MAGNETIC CHARACTERISATION OF SILICON-IRON SHEETS WITH SINGLE SHEET TESTER (SST)

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Abstract — In this paper we study a modern system used in magnetic characterization of silicon-iron sheets. We present the the basic principle of the single sheet tester, the hysteresis cycle for three types of sheets and we study the accuracy of a Single Sheet Tester (SST) and the influence of external parameters on the system of measurement by comparing our results (MAGNAT Laboratory - Electrical Engineering Department) with results obtain in the I.N.P.G. - France.
Index Terms — magnetic characterization, single sheet tester.

INTRODUCTION

For using the magnetic materials in electrotehnics we have to know their properties (power losses, magnetic permeability, B(H) dependencies). These characterization is an important operation for the metallurgy studies also [1,2].

The characterization of silicon iron sheets can be done with an Epstein frame. In this case the precision of these measuring devices it's 2 %, but the preparation of the samples it's a hard operation and that is make it difficult for automatization.

In case of using a single sheet tester device (SST) we can obtain a superior measuring precision and also more information about the material properties. The measuring through the field coil method we can eliminate the error induced by the conventional average length of a magnetic circuit. This device can be easily be automatizated.

In our study we use a SST which is based on magnetizing current method, which is an industrial method applied on large scale for characterization magnetic sheets.

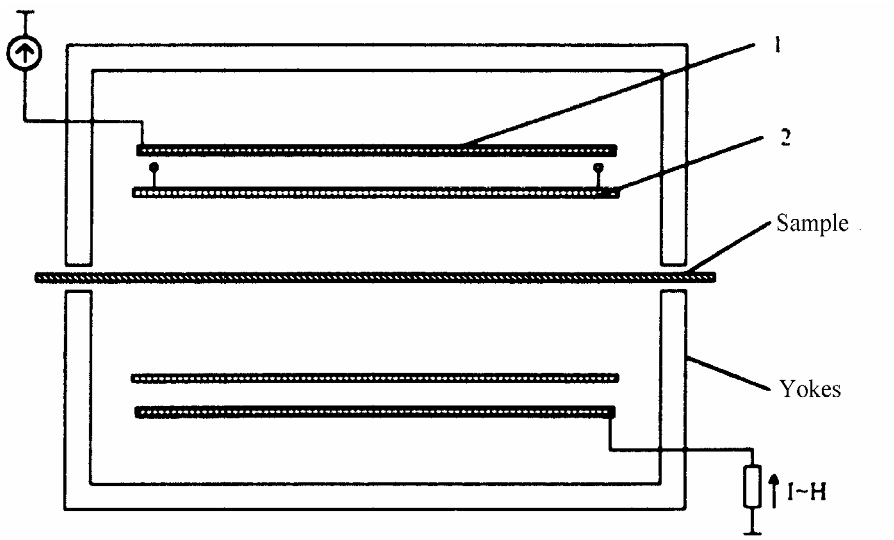

Fig. 1. Magnetizing current method.

For the measurement of the magnetic characteristics of electric sheet a material sample has to be prepared and to be exposed to a defined magnetic field in a suitable coil system.

The measuring system consists of a primary winding for the generation of a magnetic field, which generates the magnetic flux in the sheet. The magnetic field is determined by the flux, winding and the number of windings of the magnetic length of the coil.

$$H(t) = \frac{N_1 I(t)}{l_m} = KI(t) \tag{1}$$

The number of windings and the magnetic length are determined by the geometry of the measuring coil system.

The necessary current is provided by a power amplifier. The current is measured via a temperature constant, induction free precision measuring resistance.

The voltage measured at the shunt is digitized via a measuring data acquisition system at different points along the course of the primary signal.

An automatic adjustment of the dynamic leads to a very accurate measuring of the voltage with a digital resolution of 12 Bit.

The 16 Bit processor of the measuring computer converts the measured voltage into the magnetic field strength or the measured field into the primary voltage.

$$H(t) = \frac{N_1}{R_n l_m} u_1(t) \Rightarrow H_i = \frac{N_1}{R_n l_m} u_1 \tag{2}$$

With an additional measuring data acquisition system the magnetic flux or the polarization is measured.

The polarization is determined by measuring the voltage induced in the secondary winding of the coil system.

$$\frac{dB}{dt} = -\frac{u_2(t)}{N_2 A_m} \Rightarrow B(t) = -\frac{1}{N_2 A_m} \int_0^t u_2(t)dt \tag{3}$$

The secondary voltage will also be digitized with automatic dynamic adjustment and the conversion and integration are carried out by a 16 Bit processor.

The parallel acquisition of both parameters H and B with two separate acquisition systems guarantees that the measurings are carried out at exactly the same time. This way measuring mistakes caused by phase differences are avoided.

The processor system calculates all before mentioned values out of the different and integrated measuring figures. Sources of errors like analogue multipliers and integrators do not occur. This is why the high reproducibility and the drift free long time stability can be guarantied.

The measuring is made with sinusoidal polarization according to the DIN 50 462 rules. The secondary voltage also has to be sinusoidal.

