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Design and Analysis of a Novel Two-Dimensional High Frequency Magnetic Tester for Nanocrystalline Alloy Material

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➢1. INTRODUCTION

- To extend the applications of promising nanocrystalline magnetic materials in electrical engineering at high frequency, the materials must be characterized well at wide range of frequencies and fields.
- This paper proposes a novel two-dimensional (2-D) magnetic properties tester up to 20 kHz.
- The paper discusses the factors which impact on the experimental results.
- 2-D rotational magnetic properties of nanocrystalline alloy are preliminary measured.

➢2. DESIGN AND VERIFICATION OF MAGNETIC TESTER

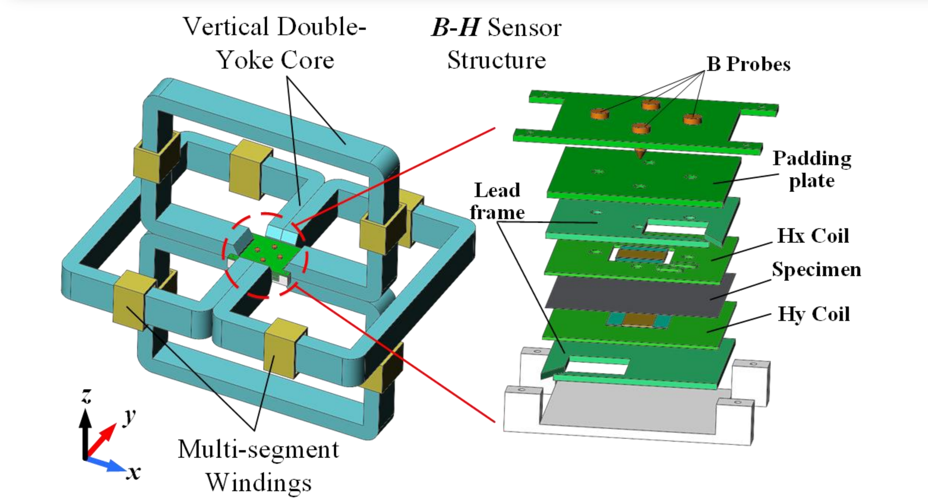


Fig. 1 (a) Schematic diagram of core structure and B-H sensing composite structure.

A novel 2-D rotating magnetic tester is designed particularly for testing properties of nanocrystalline magnetic material of $Fe_{74.5-x}Cu_xNb_3Si_{13.5}B_9$ at high frequencies under alternating and rotating excitation, as shown in Fig. 1.

The cores of the magnetic property tester are double "C-type" while the arranged in orthogonal direction. The core is made by ultra-thin nanocrystalline alloy ribbon (Thickness is 0.02 mm).

Based on tester core structure, the windings are installed in the middle part of the magnetic yoke.

