Matlab in electrical engineering

Article *in* Journal of Electrical and Electronics Engineering · October 2009

Source: DOAJ

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Abstract* – Electrical Engineering education addresses to high technologies needs from industry and business offering academic curricula which include topics such as: integrated circuits, digital signal processing, microwaves, optical engineering, bioelectronics, propagation and radiation, power electronics, control systems, communications, circuit theory, robotics, nondestructive testing. Matlab is a widely used tool in electrical engineering. It can be used to enhance and accelerate some processes, such as magnetic field measurements. The original concept of a small and easy to use tool evolved to the "tool house" [1] concept. Nowadays it is accepted that many of its toolboxes can replace traditional instruments used in advanced electrical engineering applications (SPICE). This work presents the advantage of Matlab use in magnetic field analyses for flaw reconstruction using nondestructive testing.

***Keywords:* electrical engineering, Matlab, magnetic field, nondestructive testing**

I. INTRODUCTION

At the same time Matlab is a high level programming language and an interactive development software for technical computing. It allows the user to solve very fast tasks which require a huge amount of computation. This is possible due to its embedded functions and capabilities. Matlab offers extended graphical functions having easy to use tools for data display in a various formats. In order to extend this working environment beyond its standard capabilities there are a number of tools which can be inserted offering additional features for solving electrical engineering problems with the computer. It can be successfully applied in various fields such as: image processing, signal processing, communications, statistics, optimization, system control and system processing, etc. [1].

Almost all electrical engineering curricula use Matlab at some point. Many professors/instructors believe this application must be studied during first years of the college, especially during introductive electrical engineering lectures [2]. The use of Matlab in education not only improves and accelerates learning, but also helps the students to be prepared for a productive career.

Using Matlab based curricula the professors can build the base for an education which should help the students throughout the university. From specific lectures and laboratories till complex applications in industry, Matlab offers a flexible environment for multi-functional teams and for a multi-disciplinary research.

II. MATLAB VS. SPICE IN ELECTRONICS

Matlab and SPICE are frequently used in electrical engineering education. SPICE is used to simulate big circuits, while Matlab is more appropriate for small ones. SPICE includes device models (resistors, capacitors, transistors, inductors, etc.) which are not a part of Matlab environment.

Nowadays SPICE does not allow the users to determine the poles and zeros from electrical circuits. Matlab graphical and computing nature is more appropriate to describe intrinsic or extrinsic characteristics of the semiconductors. SPICE was not written to describe the semiconductor material characteristics [3].

III. THE USE OF MATLAB IN NONDESTRUCTIVE TESTING

One of the main research activities in magnetic field nondestructive testing is the theoretic and experimental study for flaw reconstruction with minimum errors using data collected by nondestructive testing tools [4].

To simulate real problems it is sufficient to simulate artificial flaws.

The cracks generated by corrosion tensions and the cracks appearing due to material aging not only have complicated shapes but they can appear as clusters having a complex conductivity distribution.

The separation problem of a signal caused by several cracks very close as shape and position can be reduced to a post-process signal analysis by using very efficient methods [5].

Modern nondestructive testing methods based on electromagnetic field properties are a very useful tool for flaw evaluation, but the present methods cannot be used for quantitative determination and they imply huge computation associated to high costs.

In the experimental activity were followed two important objectives. The first one, mainly dedicated to detection of aged areas [6], was the determination of B-H characteristics for different samples, before and after plastic deformation. One can notice a significant change in the B-H relation. The second objective was to measure the values of the flux density very close to the ferromagnetic body (magnetic stainless pipe).

A flaw was created having the shape of 2x1 mm channel. The measurements were used for flaw reconstruction [7].

Recent researches showed that when ferromagnetic materials go beyond their elasticity limit suffering plastic deformation, their B-H constitutive characteristics changes suggesting the possibility to exploit these changes in aged areas detection. In these areas there is a big probability to appear some critical cracks.

In installations such as nuclear facilities, where is required a high security functioning level, it is compulsory the replacement of the components (e.g. heat exchange pipes) before the cracks appear. Plastic deformation appears before the cracks. Beside the classical issues known in inverse problem in electromagnetic field, specific for flaw reconstruction, in the case of aged areas there is another problem – the variation of B-H characteristics is relatively small comparing with the case of cracks.

Among the nondestructive methods suitable for conductive materials, good candidates are the methods which exploit eddy currents properties. These techniques solve many problems with the condition that parameters are known and the interpretation of the results is done by an informed person.

Eddy current testing is based on the electromagnetic induction principles and it is used to underline the variations of physical, structural and metallurgical properties for bodies with an acceptable electrical conductivity.

Nondestructive testing based on electromagnetic induction does not imply a direct contact between the parts involved in the testing process. This is an important advantage of eddy currents testing. Another advantage, in comparison with other methods, is the high examination speed, almost in real time.

The big sensitivity of this method is both an advantage and a disadvantage (some electrical properties' variations of the body under test are not interesting from the point of view of its functioning in time, but they can produce changes of the control system which are difficult to interpret).

