University doctoral (PhD) thesis booklet

Impulse based Barkhausen-noise investigation on structural steels

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Introduction

The irregular fluctuation in the magnetisation of a ferromagnetic material during a magnetisation cycle is the so called Barkhausen-noise. The phenomena became an important method, mainly for structural steel diagnostic, since its discovery about 100 years ago. Usually this method is used for examining the state of structural steels. It is very important to detect the local stress accumulation in structural components (bridges, ships, vessels, rails) in time, before a catastrophic fracture.

Nowadays, beside the practical applications, the phenomenon became interesting for the fundamental researchers, because it is an important example of self organized critical systems.

For fundamental research, it is important to prepare experiments in the most ideal configuration so we are able to compare the experimental results to the theoretical ones. In this case the experiment cannot be done in a non destructive way. Studies connected to the fundamental research usually perform the experiments on soft magnetic materials, using a slow quasi-static driving field. The results of the theoretical and simulation Barkhausen-noise models can be directly compared to the experimental results of these materials. However, the recently used theoretical models do not handle the real microscopic structure of the materials.

In the industrial methodology, the measurements are performed with a higher excitation frequency, and the noise signal comes from only a partially magnetised sample volume. Therefore, the theoretical modelling of the results of the industrial measurements is an unsolved problem. The application of the phenomenon in respect of the non destructive structure diagnostic is based on empirical correlations. The different parameters of the ferromagnetic structural materials -which affect the Barkhausen-noise- are measured with a not standardized way.

The topic of the thesis is the application of the impulse based Barkhausen-noise measurement for industrial related materials. Such measurements were not performed so far in the literature. The final goal of the study was to establish the industrial methodology theoretically.

Aims of the work were

1. Assembling the necessary measuring system for the impulse based technique, implementing the evaluation methods what can be found in the literature. Expanding the measuring technique toward the industrial applications, via upgrading the measurement and evaluation procedures.
2. Studying and explaining the effects of the experimental configuration and the excitation frequency in the case of reference structural steels. Comparing the distribution functions of the noise parameters to the results of the theoretical model what were developed for soft magnetic materials.
3. Applying impulse based measurement technique for studying the location and angle dependent noise parameters of anisotropic cold rolled

industrial steel. Determining of the connections between the noise parameters and the parameters of the microstructure.

Results

1. I have built a new shielded Barkhausen-noise measuring device what is also capable of measuring the effect of mechanical tensile stresses. I have built a data processing system with a web interface. This system functions as a database, and also calculates the results using a batch-processing method based on several PCs. With this program package I have contributed into the evaluation of the measurements on FINEMET type materials, shape memory alloys, and structural steels [K3, C1, P2].

2. I have studied the effect of the sample geometry, and the excitation frequency on S235 JRG1 structural steel. I have concluded that the sample

geometry alters the distribution functions and also the integral values of the noise parameters via the demagnetising field. I have performed experiments examining the effect of the driving frequency in the mHz range. I have developed an extrapolation technique; with which I was able to explain the effect of the driving frequency on the noise parameters. The extrapolated noise signals were in good agreement with the experimentally gained noise signals in this frequency range [C2, P3].

3. I have studied the effect of the excitation frequency in the mHz-Hz range with a compensation technique using two detector coils for JRQ reactor steel. With an increasing excitation frequency I have got decreasing avalanche size distribution exponents and increasing cut-off values. For the average avalanche shape curves, the maxima moved to the centre region and the skewness decreased

with increasing driving frequency. The experimental results can be explained both of the RFIM and the ABBM-model. We have also found that, above a threshold in the excitation frequency, the magnetisation process changes its dynamics [K2, P1]

4. I have studied the orientation and depth dependence of the Barkhausen-noise in an Ukrain cold rolled gas tube (06G2MTFBR). I have extracted samples using destructive methods from different depths, and in two orientations: perpendicular and parallel to the rolling direction. The system showed strong anisotropy and location dependency. In the case of the samples oriented parallel to the rolling direction, the noise energy curves showed two local maxima. In the case of the perpendicular samples, the noise energy small and depth independent. I have used microscope and quantitative image analysis to study the grains, the carbon precipitates, and their morphology. I

have explained the properties of the noise energy curves with the effect of the structure and distribution of the non-magnetic precipitates and crystalline grains on the domain wall movement [K1].

Published articles

[K1] **A. Bükki-Deme**, I. Szabó, C. Cserháti, *Effect of anisotropic microstructure on magnetic Barkhausen noise in cold rolled low carbon steel*, **Journal of Magnetism and Magnetic Materials**, vol. 322, 2010, o. 1748-1751.

[K2] **A. Bükki-Deme**, I. Szabó, *Magnetization Rate Dependence of the Barkhausen Noise in JRQ Steels*, **Magnetics, IEEE Transactions on**, vol. 46, 2010, o. 254-257.

[K3] G. Eszenyi, **A. Bükki-Deme**, L. Harasztosi, F. Zámborszky, J. Nyéki, Z. Erdélyi, D. Beke, és I. Szabó, *Spectral density of Barkhusen noise in FINEMET-type materials*, **Journal of Magnetism and Magnetic Materials**, vol. 322, 2010, o. 322-325.

Proceedings

[C1] L. Daróczi, **A. Bükki-Deme**, Z. Balogh, L. Harasztosi, Z. Erdélyi, D.L. Beke, T.A. Lograsso, D.L. Schlagel, *Investigation of Barkhausen noise in $Ni_2Mn(Al, Ga)$*, **Proceedings of the International Conference on Shape Memory and Superelastic Technologies, SMST-2007**, o. 607-614., Tsukuba City, Japan.

[C2] **A. Bükki-Deme**, I. A. Szabó, *Effect of non-ideal conditions on the determination of the Barkhausen noise*

parameters, **Journal of Electrical Engineering**, VOL 59. NO 7/s, 2008 (Magnetic Measurement 2008 Conference Budapest).

Posters

[P1] **A. Bükki-Deme**, I. A. Szabó, *Magnetization rate dependence of the Barkhausen noise in JRQ steels*, **19th Soft Magnetic Materials Conference**, Torino, Olaszország, 2009.

[P2] L. Harasztosi, I. A. Szabó, **A. Bükki-Deme**, Gy. Posgay, *Magnetisation amplitude and stress dependence of the Barkhausen noise in structural steel (G3-10)*, **19th Soft Magnetic Materials Conference**, Torino, Olaszország, 2009.

[P3] **A. Bükki-Deme**, I. A. Szabó, *Effect of non-ideal conditions on the determination of the Barkhausen noise parameters (M8-10)*, **Magnetic Measurements 2008 Conference**, Budapest, Magyarország, 2008.