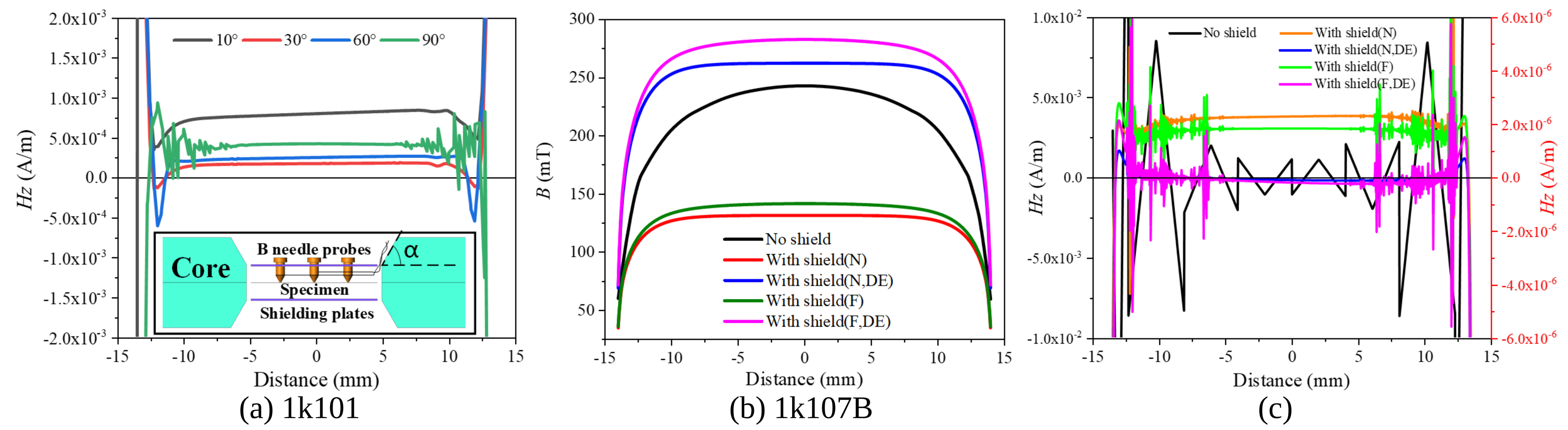

(a) 1k101 (b) 1k107B (c)

Fig. 2 (a) Hz distribution across the specimen surface of 28 mm at different α values;
(b) Effect of shielding plate on magnetic flux density distribution of specimen;
(c) Elimination of vertical magnetic field by shielding plate.

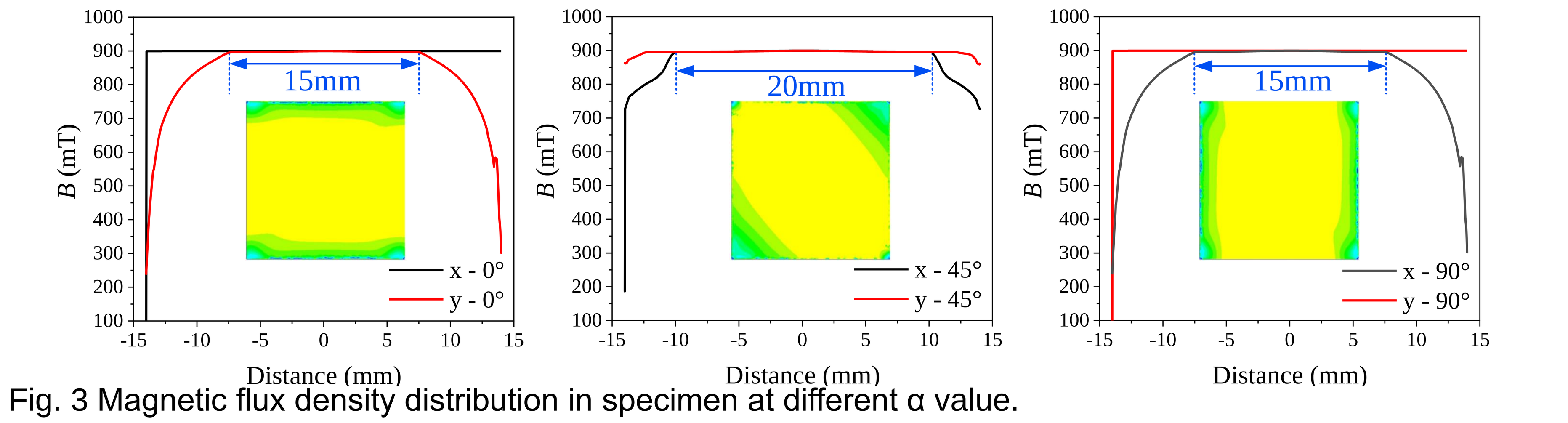


Fig. 3 Magnetic flux density distribution in specimen at different α value.

