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COMMUNICATIONS

Influence of lift off on Barkhausen noise parameters of construction steel

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The magnetic Barkhausen noise (MBN) measurement technique is a popular magnetic method used for non destructive detection of microstructural changes in ferromagnetic materials. The MBN parameters depend on the gap between the excitation yoke and measured object. To suppress the negative influence of lift off, we tried to find a parameter of the MBN, which could be independent of lift off changing in a practical range. The lift off effect was analysed experimentally on construction steel samples with various levels of carbon content. We found that the amplitude distribution is a promising parameter of MBN in this regard. Measurement results showed that the slope of amplitude distribution was roughly independent of lift off.

Keywords: Barkhausen noise, steel, yoke, lift off

1 Introduction

The magnetic Barkhausen noise (MBN) measurement methods are widely used as a non-destructive evaluation technique for inspection of ferromagnetic materials [1-4]. The MBN is closely connected with the magnetisation process in ferromagnetic materials at a slowly changing applied magnetic field. It reflects the interactions of domain walls with pinning centres at material inhomogeneities, such as grain boundaries, dislocations, inclusions and precipitates. The MBN is usually measured using a sensing coil placed perpendicularly to the measured object; magnetising field in the object is excited by a yoke. In this arrangement, the MBN parameters indeed depend on measuring conditions. Some conditions are influenced by external factors or an unpredictable human factor, so they cannot be kept constant in all cases. One example is the excitation yoke lift off caused by a variable coating thickness, sample surface roughness or sensor displacement.

Lift off problem has been investigated by various researchers. Stupakov *et al* [1] used the applied field extrapolation for overcoming problems with lift off. However, such technique is not suitable when the distance between sample and sensor is not known or not defined exactly. In that case, the applied field cannot be measured precisely, as it is for example in the case of irregular sample surface. White *et al* [2] observed that the MBN can be stabilized by application of a high flux density, but only at small lift-offs. In this paper, we tried to find a parameter of the MBN, which could be independent of lift off varied in a practical range. Method was investigated using measurements on construction steel samples with various carbon content.

2 Experimental

The MBN was measured by a single yoke system [3]. The U-shape yoke with a magnetizing coil wound on its body was made from grain-oriented steel laminates. The triangular magnetizing current of frequency 4 Hz was generated by means of a voltage-to-current power amplifier. Lift off between the yoke and sample was set to 0, 0.5 and 1 mm.

To detect the MBN, a probe with the axis normal to the sample surface was used. Signal of the probe was amplified and then filtered by an analogue band-pass filter. From the resulting signal, the envelope and amplitude distribution were determined during the whole magnetization cycle. These parameters of MBN were averaged over 10 cycles. The applied field intensity H was measured by a Hall probe placed directly to the sample surface.

Four samples of construction steel with dimensions 10 mm × 10 mm × 40 mm and various chemical composition and structure were prepared. These samples of type 12020, 12050, 12060 and 14260 have carbon content of 0.2%, 0.5%, 0.6% and 0.6%, respectively; 14260 sample is different from 12060 sample also by content of Si.

3 Results and discussion

The MBN profile dependences on lift off for 12050 sample and selected amplitude of magnetising current are shown in Fig. 1. We can see there, that the height of MBN profile decreases with lift off, due to the drop of applied field intensity caused by lift off (Fig. 2). The results for the other samples are similar as one could expect.

The amplitude distribution was calculated from the MBN voltage v measured at magnetising current amplitude of 1.4 A/m. MBN voltage v represents a noise signal

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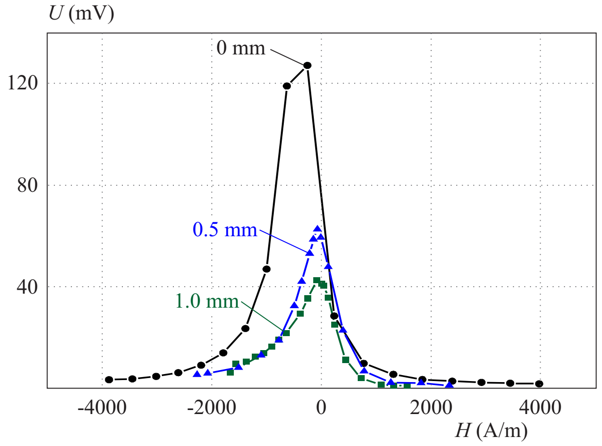

Fig. 1. MBN profile dependences at various lift offs for 12050 sample at magnetising current amplitude of 1.4 A

