Influence of the magnetic properties of yoke material on standard SST measurements on electrical steel

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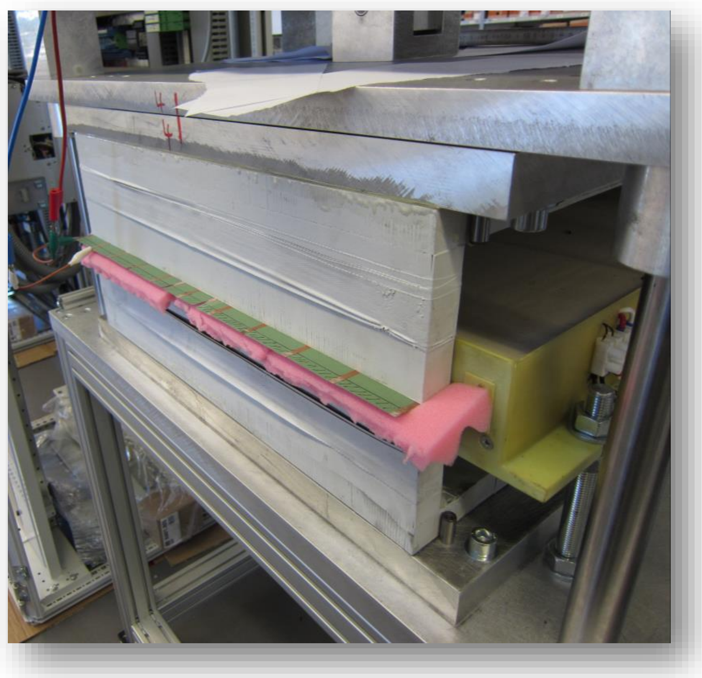
Abstract. The Single Sheet Tester (SST92) is being used as a standardized measurement method for magnetic power loss characteristics of 500 mm x 500 mm of silicon iron sheet steel samples [1]. The IEC published this standard in 1992 as a method independent of the Epstein method, whereby the influence of the flux closure yokes, made of high permeability laminated material, were neglected. The importance of the SST method has raised together with the trend of using highest permeability domain refined sheet steel because this material cannot be measured by the Epstein method.

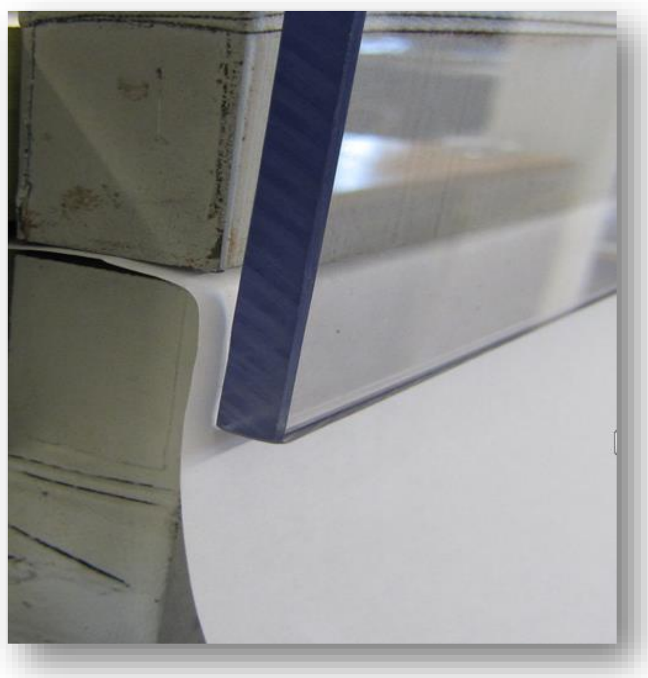
Recently a thorough measurement comparison among eleven laboratories [2] has shown that, although the greater part of the labs' results agreed remarkably well, a number of outliers appeared noticeably. Thus, the clarification of the source and the extent of the impact of the yokes on the measurement results are of great interest for developing the SST standard further. The experiments shown here demonstrate that only statistical methods can deliver relevant results and conclusions.

