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Magnetic Barkhausen Noise and Magneto Acoustic Emission in Stainless Steel Plates

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Abstract

When a slowly variable magnetic field (~ Hz) is applied through a yoke on a ferromagnetic material, discontinuous changes on the magnetic flow density are produced. This phenomenon, called Magnetic Barkhausen Noise (MBN), obeys the movement of magnetic domain walls and its frequency range is about [10-100] kHz. It involves sudden magnetization changes and localized variations of mechanical stresses which originate elastic waves known as Magneto Acoustic Emission (MAE) on the frequency range of 20 kHz up to 1 MHz. Both, MBN and MAE depend on the material microstructural characteristics and they may be considered as non-destructive evaluation techniques. This work is based on MBN and MAE tests carried out on 5 groups of different stainless steel specimens (AISI 409, AISI 430, AISI 439, AISI 441A and AISI 444), for two applied magnetic fields, parallel and perpendicular to the rolling direction.

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Key words: Magnetic Barkhausen Noise; Magnetic Acoustic Emission; stainless steel; material characterization.

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1. Introduction

In this paper, stainless steels from AISI 400 Series are studied. They are ferritic and have higher Cr concentration and lower C than martensitic ones (Carbó, 2008; Cardarelli, 2008). Their crystalline structure is BCC and they are ferromagnetic. Their high tolerance to corrosion is the fundamental characteristic to use this type of steels. They have at least 10.5 % Cr and other elements as Silicon (Si), Manganese (Mn) and Sulfur (S).

Ferromagnetic materials, submitted to a variable magnetic field, respond with the movement of their magnetic domain walls. In this situation small jumps can be seen in their hysteresis loop when the magnetic induction grows up. This phenomenon is known as Magnetic Barkhausen Noise (MBN). Additionally, magnetic domain wall movements produce variations in the stress field inside the material which gives rise to low amplitude and high frequency elastic waves known as Magneto Acoustic Emission (MAE). MBN and MAE depend on the micro structural characteristics of the material under study and they are part of the no destructive test techniques (Martinez Ortiz et al., 2010; Jiles, 1995; Freddy et al., 2007; Torres et al., 2009). The experimental evidence of the MBN was discovered by Henriech Barkhausen in 1919. From that date multiple studies were made related the influence of micro structure on the RMB, finding as an example that the amplitude of MBN increase with the grain size reduction (Torres et al., 2009). Some papers relate the MBN with the hardness and mechanical working (Freddy et al., 2007; Sullivan et al., 2004; Sullivan et al., 2004). The depth of the magnetic influence produced by an excitation frequency of 10 Hz is of the order of 10 mm. MBN is a superficial and sub superficial phenomenon because only information of near a maximum depth of 0.1 mm can be collected; on the other hand, MAE is produced in all the region affected by the magnetic field, so information about near 10 mm depth can be collected (Neyra Astudillo et al., 2012).

In this paper the characteristics of ferritic stainless steels from AISI 400 series are studied: 409, 430, 439, 441A and 444, produced by ArcelorMital Inox from Brazil (Carbó, 2008).

Preliminary studies that shall be included in a Doctoral Thesis are presented here.

2. Experimental Procedure

Most important characteristics of the stainless steel plates are described in next paragraphs.

2.1. Materials

All the studied samples were obtained from plates (original dimensions of 300.0 mm x 210.4 mm x 0.5 mm) of ferritic stainless steel of types AISI 409, AISI 430, AISI 439, AISI 441A and AISI 444, whose chemical compositions are presented in Table 1. The samples were submitted to a variable magnetic field, produced by means of a solenoid. Due to the small plate thickness, the samples had to be introduced inside the solenoid in order to have the MAE phenomenon clearly detected. Although the magnetic field was applied to the entire sample piece to give rise to notable MAE, the collected MBN was produced only below the area covered by the sensor coil. So, from each steel plate, different test sample pieces were cut according to the solenoid dimensions. On the left hand side of figure 1, one original steel plate can be seen (figure 1.a). On the right, cut samples to be tested can be seen on figure 1.b). The black arrow indicates the rolling direction. Samples used in this work (identified as "d" and "c") were cut in the rolling direction (0^o) and perpendicular to it (90^o).

Table 1. Chemical composition, % (Weight).

% (Weight)	409	430	439	441A	444
C ≤	0.08	0.12	0.07	0.03	0.025
Cr	10.5/11.75	16/18	17/19	17.5/18.5	17.5/19.5
Ti ≥	6 x C		0.20 + 4 (C+N)		
Nb≥				3 x C + 0.30	
Ti + Nb ≥					0.20 + 4 (C+N)
Mo					1.75/2.50