IV. CASE STUDY

The case study: a magnetic stainless pipe, having the inner circle of 25 mm, and the outer circle of 22 mm.

Inside the pipe is created a rectangular artificial flaw having the depth of 0.5 mm and the width of 1 mm.

The length of the flaw is sufficiently big, such that the plane parallel model to be accepted.

The flaw is created in such a manner so the rest of the pipe could be considered without flaws.

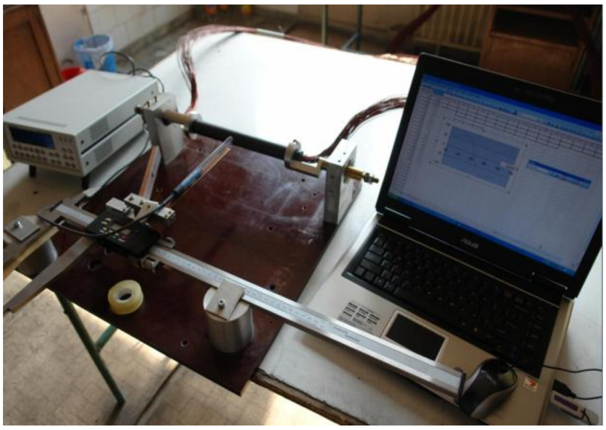
Outside the pipe there is the testing system (Fig. 1) used to measure the magnetic induction. This system can place the Hall probe along the pipe, with high precision, with a caliber and on the angle with a solver.

The normal component of the magnetic induction and the tangential component are measured.

For protection reasons in between the probe and pipe a thin plastic foil (0.1 mm) is placed.

The Gaussmeter LakeShore DSP 455 (Fig. 2) with a Hall probe is used for data acquisition.

Fig. 1 The measuring installation with the probe place in the coil's plane



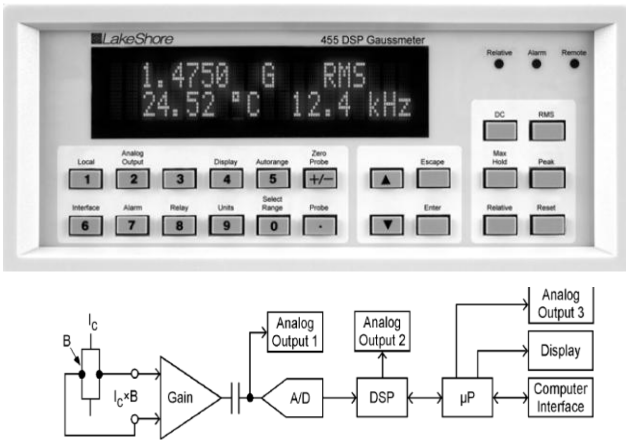


Fig. 2 LakeShore DSP 455 block diagram

The Model 455 digital signal processing (DSP) gaussmeter combines the technical advantages of DSP technology with many advanced features at a moderate price. DSP technology creates a solid foundation for accurate, stable, and repeatable field measurements.

Advanced features including DC to 20 kHz AC frequency response, peak field detection to 50 µs pulse widths, DC accuracy of 0.075%, and up to 5¾ digits of display resolution make the Model 455 ideal for both industrial and research applications. For added functionality and value, the Model 455 includes a standard Lake Shore Hall probe [8].

The sensor is the one that usually establishes the performance criteria for the given system. Many performance criteria can be applied for the measurement systems.

For signal-to-noise ratio reduction, each measured value is obtained by averaging 10 values of the same point.

Matlab is used to reduce and improve the measurement time allocated for each measurement, data acquisition being done automatically after the sensor is placed on the position.

The software developed in Matlab [9] (Fig.3) gives the user supplementary useful functions such as:

- measurement error reduction by using the mediation technique of the measured values in one point;
- zoom in, zoom out (Fig. 4),
- display the data in a graphical format immediately after the acquisition is over;
- display the portion with the flaw for a certain interval;
- compare two or more graphs for analyses and conclusions (Fig. 5);
- save the file in a certain format (.xls);
- importing and exporting data (Fig. 6);
- printing (Fig. 7);
- gives commands to the equipment to be executed directly from the computer;