I. Method A – Yoke Conductivity Measurement

In this research a contact pattern as shown in Fig.1a, placed between the top and the bottom yoke was used for interlaminar resistivity measurement. The distance between the contacts was approximately 50 mm. The both yokes were separated in order to create the required airgap as shown in Fig.1b.



a. front side

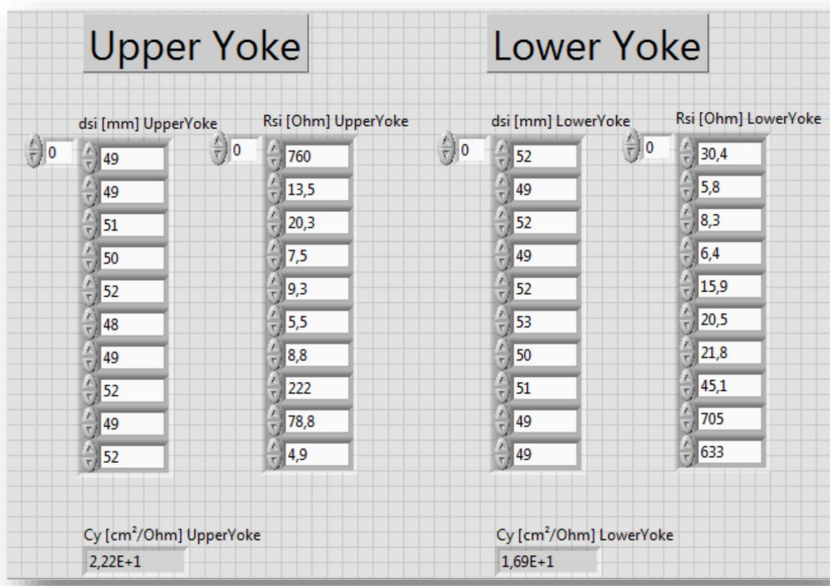


b. back side

Fig.1 Position of the contact patterns at the front (a), and additional yoke separation at the back (b) side of the yokes

To determine the conductivity factor C_Y of the yokes' laminations, the following equation, derived from the classical power loss formula, is used [2]:

$$C_Y = \sum_{i=1}^{N_S} \frac{1}{R_{Si}} \cdot d^2$$



Upper Yoke: dsi [mm] UpperYoke	Rsi [Ohm] UpperYoke	Lower Yoke: dsi [mm] LowerYoke	Rsi [Ohm] LowerYoke
49	760	52	30,4
49	13,5	49	5,8
51	20,3	52	8,3
50	7,5	49	6,4
52	9,3	52	15,9
48	5,5	53	20,5
49	8,8	50	21,8
52	222	51	45,1
49	78,8	49	705
52	4,9	49	633

Cy [cm²/Ohm] UpperYoke: 2,22E+1
Cy [cm²/Ohm] LowerYoke: 1,69E+1

Fig.2 Determination of the conductivity factor Cy of the yokes' laminations

II. Method B - Yoke Loss Measurement

A four sets of two yokes used for the flux closure in the SST500 was investigated in terms of specific power loss and interlaminar resistivity measured at the pole sides [2,3]. The loss measurement was performed for yokes in configuration as shown in Fig. 3 with a set of primary and secondary windings.

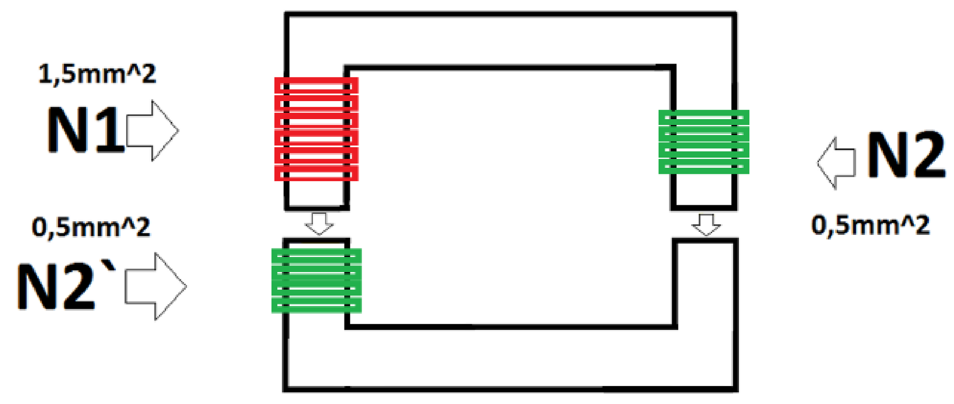


Fig.3 Yokes measurement setup

III. SST500 Measurements on the Certified Sample

The influence of the investigated yokes quality on the assembled SST500 systems was studied on a sheet certified by the national metrology institute "Physikalisch-Technische Bundesanstalt" (PTB).

