Optimization Frequency Design of Eddy Current Testing

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Abstract: The purposes of this research were to construct the nondestructive metal testing intrument by using eddy current method and to find an optimal frequency for the metal testing intrument. The testing intrument consist of a sine wave oscillator circuit which can adjust the frequency between 20 – 90 kHz, and a 50 ohms sensor circuit. There are three kinds of testing intrument. The first was the nondestructive imperfection testing by using eddy current method. The sample irons are constructed with different imperfection on surface. The output signals of testing from the sensor circuit are compared. The second was the nondestructive categorization metal testing by using eddy current method. Many kinds of metals are taken to testing. The last one was the nondestructive testing for finding the thickness of films on iron by using eddy current method. In this testing the thickness of films varied between 100 – 700 microns. In all testing, differences of the signal testing were compared to analyze the optimal frequency for the testing intrument. The results of research showed that the nondestructive metal testing intrument by using eddy current method can be used to find a different imperfective iron, categorize the metal and find thickness of films. In addition, the range of an optimal frequency is 30 kHz to 70 kHz for testing intrument.

Keywords— Nondestructive , eddy current, thickness of films, optimal frequency

1. Introduction

Nowadays Thailand has so many industrial developments; therefore, there are a lot of investors, both local and international. In order to be able to compete with other countries, Thailand needs to control its production standards and reliability [1]. Standards are the key factor for Thailand industry. That is to say, to develop industry means to develop technology for the most part. At the moment, there is technology called "nondestructive metal testing" which is widely used in the industry. This technology is used for 3 purposes, which are to ensure or assure the quality control, to test the quality according to the standards, and to keep maintenance. The widely used nondestructive metal testing method in the industry is "Eddy Current Method Testing" or ET , for example, to test metal quality or surface of metal. Eddy current could be made by high frequency magnetic field. The magnetic field happens when high frequency AC current enters primary coil. In case there is continuous space inside the work material, the eddy current will be higher. In case there is no continuous space inside the work material, the eddy current will be lower. This difference could be used to measure the continuity of the work material by using eddy current [2-4]. This research was to design and develop nondestructive metal testing intrument by using eddy current method, which consisted of oscillator circuit which can adjust frequency and a 50 ohms sensor circuit, and to examine the impact of used frequency in testing as well.

2. Analysis and Design

Design of metal testing intrument was to be used in finding imperfection of iron, categorize many kinds of metal, and to find the thickness of films on iron surface by nondestructive testing. The researchers applied the principles of eddy current to design sine wave oscillator which could adjust frequency between 20 – 90 kHz, with a 50 ohms sensor circuit. Details related to the analysis and the design could be shown in forms of blocks controlling each part of for nondestructive metal testing intrument by eddy current method as follows:

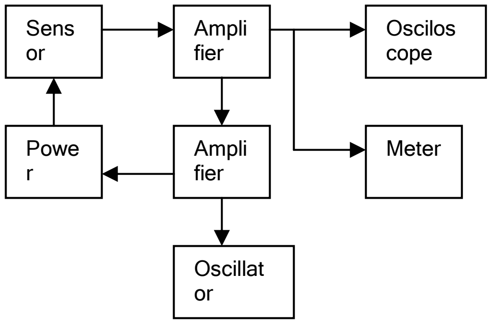

Figure 1. Components of the Nondestructive Metal Testing System by Eddy Current Method

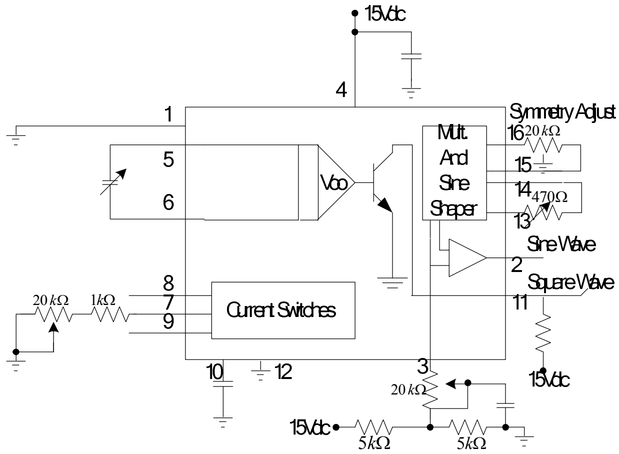

Figure 2 Wave Oscillator Circuit

2.1 Design of Wave Oscillator Circuit[5]

Sine wave oscillator circuit could be simply made by one IC in order to reduce the complexity of design and material. IC number XR2206 which could be found at a reasonable price and easy to design was used. The circuit structure was as shown in Figure 2 and the frequency is