The measuring coil system is no linear transformer. A control loop for the primary signal has to force the form of the secondary signal.

The control algorithm checks the form of the secondary voltage and controls the power amplifier in a way that the secondary voltage is sinusoidal.

The nominal voltage is generated by a highly stable, crystal controlled digital sine generator. This way a very high frequency and amplitude stability it’s reached without which the high setting point accuracy and exact measurement achieved with this SST would be impossible.

The amplitude and the frequency are adjusted by the internal processor via the externally connected PC according to the sample data input [3,4].

MEASUREMENT OF THE NON-ORIENTED (NO) SHEETS

We test a package of 6 NO sheets which have been characterized with an Epstein frame and we optain the nominal power losses of 4,02 W/kg at 1,5 T. The geometrical properties of the sample are presented in the table bellow.

Table 1: Sample properties

Sample weight [g]	32,34
Sample density [g/cm^3]	7,7
Length of sample [mm]	280
Width of sample [mm]	30
Sample thickness [μm]	500
Number of sample	1
Grade	M 470-50 A

We set the measuring parameters as follow: frequency 50 Hz, hysteresis on, demagnetizing on, and a variation loop of the magnetic flux density from 500 mT to 1750 mT with a step of 250 mT at a constant magnetic field of 30000 A/m.

We make the average results from all the 6 sheets and we obtain the follow data:

TABLE 2: Average results for NO sheets

Nr.	B_n [mT]	B_r [mT]	H_c [A/m]	S [VA/kg]	P [W/kg]	μ_r
1	500	393,5	48,86	0,69	0,5	6022,9
2	750	628,2	36,15	1,38	1,01	6775,3
3	1000	826,7	75,18	2,76	1,71	4987
4	1250	959,6	86,85	6,42	2,64	2782,4
5	1500	1018,7	97,13	28,34	4	744,81
6	1750	1039,3	108,4	223,98	5,69	142,5

where:

- B_n: the nominal value of magnetic flux density;
- B_r: the remanent value of magnetic flux density;
- H_c: the coercitiv value magnetic field strength;
- S: the apparent power losses;
- P: the active power losses;
- μ_r: the relative magnetic permeability.

We represented the hysteresis cycle at 1,5 T in 421 points and the variation of active power losses with magnetic flux density:

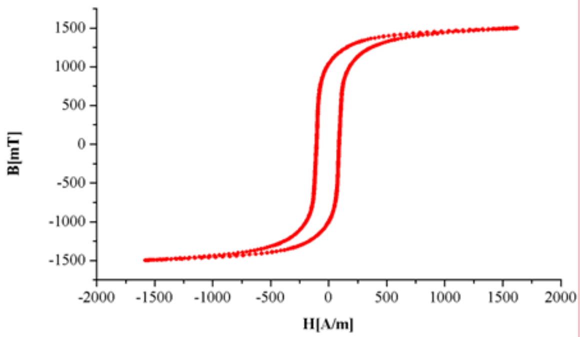

Fig. 2. The hysteresis cycle for NO sheets

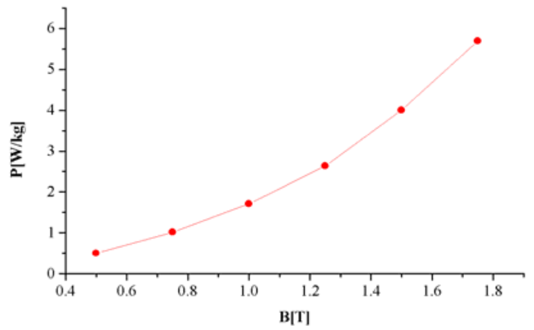

Fig.3. The active power losses.

MEASUREMENT OF THE GRAIN ORIENTED (GO) SHEETS

We test a package of 6 GO sheets. The geometrical properties of the sample are presented in the table bellow.

Table 3: Sample properties for GO sheets

Sample weight [g]	16,065
Sample density [g/cm^3]	7,65
Length of sample [mm]	280
Width of sample [mm]	30
Sample thickness [μm]	250
Number of sample	1
Grade	T 480-50 A

We set the measuring parameters as follow: frequency 50 Hz, hysteresis on, demagnetizing on, and a variation of the magnetic flux density at 500 mT, 1000 mT, 1300 mT, 1500 mT, 1700 mT, 1800 mT, 1850 mT and 1900 mT at a constant magnetic field of 30000 A/m. After each variation of magnetic flux density we make a demagnetization of the sheet.

We make the average results from all the 6 sheets and we obtain the follow data:

TABLE 4: Average results for GO sheets

Nr.	B_n [mT]	B_r [mT]	H_c [A/m]	S [VA/kg]	P [W/kg]	μ_r
1	500	409,8	11,83	0,17	0,13	21839
2	1000	833,6	16,41	0,58	0,38	23136
3	1300	1117,9	18,82	0,93	0,59	23088
4	1500	1339,5	20,36	1,20	0,76	22924
5	1700	1455,6	20,96	1,37	0,85	22451
6	1800	1587	21,69	1,58	0,97	21469
7	1850	1705,8	22,61	1,98	1,13	17594
8	1900	1800,3	24,04	3,23	1,37	9854

We make another set of measurement after 5 minutes for testing the accuracy of our device and we presented the hysteresis cycle at 1,5 T in 421 points.

