Implementation Of The Preisach Model In A Simulation Environment For Virtual Experiments With Magnetic Hysteresis

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Abstract. There is a few simulation environment to implement the Preisach model of magnetic hysteresis. In this simulation, the changes of magnetic field strength and magnetic flux density will be observed. Magnetic hysteresis are commonly used in ferromagnetic and ferrimagnetic material analysis. The relationship between magnetic field strength and magnetic flux density is then represented in a B-H curve. The idea is that the B-H curve will be analyzed using Preisach model. Then, the data that is obtained could be analyzed further.
Keywords: Preisach Model

1. INTRODUCTION

Magnetic hysteresis applications used in common electrical devices such as hard disk and solenoid. Several of electrical devices that are require memory storage and experience rapid reversal magnetism depends on ferromagnetic material. There are two types of ferromagnetic material which are hard magnetic material (larger loop area) and soft magnetic material (smaller loop area).

Magnetic hysteresis is observed in ferromagnetic materials. It causes losses (heating) or inaccuracies in the properties of electromagnetic actuators. Since it is neither a unique function nor has a unique inverse, hysteresis is extremely difficult to model. Instead, it has a memory effect (Dr.-Ing. habil. Tom Ströhla, 2021). The relationship between magnetic field strength H and magnetic flux density B is non-linear and uncertain. The B-H curve is determined by the change of H. The magnetization curve is also influenced by the material's magnetic background. In the non magnetic state, the domains are statistically distributed. When an external magnetic field is applied, the domains are initially expand

2. LITERATURE REVIEW

The hysteresis word in Geek language means "lag behind" ("On the identification of Preisach measures"). Magnetic hysteresis is a state when a certain material, ferromagnetic and ferrimagnetic material is magnetized. Then the magnetized material will be demagnetized continuously until the value of magnetic field strength and the magnetic flux density reaches zero. An experiment with a single sheet tester and a round shaped experiment has been done to analyze the Preisach model to simulate the vector hysteresis properties (Kuczmann, 2009). Magnetic hysteresis starts with the initial magnetization curve as you can see in 2.1. It is a state when a ferromagnetic material is being attached to a magnet. The magnetic hysteresis curve is reached until the maximum saturation of the material. Then, the curve will reach to the opposite maximum saturation. Thus, the hysteresis loop is made. Ferromagnetic material is used in magnetic hysteresis. Ferromagnetic material can be magnetized when it is exposed to a magnet. Some material still attained their magnetic characteristics even when the magnet is removed. To explain it a little bit easier, there is an example such as, When a screw is attached by a magnet, the screw will gain a magnetic characteristic or also known as magnetic flux density. But when the magnet is removed from the screw, the screw still have a remaining magnetic flux density. This state is also known as remanence. To simplify, remanence is a condition where the magnetic field strength H is reduced to zero but there are some magnetic flux density B left in the loop.

3. METHODOLOGY

In this chapter there is one approach to find the desired area in the Preisach plane. The idea is by using numerical integration of the Preisach function to find the desired area. Then it will be implemented in a simulation environment. Visual Studio is chosen for the programming software.
Discretization of the Preisach Plane To calculate with the discretization of the Preisach equation, the Preisach plane needs to be divided by a small region.

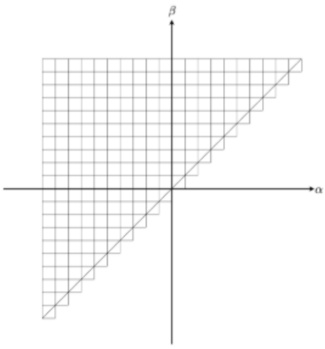

Figure 1. Preisach plane for sum calculation

To calculate, thus we need the Preisach formula then transform the original Preisach double integral formula to discretization:

$$B(t) = \sum_{i=1}^{N}\sum_{j=1}^{N} \mu(\alpha_i, \beta_j)\Delta\alpha\Delta\beta \tag{3.1}$$

Where

$$\Delta\alpha = \Delta\beta \tag{3.2}$$

$$\Delta\alpha = \alpha_{max}/n \tag{3.3}$$

Where n = Number of square in a row in the Preisach plane.

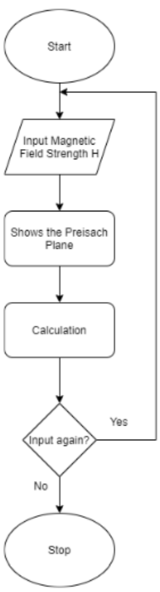

Figure 2. Flow Chart of the Program

First, the user input the magnetic field strength H value and then the value of alpha and beta created based on magnetic field strength H value . Then the program will create the Preisach plane. In the Preisach plane, there is a Preisach line that is constructed by the input value of magnetic field strength H. When the Preisach line is built, then the maximum saturation region and minimum saturation region will be calculated. From there, the magnetic flux density will be acquired. Last, the program will stop.

