SIMPLE ANALYTICAL METHOD FOR HYSTERESIS MODELLING USING LABVIEW

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Key words: Hysteresis modelling, LabVIEW program, Magnetic materials.

The paper deals with an analytical model for hysteresis cycle representation. The hysteresis curve is decomposed into a series of arcs of circle and straight-line segments. Each arc of circle or straight-line segment is expressed using analytical geometry as a function of some given parameters or calculated ones. The easiness of the proposed model is given by the small amount of input data needed to represent the hysteresis cycle in a satisfactory way. Using an inverse mapping function of 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. The analytical model was implemented with LabVIEW program using Data Acquisition Board driven. The LabVIEW programs for measurement system and analytical model can be coupled in an extended program. In this way, the time for the measurements can be reduced only at the time necessary to obtain the major hysteresis loop, and the analytical model can made the rest of the needed characteristics: reversal curve of the first kind, minor hysteresis cycles.

1. 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 [1–6].

There are many physical models used for modelling the hysteresis cycle. Many of them are not so easy to implement, require too many data to be introduced or are time consuming. A simple analytical model was presented in [1] which uses straight-line segments and arcs of circle to express the hysteresis cycle. This paper presents an improved model for modelling the hysteresis cycle having the smallest amount of input data possible suitable for soft magnetic materials. The easiness of using this model consists in the fact that it uses only nine parameters as input data,

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Rev. Roum. Sci. Techn. – Électrotechn. et Énerg., **55**, *3*, p. 261–267, Bucarest, 2010

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 and by modelling using the proposed analytical model. 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.

2. HYSTERESIS MODELLING USING STRAIGHT-LINE SEGMENTS AND ARCS OF CIRCLE

The model proposed for representing the hysteresis cycle is based on analytical equation of straight-line segments and arcs of circle. These straight-line segments and arcs of circle are used for modelling the branches of the major hysteresis cycle.

At the beginning there has been assumed that the hysteresis cycle will be symmetrical to the origin of the axes. Consequently, it is enough to construct the descending branch and then, by using an inversion, the ascending branch will be obtained.

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

As it can be seen in Fig. 1, for modelling the descending branch seven points have 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 the values of the parameters H_2 and B_2 are considered to be known;
3 − the remanence induction point;
4 − the coercive magnetic field strength;
5 − a point where the cycle curve begins to bend as an 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 to minimum possible. Finally the input data are reduced to only 9 terms, considering that the hysteresis cycle is symmetrical to the origin of the axes. The 9 terms are the following: H_s, B_s, n_s (slope of the tangent to the hysteresis cycle at the saturation point), H_2, B_2, B_r, H_c, H_6, B_6. For a better accuracy it is important that the points 2 and 6 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 a measuring system based on a LabVIEW program was written. But the modelling program can be used for every type of hysteresis cycles of soft magnetic material given in literature.

