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Characterization the clustering of the Al(Mn,Fe) phases in the eutectic of EN AW 8006 alloy

Abstract

EN AW 8006 alloy has a hypoeutectic microstructure. The eutectic of aluminum solid solution and Al(Mn,Fe) intermetallic compounds can be found in the interdendritic areas. This eutectic structure has a clustered nature. The intermetallic compounds build up clusters which clusters forms larger clusters. For the analysis of the clustered nature there are more method. The article examines these methods and shows which method identify clearly this arrangement of the intermetallic compound particles.

Keywords: aluminum, microstructure, eutectic, image analysis, clustering

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1. Introduction

Industrially more and more aluminum alloys are used in different area from the buildings to the automotive [1]. The aluminum is lightweight and with alloying and the processing technology it is possible to change the mechanical and electrical properties in a wide range. Additionally, most of the aluminum alloys have a good corrosion resistance [2]. To understand and enhance the properties of the aluminum alloys it is necessary to study and describe the microstructure, and the changes of the microstructure during the manufacturing processes [3].

One important aluminum alloy is the EN AW 8006. It has a good plasticity, so either foils can be producing easily from this alloy [1]. This is a cheap alloy in contrast to the high magnesium and copper alloying, but it has a complex microstructure. A classical foil production from DC slabs change drastically the microstructure of the alloy. The description of a complex microstructure needs more computational method [3]. In the current study the analysis of the as-cast and homogenized microstructure was described by image analysis.

The measure and description of the size and shape of the objects, here Al(Mn,Fe) phases, it is well known and generally used technique [4]. But the description of the arrangement of the objects are a hard task. Several different methods were developed mainly for the research of the particle reinforced composites [5]. These methods try to evaluate the ordering, or clustering or the random distribution [6]. All these methods search the answer for one simple question, for example: are the particles clustered? After the evaluation a purposeful measurement necessary to describe the microstructure.

A prior study [7] introduced the clustering in the Al-Al(Mn,Fe) eutectics. This method used a basic K-means algorithm to find the clusters and the cluster centers [8]. Basic feature of the K-means algorithm as all such methods that determines clusters in the microstructure either the particles clustered or not. These methods just find the clusters but does not gives information about the clustered nature of the microstructure. Additionally, the K-means algorithm can find the globular clusters well. In the examined eutectic microstructure this condition is fulfilled.

The literature of the image analysis of particle reinforced composites suggests more method to test and identify the clustering in a particle system [9]. The current study compares these methods in the metallographic analysis of eutectics in an EN AW 8006 aluminum alloy.

2. Experimental

Microstructure of an as-cast EN AW 8006 alloy was studied. The concentration of iron (1.6 w/w%) and manganese (0.6w/w%) concentration were near at the maximum value described by the standard. The samples were taken from a DC slab. The samples were heat treated isothermally at 630°C – 4 hours. The microstructure of the samples was studied by optical microscopy. One surface of the samples (perpendicular to the direction of the casting) was prepared of the samples by mechanical grinding and polishing. The polishing is finished by 1µm diamond paste. HF immersion etching was used to reveal the microstructure.

During the solidification of the EN AW 8006 alloys Al(Fe,Mn) phases are formed in different eutectic transformations. Therefore, in the microstructure the primary aluminum solid solution dendrites and the eutectic areas between them can be seen (Figure 1.). The dendrites are equiaxial, and the small particles in the aluminum solid solution matrix built-up the eutectic in the interdendritic area. The phases are spheroidized under the heat treatment, therefore, during the analysis more globular particles were found. But mainly at the boundary of the eutectic colonies rod like phases can be seen. The analysis shows that the fraction of the Al₃Fe phases is increasing with the temperature and time of the heat treatment.

Images were taken from the microstructure by optical microscopy for analyzing. The images were converted to grayscale and a square LUT was applied to all images. The images had a background illumination problem, the center of the right half is brighter. Therefore, an adaptive automatic segmentation algorithm was chosen. The Brensen algorithm gave the best result with 31pixel window size and 61 threshold value. The particles in the segmented binary images are labelled, and the clustering of the particles are examined.

The segmented binary image was analyzed. Periodicity of the eutectic phase were tested by covariance function. The clustering was analyzed by radial distribution function, morphological mosaic and by the distance from the nearest neighbors. Finally partition K-means clustering algorithm was used to determine the clusters itself, and the number of the clusters.

