Sintering Behavior of Al-Si 20 wt. % Alloyed Powder Fabricated by Gas Atomizer

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Introduction

Al alloys have been commercially attracted much attentions as candidate materials for automobiles, electrics and aerospace application because of their lightness and good mechanical properties. Properties of Al alloys can be improved by addition of alloying elements such as copper, magnesium, zinc and silicon. Among them Al-Si alloys are most attractive materials for high strength structural components because they have the low coefficient of thermal expansion, high wear resistance and mechanical properties. However, with increasing Si content the primary Si crystals become coarser, resulting in deterioration in mechanical properties. Due to a recent development in the technique for consolidation of Al alloy powders, rapid solidification of hypereutectic Al-Si alloys seems to be the most promising route to improve mechanical proerties. In this study, the Al-Si alloy powders by addition of the trace elements such as Fe, Mg and Mn were produced by the gas atomization process. And then the compacting and sintering processes were applied to obtain the high density specimens. The microstructure and mechanical properties of the atomized powders and sintered specimens were investigated with the process parameters.

Experiment Procedure

The elemental Al chips (99.5% purity) with size of 5mm and Si powders (99.7% purity) with size of 2-3mm were used for the main alloying elements in this experiment. High purity Fe, Mg and Mn were mixed as additive elements. The nominal composition of the alloy was 20%Si, 5.5%Fe, 1.2%Mg, 0.5%Mn and balance aluminum.

All elementals of the composition were melted by a high frequency induction melting furnace to prepare the master alloy ingots. From the ingots, the Al-Si alloyed powders were fabricated by a gas atomizer. The atomized powders were mechanically sieved, and their size was analyzed by the laser particle size analyzer. The microstructure of the fabricated powders was examined using an optical microscope (OM) and scanning electron microscope (SEM). Oxygen contents were also measured by the nitrogen-oxygen determinator. The thermal behavior of the atomized Al-Si alloy powders was analyzed by DSC analysis with the heating rate of 5℃ Ar atmosphere.

By using this alloy, every 3g of the atomized powder, respectively, was compacted into 16mm cylinder at room temperature and at different pressure up to 600MPa using a laboratory hydraulic press and die-wall lubrication. The green density of the aluminum compacts was determined from weight and dimensional measurements.

The sintering experiments were carried out in a tube furnace under controlled dry nitrogen atmosphere. The green compacts were delubricated under nitrogen at 400℃ for 60min and then the heating cycle was continued up to the sintering temperature in which the specimens were held for 0, 10, 30, 45, 60, 90, 120min. The sintering temperature ranges between 520℃ and 620℃. The density of the sintered specimens was measured using Archimedes method. Specimens for metallographic observation were mechanically polished and left etched in the Keller acid. The microstructures were examined using OP and SEM. All samples were machined into test specimens. Hardness measurements were performed using a Rockwell hardness tester.

Conclusions

In this experiment, the sintering behavior of Al-Si 20Wt.% alloyed powders fabricated by gas atomizer was studied systematically through density test, hardness test, OM and SEM. Based on the experiment results and discussion, the following conclusions can be drawn.

1. The mean particle size of the aluminum alloyed powder was mainly affected by atomizing pressure. The particle shape was changed from spherical to irregular by introducing oxygen in the atomizing gas. The green density of the alloyed powder depended mainly on the compacting pressure and powder composition. The green density was significantly improved when the alloyed powder did not contain Cu element.
2. The variation in the density and hardness of the sintered samples were obtained dependent on the sintering temperature, sintering time, and compacting pressure. However, the effects of compacting pressure on the hardness of the sintered sample are not conspicuous when the sintering temperature is above 580℃
3. With increasing sintering time, the size of pores in the microstructure become smaller and smaller until completely disappeared for 60 min of the sintering time. When the sintering time reaches to 120 min, there is a small increase in the Si particle size.
4. The great difference exists between density of the center and that of the edge of the sintered sample.
5. Primary Si precipitates are uniformly distributed in a matrix of Al. At the same time, Fe precipitates with a platelet shape are observed. There are many micro-pores and cracks around the Si particles.

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