EFFECT OF MEASUREMENT CONDITIONS ON BARKHAUSEN NOISE PARAMETERS

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Summary The Barkhausen noise was measured in plastically deformed low-carbon steel at various measurement conditions. Strip samples magnetized by a single yoke were used for investigation. The measurement results for different magnetizing frequencies, waveforms of the magnetizing field and cut-off frequencies of the processing filter were compared and the differences, mainly concerning the sensitivity of the Barkhausen noise on the plastic deformation, will be discussed.

1. INTRODUCTION

The Barkhausen noise method of nondestructive testing provides good sensitivity to changes in the microstructure of a ferromagnetic material. One of the issues in this method is relatively high sensitivity of measured parameters on the measurement conditions. In this paper, we tried to investigate the influence of essential measurement conditions on results of the single-yoke measurement of the plastically deformed low-carbon steel, which is a quite common measurement performed using this method. Namely, we studied the effect of the magnetizing frequency, the shape of the magnetizing field waveform as well as the choice of cut-off frequencies of the processing filter. All of these factors change the dependence between the plastic deformation and the magnitude of the Barkhausen noise.

The varied magnetizing frequency changes the Barkhausen noise mainly through the overlapping mechanism [1] and the change of the number of the domain walls in the sample [2]. The shape of the magnetizing field waveform is closely associated with the fact, whether the feedback is used to assure the defined (mainly triangular or sinusoidal) waveform of the magnetic field. Generally no feedback is used in practice and the Barkhausen noise is investigated using the defined waveform of the magnetizing current. Then the nonhomogeneity and the nonlinearity of the yoke-sample magnetic circuit cause that the magnetic field in the sample is not proportional to the current and it depends on the properties of the sample [3]. To impose the defined magnetic field in the sample, we used the digital feedback comparing the field measured by the tangential Hall probe on the sample surface with the desired waveform.

To get the Barkhausen noise from the measured induction signal in sensing coil, the signal has to be filtered using the analog and/or digital filter. A proper choice of the filter's cut-off frequencies is important to be able to suppress the disturbing noise and the low frequency component of the sensor signal and concurrently to obtain the whole useful information from the signal. The impact of all of these conditions on the measurement results will be discussed.

2. EXPERIMENTAL

A model kind of the low-carbon steel with composition (C = 0.03, Mn = 0.18, Si = 0.13, P = 0.027, S = 0.027, N = 0.007 *wt.%*) was chosen for the investigation. The strip samples were tested after unloading by a single yoke method with the PC control [4]. The driving coils were wound on the yoke legs of the same material as the sample (Fig. 1). The sample field H was evaluated directly from the magnetizing current (measurement with the defined triangular magnetizing current of the amplitude of 1 A) as well as from the magnetic field measured at the sample surface using the Hall probe (measurement with the defined triangular magnetic field of the amplitude of 2.5 kA/m). The Barkhausen noise was measured by a perpendicular sensing coil placed on the sample surface in the center between the yoke legs and consequently filtered from the signal of the sensing coil using the analog band-pass filter SR560 with the cut-off frequencies 100 Hz and 100 kHz.

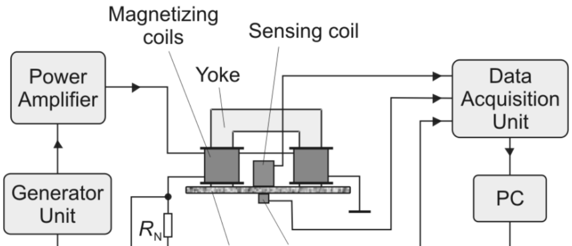

Fig. 1. Measuring set-up

3. RESULTS AND DISCUSSION

The dependencies of the root mean square (RMS) value of the Barkhausen noise on the plastic deformation for different magnetizing frequencies are shown in Fig. 2. From the figure we can see that the RMS value decreases with the deformation, mainly due to the creation of dislocations in the

