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Research article

Enhanced properties of an AA7075 based metal matrix composite prepared using mechanical alloying

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Abstract

In this study, firstly, AA7075 metal powder which average particle size 43.9 μm were manufactured by using gas atomization method. Thereafter with mechanical alloying method which powder metallurgy manufacturing methods, 10% B_4C particle reinforcements that average particle size of 49.5 μm by participating into AA7075 metal matrix composite powder mixtures were prepared. They were milled for different durations (0-8 hrs) in a high energy planetary ball mill. From these milled powders; 550°C and under pressure 500 MPa, composite materials were produced by the method of hot pressing. In SEM analysis, after 4 hrs with mechanical alloying method, B_4C particles which were homogenously distrubuted into the matrix of AA7075 were seen. Powders size increased to 1 hr and then decrease. In order to determine produced composite material's microstructural properties SEM analysis and determine physical and mechanical properties, density test and hardness test was applied. As a result of the experiments, composite density increased to 1 hr and then decrease. The hardness of composite was increased with increasing milling time and the rate of reinforcement.

Keywords: *B_4C, mechanical alloying, metal-matrix composite, powder metallurgy*

1. Introduction

Rapid advances in technology have revealed the use of new materials which have superior properties compared to traditional materials. For this reason, many researchers have been studied on the production new materials which have superior properties than natural or alloy materials. In this way, "Composite Materials" which have superior qualities than other conventional materials has been produced as the new material type [1-3]. In recent years, aluminum matrix composites (Al-MMCs) have been used for industrial applications such as automotive, especially in engine piston, cylinder liner, brake discs and drums due to light weight, high strength, high elastic modulus and high wear resistance of Al-MMCs. SiC, Al_2O_3, TiC and B_4C particles are used to improve the mechanical properties of aluminum matrix composites. B_4C particles both have superior physical and chemical properties and one of the important underground wealth of our

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country [4-6]. MMC's can be formed from solid and molten states into forging, extrusions, sheet and plate and casting. Conventional techniques like casting, spraying and forging have problems like reinforcement segregation, unwanted interfacial chemical reactions, higher porosity and poor interfacial bonding. Due to the presence of alumina particles with high melting point, conventional melting and casting is not suitable for producing dispersion-strengthened Al composites [7]. Alternatively, powder metallurgy ensures the fine alumina dispersoid is well distributed within the Al matrix, which eventually gives good final mechanical properties to the composite with sufficient physical properties. The purpose of this study was to prepare AA7075/B_4C composites by mechanical alloying and to investigate the influence of the milling time and the effect of reinforcement content on microstructure, density and hardness of the composite samples.

2. Material and Method

The as-atomized AA7075 alloy powders (Kütahya Dumlupınar University Mechanical Engineering Research Laboratory, Turkey) with an average particle size of 44 µm, B_4C particles (99.7% purity, Wacker Ceramic Company, Germany) with an average particle size of 50 µm and the density of 2.52 g/cm^3 are used as raw materials. The chemical composition of the as-atomized AA7075 alloy was given Table 1. Experimental procedure was given in Fig. 1. Fig. 2a and 2b shows the morphologies of the as received AA7075 alloy matrix powder and B_4C particles.

Table 1
Chemical composition of AA7075 alloy powders

Cu	Mg	Mn	Fe	Si	Zn	Cr	Ti	Al
1.2-2	2.1-2.9	0.3 (max)	0.5 (max)	0.4 (max)	5.1-6.1	0.18-0.28	0.2 (max)	87.1-91.4

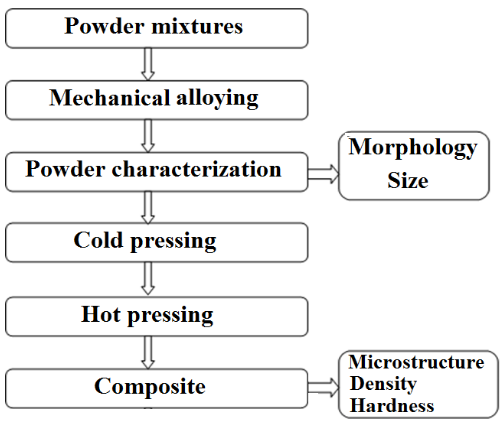
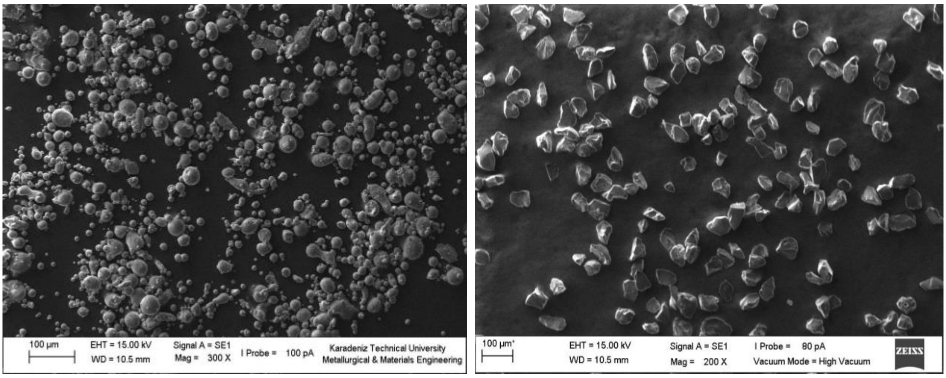


