SURFACE MAGNETIC FIELD MEASUREMENT WITH MAGNETIC SHIELDING

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In this work we would like to investigate the surface field gradient above an open sample and it is suppression by the magnetic shielding in two magnetizing systems: (i) sample magnetized by an external field of an air solenoid and (ii) sample magnetized by a single yoke. It is shown that the field gradient in the solenoid and the yoke-sample system with large air gaps is very similar. In both cases the magnetic shielding reduced the field gradient by one order of magnitude thus making hysteresis loops measurement much more precise and reliable. Field gradients calculated by finite elements analysis were in agreement with experimental results.

Keywords: magnetic hysteresis, magnetic field measurement, magnetic shielding, extrapolation

1 INTRODUCTION

Determination of the magnetic field in open samples is a very old and difficult problem. [1-6] The common approach to obtain the internal magnetic field in such samples is to measure the field near the sample surface. There is always a field gradient near the sample which usually brings large errors into field measurement and so makes hysteresis measurements unreliable and often unrepeatable [6].

Previously we developed a very effective method to solve this problem - the shielding technique [7–8]. The idea of the method is to magnetically shield a region of the field measurement thus suppressing the field gradient. In this work we demonstrate the efficiency of the shielding technique for two magnetizing systems: (i) the sample in a solenoid or 2) the (ii) sample magnetized by a single yoke. The air gaps between the yoke and the sample are unavoidable. Larger air gaps lead to larger field gradients [6]. So in this work we purposely made air gaps large – 0.4 mm as an extreme case.

2 EXPERIMENT

The sample was made of low-alloy steel. It was in the shape of a strip with dimensions 2.5×25×100 mm. The coercivity, H_C was 150 A/m and maximum differential permeability, μ_D^{MAX} – 10000.

The sample was measured in two ways: (i) placed in a uniform external field created by a 100 mm in diameter and 600 mm long solenoid; (ii) magnetized by the yoke. The yoke cross-section was 20×20 mm and distance between its legs was 40 mm. The yoke height, h was 120 mm.

The pickup coil was wound on the sample at its centre. The tangential component of the field was measured by the array of Hall sensors placed at 1,2,3,4 and 5 mm above the surface. The 3×25×30 mm^3 shielding plates were made of grain-oriented silicon steel and were placed symmetrically with respect to the sensor (see Fig. 1).

The measurements were performed at low frequency, f = 0.03 Hz. The triangular waveform of the applied current was used

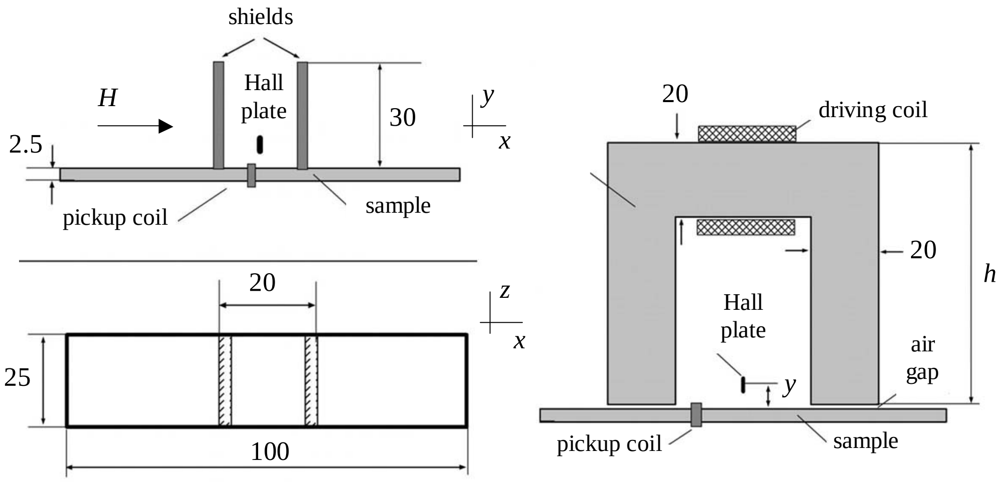

Fig. 1. The measurement setup. The sample is either put inside the solenoid or it is magnetized by the yoke

