Efficiency Improvement of Switched Reluctance Motors by Means of Using Higher Quality Laminations

Mircea Ruba, Florin Jurca, Loránd Szabó

Department of Electrical Machines and Drives, Technical University of Cluj-Napoca, Romania

Abstract *- The switched reluctance motor is a reliable machine and has received much attention in recent years. Significant effort was made to improve their performances. In this paper the increase of its efficiency will be studied by means of using higher quality iron core laminations.*

Keywords – *switched reluctance motor, efficiency improvement, laminations, finite elements analyses, optimization*

1. INTRODUCTION

The switched reluctance motors (SRM) are the most promising developments in the field of variable speed electrical drives. They have numerous advantages, as high starting torque, wide speed range, rugged and robust construction, very high reliability and low manufacturing costs [1].

Therefore in our days any improvement of the SRMs are of real interest for all specialists involved in this field.

In the paper a comparative study is given concerning the improvements of a SRM by replacing its iron cores made of higher quality laminations.

2. THE SWITCHED RELUCTANCE MOTOR

The SRM, shown in Fig. 1, is a double salient electrical machine with a passive rotor [2].

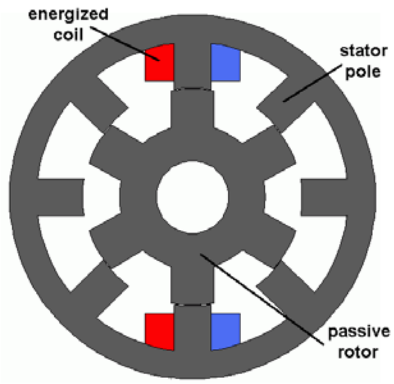


Fig. 1. The cross section of a SRM

Its torque is produced by the tendency of its rotor to get to a position where the inductance and the flux produced by the energized stator winding are maximized (the variable reluctance principle) [3].

The SRM's rotor and stator both have salient poles. The stator is formed from a stack of punched laminations. The rotor is made similarly of conventional laminations, not having any kind of winding, squirrel-cage or permanent magnets [4].

Each of its phase is independent. It typically comprises of two series or parallel connected coils placed on diametrically opposed poles of the motor. The machine's excitation is a sequence of current pulses applied to each phase in turn. The commutation of the SRM's phase currents must be synchronized precisely with the rotor position, hence the SRM requires a position encoder [1]. The SRM cannot be separated from the electronic supply device and its control [2].

The various advantages of the SRM make it an attractive alternative to the existing dc and ac motors in adjustable speed drives. The rotor position sensing requirements, the need for an electronic converter and the higher noise and torque ripple are the main disadvantages of the SRM drives.

The most usual power converter for a four phase SRM is given in Fig. 2.

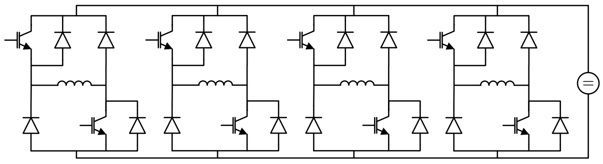


Fig. 2. The SRM's power converter

Each SRM phase is supplied thought a half H-bridge, since the SRM requires only unipolar current pulses. By the adequate commutation of the power transistors the required current sequence can be assured. The diodes are for guiding the reverse currents. The bridges of the phases are connected in parallel with a dc line.

The most common control system of the SRMs is given in Fig. 3.

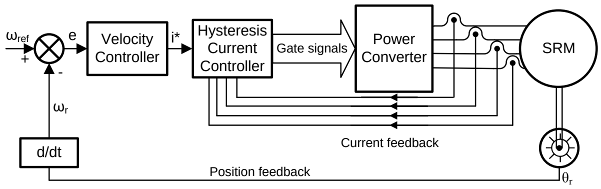


Fig. 3. The SRM's control system

Deriving upon time the output of the position encoder the angular speed can be obtained. This is compared to the imposed speed. The error between them is the input of the speed controller; witch will impose the current waveforms for the hysteresis controllers of each phase. The commutation between the phases is performed at a well-defined angular rotor position in order to maximize the developed torque. The hysteresis controllers are delivering gate signals to the power transistors of the converter [5].