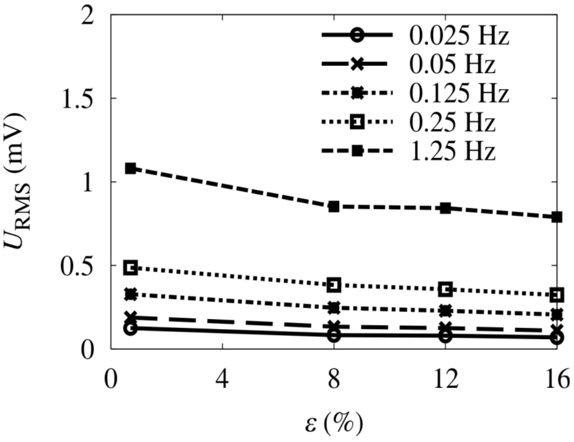

Fig. 2. The strain dependencies of the RMS value of the Barkhausen noise for different magnetizing frequencies

deformed material, which are heavy impediments to the domain wall motion. On the other hand, the magnetizing frequency has tendency to increase the RMS value of the Barkhausen noise for all measured samples. This increase of the RMS value of the Barkhausen noise with the magnetizing frequency at constant maximum field intensity is caused by raising the number of individual jumps (Fig. 3) at different positions in the sample per unit time, with consequent increase of the number of jumps which overlap in time [1]. Since the overlapped jumps add together, the Barkhausen noise raises too.

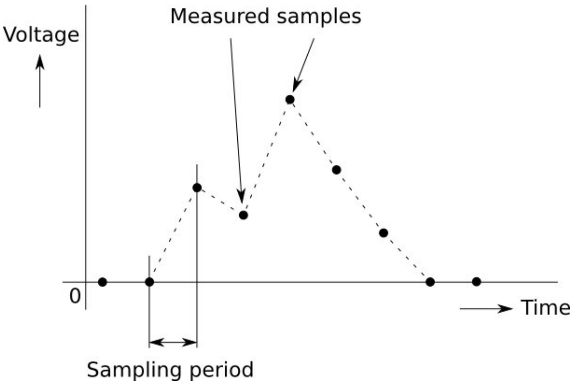

Fig. 3. Example of the Barkhausen jump

The increase of the Barkhausen noise seems to be supported by raising the number of domain walls with the magnetizing frequency and therefore increasing the number of interactions between the domain walls and pinning sites [2]. The overlapping entails that the number of Barkhausen jumps in one period of the magnetizing signal decreases above 0.05 Hz (Fig. 4). The drop of the number of jumps below 0.05 Hz is caused by decreasing the magnitude of some jumps below a measurable value. From the Fig. 4 we can see that the number of Barkhausen jumps practically does not change with the plastic deformation, which suggests that the deformation changes only the amplitude of the jumps. The increase of the sensitivity of the RMS value on deformation with decreasing magnetizing frequency (Fig. 5) can be attributed to the increase of the number of jumps and consequent relative raise of the voltage levels, which are influenced by the deformation.

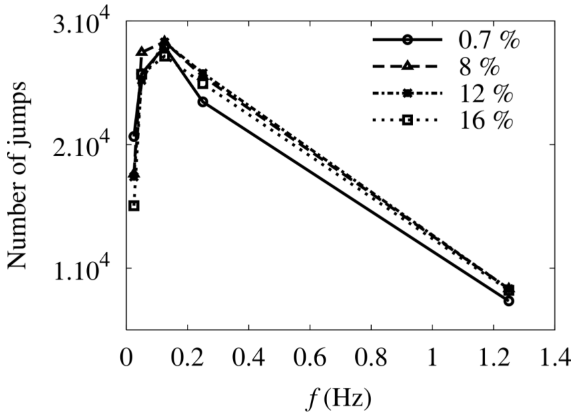

Fig. 4.Influence of the magnetizing frequency on the number of jumps

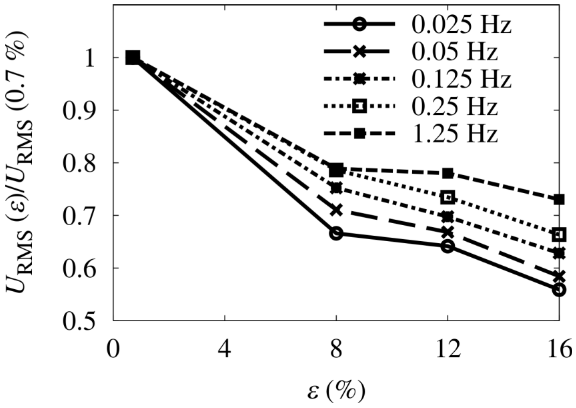

Fig. 5. Normalized dependencies of the RMS value of the Barkhausen noise on the strain for different magnetizing frequencies

