Investigation of Microstructure Inhomogeneity in SiCp-reinforced Aluminum Matrix Composites

Zoltan Gacsi[1,a], C. Hakan Gur[2,b], Andrea Makszimus[1,c], Tadeusz Pieczonka[3,d]

[1]Physical Metallurgy and Metalforming Department, University of Miskolc, Hungary;
[2]Metallurgical and Materials Engineering Department, Middle East Technical University, Turkey;
[3]Department of Metallurgy and Materials Engineering, University of Mining and Metallurgy, Poland
[a]femtangz@uni-miskolc.hu, [b]chgur@metu.edu.tr, [c]femandi@uni-miskolc.hu, [d]pieczonk@uci.agh.edu.pl

Abstract

The type, volume fraction, size, shape and arrangement of embedded particles influence the mechanical properties of the particle reinforced metal matrix composites. This presents the investigation of the SiC particle and porosity distributions in various aluminum matrix composites produced by cold- and hot-pressing. The microstructures were characterized by optical microscopy and stereological parameters. SiC and porosity volume fractions, and the anisotropy distribution function were measured to establish the influence of the consolidation method.

Keywords : Aluminum matrix composites, powder metallurgy, microstructure inhomogenity

1. Introduction

In recent years, the significance of aluminum matrix composites has being increased in a greater extent. It is due to the fact that these materials have extraordinary advantageous properties and they can be produced in a relatively cheap way using powder metallurgy methods. They are mainly used for manufacturing of aero plane parts [1], electronic components, and the parts of different traffic means [2]. The properties of products are influenced first of all by the quantity, size and shape as well as by the distribution of ceramic particles within the matrix. If the distribution of the reinforcing particles is not homogenous, the particles are clustered, and thus, act as critical points for crack initiation [3]. Therefore, the stereological description of the microstructure of such composites is a matter of great importance.

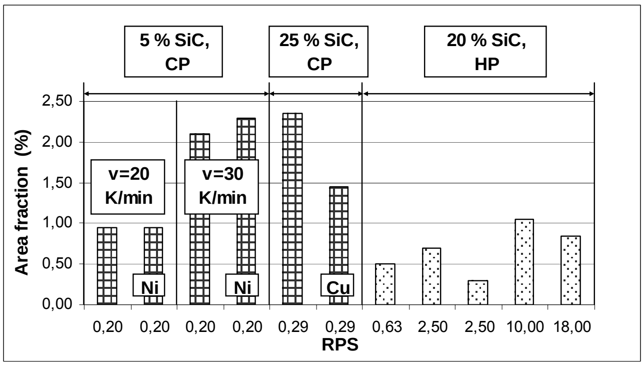
2. Experiments

The specimens were produced by using two different powder metallurgy methods of compact formation, namely cold and hot pressing. To prepare specimens by cold pressing Al and SiC powders of technical purity were used. These samples were produced at the AGH University of Science and Technology, Krakow. The powder mixtures of different compositions were homogenized in a laboratory type magnetic mixer for 30 minutes. The green compacts were produced by uniaxial cold pressing under 400 MPa pressure and without using any lubricant. The specimens were then sintered at 640 °C for 2 h using N_2 protective gas of 99.999 % purity. In the production of certain samples, Cu or Ni coated SiC particles were utilized.

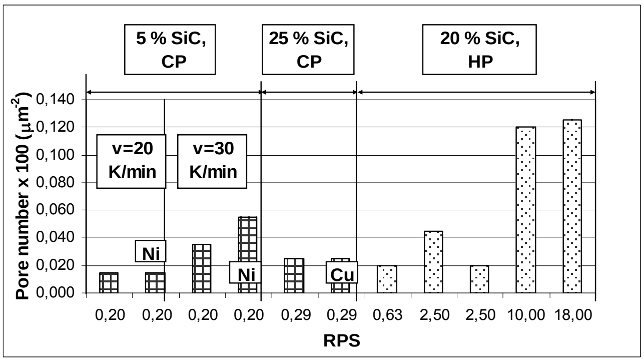
The hot-pressed specimens were produced at the Middle East Technical University, Ankara [4]. Al-powder having three different average grain sizes (25, 100, 180 μm) and two different kinds of ß-SiC powder (10, 40 μm) were used in preparation of the mixtures. 5% pure Cu powder with an average particle size of 50 μm was added to each mixture to promote densification during hot pressing. After adding isopropyl-alcohol, the powder mixture was mixed for five minutes to keep the original morphology. Then, the powder mixture was hot pressed at 600 °C (in the κ + liquid region of the Al-Cu equilibrium phase diagram) for 5 minutes under controlled N_2 gas atmosphere in a single-end die having a cross-section of 40x30 mm. During hot pressing, 40 MPa pressure was applied, and not released until the specimen was cooled down to 300°C to minimize porosity.

