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SINGLE STRIP TESTER WITH DIRECT MEASUREMENT OF MAGNETIC FIELD STRENGTH

Slawomir Tumanski — Slawomir Baranowski *

The Single Strip Tester device with direct measurements of magnetic field strength was designed, constructed and tested. Various yoke design and various magnetic field strength sensors were compared, among others H-coil sensor and thin film magnetoresistive sensor. The main drawback of H-coil sensor is rather small and noisy output signal. Most promising for SStT application is the array of thin film magnetoresistive sensors.

Keywords: magnetic materials, single strip tester, magnetic field sensors.

1 INTRODUCTION

For tests of electrical steels mainly are used standard devices – the Epstein Apparatus and the Single Sheet Tester. The Single Strip Tester is used not as often as the previous mentioned devices because it is assumed that to obtain the reliable results sufficiently large amount of the material should be tested. But from the partial results it is possible to go to the results representing the whole material. The reverse way it is not possible.

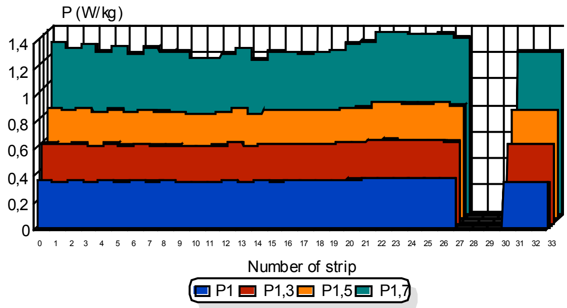

Fig. 1. The comparison of the results of investigation of 28 strip samples by the Epstein device (on the right) and the Single Strip Tester device (on the left)

To prove this conclusion we performed experiment presented in Fig. 1. We tested the grain oriented steel sample using the Epstein device and next we repeated the same test, this time strip by strip, using the Single Stripe Tester. We see that the average value of 28 strips testing is similar to the Epstein results, but moreover we know much more about the steel homogeneity. Thus we conclude that the Single Strip Tester offers much more information that the Epstein (if we test the same amount of the samples).

The most popular design of Single Strip Tester is the application of the enhanced idea of Iliovici permeameter [1]. The magnetic field strength is detected from the magnetizing current. The length of the magnetic path is established by the compensation method – as the zero field indicator the Rogowski coil is used. The special compensating coils for leakage magnetic field compensation is necessary to supply. The typical example of SStT device is presented in Fig .2.

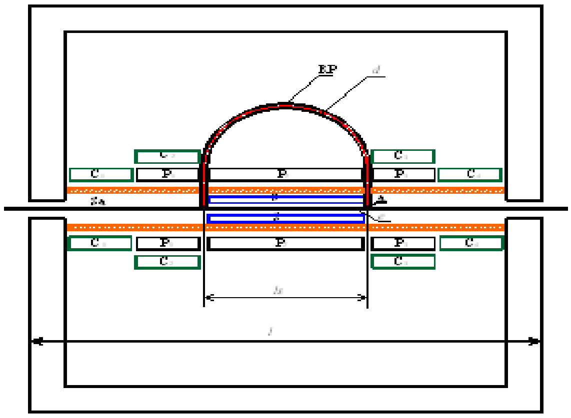

Fig. 2. The design of typical SStT device

The compensation SStT devices were presented in various papers [2, 3]. An excellent device was presented by team from Cardiif [3]. The main drawback of all theses testers was rather sophisticated electronic circuit. As usually it was necessary to apply the feedback circuit for forcing of the sinusoidal shape of flux density. But moreover it was necessary to use additional feedback circuit to follow with the change of the compensation current because its depends on the state of magnetization.

2 THE DESIGN OF SIMPLIFIED SINGLE STRIP TESTER

We tried to construct the Single Strip Tester as simple as possible. That is why we returned to the simplest idea where the magnetic field strength is directly measured by H-sensor (H-coil or MR sensor). When the magnetic field strength is determined directly as the tangential field component it is not necessary to know the length of magnetic field path.

The design of Single Strip Tester is presented in Fig. 3. We constructed this device to have later the possibility of tests of the various measuring systems. That is why we prepared two magnetizing coils systems (on the

* Warsaw University of Technology, Institute of Electrical Theory and Measurements, Koszykowa 75, 00-661 Warsaw, Poland, E-mail: tusla@iem.pw.edu.pl

sample and on the yoke) and introduced the gap between the coils to use the Rogowski coil. The H-coil system consists of four coils (with dimensions 0.5×28×45 mm each) to tests the magnetic field homogeneity on the whole sample. Each H-coil with 900 turns exhibited the sensitivity 7 mV/(kA/m). The B-coil was designed with 2 turns to obtain comparable output signals from H-coil and B-coil for typical tests conditions.

