Effect of processing conditions on the size and morphology of Al-6wt%Si powder particles prepared via SAMD technique

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Abstract
A novel method called "Solid Assisted Melt Disintegration" (SAMD) by using a soluble media (NaCl) was used to produce Al-6wt%Si powder particles. In this method, a specified amount of sodium chloride (NaCl) was introduced to aluminum alloy melt and the slurry was stirred in a specified time-temperature regime to disintegrate the alloy melt into droplets. This blend was quenched in water resulting in solidification of Al powder particles and dissolution of NaCl in water. The Al powder particles were then collected, washed, dried and subjected to laser particle size (LPS) analyzing and scanning electron microscopy (SEM) studies. In the present study the effect of using different time-temperature regimes on the size and morphology of the resultant Al powder particles was investigated and the optimum conditions for obtaining the fines spherical particles was established.

Introduction

The different processing methods for production of metallic powder particles fall into four categories that include Mechanical, Chemical, Electrochemical and Atomizing processes [1]. Among these methods, atomizing has been widely used for the production of these powders [2]. In twin fluid atomization a technique, melt fragmentation is achieved through directs impingement with a jet of another fluid such as pressurized gas (air, nitrogen, argon or helium), steam, oil or water [3]. However, the high price of inert gases such as He and Ar result in the increased cost of powder particles.

In the solid assisted melt disintegration (SAMD) technique, the melt disintegration is achieved by kinetic energy transfer from a rotating impeller to the melt via a solid atomizing medium. This cost-effective technique was successfully used for production of the mixture of aluminum-graphite particles [4] and A356 aluminum powders by using alumina particles as the solid medium [5,6]. However, in the aforementioned studies, it was necessary to use coarse alumina particles to be separated from the aluminum powders bye sieving the powder mixture.

Specific Objectives

In the present study, for the first time, a soluble atomizing medium (NaCl) was used in the SAMD technique that facilitated the separation of the Al powders from the media by solving NaCl in the water. In this study the effect of some processing parameters such as time-temperature regime on size, size distribution and morphology of produced powders is investigated.

Procedure

In the present study, Al-6wt%Si was prepared by using commercial pure Al and LM6 (Al-12.6Si) alloy in an electrical resistance furnace. About 40 g of Al-6wt%Si alloy ingot and 160 g of NaCl (average size D50=254 μm) were placed into a graphite crucible and the alloy was melted and superheated to 690°C. Then the slurry was stirred via spiral graphite impeller (d=30mm) at 1400 rpm using an electrical motor. Six different time-temperature regimes investigated in this study different from each other by stirring time and cooling conditions and are summarized in table 1.

Table 1. Different time-temperature regimes used in this study

Regime No.	Stirring time	Cooling condition
a	49	closed furnace
b	16	opened furnace
c	25*	opened furnace
d	5	air
e	5	water
f	10	water

* 5 min at 690°C then 20 min in open furnace.

At the conclusion of each time-temperature cycle, the blend was quenched in distilled water and the Al powder was collected and dried. The Al powder particles were passed through 710 μm and 500 μm sieves and the <500 μm fraction of powders were subjected to Laser Particle Size (LPS) analyzing.

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Table 2. Characteristics of produced powders via SAMD method with (a-f) time temperature regimes

Regime	Powder > 500 µm(%)	Characteristics of total powders		
		D10 *(µm)*	D50 *(µm)*	D90 *(µm)*
a	47.36	20.89	380.99	793.39
b	13.3	7.39	234.47	601.53
c	10.9	49.75	293.76	533.33
d	3.5	9.124	51.14	355.61
e	7	7.219	34.48	329.48
f	6	3.06	44.81	380.78

