Slawomir TUMANSKI

Warsaw University of Technology

New Design of the Magnetizing Circuit for 2D-Testing of Electrical Steel

***Abstract**. The magnetizing device for two-dimensional investigations of electrical steel is analysed. The sample in form of a sheet with non-limited dimensions can be used for tests. Unmovable symmetrical yoke system for magnetization of such sample is proposed and designed.*

***Streszczenie. (Nowa koncepcja obwodu magnesującego do dwuwymiarowego badania stali elektrotechnicznych).** Przedstawiono urządzenie do badania dwuwymiarowych parametrów blach elektrotechnicznych. Jako próbkę blachy można użyć arkusza o nieograniczonych wymiarach. Zaproponowano i wykonano nieruchomy, symetryczny układ magnesujący takie próbki.*

Key words: electrical steel, 2D measurements, rotational loses, anisotropy, magnetizing yoke.
Słowa kluczowe: blachy elektrotechniczne, badania dwuwymiarowe, straty rotacyjne, anizotropia, obwód magnesujący.

Introduction

The importance of 2D-testing of electrical steels (especially testing of rotational losses) is obvious for all users of electrical steels. But to date the standard describing these tests does not exist. It is because there are various concepts of such testing, including the design of the magnetising circuit.

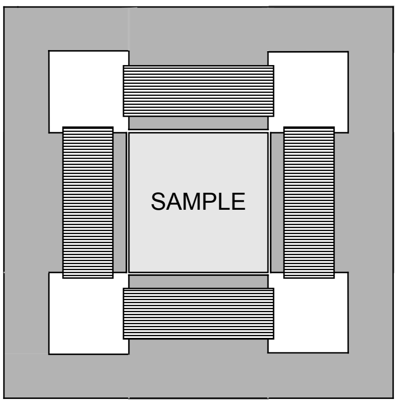


Fig.1. T sample

The most commonly used shape of the sample and the corresponding magnetising circuit are presented in Fig.1. The sample is in form of a square with dimensions 10 cm by 10 cm (sometimes 8×8 or 12×12). The tested area (two H-coils and two B-coils) is situated in the middle of the sample and this tested area is seldom larger than 4 cm by 4 cm.

Considering the design of the sample is necessary to respect two factors: the dimensions of the sample and the shape of the sample. The tested area 4 cm by 4 cm seems to be too small, especially in the case of the grain oriented steel, when the grains are with dimensions of cm range. Small tested area it is also not recommended taking into account the homogeneity of the material.

But the most important factor is the uniformity of magnetization, disturbed by the demagnetising field (shape anisotropy). Due to this field some parts of the sample can be magnetised very non-uniformly, especially all edge parts of the sample. From this point of view the sample in form of a circle should be recommended. Pfützner proposed to use the hexagonal sample [1], and Goričan applied the sample in form of a circle (Fig.2).

Both hexagonal and circular samples enable to obtain better uniformity of the field distribution in comparison with square sample. But the design of such devices is complicated, especially in the case of circular sample.

a)

b)

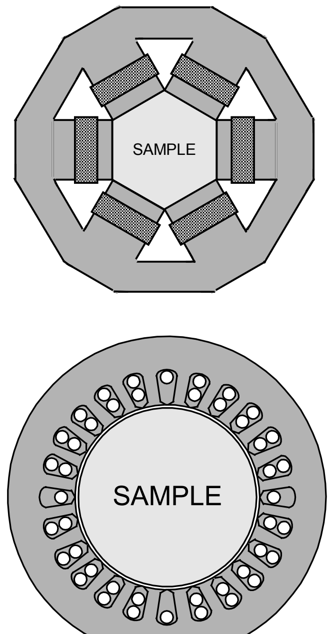


Fig.2. The RSST device with hexagonal (a) and circular (b) sample

The distribution of the magnetic field in the samples was analysed in several papers [3-4]. This magnetic field was also tested experimentally by the author. Some examples of results have been presented during SMM Conference in Düsseldorf [5].

Experimental investigations of the distribution of magnetic field in the square sample

The magnetic field in the square sample of the RSST device was determined experimentally using the Magnetovision system [6]. Thin film magnetoresistive sensor (KMZ10B of Philips) was scanned above the magnetised steel sheet and next the map of magnetic field distribution was constructed. An example of such investigations is presented in Fig.3.

