STRUCTURE AND PROPERTIES OF SPRAY FORMED Al-8Si-4Cu-0.4Mg-0.5Mn ALLOY

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Abstract

The spray deposited Al-8Si-4Cu-0.4Mg-0.5Mn alloy plates were produced on a water cooled, mild steel moving substrate. Three circular ultrasonic gas atomizers in alignment were used to produce flat deposites which were 25 mm thick, 25 cm wide and 45 cm length. The as -deposited materials showed high densities (93±3%) and fine equiaxed microstructure with uniform distribution of spherical eutectic silicon. The deposits were hot rolled for full densification and further structural refinement and were given T6 treatments prior to tensile testing. The cold formability were tested by upsetting after annealing. Experimental results indicate that spray deposited Al-8Si-4Cu-0.4Mg-0.5Mn alloy with excellent ultimate strength (411MPa) and elongation (6%) can be achieved. The alloy also shows good wear resistance, cold formability and low thermal expansion coefficient. It has great potential in making cylinders for video industry.

Introduction

Spray forming is an attractive technology to produce a number of different metallic alloys with improved properties over conventional materials. By using spray deposition a near-net-shape product can be fabricated in one integrated operation directly from the melt which offers significant economic benefits compared to ingot and PM manufacturing routes. The rapidly solidified deposits are characterized by a uniform microstructure with equiaxed grains and free of macrosegregation of alloying elements. Moreover, materials produced by spray deposition show much low oxygen content than the PM materials [1-4]. In this paper, general characteristics of spray formed Al-8Si-4Cu-0.4Mg-0.5Mn alloy are discussed, Mechanical properties, cold formability, wear resistance and microstructure of the spray deposited alloy are also investigated.

Experimental Procedures

The materials used in this investigation was Al-8Si-4Cu-0.4Mg-0.5Mn alloy (wt%). Spray deposited preform materials were prepared using the ultrasonic gas atomization-deposition system [5]. Master alloy was melted by induction heating in a graphite crucible in an evacuated tank. After attaining a temperature of 1073 K, the tank was backfilled with nitrogen. The melt was bottom poured through three circular atomizers in alignment and deposited on a water cooled, mild steel moving substrate. The spray deposition parameters are as follows: atomization gas pressure, 1.5MPa; substrate to nozzle distance, 360 mm; tank gas pressure before atomization, 0.12MPa; inside diameter of pour tube, 4 mm.

The as-deposited products were sectioned and examined for porosity, density and microstructure. The densities were measured using Archimedes method.

Deposited preforms were preheated to 673°K and hot rolled with a total reduction of 50% or more to get full compaction. In order to determine the cold formability, cold upsetting was made on the annealed materials. Test specimens were of cylindrical shape and had 10 mm length and 8 mm diameter. Tensile properties at room temperature were determined after T6 heat treatment. Wear resistance properties were evaluated on a M200 wear tester. Test conditions were as follows: the rolling material was gray iron HT250, load was 10N and 20N respectively, sliding speed was 200 rpm and sliding time was 20 min. No lubricant was used.

All specimens were polished and etched with 0.5% HF. The microstructures of as-cast, as-deposited and as-rolled materials were examined by optical microscope.

Results and Discussion

Deposits

Fig.1 shows a flat product produced on the atomization-deposition system. The deposited perform was 25 mm thick, 350 mm wide and 450 mm length. It can be seen that thickness is uniform across a width of 250 mm. It decreases towards the side edges of the product. Such borders must be trimmed before rolling.

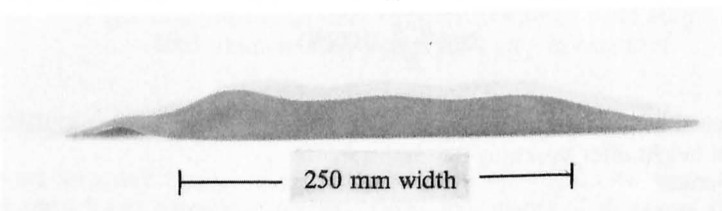

Fig.1 Flat product in spray condition

Fig.2 shows the relative density value of samples taken through the center of a Al-Si alloy preform. It can be seen that the relative densities in the bottom horizantal row are low and a porous zone is present in the area of contact with the substrate. There is also a low density region near the surface. The preform averaged 93% density.

