

## Development of Somaloy Components for a BLDC Motor in a Scroll Compressor Application

Mats Persson<sup>1,a</sup>, Göran Nord<sup>1,b</sup>, Lars-Olov Pennander<sup>1,c</sup>, Glynn Atkinson<sup>2,d</sup>, and Alan Jack<sup>2,e</sup>

<sup>1</sup>Höganäs AB, SE-263 83, Höganäs, Sweden

<sup>2</sup>Dept. of Electrical and Electronic Engineering, Newcastle University upon Tyne, UK

<sup>a</sup>mats.persson@hoganas.com, <sup>b</sup>goran.nord@hoganas.com, <sup>c</sup>lars-olov.pennander@hoganas.com,

<sup>d</sup>g.j.atkinson@ncl.ac.uk, <sup>e</sup>Alan.Jack@newcastle.ac.uk

### Abstract

*Electric scroll-compressor drives are commonly used for e.g. home appliance cooling units. The recent development of hybrid cars with internal combustion engine in combination with electrical propulsion requires new solutions to be able to cool the passenger compartment of cars at stand-still. Both application areas demand efficient motor drives to reach good economy and efficient use of limited battery power as well as competitive volume/weight for a given output. The BLDC motor is a controllable and efficient solution. A major part of the motor is the soft-magnetic core. The powder based Somaloy<sup>®</sup> material shows high resistivity and induction as the result of engineered iron particles with in-organic coating. The unique features of compacted Somaloy<sup>®</sup> components can be utilized to enhance the shape and total volume of the BLDC motor with at least maintained efficiency compared to the use of traditional laminated steel sheet cores. A careful design of the Somaloy<sup>®</sup> components can also simplify assembly and positively influence the coil configuration. This study shows a comparison between a typical laminated BLDC motor and a redesigned, Somaloy<sup>®</sup> based version adapted for a scroll-compressor application.*

**Keywords :** Somaloy, SMC, BLDC, Motor, HVAC

### 1. Introduction

Soft Magnetic Composites (SMC) are isotropic materials when it come to magnetic and mechanical properties. This enables the design of magnetic circuits in electrical machines to be made in three dimensions, opening up a new dimension for the motor designer. In addition the powder metallurgy process is well suited for the production of complex, net shaped, components with tight tolerances and a high degree of surface finish.

An SMC material typically compares with laminated steel in material performance tests with somewhat lower saturation induction, however with lower core loss at elevated frequencies. At lower frequencies the situation is reversed and lower losses are typically found in laminated steel.

This paper examines the potential of utilizing these newly gained advantages in making a competitive alternative design to a high performance BLDC motor used for a scroll compressor application. The basis of this study is to use the same rotor technology and then look for a stator design which at least matches the laminated alternative within at most the same size envelope. Success is to achieve equal or better performance with smaller size.

The improvement in the total efficiency of the refrigeration system as compared to existing switched motor systems based on induction motors is achieved by the use of a variable frequency inverter technology. This in turn

allows permanent magnet synchronous motors to be used with their inherently high efficiency. Hence this application forms a very challenging target for SMC.

The study has shown that a three dimensional SMC design matching the performance of the laminated original motor but yet in a smaller envelope. Motor performance has been simulated utilizing lamination and Somaloy materials as well as a newly developed Somaloy<sup>®</sup> 3P material and then proven in tests.

### 2. Motor Design consideration

This study is concerned with matching the efficiency and size envelope of the original motor, constructed using 0.35mm laminations, with an SMC motor constructed using the newly developed Somaloy<sup>®</sup> 3P material.

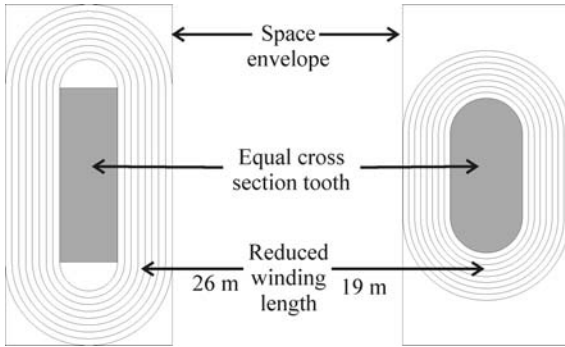
A direct replacement of the laminated motor with an SMC version will exhibit the same winding loss (same length windings) but greater iron loss (SMCs iron loss per kg is higher at 112Hz, the electrical frequency).

