Shielding Cylinder Effect in High-Speed Electric Machines

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Introduction:

In the field of electric machines, a trend towards both higher efficiency and higher power density is observed.
This has led to a growing interest for High-Speed Permanent Magnet Synchronous Machines (HS PMSMs).

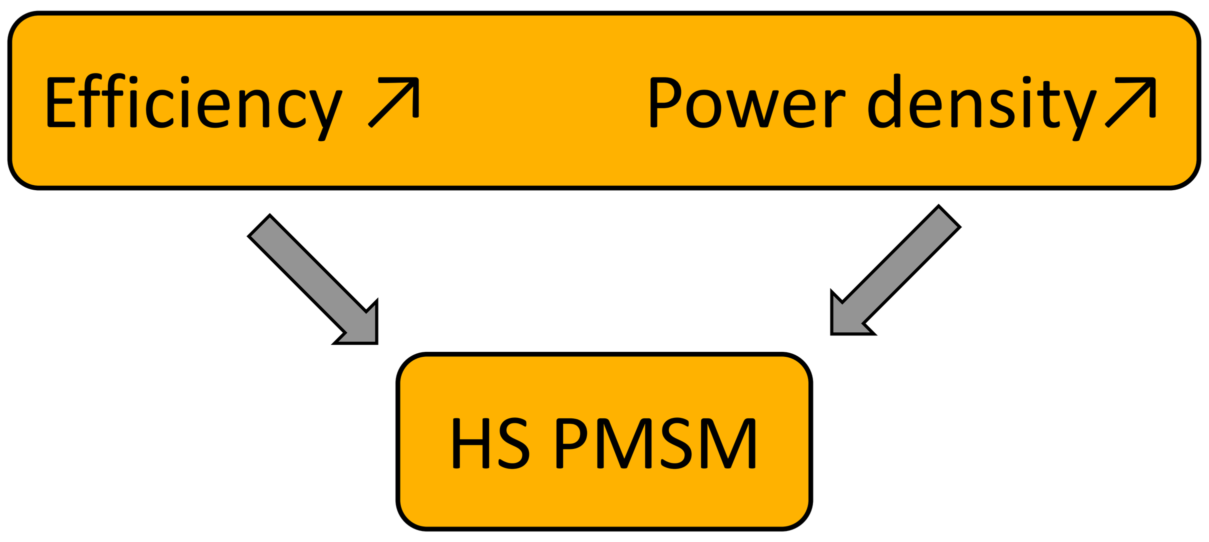

Figure 1. Interest in HS PMSM

However, demagnetization of the magnets at high temperatures is a major concern in HS PMSMs. Therefore, special attention has to be paid to the rotor losses when designing such machines.

A commonly proposed solution is the shielding cylinder (SC) [1], [2]. A conductive sleeve wrapped around the magnets, protecting them from unwanted harmonics.

Computational Methods:

Using COMSOL's Rotating Machinery interface a 5 kW slotted PMSM with shielding cylinder was modeled at various speeds (5.000 – 100.000 rpm) and SC conductivities (0 – 5.10^7 S/m).
This model was then used to compute the losses in the shielding cylinder and the magnets.

