Morphological analysis of carbon steels using fractal geometry

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Abstract. In this paper we present the preliminary results of morphological analysis of Fe₅₉Mn₃₆.₅Al₃.₁₀C₃.₅₆Cu₀.₃₇ %Wt alloy. This alloy was prepared by mechanical alloying with various milling times, then hot compacted at various pressures and finally underwent a sintering process. The samples were characterized structurally by experimental techniques such as: X-ray diffraction and scanning electron microscopy. Each micrograph was analysed by fractal dimension using the Box Counting method in 2D; this type of tool allows you to assign a numerical value to the region which has been applied the technic. This numerical value is associated with the properties obtained by experimental techniques such as microhardness.

1. Introduction
The system Fe Mn Al disordered alloys, in the austenite phase [1], arouses great interest both scientific and technological due to its mechanical and corrosion resistance properties. In order to stabilize the austenitic phase, as is known, gives the alloy optimum mechanical properties, at both room temperature and high temperature, were varied preparation methods concerning adding some alloying powder metallurgy and [2-4], which are miscible with the powder metallurgy.

We prepared add samples 3.56% Wt of C and 0.237% Wt Cu Fe Mn Al to system with the powder metallurgy process: mechanical alloying (6 and 12h), uniaxial compaction in hot (T=250°C and pressures of 400, 600 and 800MPa) and sintering (T≈1150°C). The parts obtained are made of mirror finish them by metallographic process. The pieces were analysed with scanning electron microscopy (SEM) also obtaining energy spectra at various points in each sample. In order to analyse the morphology of each sample was developed Box-Counting 2D software.

2. Mathematical method
The Fractal Geometry is a branch of mathematics, very attractive fractal objects that are possible to construct the notion of self-similarity, dynamic systems, chaos, orbits and dimension, both topological and Hausdorff, which have become useful tools in numbers disciplinary fields such as mathematics, science, art, etc. [5-7].

Besides the self-similarity, the fractal objects have an idea out of the common; the fractal dimension. The dimension that is assigned by convention to certain geometrical and physical objects, is associated with a number infinite variables, for example, a cube is assigned a triple defined directly by the thickness, the width and height thereof, then the size of this object is three. This type of dimension is known as the topological dimension.
The fractal dimension, as properly its name suggests, is a fractional dimension and is determined by a rational number. This type of dimension has been widely used for example to measure the length of the coast of an island. Dimensionality value assigned to the objects of study under some technical spreadsheets fractal dimension is a value that ensures as Mandelbrot [5] but you do not find transitional areas without a clearly defined structure, I will identify areas with fractal whose dimension is either a fraction either an integer "abnormal", which also indicates an irregular or interrupted state. Furthermore, since many objects are systems such as comments, which Mandelbrot [5], in that they are composed of many different parts, hinged together, the fractal dimension describes one aspect of this rule joint.

The Box-counting method or by counting boxes, has been used to calculate the fractal dimension of certain objects that are represented in a plane [5]. The fractal dimension calculated using the Box-Counting method meets the slope of the linear fit between the points and the size of the grid with the relation \( D = \frac{\ln(N)}{\ln(k)} \) where \( N \) is the finite number of subfigures or subsets all congruent \( k \) satisfies \( r = 1/k \) numerical value where \( r \) is a shrinkage factor. The accuracy of the method is improved with a greater number of iterations, the depth of these iterations fractal structures is not limited, that is, the size of the side of the case can be reduced many times as needed, but the processed images resolution it is the limiting factor to count points. Our goal is to apply this method of calculating fractal dimension for each micrograph obtained by SEM at the same points where energy spectra were obtained.

3. Results and discussion

Figure 1 shows a micrograph (a) for 6h and with a compaction pressure of 800MPa hot shown. To a point, was taken it samples the energy spectrum (b) which shows the alloying components and the existence of traces of oxygen attributed to air trapped in the compacted surface. Were taken spectra at several points and similar spectra were found not shown here, which shows a good homogeneity achieved during the process.

![Figure 1. Micrograph (a) of the alloy with 6 hours 800MPa and its corresponding energy spectrum (b) taken him in 1.](image)

In Figure 2, occurs the dimensional analysis method achieved with Box Counting. The figure shows the region where the zoom is performed and calculated the fractal dimension with Box-Counting.

Figure 3, shows the micrograph taken for the sample with 12 hours 400MPa at the first point where the energy spectrum was obtained, doing on the image zoom and calculated the Box-Counting dimension shown in Figure 4.
Figure 2. Fractal dimension micrograph 6 hours and 800MPa pressure spectrum one.

Figure 3. Fractal dimension micrograph 12 hours and 400MPa pressure spectrum 2.

Figure 4. Fractal dimension shows 12 hours and 400MPa pressure spectrum 2.
Similarly was made to various points, the fractal dimension obtained in each case, are summarized in Table 1. It may be noted that the dimensionality is not affected by pressure changes or by compaction hours of mechanical alloying. With what might be said that there is a process of homogenization.

| Sign-spectrum                        | Fractal dimension |
|-------------------------------------|-------------------|
| FeMnAlCu_6H_800MPa – spectrum 1     | 1.22972           |
| FeMnAlCu_6H_800MPa – spectrum 3     | 1.16096           |
| FeMnAlCu_12_400MPa – spectrum 1     | 1.16096           |
| FeMnAlCu_12_400MPa – spectrum 2     | 1.22972           |

At the points where the spectra were taken and elsewhere in the sample data Vickers (HV) microhardness were taken with a 500g load and indentation time of 5s, finding an average for the samples with 6h 800MPa a microhardness of 244.52±0.5HV and for 12h and 400MPa shows a hardness of HV 224.8±0.5. It can be concluded that there is in each sample homogenization process by the average value and additionally microhardness results are better for 6h and 800MPa. However, it is important to note that the values obtained for 6 h and 800MPa to 400MPa 12h shows are better than those reported by Cruz B et al [8] almost certainly due to the conditions of sample preparation.

4. Conclusions
Each micrograph was analysed from one side taking energy spectra at various points of the sample, finding similar spectra in each. In all spectra, the presence of traces of alloying constituents, other trace oxygen. In addition, the fractal dimension analysis using the counting method 2D cases, it was possible to assign a numerical value to each of the regions where energy spectra were obtained; corresponding to the dimensionality of the samples, where that value was calculated by the relation $D=\ln(N)/\ln (k)$ where $N$ is the finite number of subfigures or subsets all congruent $k$ satisfies $r=1/k$ numerical value where $r$ is a shrinkage factor, and has been designated in relation to roughness, irregularity or interruption state condition, with the outline of each of the analysed micrographs. Dimensionality assigned at each point of each sample was very close, which could be associated with a homogeneity achieved in the development process of each sample. This homogeneity due to alloy diffusion process, gave better results than those reported by microhardness Cruz B et al [8] for such alloys.

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