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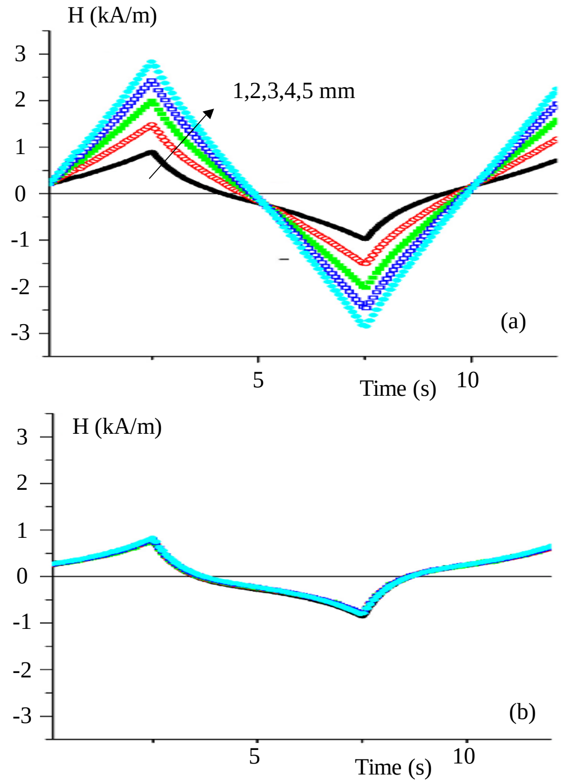

Fig. 2. The tangential field measured at different distances 1,2,3,4 and 5 mm from the sample surface in the solenoid

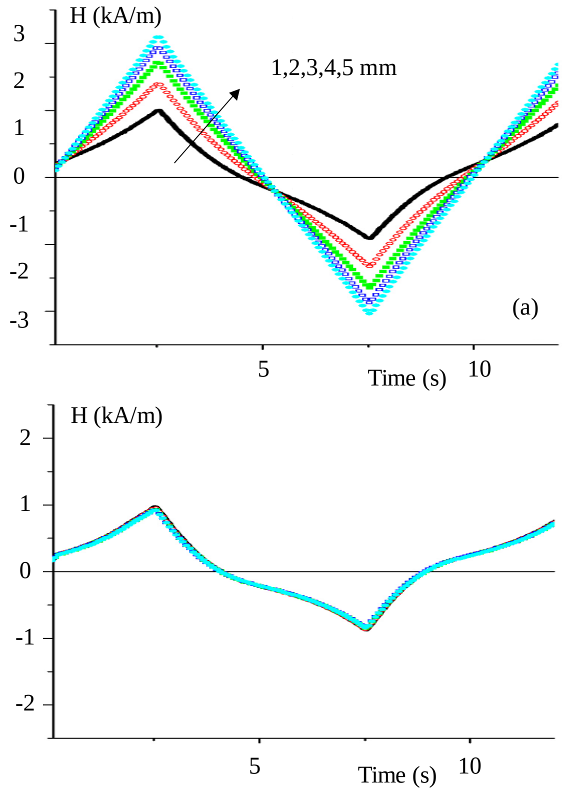

Fig. 3. The tangential field measured at different distances 1,2,3,4 and 5 mm from the sample surface in the yoke-sample setup for 0.4 mm air gaps

3 RESULTS

Conveniently the surface field is measured by a single sensor with a sensing area situated at few millimetres from the sample surface. Let us now look at such measurement in both magnetizing systems with and without shielding. In Fig. 5 the hysteresis loops are shown that were measured with the field sensor at 2 mm from the sample surface without shielding. It can be seen that the loops are very different because of the error in the measured field, which is caused by the field gradient. Also the loop using the field calculated from a current in a solenoid as a reference is shown. In Fig. 6 hysteresis measurements in the solenoid with shielding are shown. Here the loops are close due to much smaller error in the field given by much smaller field gradients. This remaining error can be further decreased by the extrapolation technique developed before [6].

