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FOLLOWING THE DUPLEX STAINLESS STEEL EMBRITTLEMENT THROUGH ANALYSIS OF BARKHOUSEN NOISE

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Abstract. *The duplex stainless steel when subjected to temperatures below 550 ° C its ferrite matrix decomposes forming finely dispersed precipitates inside this phase, hardening the material and reducing the toughness. Samples of a duplex stainless steel SAF 2205 duplex were treated at temperatures of 425 ° C and 475 ° C for times up to 200 hours in order to obtain different degrees of embrittlement. A non-destructive methodology based on interaction between density of field lines and material, in the irreversibility region of magnetic domains, was developed. This one looks for a relationship between the Barkhousen noise and the embrittlement of the material. Fields with different frequencies were applied to the material by a solenoid and the resultant signal obtained by another one. The value of the largest amplitude of the Barkhousen noise was used as a measurement parameter to characterize the embrittlement of the material. Rockwell hardness tests and Charpy impact test were performed. The results showed that the amplitude of the noise as the parameter was able to follow the embrittlement of the material under investigation in both temperatures.*

Keywords: *Duplex stainless steels, embrittlement, barkhousen noise.*

1. INTRODUCTION

When a magnetic field is applied to ferromagnetic materials, the magnetic domain walls moves discontinuously, depending on the microstructural characteristics such as grain boundaries, cracks, presence of non-magnetic particles, and even the degree of deformation (NORMANDO 2010). These movements cause a very strong magnetic induction, which takes place discreetly in the form of abrupt jumps. These abrupt jumps occur due to movement of the walls of the magnetic fields that produce a series of electrical pulses forming what is called the Barkhausen noise (Serna-Girardo, 2007).

According to Silva 2009, the ferrite phase of the duplex stainless steels decomposed at temperatures below 525 ° C by spinodal decomposition mechanism. This is the spontaneous decomposition of this phase forming initially α` consistent with the matrix and subsequent loss of coherence of this and its growth. This phase is responsible for embrittlement.

In the present work a non-destructive test based on interaction between density of field lines and material, in the irreversibility region of magnetic domains, was studied. This one looks for a relationship between the Barkhousen noise and the embrittlement of the material.

2. METODOLOGY

Samples of a duplex stainless steel SAF 2205 were treatments at temperatures of 425 ° C and 475 ° C for times up to 200 h. These were placed between two solenoids. An alternating field with frequency of 60 Hz was applied to one of the solenoids and the resulting field with the noise of interaction was detected in the other solenoid. The signals were transformed to the frequency domain in order to get the highest amplitude. This parameter was used to follow the formation of embrittlement phase.

Rockwell C hardness and Charpy impact tests were carried out on samples with the same treatments in order to analyze the hardening and embrittlement in order to compare the results with the Barkhousen noise.

3. RESULTS AND DISCUSSIONS

Figure 1 shows the *change* of the amplitude of Barkhousen noise *as a* function of aging time for samples of a SAF 2205 steel at temperatures of 425 ° C and 475 ° C. The temperature of 475 ° C is the most embrittlement kinetics, with the 425 ° C with lower one.

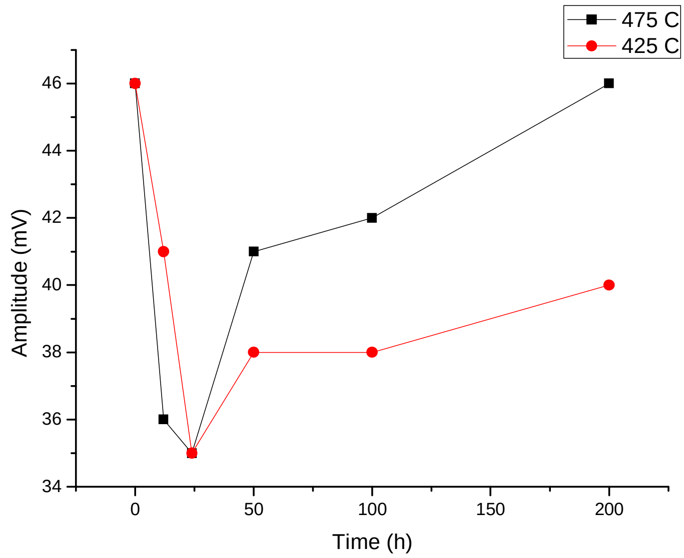

Figure 1. *Change* of the amplitude of the Barkhousen noise as *a* function of aging time, to temperatures of 425 ° C and 475 ° C.

Figure 1 shows a drop in amplitude values followed by an increase with a tendency to stabilize. The values obtained for temperatures of 425 ° C have lower values than for temperature of 475 ° C. The obtained minimum amplitude for the temperature of 425 ° C was around 24 hours, while for temperatures of 475 ° C was found to be less than this. The two curves show the same trend revealing the ability of the parameter used to follow the formation of the embrittlement phase of the material under study.

According to Silva 2009, the ferrite phase of the duplex stainless steels decomposed at temperatures below 525 ° C by the spinodal decomposition mechanism. This is the spontaneous decomposition of the ferrite phase forming initially α` coherent with the matrix and subsequent loss of coherence of this and its growth. The initial drop in amplitude values corresponds to the forming region of the coherent phase. After breaking it and growth of this phase, the finely dispersed precipitates formed begin to block the movement of magnetic domain walls and increasing the intensity of Barkhousen noise (Lo, 2007, Tavares 2010).

