BARKHAUSEN NOISE MODELOF MICRODEFECT CHARACTERIZATION

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Abstract

The testing method using Barkhausen noise (B.N) is a particular method, which can be applied on ferromagnetic materials. It is a magnetic non destructive evaluation (NDE) method and can provide very important information about the material microstructure. The work here presented documents the ability to determine the metallurgical state of steel. A new approach is studied of defects; microstructure by BN .The defects geometry, microstructure changes are treated in the mathematic model. Experimental elaboration is studied; instrumentation for measurement BN has developed.
Key words: NDT, Barkhausen noise, magnetic field, Model, defect

1 Introduction

The magnetic Barkhausen noise (MBN) technique has attracted considerable attention in recent years as a possible non-destructive technique for evaluation of microstructural parameters such as grain size, carbide precipitates, inclusions, dislocation and characterizing the magnetic properties of steel. Barkhausen noise shows magnetizing discontinuities of ferromagnetic materials, such as alloys containing iron, Co, Ni [1].

In the application of variable magnetic field on the ferromagnetic material, many processes such as the creation and the annihilation of domain and the domain wall motion's are observed. Each domain is strained along its direction of magnetisation , the magnetostriction phenomena occurs, if the domain wall motion's are sufficiently rapid, the abrupt changes in local strain give rise to the generation of elastic waves, This phenomenon is observed for certain crystals when, one records the hysteresis loop B(H) which appears made up of a succession of marches[2]. These variations of magnetisation also appear by a signal of noise at the boundaries of a detecting reel placed near material [3]; [6]; [7].

Many problems take account in the modelling of magnetic materials, especially when it is a question of combining simplicity, speed of execution and precision [4]. The aim of this work is the characterising the material microstructure E24, one proposed a simple model which enabled us to simulate the characteristics of the pinning sites which are responsible of the movement for the wall domain.

2 Theoretical approach

Consider a structure with two types of domain walls: This organisation of the magnetic microstructure results from a minimisation of energies. We suggest the movement of the wall in only one direction is ' x'.
The energy per unit area E of a domain wall element under an applied field H is given by:

$$E(\text{énergie}) = E_H + E_{dw}\{x\} \qquad (1)$$

with: $E_{dw}\{x\}$: Energy of the wall

$E_{dw}\{x\} = E_{anis} \approx 2\mathrm{K}_1\delta$ with δ thickness of the wall δ = Na (a is the distance inter atomic and N is the number of atoms in the wall).

The interaction of this field with the wall can be comparable with a force f equivalent applied on the wall.

$\mathrm{E_H} = -\frac{\partial f}{\partial t} = -2M_S Hx$, $\left|\vec{\mathrm{M}}_s\right|$ represent the value of magnetisation saturation.

The points pinning of the domain walls are in general the crystalline defects; dislocations, precipitates, inclusions, etc.

In our model, one studied the defects of cubic inclusions. At the time of its movement, the wall is pinned and stops in the medium of an inclusion. The total free energy of the wall in this case is minimum; one says that the wall is in the most stable state.

We suppose that each distance of the wall moved a distance x, the surface occupied in the crystal lattice is:

$$S = a^2 - (d - x)d$$

According to the theorem of Kersten, the density of energy surface is given $E_r = rS$ with r is the energy density of the domain wall. Under the action of the external magnetic field, when the domain wall is in the equilibrium state, $\Delta\mathrm{E} = \Delta\mathrm{E}_r + \Delta\mathrm{E}_H = 0$ with $\Delta\mathrm{E_H} = -2.M_s.\mathrm{H}$

β denotes the volume density of the inclusion

$$\beta = \frac{V(inclusion)}{V(réseau)} = \frac{d^3}{a^3} \qquad (2)$$

Knowing that the Barkhausen noise is the result of a wall domain displacement, from one inclusion to another, the wall can thus be released only if the field applied reached a critical value H_P this displacement is called the mean free path of a domain wall L.

After calculations, $\mathrm{H_p}$ is given by:

$$H_P = \frac{r}{2M_S}.\frac{d}{a^2}$$

from expression of β we have

$$d = \left(\beta.a^3\right)^{\frac{1}{3}} = a.\beta^{\frac{1}{3}}.$$

$$H_P = \frac{r\beta^{\frac{1}{3}}}{2M_S.a^2} \qquad (3)$$

One determines the time t_σ which represents the time of the distribution, by:

$$t_\sigma = \frac{L}{C_V H_P} = \frac{1}{C_V}.\frac{M_S L\,\beta^{-\frac{1}{3}}a}{K_1\delta} \qquad (4)$$

The Monte Carlo method is based on a process with drawings of lots depending from laws of probability, calculated beforehand and which contain the essence of physics, it is based on the Gaussian distribution the Barkhausen noise (MB) is:

$$e(t) = \frac{B}{\sqrt{2\pi\sigma}} \exp[-(t - t_0)^2 / 2\sigma^2] \qquad (5)$$

$B = f\left(H, \frac{dH}{dt}, \Delta\phi\right)$, H is the largest strength of the outer magnetic field, $\frac{dH}{dt}$ is magnetisation rate, $\Delta\phi$ is the increment of magnetic flux density in the magnetisation region, σ is variance of duration time [2].