The surface field measured at different distances from the sample in the solenoid is shown in Fig. 2. One can see that without shielding the field gradient is very large and it is reduced dramatically when the sensors are magnetically shielded. In Fig. 3 the results of measurements in the yoke-sample system with 0.4mm air gaps are shown. It can be seen that the field gradient is very similar with that in the solenoid. Notice that without shielding the field measured at a few millimeters from the surface is several times larger than the field on the surface. The field gradient in the yoke-sample system without air gaps (polished surfaces) was very small - 1–2% per one millimeter.

4 DISCUSSION

As it is seen in Fig. 2 and Fig. 3, the field gradient is initially large in both magnetizing systems and it is suppressed dramatically by the magnetic shielding. The reason is that the air flux is guided into the sample by the shielding plates – a working principle of the shielding.

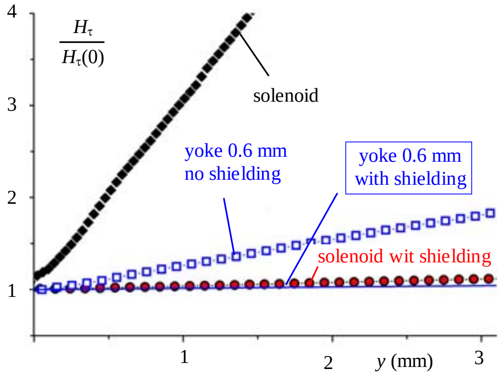

Fig. 4. Relative change of the calculated tangential field as a function of a distance from the sample surface, ***y***

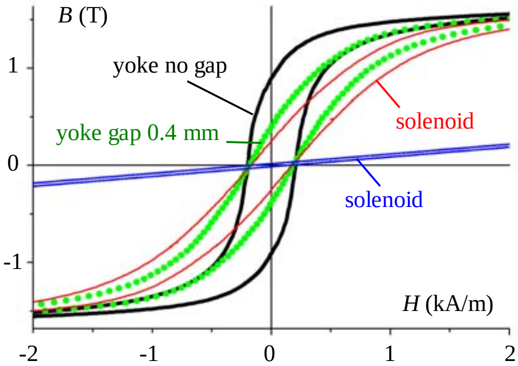

Fig. 5. The hysteresis loops measured with the field sensor at 2 mm from the sample surface without shielding

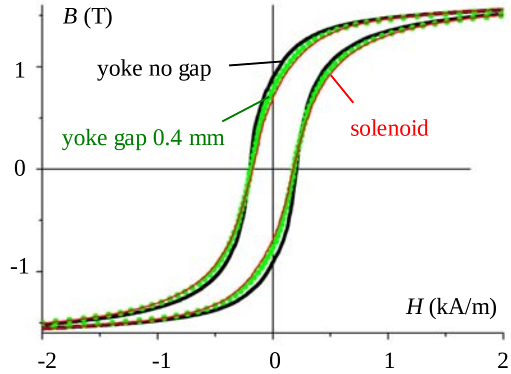

Fig. 6. The hysteresis loops measured with the field sensor at 2 mm from the sample surface with shielding

In Fig. 4 the field above the sample calculated by a finite elements modeling (2D FEMM) is shown. It is seen that results of calculation is in qualitative agreement with experimental data – initially large field gradients are effectively suppressed by the shielding.

5 CONCLUSIONS

In this work we investigated the surface field gradient above the open sample and it's suppression by the magnetic shielding in two magnetizing systems: (i) sample magnetized by an external field of an air solenoid and (ii) sample magnetized by a single yoke.

It was found that the shielding was effective in both magnetizing systems. In a solenoid initial field gradient was very large – around 100% per mm, in a yoke system dependingd on an air gap between the yoke legs and the sample. It was shown that the gradient decreased by an order of magnitude if the field sensing area was magnetically shielded by the shielding plates.

The shielding technique is so effective that even measurements of open samples in a solenoid can be made precise and reliable.

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