# A FLUXGATE SENSOR APPLICATION: COIN IDENTIFICATION

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***ABSTRACT***

*Today, coins are used to operate many electric devices that are open to the public service. Washing machines, play stations, computers, auto brooms, foam machines, beverage machines, telephone chargers, hair dryers and water heaters are some examples of these devices These devices include coin recognition systems. In these systems, there are coils at two different radius, which become electromagnets when the current is passed through them. The AC current supplied to the coils creates a variable magnetic field, which induces the eddy current on the coil during the passing of money. The magnetic field generated by the Eddy current reduces the current passing through the coil. The amount of change of current in the coil gives information about the coin; the type of metal (element) and the amount of metal (element). In this study, a new coin identification system (magnetic measurement system) is designed. In this system, the magnetic anomaly generated by the coin as a result of applying direct current to the coils is tried to be detected by fluxgate sensor. In this study, sensor voltages are acquired in computer environment by using developed electronic unit and LabVIEW based software. In the paper, experimental results have been discussed in detail.*

***KEYWORDS***

*Metal money, Coil Detection, Eddy current, Fluxgate sensor, Magnetic anomaly.*

## 1. INTRODUCTION

Nowadays, remote sensing is used for different purposes with different methods. The features that are important in all sensing methods are low power consumption, low price, being unaffected by environmental changes, high precision, high reliability and stability. Some remote sensing methods used from past to present include electromagnetic induction (EMI)[1-5], ground effect radar (GPR)[6-11] and magnetic anomaly [12-15, 18]. Magnetic anomaly is the most widely used remote sensing method due to its low price, low number of equipment and changeable sensitivity. This method is based on determining the change in magnetic field caused by an object with magnetic characteristics, which is located in an external magnetic field [20-29].

The effects of magnetic anomalies caused by coins are also determined in coin operated washing machines, play station, computers, auto brooms, foam machines, beverage machines and telephone chargers. Within these devices, there are two coils at different diameters. During the

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passing of coin through the magnetic field created by applying AC current to the coils, eddy currents are being induced in the coil. The magnitude of this current depends on the conductivity of the coin. As a result of the high Eddy current, it is expected that the magnetic field generated by the eddy current is high. So, the current changes on the coil can be detected more easily. In short, the conductivity of coin determines the current change in the coil. The conductivity of coin depends on what kind of metal it is made of and how much metal it contains. In all coin operated devices, since the metal contents of the coins are different, the conductivity of the coins and the current changes in the coil will be different. Thus, the coins can be distinguished (Fig. 1).

Figure 1. Coin determination system based on the change of current in the coil

However, the changes in current passing through the coil also depend on the winding number of the coil, the wire cross-section and its type, and the magnetic character of the core. A different detection method has been used in our study to remove the effects of these variables. In this method, it is aimed to detect the magnetic anomalies generated by the coin with magnetic sensors instead of determining the current changes in the coil.

In the presence of magnetic material, the decrease in flux density in the region of the sensor causes electrical change in the sensor and it changes the output voltage. By analysing these changes, information about the dimensions and the content of the object has been obtained.

Various sensors such as MR (Magneto-resistive), SQUID (Superconducting quantum interference devices), Hall and Coil are used to detect the magnetic anomaly [15-19]. In this method, the FLC100 Fluxgate sensor has been chosen due to its low power consumption, low price, being unaffected by environmental changes, high precision, high sensing speed, reliability and stability. In the following section of the paper, the developed experimental setup, the application of the method, and the experimental results are explained in detail.

## 2. MATERIAL AND METHOD

The block structure of the magnetic measuring system which is developed in this study with the aim of money determination is given in Figure 2.

The developed system can be classified under two headings as hardware and software. In the first phase of the study, the mechanics and the hardware part of the system are produced and then the software part is programmed with LabVIEW.

