Modelling detection of magnetic hysteresis properties with a microcontroller

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Abstract
Equipment properties for human diagnosis and treatment are challenging to acquire because of its high cost. It is necessary to develop resources that can be widely used for medical purposes and also in the industries for the electro muscular disease. This research focuses on measuring the electromagnetic fields in materials, sorting them into different types and knowing their magnetic classification using Fahy Simplex parameter method of described by H-coil can be quickly rotated with a device developed with Arduino Microcontroller. This is to solve the problem of measuring and classifying materials according to their behaviour when subjected to electromagnetic fields. This model design establishes a measure of the degree of hysteresis in articles using a relatively cheap tool and MATLAB for the analysis and Fritzing for the electronic circuit. The research is based on off-shelve hall effect sensors and an Arduino-UNO micro-controller as the interface between the sensor and the material. One of the novelties in this research is the means of attachment of magnetizing force, H, corresponding to points on a hysteresis loop, which attained a high precision as could be obtained for positions on the standard induction curve. By the use of this methodology, a smoother curve is achieved in less time than can be done with the other method.

Keywords: *Electromagnetic Fields; Magnetometer; Fahy Simplex parameter; Magnetic field; Degree of hysteresis Introduction*

I. INTRODUCTION

The scientific and technical development and technological in physical medicine offer new treatment options in magnetotherapy [1]. The world has experienced exponential growth in all areas of technology in recent time. In this technological revolution, new materials were developed to meet the constant demands for modern products and processes at a lower cost, lightweight, more exceptional durability, of a better performance [2,3]. To meet up with the pace of innovation in medical and biomedical engineering. It is necessary to develop educational resources or device that can be widely used to present the exact sciences to medical and biomedical engineering field such as enhancements in the area of measuring magnetic fields and health. Magnetic materials from its origins play extreme importance in the history of civilizations [3,4]. Their contributions range from a simple compass used for navigation through the creation of the telephone and telegraph, and recently as a means of data storage on a magnetic device [4,5]. It is also used for the development of electrical equipment, electromechanical and electronic devices, all of which gives particular attention to the study of electromagnetic characteristics and ferromagnetic materials to achieve higher efficiency and practical use of energy. Almost every physical system or device can be evaluated by simulating and analyzing their response to an external stimulus. To measure the magnetic moment in a given material, magnet samples are assessed with this equipment. It consists of an electromagnet, a source current, a magnetic-field sensor and a positioning system sample or supply chain [6-8]. Pierre Curie, in the late nineteenth century, revealed that the magnetization of a body decreases to zero at a critical value of an increase in temperature. In the twentieth century was the appearance of Quantum Mechanics, thus allowing the modern understanding of Magnetism [6-10]. The typical characterization method used measures the magnetization as a function of the magnetic field applied to a constant temperature. Magnetization curve susceptibility as a function of temperature is another property often used because it is simple and does not require magnetic fields, and it denotes how the early part of magnetization varies with temperature [11-14]. Often these properties are not sufficient to explain the magnetic behavior of materials, especially the microscopic properties, and it is also needed to use experimental techniques such as neutron diffraction, resonance magnetic and optical spectroscopy [15-16]. An essential feature of the magnetic materials is that, above a specific temperature, they lose their magnetic properties as heat is generated and cause disorderliness in the arrangement of their fundamental particles. There are magnetic-field sensors with variations in sensitivity, i.e., field detection capability, and the difficulty in reading them. Some of these sensors are SQUID magnetometer, Hall Effect sensor, and magnetometer of vibrant samples. Student finds it demanding to access these devices and to understand their principles of operation and the magnetic phenomena. When it comes to concepts related to electromagnetism, the content is associated with a vast amount of calculations and a necessary abstraction condition of mathematics for which is hard to understand. Many works have been paid to investigate several teaching resources that can support the learning process of magnetism and its applications in industries [16-18]. In this work, the development of a hysteresis-metro using the platform of Arduino microcontroller and sensor, which made it easy enough to understand the interface and help to support learning in institutions, since it operates on a simple software with part of simple plug and plays. Several authors [18,19], pointed out the use of Arduino in designing and developing experimental teaching device for medical, mathematics, programming, physics and the concepts of electromagnetism. The apparatus proposed in this paper was created, as shown in Fig. One on Fritzing and Matlab respectively. In this research, the technologies available in the domestic market were used to ensure low-cost and easy accessibility, without losing the purpose of the study.

