

Porous AlMg-SiC Composites Structure Modeling By Means of Fractal Analysis

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Abstract. This work is a continuation of the authors research in the field of ultralight metallic composite materials, based on AlMg10 alloy and SiC particles and obtained by salt dissolution method. We used for the fractal analysis the fractal geometry modeling by means of fractal dimension types of composites obtained from performed experiments. We achieved the following fractal dimensions for the samples: 1.37 (for 5% SiC sample), 1.41 (for 10% SiC sample) and 1.45 (for 15% SiC sample). Fractal analysis indicated that all the obtained samples have cells with a statistically regular form. We conclude that this kind of composite materials can be included in ultralights porous metal composite materials, with a tendency to a metal foam structure.

1. Introduction

This paper describes, on the basis of a quantitative analysis, the configurations and geometrical characteristics of the cellular composites structure (size, shape and distribution of the cells), using for this purpose the fractal geometric modeling, which will lead to the determination of the obtained porous composite fractal dimension [1].

Analyzed materials are ultra light composite materials based on AlMg10 alloy with various percent of silicon carbide (5, 10 and 15%), obtained by dissolution of salts method. This method is based on the use of particles of various salts, in the form of powders, which are soluble in suitable solvents. The method adopted by me used as soluble salt particles of sodium chloride and water as solvent and is based on the introduction in the molten metal alloy of a mixture of powders of sodium chloride and silicon carbide, followed, after cooling, by the dissolution of the sodium chloride in water [2]. Their microscopic analysis showed that these materials are part of cellular metallic materials, tending to metal foams.

2. Application of fractal analysis to the study of AlMg10-SiC porous composite materials

The analysis method, based on the properties of fractals (fragmentation to infinity, self-similarity, the shift-invariance and fractal dimension was described in [3]. So, we obtain a direct method for the study of different porous type composites, function of added SiC amount to the AlMg10 alloy [4].

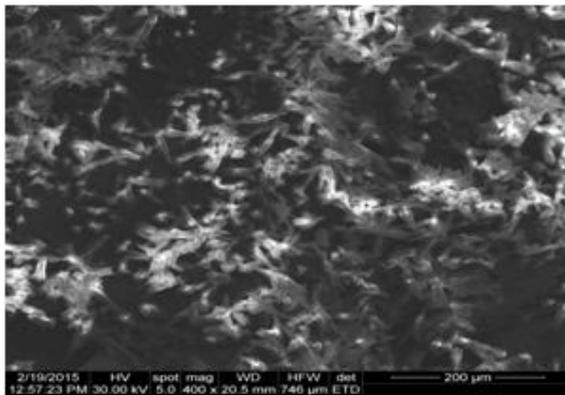
In order to quantify such changes, we follow these steps:

- (i) a black-white digitalization from each image was used in order to reproduce topographical features on the analyzed surface;

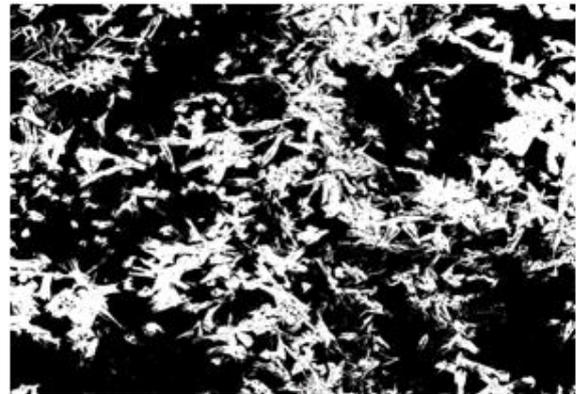


(ii) using MATLAB software, based on an existing procedural model which uses numerical optimized calculation routines, we obtain fractal dimension dependencies on cell uniformity degree for each for each investigated material.

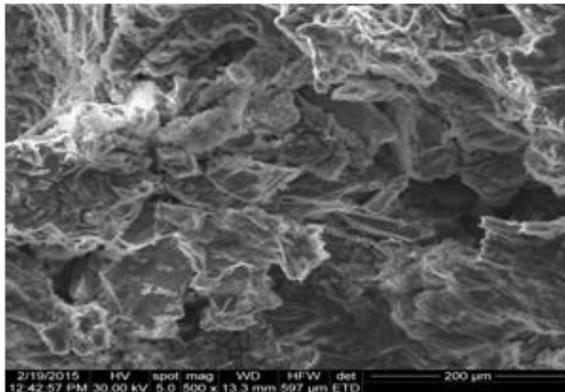
Therefore, we select three images for structural representation of the three types of obtained composites (figure 1) and we translate them to a grayscale image and then, for simplicity, we will use only a black and white picture (figure 2).