The map of magnetic field distribution in the square sample, magnetised in one direction indicated large non-uniformity of magnetisation (Fig.3a). In the central part of the sample is visible the effect of field disturbance introduced by four micro-holes (0.5 mm diameter) used for B-coils. It is hard to say that in the central tested area 4 cm by 4 cm magnetic field is uniform.

a)

b)

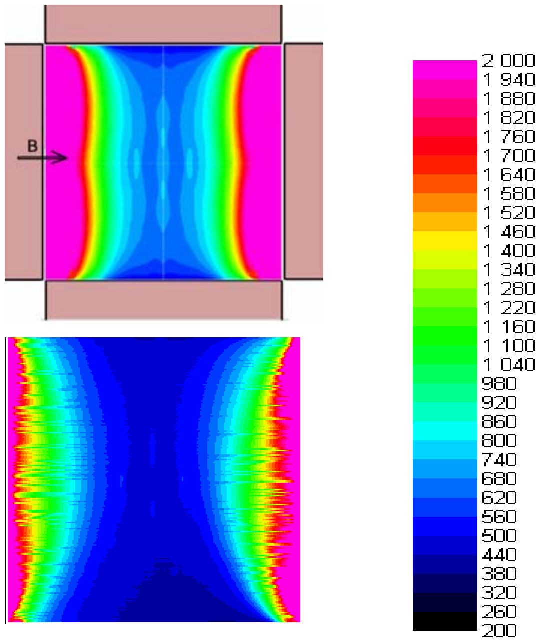


Fig.3. The results of investigations of magnetic field distribution in 10 cm by 10 cm square sample of RSST device: a) Permalloy MR sensor, b) Hall sensor (NO steel)

One of the reasons of the non-uniformity of magnetisation is the large magnetic field near the edge of the poles of the yoke. This field was as large that it was not possible to determine it using MR sensor. That is why the same investigations were repeated using small Hall sensor (Fig.3b). It is visible that while in the middle of the sample the magnetic field is about 500 A/m the magnetic field near the edge is larger than 2 kA/m.

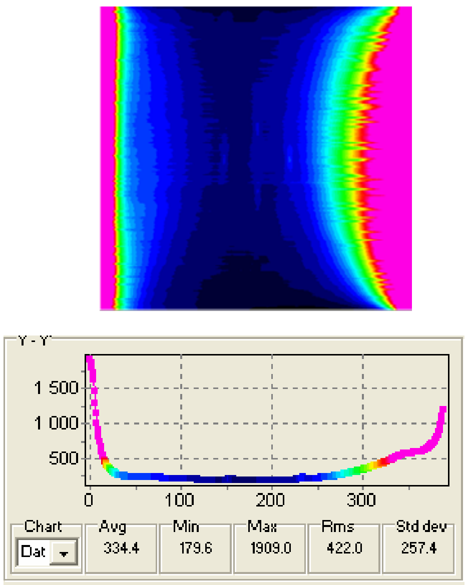


Fig. [illegible] gap (right side) and with the air gap (left side)

The uniformity of magnetisation was improved by the insertion of the small (about 0.1 mm) air gap (Fig.4). But still near the edge the magnetic field was about 2 kA/m, while in the middle was only 180 A/m. More complicated map is in the case of grain oriented steel (Fig.4). In both directions the non-uniformity of magnetic field strength is notable. And even more complicated map is in the case when the direction of magnetisation is inclined. Figure 5 presents the results of investigation when the sample was magnetised diagonally.

a)

b)

