Mechanical Stir Casting For the Fabrication and Characterization of Metal Matrix Composite

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ABSTRACT

Manufacturing of composite is one of the prominent and economical routes for development and processing of metal matrix composite materials. Composite is a multiphase material that exhibits a significant proportion of the properties of both constituting phase such that a better combination of properties is realized. The composite industry has one of the most difficulties in casting of metal matrix composites is Non-homogeneous reinforcement distribution. Properties of metal Matrix composites are advanced which are not achieved by conventional materials. These properties comprise increased strength, higher elastic modulus, higher service temperature, increase wear resistance, decreased part weight, low thermal shock, high electrical and thermal conductivity, and low coefficient of thermal expansion. In the current study, simulations were conducted for uniform reinforcement distribution for mechanical stir casting. In simulation of mechanical stir casting, B_4C particles used in aluminum metal matrix composites. Scaled-up stirring experiments were carried out in graphite crucible with the various reinforcement percentages.

Key Words:* *Mechanical Stir Casting, Simulation, Metal Matrix Composite, Reinforcement

1. INTRODUCTION

Aluminum matrix composites containing discontinuous reinforcements have begun to develop appreciably considering the recent industrial development in aviation and transportation industries. Particulate reinforced boron matrix composites (PRBCs) have many advantages over monolithic Mg alloys, such as high specific strength and stiffness, high elastic modulus, enhanced creep and wear resistances. PRBCs is very attractive to aerospace, defense and automobile industries, but its applications are severely restricted by its low ductility and fracture toughness, which justifies the study on the failure behavior of PRBCs [1]. In recent decades, new focuses in the research field of structural composites is the discontinuously reinforced aluminum alloy matrix composites. MMCs have been manufactured by various techniques such as powder metallurgy, spray deposition and several casting methods such as recasting, squeeze-casting, stir-casting and compocasting, but there exist some challenges in manufacturing the discontinuously reinforced MMCs. One of the main problems lies in the thermodynamic instability of reinforcing ceramic phases with the matrix [2]. Most of the previous studies carried out on processing of aluminium composites have utilized only larger size particles of greater than 50 lm average particle size (APS). On the other hand, incorporation of fine particles by liquid metal stir casting leads to poor distribution and agglomeration. Hence, this investigation attempts to synthesis Al–fly ash composites using fine particles of size 13 lm APS by three different routes namely liquid metal stir casting, compocasting and modified compocasting for arriving at the best synthesizing route [3]. Metal matrix composites (MMCs) are advanced materials providing properties which cannot be achieved by conventional materials such as light weight, high specific strength, high specific modulus, low coefficient of thermal expansion and good wear resistance. Among the manufacturing processes for discontinuous MMCs, stir casting and compocasting are widely used for their simplicity and low cost. However, if the process parameters are not adequately controlled, the composite shows a non- homogeneous particle distribution and then a reduction of the mechanical properties. Considerable interest is currently devoted to the study of the effects of mechanical working on MMCs and it has been shown that some improvements in strength and ductility can be observed with the application to particulate reinforced aluminium composites of plastic deformation processes, such as extrusion, rolling and forging. The ability to achieve a near net shape structural component by conventional deformation processes, which cannot be applied to ceramic and polymer matrix composites, also reduces the problems related to the secondary manufacturing processes, such as cutting, machining and joining, making their application more attractive also from an economic point of view [4-6].

There are several fabrication techniques available to manufacture MMC materials. Among the variety of manufacturing processes available for discontinuous MMC production, stir casting is generally accepted, and currently practiced commercially. Stir casting of MMCs generally involves producing a melt of the selected matrix material, followed by the introduction of a reinforcing material into the melt and obtaining a suitable dispersion through stirring [7]. The continuous evaluation of emerging trends and stimuli to introduce novel materials to meet the requirements of various strategic application leads to development of functionally gradient materials and composites. In recent years, composite materials have been used for structural and non-structural applications in aeronautical and transport industries, due to their enhanced mechanical and thermo physical properties [8]. Tape casting is a low cost process for making high quality laminated materials for which an adequate thickness control and good surface finish are required. This is one of the most widely used techniques for producing thin ceramic sheets. In this process, a well-mixed slurry consisting of a suspension of ceramic particles along with other additives, such as dispersants to assure the stabilisation, and binders and plasticizers to confer adequate strength and flexibility to the tape [9]. Thixoforming is an attractive technology which combines the near-net-shape capabilities of die casting with the mechanical properties of forging. Besides, thixoformed parts are reported to be substantially higher in quality than die castings but lower in cost than forgings. Thixoforming uses semisolid slurries with globular solid particles uniformly suspended in a liquid matrix, which can be handled as a solid when at rest and flow like a liquid when sheared during the forming operation. Among several methods developed to produce such feedstock, magneto hydrodynamic (MHD) stirring, which involves the shearing of a solidifying liquid alloy in a conventional continuous DC caster with a rotating electromagnetic field, is the most popular [10].