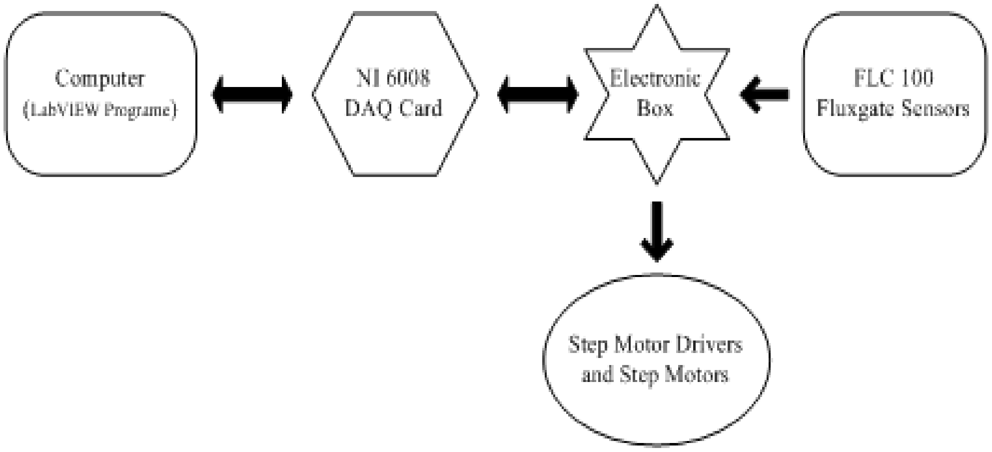


Figure 2. Block diagram of the magnetic measurement system

In the developed magnetic measurement system, the mechanical control and data acquisition is done with the NI 6008 DAQ data acquisition card, which has 8 analog inputs (12 bits, 10 kS / s), 2 analog outputs (12 bits, 150kS / s) and 12 digital inputs / outputs The developed system has 8 FLC 100 sensors with 0.5 nT sensitivity and low noise (0.1 - 10 Hz), which can be used for more accurate measurements than Hall or MR magnetometers. The sensors are mounted on a platform with 2.5 cm spacing (Fig.3a). Since NI 6008 DAQ, the card (NI 6008 DAQ) has eight analog inputs, at most eight sensors are used in the system. The total length of the sensor network is 17.5 cm. In addition, the electronic unit in the system contains an electronic card that processes data from the sensor and a stepper motor driver card.

(a) (b)

Figure 3. a) Fluxgate sensor platform, b) Electronic unit

In the study, an iron core coil with a length of 6.8 cm and a diameter of 2.4 cm is used as the magnetic field source. The coil has a winding number of 5000 and the wire thickness is 0.1 mm. (Fig.4)

Figure 4. Magnetic field source

In this study, there is a distance of 10 cm between the coil and the sensor platform and the tested coins are located in the middle of this distance. The center of the coin is set to the center of the scan plane and the sensor platform is moved to the start position of the scan. The scanning area of the sensor platform is a 10cm * 10cm area. The sensor data is collected by moving the platform at intervals of 0.2 mm along the x-axis and 0.05 mm along the y-axis.

The scanning path of the sensor platform in the "Area scan" process is given in Figure 5.

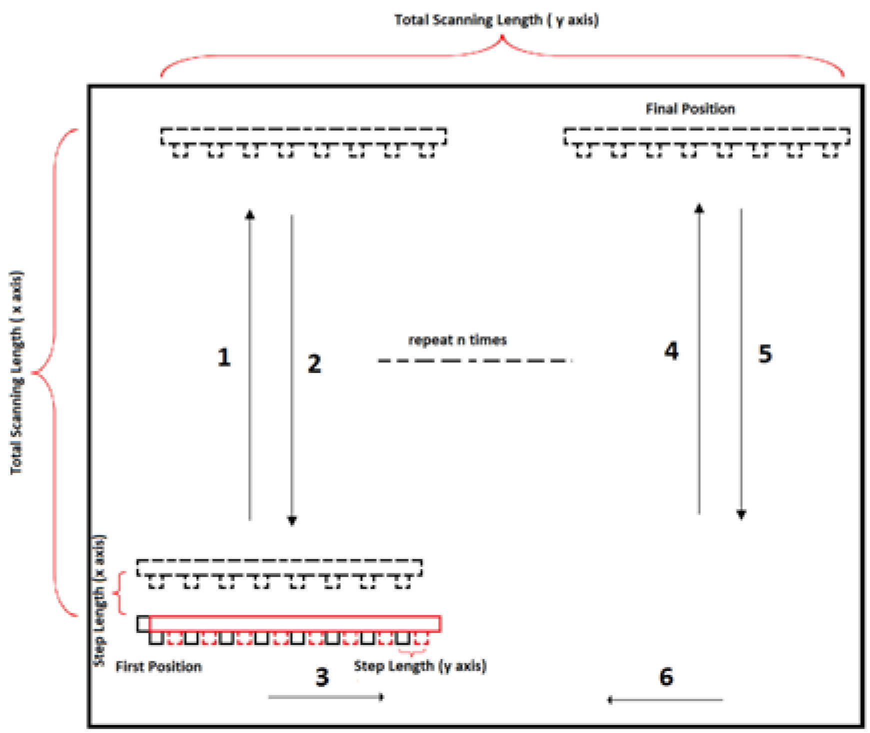


Figure 5. Scanning path of the sensor platform in the "Area scan" process

The sensor platform first moves along the x-axis at specified step intervals (Movement 1). The platform returns to its initial state after reaching the total scan length (Movement 2). The system advances along the y-axis by the user-specified step length (Movement 3) Once the system has reached the final position, it returns to its initial state of motion and ends the measurement (Movement 5 and 6).