4. RESULT

In this chapter, the double integral Preisach equation (2.2) will be analyzed further to obtain the magnetic flux density. The following Preisach function (2.7) will be used in the equation:

$$\mu(\alpha, \beta) = e^{\alpha^2/a} + e^{\beta^2/b} \tag{4.1}$$

Where

$$\alpha = (i - n)\Delta\alpha \tag{4.2}$$

$$\beta = (j - n)\Delta\beta \tag{4.3}$$

Then the disretization of the Preisach equation will be used:

$$B(t) = \sum_{i=1}^{N}\sum_{j=1}^{N} e^{\alpha^2/a} + e^{\beta^2/b}\Delta\alpha\Delta\beta \tag{4.4}$$

Next, the Preisach function will be used in the equation:

$$B(t) = \sum_{i=1}^{N}\sum_{j=1}^{N} \Delta\alpha\Delta\beta(\mu(\alpha,\beta)_{i,j} + \mu(\alpha,\beta)_{i-1,j} + \mu(\alpha,\beta)_{i,j-1} + \mu(\alpha,\beta)_{i-1j,-1})/4 \tag{4.5}$$

By using equation (4.5), the area of the maximum saturation and minimum saturation are acquired. Thus, the magnetic flux density could be obtained through:

$$B = (S_+ - S_-)/S_{max} \tag{4.6}$$

Where Smax is all of the area in the Preisach plane which is S+ area plus S− area. Discretization of Preisach equation (4.5) is used to make the calculation of double integral Preisach equation easier. For the simulation, the magnetic field strength will be applied. The input for this program is the magnetic field strength H.

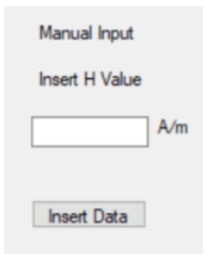

Figure 3. Preisach Plane magnetic field strength H input

From these magnetic field strength, the Preisach plane and Preisach line could be built. The graph could be seen below:

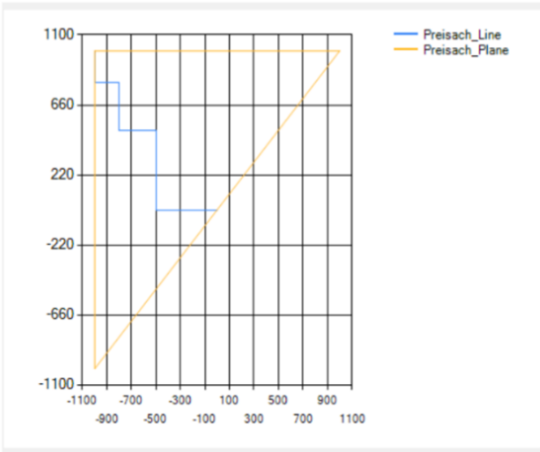

Figure 4. Preisach Plane Simulation

After the Preisach plane is built, then the program will calculate the S+ region, S− region, the region difference, total region, the minimum value of magnetic flux density, and the maximum value of magnetic flux density.

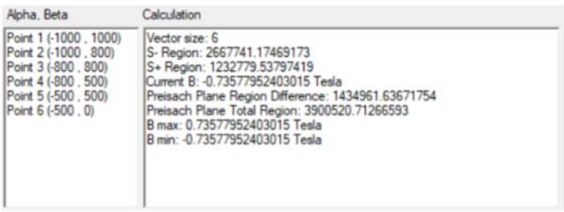

Figure 5. Calculation Simulation

From the figure 5 calculation above, the value of S+ region and S− region could be obtain with the formula in (4.5). The saturated region difference could be obtain with the formula:

$$S_{diff} = S_{+} - S_{-} \tag{4.7}$$

The total saturated region could be obtain with the formula:

$$S_{total} = S_{+} + S_{-} \tag{4.8}$$

In figure 6, the simulation works perfectly to delete a previous smaller value of magnetic field strength H and make the new state of Preisach line.

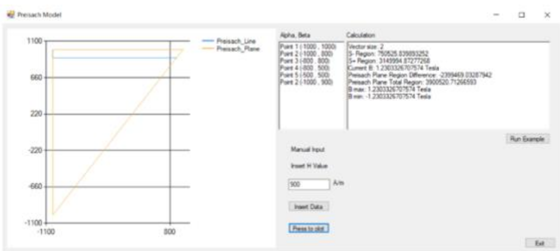

Figure 6. Preisach plane delete previous smaller H values

5. CONCLUSION

The analysis that had been done, has fulfilled some of the objective of the research. The implementation of discretization of the Preisach model helps the calculation of the Preisach plane. The calculation using discretization helps to determine the area in each region, positive and negative saturation region, in the Preisach plane. The data that is obtained through this simulation will provide to further analysis in electromagnetic equipment. Building a simulation environment in Visual Studio using C++/CLR Windows Forms extension with .NET language and C++ language is a new experience for the writer. With no experience in .NET language, this research is quite challenging to accomplish. The extension that has been used in this simulation proved that it is able to plot graph and insert desired values to the graph and has fulfilled it’s purpose.

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