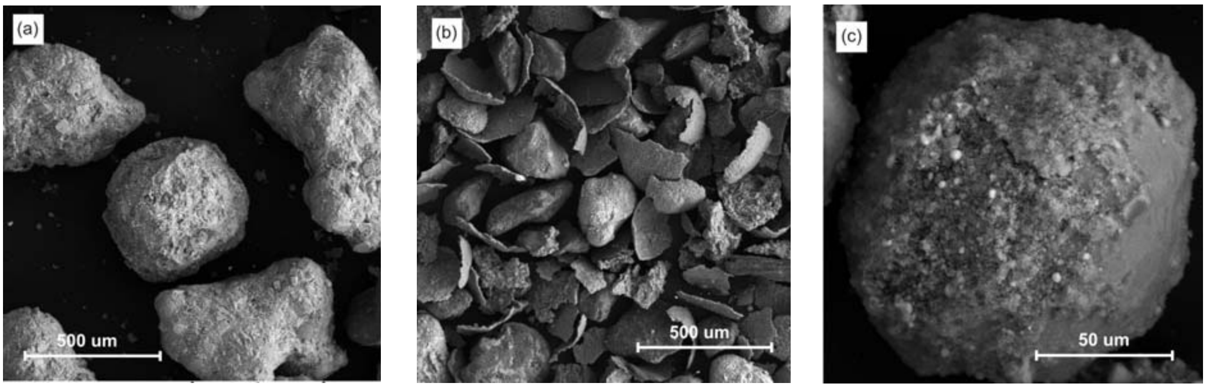

Fig. 1. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (a), (a) powder particles in the size range of 300-500 µm, (b,c) powder particles in the size range of 106-212 µm.

Different size bands of powders were subjected to SEM studies after gold coating.

Results and Discussion

The results of the size characteristics of produced powders of each time-temperature regime together with the wt% of the coarse (>500µm) powders are presented in Table 2. It can be seen that the produced powders via regime (a) are relatively coarse and show a high amount of >500 µm particles. In fact stirring for a long time in the semisolid condition (during cooling the blend in the closed furnace), result in agglomeration of the particles (Fig. 1a). Also the separation of the solid skin of the particles from the remaining semisolid or liquid droplet during stirring (Fig. 1b), resulted in formation of curved flakes in the produced powders (Fig. 1c).

In regime (b), because stirring was done in open door furnace, the cooling rate was higher and solidification was shortened. Therefore less agglomeration occurred and in general, particles became smaller and the wt% of >500 µm fraction was decreased. However, the agglomeration has also occurred in this regime (Fig. 2a), but the curved flakes do not form (Fig. 2b).

In regime (c), because stirring has been done in liquid state and high temperature, compared to regime (b), the amount of powders larger than 500 µm have decreased.

Fig. 3a shows the agglomerated powders of regime (c) and again because of a relatively long stirring time in semisolid state, curved flakes formed to some extent (Fig. 3b).

In regime (d), because of the efficient isothermal stirring of the liquid and cooling in air without stirring, agglomeration has not occurred and the total particle size and the percentage of powders larger than 500 µm have decreased considerably due to prevention of agglomeration of droplets before the end of solidification. Typical SEM micrographs of these powders are shown in Fig. 4(a,b) revealing a relatively spherical morphology with no sign of curved flakes.

Further increase of the cooling rate in regime (e) as compared with (d) was achieved by water quenching and resulted in less agglomerated particles (decreased amount of >500 µm particles) and finer size distribution (Table 2).

As shown in Fig. 5(a,b), the powder particles are more spherical with no sign of formation curved flakes. However, the increased stirring time in regime (f) to 10 min did not help in decreasing the average particle size. Also the morphology of powders did not change significantly as compared with regime (e) (Fig. 6(a,b)).