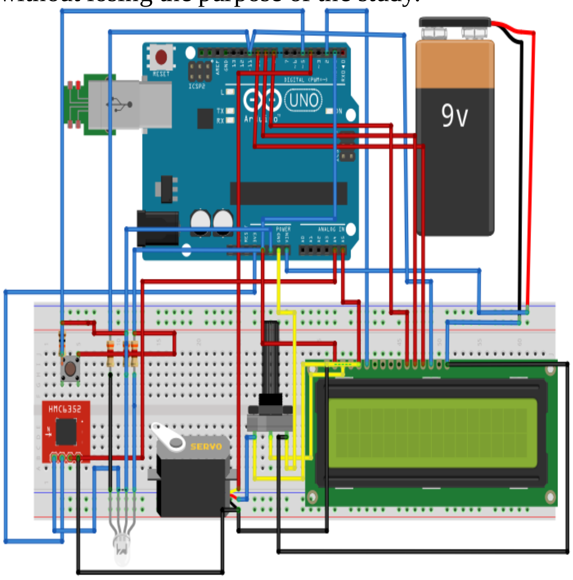

Figure. 1: Breadboard connection of the device to Fritzing software

The intention is to design and establish a magnetic-field measuring device using Arduino at this core temperature without generation of heat by the method to disorient the magnetic particles of the materials. The methodology and results presented by researchers [19] were extended over more advanced further analytical techniques of using a 12volt generated device by a computer system connected to the Arduino UNO to produce the necessary voltage needed for the device to run. This reduces heat generated by the device, thereby keeping the arrangement of the particles intact without being disorganized. An open-sourced software Arduino and a commercial one, MATLAB, were used for analytical simulation of the device to determine improvement, accuracy, and reliability of the result obtained. Hence, a low-cost method for magnetic field measurement for medical application to measure the degree of hysteresis, which is easy to operate and control is proposed. The results obtained were satisfying enough to satisfy the objectives of the research, which make it applicable to the industries and institutions.

II. MATERIALS AND METHODS

In this section, we describe the materials used and the technical procedures used for the construction of the apparatus of magnetic measurements. For this particular application, the main reasons for using hall effect sensors are due to the following factors: performing data acquisition, cost, and ease of purchase. One of the features is the durability, easy control interface, the operational stationary inlet, and high-speed operation of the sensing device and solid-state magnet operated over a wide range of temperature between 20OC to 125OC [18,19]. The dual-axis magnetic sensor is the primary device to get the measurements and the pushbutton for selecting the mode-functions, while the display of the readings is shown on the LCD screen. The servo motor is the main module to control the dual-axis magnetic sensor DC-SS503 with integrated I2C bus alongside with the resistor 320ohm connected in parallel all powered by 12volt battery [19,20]. The specific template for the selected effect sensor was the A1301, the Allegro manufacturer. The primary requirement that led to the decision by this sensor was the type of output signal. The size of the Hall Effect sensors available in the market provides the output signal in the form digitally; digital signal has difficulty in the interpretation of reading data. For the chosen sensor to produce the output signals proportional to the magnetic field of the applied analogue format, and the sensitivity of the sensor to be 2.5MV/G. It set a proper insulating varnish for the application was used in equipment, electronics, and isolates, keeping the firm winding. The power of the loop needs to be stable and to achieve this goal; it used a sealed battery. The coil drive was used as a rheostat. The placement of the samples within the support is given to the use of a stepper motor. To control the stepper motor, it was necessary to choose a microcontroller and was selected the Atmega328P-PU. This microcontroller can be arranged on a platform with some facilities chipped; the Arduino is one of these platforms [20]. The combination of all this component and connection for magnetic field detection makes this research novel in the field of hyperthermia to eliminate tumors, malignant and for application of drugs treatment and production in the medical line. All these boards are based on the use of a microcontroller, varying the model of this microcontroller, the inputs, outputs, memory, oscillators, voltage regulators and the software. Among the plates available for more accessibility and a simple model is the Arduino UNO. The project concerned, the simple proposed model presents sufficient resources for the implementation of this equipment, so the selected model was the Arduino UNO. In addition to the card interface (IDE) of the

Arduino programming is also available in Arduino IDE software and Fritzing software shown Fig. 1.

