International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869, Volume-1, Issue-9, November 2013

# Use of Modified Stir Casting Technique to Produce Metal Matrix Composites

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*Abstract*— **Metal Matrix Composites (MMCs) are highly attractive for large range of hi-tech engineering applications because of their useful properties. However the methods used to produce these composites are constantly evolving particularly in getting rid of non-uniform distribution of the reinforcement. Stir casting is the most commonly used method for production of particulate reinforced cast metal matrix composites. A recently developed modification of stir casting has been used in the present investigation to produce aluminum-magnesium matrix composites reinforced with silicon carbide. The tensile properties of the resulting composites are measured. The improvements in the tensile properties are appreciable. The matrix alloy was also prepared using the same plunger technique. Here the usual solid shaft stirrer is replaced by a hollow spindle stirring mechanism through the additions of particulate silicon carbide and magnesium turnings were introduced in small cylindrical capsules. In the present work the XRD was used to detect the presence of SiC. Tensile strength of the prepared composite materials are much higher than the matrix showing the effectiveness of the Modified stir casting technique.**

*Index Terms*— **AMMC-Aluminum Metal Matrix Composites; Stir Casting; Hollow Shaft.**

## I. Introduction

Particle reinforced metal matrix composites (MMCs) are now recognized as important structural materials for application in aerospace and automotive parts. The reinforcement of light weight aluminum alloys with short fibers, platelets and particle of ceramics such as silicon carbide or alumina results in composite of high specific strength and stiffness suitable for engineering applications like aerospace and automotive [1-9]. There are several routes by which the reinforcement may be introduced in the matrix. The plunger technique is an effective method for preparation of light weight MMC [10, 11]. The microstructure and property of resulting composite material depends on production method, type and amount of reinforcing particulates. In order to get desirable properties in composites, factors such as nature and choice of the metal matrix, the kind of dispersed particulates making the composite and the technique involved in the composite production, are important and must be standardized [2,3,15-17].

Most convenient metal matrices used are of light weight metals like aluminum, magnesium and their alloys. Generally ceramic materials with moderate to high strength and high modulus are used as reinforcement particles. Most widely used particulate reinforcements are SiC, $Al_2O_3$, fly ash, $TiB_2$, and $B_4C_3$ [1, 2, and 9]. Though varieties of other materials have also been tried during the past years, **SiC** is easily available and economic**.** The processing technique for preparation of MMC includes solid state processing and liquid metal processing. Of the two liquid metal processing involve various types of solid particulate incorporation methods such as pressure infiltration, centrifugal casting, ultrasonic infiltration, spray casting and stir casting processes [1-3].

Good wetting between solid ceramic particles and liquid matrix metal is essential to get uniform dispersion and satisfactory properties in MMC. Alloying elements such as magnesium, lithium, calcium or zirconium are added for inducing wettability [1, 12-14]. Magnesium in addition to improving the wettability also increases the strength by solution strengthening aluminum matrix metal matrix composites AMMC [1-4].

## II. Experimental Procedure

### A. Setup

A common basic laboratory model stir casting apparatus was improved upon to suit the present work. The usual impeller solid shaft was substituted by hollow mild steel tube as the spindle. The basic arrangements of a laboratory scale stir casting apparatus with assembly modifications which has been used to prepare the aluminum metal matrix composites (AMMC) is described elsewhere[10, 11].

The Modified Stir Casting Technique is a unique method adopted for introducing the hard ceramic particles into the matrix melt. Capsule containing ceramic particulate is pushed inside melt directly by a plunger rod. The plunger (steel rod) as shown in ***Fig.1***, containing ceramic ***(SiC)*** particles or magnesium as the case may be wrapped with Al foil, in capsules made of perforated mild steel tube, is introduced to a depth of the melt through the rotating hollow spindle. The Al foil wrapping melts in the super heated Al-melt in less than 30 seconds and the contents (magnesium turnings or the ***SiC*** particles) are set free into the melt and get dissolved/dispersed almost uniformly in the melt due to vigorous stirring effect of the rotating spindle. The liquid aluminum enters into the capsule melting the aluminum wrapping dissolving magnesium turnings instantly improving the magnesium recovery. As the silicon carbide particles are charged immediately after the magnesium the dispersion of the

Manuscript received Nov. 17, 2013.

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particles inside the melt is more effective. It may be mentioned that influence of magnesium on wettability fades away with time. The melt was then poured into graphite molds to get plate shaped castings.