For each movement of a wall domain from one inclusion to another, we remark pulsation Gauss.

In the statistical theory, the distribution of Gauss can be considered near to zero: e(t)= 0 for $t_\sigma = 6\sigma$

where : $$\sigma = \frac{1}{6C_V} \cdot \frac{\mu_0 \, I_s L \, \beta^{-\frac{1}{3}} a}{K_1 \delta} \qquad (6)$$

M_S : the saturation magnetisation.

Signal MP is given by: $$MP = \left(C_r \frac{t_T . L^2}{\sigma} \right) . L = C_d . L \qquad (7)$$

With: $$C_d = C_r \frac{t_T . L^2 \, 6 C_V K_1 \delta}{M_S a L \, \beta^{-\frac{1}{3}}}$$

In order to estimate the mean free path, it is necessary to make an assumption about the arrangement of the active pinning sites. A suitably basic first approximation is to consider all the pinning sites as points arranged in a simple cubic lattice, with one site per cube of side l, where

with : $$l\{H\} = \left(\frac{1}{N\{H\}} \right)^{\frac{1}{3}} \qquad (8)$$

3 Experimental results

A basic configuration for Barkhausen noise measurements is shown in figure 1. The use of materials raises the question of the choice of material, adapted best to the applications considered. The alloys iron carbon in particular steels play a capital role in current technology. In spite of the appearance of new materials coming to compete with steels, the system iron carbon remains of capital importance in the industrial world.

The samples used in this study are E24 an (100 × 50 × 10) mm^3, during the measurement at 0.7Hz magnetic field H using a triangular wave form of high amplitude (field about 200A/cm) is applied. The voltage is passes through a power amplifier, a coil around a core was used to generate the sweep field for BN generation, a induction coil placed between the coil around and sample.

Since the coil placed on the surface sample does not intersect the flux changes in the plane of the specimen, the output of the coil was fed to a preamplifier, passed through a band passe [3-300]Khz, and was observed on a computer scope, an IBMPC based instrument with a 16 –channel analog –to-digital(A/D), software permit to draw the envelop, to found the number , the height of pick.

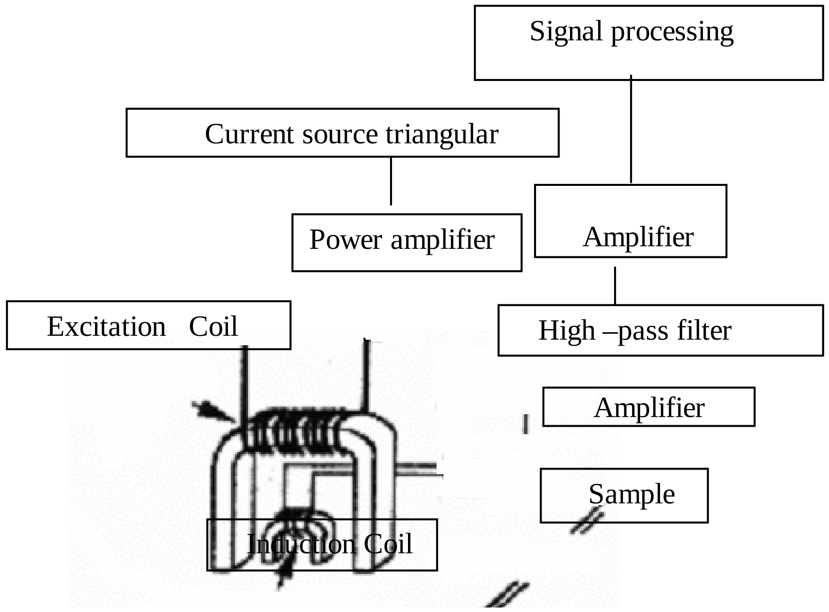

Figure 1: Synoptic of BN acquisition

From the results experimental (figure 2) one found the number total of inclusion is 511 for the total time of acquisition t=0.05s.

In general, inclusions are distributed by chance and of various sizes, however, our problem is solved by supposing a periodic distribution of inclusions of equal sizes.