$$f = \frac{1}{RC} \quad (1)$$

2.2 Design of Circuit for Electrical Voltage Amplification

Signal from oscillator circuit must be amplified so that it could be used in a practical way. Therefore, circuit for electrical voltage amplification must be designed by using op-amp number CA3130. This circuit would work faster and could be used with different range of frequency. Principle in design and practice was based on inverting type signal amplifier circuit. Gain rate depends on R_i and R_f and could be calculated by amplifier rate A_{CL} of circuit in Figure 2 as shown in the following equation:

$$A_{CL} = -\frac{R_f}{R_i} \quad (2)$$

Therefore, output could be calculated by the equation:

$$V_O = -\frac{R_f}{R_i} x E_i \quad (3)$$

2.3 Design of Circuit for Electrical Power Amplifier

Signal from oscillator circuit had to be amplified by inverting type amplifier circuit. The output signal was higher but that signal could not drive 50 ohms; therefore, this signal had to be amplified by transistor amplifier circuit. Transistor number H1061 was electrical power amplifier so that it could distribute voltage to 50 ohms sensor circuit

$$A_v = \frac{v_o}{v_{in}} = \frac{\beta R'_L}{r_\pi} \quad (4)$$

$$A_i = \frac{i_o}{i_{in}} = A_v \frac{Z_{in}}{R_L} \quad (5)$$

$$G = A_v A_i \quad (6)$$

$$V_o = A_v V_{in} = -V_s \quad (7)$$

2.4 Design of Sensor Circuit

Inductive coil was an electrical load. Electrical current which runs through coil would induct because magnetic lines of force took place inside inductive coil. Voltage drop for inductive coil from circuit could be calculated by the following equation:

$$V_L = L\frac{di_L}{dt} = L(\omega I_m \cos \omega t) = \omega L I_m \cos \omega t \quad (8)$$

When sensor circuit was used to test imperfection of metal by using nondestructive eddy current method and sensor circuit got closer to metal. The inductance value of the coil would change. This change was due to various reasons like metal type, size of imperfection, distance and oscillator frequency. Thus, inductance value of sensor changed differently.

3. Experiment

This experiment was to construct 3 kinds of nondestructive metal testing by eddy current method as follows[6-8]:

1. The first was to do a nondestructive test of metal imperfection by using eddy current method. The test was a simulation by making different imperfection size on metal and then sensor circuit was used to test

by adjusting frequency between 20 – 90 kHz during the experiment.

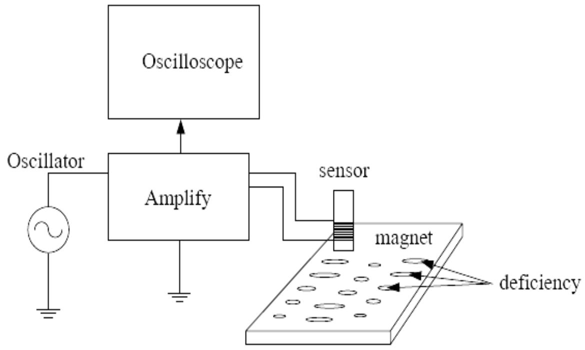

Figure 3 A Nondestructive Test of Metal Imperfection by Using Eddy Current Method

2. The second was to do a nondestructive categorization of metal by using eddy current method. The test was a simulation by taking many kinds of metal (iron, copper, brass, aluminum and stainless steel) to the test in order to categorize metal. The test was done by sensor circuit with a 50 ohms circuit and the frequency used was around 45 kHz during the test.

