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INFLUENCE OF WINDING SCHEME ON THE IRON-LOSS DISTRIBUTION IN PERMANENT MAGNET SYNCHRONOUS MACHINES

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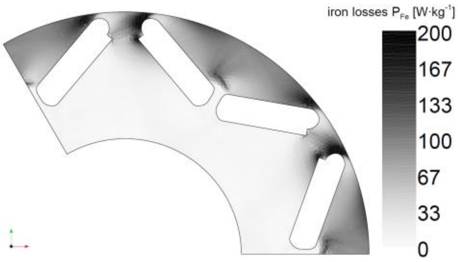
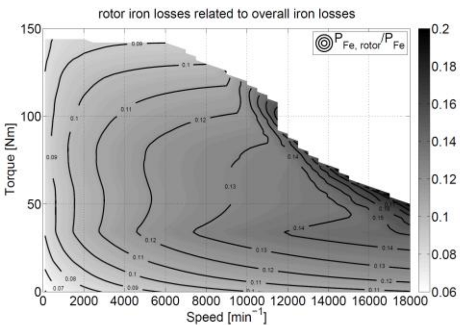
The influence of winding scheme (single-tooth, distributed (pitched, unpitched)) on iron-loss distribution in rotor and stator of electrical machines is to a large extent unknown. At present windings are primarily selected with respect to back-EMF harmonics and torque fluctuation. The influence of iron losses and in particular their local distribution (of these heat sources) in the machine is disregarded [1]. Moreover minor-loop hysteresis losses are not considered in most of the used iron-loss models. This leads to inaccurate results [2] and to an erroneous analysis of loss-distribution, *i.e.*, heat source prediction.

For interior permanent magnet synchronous machines (IPMSM) the rotor temperature has to be considered. For variable-speed drives losses have to be calculated for every operating point. Hence the distribution of iron losses is investigated in the full paper for various operating points of an IPMSM. The influence of winding scheme on iron losses and iron-loss distribution is investigated using the in-house Finite Element package *pyMOOSE* [3]. The iron losses are determined by means of the IEM-Formula which has been presented in [2, 4].





The iron-loss distribution in the rotor of an IPMSM with single-tooth winding at 6,000 min^{-1} and 100 Nm is shown on the left (top). It can be seen, that the iron-loss density close to the rotor surface is significantly higher when compared to the bulk material. The iron-loss density close to the rotor surface is higher for machines with a higher number of stator teeth (distributed winding) due to higher slot harmonics. However, it decreases for such machines within shorter distances from the rotor surface.

The iron losses are calculated for various operating points in speed and torque. Field-weakening is considered so that at no point the maximum supply voltage will be exceeded. The evaluation of the ratio between rotor iron losses and overall iron losses is visualized on the left (bottom). Obviously the ratio between rotor and stator iron losses reaches up to 0.2 at speeds above 10,000 min^{-1} and maximum possible torque. The rotor iron losses are studied in detail in the full paper. To produce comparable results, the losses are calculated at the same torque-speed operating-points. All stators are optimized to yield the highest torque while leading to lowest flux distortions.

[1] YAMAZAKI, K.: “Torque and Efficiency Calculation of an Interior Permanent Magnet Motor Considering Harmonic Iron Losses of Both the Stator and Rotor,” *IEEE Trans. Magn.*, vol. 39, pp. 1460-1463, 2003.
[2] STEENTJES, S. - VON PFINGSTEN, G. – HOMBITZER, M. – HAMEYER, K.: “Iron-loss model with consideration of minor loops applied to FE-simulations of electrical machines,” (to appear in) *IEEE Trans. Magn.*, vol. 49, no. 7, 2013.
[3] www.iem.rwth-aachen.de
[4] STEENTJES, S. – LEßMANN, M. – HAMEYER, K.: “Semi-physical parameter identification for an iron-loss formula allowing loss-separation,” *J. Appl. Phy.*, vol. 113, iss. 17, 2013.

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