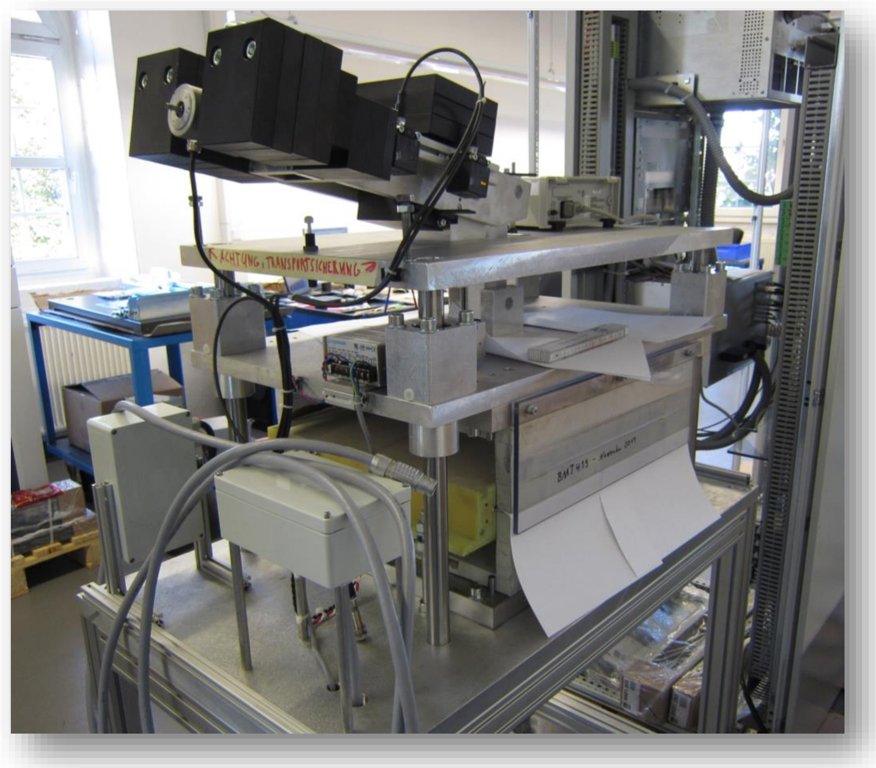


Fig.4 SST 500 assembled for standard loss measurement

IV. Results

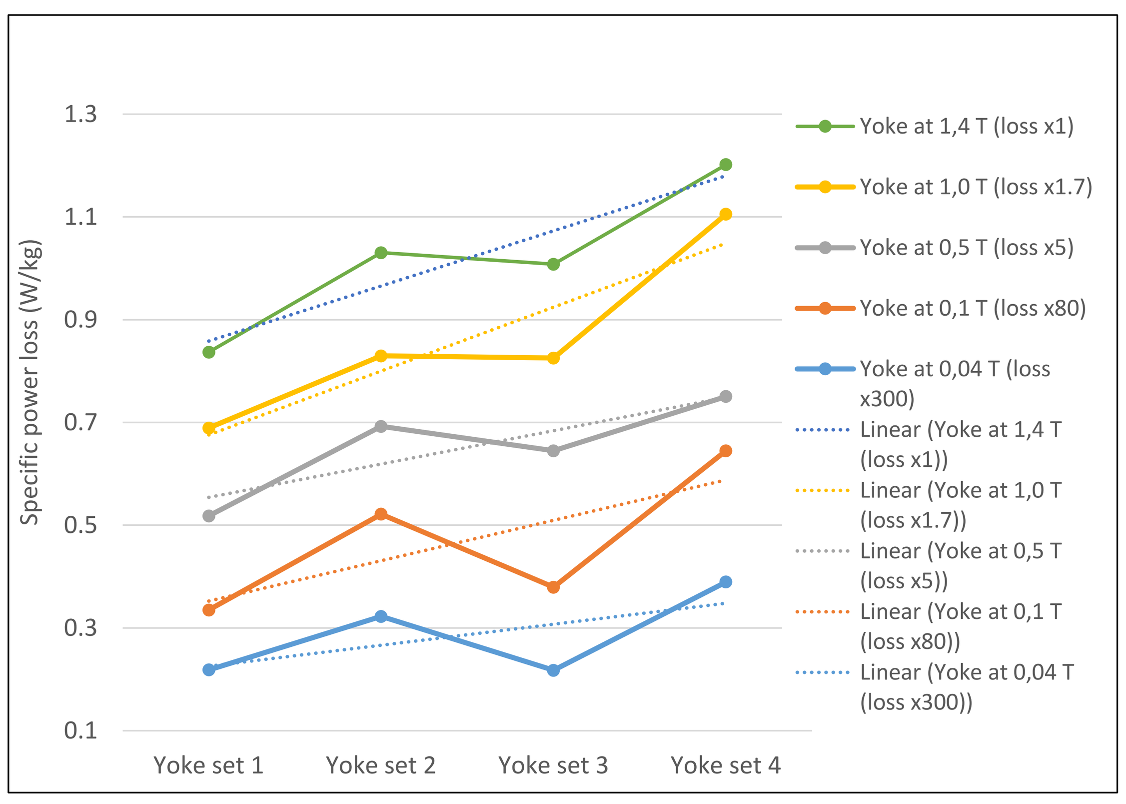


Fig. 5 Trends comparison of loss of