Three different algorithms are tested. The first is the radial distribution function. Generally used the radial distribution function [6]. Circular areas are grown from the centers of the objects, and the number of objects, or pixels registered as a function of the radius of the circular areas. This function is sensitive to the clustering. Another method is the analysis of the morphological mosaic [5]. The most time used tessellation technique is the Voronoi diagram [9]. The computational geometry frequently uses this method. The problem of this method, that it assumes the object as a point. Here emerges the problem of the characteristic point, and the method neglect the shape of the object. With a continuous dilatation of the objects a tessellation can be made, which is sensitive to the size and the shape of the object. This method is the morphological mosaic method. The analysis of the size distribution of the cells from the mosaic can show the clustering of the objects. Equivalent method to analyze the distribution of the distance between the nearest neighbors [6]. Mathematically these methods are the same basis because all methods examine the distance of the neighboring particles, but all of them have a different sensitivity. In the analysis all method is tested in the eutectic microstructure to choose the best one.

3. Results and discussion

Figure 1 shows the optical micrographs taken from the microstructure of the examined samples of EN AW 8006 alloy. The solid solution is light and the intermetallic compound particles are dark gray on the micrographs. Figure on also show the segmented images where the intermetallic particles are black in white background. The radial distribution function, the morphological mosaic and the distance between the nearest neighbors are analyzed. Both microstructure are clustered.

Figure 2 shows the radial distribution function of the images. Image A taken from that area which contains larger and small intermetallic phases. The average distance between the phases is greater. Therefore small clustering can change drastically the distribution of the distances. This can be seen in the radial distribution function. The slope changes of the curve. Where the objects are close to each other the slope of the curve is larger. Image B taken from that area which contains smaller intermetallic phase but more. The same clustering of the object causes smaller changes in the distribution of distances. The slope of the radial distribution function varies within a small range. The radial distribution function does not reveal the clustering of the phases.

Figure 3 shows the morphological mosaic of the images. It can be seen larger and smaller cells in the mosaic structure. Therefore the size (area) distribution of the cells is studied. In both cases (image A and B) the distribution are multimodal, which shows the clustering. In case of image A a larger effect can be seen, but the distribution of image B also shows two size classes which can be determine numerically. In both cases the morphological mosaic reveals the clustering of the intermetallic phases.

Figure 4 shows the nearest neighbors and the distance between these. The distance distribution is examined in this method. In image A multimodal distribution can be seen, which clearly shows the clustering. But in the case of image B a normal monomodal distribution was got by the analysis. In this case the clustering of the intermetallic phases is not revealed.

To compare the three different method only the morphological mosaic reveals the clustering nature of both images. In a clear situation, in case of image A the other methods also shows the clustering. But in case of image B, which contains smaller particles which are closer to each other, the other methods did not reveal the clustering. So in the image analysis of the microstructure of EN AW 8006 alloys, the morphological mosaic is that method which can detect the clustering.

4. Conclusions

EN AW 8006 alloy has an eutectic microstructure between the primary dendrites in an as-cast state. This eutectic has a complex structure. The Al(Mn,Fe) intermetallic compounds build up small clusters which clusters make large clusters. For description and identification of the clustering the literature suggests more method: radial distribution function, morphological mosaics and the analysis of the distance between the nearest neighbors. The previous analysis shows the results of the mentioned methods. The results show that the analysis of the morphological mosaic gives the best description of the clustering. A previous analysis pointed out, that the combination of the morphological mosaic and the K-means clustering method can be used to the detailed description to the eutectic structure of EN AW 8006 alloy.

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Figure captions

Fig. 1. The analyzed micrographs and the segmented intermetallic phases of the EN AW 8006 samples.

The majority of the intermetallic phases are globular due to the applied heat treatment (630°C/4h). In the following the article refers to the left image as A, and B to the right.

Fig. 2. The not normalized radial distribution function of the image A and B. In case of image A small variation of the slope can be observed, which shows the clustering.

Fig. 3. The morphological mosaic of the images and the distribution of the cells according to the cell area. In both cases a multimodal distribution was measured which show the clustering.

Fig. 4. The nearest neighbor map and the distance distribution of the images. In case of image A a clear multimodal distribution was measured, but in case B the clustering do not observed in the distribution.