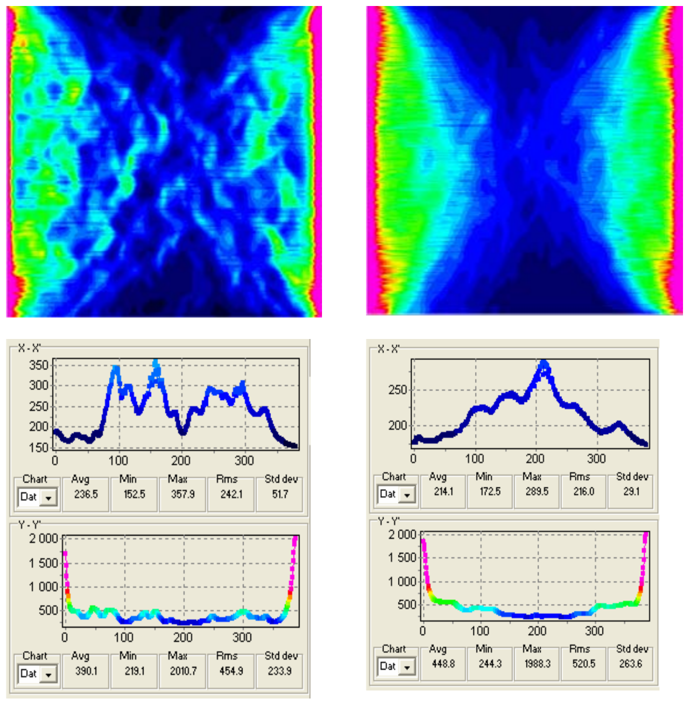


Fig.4. The magnetic field distribution in the sample prepared from grain-oriented steel (a – rolling direction, b – perpendicular to the rolling direction)

a)

b)

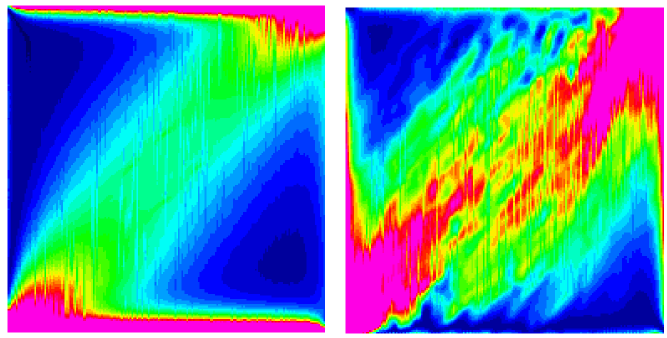


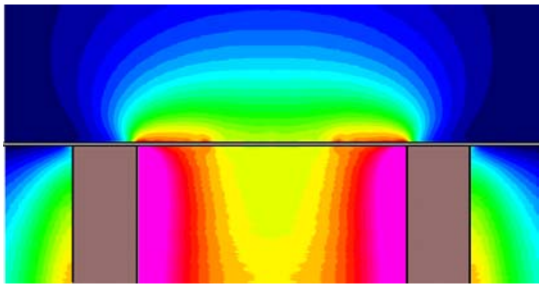
Fig.5. The distribution of magnetic field in the sample magnetised diagonally (a – NO steel, b- GO steel)

Presented results of investigations indicated that generally the square sample is magnetised very non-uniform and to obtain sufficient large tested area the sample dimensions should be much larger than 10 cm. The tested area should be for example about 10 cm by 10 cm and then the sample should be considerable larger, correspondingly 20 cm by 20 cm.

The design of the magnetising circuit

Assuming that the sample is in form of a sheet with dimension 20 cm by 20 cm it is practically not possible to construct the conventional magnetising circuit presented in Fig.1. The best solution would be to place the sheet on the rotating asymmetrical C-yoke. Such magnetising circuit was constructed by the author [7]. Unfortunately the errors of the results were significant – for hard direction of magnetisation even about 10%. From discuss during the 2DM 04' Conference in Gent the asymmetrical yoke system was practically exclude due to the remarkable errors introduced by the planar eddy currents [8]. The confirmation of this statement are the results of experimental investigations presented in Fig.6.

a)



b)

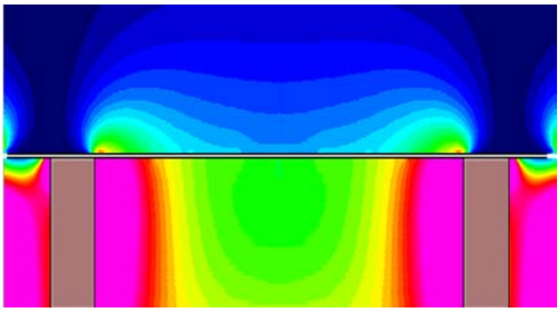


Fig.6
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distance between the poles 20 cm)

Near the poles of the yoke exists large magnetic field disturbing the uniformity of magnetisation. Even enlargement of the distance between the poles did not improve this uniformity (Fig.6b). Though the area of uniform field distribution below the sample increased, but the difference between the magnetic field strength below and above the sample is significant.

