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On the role of magnetic field intensity for better micro-structural characterization during Barkhausen Noise analysis

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On the role of magnetic field intensity for better micro-structural characterization during Barkhausen Noise analysis

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Abstract. Barkhausen Noise analysis is a popular and preferred technique for micro-structural characterization. The root mean square value and peak value of Barkhausen Noise burst are important parameters to assess the micro-hardness and residual stress. Barkhausen Noise burst can be enveloped using a curve known as Barkhausen Noise profile. Peak position of profile changes with change in micro-structure. In the present work, raw signal of Barkhausen Noise burst was obtained from Ni based sample at various magnetic field intensity to observe the effect of variation in field intensity on Barkhausen Noise burst. Raw signal was opened using MATLAB to further process for microstructure analysis. Barkhausen Noise analysis parameters such as magnetizing frequency, number of burst, high pass and low pass filter frequency were kept constant and magnetizing field was varied in wide range between 200 Oe to 1200 Oe. The processed profiles of Barkhausen Noise burst obtained at various magnetizing field intensity clearly reveals requirement of optimum magnetic field strength for better characterization of micro-structure.

Keywords: Barkhausen Noise, Signal Processing, Magnetizing field strength

1. Introduction

Microstructural characterization of materials by non-destructive techniques is essential for the assessment of heat treatment and subsequent changes in microstructure. Conventional techniques like metallographic inspection, scanning electron microscopy (SEM), etc are more time consuming laboratory based techniques. Barkhausen Noise (BN) measurement is considered as an advanced technique for microstructural characterization of ferromagnetic materials [1]. Barkhausen noise is attributed to the irreversible movement of magnetic domain walls during a cyclic magnetisation process [2]. Domain walls movement is strongly influenced by microstructural inhomogeneities such as precipitates, grain boundaries and dislocations. The change in global magnetization of material due to domain wall motion induces BN signal as voltage pulses in the pickup sensor on the surface. Barkhausen Noise (BN) signal is sensitive to composition and microstructure of the materials including grain size and texture, internal and external stresses as well as the detection system itself [3]. Previous studies [1 & 3-5] have demonstrated the applicability of MBN technique for assessment of microstructural changes produced by heat treatment in a number of ferromagnetic alloys. Moorthy et al. [1, 4] showed the effect of different microstructural features on the MBN profiles in 2.25Cr–1Mo steel and 9Cr–1Mo steel by systematically tempering the quenched or normalized specimens by various durations. Blaow et al. [5] observed single peak profile and three peak profile while characterizing high carbon steel, Ovako 677 heat treated under various conditions to produce a range of distinct microstructures. Vashista *et al.* successfully applied Barkhausen Noise analysis technique for assessment of residual stress upon grinding of steel in conventional grinding domain [6-9] super-abrasive grinding domain [10] and high speed super-abrasive grinding domain [11] as well processed the Barkhausen Noise signal profiles for addressing the issue of ferromagnetic materials exhibiting poor magnetic response [12]. Previous researchers analyzed the effect of BN analysis parameters such magnetizing field strength, excitation frequency on signal profiles, but they varied these parameters in limited range. In the present work effect of applied magnetic field intensity on BN signal profiles has been discussed while varying the intensity of magnetic field in wide range.

2. Experimental details:

Barkhausen Noise measurement was performed by Magnetic Barkhausen Noise analyzer (Magstar) on pure nickel sheets. The measurements were conducted over a wide range of applied magnetic field strength (while keeping the excitation frequency constant) to study the effect of variation in magnetic field intensity on Barkhausen Noise (BN) signal profile. Band pass filter frequencies (high pass filter and low pass filter) was kept constant to avoid the skin depth effect and three BN burst were considered for analysis purpose with 10 db gain. The BN signal is typically passed through a band-pass filter. The frequency of this filter was adjusted for maximum sensitivity at a near surface depth where possibility of maximum changes presents. The sample was demagnetized before each and every measurement to minimize the effect of previous magnetization cycle. Figure 1 shows the screen shot of display of BN burst along with applied magnetizing field (sinusoidal form).

