

Hysteresis Modelling of Soft Magnetic Materials using LabVIEW Programs

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Abstract—The paper deals with an analytical model for hysteresis cycle representation. The hysteresis curve is decomposed in a series of arcs of circles and segments of lines. Each arc of circle or segment of line is expressed using analytical geometry as a function of some given parameters or calculated ones. The easiness of the model proposed is given by the small amount of input data needed to represent the hysteresis cycle in a satisfactory way. Using an inverse mapping function from major hysteresis branches the minor cycles, reversal curve of the first kind or curve of first magnetization can be obtained. Finally a comparison between the measured data and modelled ones was made.

Index Terms—soft magnetic materials, modeling, magnetic hysteresis

I. INTRODUCTION

For magnetic materials one of the most important characteristics is the hysteresis cycle. In numerous technical applications it is necessary to have a mathematical representation of magnetic characteristics in form $M = f(H)$ or $B = f(H)$ in order to calculate magnetic field especially in various machines or apparatus [1]–[5].

For example, some modelling program for electrical motors, like Flux 2D or 3D, need parameters extracted from first magnetisation curve to can model the behaviour of the magnetic flux. The modeling program can give this curve starting from major hysteresis loop.

There are many physical models used for modelling the hysteresis cycle [5]. Many of them are not so easy to implement and require too many data to be introduced or are time consuming. A simple analytical model was presented in [1] which uses segments of line and arcs of circle to express the hysteresis cycle. In [1] is presented the model using 11 parameters and hard magnetic materials. This paper presents an improved model for modelling the hysteresis cycle having the smallest amount of input data possible usable for soft magnetic materials. It is impossible to compare the two analytical models because the magnetic material modelled is different. The easiness of using this model consists in the fact that it uses only nine parameters as input data, is very quick computed and give a good approximation of the measured hysteresis cycle.

Finally a comparison was made between the hysteresis cycles obtained from measurements using an industrial installation (Brockhaus Messtechnik) and by modelling using the proposed analytical model. The material in study was the electrical steel sheets type M800-65A used for electrical machines manufacture. These results were plotted on the same graph for comparison of the results in order to make some remarks about the easiness to implement the model in practice.

II. HYSTERESIS MODELLING USING SEGMENTS OF LINES AND ARCS OF CIRCLE

The model proposed for representing the hysteresis cycle is based on analytical geometry. First step is to write the analytical form of equations representing segments of line and arcs of circle. These segments of line and arcs of circle are linked together for modelling the branches of the major hysteresis cycle.

For start it was made the supposition that the hysteresis cycle will be symmetrical to the origin of the axes. Consequently it is enough to construct the descending branch and after that using an inversion it will be obtained the ascending branch.

For modelling the descending branch, several reference points were considered and between them will be considered an arc of circle or a segment of line.

As can be seen in Figure 1, for modelling of the descending branch there are seven points to be considered, as follows:

- 1 the saturation point where the parameters H_s , B_s and the tangent to the hysteresis cycle must be given.
- 2 the inflexion point between two arcs of circle, where is supposed to know the values of the parameters H_2 and B_2 .
- 3 the remanence induction point
- 4 the coercive magnetic field strength
- 5 a point where the cycle start to bend in a arc of circle shape
- 6 a point where two arcs of circle are joined,
- 7 the negative saturation point.

It is important to remark that the number of points needed to represent the hysteresis cycle is reduced at minimum possible. Finally the input data are reduced at only 9 terms, considering that the hysteresis cycle is symmetrical to origin of the axes. The 9 terms are the follows: H_s , B_s , n_s (slope of the tangent to the hysteresis cycle in the saturation point), H_2 , B_2 , B_r , H_c , H_6 , B_6 . For better accuracy it is important that the points 2 and 6 to be correctly placed on the hysteresis loop.

It is possible to use a program to correct the position of these two points in order to obtain the smallest error between the measured cycle and the modelled one. These corrections are possible if the measured data have enough points for better accuracy. For this reason it was made a measuring system based on a LabVIEW program. But the modelling program can be used for every type of hysteresis cycles given in literature.

