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DETERMINATION OF STRUCTURAL CHANGES BY BARKHAUSEN NOISE ANALYSIS

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Abstract: This article focuses on the method for detection and characterization of structural changes of magnetic materials due to tensile stress using Barkhausen effect. The range of the change is determined from the root mean square value of the Barkhausen signal.

Keywords: Barkhausen noise, tensile stress, amorphous ribbon

1 Introduction

Barkhausen noise is caused by the discontinuous changes in the magnetization of a ferromagnetic material magnetized by an external magnetic field. The motion of domain walls is reversible only in a narrow interval of small magnetic fields. When magnetic field increases, the motion is influenced by the structural obstructions, such as dislocations, inclusions and voids. After releasing from these obstructions, the motion of domain walls is irreversible and magnetization changes discontinuously. These changes of magnetization can be detected by a sensing coil as a high frequency stochastic signal.

It has been found that the Barkhausen signal of amorphous magnetic alloys is influenced mainly by a stress [1,2], due to the lack of crystallinity. The aim of this work is to study this influence for amorphous ribbon with composition $Fe_{40}Ni_{40}B_{20}$, 6 mm wide and 23 μm thick, used for magnetoelastic sensors.

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2 Influence of tensile stress on Barkhausen signal

The voltage U_{BS} generated by the Barkhausen signal in the sensing coil is proportional to the rate of change of irreversible magnetization $\mathrm{d}M_{\mathrm{irr}}/\mathrm{d}t$ according to equation [1]

$$U_{\mathrm{BS}} = NA\mu_0\gamma \frac{\mathrm{d}M_{\mathrm{irr}}}{\mathrm{d}t} = NA\mu_0\gamma \frac{\mathrm{d}M_{\mathrm{irr}}}{\mathrm{d}H}\frac{\mathrm{d}H}{\mathrm{d}t} \tag{1}$$

where N is the number of turns of the coil, A is the cross-section of amorphous ribbon, and γ is dimensionless parameter which represents the fraction of irreversible magnetization change, which occurs as Barkhausen events. The applied stress σ changes the induced magnetoelastic anisotropy and can be represented by an effective magnetic field H_σ

$$H_\sigma = \frac{3}{2}\frac{\sigma}{\mu_0}\left(\frac{\partial\lambda}{\partial M}\right) \tag{2}$$

where differential magnetostriction $\partial\lambda/\partial M$ is positive for $\mathrm{Fe_{40}Ni_{40}B_{20}}$. Tensile stress ($\sigma > 0$) applied on this material therefore increases the differential susceptibility χ'_σ according to equation [3]

$$\chi'_\sigma = \frac{\mathrm{d}\left(M_{\mathrm{rev}} + M_{\mathrm{irr}}\right)}{\mathrm{d}H} = \frac{\chi'_0}{1 - \chi'_0\left(\dfrac{\mathrm{d}H_\sigma}{\mathrm{d}M}\right)} \tag{3}$$

where χ'_0 is differential susceptibility in the absence of tensile stress. Increasing of differential susceptibility causes the increase of irreversible differential susceptibility $\mathrm{d}M_{\mathrm{irr}}/\mathrm{d}H$, and Barkhausen signal too.

3 Experimental results

The system for measuring Barkhausen noise and hysteresis loop is shown in Fig. 1. The amorphous ribbon is placed inside a solenoid coil, which produces triangle magnetic field along ribbon axis with frequency 5 Hz. The magnetizing current is driven by an arbitrary waveform generator with the output amplified by a power amplifier. The output "low frequency" signal from the sensing coil is amplified by the operational amplifier and used for measuring the hysteresis loops. The Barkhausen signal is separated from the "low frequency" signal by the band pass filter with cut-off frequencies 1 kHz and 30 kHz and amplified by the amplifier with gain 100. Since this "high frequency" signal also contains environmental noise and noise of all amplifiers in the signal path with amplitudes below 0.2 mV, a voltage treshold ± 0.2 mV was used to remove this