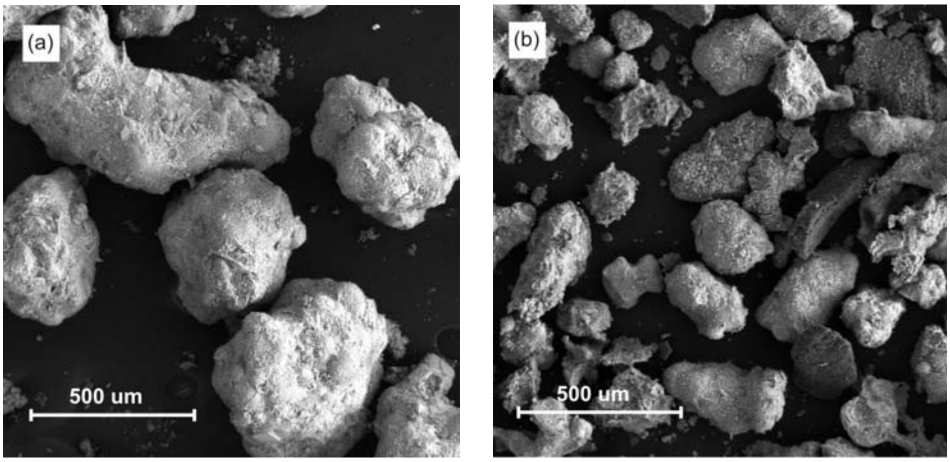

Fig. 2. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (b), (a) powder particles in the size range of 300-500 µm, (b) powder particles in the size range of 106-212 µm.

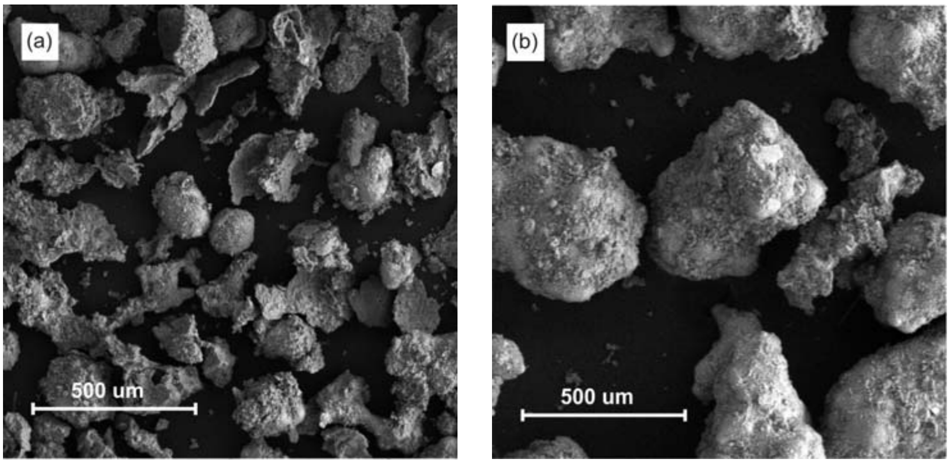

Fig. 3. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (c), (a) powder particles in the size range of 106-212 µm, (b) powder particles in the size range of 300-500 µm.

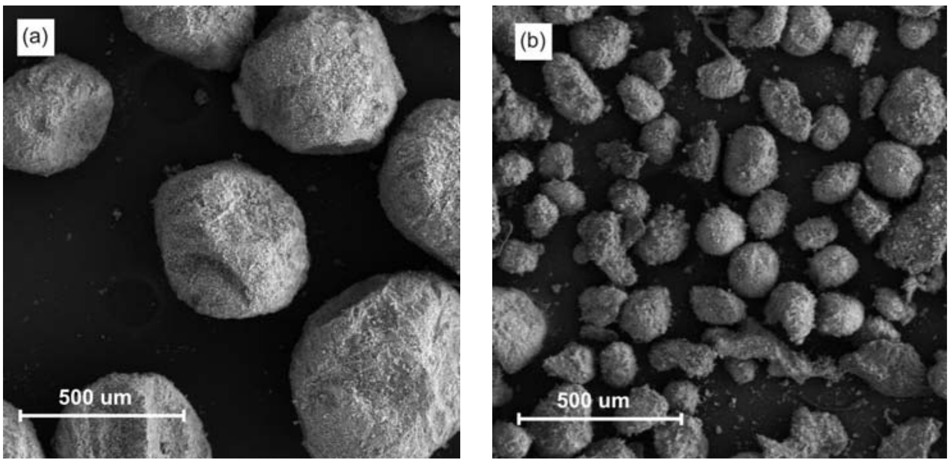

Fig. 4. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (d), (a) powder particles in the size range of 300-500 µm, (b) powder particles in the size range of 106-212 µm.