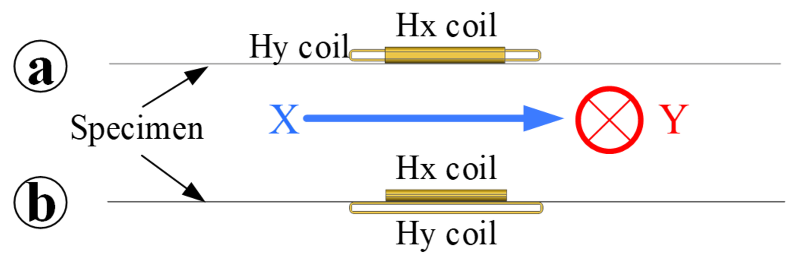


Fig. 4 Two placement methods of H-coil.

There are two main methods for magnetic field intensity H measurement based on 2-D magnetic properties measurement. One is the cross-type H-coil method. Since the thickness of specimen is approximately 0.02 mm, it is very thin compared with that of H-coil. The second structure is adopted to ensure that the H signals collected in the x and y direction are as precisely as possible.

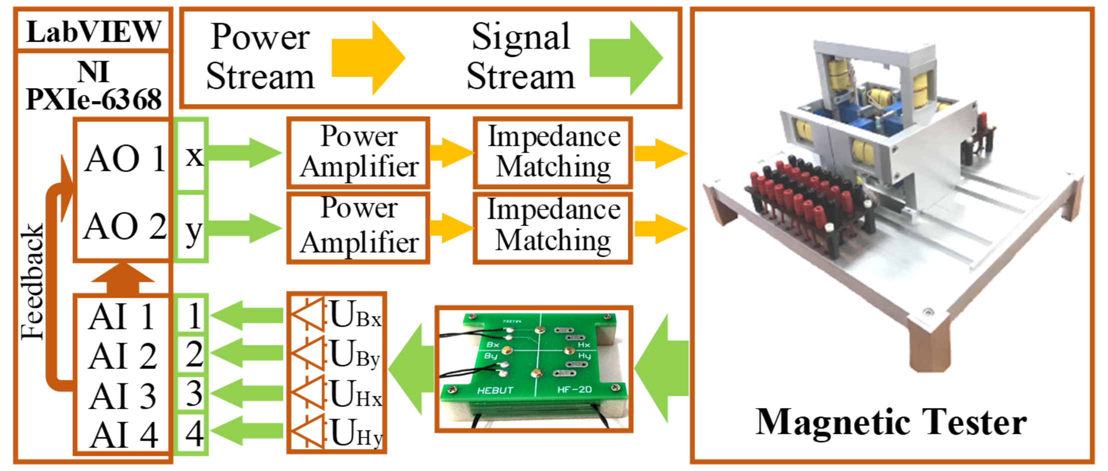


Fig. 5 Data acquisition and excitation feedback control system.

The voltage signals U_{Hx}, U_{Hy}, U_{Bx} and U_{By} measured by sensor need to be amplified by signal amplifier, and then transmitted to NI 6368 for four-channel synchronous acquisition. Meanwhile, the output signal of acquisition card is controlled by frequency-domain feedback control method to control ***B*** into ideal waveform.

➢3. MEASUREMENT ERROR ANALYSIS OF MAGNETIC TESTER

There will be various error sources in the experiment, which will lead to a certain difference between the measurement results and theoretical values. By comparing and analyzing the experimental data, the actual error source can be found. Ac-cording to the conclusion drawn from the experimental analysis, the testing device can be better optimized.

The possible error sources are as follows:
1) Irregular core structure and shape;
2) Interchannel delay of data acquisition card;
3) Irregular stray field;
4) Micro-deformation of specimen.

