The Effect of Milling Time on Aluminum- Silicon Carbide Composites Fabricated by Powder Metallurgy

Mustafa Khaleel Ibrahim*, Jamaliah Idris
Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia. Corresponding Author
Corresponding author

e-mail: mustafakhaleel4@gmail.com

Abstract— To fabricate aluminum- silicon carbide composites, 10 vol% of the silicon carbide powders at size of 20 µm mixed with aluminum powders, Those mixtures were ball-milled for 0, 40, 80, and 120 minute in a planetary ball mill at speed of 200 rpm using zirconia balls.The ball- to powder mass ratio 10:1. The mixed powders are die-pressed at room temperature under a pressure of 10 ton in a 12.7 mm internal diameter cylindrical stainless steel die. The aim of this study is to develop Al – 10 vol %SiC composite by mechanical alloying; the main steps in mechanical alloying are milling, compacting and sintering. Aluminum and silicon carbide powder are mixed by ball milling and it was then sintered at 550° C for 5 hours. The parameter to control the microstructure of the composites is milling time. Microstructure and hardness of the composite were investigated. The results are showed that hardness of the composites has increased as the time of the milling increased. The maximum value of hardness can be obtained at 80 minute milling time. After 80 minute milling time, the hardness starts to drop for Al- silicon carbide composite. Microstructure plays important role in controlling the hardness of the composites.

Index Terms—; Milling time; particles size reduction; reinforcement dispersion; mechanical properties XRD; SEM; EDX.

1 INTRODUCTION

Mechanical alloying (MA) as a powder processing technique is involve repeated deformation, fracturing and welding of powder particles. Mechanical alloying has been widely used to synthesize a variety of materials, similar to intermetallic compounds, (non-equilibrium), supersaturated solid solutions, or to the formation of unstable or stable carbides, borides, silicides, nitrides, etc. It is known that the addition of ceramic hard particles to aluminum alloys is increase the strength, micro-hardness, and wear resistance. But, it is essential to have an optimal milling parameters (in this study, sintering time, sintering temperature and compact pressure were considered as milling parameters) to achieve excellent mechanical properties. Otherwise, inhomogeneous or agglomeration distribution of SiC reinforcement can lead to decreasing in strength, ductility, and toughness of the composite. The mechanical properties can be enhanced when the milling parameters are optimal [1]. Nowadays, Al-based composites reinforced with ceramic particles are demanded because of their high strength-to-weight ratios and enhanced mechanical properties such as high specific stiffness wear resistance and fatigue resistance. Those metal matrix composites (MMCs) considers as the excellent candidates, and energy dispersive X-RAY analysis that applied as structural materials in the automobile industry and aerospace [2].

- *Mustafa Khaleel Ibrahim is currently pursuing Ph.D degree program in mechanical /material engineering in Universiti Technologi Malaysia, Malaysia, PH-+6-0187736749. E-mail: mustafakhaleel4@gmail.com*

2 MATERIALS AND PROCESSING

In this study, technical grade aluminum was reinforced with 10 vol. % of silicon carbide with particles size of 20µm. During milling the size, shape and chemical composition of aluminum particles are observed by scanning electron microscopy (SEM), X- RAY diffraction (XRD) and energy dispersive X-RAY analysis (EDX). Shown in figure 1: A, B and C for aluminum.

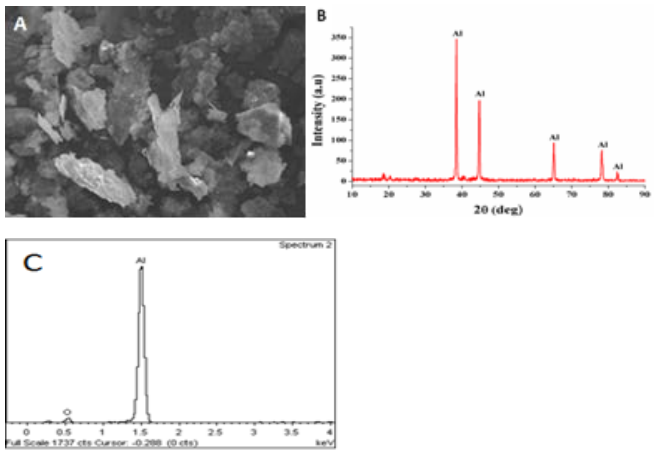

Figure. 1. A, B and C

And for silicon carbide scanning electron microscopy (SEM), X- RAY diffraction (XRD), (EDX). Shown in figure 2: A, B and

C.

