THE MICROSTRUCTURE AND PROPERTIES OF ALUMINIUM COMPOSITE REINFORCED WITH 65 μm ALUMINA PARTICLES VIA POWDER METALLURGY

Khairel Rafezi Ahmad, Wong Jing Lee, Ruhiyuddin Mohd Zaki, M.N. Mazlee, M.W.M. Fitri, S.S. Rizam and J.B. Shamsul
School of Materials Engineering, University Malaysia Perlis, 02600 Jejawi, Arau, Perlis

Abstract

This article will report the effect of weight percentage on the microstructure and properties of alumina particle reinforced aluminum metal matrix composite. This involved fabrication of aluminum composite via powder metallurgy route. Composite samples were prepared based on 5 to 20 wt% of 65 μm Al_2O_3 reinforcement. The matrix and reinforcement materials were mixed in rotating mixer. The sample were cold pressed at 250 MPa and sintered at 600 ^{0}C for 5 hours. This paper will report the microstructure, bulk density and hardness value of the composites. Microstructural analysis was carried out using SEM. SEM micrographs indicate that Al_2O_3 particulates homogeneously distributed in aluminum matrix. Al-5%Al_2O_3 gives the lower bulk density and Al-20%Al_2O_3 gives the highest hardness value (41.93 HV).The density and the hardness value of composite samples increase with the increasing of weight percentage.

Keywords : Aluminium matrix, ceramic particles reinforcement, alumina particles, powder metallurgy

Introduction

There has been a major interest in developing metal matrix composites (MMC) for the past three decades. This is because it offers a few unique mechanical properties such as low density, high strength, high stiffness, high wear resistance and other attractive properties. Nowadays a lot part in automobile industry like pistons, connecting rods, gudgeon pins, cylinder liners, valve, train part and brake pads and disc made from MMC materials. The use of MMC materials is also being explored in other application including aerospace, electronic, structural and sporting goods [1-4]. Particle reinforced MMC represent a group of materials where the hardness, resistance of the reinforcement are combined with the ductility and toughness of a matrix materials. Aluminum is the most frequently used matrix material due to its low density. Because of its extreme hardness and temperature resistant properties, Al_2O_3 ceramic particles are often used as a reinforcement within the aluminum matrix. This type of composite is more frequently used in the automotive industry today, particularly in various engine components as well as brake and rotors [5]. The powder metallurgy route is more widely used for the manufacture of MMCs because it offers some advantages compare to other methods. One of the main advantages of this process is the lower temperatures, hence decreased possibility of chemical reaction between the matrix and reinforcement phases. Other advantages include the possibility of incorporating many types of matrices and reinforcement phases in the same composite system. In addition, a higher fraction of reinforcement particles may be included in the composite when compared against the rheological limitations of casting processes [6]. The casting process is the most economical process. However, it has some restrictions due to the matrix alloy and density of the reinforced phases. Therefore, the volume fraction and the size of the reinforcements that can be added are very limited. It is also possible that some defects (e.g voids because of shrinkage) can form in the cast [7].

Experimental

The raw material used consists of aluminum powder and alumina powder. High purity aluminum powder (BHD 99.5%) in form of flaky shaped powder particles was produced by BDH Laboratory Supplies, England, where as alumina powder with approximately 65 um was supplied by Pace Technologies, USA, in form of rectangular and sharp at the edges. Different weight fractions of Al_2O_3 particles were mixed with aluminum in a mixer. The weight fractions of Al_2O_3 in the samples are given in Table 1.

Table 1: Weight fractions of Al_2O_3 in the samples.

Sample	P0	P1	P2	P3	P4
Al_2O_3 wt%	0	5	10	15	20

Al-Al_2O_3 powder mixtures were compacted using hydraulic hand press. The powders were compacted at 250 ± 5 MPa. In order to avoid damage of the components during ejection, the compaction pressure was decreased to 5 MPa immediately after maximum pressure was obtained. The die used in this study was 40mm x 10mm x 5mm. Die wall lubrication was applied by brushing a thin layer of graphite powder over die cavity and the top punch. Sintering was carried out at 600^{0}C for 300 minutes in the furnace at inert

atmosphere. Heating rate was kept constant at $5^0C/min$. Microstructural analysis was carried out under *Scanning Electron Microscope (SEM).* The sintered density was determined by weighing the samples in both air and water. Hardness values was determined by using a Vickers microhardness pyramidal diamond testing machine with a load of 10 g and dwell time of 15 seconds. The Vickers hardness value is defined as the load divided by the pyramidal area of the indentation, in kg/mm^2.