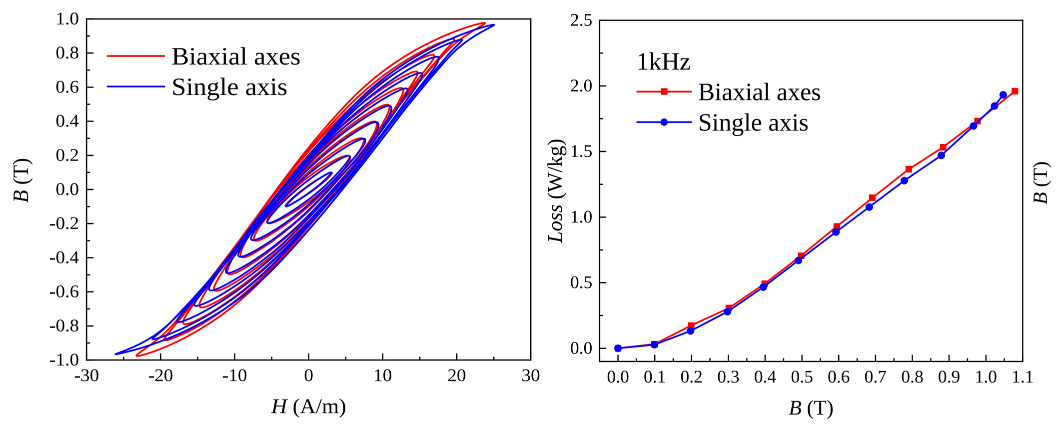


Fig. 6(a) Hysteresis loops and corresponding losses of the sample being magnetized along x-direction with or without y-direction yoke.

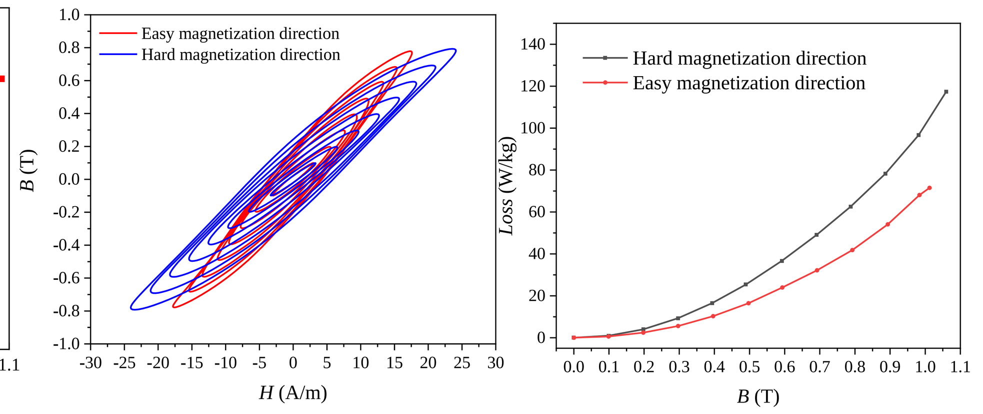


Fig. 6(b) Hysteresis loops and losses when the sample is magnetized at 20 kHz along x-direction and y-direction.

Fig. 6 (a) Fig. 9 shows the hysteresis loops and corresponding hysteresis losses at different magnetizations along x-direction when y-direction pole is present or absent.

Fig. 6 (b) shows that two series of loops are in good agreement though magnet-ization along x-direction is easier than that along y-direction.