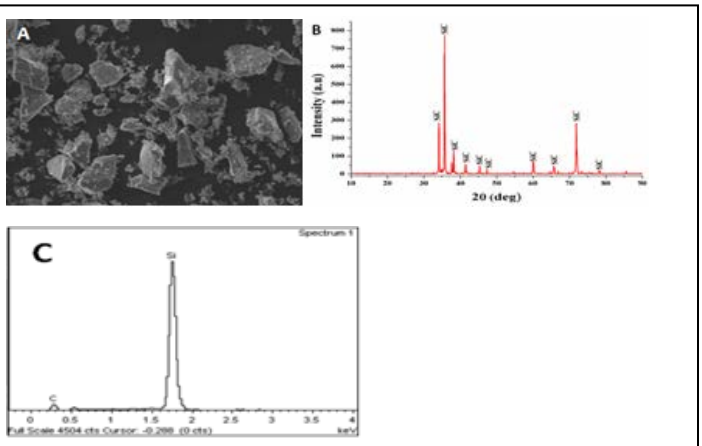

Figure. 2. A, B and C

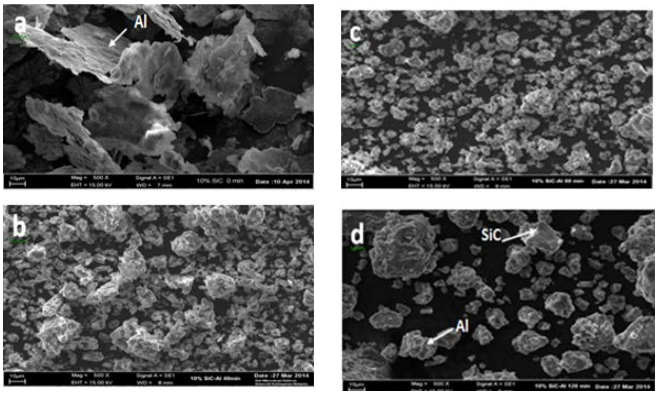

Figure. 3. SEM images of 10%Sic- Al powder composite, at milling time (a) 0 minute, (b) 40 minute, (c) 80 minute and (d) 120 minute, of 500 x magnification.

TABLE 1

MILLING PARAMETERS FOR MIXING ALUMINUM AND SILICON CARBIDE POWDERS

Planetary milling	Milling conditions
Ball to powder mass ratio	10:1
Powder amount, gram	15
Speed, rpm	200
Milling time, minute	0, 40, 80, 120
Balls material	Zirconia
Atmosphere	Air
Machine type	Planetary PM 400

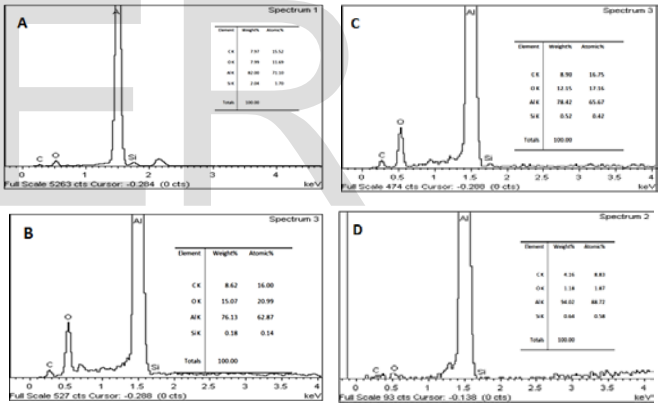

Figure. 4. EDX of 10%Sic- Al powder composite, at (a) 0 minute, (b) 40 minute, (c) 80 minute and (d) 120 minute milling time.

3 RESULTS AND DISCUSSIONS

3.1 POWDER MORPHOLOGY

Aluminum powder is mixed with silicon carbide at different milling times 0, 40, 80 and 120 minutes. Silicon carbide with percentage 10% the rest is aluminum. During Study the Effect of the milling time on the particles size and distribution that occurs. We are observed by scanning electron microscope (SEM) two important effects, at milling times of 40 and 80 minutes shown decreasing in particles size. But at 120 minute milling time appears increasing in particles size because of work hardening due to not good dispersion of 10%SiC which causes agglomeration, Shown in figure 3 (A and B).