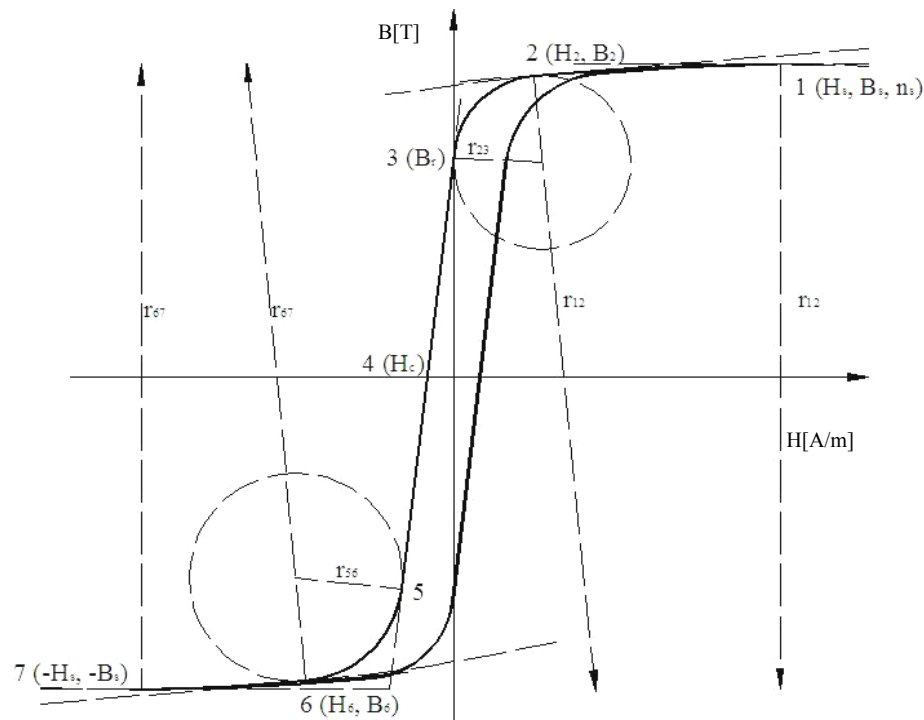


Figure 1. Considered points on the descending branch used for analytical modelling of hysteresis cycle.

III. REPRESENTATION OF HYSTERESIS CYCLE USING THE PROPOSED ANALYTICAL MODEL

A short description of the calculus made for obtain the hysteresis cycle using this model is given below. From point 1 to point 2 is drawn an arc of the circle. For this arc the parameters of point 1 (H_s, B_s, n_s) and point 2 (H_2, B_2) are

known. In order to obtain an arc of the circle it was necessary to know the radius and the centre of the circle. For this reason it was calculated the median point of segment 1-2 and the slope of the normal in this point. Intersecting the normal to the slope n_s in point 1 with the perpendicular to the cord in the median point, we obtain the coordinates of the centre of the circle which passes trough points 1 and 2.

