Dependence of Barkhausen jump shape on microstructure in carbon steel

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The present work presents measurements of the Magnetic Barkhausen Noise (MBN) in commercial AISI/SAE 1005 steel samples for different grain sizes. The correlation between the shape of the MBN jump and the grain size is established. The results show the existence of types of MBN jumps. Also, the outcome shows that one of these types of MBN jumps become “squarer” with the decrease of grain size.

Keywords: Magnetic barkhausen noise; microstructural defects; grain size; plain steels.

Se presenta las mediciones del Ruido Magnético de Barkhausen (MBN) en muestras de aceros comerciales AISI/SAE 1005 con diferentes tamaños de granos. Se establece la forma del salto MBN y el tamaño de los granos. Los resultados obtenidos muestran la existencia de diferentes saltos de MBN. Además, se muestra que uno de esos tipos de saltos (MBN) resultan “cuadrados” con el decrecimiento del tamaño de los granos.

Descriptores: Ruido magnético de barkhausen; defectos de microestructura; tamaño de granos; acero plano.

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1. Introduction

The Magnetic Barkhausen Noise (MBN) is produced by the irreversible jumps of domain walls in ferromagnetic materials[1]. These jumps are caused by the presence of defects in the lattice, such as grain boundaries and second phase particles. Thus, the dynamics of these jumps depends on the microstructure [2-4].

In particular, it has been shown that the jumps of the 90° domain walls are produced, mostly, at the grain boundary and the 180° domain wall jump is produced by the presence of second phase particles [1,5].

The correlation between the microstructural features and the mean parameters of the MBN signal has been studied in many works [2-6]. Additionally, the behavior of the MBN profile for different microstructure and values of applied tension have been analyzed [3,7,8].

On the other hand, the dependence of MBN jump shape on the microstructure has received less attention [3,7-11]. The present work is undertaken to establish the dependence of the MBN jump shape on the microstructure. In particular, the dependence of jump shape with the grain size in ANSI/SAE 1005 is studied.

2. Experimental setup and materials

The measurement system is schematically shown in Fig. 1. A Personal Computer (PC) with a data acquisition device (with A/D, D/A and D/D channels) supplies a sinusoidal wave of 1 Hz, which is amplified by a bipolar source Kepco BOP20-20D that feeds the magnetic circuit in order to magnetize the sample with a magnetic field of $\pm\, 2.13 \times 10^4$ A/m,

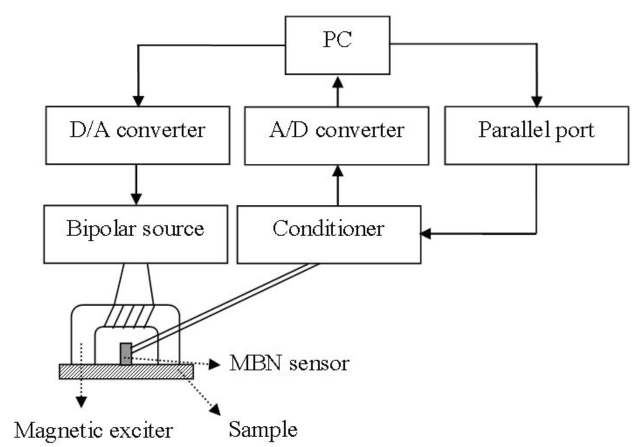

FIGURE 1.Experimental setup

producing magnetic saturation in the samples. The MBN sensor output is amplified and band pass filtered (1-100 kHz). The MBN signals were visualized using a digital oscilloscope and a data acquisition device performed the digital acquisition with a sampling frequency of 200 kHz. For all the experimental measurements, the used samples (120 mm $\times$ 42 mm $\times$ 1,2 mm) were made of commercial ASTM 36 steel. The samples were cut along the transverse direction of the cold rolling sheet.

3. Results and discussions

Figure 2 shows the microstructures of 1005 for different grain sizes in the AISI/SAE 1005 steels samples.

