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Stress Measurement on Carbon Steel Specimen by Consideration of Magnetic-Barkhausen-Noise

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ABSTRACT: In general, all manufacturing processes introduce residual stresses in the manufactured component. Residual stresses affect the design and fabrication of engineering structures, and their field service. So, for structural integrity studies, improvement and development of experimental procedures to determine the residual stresses were be considered by many researcher. In this study, design and prototyping of an appropriate system for non-detective residual stresses evaluation by considering of magnetic-Barkhausen noise were be present. The magnetic-Barkhausen noise analysis used in ferromagnetic materials is based on analysis of rapid irreversible magnetization changes called Barkhausen jumps. Developed system were used to obtained noise voltage level on some loaded carbon steel specimen. The magnetic-Barkhausen noise were dependent to stresses magnitude and direction on the specimen. By this, an appropriate relation for calculation of the stresses from measured voltage were be obtained. Relation coefficient were be corrected by presented calibration procedure. According to obtained results, the magnetic-Barkhausen noise techniques is capable to evaluation of some chemical, physical and mechanical character like residual stress on the industrial component.

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1- Introduction

The structural engineer often needs to estimate the continuum stress distribution over a field within a component to perform a defect tolerance assessment. In practice, stresses cannot be measured directly; instead the stress must be inferred from a measure of the elastic strain, displacement or secondary quantity, such as the speed of sound, or magnetic signature that can be related to the stress [1, 2].

It has long been known that the magnetic properties of ferromagnetic materials are sensitive to internal stress. When a ferromagnetic material is subjected to a varying magnetic field, the magnetic induction during magnetization varies in discrete steps, as the magnetic domain walls have to overcome various types of obstacle during their movement. These discrete changes in magnetization, known as "Barkhausen jumps", can be seen as steps in the hysteresis curve [3, 4]. Barkhausen noise (BN) is detected as a series of voltage pulses appearing on a coil placed near or around a ferromagnetic sample subjected to a time-varying external field [5].

The Barkhausen effect was discovered in 1919, but it was many years before its potential as a nondestructive evaluation (NDE) tool was realized. It is now one of the most popular magnetic NDE methods for investigating intrinsic properties of magnetic materials such as grain size, heat treatment, strain and other mechanical properties such as hardness. The primary advantages of magnetic methods are that they are very rapid and cost effective [6, 7].

Use of the Barkhausen effect for measuring stress is based on the fact that the size, shape, and arrangement of the domains in a bulk ferromagnetic material, and thus the detailed domain dynamics are strongly influenced by the state of mechanical stress among other influential factors [8].

In this study, design and prototyping of an appropriate system for non-detective residual stresses evaluation by considering of Magnetic Barkhausen Noise (MBN) were be considered. Then, an appropriate relation for calculation of the stresses from measured voltage were be obtained. Relation coefficient were be corrected by presented calibration procedure. Calibration procedure is very important for accurate and reliable results. Each material having remarkably different micro-structure should be separately considered for calibration.

2- Testing Equipment and Procedure

Stress measurement system consists of function generator, power amplifier, magnetic probes, the incoming voltage amplifier, analog to digital converters and data analysis computer.

The developed setup of stress measurement system with

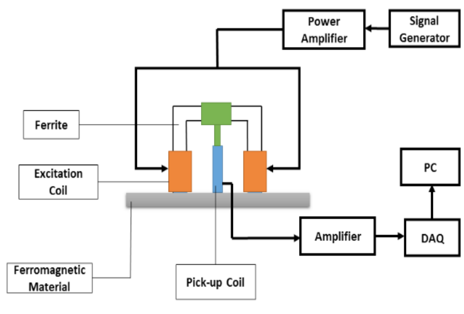

Fig.1. The developed setup of stress measurement system with magnetic Barkhausen method

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magnetic-Barkhausen method was shown in Fig.1.

A bar of St 37 carbon steel was machined along the rolling direction to produce an ASTM E8 standard specimen for tensile testing. The specimen was subjected to uniaxial tension using a tensile test machine. The specimen was magnetized with a Barkhausen probe consisting of a magnetizing coil wound around a ferritic C-core electromagnet in different case of applied stresses.

