Mechanical Properties of Al-Si Composite Powders produced by Gas Atomization Process

[1)]Jin-Chun Kim, [1)] LiFe Wang, [2)]In-Sang Chung and[1)]Yong-Jin Kim
1)Nanopowder Materials Group, Materials Technology Department
Korea Institute of Machinery and Materials
66 Sangnam-dong, Changwon, Kyungnam, 641-010, Korea
2) Department of Metallurgucal Engineering, Kyungpook National University,
1370 Sankyuk-dong, Daegu, 702-701, Korea

1. Introduction

Powder metallurgy (P/M) process is one of the attractive processing routes for fabricating near-net shaped components with high productivity and low cost[1]. In particular, P/M Al alloys can be commercially used as candidate materials for automobiles, electrics and aerospace applications because of their lightness and mechanical properties [2]. Among them Al-Si alloys are the most interest materials for high strength structural components because they have the low coefficient of thermal expansion (CTE) and high wear resistance and mechanical properties[3]. The mechanical properties of Al-Si alloys are dependent on the volume fraction and size of the eutectic Si particles.

In this paper, Al-Si powders with high Si content were fabricated by the gas atomization process. The hot-press and hot-extrusion processes were applied to obtain high-density specimens. Microstructures and mechanical properties of consolidated Al-Si specimens were studied.

2. Experimental Procedure

Elemental Al chips (99.5% purity) with size of 5mm and Si powders (99.7% purity) were used for the main alloying elements in this experiment. Two different nominal powders(VN1 and VN4) were fabricated. The atomized powders were mechanically sieved.

As-received atomized powders were hot-pressed at 450℃ for 30min under 100MPa with diameter of 16mm and height of 10mm. The compacted billets were extruded into rectangular shape (54.5mmX10.5mm) using a hydraulic press at a temperature of 400℃. The extrusion ratio was 11:1. Graphite for the die lubrication was used in this experiment. Actual density of the compacted and hot-pressed samples was calculated from the weight and volume measurement methods and the Archimedes method. Hardness measurements were performed using Rockwell hardness tester. Tensile tests in this experiment were carried out with a cross head speed of 1 mm/min.

The consolidated Al-Si specimens were mechanically polished, and their microstructures were evaluated after etching treatment in the Keller acid. All samples were also observed by OM and SEM.

3. Results

Average size of the VN1 powder prepared under 2MPa was about 145㎛. However, under 3MPa, the average size was drastically decreased into 80㎛. The average size of VN4 powders produce under 2MPa was 158㎛. The as-atomized Al powders produced under

nitrogen atmosphere had nearly spherical shape with slightly rough surface containing small amount of fine satellite particles. The size of primary Si particles varied approximately in the range of 8-10㎛.

The compacting ability of the powders was similar in all examined cases of atomizing conditions. The relative green densities were about 70% at 300MPa and reach to 80% at 600MPa. The relative green densities increased from 70-73 to 80-83% when increasing a compaction pressure from 300 to 600 MPa. In this study, we could get high densified specimens, which have above 96% of the theoretical density by hot pressing at 400℃. The hardness of the hot-pressed specimens increased with the addition of Fe elements. The harness of VN4 specimen was 84.6HRB, which shows the Cu element also affects the hardness.

After extrusion, the solidification structures was severely broken by the deformation, and the primary eutectic Si particles in the Al matrix were aliened along the direction of the extrusion. The eutectic Si size decreased from 5-8㎛ to 2-3㎛ during the extrusion deformation. The coarsening of Si particles was not happened during the hot extrusion process in this experiment. The severe deformation clacks were not observed in this specimens, but some small pores indicated by arrows observed after extrusion.

The ultimate tensile strength (UTS) was also changed with the addition or subtraction of alloying elements. The UTS values of hot extruded VN1(-100mesh), VN1(-200mesh), VN4(-100mesh) and VN4(-200mesh) specimens were about 520MPa, 532MPa, 474MPa and 461MPa, repletively, which were much higher than that of conventional hypoeutectic Al-Si alloys.

4. Summary

The microstructure and mechanical properties of the hypereutectic prealloyed Al-Si powders prepared by the gas atomization process were described in this paper. With increasing the gas pressure of the atomization, the average powder size was decreased from about 145㎛ to 80㎛. The primary eutectic Si particles were uniformly distributed in the Al matrix and their size varied in the range of 8-10㎛. . The high densified specimens with above 96% of the theoretical density were fabricated the hot pressing process. The UTS mechanical properties of VN1 specimens were much higher than that of conventional hypoeutectic Al-Si alloys.

Acknowledgement

This research was supported by a grant from the Center for Advanced Materials Processing (CAMP) of the 21st Century Frontier R&D Program funded by the Ministry of Science and Technology, Republic of Korea.

References

[1] A. Fujki, Mat. Chem. Phys. , Vol 67, 298(2001).
[2] I. J. Polmer, Light Alloys, Arnold, London, 1995
[3] H. Yamagata, Materials Science Forum, 304-306 (1999) 797