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Soft Magnetic Composites

Soft Magnetic Composites (in short SMC) are basically pressed iron powder where the particles are kept separated with an electrically insulated layer. Today SMC material challenges traditional material such as soft magnetic ferrites and electrical steels in applications with alternating magnetic fields.

The powder metallurgy (P/M) industry has for long time used SMC materials to manufacture high frequency inductive components for various filter and power conversion applications, but more recently the SMC material group has been expanded to also include alternatives to laminated electrical steels in applications in the low to medium frequency range, such as rotating machines, sensors and fast switching solenoids.

There are three main features offered by the SMC technology;

1. Unique combination of magnetic saturation and low eddy current losses.
2. 3D-flux carrying capability.
3. Cost efficient production of 3D-net shaped components by the P/M process.

Electrical Motors

Material, motor designs and manufacturing has been optimized for a 2-Dimensional flux over a very long period of time, and a simple “drop–in” replacement of a laminated core by a SMC core, will in the most cases result in equal performance, at the same cost.
The key to success is hence found in exploiting the 3-dimensional flux capability of the material. The possibilities for the designer to use new motor topologies with shape, winding, and assembly solutions beyond today’s standards, opens for benefits such as better performance, reduced size and weight, fewer parts, and lower cost.

A 3-Dimensional design can be adopted for virtually all normal motor topologies, but some topologies are more suited than others.
For instance, a 3D-designed universal motor can significantly reduce the copper-wire and increase the performance of the application, but despite this it has proven difficult to commercialize SMC in both induction and universal motors, as these motors operate at low net frequency, which allows them to use thick, low cost lamination.
Furthermore, SMC has a lower permeability than laminations, and this influences the magnetic flux in the circuit, and needs to be compensated by adding more iron.

But the current trend toward high efficiency permanent magnet motors, and features such as variable speed, increases the competitiveness for the modern SMC materials.
It has been shown that using SMC components in a redesigned, state-of-the art radial flux Brushless DC-motor, the performance could be matched by a motor taking up a significantly lower volume.

Perhaps the most suitable motor topologies for the SMC materials are however various kinds of novel Permanent Magnet Synchronous Machines like Axial-flux machines, Claw pole machines and Transverse-flux machines.

The Claw pole / TFM machines have a 3D flux path and are therefore difficult to manufacture with laminations, but by using the powder metallurgy technology, and utilizing the magnetic isotropy characteristic of the SMC-material, they can be designed and fabricated easily.

Fast switching actuators and pulse transformers

The SMC technology is very well suited for fast switching actuator applications as the response of the material is fast. Moreover, the high magnetic saturation means that high force can be obtained. Compared to competing technologies both the material and process are cost efficient and there is also a possibility for making compact 3D-designs.

SMC has been used for a long time as a core material for fast switching actuators in diesel fuel injectors for passenger cars, but there is certainly a potential to breakthrough other applications in the field of fast switch actuators such as

- Vibration damping
- Magnetic bearings
- Electromagnetic valve actuation
- Electromagnetic suspension

The SMC technology has also been used for a considerable time in ignition systems as the core in the pulse transformer. It is central for both fast switching actuators and ignition systems to have materials with good B-H characteristics and high saturation, which can both be achieved with modern SMC materials.

Inductors for power electronics

The use of power electronics is increasing in all kind of applications. The demand for high efficiency motor solutions and new applications such as distributed energy generations require converters and controls which also generates transient’s and noise in electrical current.

To protect equipment and not polluting the grid, the market for various filters is increasing. Powder technology offers several advantages in these applications compared to steel sheets, especially at the frequency ranging from kHz- to MHz. Two major benefits have been low eddy-current losses and the ability to store energy in the distributed air gap between particles instead of using a physical air gap. However, compared to steel sheets, SMC has suffered from lower saturation, and higher losses at low base and ripple frequencies. There is a trend towards higher frequencies, which increases the competitiveness of SMC materials, which offer lower eddy-current losses than laminates.

Another factor is that the development of new SMC materials with higher saturation and lower losses in frequencies ranging from 1 to 50 kHz now makes it possible to target applications that uses gaped laminated inductor cores.

Switching from lamination to SMC new features can be used to create benefits. The 3D properties and 3D shaping can be used to make “new” compact geometries that for instance are common for soft ferrites, such as the pot core.

Summary

The material development of SMC materials has led to materials with increased performance such as lower losses, higher permeability and increased mechanical strength. For successful implementation of SMC in electrical machines, 3D-designs are very important. Examples of motor topologies that suite the technology are Transverse Flux/Claw pole, axial flux and linear machines.

The combination of high magnetic saturation, fast response and cost-efficient production of compact 3D shapes make the SMC technology very attractive for fast switching actuator applications. Inductive components made of lamination which today require a gaped structure, can be challenged by the new SMC materials.