The LabVIEW program, developed by National Instruments, is used to program the measurement and motion control system. LabVIEW has a graphical programming language which is also called data flow programming and consists of two different interfaces, block diagram and front panel. Block diagram is the section where programming is performed. The front panel can be defined as a "user interface" where users can enter variables and observe the results.

In the program, the "event case" structure is used in general. With this structure, the user can perform a desired operation after entering the preliminary information.

The sensor data received by the program is instantly saved in Excel format with a ".tdms" extension. Into the register file, the positions of the sensors in the x and y axes and the sensor output voltages are recorded.
The front panel (control panel) of the LabVIEW-based program developed for the magnetic measurement system is shown in Figure 6.

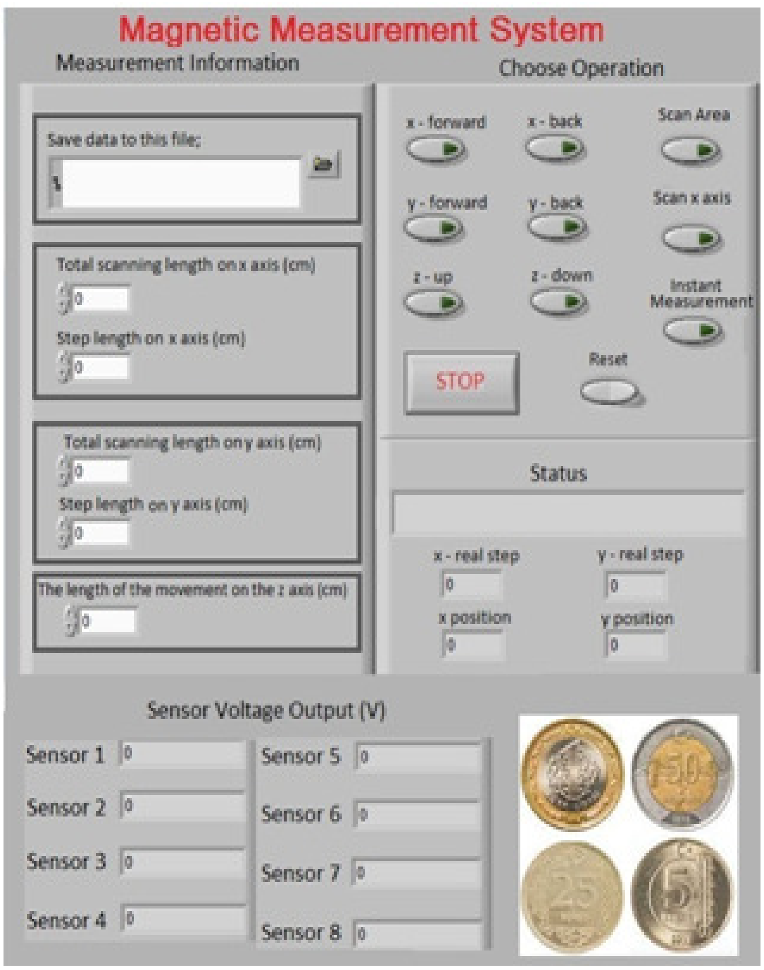


Figure 6. Control panel and sections of the developed LabVIEW based program

## 3. EXPERIMENTAL RESULTS

The technical information of the coin samples which are tested with the magnetic measuring system is given in Table 1.

| Reverse of the Coin | Obverse of the Coin | Diameter | Thickness | Mass | Elements |
|---|---|---|---|---|---|
|  |  | 17.5 mm | 1.65 mm | 2.9 g | 65% Cu<br>18% Ni<br>17% Zn |
|  |  | 18.5 mm | | 3.15 g | |
|  |  | 20.5 mm | | 4 g | |
|  |  | 23.85 mm | 1.9 mm | 6.8 g | Outer Ring:<br>79 % Cu,4% Ni,17% Zn<br>Inner Circle:<br>65% Cu,18% Ni,17% Zn |
|  |  | 26.15 mm | | 8.2 g | Outer Ring:<br>65% Cu,18% Ni,17% Zn<br>Inner Circle:<br>79% Cu,4% Ni,17% Zn |

In this study, 15 volts of voltage and 0.5 amp current are applied to the coil which is used as a magnetic field source. The coin to be tested is placed 5 cm away from the coil. Then, the fluxgate sensor platform, 5 cm away from the coil, is brought to the beginning of the scan. After that, the platform is scanned a surface area of 10 cm * 10 cm (Fig. 5). The collected sensor data is processed in Origin which is a 3D drawing program. The graphs obtained for each sample are shown in Figure 7.