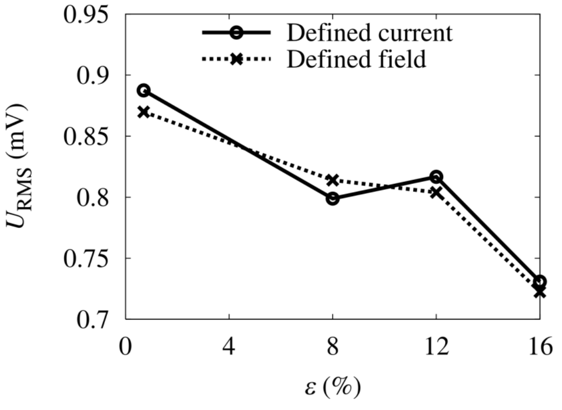

Fig. 6. The RMS value of the Barkhausen noise as a function of the strain for defined magnetizing current, resp. defined magnetic field with frequency of 1 Hz

The comparison of the RMS values of the Barkhausen noise for the defined magnetizing current, resp. defined magnetic field is shown in Fig. 6. The amplitude of the sample field in the mode with the defined magnetic field was chosen such that the amplitude of the magnetizing current for the case of the 0.7 % deformed sample measured in this mode was equal to the amplitude of the magnetizing current in the mode with the defined magnetizing current. Differences in the sample field shape and the amplitude between these two modes caused only slight discrepancy between the RMS values of the Barkhausen noise of these modes, therefore it is advisable to consider the necessity of using the feedback in this case. Such a slight difference is likely to be caused by relatively small amplitude of the magnetizing field, when the nonlinearity of the yoke-sample circuit is also small.

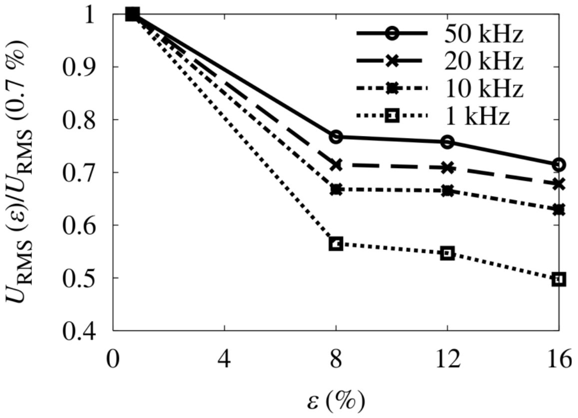

Fig. 7. Normalized dependencies of the RMS value of the Barkhausen noise on the strain for different cut-off frequencies of the low-pass processing filter

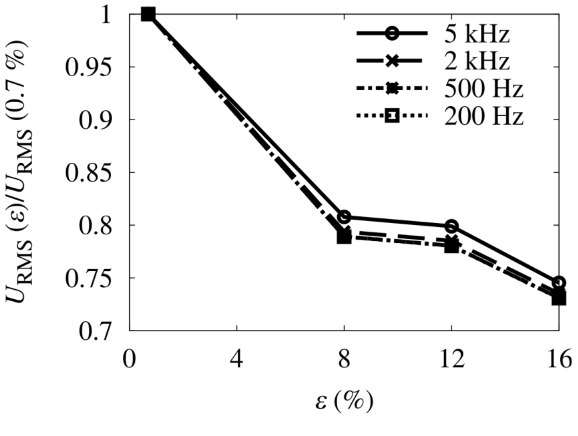

Fig. 8. Normalized dependencies of the RMS value of the Barkhausen noise on the strain for different cut-off frequencies of the high-pass processing filter

Finally, we studied the influence of the cut-off frequencies of high-pass as well as low-pass filter on the Barkhausen noise of the plastically deformed samples. At first, we applied the digital low-pass Butterworth filter of 4th order on the measurement results at varied cut-off frequency, which was chosen from the range of the typical sampling frequencies of moderate A/D data acquisition systems (Fig. 7). The sensitivity of the Barkhausen noise on the plastic deformation changed significantly with the cut-off frequency, mainly in the low strain region. We can see that by decreasing the cut-off frequency to an uncommonly low value, it is able to notably increase the sensitivity. Then we applied the digital high-pass Butterworth filter of 4th order with varied cut-off frequency, which should be sufficiently high to be able to suppress the low frequency component of the inducted voltage from the sensing coil (Fig. 8). In this case, the change of the RMS value with the cut-off frequency is not so pronounced as in the case of the low-pass filter.

4. CONCLUSION

Optimizing the frequency of the magnetizing process can increase the sensitivity of the Barkhausen noise on the plastic deformation. The same effect can be achieved by choosing suitable values of the cut-off frequencies of the processing filter. Using the defined magnetic field in the sample at small amplitudes of the field changes the RMS value of the Barkhausen noise only slightly in compare with the case of the defined magnetizing current.

Acknowledgement

This work was supported by VEGA Grant No. 1/3116/06.

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