Result and Discussion

Figure 1 shows the SEM micrograph of Al-Al_2O_3 composites. The distribution of the alumina particles in the aluminum matrix is noticeably uniform. There is no large agglomeration of particles. However, porosity can be viewed. Porosity may due to improper compaction or particles pull out during grinding and polishing.
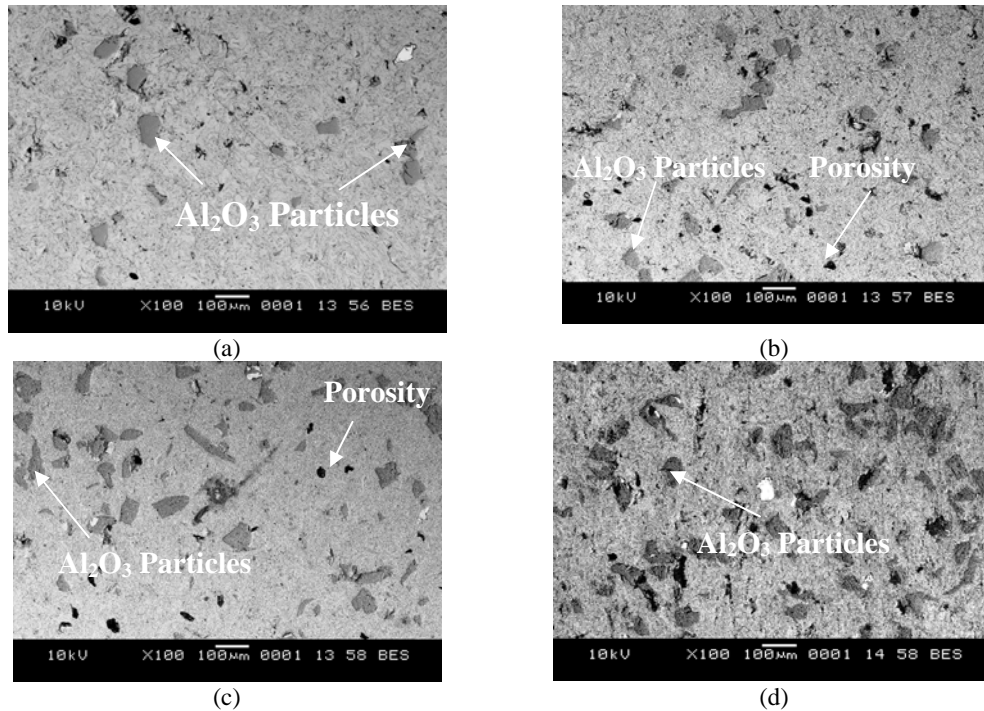

Figure 1: SEM micrographs of Al-Al_2O_3 composites (a) P1, (b) P2, (c) P3, and (d) P4.

In the processing of powder materials using powder metallurgy route, green compact was sintered to decrease the porosity and the density. In general, the increase in density depends on the kind of powder materials and the sintering conditions such as temperature and time. However, for a green compact made from mixed composite powders (Al and Al_2O_3 powders), the density change is affected not only by sintering conditions but also influence by the combination and volume fraction or weight percentage of the composite powders. The density of composite increases with the increasing amount of Al_2O_3 as shown in Figure 2. This is because density of Al_2O_3 powder ($3.7gcm^{-3}$) is higher compared to the density of aluminum powder ($2.4gcm^{-3}$). However the increasing percentage of Al_2O_3 particulates in aluminum matrix will not give dramatically increase in density value. The density of composites is in the range of 2.44 to 2.60 gcm^{-3} depending on the percentage of reinforcement.