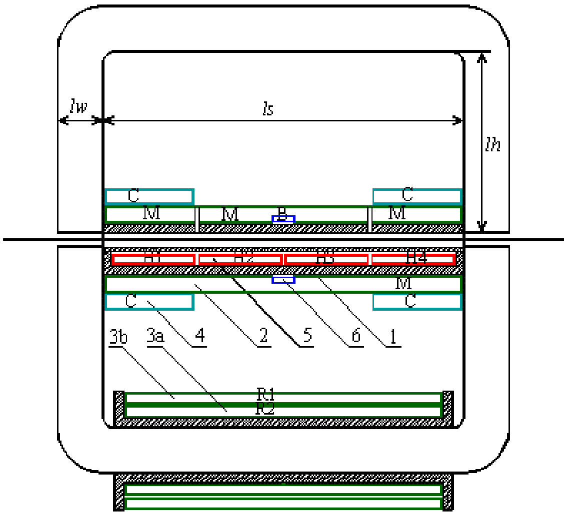

Fig. 3. The magnetizing circuit of the investigated single strip tester (2 – magnetizing coils on the sample, 3 – magnetizing coils on the yoke, 4- compensating coil, 5 – H-coils, 6 – B-coil)

The dimensions of the magnetizing yoke were chosen to enable the investigation of the almost whole 3cm strip of 25 cm Epstein frame. The yoke with coils is presented in Fig. 4.

Fig. 4. The construction of the Single Strip Tester

3 THE EXPERIMENTAL RESULTS

Fig. 5 presents the results of measurements of the magnetic field above the non-oriented steel sample magnetized to about 1 T. First of all it is visible that the signal of the sensor is rather small and noisy. After digital integration the output signal is much better. But for tests of grain-oriented steel samples, when the magnetic field strength is significantly smaller the output signal on the level of about part of mV is not satisfying.

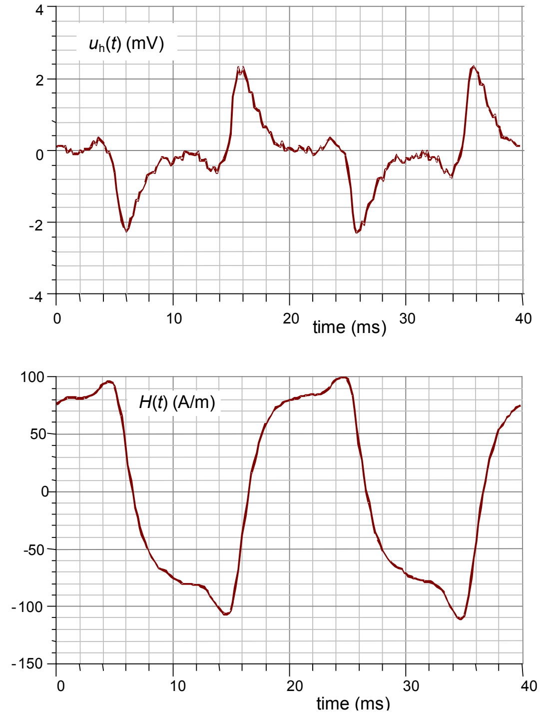

Fig. 5. The results of measurements of the *H*-coil sensor signal and calculated numerically magnetic field strength signal

Fig. 6 presents the comparison of the output signal of three various H sensors: as a voltage on the 0.2 Ω resistor in the magnetizing circuit, as the output signal of KMZ10B MR sensor and as the signal from the H-coil sensor.

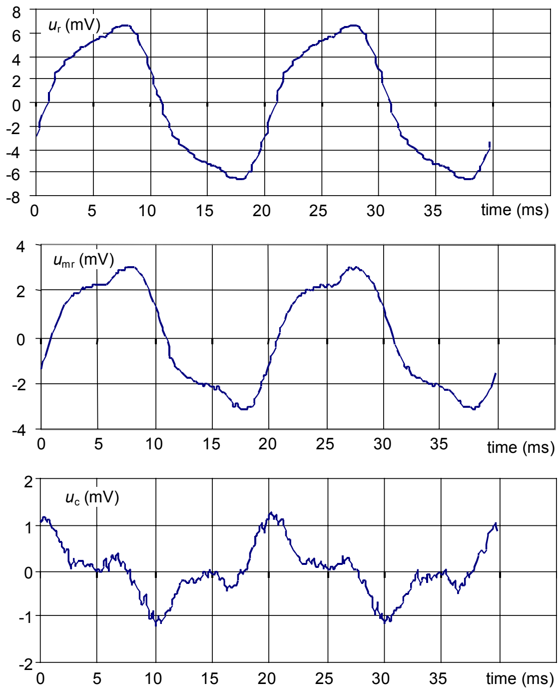

Fig. 6. The comparison of three various methods of magnetic

field strength measurements: u_r – from the magnetizing current, u_{mr} – from the Permalloy MR sensor KMZ10B of Philips, u_c – from the H-coil.