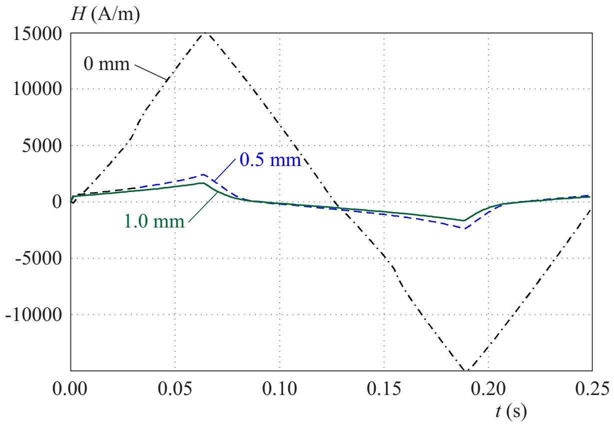

Fig. 2. Applied fields for 12050 sample and all lift offs at constant magnetising current amplitude of 1.4 A

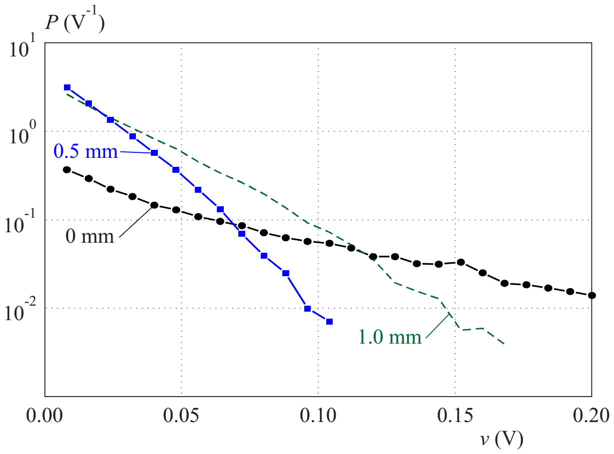

Fig. 3. Amplitude distribution of MBN voltage for 12050 sample and various lift off at constant magnetising amplitude of 1.4 A

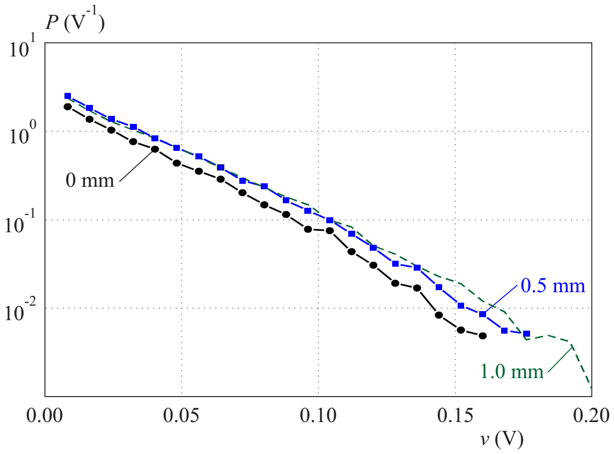

Fig. 4. Linear amplitude distributions of MBN voltage for 12050 sample at various lift off and magnetising current $I_{\rm m}$ values in Tab. 1

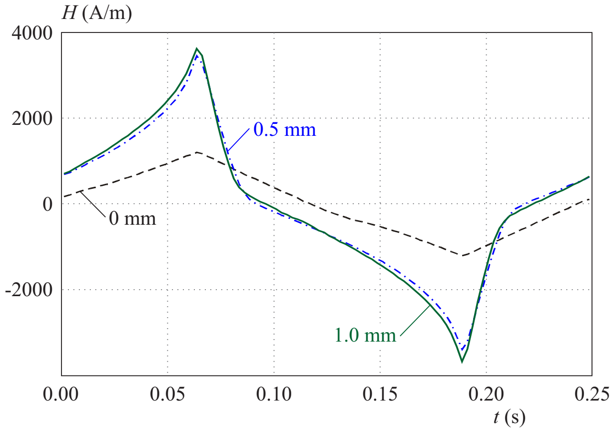

Fig. 5. Applied field for 12050 sample and all values of lift off at linear $P(v)$ dependence, magnetising current im values at tab. 1

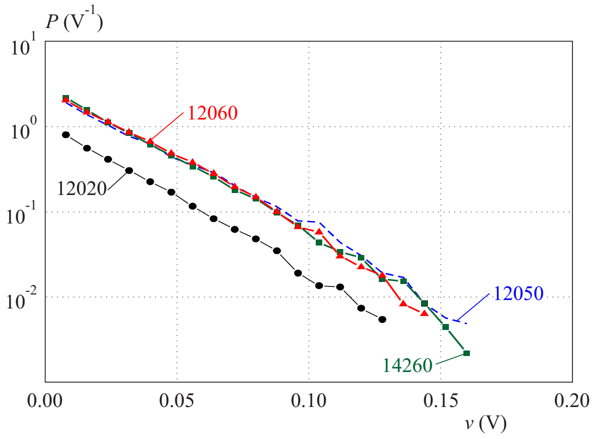

Fig. 6. Linear amplitude distribution of MBN for all samples and zero lift off

induced across sensing coil after its processing by amplifier and band pass filter with upper cutoff frequency of 200 kHz. This amplitude distribution $P(v)$ for 12050 sample and all lift-offs is depicted in Fig. 3.