Cold Formability

Table I shows the result of cold upsetting. Deposited material can be reduced to a upsetting ratio of 56% without cracking. However cold formability of as-cast materials is much worse than that of as-deposited. The cracking occurred at a upsetting ratio of 43%.

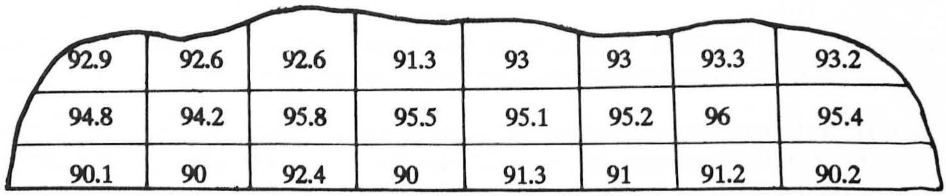

Fig.2 Relative density of samples taken through the middle of a Al-Si alloy preform. 100% density is 2.78 g/cm^3.

Table I. Critical upsetting ratio of annealed Al-8Si-4Cu-0.4Mg-0.5Mn alloy tested at room temperature

Condition	upsetting ratio $\epsilon(\%)^*$					
	36	40	43	48	56	68
as-deposited+hot rolling	O	O	O	O	O	X
as-cast+extrusion	O	O	Δ	Δ	X	X
P.M+extrusion	O	O	O	O	Δ	X

$$.^*\epsilon=\frac{H-h}{H}\times 100(\%)$$

where H-original height of upsetting specimens
h-final height after upsetting
O-no crack
Δ-little crack
X-broken

Mechanical and physical properties

Comparison of mechanical and physical properties of Al-8Si-4Cu-0.4Mg-0.5Mn alloy produced by various processing route is listed in Table II.

It can be seen that tensile strength of as-deposited materials at room temperature is 411 MPa and is about 86MPa higher than that of as-cast material. The yield strength and elongation of as-deposited alloy has two times higher than conventional cast alloys.

Table II. Mechanical properties of alloy produced by various processing route

condition	σ_b(MPa)	$\sigma_{0.2}$(MPa)	δ(%)	density g cm^{-3}	thermal expansion (20-200°C)x10^{-6}
As-cast+T6	325	165	3		
As-deposited+hot rolled+T6	411	317	6	2.78	21.8

Wear resistance properties

Fig.3 shows the comparison of wear resistance properties between spray deposited Al-8Si-4Cu-0.4Mg-0.5Mn alloy. 6061 aluminum alloy and HT250 gray casting iron. The results indicate that wear resistance of deposited alloy is higher than that of 6061 aluminum alloy and HT250 gray casting iron. For example the weight loss of 6061 alloy is equal to that of gray iron. However weight loss of Al-Si alloy only equal to 1/5 of gray iron .

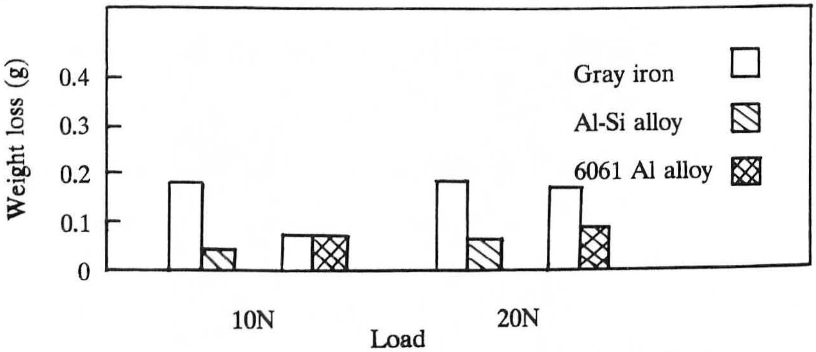

Fig.3 Comparison of wear resistance between Al-Si alloy. 6061 alumina alloy and HT250 gray casting iron

Microstructure

Fig.4 shows structure typical of a casting Al-Si-4Cu-0.4Mg-0.5Mn alloy. It consisted of dendritic particles of eutectic silicon and $CuAl_2$ in a matrix of aluminum solid solution.