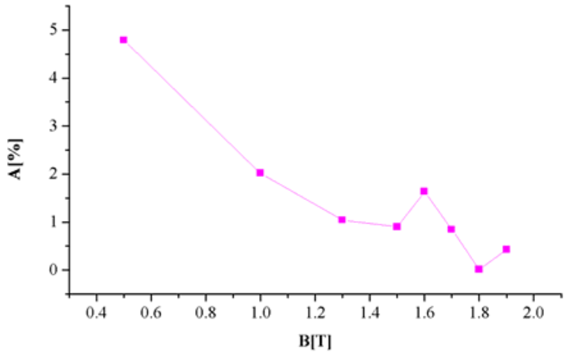

Fig. 4. Acqurancy variation with magnetic flux density.

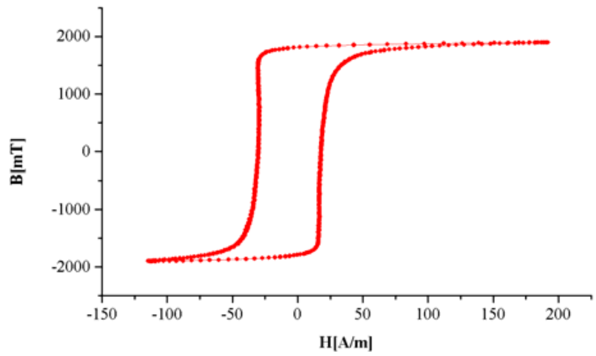

Fig. 5. The hysteresis cycle for GO sheets at 1,9 T.

MEASUREMENT OF THE AMORPHOUS SHEETS

The amorphous thin layers are materials with small power losses (from 3 to 4 times less than the GO sheets) and with reduce saturation of the magnetic flux density.

We obtain the follow values:

TABLE 5: Average results for Amorphous sheets

Nr.	B_n [mT]	H [A/m]	S [VA/kg]	P [W/kg]
1	1000	7	0,1494	0,12
2	1100	7	0,1774	0,13
3	1200	9	0,2178	0,15
4	1300	13	0,2942	0,17
5	1400	28	0,5162	0,2
6	1500	141,43	2,30	0,25

The variation of active power losses with magnetic flux density are:

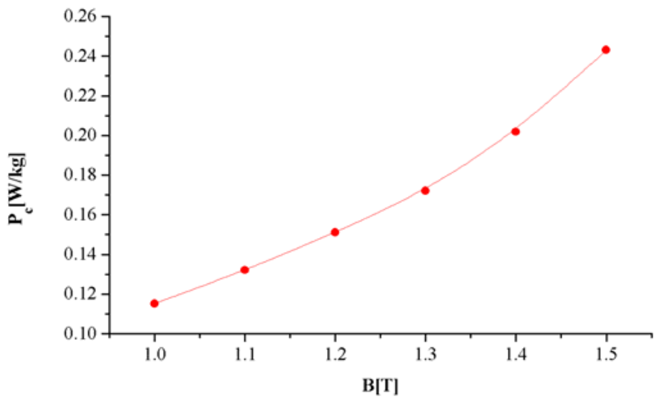

Fig. 6. The active power losses.

CONCLUSIONS

The method of magnetizing current can be used for measuring in extreme condition of the materials, because the electric voltage which correspond to the electrical currents measured on the resistance generate powerful signals that can't be disturb by the measuring noise.

All our measurements was compared with measurements done at LEG in Grenoble. We note that the results obtain with the device from our laboratory are similar to the results obtain in France, the small differences between the results are due to the quality of the tested samples. For example we present the iron losses measured in two laboratories at 50 Hz:

Table 6: Example for NO sheets

B[T]	0,5	1	1,5	1,75
P[W/kg] (Magnat)	0,62	2,01	4,35	6,17
P[W/kg] (Grenoble)	0,86	2,72	6,26	8,41

Table 7: Example for GO sheets

B[T]	0,5	1	1,3	1,5	1,7	1,8	1,85	1,9
P[W/kg] (Magnat)	0,13	0,38	0,59	0,76	0,85	0,97	1,13	1,37
P[W/kg] (Grenoble)	0,103	0,34	0,56	0,74	1,02	1,29	1,50	1,72

For testing the precision of magnetizing current method use in our SST, we compare results obtain for GO sheets at 1,5 T with the some obtain with the SST in I.C.P.E. – C.A., based on the field coil method.

Table 8: Results obtain from the two methods

B[T]	1,5
P[W/kg] (Magnat)	0,76
P[W/kg] (I.C.P.E. – C.A.)	0,89

It is preferable to use the magnetizing current method to measured materials with small power losses and the field coil method in the case of high magnetic fields.

From the accuracy test we observed that at small values of magnetic flux density the measurement is affected by external factors and at high values the influence of external factors are minimal.

The method of SST systems can be used in industrial quality control and also for magnetic characterization of materials in laboratories.

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