the measured yokes (Method B)

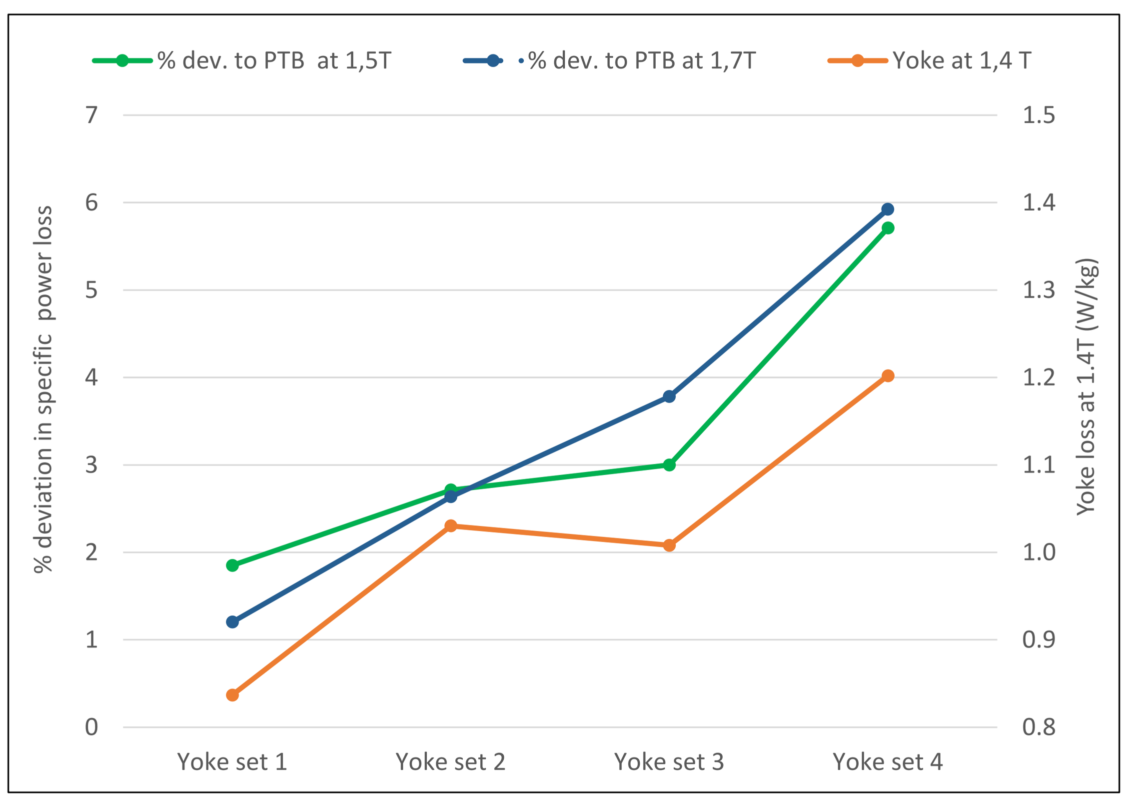


Fig.6 Trends comparison of the % deviation of the SST measurement data vs. PTB data regarding to the Yoke loss at 1.4T