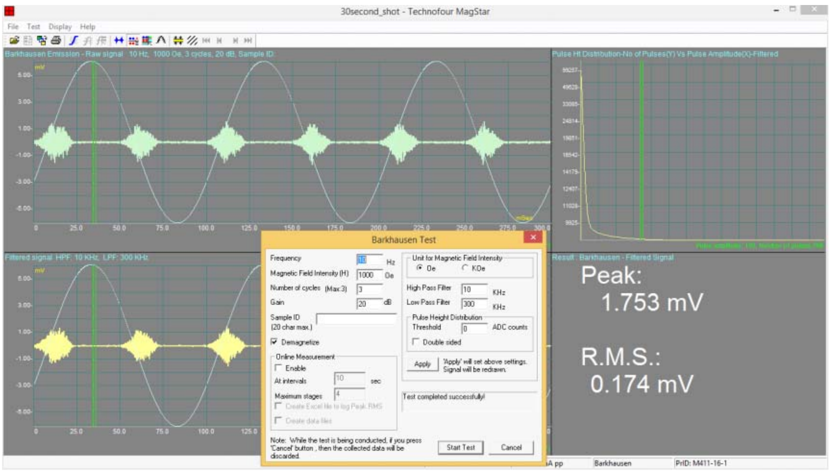


Fig. 1 Screen shot of BN burst along with applied field

Barkhausen Noise bursts generally enveloped using a curve profile for analysis purpose as interpretation of raw BN signal for useful information is difficult. Barkhausen Noise raw signals were analyzed in MATLAB using filtering and sampling and single peak fit with Gaussian distribution was employed to fit into this modified signal [refer fig. 2 (a) and (b)] with Levenberg Marquardt algorithm.

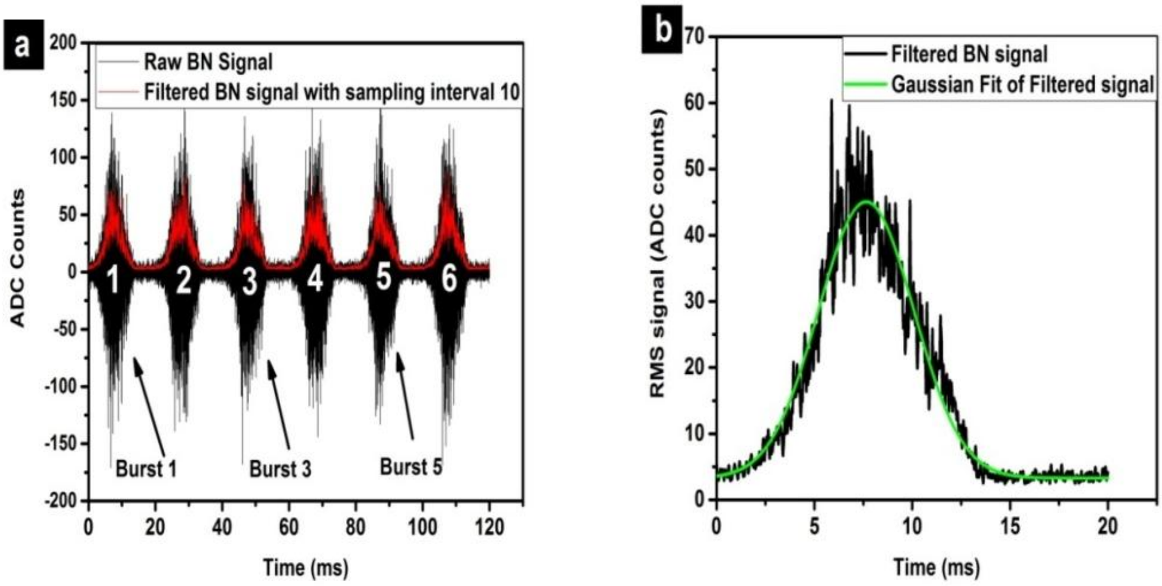
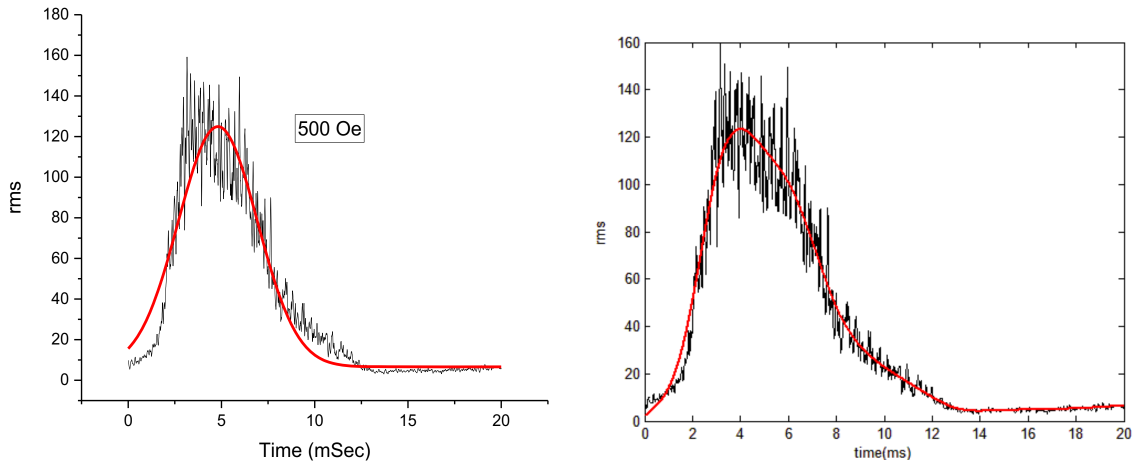