The sample without any tensional loading using by developed device has been tested and noise voltage recorded as Barkhausen signals value. Then a certain level of stress was applied to the samples and Barkhausen signal value corresponding to each stress is recording. All results recording were repeated for several time on the each specimen. For insurance of value repeatability, each data recording were down on three samples. Using Excel software, the average calculated signals, as shown in Table 1, calculated and used for future studies.

Table 1. The BN voltage recording in each test and its average

Applied stress MPa	First recording mV	Second recording mV	Third recording mV	Average value
0	247.6	282.8	253.0	261.1
30	391.8	392.0	382.9	388.9
60	374.5	407.9	489.7	424.0
90	510.9	483.4	479.9	491.4

Probe placement on samples when samples are subjected to certain loading, is presented in Fig. 2 and it is tried that all testing condition were be similar for each results recording.

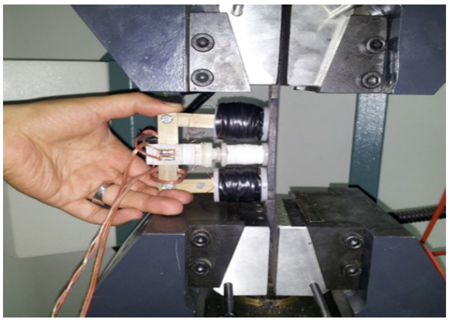

Fig.2. Testing condition during Barkhausen signal recording.

3- Results and Discussion

By consideration of obtained results it seems that Barkhausen effect value related to existing stress on specimen by a linear approximation. The relation called calibration relationship is unique equation for each material and stress measuring system. In this study, the calibration procedure is performed for steel ST37 as shown Fig.3.

According to Fig.3, the stresses value may be estimated by using a certain relation with acceptable deviation as Eq.(1).

Table 2. The existing stress, average voltage and error in using Eq. (1).

Applied stress MPa	Average value mV	Estimated Stress MPa	Measuring Error (%)
45	405.4	50.3	11.7
75	435.3	61.9	17.4

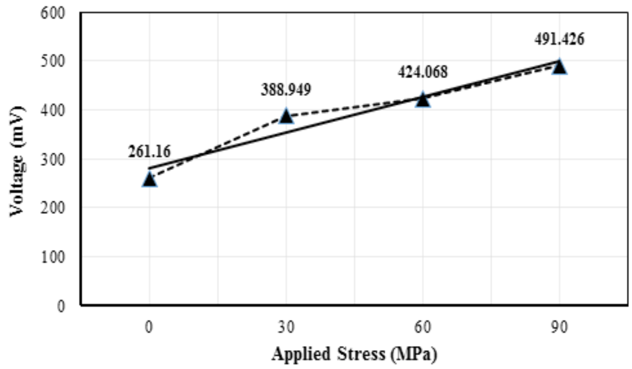

Fig.3. Variation of average of signal voltage to existing stress.

$$\sigma = 0.388 \times V - 107 \quad (1)$$

In this equation the parameters V and σ are noise voltage (mV) and stress (MPa) respectively. Using Eq.(1), for two different level of stress, the average Barkhausen noise signal were obtained. The estimated stresses and average noise voltage and measuring error were present in Table 2.

By employment of the results presented in Table 2, the new analysis was conducted and modified relation were obtained as:

$$\sigma = 0.403 \times V - 111.4 \quad (2)$$

This relation is higher accuracy and more reliable and may be used to stress estimation on carbon steel specimen.

4- Conclusions

In this research, the stress measurement device based to Barkhausen noise signal analysis were designed and prototyped. Then the relationship between surface tension stress and the signal voltage level were investigated and calibration equation for this case were obtained. For considered material the recorded average Barkhausen noise voltage increased continuously with increasing elastic stress. According to the results, Barkhausen noise signal analysis methods have the potential for comparing, monitoring and evolution of physical, mechanical, metallurgical characterizes and existing stresses test-pieces. Magnetic stress measurements have the advantage of being quick, cheap to undertake and portable, and thus ideal for performing in-situ measurements.

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