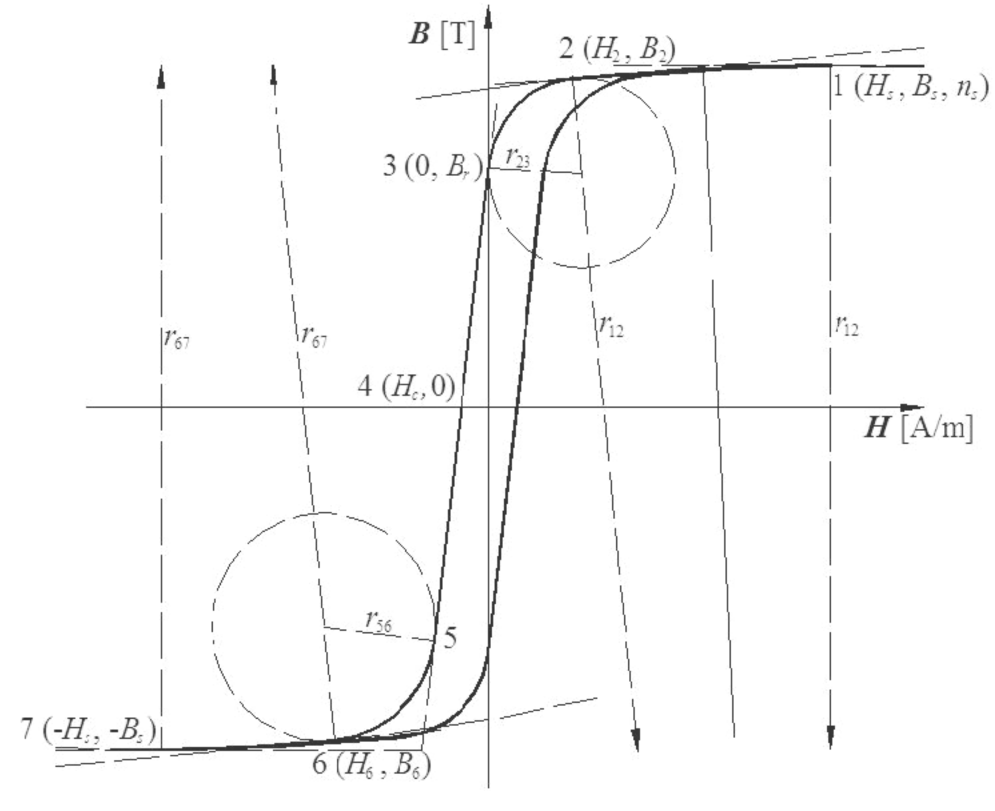

Fig. 1 – Considered points on the descending branch used for analytical modelling of the hysteresis cycle.

3. REPRESENTATION OF THE HYSTERESIS CYCLE USING THE PROPOSED ANALYTICAL MODEL

A short description of the calculation made for obtaining the hysteresis cycle using this model is given below. From point 1 to point 2 an arc of the circle is drawn. 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 there was calculated the median point of segment 1-2 and the slope of the normal at this point. Intersecting the normal to the slope n_s at point 1 with the perpendicular to the cord at the middle point, we obtain the coordinates of the centre of the circle which passes trough points 1 and 2.

