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The influence of solidification rate on structure parameters of aluminium-matrix particulate composites

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ABSTRACT

Aluminium alloy-matrix composites with ceramic particulates (Graphite, SiC, Al₂O₃, TiC) were synthesised using liquid metallurgy route.

The microstructural characteristics of composites are studied, using scanning electron microscope. Experiments using various cooling rates show that primary cell size is slightly smaller in AlSi12CuNiMg ceramic particles composite compared to the base alloy. The microstructure of rapidly solidified composites revealed a more homogeneous ceramic particles distribution because of the reduced time the composite is in a molten state.

INTRODUCTION

Cast aluminium matrix particulate composites which contain a discontinuous ceramic phase (SiC, Al₂O₃, Graphite, TiC) possess many useful properties and represent a class of inexpensive tailor-made materials for a variety of engineering applications.

In recent years considerable work has been done on the quantification of evolution of solidification microstructures in particle dispersed alloys [1-4].

However the understanding of solidification microstructure formation is difficult due to the unrestricted mobility of the ceramic particles in solidifying melt.

This work was undertaken to determine the role of solidification rate over structure parameters of the aluminium - matrix particulate composites.

EXPERIMENTAL

The composite were prepared by dispersing heat-treated uncoated ceramic particles (average size 30...120 μ m) i.e., graphite (Gr 5%vol.), alumina (Al₂O₃ 5%vol.), silicon carbide (SiC 15%vol.) and titanium carbide (TiC 15%vol.) on the vortex of the aluminium alloy Al-12.5 Si-1.3 Cu-1.8 Ni-1.5 Mg, bal.Al) at 1073 K.

Argon purified gas were used to degas the melt after the dispersion of ceramic particles.

Cylindrical samples, 30 mm in diameter and 180 mm in length, were casted in iron and copper moulds from the molten composite.

Rapidly solidified composites were prepared by melt spinning unit which includes a rotating copper disc.

More complete description of composite preparation technique are given elsewhere [5].

The microstructure of cast composites were examined by optical and scanning electron microscopes. Keller's reagent were used for etching the samples. LECO Testing Machine (M4006 Hardness Tester). Using Vickers diamond pyramid indenter were used to measure the microhardness of the samples

RESULTS AND DISCUSSIONS

The presence of ceramic particles in aluminium melts affects the solidification microstructures compared to the basic alloy (Figs.1-3).

Experiments using various cooling rates show that primary cell size is slightly smaller in AlSi12CuNiMg composite compared with the basic alloy without any reinforcement (Tab.I).

The microstructure of rapidly solidified composites at casting in copper static mould and of melt spun-ribbon revealed that more fine dendrite or cells are achieved and this alloys fewer ceramic particulates to be segregated in the intercellular and interdendritic boundaries, thereby giving a more homogeneous particle distribution because of the reduced time the composite is in a molten state.

Rapidly solidified structures give therefore the best ceramic particles distribution due to finer dendrite size (see Figures 3 a,3 b).

It can be also inferred from the above results that dispersion of ceramic particles delays the extraction of heat from the matrix, due to lower thermal conductivity of the composite:

$$\lambda_{eff} = \frac{2\lambda_L + \lambda_P + 2\theta(\lambda_L - \lambda_P)}{2\lambda_L + \lambda_P + \theta(\lambda_L - \lambda_P)} \cdot \lambda_L$$

where θ is the volume fraction of particles.

The microhardness of the matrix of AlSi12CuNiMg/SiC, 15 % vol. composite, increasing of cooling rate (Fig.4).

Increasing of microhardness could be attributed to the morphological changes in the eutectic silicon particles of the matrix, at different cooling rates.

The calculated data of λ_{eff} are: for Gr = 108.2; SiC = 90.8; Al2O3 = 6.9; TiC = 96.9.

CONCLUSIONS

1.The presence of ceramic particles (i.e. Graphite, SiC, Al2O3, TiC) in aluminium melts affects the solidification microstructures compared with the base alloy.

2.Primary cell size is slightly smaller in AlSi12CuNiMg

15 % vol. ceramic particles composite compared with the base alloy without any reinforcement

3. Much finer dendrite or cells are achieved in samples cast in copper static mould and in rapidly solidified composite by melt spinning unit and this alloys fewer ceramic particles to be segregated in the intercellular and interdendritic boundaries.

4. Increasing in the microhardness of the samples with increasing in cooling rate could be attributed to the morphological changes into the eutectic silicon particles of the matrix.

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TABEL I. Cell size values of AlSi12CuNiMg/Cp composites

Mould	Average cell size, μm	
	AlSi12CuNiMg alloy	Composite
sand	80 - 120	72 - 105
iron	32 - 58	26 - 52
copper	20 - 26	8 - 20
melt-spinning	10 - 18	2 - 8

Fig.1. SEM of AlSi12CuNiMg alloy.

Fig.2. SEM of AlSi12CuNiMg / Gr cast in copper mould.

a)

b)

Fig.3 a,b.Rapidly solidified structures of AlSi12CuNiMg with TiC composite.

Fig.4. The Vickers microhardness of the matrix of AlSi12CuNiMg / SiCp, 15 % vol. composite