Fig. 2 Raw Barkhausen Noise signal along with Gaussian fit

Although Gaussian fit curve into filtered signal indicates that the curve passes through mean positions of filtered raw BN signal, but the Gaussian fit deviates from the mean position when BN measurement were carried out at higher magnetizing field intensity as can be easily depicted from Fig. 3 (a), in which the BN signal was gathered at 500 Oe. Hence, we attempted best fit curve which ensures that curve would pass through the mean position of filtered signal. Figure 3 (b) shows the filtered BN signal along with best fit curve which passes through the mean positions of the filtered signal.



(a) **(b)**

Fig. 3 Filtered BN signal along with Gaussian fit curve (a) and with best fit curve (b)

3. Results and discussion:

It is expected that the measurement and analysis of envelope or rms voltage profile of the MBN signal would give more information on the magnetisation process and the influence of different microstructural phases on it. Barkhausen Noise filtered signal profiles along with best fit curve obtained at different magnetizing field intensity is shown in fig.4. Effect of variation in applied magnetic field strength can be easily distinguished on Barkhausen Noise profiles as presented in fig.4.

Increase in magnetic field intensity not only increased the amplitude of BN signal profile but also causes changes in shapes. Wider signal profile with low amplitude was obtained at the lower magnetic field strength (i.e. 200 Oe) as represented in Fig. 4 (a), then after amplitude of profiles increases with reduction in widening of profiles.