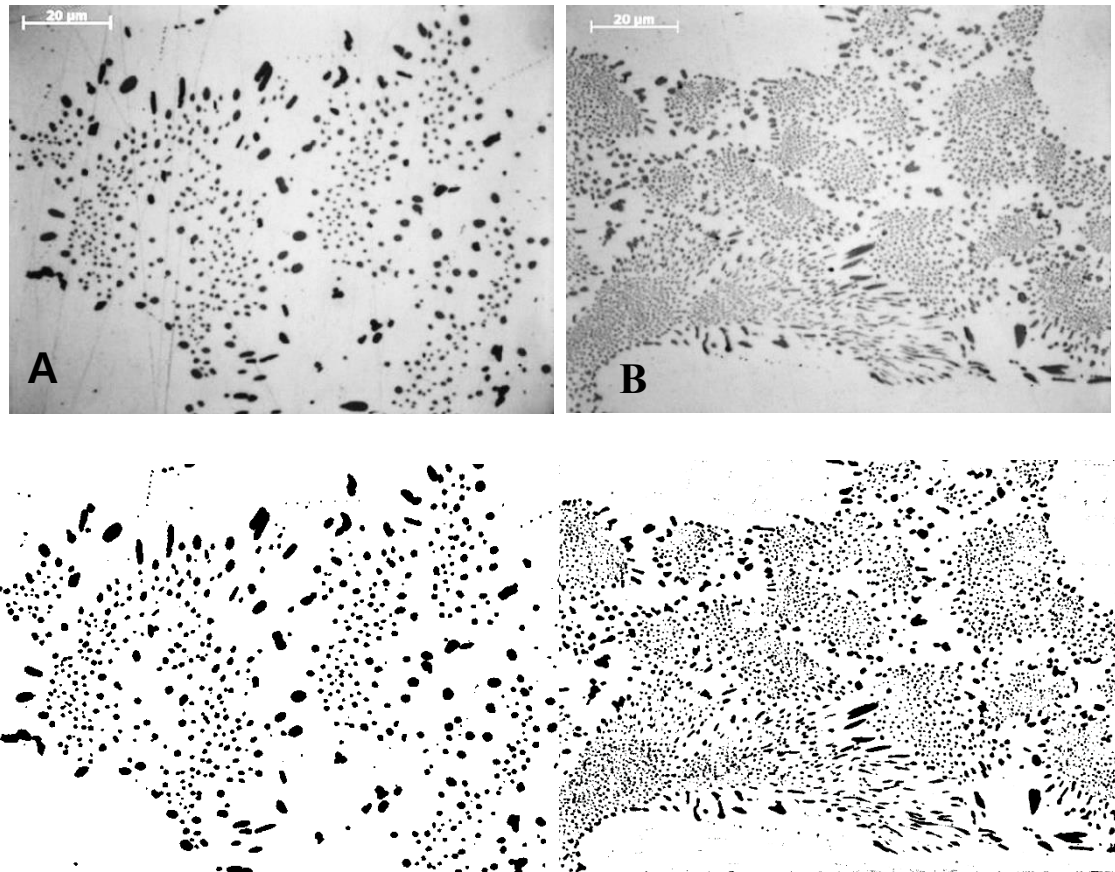


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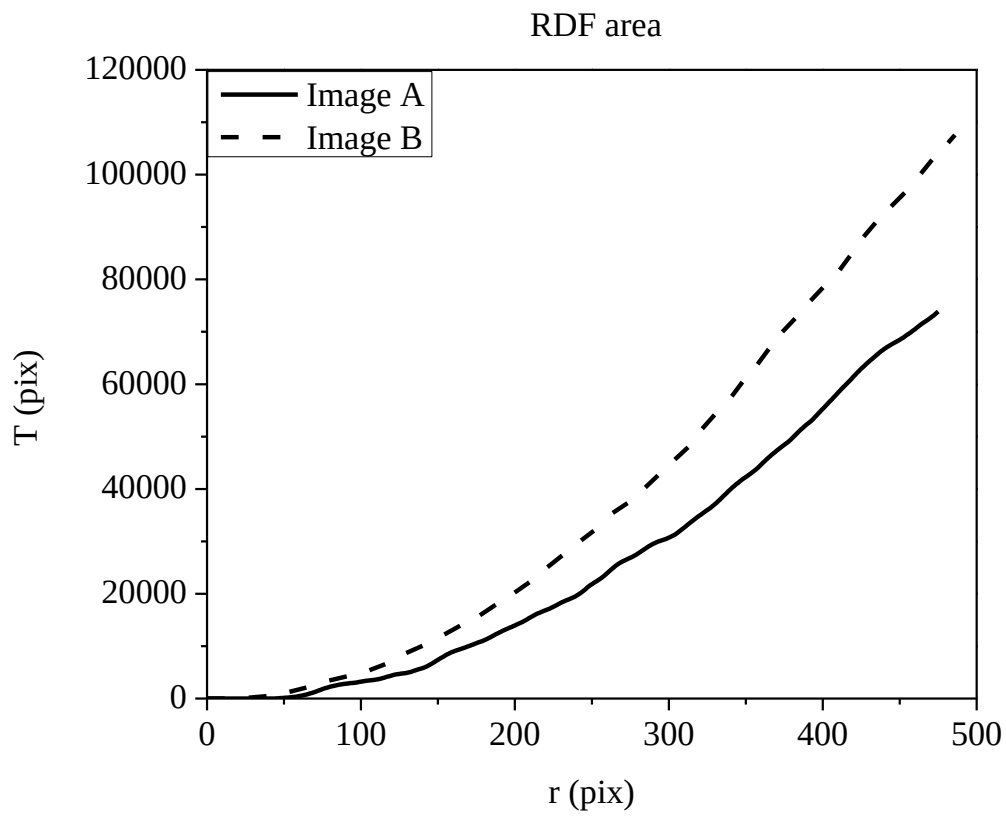