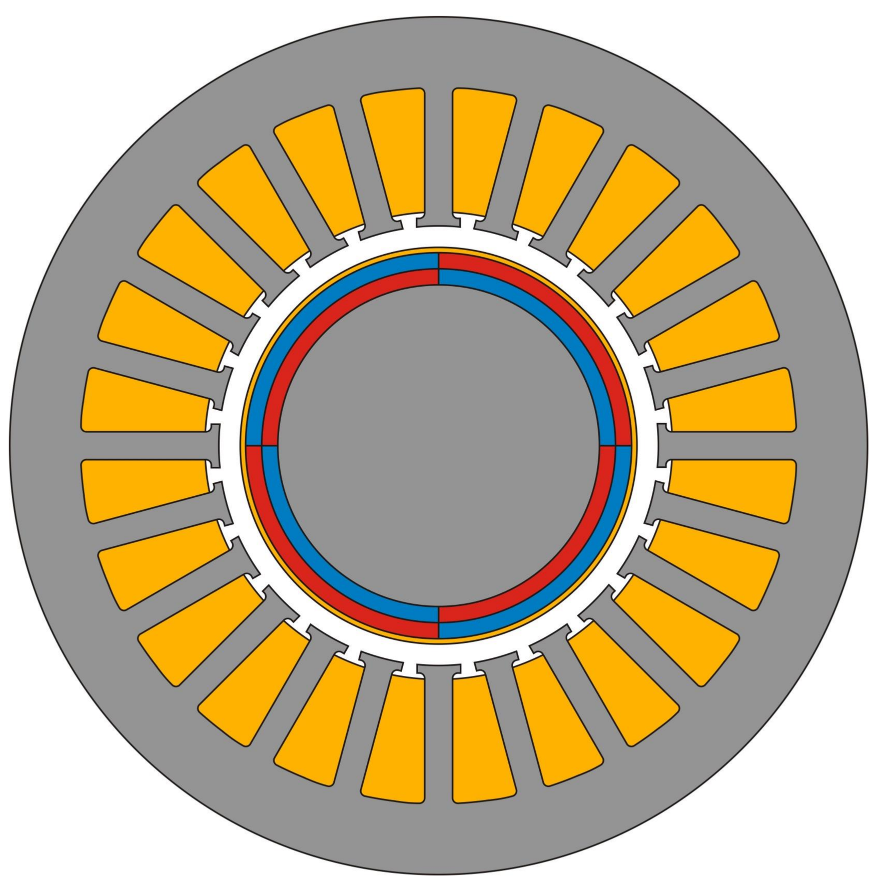

Figure 2. Machine geometry

Results:

The following graphs show the SC and magnets losses as function of the rotational speed and this for different SC materials (copper, inox and air)