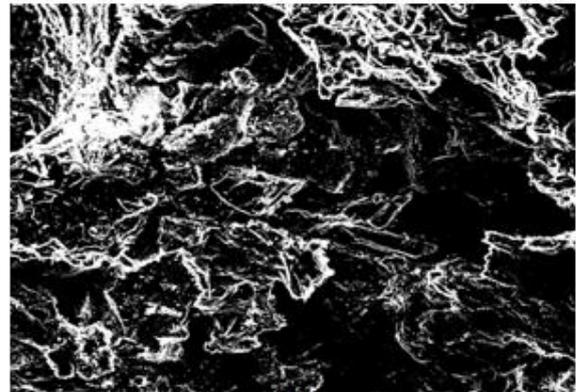
a.



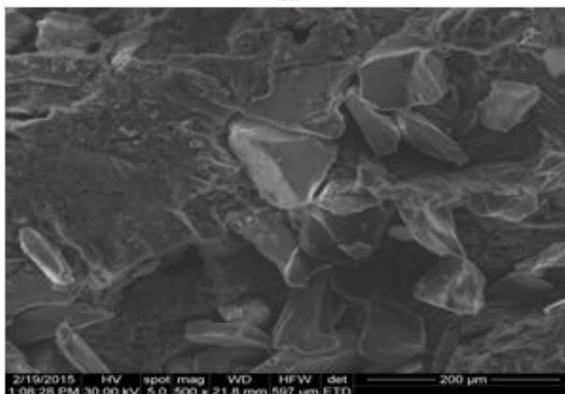
a.



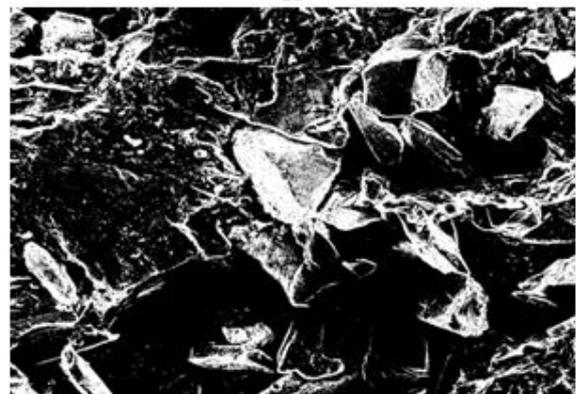
b.



b.



c.



c.

Figure 1. Electron microscopy image:
a – AlMg10 - 5% SiC, b – AlMg10 - 10% SiC; c – AlMg10 - 15% SiC. X500.

Figure 2. Electron microscopy image in black and white of AlMg10-SiC alloy with 5% SiC (a), 10% SiC (b) and 15% SiC (c).

The dependence of fractal dimension on the cell uniformity degree for the analyzed three composites types are presented in tables 1 ÷ 3 and 3 ÷ 5 figures.

Table 1. Values of β and D_f for composite sample AlMg10 - 5% SiC.

Analyzed cell	Fractal dimension D_f	Cell uniformity degree β
1	1,2745	0,8891
2	1,2222	0,7488
3	1,4438	0,4735
4	1,1849	0,6006
5	1,0842	0,8375
6	1,1734	0,8934
7	1,3499	0,3738
8	1,2858	0,7881
9	1,3728	0,9542
10	1,1759	0,8054