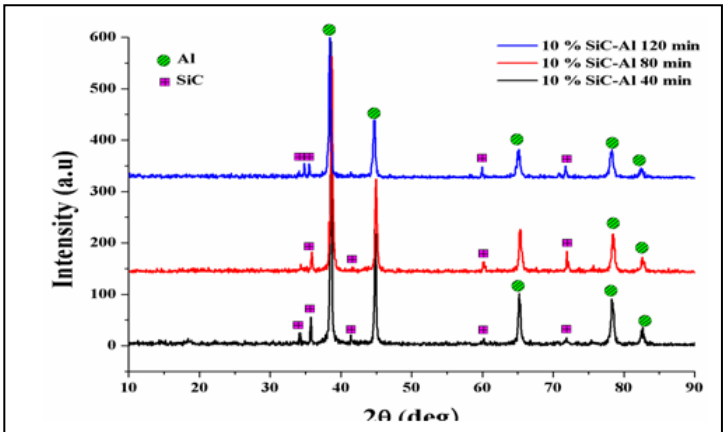

Fig. 5. X- RAY diffraction (XRD) of 10%Sic-Al powder composite.

3.2 MICROSTRUCTURE AFTER COLD PRESS AND SINTERING

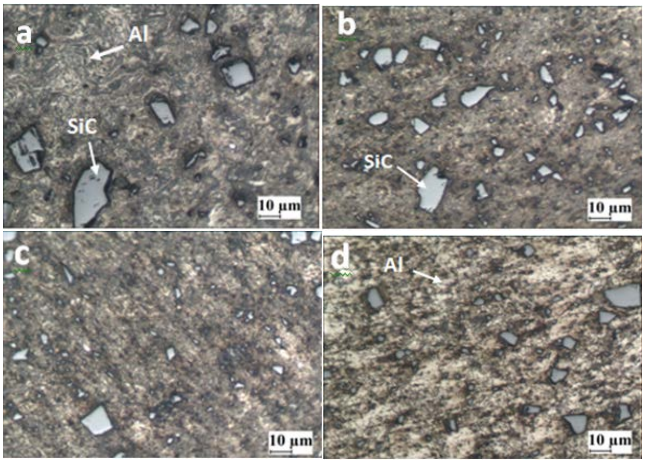

Figure. 6. optical microscope images of 10%Sic- Al samples after hydraulic press and sintering of 550°C for 5 hours, at milling time of pressed powder (a) 0 minute, (b) 40 minute, (c) 80 minute, (d) 120 minute.

Figures 10 show the optical microscope images of the 10%Sic- Al composites. For 0 minute, Silicon carbide is not fully distributed in the aluminum matrix but the grains structure can be observed clearly. With increasing the time of milling to 40 and 80 minute, the grains structure are started to disappear may be because of the response from the aluminum matrix to the deformation. The porosity near the SiC particles also can be observed in the sample. When milling time of 120 minute, the composite start to segregate due the heavily deformation of the matrix [7-8].

3.3 HARDNESS TEST

The test performs with load of 10kg on the samples of aluminum- silicon carbide composite with dimensions 12.7mm in diameter and 4.5mm in height. The hardness increases with increasing the milling time the maximum hardness is at 80 minute milling time because of the response from the matrix to the deformation. During this stage, the deformation may produce lattice distortion in the matrix aluminum, and then this lattice distortion creates lattice strain and increase the dislocation which is the main hardening mechanism. After 120 minute milling time, the effect of dislocation is not the main factor because of the major influence controlled by the elongated matrix grain size that may causes segregation [4], [6] & [7].

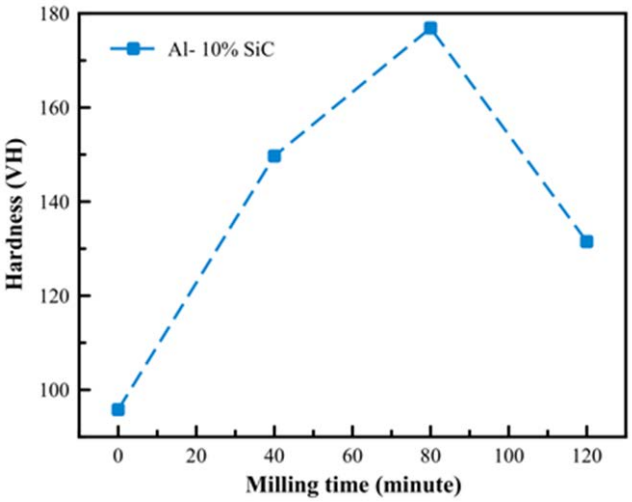

Figure. 7. Relationship between hardness and milling time of Al-10% SiC composites.

3.4 COMPRESSION TEST

The samples are produced by hydraulic press with dimensions of 10mm in height and 1.5mm in diameter and then are sintered with 550°C for 5 hours.