The microstructure of as-deposited alloy appears in a uniform distribution of spherical eutectic silicon particles. Porosity is a characteristic feature of the spray deposited materials (Fig.5). After hot rolling of 50%, the specimen has been completely compacted (Fig.6)

The as-deposited alloy has already been used as a cylinders for video which are required to have simultaneously high wear resistance and low coefficient of thermal expansion as example in Fig.7. The cylinder was produced by the process of spray deposition, rolling, cold die forging and finish machining.

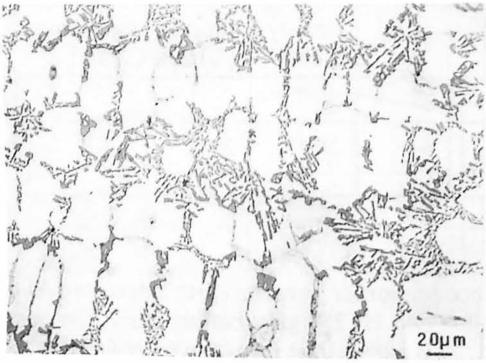

Fig.4 Microstructure of as-casted alloy

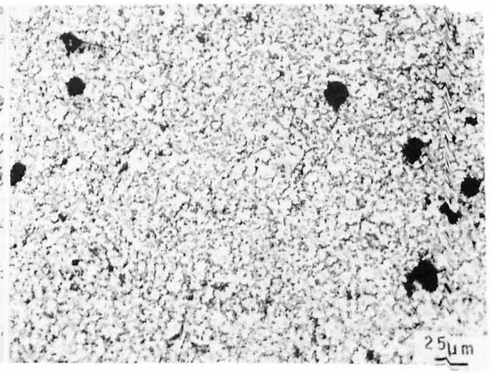

Fig.5 Microstructure of as-deposited alloy

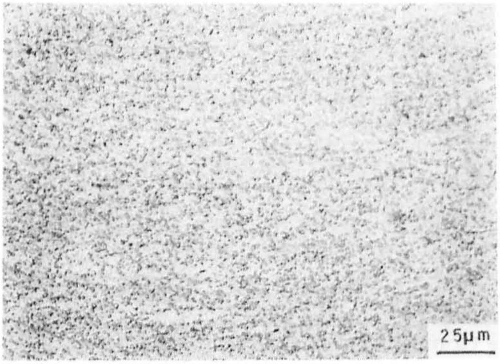

Fig.6 Microstructure of hot rolled and T6 heat treated specimen

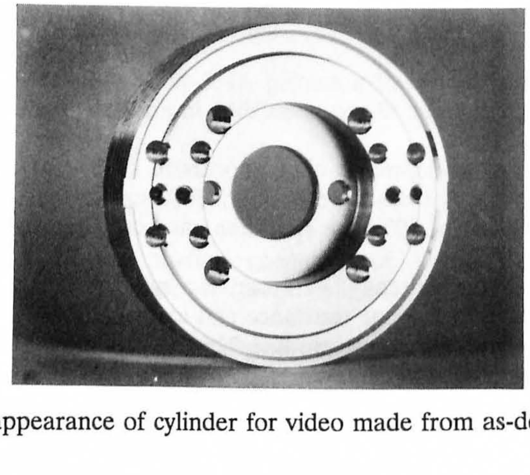

Fig.7 External appearance of cylinder for video made from as-deposited Al-Si alloy

Summary

1. Using three circular atomizers in adlignment, the flat deposited material can be achieved. It has fine equiaxed microstructure with uniform distribution of spherical eutectic silicon particles.

2. After rolling and heat treatment, the alloy shows good mechanical properties (strength, ductility, wear resistance etc) which makes it suitable to be used as wear resistant material.
3. As-deposited alloy shows excellent cold formability. It can be cold formed easily into complex workpiece for industrial application.

References

1. A.R.E.Singer, Metal Powder Report, 41, (1986), 119

2. R.G.Brooks, C.Moore, A.G.Leatham and J.S.Coombs. Powder Metallurgy 2, (1977), 100.

3. E.J.Lavernia and N.J.Grant. Materials Science and Engineering 98, (1988), 381.

4. E.J.Lavernia, R.Rai and N.J.Grant, International J.Powder Metall., 22 (1986), 9.

5. Y.C.Zhang et al., Aluminum-Lithium Alloy 5, ed. T.H.Sanders, Jr. and E.A.Starke, Jr (Birmingham, Materials and componetent Engineering Publications, 1989), 95.

6. N.Amano et al. Metal Powder Report 44, (1989), 186.