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MICROSTRUCTURE AND MECHANICAL PROPERTIES OF AL–Al_2O_3 MICRO AND NANO COMPOSITES FABRICATED BY A NOVEL STIR CASTING ROUTE

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ABSTRACT

In this study, in order to improve the wettability and distribution of reinforcement particles within the matrix, a novel three step mixing method including heat treatment of nano particles, injection of heat-treated particles within the melt by inert Argon gas and stirring the melt at different speed was introduced for addition of Al_2O_3 particles to the molten A356 aluminum alloy. The influence of various processing parameter such as the heat treatment of nanoparticles, injection process, stirring speed, reinforcement particle size and weight percentage of reinforcement particles from 1 to 10 wt.% on the microstructure and mechanical properties of composites were investigated. The results showed the poor incorporation of nano particles in the aluminum melt prepared by the common condition while the use of heat-treated particles, injection of particles and the stirring system were improved the wettability and distribution of the nano particles within the aluminum melt. Also, it was revealed that the amount of hardness and porosity increased as weight percentage of nano Al_2O_3 particles increased.

KEYWORDS: *Al-Al_2O_3 nanocomposite, Microstructure, Stir casting, Wettability and distribution*

INTRODUCTION

Aluminum matrix composites (AMCs) reinforced with nano-sized Al_2O_3 particles are an interested group of advanced materials widely used for high performance applications such as in automotive, military, aerospace and electricity industries because of their improved physical and mechanical properties such as their superior strength to weight ratio, good ductility, high strength and high modulus, low thermal expansion coefficient, excellent wear resistance, excellent corrosion resistance, high temperature creep resistance and better fatigue [1-5].

The production methods of these composites can be categorized into three types: solid state methods, semi-solid state methods and liquid state methods. Liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production and compared to other routes, has some important advantages, e.g., the wide selection of materials, better matrix–particle bonding, easier control of matrix structure, simple and inexpensive processing, flexibility and applicability to large quantity production and excellent productivity for near-net shaped components. However there are some problems associates with stir cast producing of AMCs. Poor wettability and heterogeneous distribution of the reinforcement material are two major problems in this method [6-9].

Wettability and distribution of reinforcement particles becomes more difficult when the particle size decreases to the nano scales. This is due to the increasing the surface area and surface energy of nano particles, caused an increasing tendency for agglomeration of reinforcement particles.

EXPERIMENTAL

A novel three-step mixing method for addition of Al_2O_3 particles to the molten aluminum was presented:

(i) Preheating of reinforcement particles at 1100 °C for 20 min in an inert atmosphere

(ii) Injection of heat-treated particles within the melt by inert argon gas

(iii) Stirring of the melt before and after incorporation of particles in the aluminum melt at different speed of 200, 300 and 450 rpm.

The influence of various processing parameter such as the heat treatment of nanoparticles, injection process, stirring speed, reinforcement particle size and weight percentage of reinforcement particles from 1 to 10 wt.% on the microstructure and mechanical properties of composites were investigated.

The matrix grain size, morphology and distribution of Al_2O_3 nanoparticles were recognized by scanning electron microscopy (SEM), optical microscope (OM) equipped with image analyzer, energy dispersive spectroscopy (EDS) and X-ray diffraction (XRD). The density of the samples was measured by the Archimedes's method. Also the hardness of samples was investigated.

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Table1: Grain Size and volume percent of Al_2O_3 particle on the surface of samples

Sample	Average Volume Percent of Al_2O_3 Particles* $AVP = \frac{\sum_1^n volume\ percent\ i}{n}$	Distribution Factor $DF(\%) = 100 - \frac{\lvert max(or\ min)VP - AVP \rvert \times 100}{AVP}$	Wettability Factor $WF(\%) = 100 - \frac{(VP\ of\ injected\ Al2O3\ particles - AVP) \times 100}{VP\ of\ injected\ Al2O3\ particles}$	Grain size (µm)
S5m.p1	0.53	23	10.75	500
S5m.p2	0.87	69	21.22	100
S5m.p3	3.35	64	81.70	83
S5m.p4	3.56	85	86.82	75
S5m	3.29	93	80.24	55
S5m.p6	2.94	93	71.71	48
S1m	0.82	89	100	52
S3m	2.34	89	88	58
S10m	6.18	92	75.36	71

