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Modelling of the magnetic field in Barkhausen measurement method

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In this paper were presented results of modelling magnetic field in Barkhausen measurement method for the residual stress and mechanical properties determination.
The different shapes of the magnetising yoke pole shoe were analysed. The principle of operation and structure of experimental Barkhausen apparatus were described.

1. INTRODUCTION

One of the stages of technological process of manufacturing steel products as shapes or seamless tube is monitoring of the material's state. For quick and on-line method of determination material properties can be used only non-destructive method. These methods are X-ray, ultrasonic and magnetic. The magnetic method bases most often on discovered in 1919 physical phenomenon in ferromagnetic materials- Barkhausen effect. During magnetising of these materials, cyclic external magnetic field causes movement of Bloch walls and periodic rebuilding and resizing of domain structure. These changes appear in local disturbance of flux density, which can be detected by meter circuits with small measuring coil. Received from measuring coil have a form of wide spectrum noise called voltage Barkhausen noise (VBN)
States of microstructure, stresses, and dislocation have influence on intensity and parameters of measured Barkhausen. Dependencies of VBN parameters in function different materials properties are used for determination for e.g. estimate of residual stress level.
In practical method on VBN the influences have also parameters of magnetisation process – frequency or magnetic field intensity and they must be taking into consideration.

2.BARKHAUSEN EQUIPMENT

In figure 1 was presented block diagram of the experimental Barkhausen testing equipment for tubes, in classical configuration. It is composed of two sections. The first include oscillator and power amplifier. The oscillator generate triangle wave and could be tuned in range 1Hz to 50Hz.

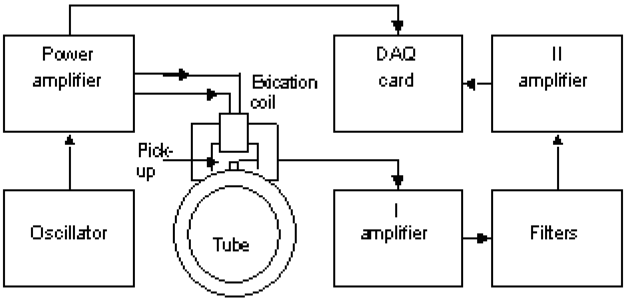

Figure1. Schematic diagram of Barkhausen equipment

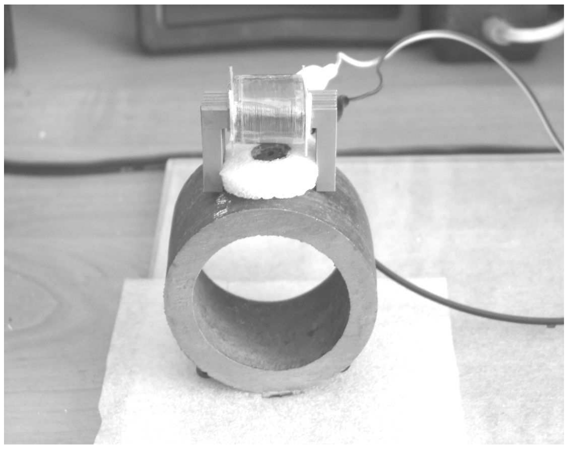

Figure 2. Experimental set-up

Next the signal is gained in bipolar power amplifier with adjustable gain. Output current is driving excitation coil on magnetic yoke. The value of it was measured and controlled by use PCI 1711 data acquisition card, which measure voltage drop on standard resistor. In result of cyclic process of magnetisation of ferromagnetic materials, movement of domains causes disturbances of magnetic flux density, which induces in measuring coil voltage signal.

Small voltage from pick-up coil at the first is amplified preliminary in first amplifier. Next, in filters are eliminated undesirable frequencies. The high-pass filter with 3dB cut-off frequency 1kHz eliminates first and others harmonic of the magnetisation current that are much bigger than Barkhausen signal. After the gain in second amplifier, the conditioned signal is digitised and sampled by use DAQ card with maximum 100 kHz sampling rate. On the basis of VBN signal parameters as voltage, frequency spectrum, and value of magnetisation current, will be evaluate level of the circumferential residual stresses and microstructure in seamless tubes. The view of the excitation yoke and pick-up coil are presented in fig. 2.

Mentioned above values are used as input data for the neutral networks. As output data from neutral networks is estimated level of residual stresses.

3.MODELLING OF THE MAGNETIC FIELD

One of the main problems at Barkhausen measurement is direct measurement of magnetic flux density. Until now, this value was determined indirectly, mostly trough measurement of the voltage on the terminal of the additional coil on the electromagnet yoke. Such way, very often is not sufficient because is measured flux density in yoke, not in tested specimen or materials. It is common knowledge that value of flux density in testing materials depends not only on value of magnetisation current, but also depends on shapes of the yoke's pole shoes and state of surface as roughness and rolling scale.

