Journal of Magnetism and Magnetic Materials 386 (2015) 25–30

Contents lists available at ScienceDirect

Journal of Magnetism and Magnetic Materials

journal homepage: www.elsevier.com/locate/jmmm

Construction and calibration of a low cost and fully automated vibrating sample magnetometer

T.M. El-Alaily [a,*], M.K. El-Nimr [a], S.A. Saafan [a], M.M. Kamel [a], T.M. Meaz [a], S.T. Assar [b]

[a] Physics Department, Faculty of Science, Tanta University, Tanta, Egypt
[b] Engineering Physics and Mathematics Department, Faculty of Engineering, Tanta University, Tanta, Egypt

ARTICLE INFO

Article history:
Received 14 January 2015
Received in revised form
10 March 2015
Accepted 14 March 2015
Available online 17 March 2015

Keywords:
Vibrating sample magnetometer
Magnetic materials
Magnetic hysteresis
Data acquisition.

ABSTRACT

A low cost vibrating sample magnetometer (VSM) has been constructed by using an electromagnet and an audio loud speaker; where both are controlled by a data acquisition device. The constructed VSM records the magnetic hysteresis loop up to 8.3 KG at room temperature. The apparatus has been calibrated and tested by using magnetic hysteresis data of some ferrite samples measured by two scientifically calibrated magnetometers; model (Lake Shore 7410) and model (LDJ Electronics Inc. Troy, MI). Our VSM lab-built new design proved success and reliability.

1. Introduction

Nowadays, investigating the magnetic hysteresis loops of studied magnetic materials is one of the basic important tools of their characterization [1–4]. Different magnetic properties e.g. saturation magnetization, coercivity and retentivity of samples can be determined from the magnetic hysteresis curves too. Moreover, both ferrimagnetic and ferromagnetic materials may be classified as either soft or hard according to their magnetic hysteresis characteristics [5]. Therefore, magnetic hysteresis loops of a magnetic material can participate in determining its basic fields of applications.

The most widely used instrument for measurements of magnetization and the magnetic hysteresis of magnetic materials is the vibrating sample magnetometer [6–12]. This instrument is credited to S. Foner and is sometimes referred to as a Foner magnetometer [13, 14]. After Foner's magnetometer, many modifications and improvements of this instrument had been introduced. However, the basic principle remains the same [15]. The present paper illustrates the construction, calibration and testing of a new simple, low cost and fully automated vibrating sample magnetometer.

2. System design

It's worth mentioning that using commonly available and low cost components was an important issue while designing the system. Fig. 1 shows a block diagram of the designed system; where the sample is placed into a glass tube which is inserted into a hollow teflon rod which is tightly fixed to an 8 Ω audio speaker. The glass tube is accurately centered between the two poles of a water-cooled Oxford electromagnet (100 V, 2 A). The circuit of the electromagnet has been modified to be controlled by an analog signal from a portable data acquisition model (NI myDAQ) [16]. The NI myDAQ is also used to generate a sine wave signal at any desired frequency to vibrate the audio speaker and consequently the sample. The vibrating signal is amplified by a common audio amplifier with its output connected to the audio speaker.

It may be useful to mention that the teflon rod is consisted of two coaxially overlapping cylinders, one of the two cylinders is fitted tightly into the audio speaker and the other is allowed to move coaxially up and down inside the fixed cylinder to set the position of the sample and to allow an easy change of the sample tube. A photographic image of the vibrating system is shown in Fig. 2.

The magnetic field direction can be reversed by reversing the direction of the current through the electromagnet coils. To achieve this purpose, two electromechanical contactors, M1 and M2 have been used to change the magnetic field direction. The magnetic field direction control circuit is illustrated in Fig. 3.

* Corresponding author.
E-mail address: toson_alaily@yahoo.com (T.M. El-Alaily).

http://dx.doi.org/10.1016/j.jmmm.2015.03.051
0304-8853/© 2015 Published by Elsevier B.V.

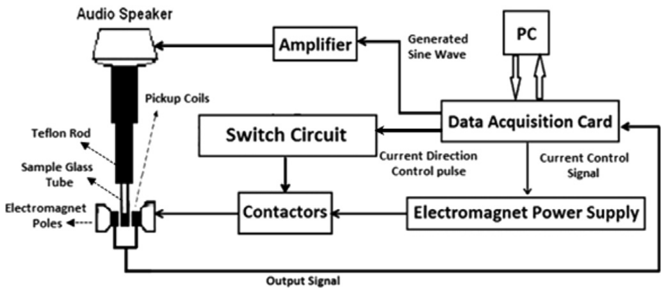

Fig. 1. Block diagram of the designed system.