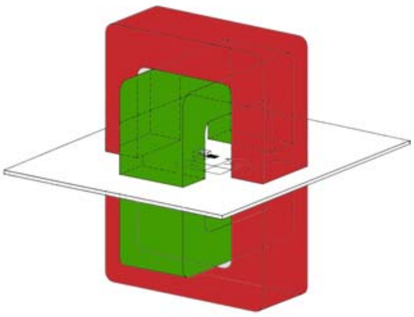

Fig.7. The proposal of the magnetising circuit for two-dimensional testing of electrical steel

Thus for 2D measurements the asymmetrical rotating yoke system exhibits several important drawbacks. In For such measurements the symmetrical yoke system is preferable. Due to mechanical obstacles it is very difficult to construct rotating symmetrical yoke system. That is why the un-movable magnetising yoke system was proposed [9]. The idea of such yoke system is presented in Fig.7. Two orthogonal pairs of the yoke magnetise the sheet sample in X and Y directions. The direction of magnetisation can be varied by the change of the current in both winding coils of the yokes. Another possibility is the change of the number of turns in both winding coils.

The idea of the magnetising circuit presented in Fig. 7 was demonstrated during the 2DM 02' Conference in Lüdenscheid [9] as the result of considerations concerning choice of the yoke for such investigations. The proposed yoke system was designed and constructed. This testing device is shown in Fig.8.

Fig.8. The design and construction of the 2D magnetising system (only the bottom part is shown)

The discuss during the 2DM 04' Conference in Gent pointed several drawbacks of proposed magnetising yoke. One of them is the location of the windings in the bottom part of the yoke – better solution is to wound the coils on both side parts of the yoke [12]. It is necessary more detailed investigate the placement of the magnetising coils.

Conclusions

Presented considerations and experimental results proved that the conventional 10 cm by 10 cm sample is too small for reliable testing of typical electrical steel. The best sample for two dimensional testing of electrical steel is a sheet with sufficient large dimensions, for example 20 cm by 20 cm. The modified type of magnetising circuit is proposed. It is symmetrical, two orthogonal yoke system with variation of the direction of magnetisation by the change of the winding ratio in x, y yokes.

REFERENCES

[1] Hasenzagl A., Weiser B., Pfützner H. – Novel 3-phase excited single sheet tester for rotational magnetization, J.Magn.Magn.Mat., 160 (1996), 180

[2] Goričan V., Hamler A., Hribernik B., Jesenik M., Trlep M. – 2D measurements of magnetic properties using a round RSST, Proc. 2DM 00' Conference, Badgastein, (2000), 66

[3] Sievert J., Ahlers H., Enokizono M., Kauke S., Rahf L., Xu J.,- The measurement of rotational power loss in electrical sheet steel using the vertical yoke system, J.Magn.Magn.Mat., 112 (1992), 91

[4] Jesenik M., Goričan V., Trlep M., Hammler A., Štumberger R., Calculation of the rotational magnetic fields in the sample of the rotational single sheet tester, Przegl. Elektr., (2003), 920

[5] Tumanski S., Pluta W., Soinski M., - Analysis of magnetic Fidel distribution In the ample of RSST device, Proc. SMM16 Conf., Düsseldorf, (2004) , in printing

[6] Tumanski S., Liszka A. – The methods and devices for scanning of magnetic fields, J.Magn.Magn.Mat., 242-245 (2002), 1253

[7] Tumanski S., Bakon T., - Measuring system for two-dimensional testing of electrical steel, J.Magn.Magn.Mat., 223 (2001), 315

[8] Sievert J. – Private communication, 2004

[9] Tumanski S. – Which magnetizing circuit is suitable for two-dimensional measurements, PTB Bericht, PTB-E-81 (2002), 151

[10] Meydan T. – Private communication, 2004

Author: *prof. Slawomir Tumanski, Warsaw University of Technology – IETiSIP, E-mail: tusla@iem.pw.edu.pl*