Soft Magnetic Composite Core – A New Perspective For Small AC Motors Design

L. Petkovska and G. Cvetkovski

Ss. Cyril and Methodius University
Faculty of Electrical Engineering and Information Technologies
Karpos II bb, P.O.Box 574
1000 Skopje, Macedonia
phone:+389 70 380940, fax:+389 2 3064262
e-mail: lidijap@feit.ukim.edu.mk ; gogacvet@feit.ukim.edu.mk

1. Introduction

In the paper is presented a new design of a small permanent magnet AC motor, based on the application of the soft magnetic composite (SMC) material, patented under the trade name Somaloy™500 Hoganas. The new possibilities and perspectives of the SMC are analysed.

A detailed analysis of advantages of stator core made of SMC, in comparison with the laminated steel is presented; particular emphasis is put on the losses and efficiency of motor.

Key words

Single-phase Permanent Magnet Motor, Soft Magnetic Composite Materials (SMC), Finite Element Method (FEM), Losses, Efficiency.

2. Background

Continuing advances in materials research has put in reality the ability to produce high quality materials with soft magnetic properties, thus competing with steel laminations at a similar production cost, or even cheaper. The soft magnetic composite (SMC) materials are well suited for use in alternating magnetic fields as the eddy currents are significantly restricted. This fact allows using SMCs in building cores of AC electrical motors; the output is more compact design of electrical machines.

This paper proposes new options for design of a small AC non–conventional machine, in which it has been efficiently utilized the SMC material.

3. The Concept

The concept of development the new design of an electric motor starts with a detailed case study of the selected *reference* model. First the motor as is originally produced with magnetic core made of laminated steel is analyzed. Before the new design is developed, constraints and targets to be reached are defined: • to keep equal or even to get smaller motor size; • to redesign stator core for Somaloy® application; • to maintain or improve the motor efficiency; • to keep the original rotor design.

It has been shown that the direct replacement of electrical sheets with SMC is not reasonable, as electrical machines will have poorer performance because the SMC lower permeability and lower saturation flux density. In order to achieve more benefits of the SMC, we improve the motor construction and introduce an *optimized* model. These steps are depicted in Fig. 1.

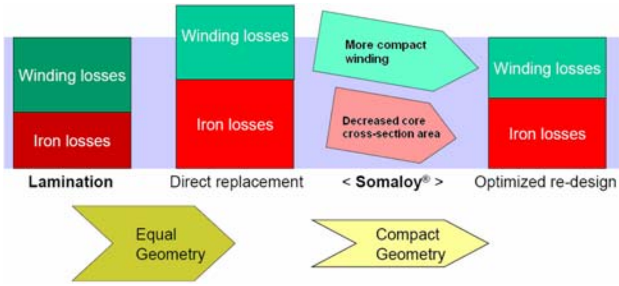

Fig. 1. The concept of a development the motor design

4. Practical Application

The proposed concept is applied on a single-phase permanent magnet synchronous motor for drain pump with rated data: U_n = 230 V @ 50 Hz; I_n = 0.25 A; P_{1n} = 26 W; n_n = 3000 rpm. The 2 pole permanent magnet rotor is made as ferrite cylinder, with characteristics: coercivity H_c=–240 kA/m; remanence B_r=0.354 T; magnetization of the rotor – parallel. In Fig. 2 there is presented the the 3D motor topology. In our study, this motor is adopted to be *reference* model (RM).

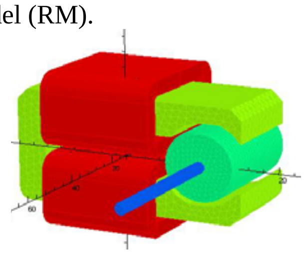

Fig. 2. The 3D topology of the reference motor – *RM*

In accordance with the proposed concept, presented with a flowchart in Fig. 1, the applied methodology comes out naturally; it is consisted of the following procedures:
• We start with the existing motor – the original model, which is used as *Reference – RM*;

• After, by simple replacement of the stator laminations with SMC material, we derive new model *Somaloy – SM*; • Finally, at the same rotor geometry, the stator structure is optimized and *Optimised – OM* model is developed.

From our experience Finite Element Method (FEM) has been proved as powerful method for magnetic field analyses and for numerical calculations of an electrical machine characteristics; FEM is applied in this study.

FEM calculations are carried out at various loads of the motor, by changing the excitation currents in stator winding; the rotor is freely rotating along one revolution (360^o). Series of FEM simulations are carried out. For the assessment of motor performance, the most important characteristics are calculated numerically.

The three models of the studied motor are analyzed by the same methodology, and the results are presented comparatively in figures and in tables. As an example, in Fig. 3 is shown the electromagnetic torque characteristic.