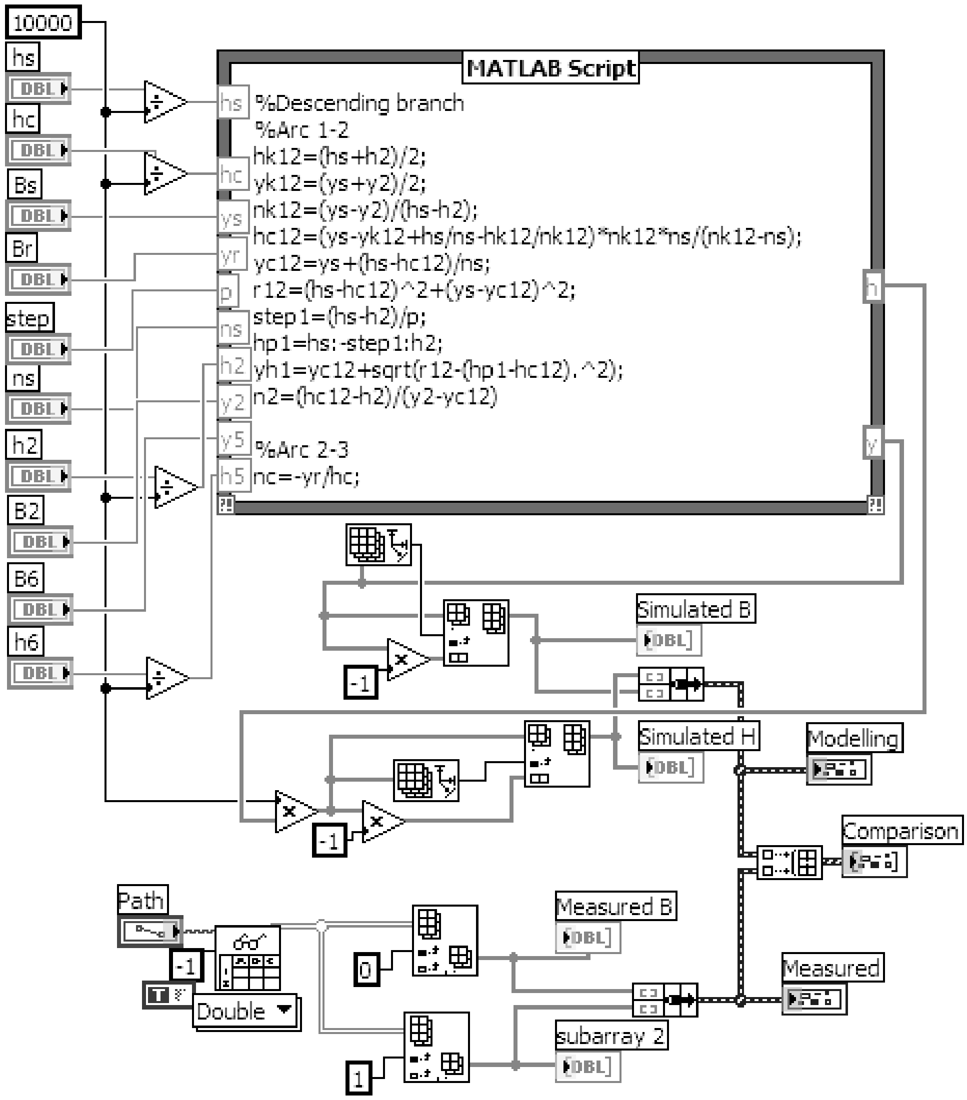

Fig. 2 – LabVIEW program used for analytical modelling of hysteresis.

From this results, the radius of the circle can be calculated and the arc of circle from 1 to 2 can be drawn. Also, we can calculate the slope at point 2 named

n_2. In the same manner it was drawn the arc of circle from 2 to 3, knowing the coordinates of points 2 and 3.

For obtaining the coordinate of point 5 an inverse calculation was made, starting from point 7. We know the coordinate of point 7 and 6 and we can construct the arc 6-7 in a manner described for the arc 1-2. Then knowing the coordinates of point 6 and the slope of the straight-line segment 3-4-5 it is possible to construct an arc of circle which is tangent at point 5 to line 3-4-5 and pass through point 6. Then it is possible to construct the straight-line segment from point 3 to 5.

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

In Fig. 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.