In recent years much research has been done all around the world in an effort to improve the SRM's performance and efficiency, to make them more competitive for several applications.

Novel modular constructions were proposed to increase the fault tolerance of the machine [6], [7], [8], [9]. Advanced control strategies were developed to decrease the torque ripples of the SRMs [10], [11], [12]. Significant effort has been also made also for the vibration and noise reduction of these machines [13], [14], [15]. The SRMs can be improved also by manufacturing them from high quality soft magnetic materials [16], [17], [18].

3. DEVELOPMENT OF AN OPTIMIZED SRM

The target of the research was to develop an improved 8/6 poles SRM having 3 kW rated power and 1500 r/min rated speed.

A specific design algorithm was applied for the basic sizing of the machine [19].

The iron core of the SRM was considered to be manufactured of non-oriented fully processed electrical steel. Two types of laminations were taken into account M400-50A and M330-50A, both of 0.5 mm thick. Their specific losses measured according to the IEC 60404-2 standard are given in Table 1 [20].

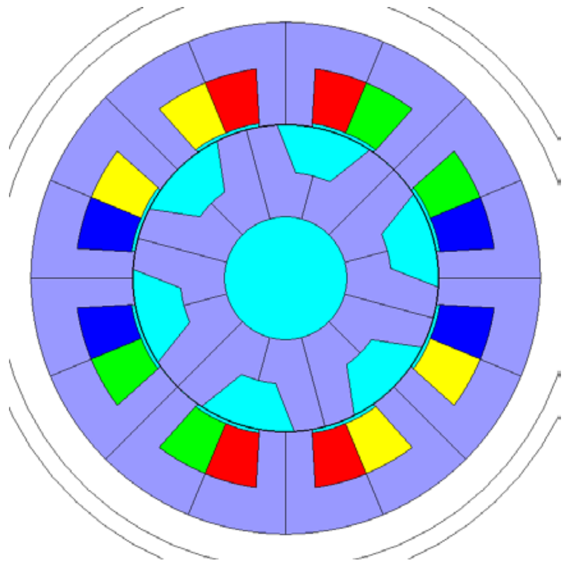
Table 1 – Specific losses of the electrical steels

Electrical steel	Maximum specific total losses [W/kg] @	
	1.5 T	1 T
M330-50A	3.3	1.35
M400-50A	4	1.75

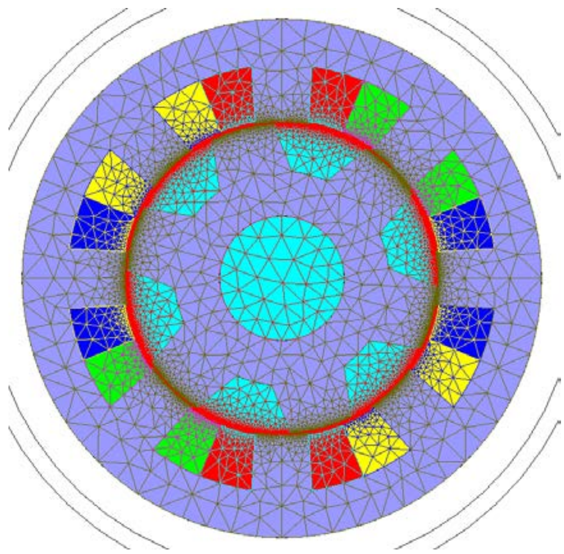
As it can be observed, the specific losses of the M330-50A electrical steel are round 20% less than those of the M400-50A type.

The designed SRMs were analyzed by means of advanced finite elements method (FEM) based numerical field analysis. The Flux 2D program package of Cedrat was applied [21].