Suggested new way of the induction determination is based on the modelling of magnetic field by use of the finite element method (FEM). FEM lets to determine distribution intensity of the magnetic field and flux density by taking into consideration air gaps and different shapes of excitation yoke. Calculations of magnetic field joined with results of residual stress

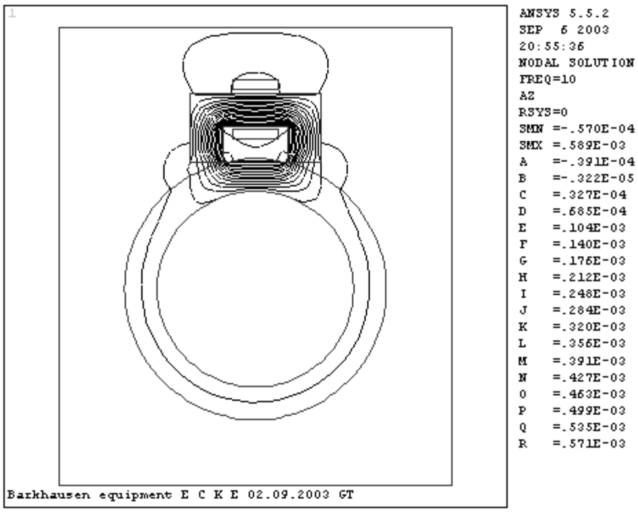

Figure 3.Flux lines. Air gap between yoke and tube

modelling can be use for theoretical modelling of Barkhausen effect and theoretical study of different microstructure stress and magnetisation conditions on Barkhausen noise.

The computations were prepared by using ANSYS 6.1 commercial package software. Electromagnetic calculations are based on fundamental Maxwell's field equations, Biot-Savart and Ampere laws.

Were analysed three different shapes of the pole shoes of the yoke: square, rounded and concave profiled. Was analysed also case with air gap between yoke and tubes.

For each shape of the magnetisation yoke, were prepared special files – scripts that included description of the geometry of the yoke, excitation coil and tested tube, and the parameters as the number of coil turns or value magnetisation current. Number of cooper coil turns for simulations was 600 as in experimental set-up. For presented results the current density was $2A/mm^2$.

Magnetic permeability of air and cooper coil was 1. Magnetisation curve B =f(H) of the steel was tabled and written down in each scripts. Although for experiment were used tubes made from C45 steel, for modelling was used accessible St3S steel magnetisation characteristic.

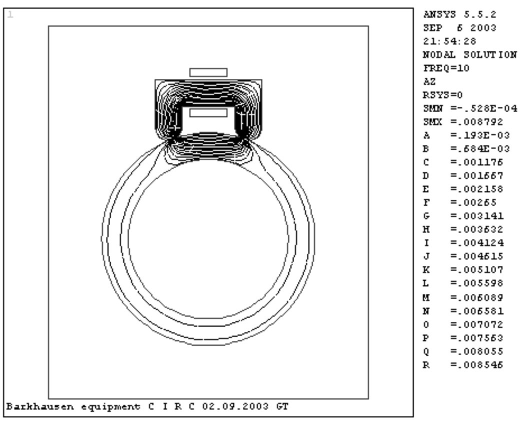

Figure 4. Flux lines. Rounded pole shoes of the yoke

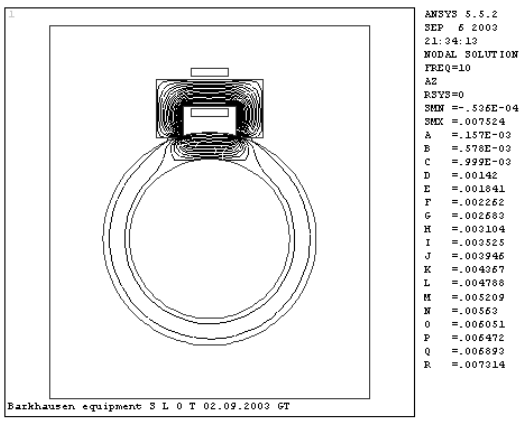

Figure 5. Flux lines. Square pole shoes of the yoke

4.RESULTS AND SUMMARY

As results of investigated simulations were assigned two-dimensional distribution of magnetic field. In each nodal of finite element mesh were calculated summary and component value of magnetic field H and magnetic flux density B, in tube and yoke. Moreover the results were presented in vector form and presented in fig3-6 contour line of equipotential of magnetisation flux AZ.The most favourable case of magnetisation is showed in fig.6. The flux lines have the smallest relative gradient and the distribution of flux density is the most uniform. Average value of B near surface the tubes is 1.5TThe worst case is when between yoke and material is air gap (Fig.3). Presence of gap causes “effluent” of the magnetic flux density. In this case value of B in place of locate pick-up coil is only 50mT.The others cases (Fig.4, 5) are similar. The value of B is adequately 0.7 T at square and 0,75 T at rounded shape of shoe poles. But in these cases on the contact between yoke and tubes during modelling were done the most mistakes followed from size of used finite element.

In the next stage of research received results will be verified by experimental determination of values magnetic flux density in each cases.

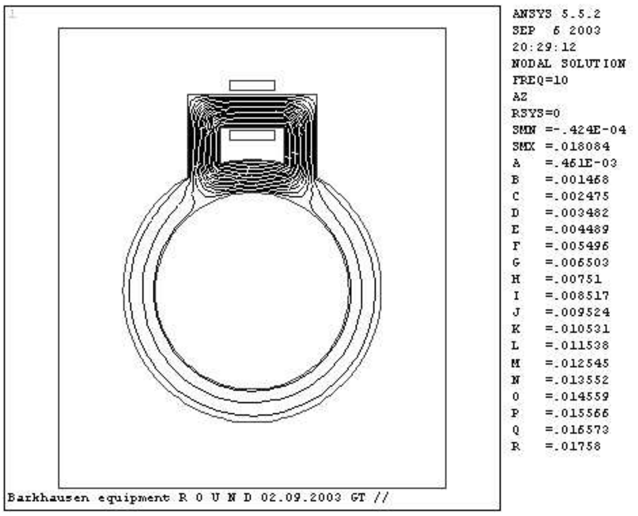

Figure 6. Flux lines. Concave profiles of shoe poles.

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