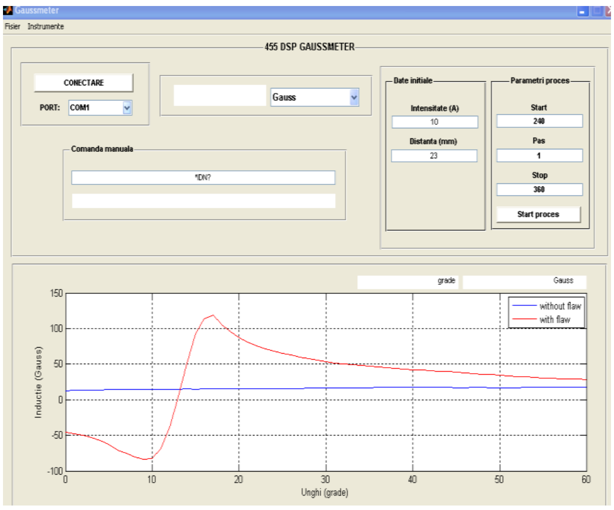


Fig. 3 User interface

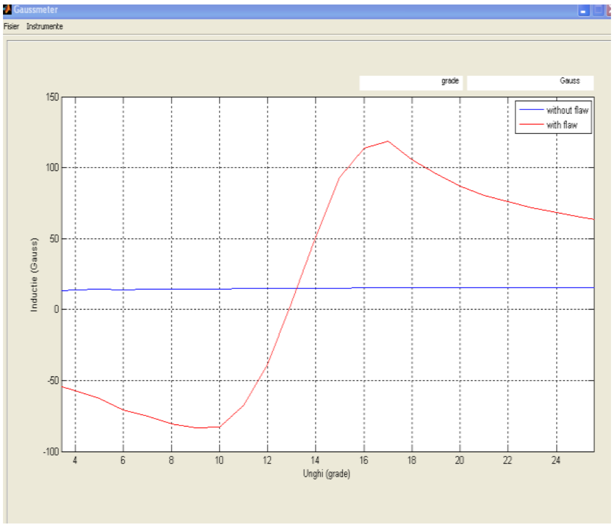
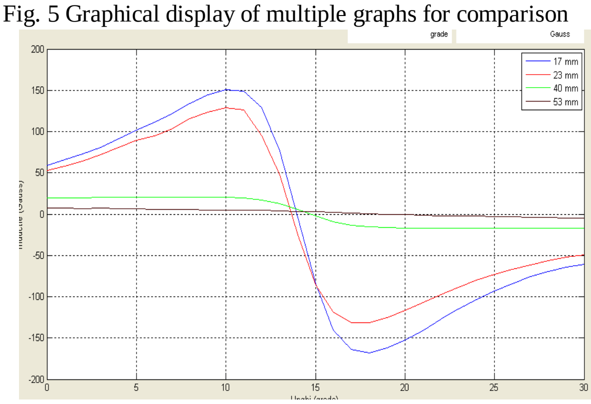


Fig. 4 Zoom function

Fig. 5 Graphical display of multiple graphs for comparison



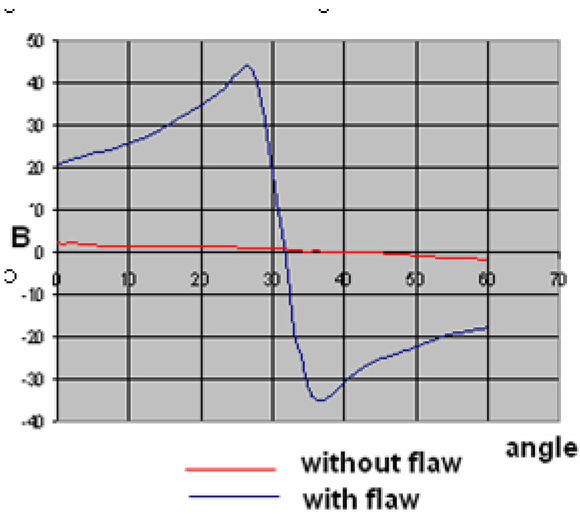


Fig. 6 Exporting graphs

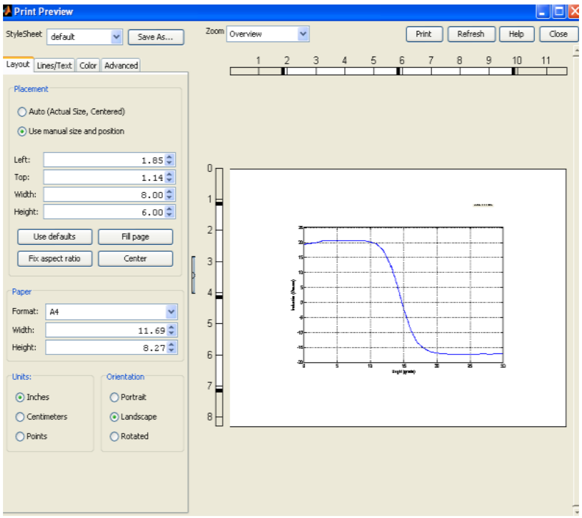


Fig.7 Printing function

V. CONCLUSIONS

Using Matlab to measure magnetic induction, at the pipe's surface, close to the flaw, the measuring time of data was diminished considerably.

The measurements are affected by noise – an error which should be eliminated. Because the errors in the case of flaw detection and reconstruction should be minimal, B-H characteristics variations are very small and taking into considerations that a small measurement error can lead to big variations in the system, by averaging we obtained values very close to real ones.

In this case, Matlab is very useful for data analyses. Its interactive and graphical nature allows the user to analyze and give immediate results being very appropriate to improve learning by a better understanding of electrical engineering fundamental concepts.

Future work should concentrate upon implementing in Matlab the algorithms developed for flaw shape reconstruction [9] and to their integration in a friendly-user interface.

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