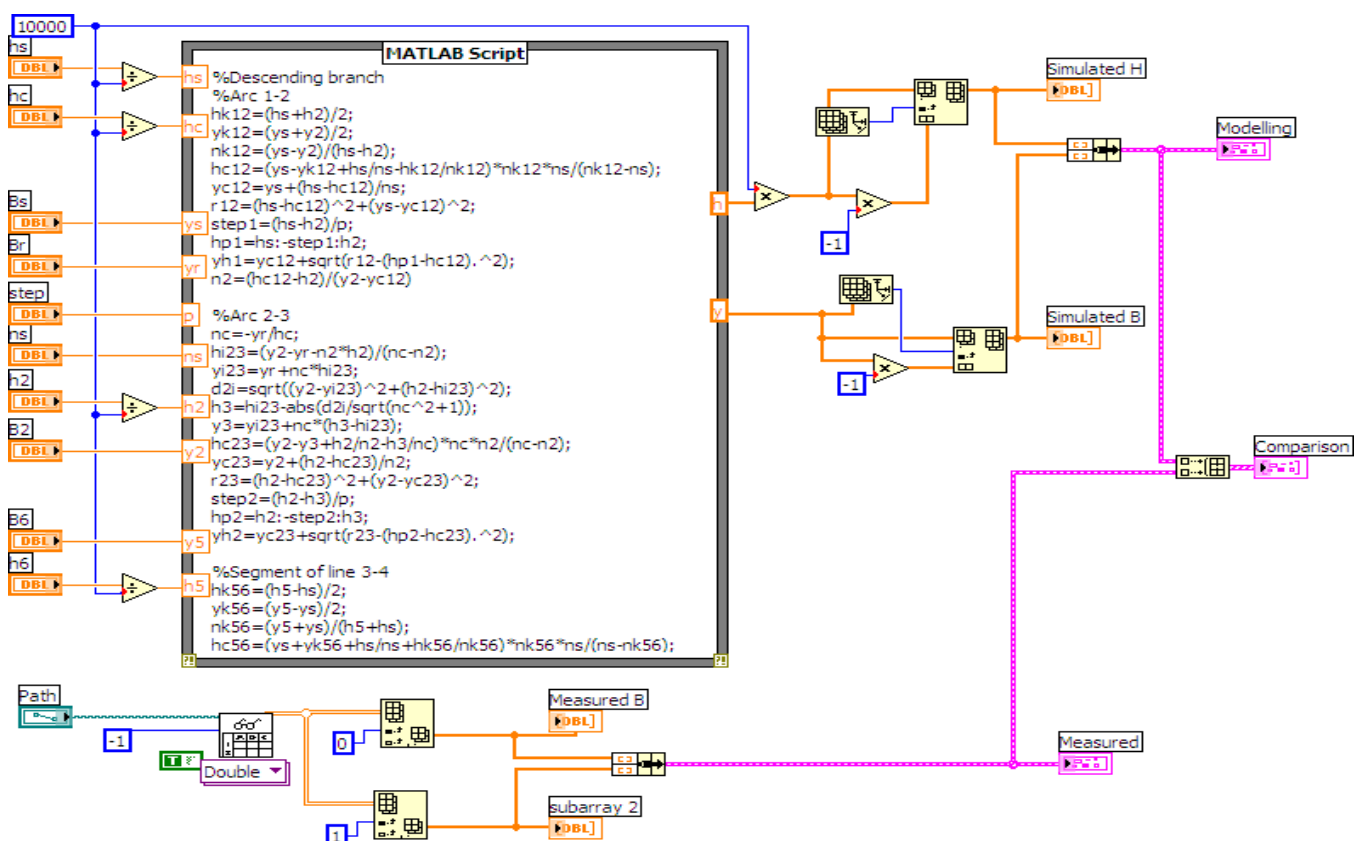


Figure 2. LabVIEW program used for analytical modelling of hysteresis.

From this results the radius of the circle can be calculate and the arc of circle from 1 to 2 can be drawn. Also we can calculate the slope in point 2 named n_2 . In the same manner it was drawn the arc of circle from 2 to 3 knowing the coordinate of point 2 and 3. For obtaining the coordinate of point 5 it was made an inverse calculation, starting from point 7. We know the coordinate of point 7 and 6 and can construct the arc 6-7 in a manner described at arc 1-2. After that knowing the coordinate of point 6 and the slope of the segment of line 3-4-5 it is possible to construct an arc of circle which is tangent in point 6 and to line 3-4-5. After that it is possible to construct the segment of line from point 3 to 5.

The segment of line from 3 to 5 is calculated having the slope of the line and points of intersection 3 and 5. Slope is determined by the remnant induction (point named 3) and - the coercive field strength (point named 4).

In Figure 2 is presented the LabVIEW program which has a MathLAB script block in which the main program was realized. The plotting and other controls are made by VI

modules from LabVIEW to give a friendlier interface to the user and real time control of program.

The program can be implemented in other programming languages but the results will be the same. For our program the results are the plotted in a graph, and the result of measuring system was plotted on other graph and for comparison these two characteristics are plotted on the same graph as can be seen in Figure 3. The material used for comparison was a steel sheet type M800-65A having the thickness of 0.65 mm. For this material in the minimum magnetic polarization for a magnetic field of 10000 A/m is 1.78 T. The measurements have been made using Epstein frame method on an automated device from Brockhaus Messtechnik type DEM-25N.

The initial modelling program was improved by adding other program lines which can construct the reversal curves of the first kind, starting from major hysteresis loop using an analytical method called inverse mapping. The reversal curve of first kind can be seen in Figure 4.