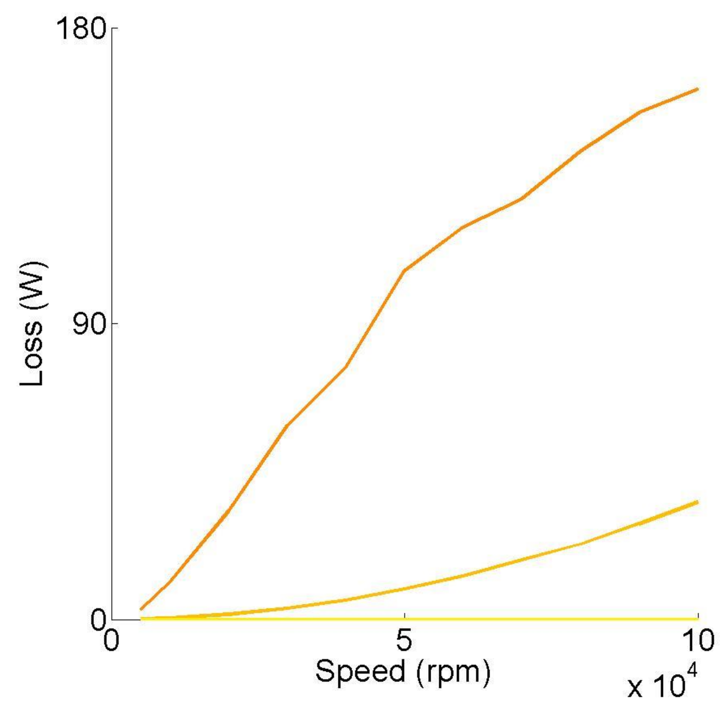

Figure 3. SC losses

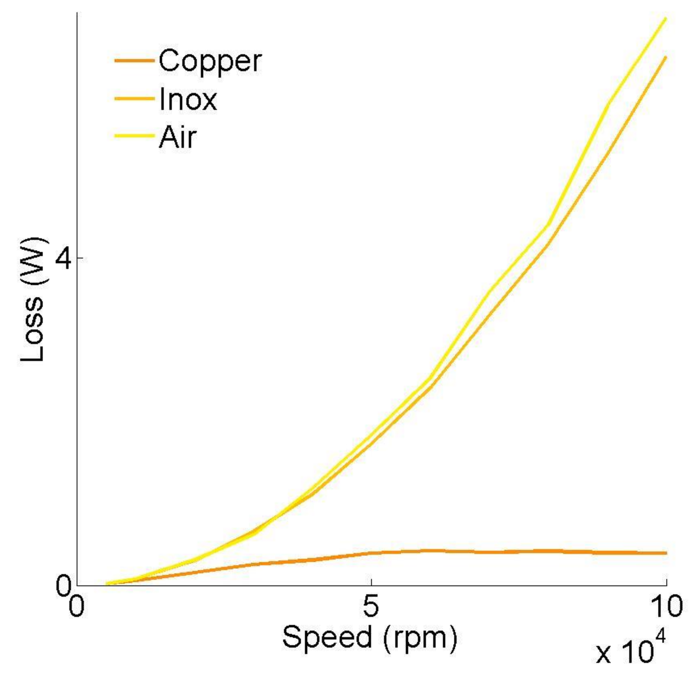

Figure 4. Magnet losses

Higher SC conductivities seem to result in lower magnet losses. However, SC losses are higher for high SC conductivities. The total rotor losses are shown in Figure 5.

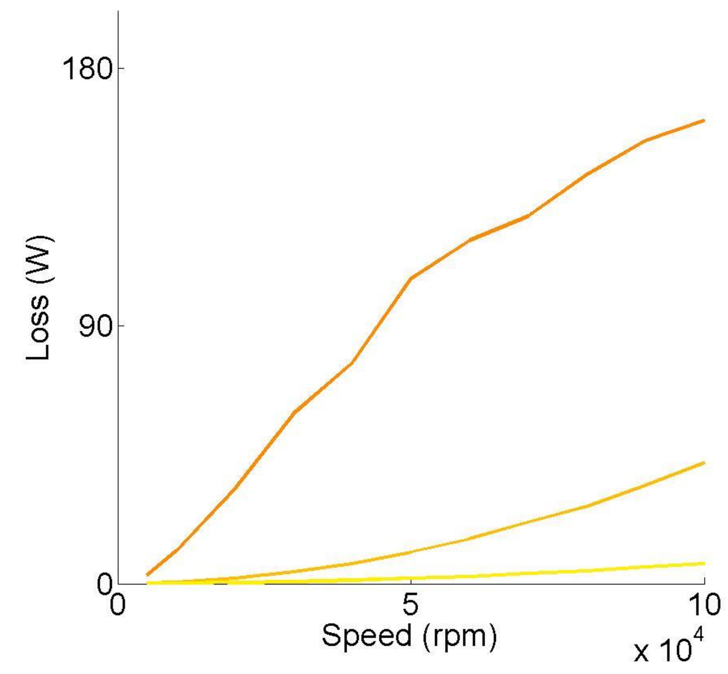

Figure 5. Rotor losses

Conclusions:

The initial, quadratic, increase in magnet and sleeve losses is explained by a constant resistance and a frequency dependent current.

When the penetration depth reaches the thickness of the SC, the current will be constant and the resistance will vary with $\sqrt{f}$. Causing a $\sqrt{f}$ dependency of the losses.
The SC will now act as a shield for higher harmonics and thus the magnet losses will decrease.

These effects can be clearly seen in Figures 3-5 for the machine with a copper SC.

References:

1. Fengzheng Zhou, "Study of Retaining Sleeve and Conductive Shield and Their Influence on Rotor Loss in High-Speed PM BLDC Motors", IEEE Trans. on Magn., vol. 42, no. 10, pp. 3398-3400, Oct. 2006
2. Shuangxia Niu, "Eddy Current Reduction in High-Speed Machines and Eddy Current Loss Analysis With Multislice Time-Stepping Finite-Element Method", *IEEE Trans. on Magn., vol. 48, no. 2, pp. 1007-1010, Febr. 2012*

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