1) *DESIGN OF SOFTWARE AND CODING*

A one-quadrant Direct Current (DC) drive to hysteresis current control with speed regulation was designed to help simulate the equipment. The circuit is based on Simscape Power Systems™ of the DC5. It was model on a one-quadrant chopper buck converter drive of a DC motor. The DC motor of HP supplies with a constant approximately 150V DC. The voltage in the armature is supplied by an IGBT buck converter controlled by two regulators. A 220 V DC voltage source feeds the converter. The first regulator is a PI speed regulator, followed by a hysteresis current regulator. The speed regulator armature controller to obtain an output of the electromagnetic torque needed to reach the desired speed. To avoid sudden changes that could cause overloading of current on the armature and destabilize the system. The armature current is controlled by the current regulator by delivering the correct pulses to the IGBT device to maintain the flow in the armature within the hysteresis loop. The frequency of the IGBT device is limited by the motor inductance and an external inductance placed in series with the armature circuit.

2) *HYSRERESIS MEASUREMENT*

The hysteresis loop for the hysteresis-meter is plotted by drawing the magnitude of the magnetic field strength H against the importance of the magnetic induction B of the material. The flow of current through the coil causes a magneto-motive force F to generate along the path. Which dependent mostly on the distance travelled by the magnetic field lines. Therefore, the magnetic circuit length like the system results in a substantial magnitude of magnetic field strength H of A/m as the unit, which can be described by equation 1.

$$H = \frac{I.N}{L_c} \qquad (1)$$

This magnetic field magnetizes the material. This principle of magnetization is called magnetic induction or a magnetic flux density *B*. This degree of magnetization was measured directly by a hall magnetic sensor. However, bring a sensor to sense a magnetic property’s material require to put the sensor in the magnetic path and open the core. Therefore, this will cause a definite change of the susceptibility which makes measurement difficult [20,21]. The algorithm flow of the control system for Hysteresis-meter is shown in Fig. 2a

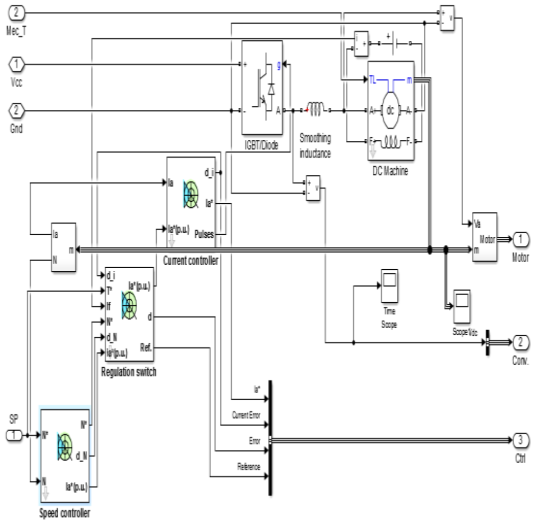

Figure 2a: Algorithm flow of the control system for Hysteresis-meter

3) *Development Hysteresimetro*

To visualize the design structure, the initial design can be seen in Figure 2b, showing the coil with sensors installed on the motor and belt, along with the sample port. To facilitate machining on the lathe, the cylinder spindle holder is used to rotate the bobbin. The motor is placed in steps and strap gears, therefore, when moving the step motor, the belt will move the sample from the door to the center of the coil. That we will have the strength of the field with different pressure. Using the capabilities of the ADC, we convert this voltage into numbers. This figure shows the field strength and is displayed on the LCD. The Arduino has six ADC channels. All can be used as inputs for analog voltage.

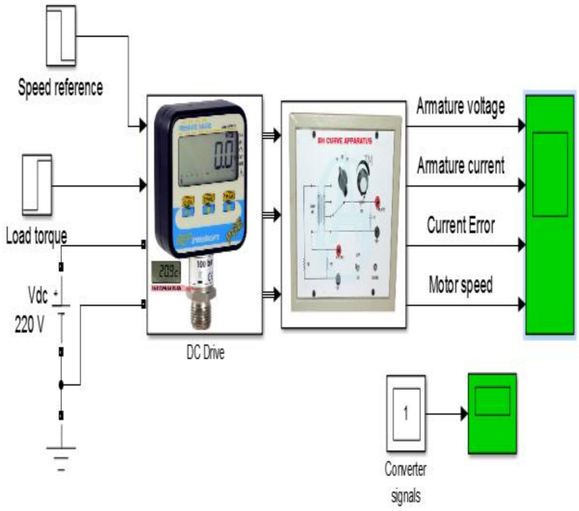

Figure 2b: DC Drive of Hysteresis Current Control Hysteresis-meter.