Figure 3 show the Vickers hardness values versus the increasing weight percentage of reinforcement. The microhardness value increases linearly with the weight percentage of alumina particles. Unreinforced Al composite has the lowest hardness number, 31.99 HV, where as Al composite reinforced with 20 wt% of Al_2O_3 has the highest hardness number, 41.93 HV. This explains that, with the increasing number of hard alumina particles, the hardness of the Al matrix will increase. Study carried out by Khairel et. al. (2003), explained that alumina act as a barrier to dislocation flow in aluminum matrix. Therefore, the increasing of alumina will give more barriers and dislocation density [8]. Rodr´ıguez et. al. (2006), also said that, microstructure and mechanical response of the matrices is modified due to the reinforcement. The grain size of the matrices is reduced respect to the unreinforced alloys, it is observed a higher dislocation density in the matrices and the nucleation of incoherent precipitates is favored by the presence of reinforcements due to the higher defect's density. For these reasons the matrices are expected to be harder than the unreinforced alloys. [9]
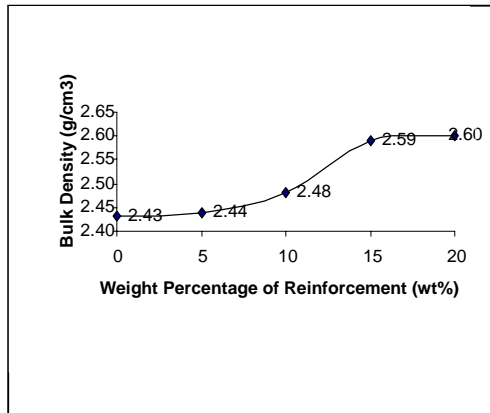
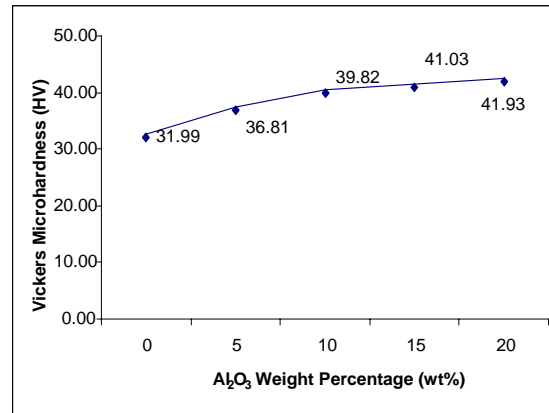Figure 2. Density of composites versus weight percentage of reinforcement.

Figure 3: Vickers microhardness versus weight percentage for Al MMC reinforced with Al_2O_3 particles.

Conclusion

The production of Al_2O_3 particle reinforced aluminum matrix composites in the form of net shape component can be achieved by use of conventional P/M route cold uniaxial pressing and sintering processing technology. The hardness values and density of the composites increase with the increasing percentage of Al_2O_3.

References

[1] M. A. Zamzam and A. M. El-Kharbotly. 1993. Hot Sintering of Coarse Two-Phase Al_2O_3 Powder Composites. *Key Enginering Materials Vol. 79-80.* pp 175-186.

[2] X. X. Yu and W. B. Lee. 2000. The design and Fabrication of an Alumina Reinforced Aluminum Composite Materials. *Composites Part A 31*, pp. 245-258.

[3] Y. Murakami. 1994. Aluminum-Based alloys. *Materials Science and Technology Vol. 8: Structure and Properties of Non-ferrous alloys*, VCH, Weinheim, pp. 215-274.

[4] K. H. Matucha. 1994. Introduction: Some Economic Aspect of Nonferrous Metals. *Materials Science and Technology Vol. 8: Structure and Properties of Nonferrous Alloys*, VCH, Weinheim. pp. 2-22.

[5] Frank Muller and John Monaghan. 2001. Non-conventional Machining of Particle Reinforced Metal Matrix Composites. *Journal of Materials Processing Technology 118.* pp. 278-285.

[6] Gheorghe and H. J. Rack. 2000. Powder Processing of metal matrix composite. *Comprehensive Composite Materials Vol. 3*. Elsevier. Oxford. pp. 679-698.

[7] O. Yilmaz and S. Buytoz,. 2001. Abrasive wear of Al_2O_3 reinforced aluminum based MMCs. *Composite Science and Technology 61*. pp. 2381-2392.

[8] Khairel Rafezi Ahmad, J. B. Shamsul, Luay Bakir Hussain and Zainal Arifin Ahmad. 2003, The Effect of Reinforcement Particle Size on the Microstructure and Hardness of Al/(Al_2O_3) Composite via PM Route, *12th Scientific Conference and 13th Annual General Meeting of Electron Microscopy Society of Malaysia*, Langkawi.

[9] J. Rodr´Iguez, M.A. Garrido-Maneiro, P. Poza and M.T. G´Omez-Del R´Io, (2006). Determination of Mechanical Properties of Aluminum Matrix Composites Constituents, Materials Science and Engineering, 437, pp. 406-412.