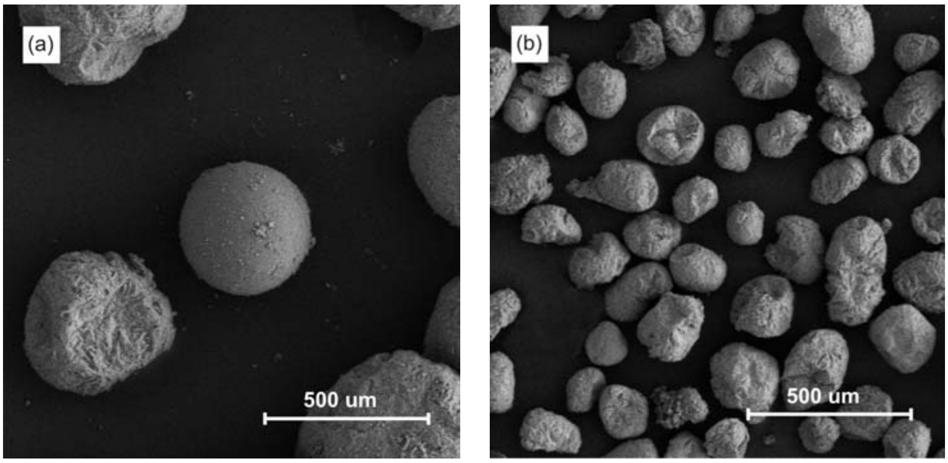

Fig. 5. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (e), (a) powder particles in the size range of 300-500 μm, (b) powder particles in the size range of 106-212 μm.

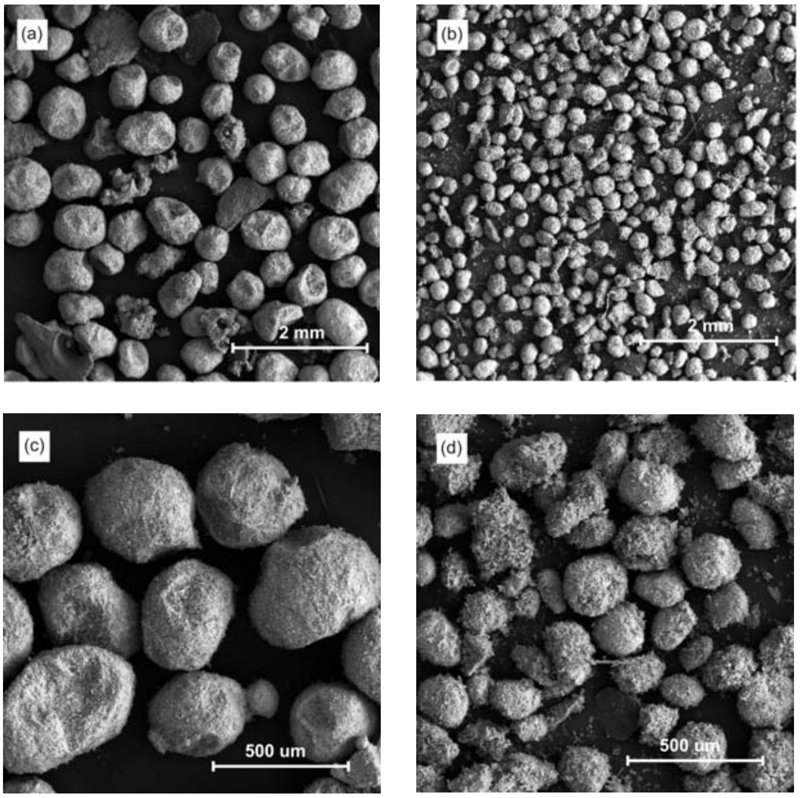

Fig. 6. Typical SEM images of Al-6wt%Si powder particles produced by SAMD process via regime (f), (a),(c) powder particles in the size range of 300-500 μm, (b),(d) powder particles in the size range of 106-212 μm.

Conclusions

1. SAMD technique can be modified by using NaCl instead of Al_2O_3 as the atomizing medium. The NaCl particles help in disintegration of the Al melt into droplets and easily be separated from the solidified Al powders by dissolution of NaCl in the mixture in water.
2. By using different time-temperature regimes for the production of Al powder, different size distributions and morphologies can be achieved.
3. The most spherical powder particles together with the finest particles are obtained by stirring the mixture of NaCl and Al melt for 5 min at 690°C and quenching the slurry in water.

References

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