UNO ADC has a resolution of approximately 10 bits. The integer value is between 0-210 and 1,023. This means that it will will map the input voltage between 0 and 5 volts by an integer value between 0 and 1023 for every 5/10 of 4.9. mV per unit of voltage flow the sensor is placed and attached with glue inside the support, as shown in the connection of the component in Figure 3.

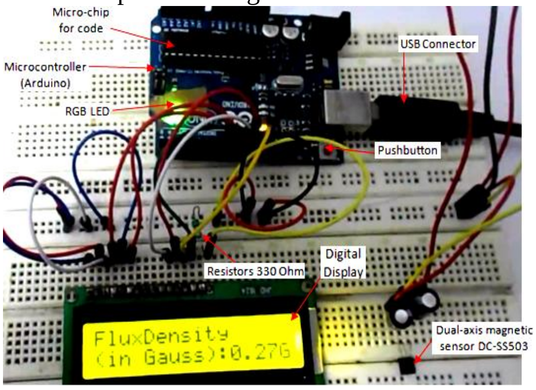

Figure 3: Experimental setup of Magnetic Field Measurement with an Arduino micro-controller.

Once positioned sensors, was rolled coil in the recessed area of *TECHNYL support*. The support was turned to have the recess that allowed these sensors to have a coil wound with lower difficulty and quality increase in the result — on the plate where the connectors of the sensors were fixed, mounted to a type button *"Push-bottom"*. To start the stepper motor travel positioning the sample and beginning sensor readings when specimens were appropriately placed in the center sensor for connecting each of the sensors. These wires were attached to a plug-in the pin, so the welding time has been reduced considerably. Connectors were mounted in place in a heat shrink cover each of the sensor terminals, these being isolated from each other. With the position sensors used to allocate the lines field produced by the inductor fall perpendicularly to the sensor element. This one positioning makes the acquisition of the magnetic field measurements more reliable. This program waited until the button was pressed. While the engine was not the positioning step, the outputs of the sensors would be read. When you reach the centre position, was initiated acquisition data and data were made available to the serial port of the Arduino and so collected from an application that linked data from the serial port to a data file in Excel format). When the button was pressed again, the motor would return the sample to the starting position. The Hall Effect sensors were connected to analogue ports 0 to 4 on platform Arduino. The button was connected to the digital port 1, and the stepper motor drive was timed resulting from several calibration measurements. The equipment was assembled, and several tests were carried out with samples of varied commercial ferries. Four samples were chosen ferromagnetic materials in the form of ferrites used in making the core inductors and transformers. The content is magnesium ferrite (MnZn presents a high permeability and low resistivity) is used as a core for frequencies up to 50 MHz and has MGZN low permeability having high resistivity can be used in rates the hundreds of MHz. We use the ground samples by mechanical process maceration.

The magnetic flux density was measured without tampering the magnetic circuit of the system. The electron magnetic force (EMF) in the windings is directly proportional to the change in flux $d\emptyset$ within the core, as shown in Equation 2.

$$E = -N.\frac{d\emptyset}{dt} \tag{2}$$

Since the product of the magnetic induction and the cross sectional area is equal to flux the density of the core $\emptyset = B{\cdot}A_c$, Therefore, the relationship between the EMF and change of induction is expressly as equation 3 and a further integration due to change in induction dB as a function of time B result into equation 4

$$dB = \frac{dt.E}{-N.A_c} \tag{3}$$

$$B(t) = \int_{0\,s}^{t} \frac{E(t)}{-NA_c} dt \tag{4}$$

With the use of Arduino, you can control many different directions and the speed of the motor step by step. You need an additional ULN2003 circuit controller from Arduino, which provides the correct drive to adjust the motor winding. ULN2003 is a series of high voltage and high current Darlington transistors. There are seven pairs of Darlington collectors with standard items. Each channel supports a maximum current of approximately 500 mA and 600 mA. This component is beneficial and is aimed at a wide range of DC motor solenoids, LED display, print head and high-power buffer. The same Atmega 328 microcontroller was used in the selected Arduino UNO platform sensor to read the Hall effect values. The interface of the Arduino card facilitates the detection of the device when reading the values in the USB port of the monitor on the monitor. In this way, both the position of the sample and the measured magnitude of the test take place automatically.