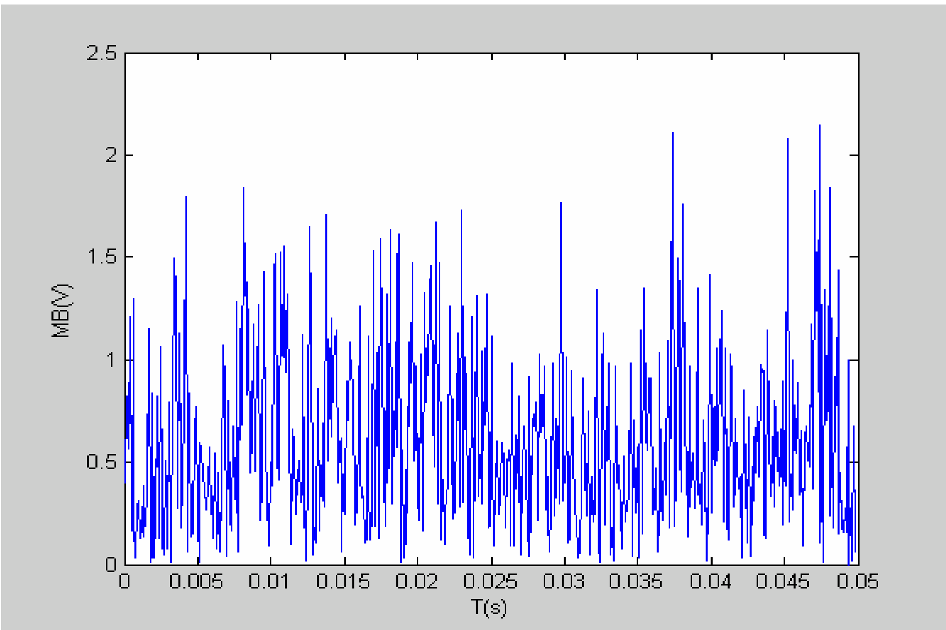

Figure 2: Variation MP as a function to T

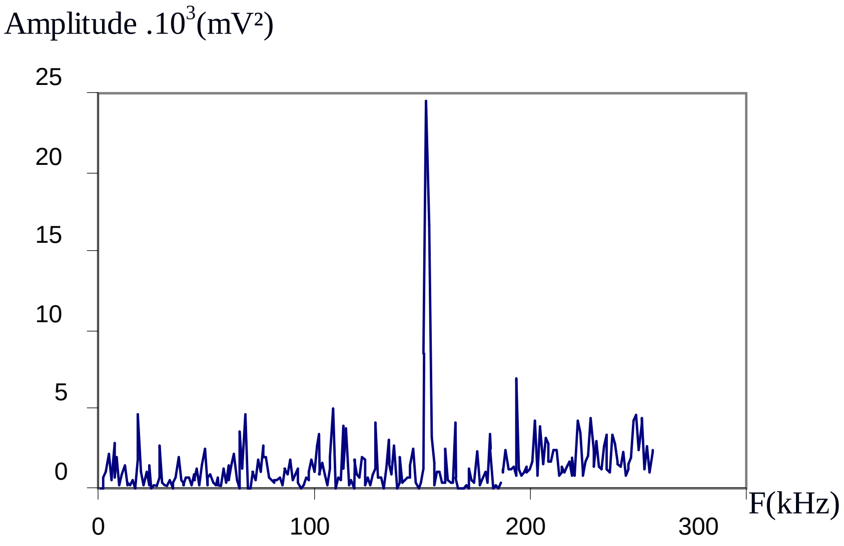

Figure3: Density spectral variation of E24

The interpretation of the results concerning the signal of the Barkhausen noise is difficult because several microstructural parameters change simultaneously. In general, the inclusion are randomly distributed and of various sizes. However, the problem is solved by assuming a periodic distribution of inclusions of equal sizes. The variations of the mean free path according to the duration of impulse of the Barkhausen noise is shown in figure 4.

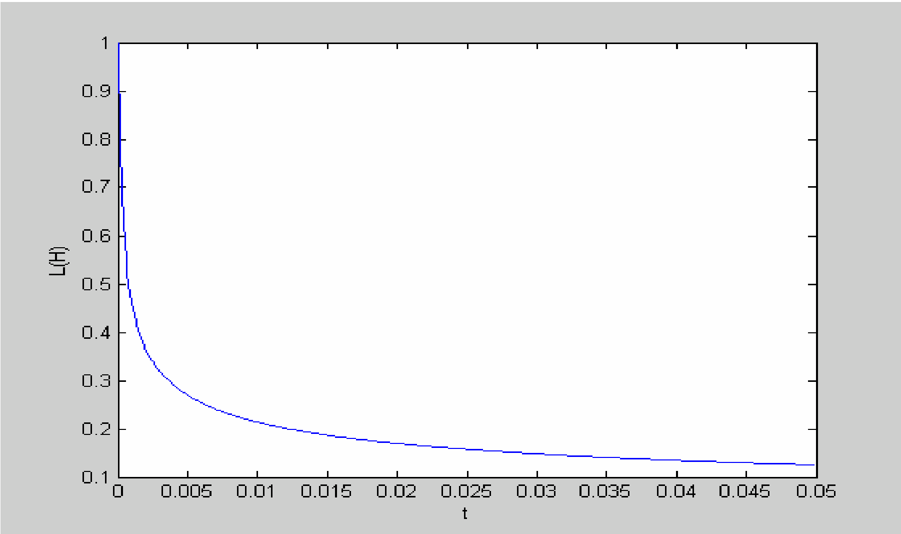

Figure4: Variation L(H) as a function to t

4 Conclusions

In the above analysis, we have considered the case where the moved a distance x. The results obtained arise under several axes: Numerical determination of the position of the jump and the amplitude of Barkhausen. The experimental test carried out and studied in this article give us an outline on the importance of the Barkhausen technique in the field of the non destructive testing.

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