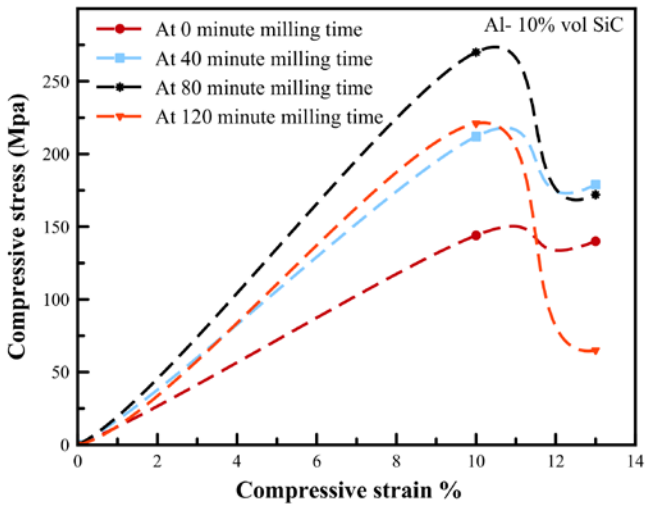

Figure. 8. Compressive test of 10%SiC –Al composite samples.

Figure 8 for (a) at o minute shows the maximum compressive strength at 144Mpa which were increased with the increasing

in milling time, for (b) at 40 minute milling time the compressive strength increased to 212Mpa, while (c) at 80 minute milling time the compressive strength increased to 270Mpa and for (d) at 120 minute milling time the compressive strength starts to drop to 221Mpa due to work hardness and the increasing of the temperature wkich causes segregation.

4 Conclusions

With increasing the milling time 0, 40, 80 and 120 minutes, the aluminum- silicon carbide powders morphologies were initially as the stuck aluminum flakes containing silicon carbide particles, and gradually, with fragmenting these flakes the particles size reduces with increasing of the milling time only at 120 minute milling time the particles are increased in size for 10% SiC- Aluminum composite because of work hardness.
With increasing the amount of the reinforcement particles, cold welding and fracture mechanisms were active faster and a homogeneous structure was attained. The stress–strain curves obtained from the phased and continuous compression tests indicate to a decrease in ductility and an increase in strength of the specimens with increasing time of the milling, the amount and size of the reinforcement and initial density of the porous sample. The hardness and compressive stress increases with increasing time of the milling but with increasing of milling time more than 80 minute causes drop in hardness and compressive stress because of increasing of deformation of the grains causes segregation between the aluminum and silicon carbide [5] & [8].

Acknowledgment

The authors would like to thank the Malaysian Ministry of Education (MOE) and Unversiti Teknologi Malaysia for providing the support and facilities for this study.

References

[1] Abdellahi, M., Bhmanpour, M., & Bahmanpour, M. (2014). Optimization of process parameters to maximize hardness of metal/ceramic nanocomposites produced by high energy ball milling. Ceramics International, 40(10), 16259-16272.

[2] El-Daly, A. A., Abdelhameed, M., Hashish, M., & Daoush, W. M. (2013). Fabrication of silicon carbide reinforced aluminum matrix nanocomposites and characterization of its mechanical properties using non-destructive technique. Materials Science and Engineering: A, 559, 384-393.

[3] Canakci, A., Varol, T., & Ertok, S. (2012). The effect of mechanical alloying on Al2O3 distribution and properties of Al2O3 particle reinforced Al-MMCs.

[4] Jamaludin, S. B., Noor Ashiqin, A. R., Shamsudin, S. R., Wahid, M. F. M., & Kamardin, A. (2007). The Effect of Milling Time on Microstrucutre and Hardness of the Aluminium Silicon Carbide (Al-10 wt% SiCp) Composite.

[5] Hassani, A., Bagherpour, E., & Qods, F. (2014). Influence of pores on workability of porous Al/SiC composites fabricated through powder metallurgy+ mechanical alloying. Journal of Alloys and Compounds, 591, 132-142.

[6] M. YANG and V.D. SCOTT, J. Mater. Sci. 26 (1991) 1609.

[7] M. SUERY and G. L'ESPERANCE, Key Eng. Mater. 79-80 (1993) 33.

[8] El-Daly, A. A., Abdelhameed, M., Hashish, M., & Daoush, W. M. (2013). Fabrication of silicon carbide reinforced aluminum matrix nanocomposites and characterization of its mechanical properties using non-destructive technique. Materials Science and Engineering: A, 559, 384-393.