In Fig. 4 the solid model and the automatically generated solution mesh are given for the basic structure of the designed SRM.



a) the built up solid model



b) the generated mesh

Fig. 4. The SRM model in Flux 2D

In order to obtain the best solution a simple, but yet efficient optimization method was applied. The optimization target was to maximize the efficiency of the SRMs. During the iterative optimization the main dimensions of the machine were varied. Totally 81 variants were taken into account for each case. The main characteristics of each variant taken into study were saved and finally compared.

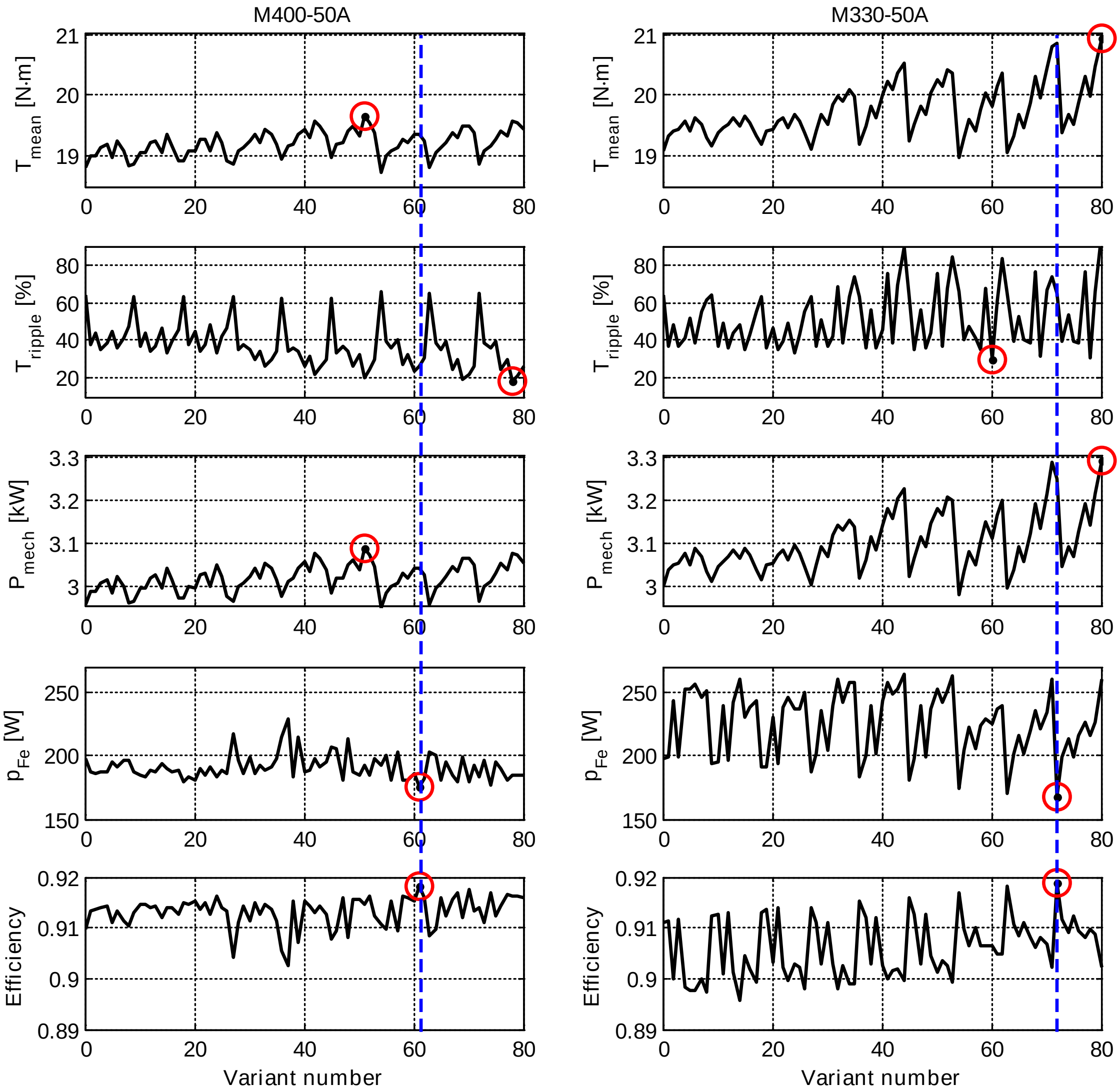


Fig. 5. The main results of the optimization

In Fig. 5 the mean torque, the torque ripple, the iron losses and the efficiency for each variant taken into study during the optimization are plotted. After a carefully study of the plots it was concluded that the best variant (having the highest efficiency) for the SRM built up of the M400-50A type lamination is that having number 62 and for the other SRM variant no. 73. The efficiencies of these variants are very similar, 0.918 and 0.919, respectively.