II MATERIALS AND METHODS

2.1 Matrix Material

Alloy AA356.0 has good machinability by using sharp, carbide-tipped (or better) tools with high raked and clearances abrasiveness can be overcome and high tool wear can be minimized. Moderate to fast speeds are recommended. Electroplated finishes are very good. Chemical conversion coatings give very good protection, but anodized appearance is only fair. Mechanical finishes on AA356.0 are good. All common welding method are excellent for joining this alloy. Brazing is not performed. This alloy has very good resistance to most common forms of corrosion.

2.2 Reinforcement material

“Boron Carbide Semiconductors & Electronics” has emerged as a prominent field with respect to technology due to its exceptional advantages over conventional “Boron-based Semiconductors & Electronics”. BCs material improves the efficiency of a semiconductor device by more than 20% and also facilitates production and usage of devices with much smaller form factor. Advanced features of Boron carbide useful for semiconductors are inherent radiation- resistance, high-temperature operating capacity, high voltage and power handling capacity, high power efficiency and flexibility to be used a substrate. Use of BCs in specifically the industrial, power, solar & wind sector (for power applications) also enables smaller heat sink, passive, and magnetic nature in system designs. BCs electronics also find applications in electric vehicles and hybrid electric vehicles, rail transportation, power supply units, photovoltaic applications, converters & inverters, and many more. Over the next ten years, Boron Carbide will become a part of mass manufacturing in the Semiconductors & Electronics industry. The other major sectors (other than power semiconductors) where BCs has scope in the semiconductor industry are opto-semiconductors (LEDs, Laser Diodes and Lighting) and high-temperature semiconductors (extreme temperature & rad-hard environment specific).

Boron Carbide (BCs) has become the choice for most of the next generation power semiconductor devices and high-temperature semiconductor devices and is quickly replacing the existing Boron technology. The various properties of Boron carbide such as wider band gap, larger critical electric field, and higher thermal conductivity let the BCs devices operate at higher temperatures and higher voltages offering higher power density and higher current density than the pure Si devices. These properties allow the BCs discretes such as Schottky diodes, MOSFETs, and the other advanced transistors to operate at much higher voltage levels, which are difficult for the counterpart Si devices. The BCs devices also help in reducing the conduction and switching losses, thereby offering higher efficiency in electronic systems.

2.3 Experimental procedure

For AA356/BCs metal matrix composite development pure AA356 alloy ingot and BCs average particles size 50 µm were mixed. The A A356 alloy ingot was melted in a graphite crucible. The required quantities of BCs particles were added in weight percent. The ceramics particles were mixed in a designed mixer by stirring for 5 minutes. The casting temperature was maintained at 700 degree centigrade. Schematic diagram of electromagnetic stir casting is given in Figure 1.