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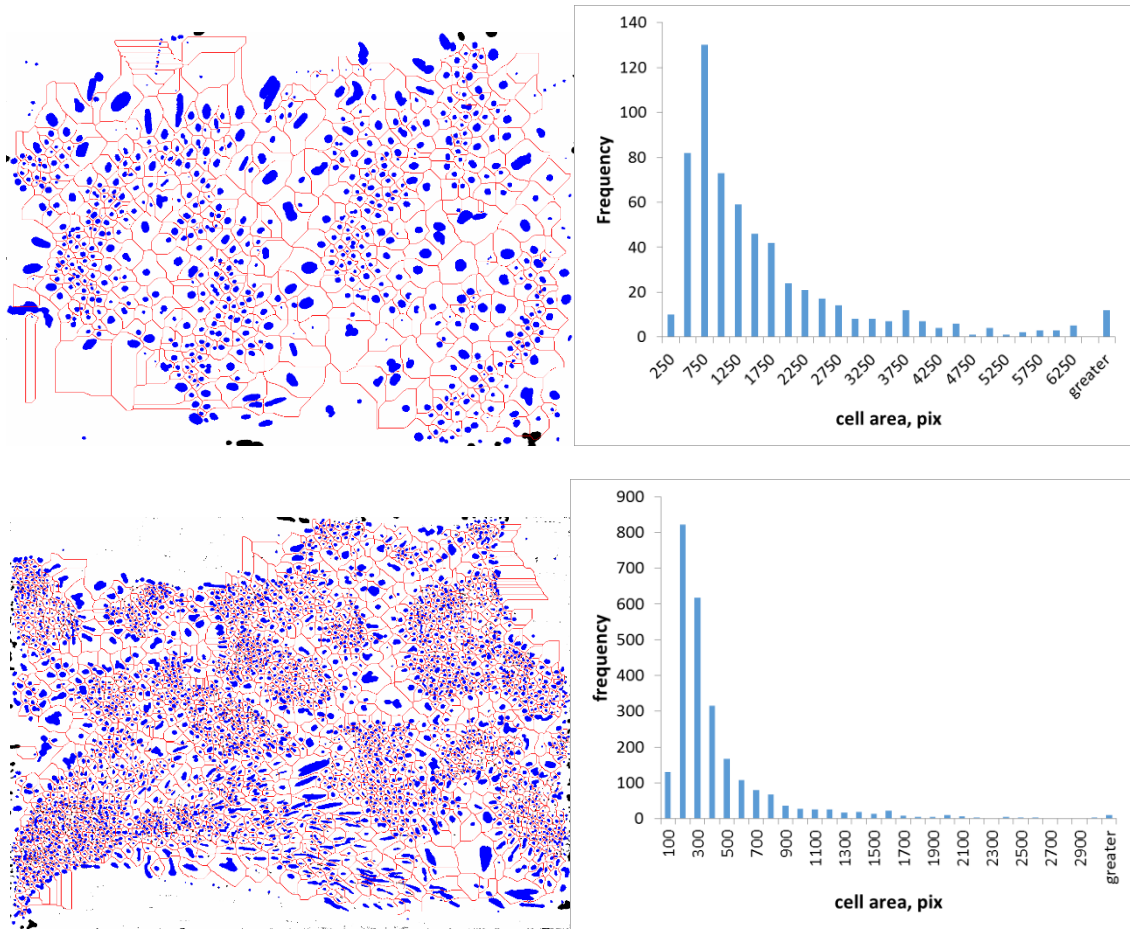


