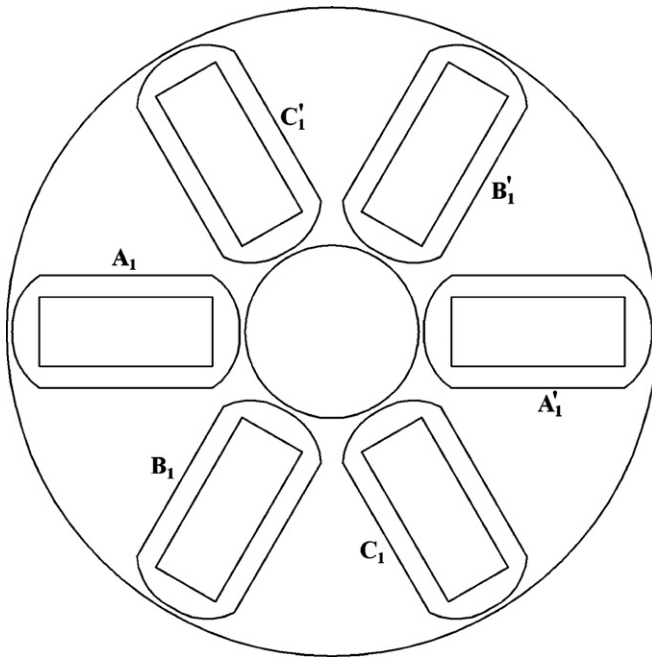


Fig. 1. Cross-section of the one side of stator blocks at DSRM.

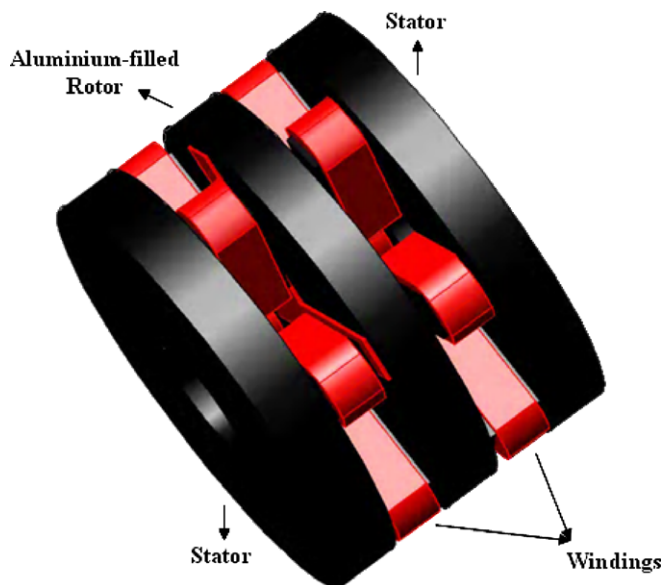


Fig. 2. 3D model of the disc type LSRM.

Table 1

Characteristic parameters of the proposed DSRM

Phase number	3
Stator pole width	16 mm
Stator pole height	40 mm
Stator depth	35 mm
Rotor pole width	16.4 mm
Rotor depth	20 mm
Air gap width	0.25 mm
Steel type	M19

the clockwise direction continuously. A reverse direction sequence can be deduced in a similar manner. Since the prototype has four rotor poles, a gating sequence based on the above description is developed such that the translator experiences continuous clockwise or counterclockwise motion. Fig. 2 shows the motor structure of the proposed DSRM with three phases in a three-dimensional form.

The stator and rotor platforms of the motor are built using M19 steel sheets. All the laminated plates are produced using a standard press tool for fabrication of the motor. The parameters of the proposed DSRM are summarized in Table 1.

It is widely accepted that the radial attractive force between the stator and rotor is the dominant source of the vibration and acoustic noise in SRM's with doubly salient structure. Some basic acoustic noise sources of SRMs are listed as follows [15]:

- Because of the doubly salient structures, the rotor poles behave like blades.
- Nonuniform characteristics of materials produce mechanical dynamic unbalance of the motor, and a non-uniform magnetic flux causes both magnetic and mechanical forces on the rotor.



Fig. 3. Force distributions of the proposed DSRM.

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