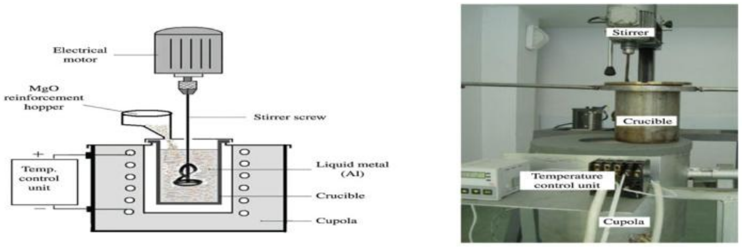

Figure 1: Schematic diagram of mechanical stir casting route

III RESULTS AND DISCUSSION

Stirrer speeds as a slightly larger than 1/50 s were essential to imprison the flow pattern in the stirring speed range investigated. Faster stirrer speeds up to 1/1200 s did not affect captured image quality. Aperture control with automatic shutter speed settings did not produce good photographs due to the low shutter speeds recorded for the aperture range investigated (<1/60 s). Integral camera flash, with a white background to the Pyrex beaker, proved the best lighting solution. With this setup internal flow pattern were captured in 0.1% BCs fluids and external flow of the fluid could be observed in the 5% BCs fluid mixtures. At 50 rpm no dispersion of the particles occurred irrespective of blade angle or fluid. Uniform particulate dispersion times for a 5% BCs water mixture, for different stirring speeds above 50 rpm. It is observed that at 100 rpm and with 0 and 30◦ blade angles no uniform dispersion resulted, but with 45 and 60◦ blade angles there was full particulate dispersion. It is further observed for all stirring speeds that dispersion rates increase with increasing blade angle. Uniform particulate dispersion times for a 5% BCs glycerol/water mix (with 300mPa s viscosity), for the different stirring speeds results at 200, 250 and 300 rpm the range of dispersion time for three-, four- and turbine-bladed stirrers are 1920– 2700, 1680– 1980 and 900– 1320 s, respectively. Though therewas a tendency for reduced dispersion time with higher blade angle, it was found that for most cases the 60◦ angle produced the lowest dispersion times. The turbine stirrer again produced the lowest dispersion time.

Very similar results were observed for the higher viscosity (500, 800 and 1000mPas) glycerol/water mixtures tested. Uniform dispersion times for 10% BCs particles in glycerol/ water solution for different stirrer types and heights, H. Due to high vortex formation in water at higher stirring speeds and the lack of dispersion in the glycerol/water mixture at lower speeds, a stirring speed of 150 rpm was used in water and 200 rpm in the glycerol/water Mixture. In all cases, particulate settling times measured were independent of stirrer types and stirring speed. Approximately 90% of all particles settled within 60 s in water and complete settling was recorded after 180 s. The time at which particulate settling occurred in the glycerol/water mixtures was evident from the emergence a clear layer, absent of BCs particles, at the top of the mixture. It is clearly evident that at higher stirring speed in water the vortex height increases. Much greater vortex height is also observed in the water mixtures compared with the glycerol/ water mixtures. No vortex was present in glycerol/water mixtures for stirring speeds below 200 rpm. Air entrapment was also observed in all fluids at speeds above 300 rpm, though this was surprisingly more evident in the higher viscosity fluids.

IV CONCLUSIONS

Superior blade angles and minor viscosity outcome in reduce particulate dispersion time. A smallest amount stirring speed of 100 rpm is required for uniform spreading to happen.

REFERENCES

1. X.J. Wang, K. Wu, W.X. Huang, H.F. Zhang, M.Y. Zheng, D.L. Peng, “Study on fracture behavior of particulate reinforced boron matrix composite using in situ SEM” Composites Science and Technology 67 (2007) 2253–2260.
2. M. Emamy , M. Mahta, J. Rasizadeh, “Formation of TiB2 particles during dissolution of TiAl3 in Al–TiB2 metal matrix composite using an in situ technique” Composites Science and Technology 66 (2006) 1063–1066.
3. T.P.D. Rajan, R.M. Pillai a, B.C. Pai a, K.G. Satyanarayana b, P.K. Rohatgi, “Fabrication and characterisation of Al–7Si–0.35Mg/fly ash metal matrix composites processed by different stir casting routes” Composites Science and Technology 67 (2007) 3369–3377.
4. L. Ceschini a,*, G. Minak b, A. Morri, “Forging of the AA2618/20 vol.% Al2O3p composite: Effects on microstructure and tensile properties” Composites Science and Technology 69 (2009) 1783– 1789.
5. Hou shuping, Zhao Weimin, "Progress in the micro modelling of the casting solidification process" Journal of Materials Processing Technology 123 (2002) 361-370.
6. S. Naher, D. Brabazon, L. Looney, “Simulation of the stir casting process” Journal of Materials Processing Technology 143–144 (2003) 567–571.
7. S. Naher, D. Brabazon, L. Looney, “Development and assessment of a new quick quench stir caster design for the production of metal matrix composites” Journal of Materials Processing Technology 166 (2004) 430–439.
8. S. Balasivanandha Prabu, L. Karunamoorthy, S. Kathiresan, B. Mohan, “ Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite” Journal of Materials Processing Technology 171 (2006) 268– 273.
9. S.M. Olhero, J.M.F. Ferreira, “Rheological characterisation of water-based AlN slurries for the tape casting process” Journal of Materials Processing Technology 169 (2005) 206– 213.
10. Yucel Birol, “ A357 thixoforming feedstock produced by cooling slope casting” Journal of Materials Processing Technology 186 (2007) 94– 101.