3. Measurement method

The investigations were focused on determining the distribution of pores and SiC particles on the samples. The measurements of stereological parameters were performed on the cross-sections of the specimens, parallel and perpendicular to the direction of pressing by using a Quantimet Leica Q550 Imaging Workstation type image analyzer. In both directions a “marking line” was drawn at a distance of 1 mm from the surface and from the side of specimen for reproducibility of the measurements and identification of the evaluation area. For each evaluation area (measured frame along the marking lines) the ratio of Al/SiC and porosity/solid areas, the number of SiC particles and pores and as well the anisotropy have been determined. In each sample, 10 to 80 evaluation areas were examined depending on the magnification.



(a)



(b)

Fig. 1 As a function of RPS (D_{Al}/D_{SiC}) (a) the average area fraction of porosity, (b) pore number

4. Results

Comparing two methods of powder mixture consolidation used in this study it can be stated that the average porosity/measured area ratio of hot pressed (HP) specimens is always markedly lower than that for cold pressed (CP) ones. The porosity area fraction shows also an increasing tendency by increasing the relative particle size (RPS) which equals to the Al/SiC powder size ratio. The heating rate seems to be also an important technological parameter for the cold-pressed specimens. They become more compact at a lower heating rate owing to the longer time available to rearrange the particles before the stiff skeleton is formed. Coating the SiC particles by Cu lowers the sintered porosity because of the liquid phase appearing in the system, while the Ni-coating does not cause a similar effect.

It is well known that internal and external friction acting during uniaxial pressing of metal powders produces non uniform porosity distribution within the compact. When the mixture of metal and hard ceramic powders is pressed the porosity distribution becomes more complicated because it is also influenced by the inhomogeneity of the mixture. Thus, the pores have been observed i) in the Al-matrix, ii) between the Al-matrix and SiC, and iii) between the SiC particles. Sintering process changes the pore distribution only in a minor scale, in particular pores ii) and iii) type remain unchanged. So, the SiC-distribution and the appearance of porosity are in close relationship, especially where the SiC particles are grouped there the porosity between them markedly increases.

Comparing the porosities of the samples it can be stated that a less number of pores with a larger size develop due to cold pressing and sintering procedure, however, hot pressing results in more pores with smaller size. This effect can be seen more clearly when powder mixture has a high RPS, which has also the greatest number of pores. In such cases, the SiC particles appear to be clustered around the Al boundaries in the form of a continuous network, and this clustering becomes more evident with increasing amount of SiC. It is worth to note that some large pores were also observed in hot pressed compacts as well.

5. Conclusion

Distribution of SiC particles and pores in aluminum matrix composites produced by cold- and hot-pressing was investigated. To establish the influence of the consolidation method SiC and porosity volume fractions, anisotropy distribution function were determined via optical microscopy and stereological parameters. The experimental results showed that the amount of porosity in the hot pressed specimens is always lower than that in the cold pressed ones. The change of SiC anisotropy parallel to the direction of pressing indicates that the SiC particles are arranged in a different way during the cold- and hot pressing.

In the cold pressed and sintered specimens the heating rate for sintering influences the final density, and the amount of porosity increases if the relative particle size increases. These samples have few large pores while during hot pressing more fine pores develop. The coating of SiC particles with Cu lowers the amount of porosity while Ni-coating does not result in such an effect.

6. References

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