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

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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 Al₂O₃ reinforcement. The matrix and reinforcement materials were mixed in rotating mixer. The sample were cold pressed at 250 MPa and sintered at 600 °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 Al₂O₃ particulates homogeneously distributed in aluminum matrix. Al-5%Al₂O₃ gives the lower bulk density and Al-20%Al₂O₃ 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, Al₂O₃ 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 Al₂O₃ particles were mixed with aluminum in a mixer. The weight fractions of Al₂O₃ in the samples are given in Table 1.

Table 1: Weight fractions of Al₂O₃ in the samples.

<table>
<thead>
<tr>
<th>Sample</th>
<th>P0</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al₂O₃ wt%</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>15</td>
<td>20</td>
</tr>
</tbody>
</table>

Al-Al₂O₃ 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°C for 300 minutes in the furnace at inert
atmosphere. Heating rate was kept constant at 5°C/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/mm².

Result and Discussion
Figure 1 shows the SEM micrograph of Al-Al₂O₃ 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 be due to improper compaction or particles pull out during grinding and polishing.

![SEM micrographs of Al-Al₂O₃ composites](image)

Figure 1: SEM micrographs of Al-Al₂O₃ 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 Al₂O₃ powders), the density change is affected not only by sintering conditions but also by the combination and volume fraction or weight percentage of the composite powders. The density of composite increases with the increasing amount of Al₂O₃ as shown in Figure 2. This is because the density of Al₂O₃ powder (3.7gcm⁻³) is higher compared to the density of aluminum powder (2.4gcm⁻³). However the increasing percentage of Al₂O₃ 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, whereas Al composite reinforced with 20 wt% of Al₂O₃ 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 Khairil 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]. Rodríguez 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]
Conclusion

The production of Al$_2$O$_3$ 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$_2$O$_3$.

References