By taking advantage of the isotropic properties of SMC efficiency can be matched through design.

The ability to press rounded SMC teeth, figure 1, provides a significant reduction in winding length (19m compared to 26m), hence reducing winding loss.

Pressed separately, the rounded SMC teeth are wound using the more efficient bobbin winding process which

gives a slot fill factor exceeding 65% (coil insertion with the laminated motor gives a slot fill factor of 44%). The compacted winding releases space into which the tooth is enlarged. The increased tooth cross sectional area reduces magnetic flux density, and therefore iron loss.



**Fig. 1. Winding arrangement for a rectangular laminated tooth (left) and a rounded SMC tooth (right).**

The rounded tooth has no sharp corners; consequently thinner ground wall insulation is used. For mass production this could even be applied directly to the tooth surface.

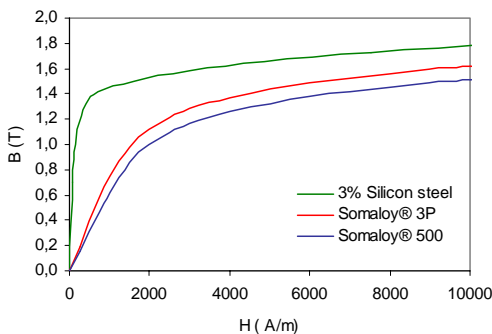
The separately pressed coreback is extended beyond the teeth. This provides additional cross sectional area (reduced flux density and iron loss) whilst maintaining slot space for the winding.

Overall, iron loss is slightly higher than the original laminated motor. This is more than offset by the reduction in winding loss due to the shorter winding.

### 3. Material properties

In a direct comparison of material performance SMC materials still comes out second to laminations at frequency and induction levels at which this machine operates.

Material performance of SMC materials are constantly improving and the material utilized in this study, Somaloy® 3P represents a major improvement in terms of permeability, induction level and core loss compared to earlier Somaloy materials.



**Fig. 2. Magnetizing curves of laminated steel two Somaloy materials.**

**Table 1. Loss comparison (laminated steel and two different Somaloy materials at 1,3T and 112Hz)**

Core loss (W/kg)	Laminated steel	Somaloy 500 + 0.5% Kenolube CC800MPa	Somaloy 3P
@1.3T, 112Hz	6.2	21.6	16.6

### 4. Motor Performance

Operating at 3360rpm the laminated motor delivers 2.1 Nm of torque at an efficiency of 91.2%. The SMC counterpart (figure 3) is designed to match this speed, torque and efficiency.



**Fig. 3. Cut view of Somaloy stator (left) with small copper end windings, tooth component (right) and core-back (middle).**

Total axial length has been reduced from 95mm to 60mm and copper mass is reduced from 762g to 533g.

Efficiency is matched through the change in the balance of electromagnetic losses (winding loss : iron loss). For the laminated motor this is 55% : 45%, changing to 42% : 58% for the SMC motor, the reduction in winding loss more than offsetting the increase in iron loss.

### 5. Summary

A laminated stator for a high performance permanent magnet motor has been carefully redesigned using a Somaloy material. The result is a motor with better or equal performance that is 30% shorter and uses 30% less copper.

### 6. References

1. L. O. Hultman, A. G. Jack "Soft magnetic composites – motor design issues and applications" PM<sup>2</sup>TEC 2004 International Conference on Powder Metallurgy & Particulate Materials, in Chicago, USA, on June 17, 2004
2. A.G. Jack, B.C. Mecrow, P.G. Dickinson, D. Stephenson, J.S. Burdess, N. Fawcett, J.T. Evans, "Permanent magnet machines with powdered iron cores and pre-pressed windings" IEEE Trans on Industry Applications, July/August 2000
3. A.G. Jack B.C. Mecrow, S.A. Evans PEMD (2004) Edinburgh Low cost SMC brushless DC motors for high volume applications in the automotive sector.