The Vrms of the MBN signals corresponding to the three grain sizes is shown in Fig. 3. It can be seen from figure that the Vrms decrease with the grain size. Previous works have reported similar results in others carbon steels [2-3]. This phenomenon has been attributed to the decrease of the number of domain walls per unit area with the increase of grain size. However, the Vrms is an average magnitude and does not give detailed information about the jumps dynamics. That is the reason for which it is necessary to use another magnitude.

It is known that the MBN jumps are caused, mostly, by the interaction of 180° domain walls with the second phase particles (Type I) and also are produced by the interaction of 90° domain walls with the grain boundaries (Type II) [1,5,12]. The jumps Type I are produced for low applied field and the jumps Type II are produced for high applied field. According to this, the MBN jumps corresponding to the two types are extracted from the signal normalized and averaged [3,13]. The results are shown in Fig. 4. It can be seen from these curves that the jump Type I is sharper and the peaks Type II are "square". It can also can be seen from the figures that there is no dependence of the shape of Type I jumps on the grain size. This fact is evident because

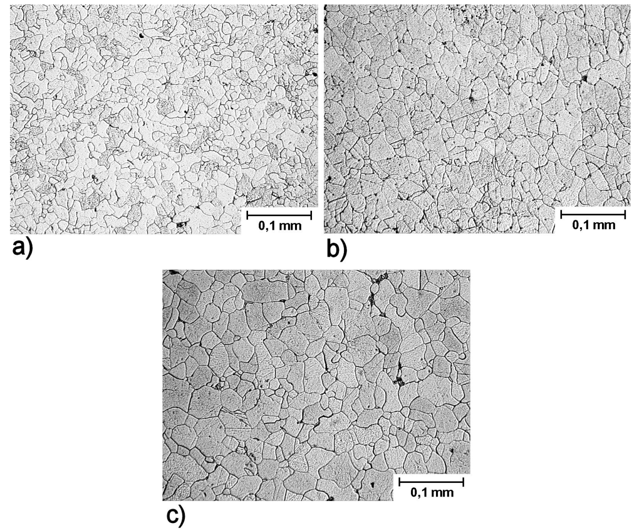

FIGURE 2. Microstructures of 1005 for different grain sizes. a) 910°C, 1 hour, grain size (22 μm), b) 940°C, 2 hours, grain size (32 μm) c) 970°C, 3 hours , grain size (45 μm). Zoom 150x

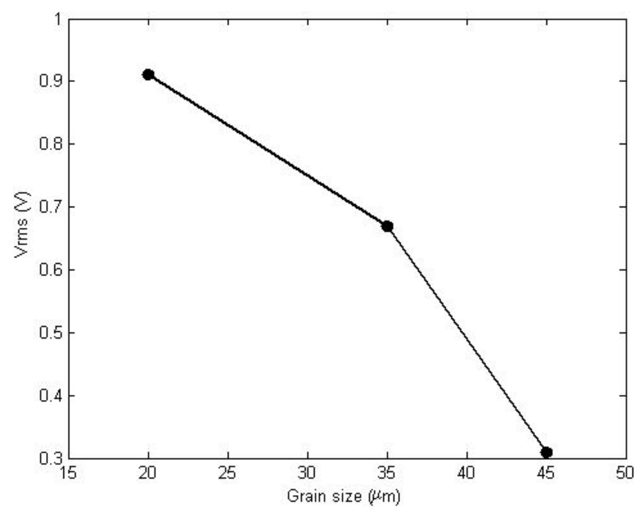

FIGURE 3.Dependence of Vrms of MBN signal on the grain size.