III. RESULTS AND DISCUSSIONS

With the increasing use of electromagnetic devices, the need for research base of electromagnetism has become one of the areas of great interest in the study of Physics. Industrial equipment that measures magnetic field has a high cost, and that is why this study aimed to build a low - cost equipment, capable of measuring the magnetic field and variations in this field by outside interference with commercial Hall Effect sensors. The measurements of this equipment were equivalent in several respects to other industrial devices. After the calibration, values detected corresponded to the expected values within absolute accuracy. Thus, it was possible to construct a device that serves as a teaching tool in classes. Using a method like this in class, students will have access to the practical situations before discussing it theoretically. When simulating the motor armature voltage and current, there was a signal in the IGBT pulses and the motor speed of the device. The current and speed references with the reference voltage and current error of the system are also displayed, as shown in Fig 4A. The speed reference is set at 500 rpm at 0second of time with an initial loading factor of 15 Nm torque. The motor speed follows the reference ramp accurately 252 rpm/s and reaches steady-state of about 2.5seconds. The armature current follows the current reference accurately and stays within the limit hysteresis band which is explained by Fig. 4B. The recovery of the motor speed was fast and is back at 500rpm of 3second.

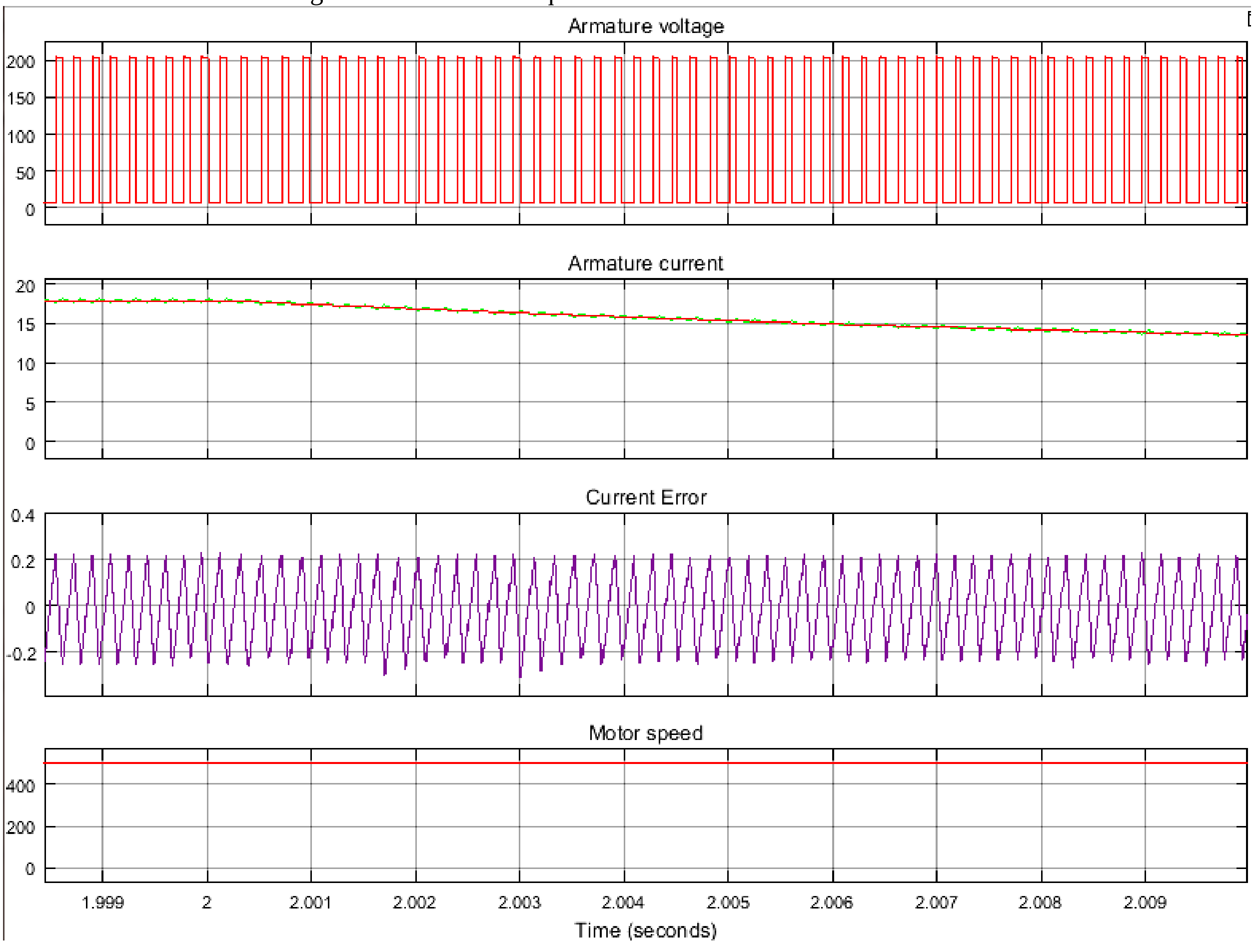

Figure 4A: Processing measure data with Matlab of the armature parameters of the coil, the current and current error and the speed as a function of time.