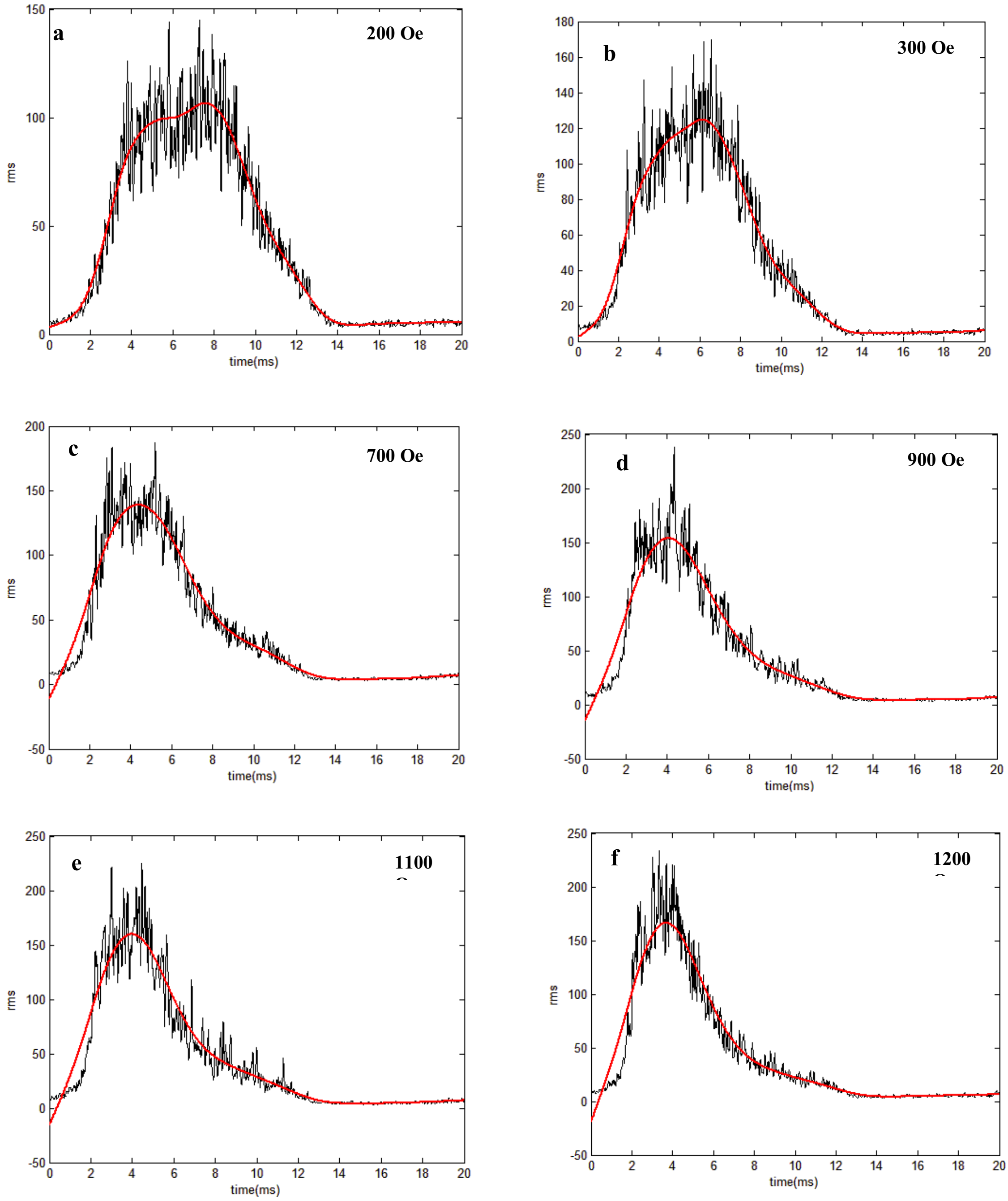


Fig. 4 BN signal profiles at various magnetizing field intensity (a-f)

The peak position of BN signal profile is an important parameter for analysis of micro-structural changes. Figure 5 (a) and (b) represent the best fit curve of different BN profiles clubbed together for comparison purpose. Profile curve obtained at lower magnetic field clearly depict that applied field was not enough for an appropriate and stable form of curve, thus a minimum magnetic field strength is essential for material characterization.

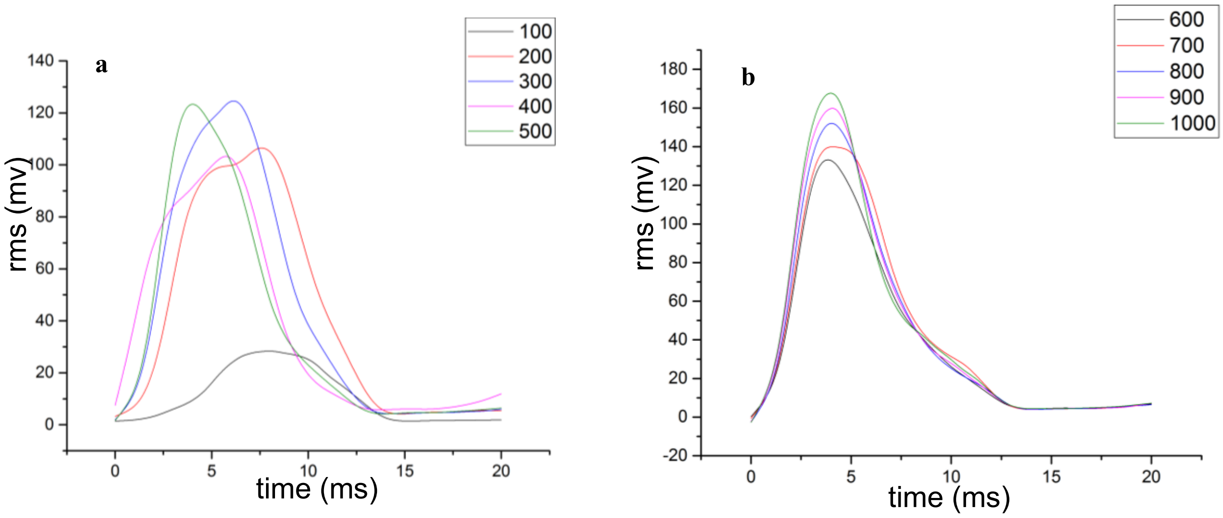


Fig. 5 Comparison of BN signal profiles at lower magnetic field (a) and higher field (b)

In Figure 5 (a), it quite interesting to note that peak position is not shifting on x-axis with increase in magnetic field strength; this may be attributed to no microstructure changes in the entire experiment domain. Typically micro-structural changes or dual phase in the material generates multiple peaks in the BN signal profiles, but in the present study single peak profiles were obtained at lower magnetic field strength. But, interestingly a second peak appears when the strength of magnetic field increases from 600 Oe.