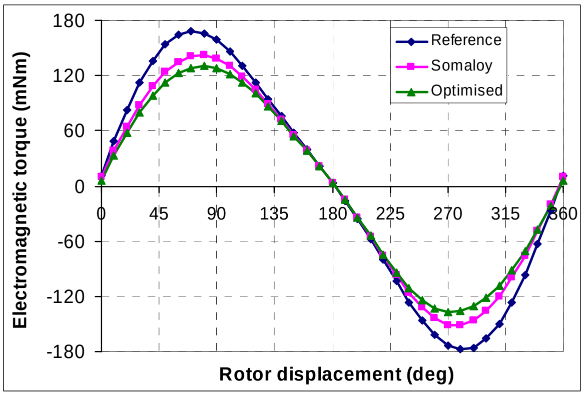

Fig. 3. Electromagnetic torque characteristics

The analysis of the results is carried out at specified operating conditions, when • the winding current is kept at rated value I_n, and • the output (shaft) torque is kept T_n, the same as in reference motor. The calculated quantities, under these circumstances are given in Table I and II.

TABLE I. – Comparison of FEM results

	RM	SM	OM
Rest position δ_o	7.1^o	8.5^o	8.0^o
PM flux Φ_{PM}	1.35×10^{-04} Vs	1.28×10^{-04} Vs	1.25×10^{-04} Vs
Rated load δ_n	10^o	18^o	17.5^o
Rated torque T_{em}	48.23 mNm	59.35 mNm	52.07 mNm
Rated flux Φ_n	1.91×10^{-04} Vs	1.67×10^{-04} Vs	1.58×10^{-04} Vs
Pull–out δ_{max}	90^o	90^o	90^o
Peak torque T_{max}	158.63 mNm	138.35 mNm	127.79 mNm
Flux per pole Φ	6.01×10^{-05} Vs	5.23×10^{-05} Vs	4.83×10^{-05} Vs

TABLE II. – Comparison of losses and power

	RM	SM	OM
Iron loss P_{Fe}	3.72 W	6.78 W	4.57 W
Copper loss P_{Cu}	10.62 W	10.62 W	10.09 W
Friction loss P_{fr}	1 W	1 W	1 W
Total loss ΣP_{loss}	15.34 W	18.4 W	15.66 W
Rated power P_n	10.66 W	10.66 W	10.66 W
Shaft torque T_n	34 mNm	34 mNm	34 mNm
Input power	26 W	29.06 W	26.32 W
Efficiency η	41 %	37%	40.5 %

In Fig. 4, the results of loss calculations are presented; the figure itself is enough illustrating the features of the three developed and studied motor models.

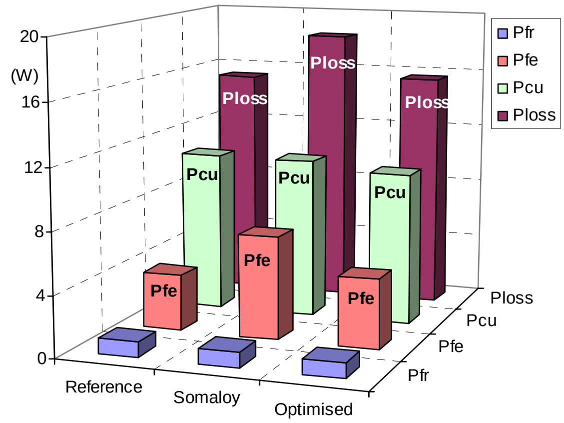

Fig. 8. Comparison of the losses

5. Analysis of Results

The analyses of results are carried out by presented tables and figures, and are given in the full paper. First, observations are focussed on the values of: • the angle of rest position δ_o; • the rated load angle δ_n; • the rated electromagnetic torque T_{em}; • the pull–out (peak) torque T_{max}; • the flux per pole Φ. After, the emphasize is put on • the losses and • the efficiency.

6. Conclusions

This paper has presented an overview of attractive research directions for the application of soft magnetic composites in the design of AC machines, applied on the conventional small AC motor of a synchronous type. The benefits of replacing the conventional laminated cores in the electrical motors with the powdered iron composites are considerable, resulting in a compact design. In brief they include: • simple production of the stator core and windings and hence reduced production costs; • the unity iron stacking factor; • the reduced copper volume, i.e. reduced copper loss; • lower eddy current loss; • an increase in overall efficiency.

But these advantages are accompanied by a number of drawbacks, discussed in the full paper.

In summary, it appears that the use of SMC materials in machine design is interesting and challenging research area for the near future. It is expected the improvements in materials and their applications to be achieved.

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