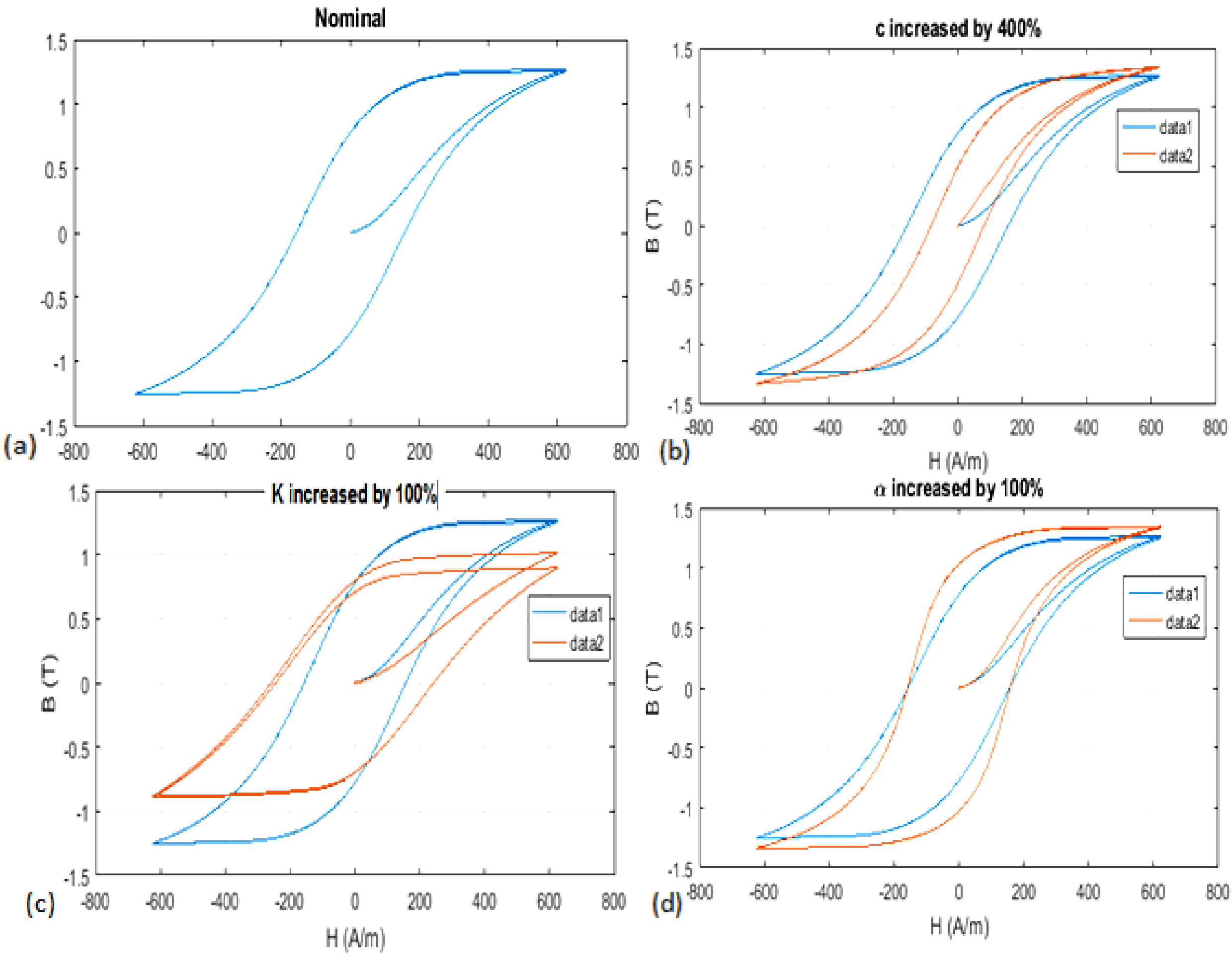

Figure 4B: Hysteresis loop for a ferromagnetic material (a) BH-loops of Nominal (b), BH-loops with C increase by 400% passive with the saturation point (c) BH-loops with K increase of 100% and the saturated point (d) BH-loops with $a\ \alpha\ increase$ by 100% and the saturated point

The was increased in the current to approximately 16.7A to generate a higher electromagnetic torque to maintain the reference speed. At 3seconds of the operational time, the speed reference decreases to 350 rpm which makes the armature current to drop for the momentum to decline following the negative rate, the slope of -250 rpm/s as shown in Fig. 5a when loading the torque