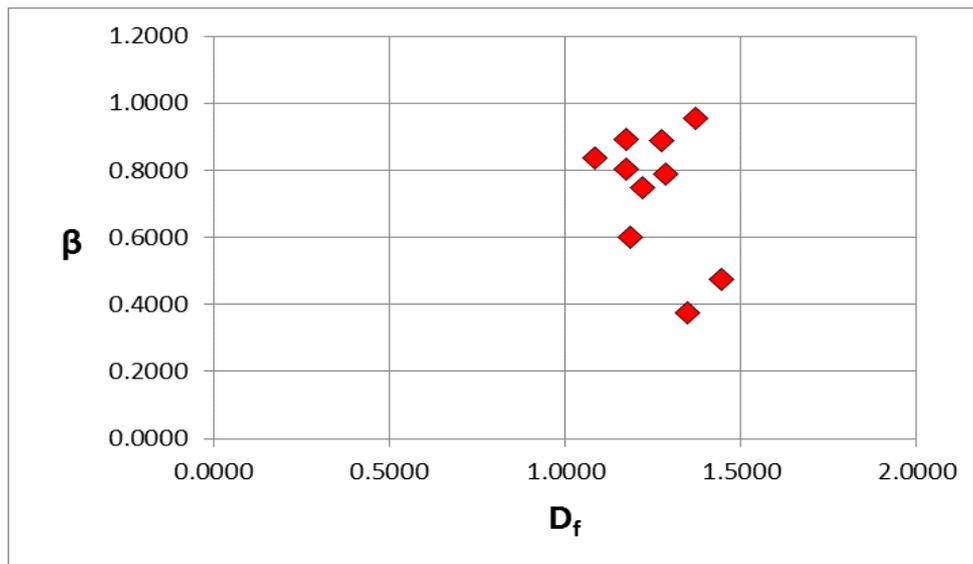


Figure 3. Logarithmic correlation $D_f - \beta$ for composite sample AlMg10 - 5% SiC.

Table 2. Values of β and D_f for composite sample AlMg10 - 10% SiC.

Analyzed cell	Fractal dimension D_f	Cell uniformity degree β
1	1,2933	0,4748
2	1,1939	0,5723
3	1,5033	0,8234
4	1,3703	0,9883
5	1,2943	0,9383
6	1,1657	0,8494
7	1,2228	0,6308
8	1,5771	0,7569
9	1,4144	0,9897
10	1,3557	0,9799

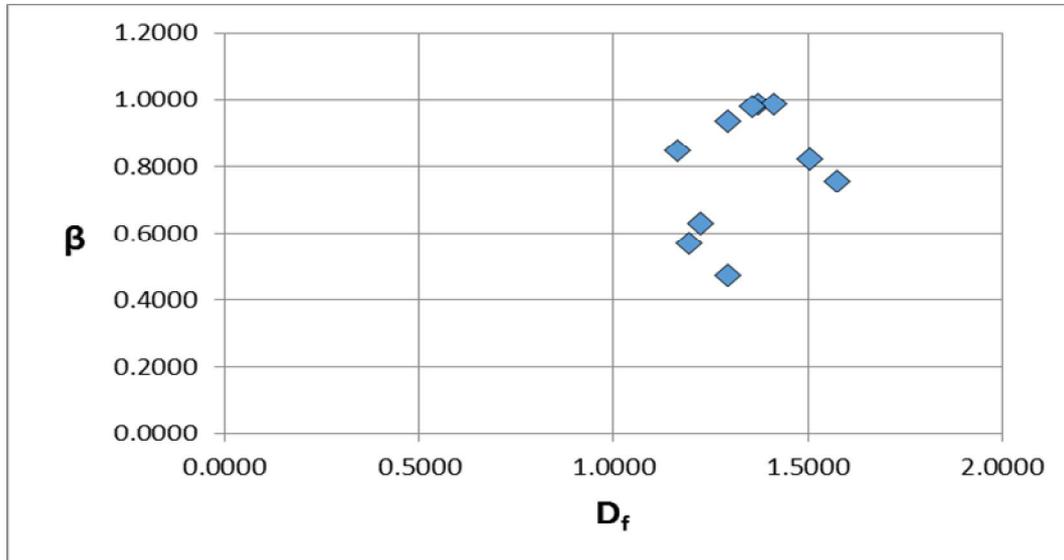


Figure 4. Logarithmic correlation $D_f - \beta$ for composite sample AlMg10 - 10% SiC.

Table 3. Values of β and D_f for composite sample AlMg10 - 15% SiC.

Analyzed cell	Fractal dimension D_f	Cell uniformity degree β
1	1,0099	0,8782
2	1,1461	0,6480
3	1,2520	0,9684
4	1,1955	0,9808
5	1,2778	0,4255
6	1,4601	0,8479
7	1,3002	0,9553
8	1,2299	0,9835
9	1,2889	0,9606
10	1,4546	0,9898

It can be observed that, in the case of composite sample AlMg10 - 5% SiC (table 1 and figure 3), the earliest cell form exhibiting a tendency for levelling (with a degree of cell uniformity β closest to value 1) appears in a total of three cases, namely for positions 1, 6 and 9. The optimal fractal dimension is that for position 9 for which the value of fractal dimension $D_f = 1.3728$ is closest to the theoretical fractal dimension $D_f = 1.66$.

