# Compressive Behavior of 7xxx Series Al Composites Reinforced with $Al_2O_3$

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**Abstract**

*Mechanical properties of 7xxx series Al metal matrix composite (MMC) powders containing different amounts of ceramic were investigated. The ceramic contents of the starting powders were 5 wt.% or 10 wt.%. The powders were uniaxially cold compacted using a cylindrical die with a compacting pressure of 250 MPa and were sintered at 620°C in a dry $N_2$ atmosphere for 60 min. For the heat treatment, sintered parts were solution treated at 475°C and aged at 175°C. Compression tests were conducted to reveal the effect of $Al_2O_3$ particle content on the mechanical properties of the composites. Fractography was examined using a scanning electron microscope.*

**Keywords : Mechanical properties, MMC, $Al_2O_3$ particle, Fractography**

## 1. Introduction

Aluminum and its alloys have high electric and thermal conductivities, low specific gravities, high strength-to-weight ratios and high corrosion resistances. Mechanical and corrosion properties can be improved by adding an alloying element, changing the fabrication process or heat treating [1].

Metal matrix composites (MMCs) have received much attention from researchers because of their marked improvement in mechanical properties [2]. Until now, Al MMCs were made using conventional production processes such as casting, thixoforming and spray deposition. However, these processes have problems in uniform microstructure, production cost and back-end machining [3]. To overcome these problems, powder metallurgy (P/M) processes using Al MMCs have been widely studied [4~6].

In this study, the compressive behavior of 7xxx series Al-blended and $Al_2O_3$-reinforced composite powders were investigated. To discover the effect of $Al_2O_3$ particles on compressive properties, 7xxx series Al-$Al_2O_3$ MMCs were investigated and compared to a sintered part using 7xxx series Al blended powder.

## 2. Experimental and Results

The starting powder for the experiments, AMB 7775 (Al-7.0Zn-1.0Cu-2.5Mg-1.5Acrawax C wt.%, Ampal, USA), was fabricated by blending each elemental powder with Acrawax C, a lubricant. Composite powders called AMB7905 and AMB7910 were used. Each composite powder contained 5 wt.% and 10 wt.% $Al_2O_3$ particles, respectively, mixed in the 7xxx series Al blended powder, AMB7775. The Al matrix powder had an average particle size of approximately 50 ㎛ and the mean particle size of the additive elements was less than 20 ㎛. The $Al_2O_3$ ceramic had a mean particle size of about 100 ㎛. The powders were blended in a 3-D tubular mixer. The powder mixtures were uniaxially cold compacted using a cylindrical die with a compacting pressure of 250 MPa. The diameter of the cylindrical die was 9 mm. Acrawax C was removed by heating the mixture at 350°C for 1h. This removal process was determined by previous TG (thermogravimetric) analyses. Specimens were sintered at 620 °C in a dry $N_2$ atmosphere for 1 hour. The heating rate was 20°C/min.

The sintered and aged microstructure was examined using optical microscopy (OM). Solutionizing and aging treatments were performed at 475°C for 1 hour and 175°C for 4 hours, respectively. After aging, a compressive test was performed at a constant strain rate ($\nu=1\times10^{-3}$/s) using sub-size cylindrical samples of 9 mm diameter. Each test was performed 5 times and the average value was calculated. Fractography and cross-section analysis were conducted using SEM.

Figure 1 shows the microstructures AMB7910. AMB7775 which has non $Al_2O_3$ additives shows some pores around triple point than AMB7905 and AMB7910 and shows more homogeneous microstructures. It is believed that the grain refinement was influenced by dispersed $Al_2O_3$ reinforcement particles because grain growth was suppressed by the ceramic phase.

Figure 2 shows the changes in compression properties with different amounts of $Al_2O_3$. It is believed that the increases in compression properties are influenced by rigid structure which is brought by added ceramic phase. Also, it is thought that the addition of $Al_2O_3$ particles causes the dispersion strengthening effect and the grain refinement.