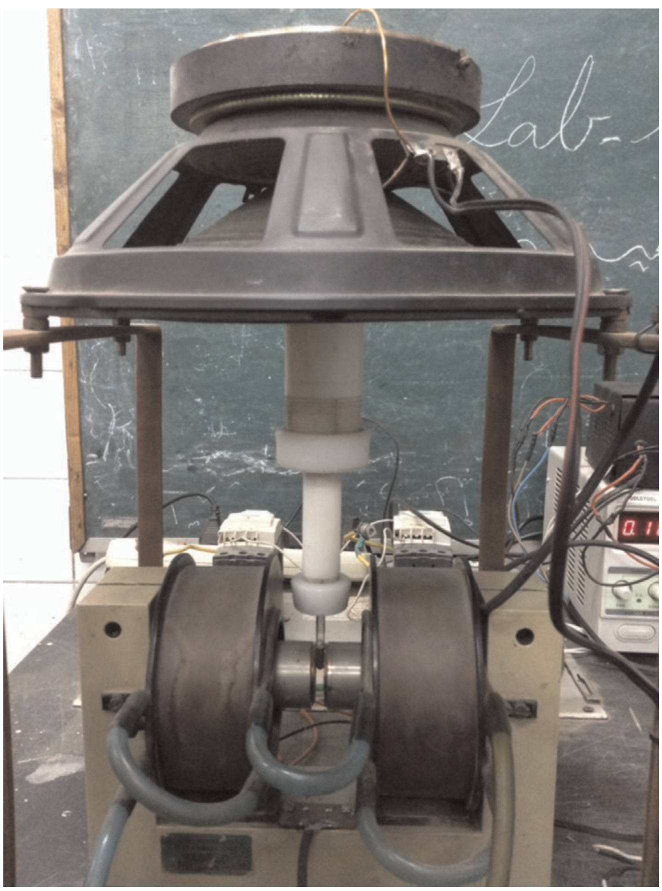

Fig. 2. A photographic image of the vibrating system.

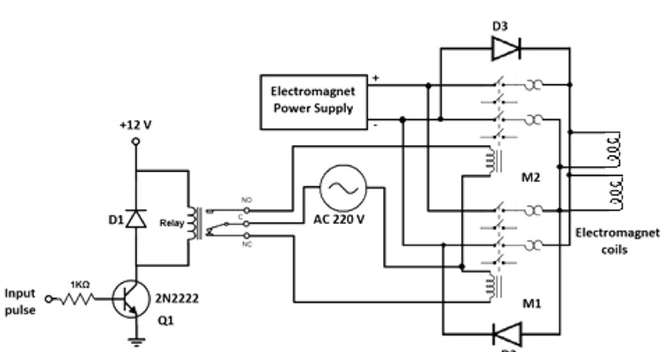

Fig. 3. Magnetic field direction control circuit.

The input terminals of M1 and M2 are connected in parallel with each other and with the output of the electromagnet power supply. Whereas, their output terminals are connected reversely with each other and also in parallel with the two coils of the electromagnet. The transistor Q1 is used to switch the power to either M1 or M2. The transistor Q1 is driven by the output pulse from NI myDAQ. D2 and D3 are two protecting diodes used to protect the power supply of the electromagnet from any probable opposite high voltage that may be induced in the coils of the electromagnet.

3. Signal detection

A pair of pick-up coils connected in series (each of which has about 1200 turns of a copper wire of diameter 0.1 mm) is stacked on the poles of the electromagnet. The axis of each pick-up coil is adjusted in the axial direction of the magnetic field of the electromagnet. The sample is magnetized by the magnetic field of the electromagnet poles. This magnetized sample induces a voltage in the pick-up coils with the same frequency due to its vibration and its amplitude will be proportional to the magnetization in the sample [17–19].

The pick-up coils are connected to a passive low pass filter circuit (Fc=80 Hz) to reject the high frequency noise from the outside. The output of the filter circuit is connected to the analog input channel of the data acquisition unit which uses the technique of a lock-in amplifier in measuring the pick-up signal. It is worth mentioning that this technique is suitable for measuring signals which are imbedded in a high amplitude noise. This has been achieved by using the “Spectral Measurements” function in the Labview program which will be discussed below.

4. Control program and operation

The system is controlled by the Labview program and the data acquisition unit [19]. The program allows the user to choose the suitable vibrating frequency before starting. At the beginning of the operation, the magnetic field is increased from the lowest to the highest value gradually then it is decreased to reach zero field. The previous procedure is repeated in the other direction to make a full loop. During producing each magnetic field value the data acquisition card measures the output signal of the pick-up coils. The “Spectral Measurements” function on the Labview program which performs FFT-based Spectral Measurements is used to extract the vibrating frequency only from the output signal and measure its amplitude. In other words, the NI myDAC along with the Labview program are performing a role of a lock-in amplifier. The Labview program displays the resulted magnetic hysteresis loop on an X–Y chart in which the X-axis represents the applied magnetic field in units of Gauss and the Y-axis represents the magnetization in units of emu/g. Fig. 4 shows the front panel of the VSM operating program.

5. System calibration

The X-axis has been calibrated to represent the magnetic field by applying a certain current in the coils of the electromagnet and measuring the obtained magnetic field at the center of the electromagnet by a Gauss meter model (KOSHAVA 5). Then these values of the magnetic field have been used in the operating program of the instrument.

On the other hand, the Y-axis which represents the magnetization in the sample has been calibrated by using the hysteresis