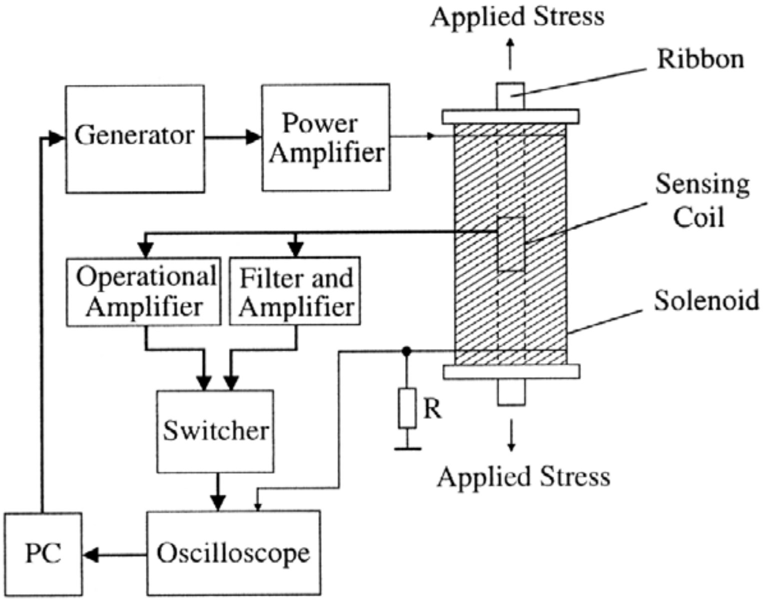
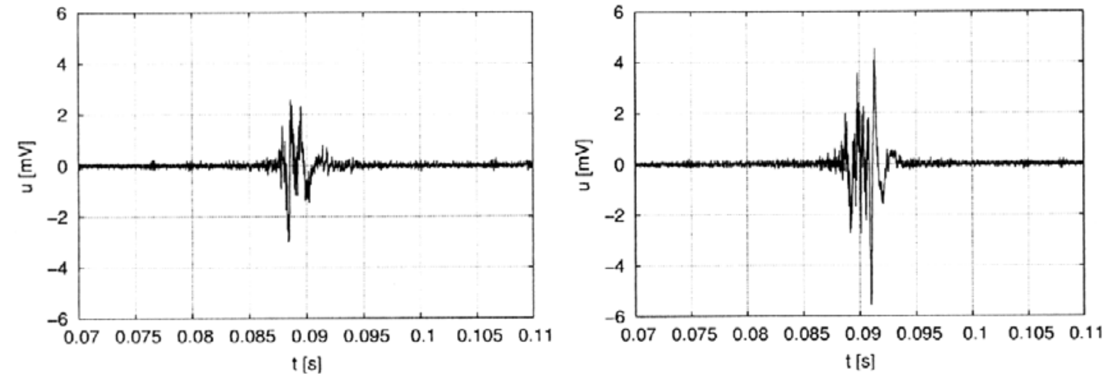


Fig. 1. System for magnetic measurements.

background noise. The personal computer PC reads the signals from the oscilloscope and displays the hysteresis loop and root mean square value of the Barkhausen signal.

The Barkhausen signal was measured under tensile stresses 0, 10, 20 and 30 MPa. Fig. 2 shows the change of the Barkhausen signal with the applied tensile stress. From the measured values it follows that the Barkhausen emission increases with the tensile stress, what corresponds to the equations (1), (3). This is also demonstrated in Fig. 3, which shows the influence of tensile stress on root mean square value of the Barkhausen voltage at different amplitudes of the magnetic field. The change of root mean square value of the Barkhausen signal



a) b)

Fig. 2. Bakhausen signal for tensile stresses 10 MPa (a) and 30 MPa (b).

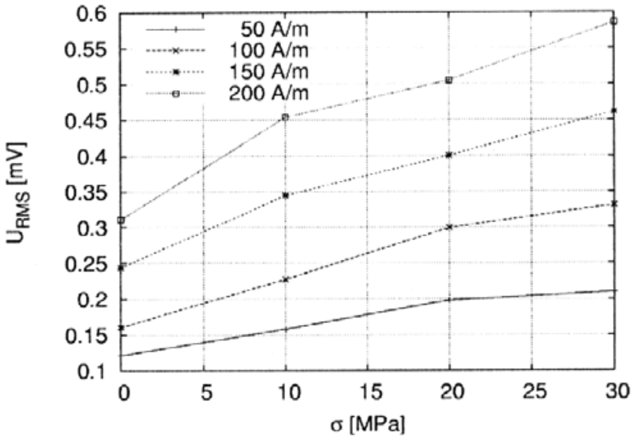


Fig. 3. Influence of tensile stress on RMS value of Barkhausen signal at different amplitudes of magnetic field.

decreases at higher tensile stresses, what is caused by decreasing of differential susceptibility because of saturation effect, when all magnetic domains are oriented in direction of applied stress. The root mean square value of the Barkhausen signal also increases with the amplitude of magnetic field, since increasing amplitude of magnetic field causes rising of the rate of magnetic field at constant frequency.

4 Conclusions

This work reveals that Barkhausen emission of amorphous ribbon $Fe_{40}Ni_{40}B_{20}$ with positive differential magnetostriction increases with tensile stress, what corresponds to the simple model described above. Barkhausen activity was also strongly influenced by the amplitude of triangle magnetic field, which changes the rate of magnetic field. The presented results suggest that Barkhausen noise analysis can be used as a powerful technique in stress measurements and internal stress analysis of amorphous magnetic alloys. This work was supported by VEGA project 1/0143/3.

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