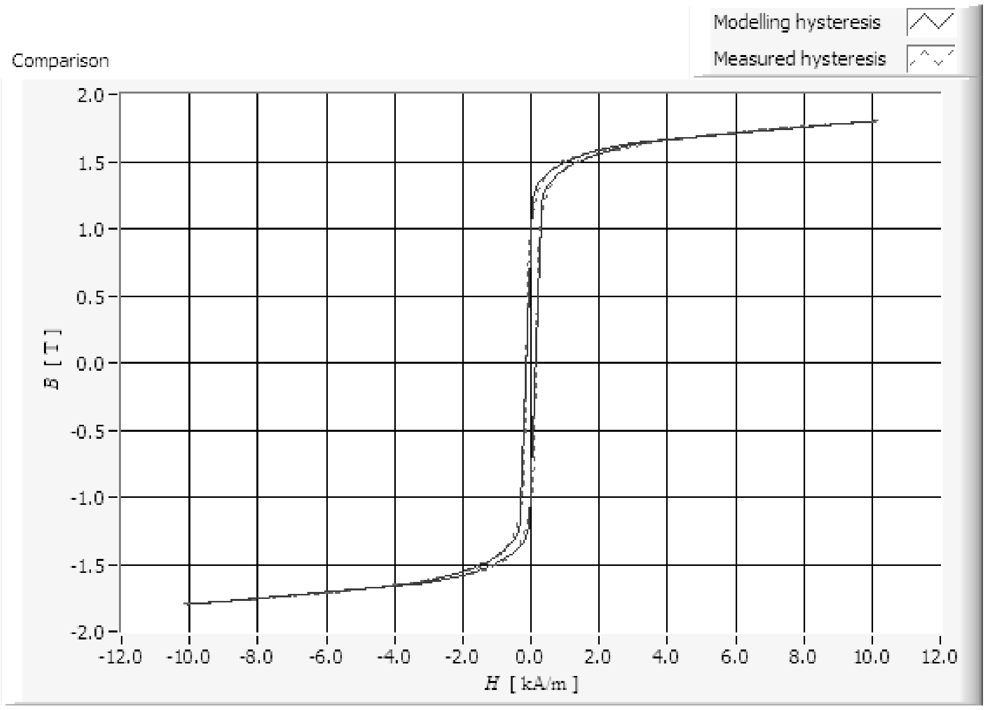

Fig. 3 – Comparison between measured and modelled hysteresis cycle obtained.

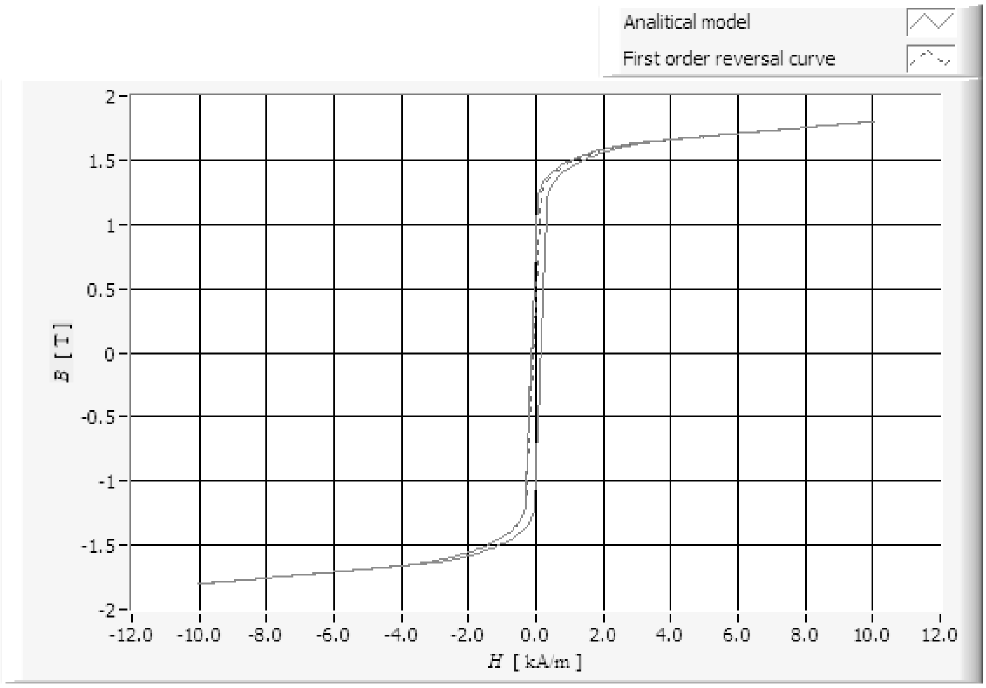

Fig. 4 – Reversal curve of first kind obtained using inverse mapping function.

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 comparing these two characteristics they are plotted on the same graph, as can be seen in Fig. 3.

The modelling program can be further improved by adding other program lines, which can construct the reversal curves of the first kind, or minor hysteresis loops, starting from the major hysteresis loop using an analytical method called inverse mapping (Fig. 4).

4. CONCLUSION

The analytical model for hysteresis cycle representation based on the decomposition into a series of arcs of circles and straight-line segments 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 for soft magnetic materials. The model was tested on various soft magnetic materials used in industrial devices, and the approximation was satisfactory.

ACKNOWLEDGEMENT

This paper is supported by The National University Research Council of Romania (CNCSIS) under the contract number 848/2009

Received on Februry 3, 2009

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