The optimization procedure also increased the mean torque of the two SRMs from the initial rated value equal to 19.1 N·m to 19.37 N·m in the case of the SRM having M400-50A type laminations and to 20.8 N·m in that having its iron core made of M400-50A type electric steel. These mean an increase by 1.41% and 8.9%, respectively. As it can be seen the improvement in the case of the SRM having higher quality iron core is more significant.

The best found SRM was supposed to a final electromagnetic checkout. The flux lines and the color map of the flux density in the SRM for the position of the rotor from the beginning of the conduction period are given in Fig. 6 and 7.

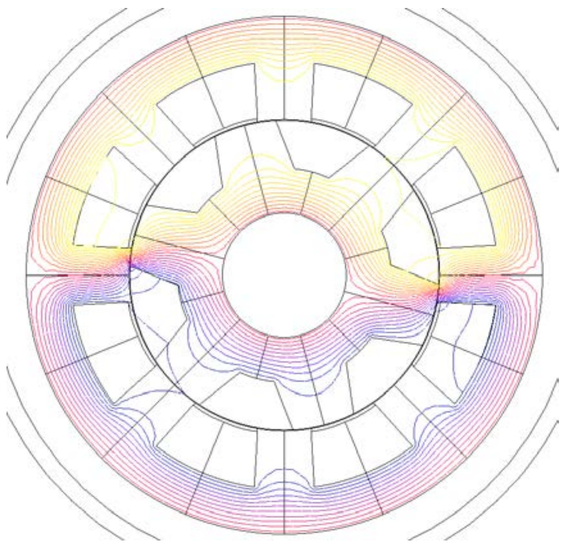


Fig. 6. The flux lines of the optimized SRM

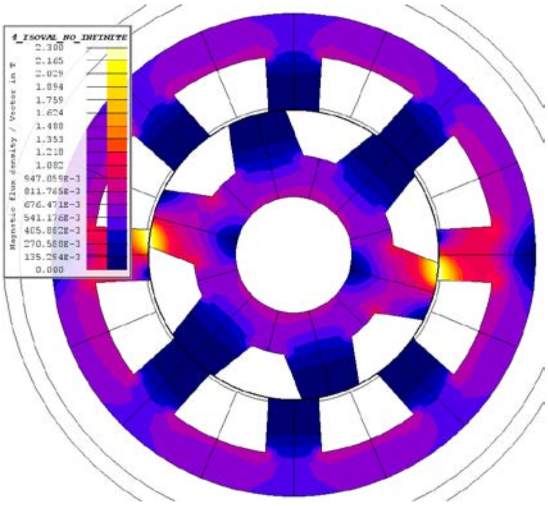


Fig. 7. The color map of the flux densities in the optimized SRM

As it can be seen, the obtained results are in accordance with the theoretical expectations.

4. CONCLUSIONS

In the paper it was proved, that the performances of a common 8/6 poles SRM can be enhanced also by simple approaches. Its overall performances were improved by manufacturing its iron core of higher quality non oriented fully processed electrical steel, and its efficiency was maximized by means of a simple FEM-based optimization process.

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Mircea Ruba
Department of Electrical Machines and Drives
Technical University of Cluj-Napoca
28, Memorandumului st., Cluj-Napoca, Romania
mircea.ruba@mae.utcluj.ro