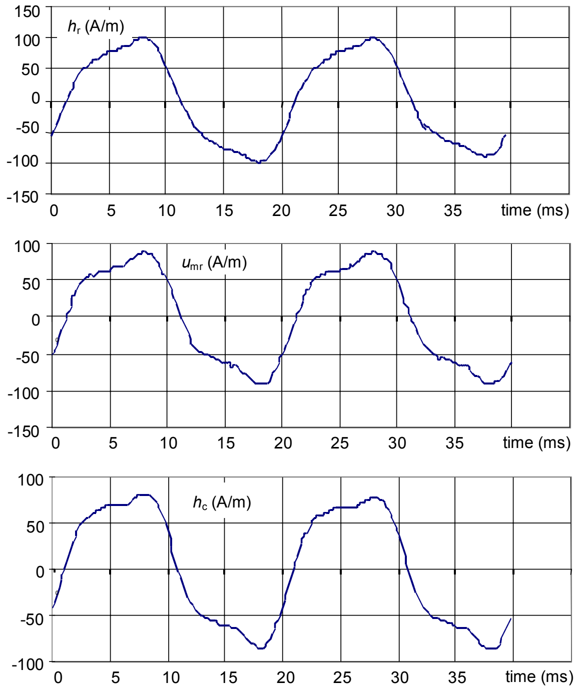

Fig. 7. The comparison of H-signal determined by means of three various methods

Figure 7 presents the comparison of the final results – magnetic field strength signal after numerical calculations. All three signals were very similar – the best one (less noisy) is signal obtained from the magnetizing current. Disadvantage of this method is the insertion of the resistor into the magnetizing circuit and necessity of magnetic leakage compensation. The comparison of all output signals on one plot is presented in Fig.8.

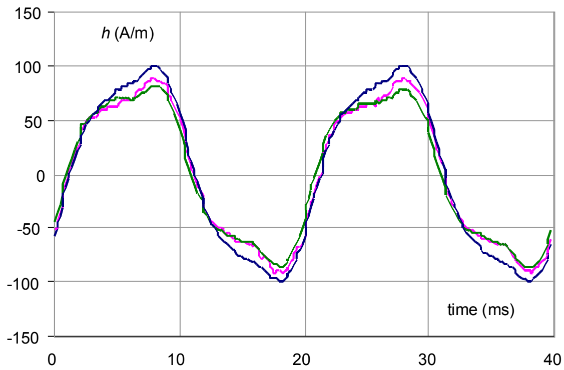

Fig. 8. The comparison of various methods of determination of magnetic field strength the output measured magnetic field strength.

Quite satisfying is also the output signal from the MR sensor. With sensitivity of 50mV/1kA:m this sensor enables measurements of typical values of magnetic field strength with the output signal larger than 1 mV. Moreover this sensor detects directly the magnetic field strength (not dH/dt as in the case of H-coil sensor) and therefore it is not necessary to use the integration of the signal. The drawback of this sensor is its small dimensions, about 1mm by 1mm. Only in the case of non-oriented steel sample was possible to compare all three sensors, because in the case of grain-oriented steel the influence of the grain structure is much significant.

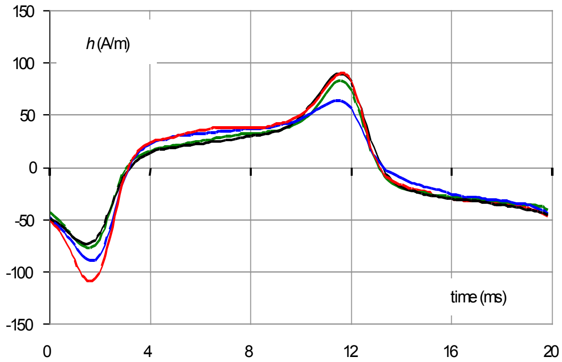

Fig. 9. The magnetic field strength determined by each of four H-coil sensors.

Figure 9 presents the comparison of the output signal obtained from each individual H-coils. The difference between these signal is of about 10%. Probably the main reason of these differences in non-uniformity of magnetic field above the sample. It is also possible that the sensitivity of the H-coils was slightly various.