and the system stabilises at a particular time, approximately 4secons around the reference point, as shown in Fig. 5b The properties of raw material were measured using the developed device. It was ensured that the value on the display screen of the PC was stable before taking the readings serially. The amount of the magnetic text of the x, y, and z-direction are shown in Fig.

5a, X-axis is the time in the second's effect series of the magnetic field for the *magnetometer*, and the Y-axis is the magnetic field in the Milligauss output of the system for each set of experiments.

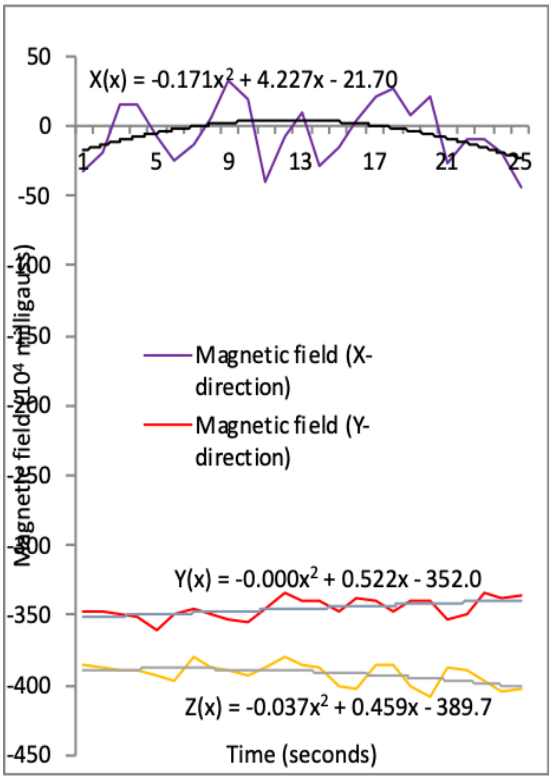

Figure 5a: The X, Y, and Z coordinate of measurement with the device.