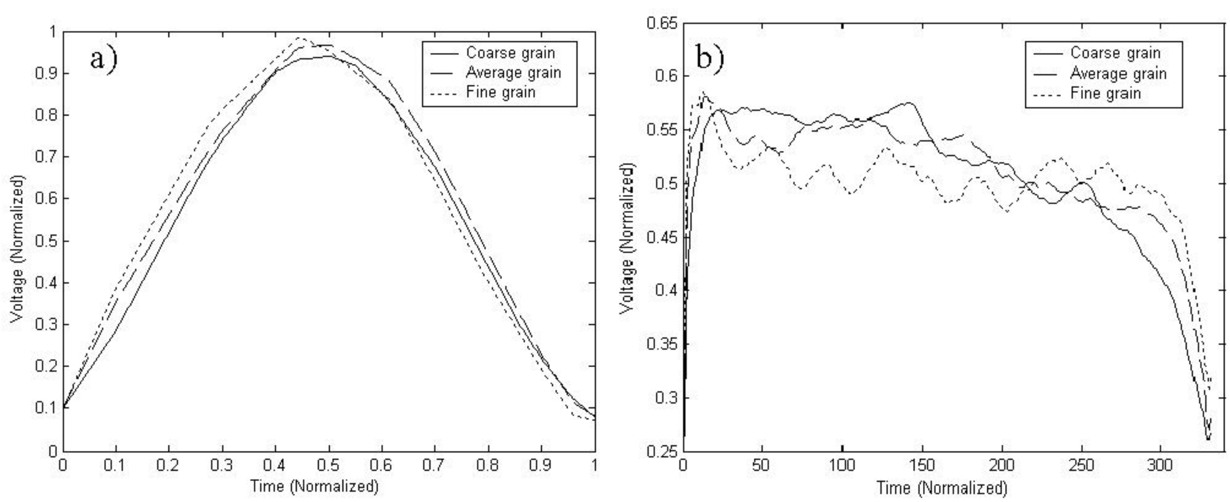

FIGURE 4.Shows the shapes of the MBN jumps for the three grain sizes.

these types of jumps depend on the number of second phase particles. However, the jump Type II depends on the interaction between the 90° domain wall and the grain boundary that is the cause for which it depends on the grain size Fig. 4b. Shows that the jumps Type II become "squarer" with the decrease of the grain size.

4. Conclusions

The Vrms of the MBN decreases with the grain size. However, this dependence is not useful in the analysis of the domain dynamics and interaction with the lattice defects.

On the other hand, the study of the MBN jump shape corroborates the presence of different types of jumps. Additionally, the outcomes reveal that the jumps produced by the 90° domain wall movement depend on the grain size.

1. D.C. Jiles, *Czechoslovak Journal of Physics* **50** (2000) 893.
2. J.A. Pérez-Benitez, L.R. Padovese, J. Capó-Sánchez, and J. Anglada-Rivera, *J. Magn. Magn. Mater* **263** (2003) 72.
3. J. Anglada-Rivera, L.R. Padovese, and J. Capó-Sánchez, *J. Magn. Magn. Mater* **231** (2001) 299.
4. R. Bladev, T. Jayakumar, V. Monrthy, and S. Vaidyanathan, *Russian Journal of Nondestructive Testing* **37** (2001) 789.
5. J.A. Pérez-Benitez, J. Capó-Sánchez, J. Anglada-Rivera, and L.R. Padovese, *J. Magn. Magn. Mater* **288** (2005) 433.
6. J. Degauque, B. Asti_e, J.L. Porteseil, and R. & Vergne, *J. Magn. Magn. Mater* **28** (1982) 149.
7. B. Augustyniak, *J. Magn. Magn. Mater* **196** (1999) 79.
8. G. Gatelier-Rothea, J.Chicio, R. Fourgeres, and P. Fleischman, *Acta Mater* **46** (1998) 4873
9. H.T. Jeong, D.G. Park, J.H. Hong, Y.S. Ahn, and G.M. Kim, *Journal of the Korean Physical Society* **34** (1999) 429.
10. G. Durin, C. Beatrice, C. Appino, V. Basso, and G. Bertotti, *J. Appl. Phys* **87** (2000) 4768.
11. C. Hakan Gur and Ibrahim Cam, *Materials Characterization* **58** (2007) 447.
12. A. Seeger, H. Kronmuller, H. Rieger, and H. Trauble, *J. Appl. Phys.* **35** (1964).
13. J.R. Petta, M.B. Weissman, and K.P. O'Brien, *Phys. Rev. E* **54** (1996) 1029.