In the case of AlMg10 - 10% SiC sample the nearest types of cells with a tendency for levelling (table 2 and figure 4) appears in the positions 4, 5, 6, 9 and 10, in a greater number of cases as compared to previous sample. In this case, the fractal dimension closest to the theoretical value is that in the position 9, for which $D_f = 1.4144$.

For the third sample AlMg10 - 15% SiC we can observe from table 3 and figure 5 that the tendency for levelling grows – positions 3, 4, 7, 8, 9 and 10. The fractal dimension closest to the theoretical value is that in the position 10, for which $D_f = 1.4546$.

So, it can be concluded that the composite materials obtained by this method can be included in ultralight porous metallic composite materials, with a high tendency to metal foam structure (morphology).

Also, we can conclude that the AlMg10 - 15% SiC composite sample has the highest cell uniformity and the nearest fractal dimension to theoretical value versus all analyzed samples, what issues him to be closest to the concept of porous composite material.

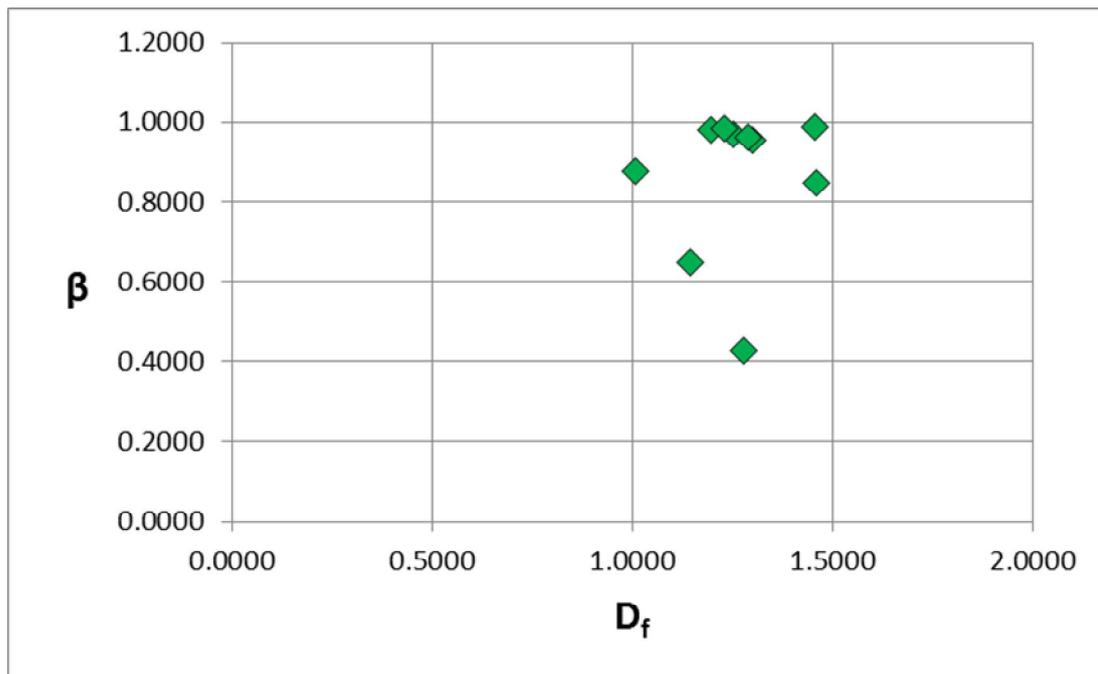


Figure 5. Logarithmic correlation $D_f - \beta$ for composite sample AlMg10 - 15% SiC.

This issue can be explained by increased stability of the cell walls and connection bridges between cells due to the growth of SiC particles percentage added in AlMg10 alloy groundmass.

3. Conclusions

Fractal analysis confirms that the AlMg10 - SiC composite materials obtained by salt dissolution method can be included in ultralight porous metallic composite materials, with a high tendency to metal foam structure. The closest to this structure is the composite with 15% SiC, fact explained by the increased stability of the cell walls and connection bridges between cells due to SiC particles.

We can recommended fractal analysis for the study of various complementary reaction mechanisms associated to fractal behavior of cellular composites, such as, for example, deformation or impact behavior, vibrations damping, which represents new research directions associated with the fractal character of these types of composites.

References

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