RESULTS AND DISCUSSIONS

For studying the effects of each process on distribution and wettability of reinforcement particles in the cast composite samples, a quantitatively analysis was applied. The results (table 1) showed the poor incorporation and heterogeneous distribution of nano particles in the aluminum melt prepared by the common condition, while particle heat treatment and injection of the particles within the melt by inert gas help the particulate reinforcements to wet better in the molten matrix and the stirring process has the important effect on improving the reinforcement distribution. Distribution of particles in the different composite samples is uniform and the best distributions of reinforcements in composites microstructure has been found at stirring speed of 300 rpm. Also Wettability of particles within the molten matrix had been decreased by increasing the reinforcement percentage and decreasing the reinforcement size. It has been found that the three step mixing method has only the ability to fabricate samples up to 5 wt.% of micron sized and 3 wt.% of nano sized Al_2O_3 reinforcement successfully.

Fig 1 shows the microstructure of composite samples containing 3 weight percent of nano sized Al_2O_3 particles fabricated with optimized condition. Microstructure of these composites containing the primary a-Al dendrites and eutectic silicon, While Al_2O_3 particles were segregated at inter-dendrites regions and in the eutectic silicon. Also another intermetallic compounds such as Mg2Si, FeSiAl5and Al4C3 were observed at the eutectic phase.

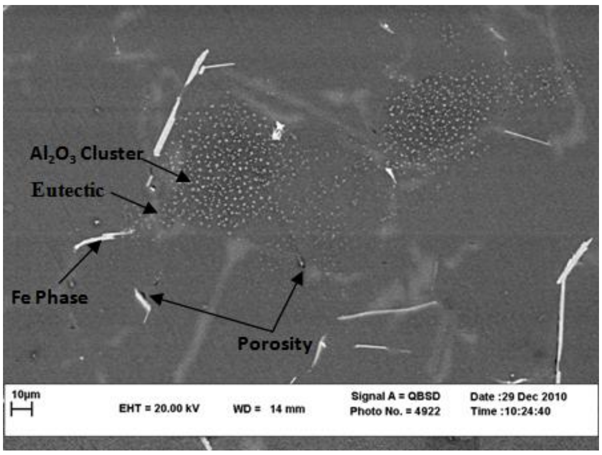

Figure1: SEM images of Al-3% Al_2O_3 nanocomposite

Also it was revealed that the amount of hardness and porosity of composite samples increased with increasing the weight percentage of Al_2O_3 particles and decreasing the particle size.

CONCLUSION

The results showed the poor incorporation of nano particles in the aluminum melt prepared by the common condition while the use of heat-treated particles, injection of particles and the stirring system were improved the wettability and distribution of the nano particles within the aluminum melt. Also, it was revealed that the amount of hardness and porosity increased as weight percentage of nano Al_2O_3 particles increased.

REFERENCES

[1] M K SURAPPA, Sadhana Vol. 28, Parts 1 & 2, February/April 2003, pp. 319–334.

[2] H. Mahboob, S. A. Sajjadi and S. M. Zebarjad, Powder Metallurgy (2009)

[3] M. Kok, Journal of Materials Processing Technology 161 (2005) 381–387

[4] A. Mazaherya, H. Abdizadeha, H.R. Baharvand, Materials Science and Engineering A 518 (2009) 61–64

[5] S.M. Zebarjad, S.A. Sajjadi, Materials and Design 28 (2007) 2113–2120

[6] Y. Tsunekawaa, H. Suzukib, Y. Genma, Materials and Design 22 (2001), 467_472

[7] JASMI HASHIM, Jurnal Teknologi, 35(A) Dis. 2001: 9–20

[8] Manoj Singla, D. Deepak Dwivedi, Lakhvir Singh, Vikas Chawla, Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009

[9] J. Hashim, L. Looney, M.S.J. Hashmi, Journal of Materials Processing Technology 92-93 (1999)