Fig. 1 The developing procedure of the composites



(a) (b)

Fig. 2 The initial morphologies of the received AA7075 powders and B_4C particles

3. Results and Discussion

3.1. Particle Size

Fig. 3 shows the change of particle size with increasing milling time. It can be seen that particle size decreased during the initial stage of mechanical alloying (0.5 hr). However, the increase of particle size was observed between 0.5 and 1 hr of milling time due to cold welding process. With increasing milling time, work hardening of powders causes brittle of powders and fracturing process becomes effective process. It was observed that milling time has a significant effect on the particle size of composite powders [8].

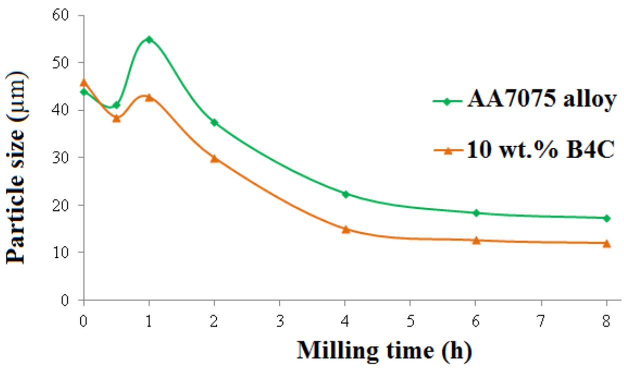


Fig. 3 The change of particle size with milling time

3.2. Density

Fig. 4 shows the change of density with increasing milling time. The compaction mechanism of powders can be explained as follows: (I) sliding and rearrangement of the particles, (II) elastic deformation of ductile powders and fragmentation of brittle solids, and (III) plastic deformation of bulk compacted powders. At the first stage of the compaction process, particle sliding and rearrangement of the powders are the dominant mechanisms of consolidation. When the applied pressure increases, the movement of the particles is restricted and the energy applied to the compact powder is spent generally through the process of fragmentation and plastic deformation of powders [9]. It should be noted that density increased between 0 and 1 hr of milling time. This can be attributed to the ability of filling the pores by small and ductile powders. With increasing milling time of the powder particles are exposed to work hardening and compaction (pressing) becomes difficult. As a result of the work hardening density values decreased with increasing milling time.

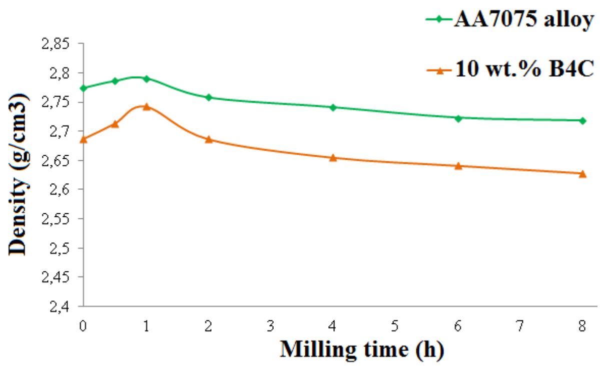


Fig. 4 The change of density with increasing milling time

3.3. Hardness

The result of hardness for different milling time and different composition is shown in Fig. 5. The hardness values increase with increasing milling time and with the reinforcement content. Mechanical alloying accelerated a high degree of deformation and reduces the grain size to finer level. As can be seen in Fig. 5, increasing milling time fractures coarse powder particles into fine particles due to cold welding and plastic deformation. The increase in hardness values can be explained more homogeneous distribution of reinforcement particles, increasing work hardening on the ductile particles [10-11].

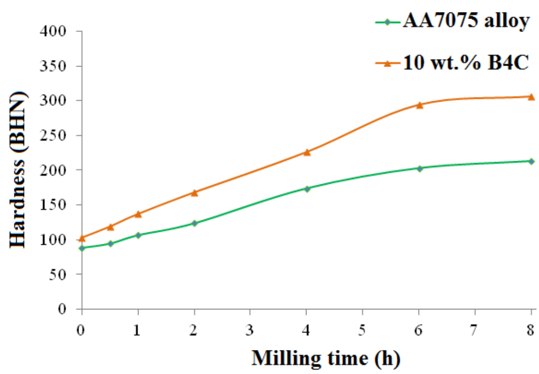


Fig. 5 The change of hardness with increasing milling time

3.4. Microstructure

Fig. 6 shows the distribution of B_4C particles in the AA7075 matrix in the powders containing 10 wt% B_4C. B_4C particles accumulated in the regions between the AA7075 matrix powders in the first stage of 0 and 0.5 hr of milling time (Fig. 6a and Fig. 6b). Agglomeration behavior of the B_4C particles was seen more clearly in Fig. 6a and Fig. 6b.