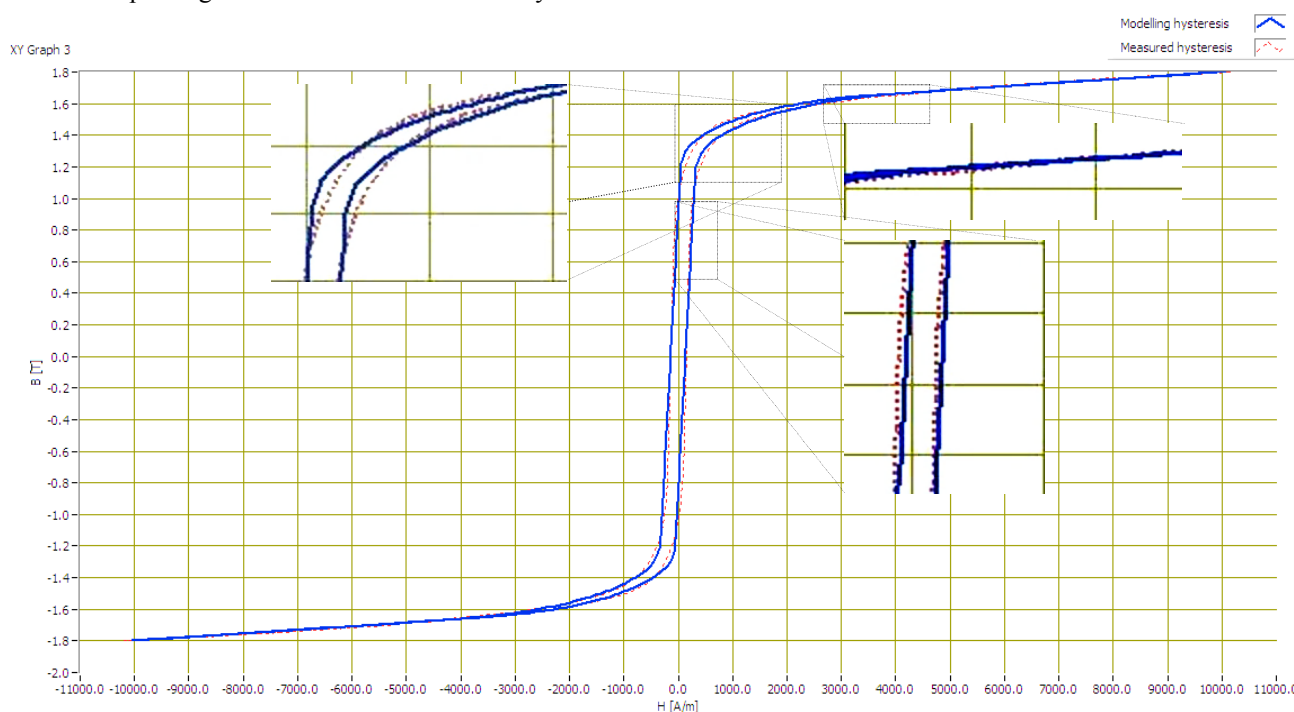


Figure 3. Comparison between measured and modelled hysteresis cycle obtained.

Any point of the minor or reversal curves can be expressed starting from ascending or descending branch of major hysteresis loop using one of following expressions [1]:

$$H = H_{ab} + (H_1 - H_{ab1}) \cdot \Psi_{ab}(B) \quad \forall B \in [-B_s, B_s] \quad (1)$$

or

$$H = H_{db} + (H_2 - H_{db2}) \cdot \Psi_{db}(B) \quad \forall B \in [-B_s, B_s] \quad (2)$$

where:

H - is the value of magnetic field calculated using inverse mapping function

H_1, H_2 - is the value of starting point for minor loop or reversal curve on ascending respectively descending branches

H_{ab}, H_{db} - abscissa of a point placed on the ascending or descending branches of major hysteresis loop

H_{ab1}, H_{db2} - corresponding value for H_1, H_2 on the major hysteresis loop

$\Psi_{ab}(B), \Psi_{db}(B)$ - auxiliary mapping functions for ascending and descending branches