As the lift off increases, the result corresponds to the behaviour observed in Fig. 1, indicating a gradual decrease of the maximum MBN voltage. There is also a substantial change of $P(v)$ slope with lift off. At zero lift off, the left half of $P(v)$ dependence is curved. When increasing the lift off to 0.5 mm, the curvature of $P(v)$ dependence decreases and it becomes to be approximately linear (when scattering is neglected). After further increase in the lift off, the $P(v)$ dependence steeply bends downs at the right end of the curve. Linear $P(v)$ dependence for all samples and lift off values was achieved by a manual adjusting of magnetising current amplitude. From the results, it is evident that all such dependences have practically the same slope and they can be approximated by a function $P(v) = k\,10^{-\alpha v}$.

An example of such $P(v)$ dependences for 12050 sample at all lift-offs is in Fig. 4, respective constants k, α, given by a linear fit together with correlation coefficient r , as well as the current magnitude $I_{\rm m}$ for these cases are in Tab. 1.

Table 1. Sample 12050, lift-off changed

Lift-off	Manually		Linear fit	
(mm)	$I_{\rm m}$ (A)	$k(\mathrm{V}^{-1})$	(α^{-1})	$\lvert r\rvert$
0	0.15	2.985	16.95	0.996
0.5	1.50	3.917	16.26	0.997
1.0	2.20	3.794	14.74	0.995

Apart from the same slope of all $P(v)$ curves, it is clear from Fig. 4, that the $P(v)$ dependence for zero lift off is significantly below the others. This can be explained by the applied field variation with lift off. From the applied field waveforms shown in Fig. 5, we can see that the waveforms for nonzero lift offs are almost the same. On the other hand, at zero lift-off, the field has different waveform with lower amplitude. The rise of nonzero lift off $P(v)$ dependences in comparison with the zero lift-off one can be attributed to magnetization processes raised at the most steepness part of the field waveform near the maximum of the field. Nevertheless, the rise of $P(v)$ curve does not change its slope.

Another example of $P(v)$ dependences for all samples and zero lift-off is in Fig. 6; magnetising current amplitude was set to get this dependence linear for each sample individually. Such slope of $P(v)$ curves can be explained by the ABBM model of MBN [4]. From this model, it follows that the slope of MBN amplitude distribution is dependent on the permeability and field rate of change. Variation of the slope of amplitude distribution with microstructural changes was shown for example in [3], where the MBN changes by plastic deformation were investigated. In the present work, it follows from measurements of hysteresis loops, that all steel samples have practically the same differential permeability $\mathrm{d}B/\mathrm{d}H$ around the coercive field. Further, from the applied field waveforms for 12050 sample shown in Fig. 6 it follows that in the region of zero field, where the main magnetization processes rise (see Fig. 1), the slope of all field waveforms is approximately the same. The field rate of change in this region was about 2×10^4 kA/m/s providing the linear $P(v)$ dependence. All this suggests that the slope of linear $P(v)$ dependences could be also the same. This is consisted with Fig. 4 and Fig. 5.

We can conclude that when the $P(v)$ dependence is linear, its slope is independent of lift off but it depends on the microstructural parameters. The applied field rate of change around zero field is also independent of lift off, so the applied field might not to be measured exactly. It follows that when we will be controlling the $P(v)$ dependence to the linear shape (for example by a digital feedback), we could achieve that the measured parameter (slope of the $P(v)$ dependence) would be independent of lift off and it will be dependent only on properties of the investigated material. Design of an appropriate digital feedback for such purpose is a task for a future work. It should be noted that the development of such feedback is complex, since the smoothness and stability of the $P(v)$ dependence is influenced by many factors, such as the signal to noise ratio and distortion of the applied field waveform.

4 Conclusions

Influence of the yoke lift-off on MBN measurement was studied. The purpose of work was to find an appropriate parameter of MBN, which would be moreorless independent of lift off. Experimental results proved that the promising parameter in this regard is the amplitude distribution of MBN.

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