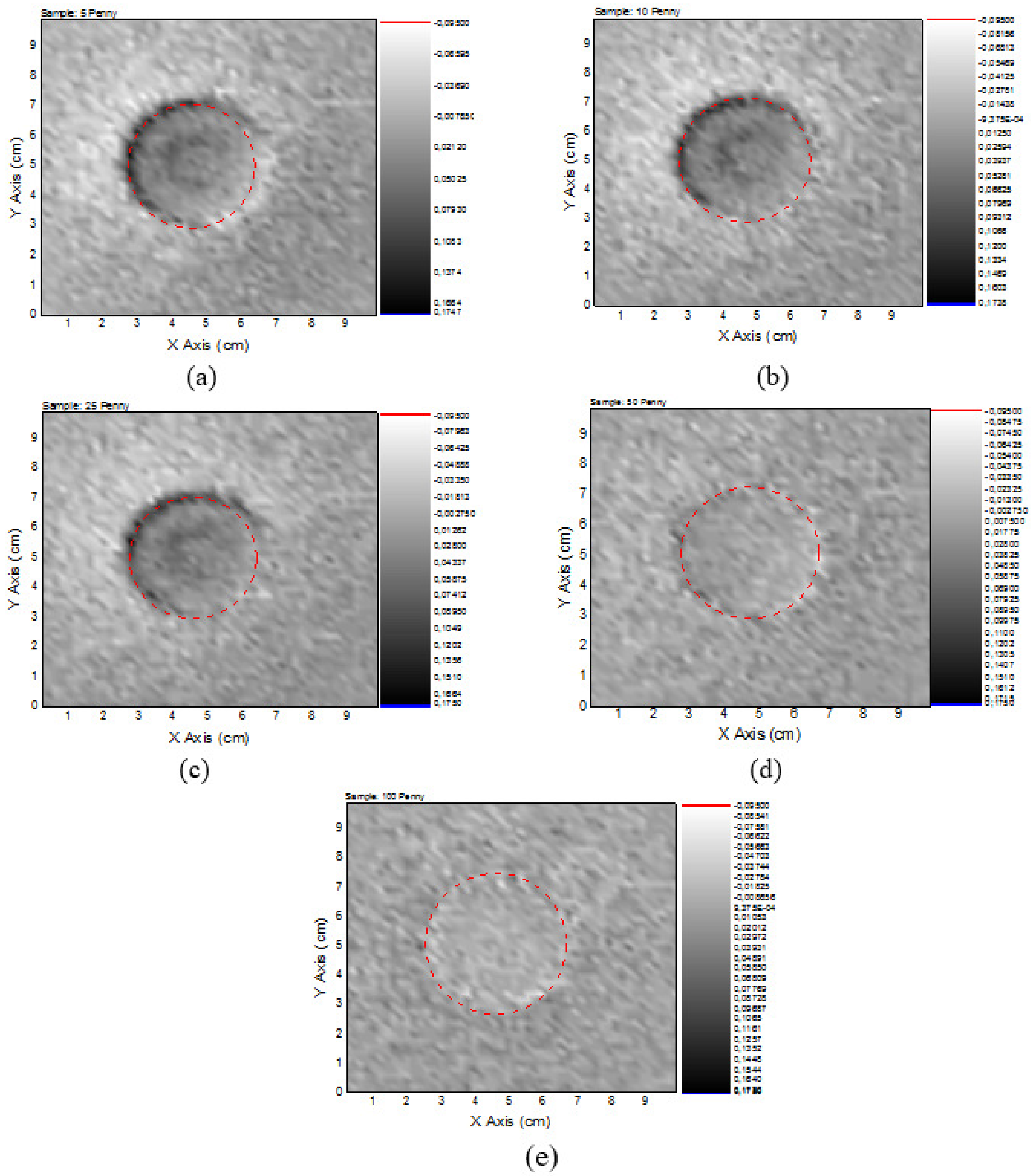


Figure 7. The graphs of tested coin samples a)5 Kurus, b)10 Kurus, c)25 Kurus, d)50 Kurus, e)1 Turkish Lira

## 4. Discussion and Conclusion

When we look at the experimental graphs obtained in the study, it is seen that there is a magnetic field change in the scan area as much as the cross section of the magnetic field source of the coil. It is also clear that the change shown in Figure 7a, b, c are different from that of Figure 7d, e. In this work, it is necessary to focus on the magnetic character, not the conductivity of metal particles. To concentrate the magnetic flux produced by the coil in the coin, the coin must have high magnetic permeability. As it is known, metals with the highest magnetic permeability are Fe, Ni, Co. So it is important that the tested coins contain these metals or not and what amount they contain. Table 1 shows that 5, 10 and 25 Kurus contain 18% nickel, 50 and 1 Lira contain 17% Nickel. A decrease in the Ni ratio will reduce the magnetic flux density on the platform side of the coin. That's why the graphics in Figure 7d and Figure 7e (for 50 Kurus and 1 Lira) are different from the others. Therefore, this measurement system can be able to identify groups of coins that have different Nickel content. If the diameters of the coins are determined by optic methods (as seen in Fig 1.), all the coins will be classified.

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