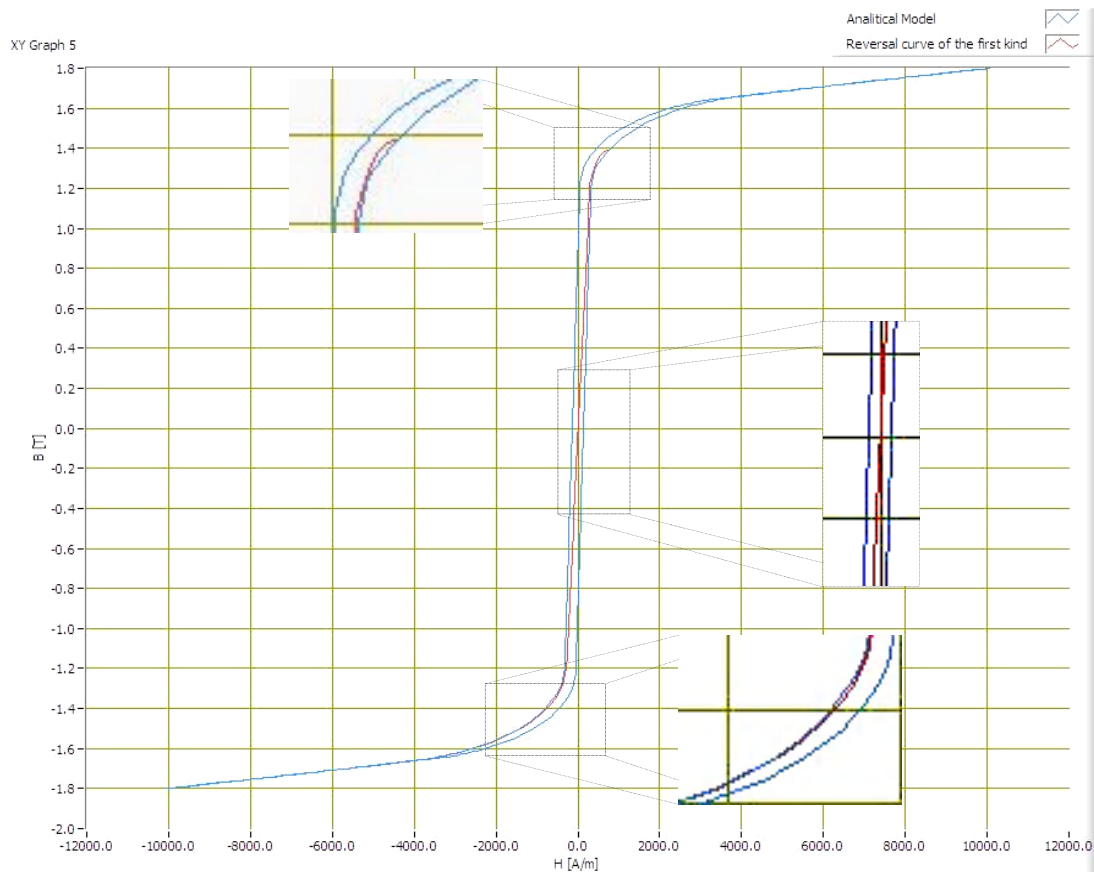


Figure 4. Reversal curve of first kind obtained using inverse mapping function.

For auxiliary function it was used the following expression:

$$\Psi_{db}(B) = \left[\frac{B + B_s}{H_{db2} + H_s} \right]^w \quad (3)$$

where

$$w = \left(1 + \frac{H_2}{H_s} \right)^v \cdot \left[1 + \left(\frac{2}{\pi} \arctan g \frac{B}{uB_s} - q \right) \right] \forall H_2 \in [-H_s, H_s] \quad (4)$$

the following constants results after identification and have been used for representations: $g=1$, $q=0.2$, $u=0.5$ and $v=3.5$.

IV. CONCLUSION

The analytical model for hysteresis cycle representation based on the decomposition in a series of arcs of circles and segments of lines is developed and implemented with LabVIEW program using Data Acquisition Board driven. The proposed modelling program approximates in a satisfactory way the measured hysteresis cycle. The model was tested on other hysteresis cycles obtained from industrial devices, and the approximation was satisfactory. Using two inverse mapping functions can be obtained the minor hysteresis cycles. This model is easier to implement taking into account the small amount of data needed for input.

A disadvantage is fact that all analytical models can predict the behaviour of the material on different excitation but cannot predict the phenomenon which takes place inside

of the material. Even if the Preisach model is more used for modelling the hysteresis cycle the amount of input parameters is greater than those needed for our model, and need to make some extra experimental measurement in order to determine the probability function. The error between the measured and modelled data will be presented in further works which adjust the position of point 2 and 6 to obtain the minimal error.

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REFERENCES

- [1] A. Nicolaide, Magnetism and Magnetic Materials, Transilvania University Press, Brasov, Romania, 2001.
- [2] E. Della Torre, Magnetic Hysteresis, IEEE Press, New York, 1999
- [3] A. Nicolaide, Electromagnetics, Transilvania University Press, Brasov, Romania, 2002.
- [4] S. Motoasca, A. Nicolaide, E. Helerea, Simple Analytical Method for Hysteresis Modelling using LabVIEW, JOAM, Vol 10, ISS 7, p.1847-1852, july, 2008.
- [5] Sarospataki, E., Kuczmann, M., Realization of the Jiles-Atherton Hysteresis Model Applying The LabVIEW And MatLab Software Package, Journal of Electrical Engineering, Vol 57. No 8/S, 2006, pp. 40-43.