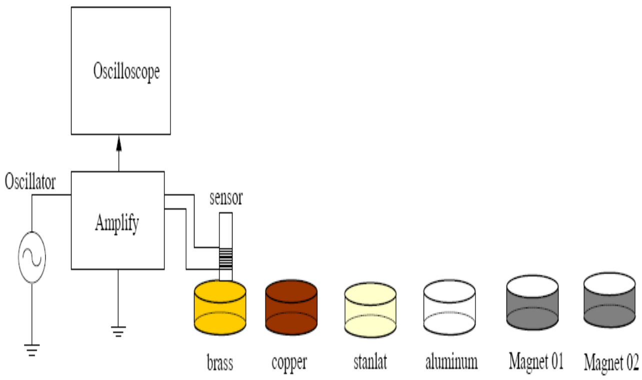

Figure 4. A Nondestructive Test of Metal Categorization by Using Eddy Current Method

3. The third was to do a nondestructive test for finding the thickness of films on iron by using eddy current method. The thickness of films in the test varied between 100 – 700 microns. The test would increase 100 microns of film thickness on each time and the frequency used was between 20 – 90 kHz in order to find out the optimal frequency. It was found that the frequency between 30 – 50 kHz showed the most obvious results of signal change. This frequency was then was the optimal frequency.

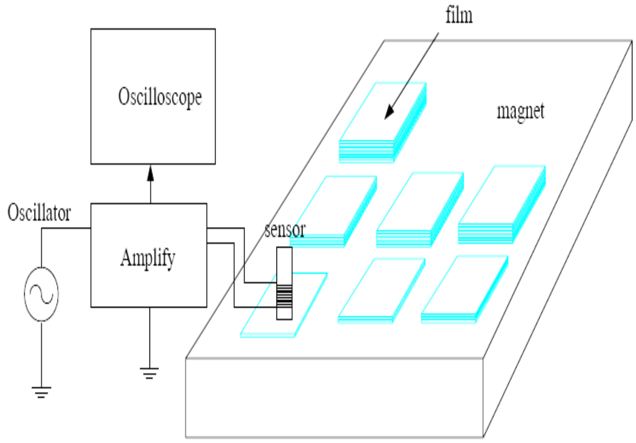

Figure 5. A Nondestructive Test to Find the Thickness of Films on Iron by Using Eddy Current Method

4. Results

4.1 Results for Nondestructive Test of Metal Imperfection

Nondestructive test of metal imperfection by using eddy current method was the test to find out the differences of imperfection in iron. Sample iron had been drilled with different width and depth on surface. The frequency used was between 20 – 90 kHz and then the output signals were plotted in a graph to compare the differences of imperfection.

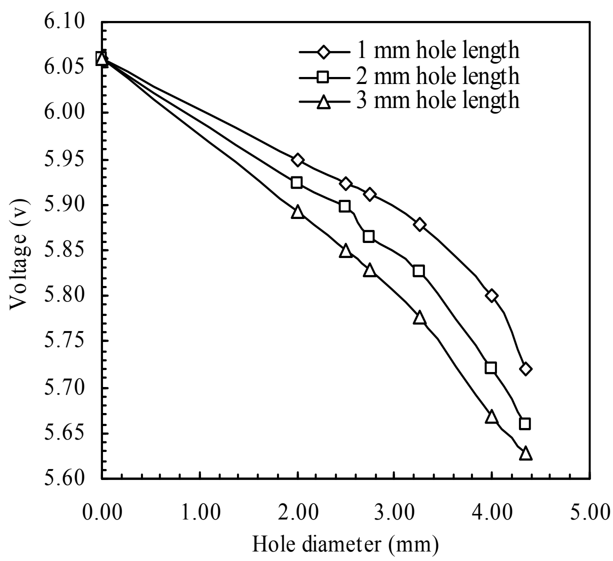

Figure 6. Iron imperfection at 40 kHz

4.2 Results for Nondestructive Test of Metal Categorization

Nondestructive test of metal categorization by using eddy current method was the test to find out the differences in kind of metal (iron, copper, brass, aluminum and stainless steel). The frequency used was around 45 kHz. The output signals were plotted in a graph as shown in Figure 7.

4.3 Results for Test of Film Thickness on Irons

Nondestructive test of film thickness on iron by using eddy current method was the test to find out differences in film thickness. Films with 7 different kinds of thickness were used for the test with different frequency. The output signals were plotted in graph to show the relationship towards to film thickness as Figure 8-9.