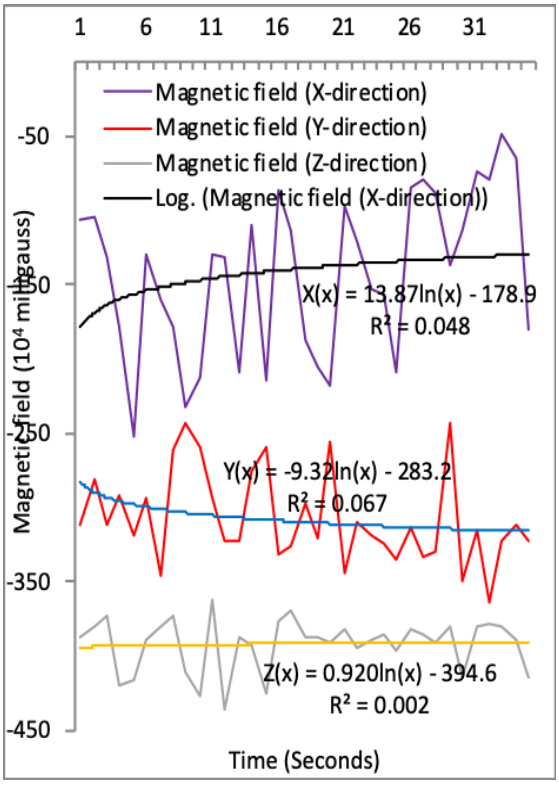

Figure 5b: The X, Y, and Z coordinate of analysis with simulation software.

We then move the magnet to match the area next to the sensor and write the reading value for each position associated with the sensor. For each value, we will remove the corresponding values when the magnet is away from the device to remove the Earth's magnetic field. Benefits will be shown after receiving all benefits. To determine the SX and SY matrix from the values measured with the measured values for X and Y respectively, it is logged in the MATLAB software, which makes the spatial distribution of the measurements reliable. This is repeated, and the values are shown in Figures 5a and 5b showing the histogram curve of the TH50 and the loop element in the first quadrant. Measurements taken from the sample after heat treatment to reduce stress can be seen in Figure 6. Observed values for magnetic fields.

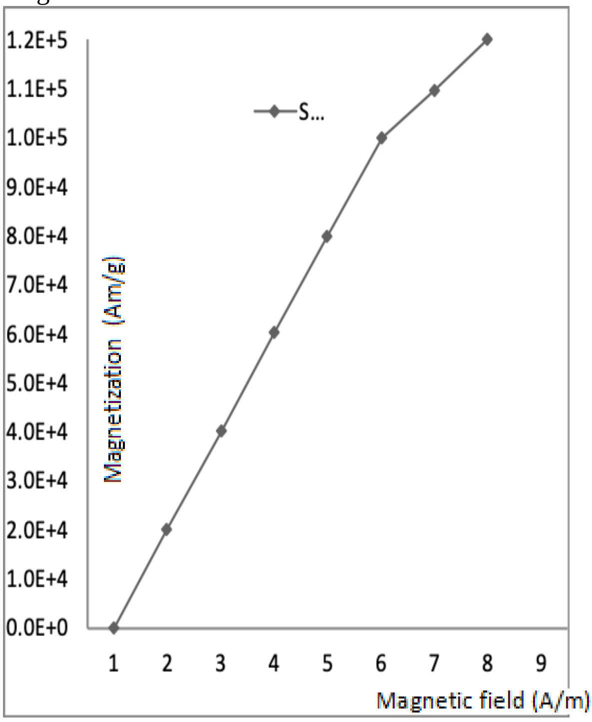

Figure 6: Experimental Hysteresis curve for Sample in the first quadrant.

IV. CONCLUSIONS

This research presents the results of the data acquired from the measurement of the magnetic field using Arduino and simulations of the average values of the material. The result obtained shows the possibility and verification of the consistency of the device, which showed satisfactory results and its applicability in Institutions and industries. The following conclusion can be reached.

[1]. Arduino UNO was incorporated into the system with a series of embedded magnetic sensors along the magnetic field. It established the types of materials for their magnetic classification and solved the problem of measuring areas, and sorting articles according to their behavior when subjected to electromagnetic fields.

[2]. The Fahy Simplex parameters are one the determinant for standard induction and hysteresis data and loop for permanent magnetic materials. It was discovered that the advantages are the convenience of operation and simplicity and its

ability to indicate the average hysteresis properties of inhomogeneous materials.
[3]. The treatment of data acquired was due to typical values and building graphics. Fundamental values were mathematically obtained and compared to the benefits received experientially by analyzing the charts, which were possible to verify linearity equipment, which showed satisfactory results.
[4]. The necessary parameters of electric, magnetic and electromagnetic field were proposed and established for Histeresimetro. The optimization of a density magnetic field to enhance the sensitivity of the device was introduced and measures the degree of hysteresis materials with a reduced cost that favor an economic effect.
[5]. The interface between the sensors and the user is made through an Arduino UNO. The cost of energy and heat generation during magnetic field measurement was minimized.

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