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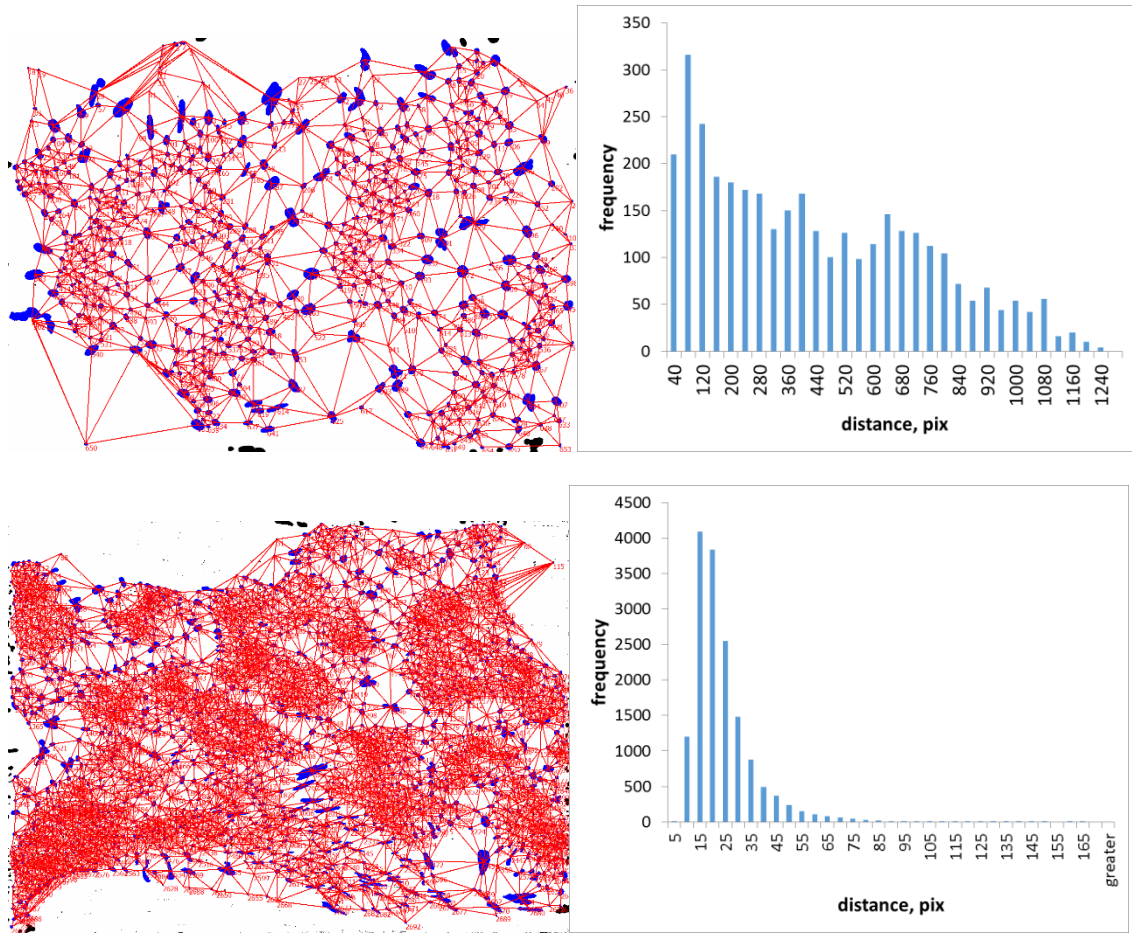


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