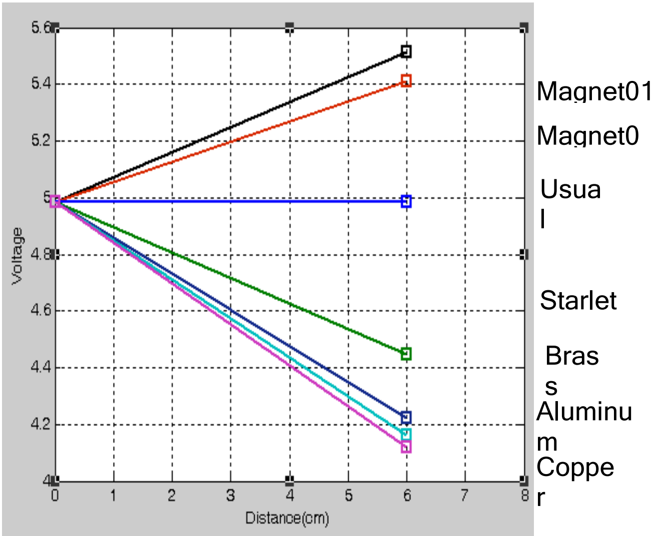

Figure 7 Graph for Electrical Attribute of Metal

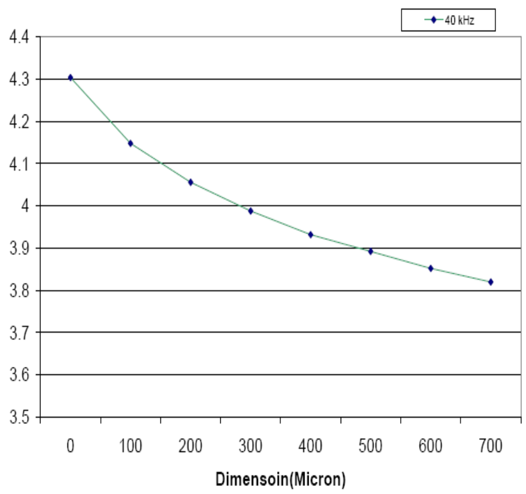

Figure 8 Typical Test at 40 kHz

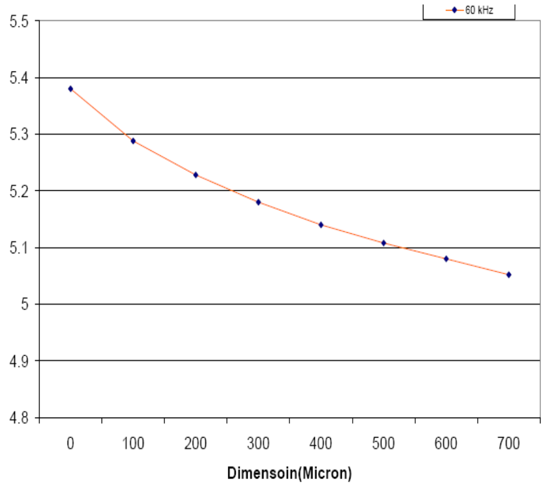

Figure 9 Typical Test at 60 kHz

5. Conclusions

This research was to propose how to design and construct nondestructive metal testing intrument by using eddy current methods. There were 3 kinds as follows:

1. Nondestructive test of metal imperfection by using eddy current method was a simulation test by making different imperfection size and then 50 ohms sensor circuit was used to test. It was found that the frequency between 50 – 70 kHz showed the most obvious differences and it was suitable for this kind of test.

2. Nondestructive test of metal categorization by using eddy current method was a simulation test by taking many kinds of metal to the test and then 50 ohms sensor circuit was used to test. It was found that iron showed the obvious differences and it was suitable for this kind of test.

3. Nondestructive test of film thickness on iron by using eddy current method was done by testing films with thickness of 100 – 700 microns. The test would increase 100 microns of film thickness on each time and the frequency used was between 20 – 90 kHz in order to find out the optimal frequency. It was found that the frequency between 30 – 50 kHz showed the most obvious differences and it was suitable for this kind of test.

From this study, it could be concluded that the testing instrument of eddy current method could be used to do nondestructive metal tests or related work in any industry. Due to the patent reason, the information of this instrument does not show in more detail.

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