Albuquerque et al, 2010 showed similar results following the formation of α` phase through sonic velocity measurements, for the same times and temperatures used. The results of sonic velocity as a function of aging time showed similar effects to those obtained in this study. Both techniques were able to follow the embrittlement phase.

The change of Rockwell C hardness and the absorbed energy as a function of aging time at 425ºC temperature is illustrated in Figure 2. It can be seen that there is a ductile well defined threshold for times up to 50 hours. From 100 hours the samples have low absorbed energy characteristic.

Figure 3 shows the change of hardness and absorbed energy in Charpy test as a function of aging time at a temperature at 475º C. It is observed the presence of two-stage hardening. Stage I is shows that there is a high hardening rate. In stage II have a lower hardening rate followed by a trend towards a plateau. The analysis of the energy absorbed during the impact test shows that the material has become brittle in the second stage.

The presence of two stages of hardening was observed in other systems that had spinodal decomposition (Choo et al., 1997. KRATOCHVIL et al., 1984). A rapid increase in hardness in stage I being followed by a transition level.

Then the second stage starts with a low hardening rate and tending to a hardness level. According Choo et al. (1997), the two sources responsible for the hardening stage I and II are the spinodal decomposition and growth of the ordered phase particles, respectively. The second stage corresponds to the region of lowest energy absorbed in Figures 2 and 3, wherein the material is embrittled.

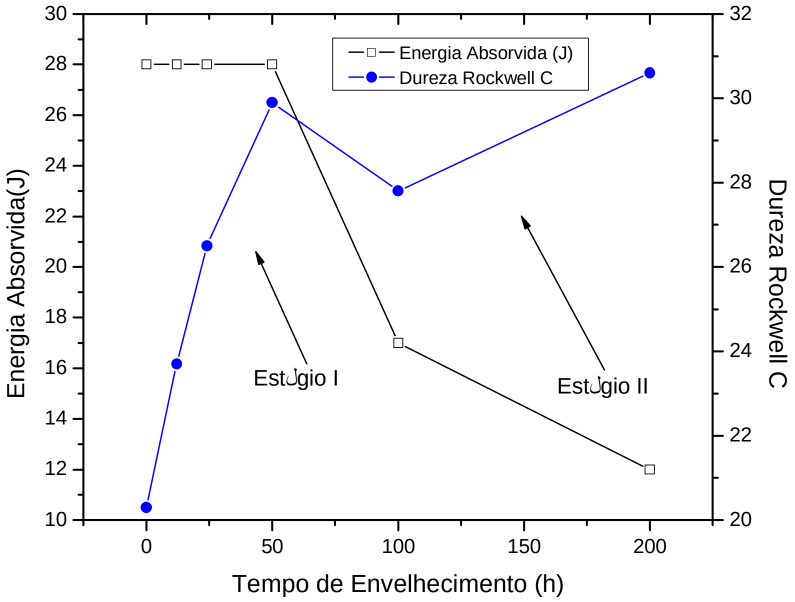

Figure 2 - Change of Rockwell C hardness measurements and the absorbed energy as a function of aging time at temperature 425 ^{o}C.

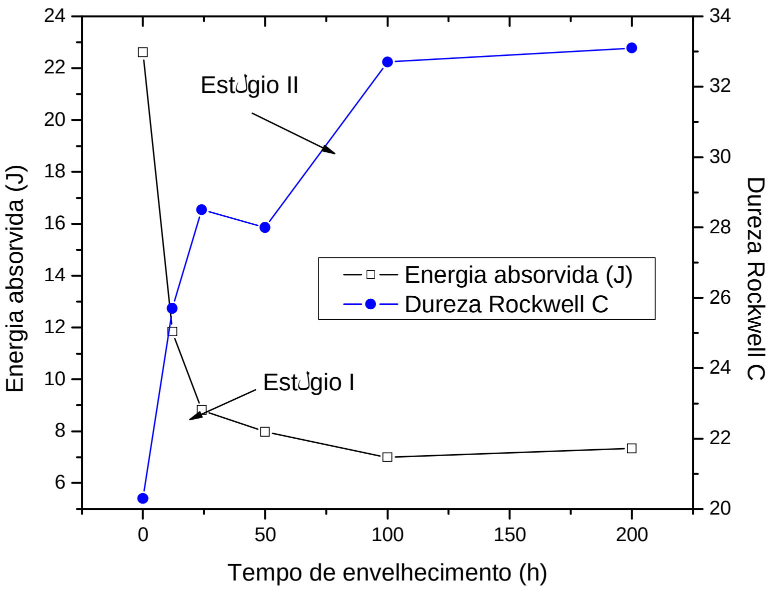

Figure 3 - Change of Rockwell C hardness measurements and energy absorbed as a function of aging time at temperature of 475 ^{o}C.

The amplitude values were capable of detecting the two stages of hardening, with a fall in the first stage and an increase in the latter. This shows that the parameter is able to follow the formation of the embrittlement phase in the study material.

4. CONCLUSIONS

The amplitude of the barkhousen noise was used to follow de embrittlement phase of a duplex stainless, leading to the following conclusions:

The amplitude was able to follow the two stage of hardening and the embrittlement of the material studied.

It shows that fine dispersed particles lets difficult the movement of the walls domain and the second stage.

5. ACKNOWLEDGEMENTS

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