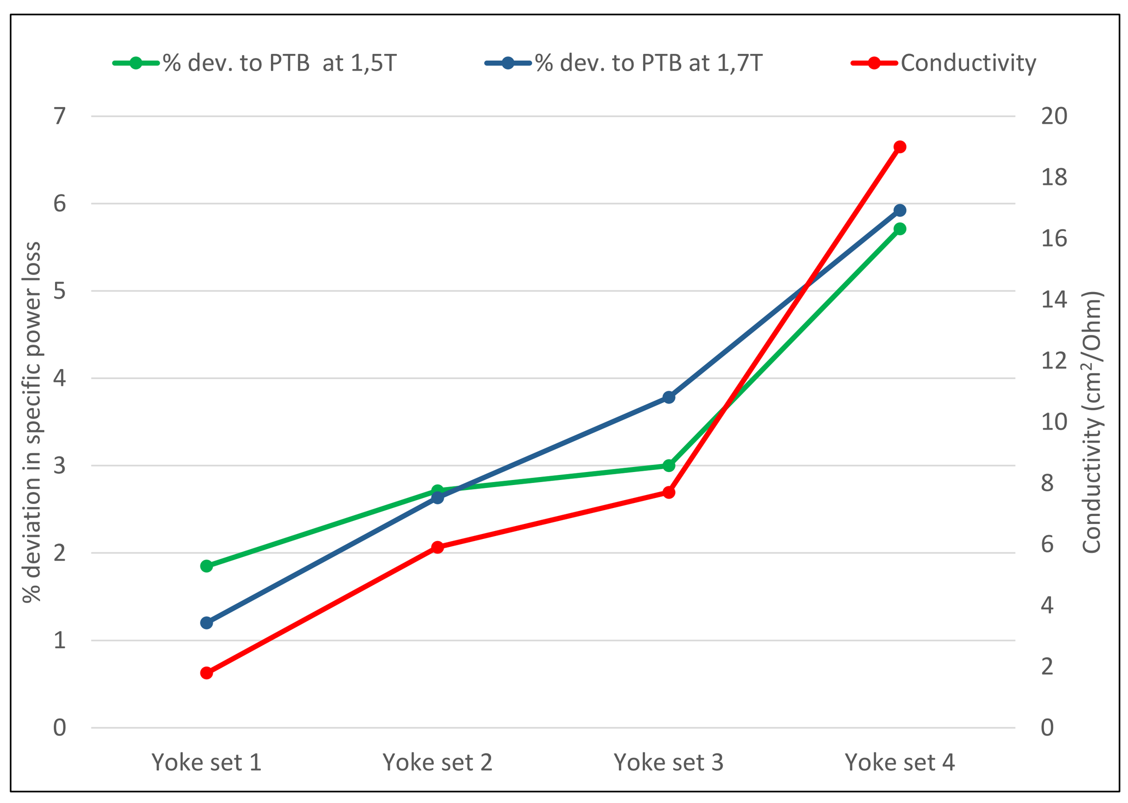


Fig.7 Trends comparison of the % deviation of the SST measurement data vs. PTB data regarding to the conductivity (Method A)

V. Conclusion

The specific power loss of the investigated sets of yokes, interlaminar conductivity at the poles sides as well as discrepancy of the measured loss to the certified data sheet shows interrelation between the parameters. An increase of the yokes' conductivity increases the power loss of the yokes, hence the high discrepancy of the SST data to the certified data of grain oriented sheet is observed.

[1] IEC publ., 60404-3 Ed.2.2, 2010: Magnetic Materials – Part 3: Methods of measurement of the magnetic properties of electrical steel sheet and strip by means of a single sheet tester.
[2] IEC/TR 62981 Ed.1, Studies and comparisons of magnetic measurements on grain-oriented electrical sheet steel determined by the Single Sheet Test (SST) method and Epstein test method, to be published in August 2016; and C. Appino, et al., Int. Workshop on 1&2-DM. Magnetic Measurement and Testing, Torino, September 2014.
[3] J. Sievert, H. Yang, X. Guo, A. Lin and X. Zhou, Int. Workshop on 1&2-DM. Magnetic Measurement and Testing, Torino, September 2014.

TIANJIN 2DM 2016
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第14届一维和二维磁特性测量国际研讨会
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