Fig. 6a shows that the low milling time is not suitable to produce uniform composites. Therefore, to investigate the particle distribution, up to 8 hrs milled samples were studied and the effect of the milling time was investigated. The results showed that an increase in milling time resulted in the fragmentation of hard particles and homogeneous distribution due to the impacts of balls (Fig. 6e).

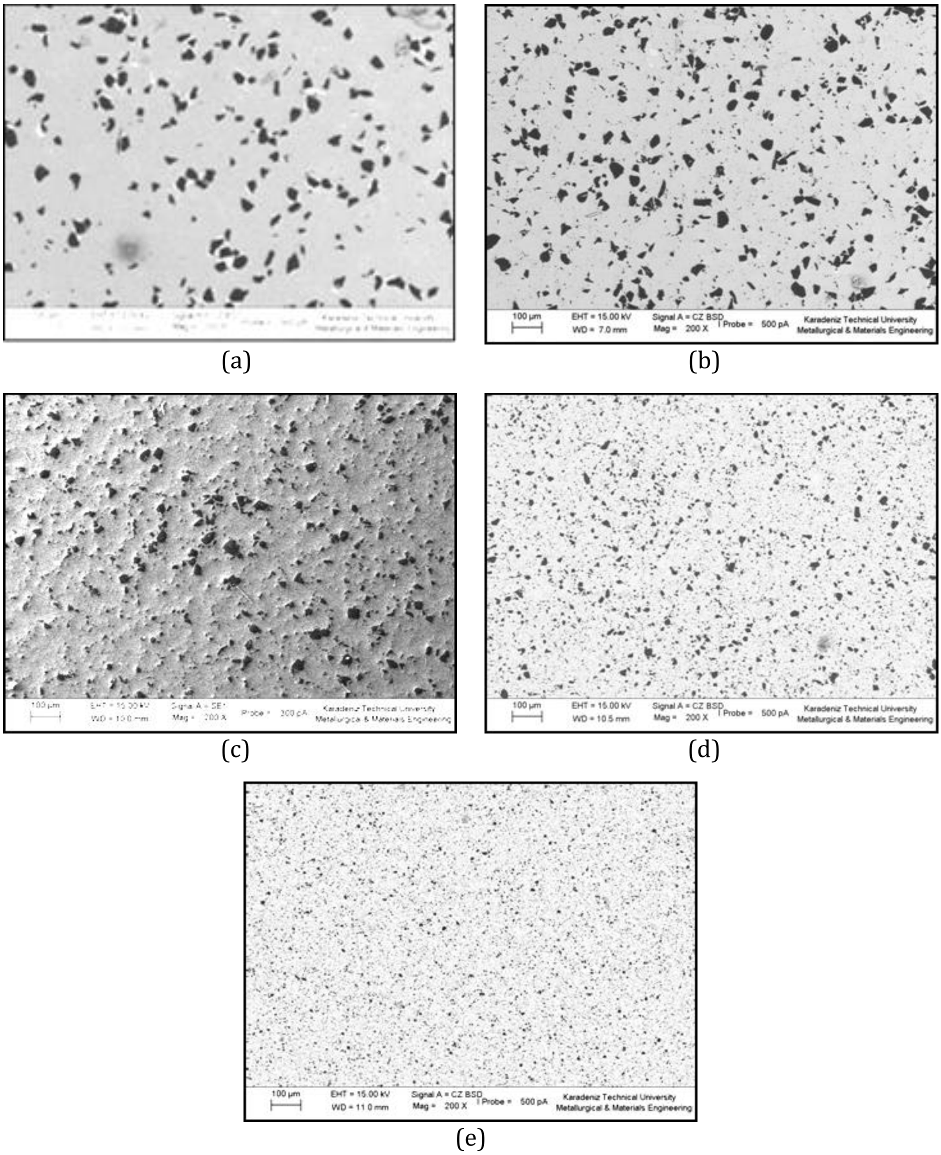


Fig. 6 The microstructure of AA7075 10 wt% B_4C (a) 0, (b) 0.5, (c) 2, (d) 4, and (e) 8 hrs

4. Conclusions

The mechanical alloying method can be used to produce AA7075 10 wt% B_4C particulate composites in which the B_4C particles are distributed uniformly within the AA7075 matrix alloy. It was observed that the milling time and B_4C content has a great influence on the particle size of the milled powders. The particle size decreased until the creation of a balance between the rate of welding and fracturing. The composite density decreased with an increasing the milling time in the consolidated samples. The compressibility of the composite with reinforced B_4C particles increased as compared to the AA7075 alloy powder with reinforced for the same milling time. The addition of B_4C particles and increasing milling time cause the hardness to increase.

Acknowledgements

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