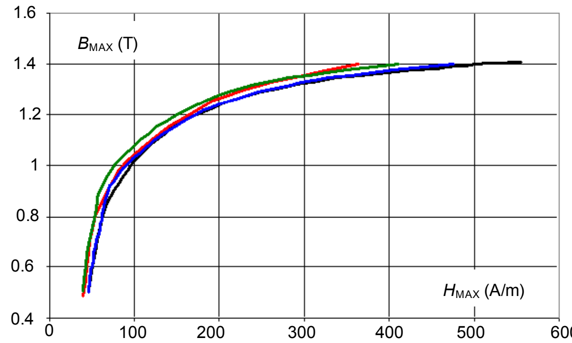

Fig. 10. The comparison of the magnetizing cureves determined using the H-coil sensor validated with various methods

The results of validation of H-coils sensor method depend on the test method. The sensitivity of the H-coil was determined in the air using Helmholtz coils, on the steel sample by comparison with current method and on the sample by comparison with the MR sensor. The differences were of about 10% and it is hard to say which method of the validation is the best. The comparison of the magnetizing curves determined using H-coil sensor validated with various test method is presented in Fig. 10

4 CONCLUSIONS

Figure 11 presents the front panel of the software designed for the SStT device. The developed Single Strip Tester is really very simple. For most typical samples due

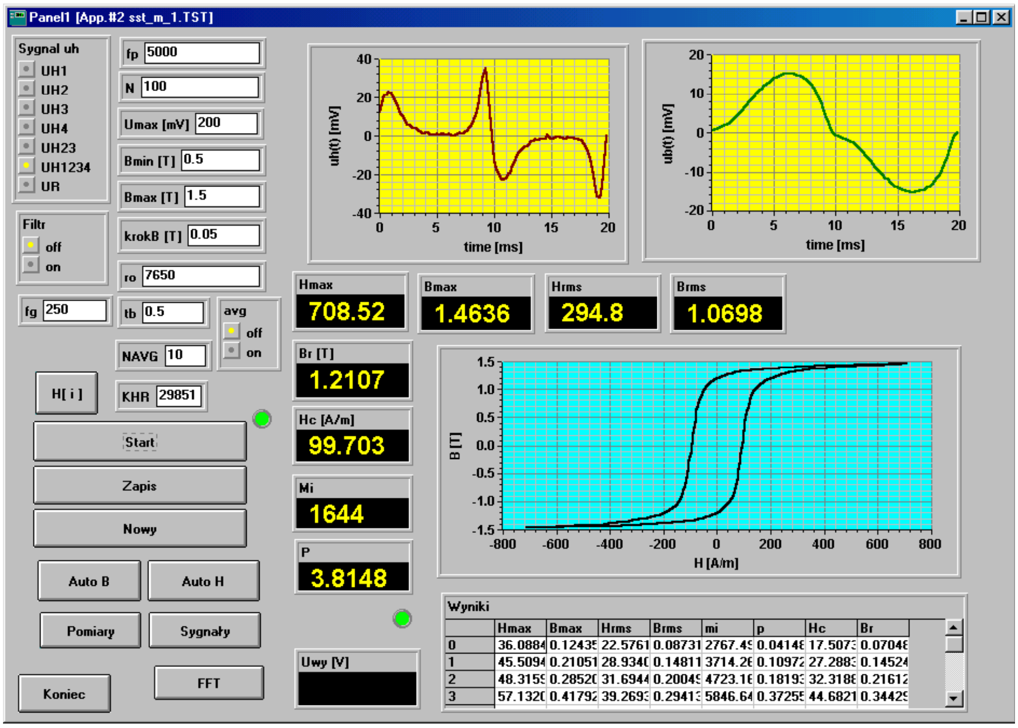

Fig.11. The front panel of the software developed for constructed Single Strip Tester

to small power necessary to magnetize the sample it was sufficient to apply only analogue feedback to ensure the sinusoidal shape of the flux density.

The main drawback of direct measurements of magnetic field strength by means of H-coil sensor is relatively small and noisy output signal. More promising for direct magnetic field measurements is permalloy MR sensor. But to obtain large and reliable output signal it is necessary to use the array of the sensors. The first result with the array of 16 MR sensors was hopeful.

The comparison of results obtained by direct and un-direct (current) method exhibits that the difference between these results were not larger than 10 %, assuming that the magnetic path length is equal to the length of the magnetized sample (the leakage in the yoke and gaps were not taken into account). Thus for less accurate measurements also SStT device without compensation can be used – but in this case the yoke should be prepared very cautiously.

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Slawomir Tumanski (DSc, PhD), born in 1945 and graduated from the Faculty of Electrical Engineering of the Warsaw University of Technology, in 1968. He is the Editor-in-Chief of Polish scientific journal “Przegląd Elektrotechniczny” (Electrical Review). He is professor in Warsaw University of Technology. Active in magnetic measurements, industrial measurements and non-destructive testing of materials.

Slawomir Baranowski is PhD student in Warsaw University of Technology.