Literature survey indicates that pure nickel may contain carbon, silicon, manganese and iron. Pure nickel is generally considered soft magnetic phase while other constituents are hard to magnetize. The sharp slope changes in the BN signal profiles indicating the overlapping distribution of pinning strength of soft and hard phases. The higher peak 1 indicates the motion of nagnetic domain walls through the grain boundaries sweeping across the soft magnetic phase. On the other hand the lower peak 2 indicates the motion of magnetic domain walls in the harder phase which restricts the movement due to different orientation.

Barkhausen Noise signal profiles (refer Fig. 5) indicate clear merging of two peaks shown by the sharp change in the slope of best fit curve. It is well known fact that BN signal profiles occur over a wide range of applied magnetic field strengths, which depends on the allocation of pinning strength of microstructural obstacles to motion of magnetic domain walls in response to applied range of magnetisation. Barkhausen Noise signal profile may contain single peak or single peak with slope changes or double peak profile, depending on presence of single distribution or overlap of two dissimilar distributions or widely separated distributions of pinning strength of microstructural obstacles. Nevertheless, the shape of BN profiles also depends on many factors sensitivity of the BN sensor coil, frequency response and applied magnetic field strength. Application of magnetic field intensity enables the magnetic domain walls to interact with different types of microstructural features. In this way application of higher magnetic field is essential for better characterization of microsctuctural features of ferromagnetic materials.

4. Conclusions:

Following conclusion may be drawn from this experimental study:

- Barkhausen Noise signal is a signature of a material microstructure, but its dependence on BN measurement equipment (pickup coil, probe, sensor, etc) and specimen geometry, along with applied frequency and magnetic field intensity, have posed the complexity to decode the necessary information.

- Proper analysis of raw BN signal with appropriate profile curve is essential for better analysis of peak profile.
- Variation in applied magnetic field strength changes the BN curve profile; a minimum magnetic field strength is required for obtaining the suitable profile of BN signature.
- Increase in magnetic field strength increases the amplitude of BN signal and at particular magnetic field strength optimum profile curve is obtained that may be employed for characterization of ferromagnetic magnetic.

5. Acknowledgments

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6. References:

[1] Moorthy V, Vaidyanathan S, Jayakumar T, Raj B 1997 Microstructural characterization of quenched and tempered 0.2% carbon steel using magnetic Barkhausen noise analysis, *J. of Magn. and Magn. Mater* 171 179 -189.

[2] Moorthy V, Shaw B A, Evans J T 2003 Evaluation of tempering induced changes in the hardness profile of case-carburised EN36 steel using magnetic Barkhausen noise analysis, *NDT&E Inter.* 36 43–49

[3] Yi J, Lee B, Kim H C 1994 Nondestructive evaluation of isothermally annealed 12% CrMoV steel by magnetic BN measurement, *J. of Magn. and Magn. Mater* 130 81-91

[4] Moorthy V, Vaidyanathan S, Jayakumar T, Raj B 1998 On the influence of tempered microstructure on the magnetic Barkhausen emission in ferritic steels, *Philos. Mag.* A 77 1499-1514

[5] Blaow M, Evans J T, Shaw B A 2005 Magnetic Barkhausen noise: the influence of microstructure and deformation in bending, *Acta Mater.* 53 279–287

[6] Vashista M, Paul S 2009 On the critical behaviour of Barkhausen noise parameters in surface grinding, *Inter. J. of Abr. Technol.* 2(2) 184-206

[7] Vashista M, Paul S 2009 Correlation between surface integrity of ground medium carbon steel with Barkhausen Noise parameters and magnetic hysteresis loop characteristics. *Mater. & Design.* 30 1595–1603

[8] Vashista M, Ghosh S, Paul S 2009 Application of micro-magnetic technique in surface grinding of AISI 1060 steel for assessment of surface integrity, *Mater. & Manuf. Proces.* 24(1) 1-9

[9] Vashista M, Gaddam A, Paul S 2012 Study of surface integrity of ground bearing steel using Barkhausen noise measurement, *Inter. J. of Adv. Manuf. Technol.*, 63 771-783

[10] Vashista M, Kumar S, Ghosh A, Paul S 2010 Surface integrity in grinding medium carbon steel with miniature electroplated monolayer cBN wheel, *J. Mater. Engg. & Perform.* 19(9) 1248-55

[11] Vashista M, Paul S 2008 Study of effects of process parameters in high speed grinding on surface integrity by Barkhausen noise analysis, (Proceed. of Institute of Mech. Engg. UK, Part – B), *J. Engg. Manuf*., 222(12) 1625-37

[12] Vashista M, Paul S 2011 Novel processing of Barkhausen noise signal for assessment of residual stress in surface ground components exhibiting poor magnetic response, *J. of Magn. and Magn. Mater.*, 323(21) 2579-84