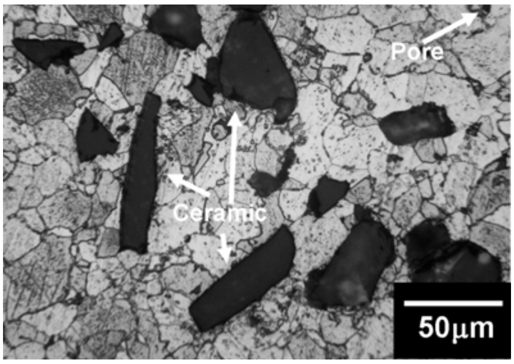


**Fig. 1. Optical micrographs of AMB7910.**

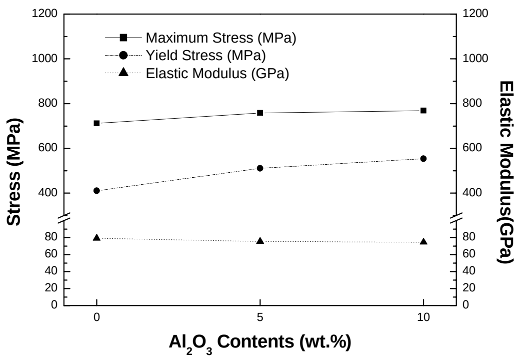


**Fig. 2. Effect of $Al_2O_3$ reinforcement particle addition on compression properties of AMB7775.**

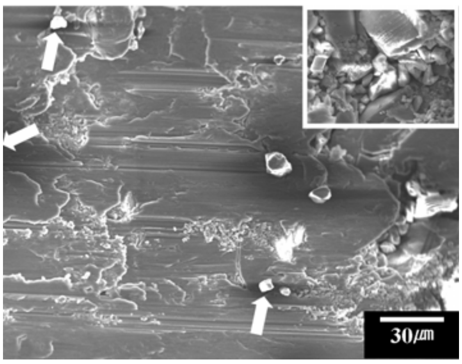


**Fig. 3. SEM fractographs of AMB7910.**

Fig. 3 shows the fractographs of AMB7910. The compression stress loaded horizontally in these fractographs. In case of AMB7775 fracture surface, it shows the transgranular and tearing fracture surface with some pores which are indicated by white arrows and some oval dimples lower side of Fig. 3. Generally, these pores, which can be act as the fracture origin, decline the mechanical property of the specimens. But in case of oval dimples, these dimples which are different from pores are formed as the subsurface void intersected the wall of larger void and coalesced. In fig. 3, $Al_2O_3$ reinforcement particles were shown and indicated by white arrows in SEM fractographs. Some of the fracture surface in AMB7905 and AMB7910, intergranular fracture was partially observed with vein pattern that is shown in Fig. 3 in the white box area.

## 3. Summary

Effect of 5 and 10 wt.% $Al_2O_3$ ceramic particle addition on compression behavior of 7xxx series Al blended powder was investigated. As the ceramic reinforcement particle added to AMB7775 the elimination of pores and grain refinement was somewhat happened. It is thought that ceramic particles hindered grain coarsening during heat treatment. And there is significant increase in yield stress after ceramic particle addition about 35 pct. It is caused by rigid structure from the dispersion of ceramic particles. So, it is considered that the strengthening mechanism of this composite is combination of age and dispersion hardening with $Al_2O_3$ particles. It is believed that the differences in thermal expansion coefficient caused rapid volume change during heat treatment and delamination of interface between Al matrix and ceramic particles.

From the fractography analysis, AMB7775, AMB7905 and AMB7910 show the transgranular and tearing fracture surface with some pores and oval dimples. The pores are gradually eliminated by the addition of $Al_2O_3$ reinforcement particles. And some part of the ceramic reinforced specimen shows the intergranular fracture with vein pattern.

## 4. References


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