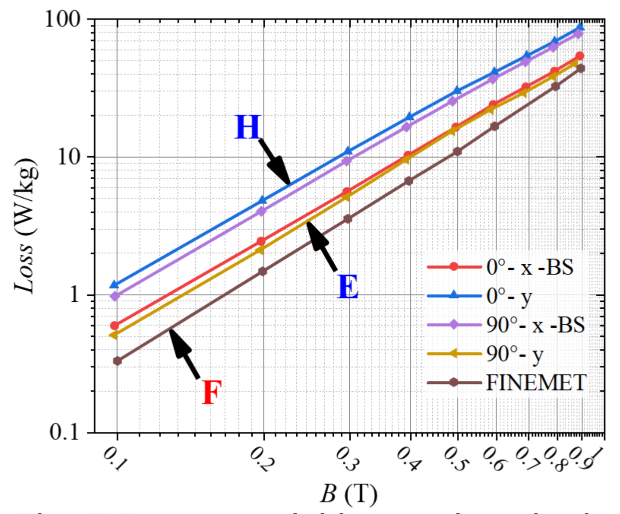
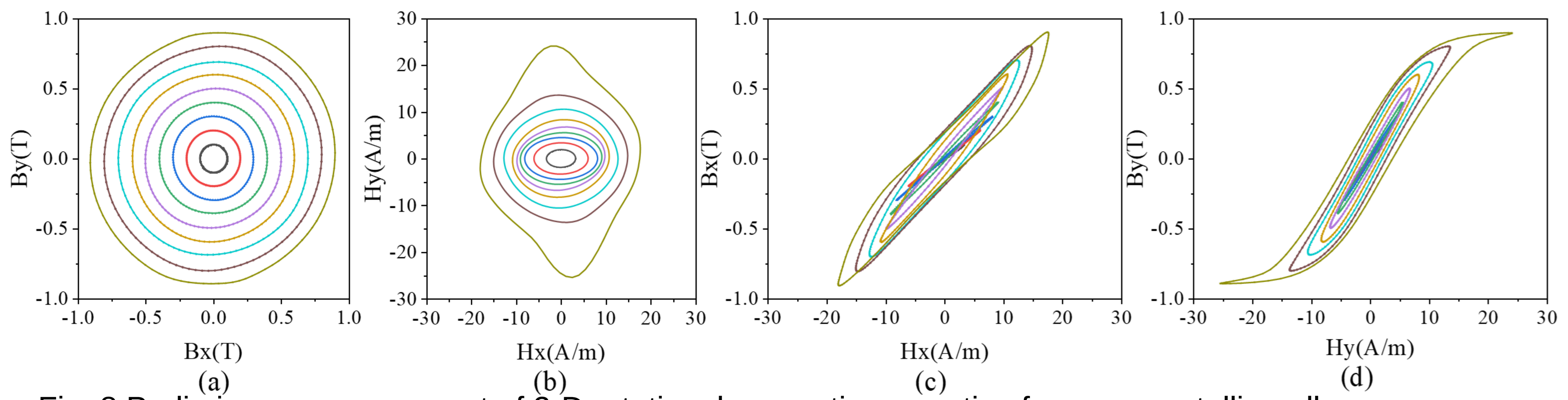


Fig. 7 Data acquisition and excitation feedback control system.

In Fig. 7, F represents the loss curve of nanocrystalline alloy FINEMET, E and H denote the loss curve of easy and hard magnetization directions respectively. It can be seen that there is difference between losses of the two directions, which indicates that the nanocrystalline alloy has slight anisotropy.

Meanwhile, by comparing the experimental data with the loss of FINEMET, it is found that the difference between the measured values and the data with data provided by manufacturer is within a reasonable range. The reason for the difference is that the nanocrystalline alloy used in the experiment have a slightly worse performance than those produced by Hitachi Metal.

➢4. MEASUREMENT OF 2-D MAGNETIC PROPERTIES


(a) (b) (c) (d)
Fig. 8 Preliminary measurement of 2-D rotational magnetic properties for nanocrystalline alloy.

Based on the design and analysis of the magnetic tester, the 2-D rotational magnetic properties have been preliminarily tested. In Fig. 8, the B loci are controlled into a circle to measure the 2-D magnetic properties of nanocrystalline alloy in the anticlockwise direction at 1 kHz from 0.1 T to 0.9 T. It can be seen that B is a standard circular loci, and the corresponding magnetic field intensity *Hx* and *Hy* can be obtained.

➢5. CONCLUSION

(1) With the designed excitation structure, the magnetic flux density distribution in the specimen has well uniformity.
(2) The vertical field intensity Hz can be obviously weakened by adding ferrite shield plate.
(3) By comparing the measured alternating magnetic properties, the influence of the other axis on the uniaxial measurement and the difference between the two axes are verified.
(4) The loss of the specimen and FINEMET is compared at 20 kHz, which proves that the tester has good accuracy.