CORE LOSSES IN CLAW POLE PERMANENT MAGNET MACHINES WITH SOFT MAGNETIC COMPOSITE STATORS

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Introduction

This paper outlines the core loss calculation in a claw pole permanent magnet soft magnetic composite (SMC) machine by using a finite element analysis of magnetic field. The total core loss is computed by separating the hysteresis (alternating and rotational, both purely circular and elliptical), eddy current, and anomalous losses in each element, when the rotor rotates. The coefficients for each loss component are determined by a loss separation procedure and the experiment data obtained by a single-sheet two-dimensional core loss testing system [1].

Measurement and Modeling of Iron Loss in SMC Sample

Fig. 1 illustrates the measured alternating and rotational core losses of a block SMC sample.

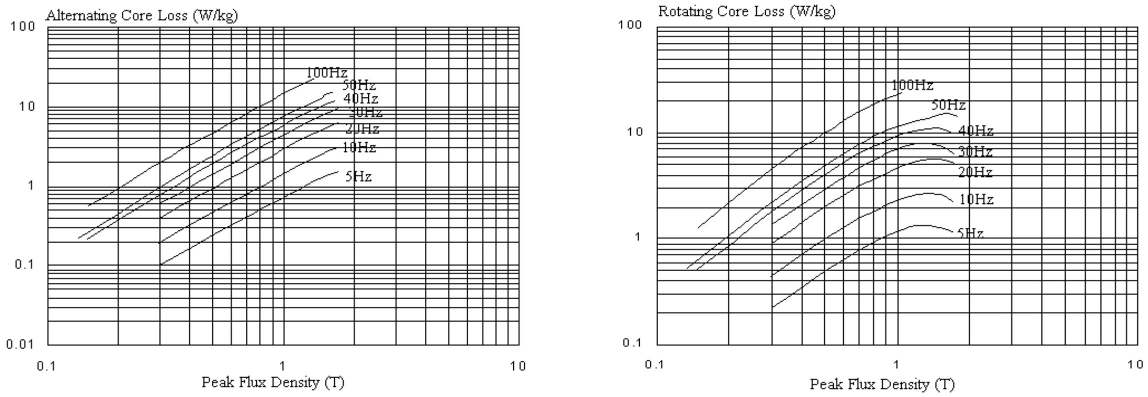

Fig. 1 (a) Alternating & (b) circular core losses of SMC sample at different frequencies

For alternating core loss modeling, standard practice is to separate the loss into three parts: hysteresis, eddy current and anomalous losses, $P_a=C_{ha}fB^h+C_{ea}(fB)^2+C_{aa}(fB)^{1.5}$, where B is the peak value of flux density, f the frequency, and C_{ha}, h, C_{ea}, and C_{aa} are coefficients. By fitting the model to the experimental results in Fig. 1(a), these constants are deduced as C_{ha}=0.1402, h=1.548, C_{ea}=0.00000123, and C_{aa}=0.0003645.

Similarly, the specific core loss with a circular rotating flux vector $\boldsymbol{B}$ can also be separated into three parts as $P_r=P_{hr}+C_{er}(fB)^2+C_{ar}(fB)^{1.5}$, where P_{hr} is the rotational hysteresis loss, and C_{er} and C_{ar} are coefficients for the rotational eddy current and anomalous loss components.

The rotational hysteresis loss behaves very differently from its alternating counterpart. To model the rotational hysteresis loss, a novel formulation was proposed in [2]. It is postulated that the specific rotational hysteresis loss per cycle can be expressed in terms of four parameters, a_1, a_2, a_3, and B_s, by

$$\frac{P_{hr}}{f} = a_1\left[\frac{1/s}{(a_2+1/s)^2+a_3^2} - \frac{1/(2-s)}{[a_2+1/(2-s)]^2+a_3^2}\right], \text{ where } s = 1-\frac{B}{B_s}\sqrt{1-\frac{1}{a_2^2+a_3^2}} \qquad (1)$$

By fitting the above formulations to the rotational loss curves in Fig. 1(b), the coefficients are obtained as C_{er}=0.00023, C_{ar}=0, a_1=6.814, a_2=1.054, a_3=1.445, and B_s=2.13 T.

The core loss with an elliptical flux density vector can be predicted from the alternating and purely circular formulations [2].

3D Magnetic Field Analysis and Core Loss Calculation

Fig. 2 shows the calculated 3D flux density locus in an element of the claw pole. It is shown that the flux density is really three-dimensional and the locus of ***B*** is rotating (elliptical). In the same way, it can be found that the flux density in the stator yoke and the side plate basically varies in one direction only and alternating core loss models can be used. Fig. 3 shows the core loss calculation for different frequencies or rotor speeds.

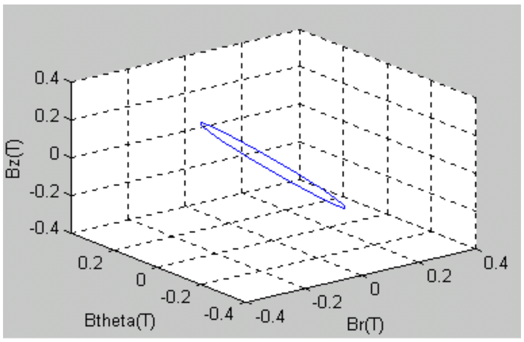

Fig. 2 Flux density loci at the claw poles

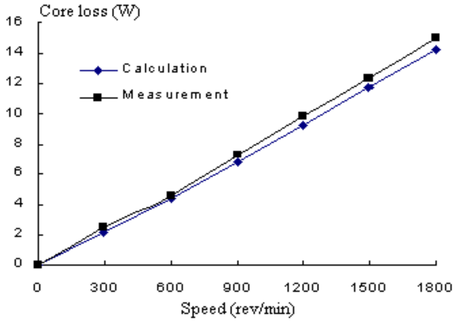

Fig. 3 Core loss calculation and measurement

Core Loss Measurement and Conclusions

Fig. 3 also illustrates the core loss measurements of the claw pole PM machine by the dummy stator method, replacing the SMC stator with a wood tube. The comparison between the calculated and measured core losses shows that the proposed core loss models and calculation methods are practical. More details will be discussed in the extended full paper.

References

[1] J.G. Zhu, V.S. Ramsden, IEEE Trans. Mag. 29, 2995, (1993)

[2] J.G. Zhu, V.S. Ramsden, IEEE Trans. Mag. 34, 2234, (1998)