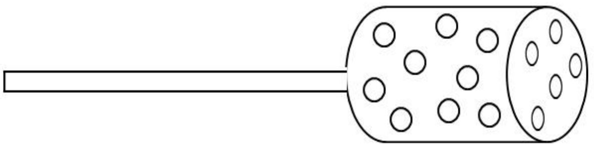

Fig 1: Perforated steel capsule welded to plunger rod

*B. Materials:*

The Al-Mg alloy and Al-Mg-SiC MMC was prepared from commercially pure Al supplied by NALCO, India in the form of 20 kg ingot. Chemical composition of the Aluminum used is given in Table 1.

**Table-1 Chemical composition of Aluminum ingot used.**

| Al | Si | Fe | V | Mn | Cu |
|---|---|---|---|---|---|
| 99.76 | 0.08 | 0.15 | 0.006 | 0.003 | 0.001 |

Magnesium metal turning was used for preparation of Al-Mg alloy. The composition Mg turning is given in Table-2.

**Table- 2 Chemical composition of Magnesium turning used for alloying.**

| Mg | Al | cu | Fe | Pb | Mn | Ni | Si | Zn |
|---|---|---|---|---|---|---|---|---|
| 99.68 | 0.05 | 0.005 | 0.05 | 0.005 | 0.1 | 0.005 | 0.1 | 0.005 |

Silicon Carbide particles of 600 mesh size were collected for MMC preparation. The Composition of SiC particles is given in Table-3.

**Table- 3 Chemical composition of Silicon Carbide particles used for MMC preparation.**

| SiC | $SiO_2$ | Si | Fe | Al | C |
|---|---|---|---|---|---|
| 98,8 | 0.41 | 0.3 | 0.09 | O.1 | 0.3 |

*C. Procedure:*

Aluminum were cut from Al-ingot and was melted in a cast iron cylindrical crucible (coated with alumina cement) in a pit furnace with resistance heating. The furnace temperature was maintained at $800^0$C (well above melting temp $660^0$C of aluminum). Then the capsule / bullet charged with pieces of Mg-chips or Silicon carbide particulates as the case may be were added to the Al melt [5, 6]. The mixer was turned on and set to the predetermined speed of 500 r.p.m [15, 18]. The process was completely safe and smooth. It can be used effectively to make alloy addition of low density and highly volatile/ inflammable elements with minimum loss and high safety [10, 11].

Then previously prepared silicon carbide particulate (10 wt %) bullet charges were introduced one after the other into the Al-Mg alloy melt. Then crucible was lifted and the melt was poured into previously readied mould made of fire bricks joined by fire clay. The mould size was (18×8×5) $cm^3$. The samples for XRD analysis and tensile test were prepared from ingot of MMC (Al-3%Mg-10%SiC).

## III. Results and Discussion

*A. XRD Analysis*

XRD of prepared MMC was conducted by the machine

Name: X'Pert
Company: PAN alytical
Product no-PW3040/00
Scanning Range – $25^0$-$85^0$
voltage-30KV
Current-20milli amp

X ray diffraction analysis (fig 2) shows the presence of aluminium, MgO and $MgAl_2O_4$. It shows that some magnesium gets oxidized leading to the formation of MgO and spinel. Both of these are used as reinforcement in aluminium matrix composites [19, 20]. Fig 3 shows the microstructure of the composite specimen. It shows a uniform distribution of the SiC reinforcement.

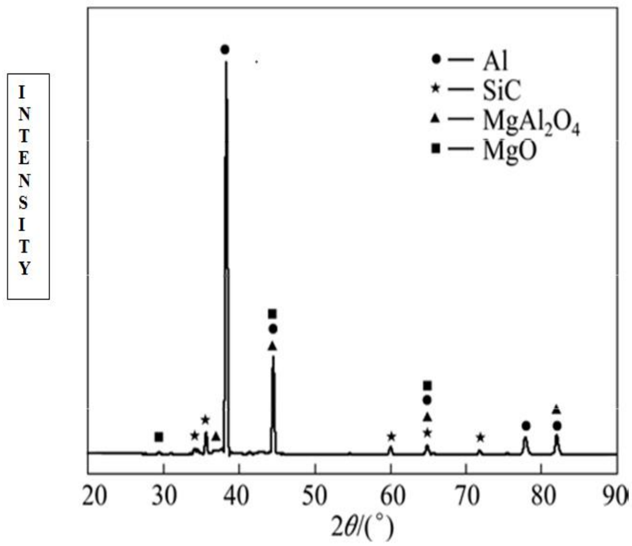


Fig 2: XRD pattern of Al-3%Mg-10%SiC MMC

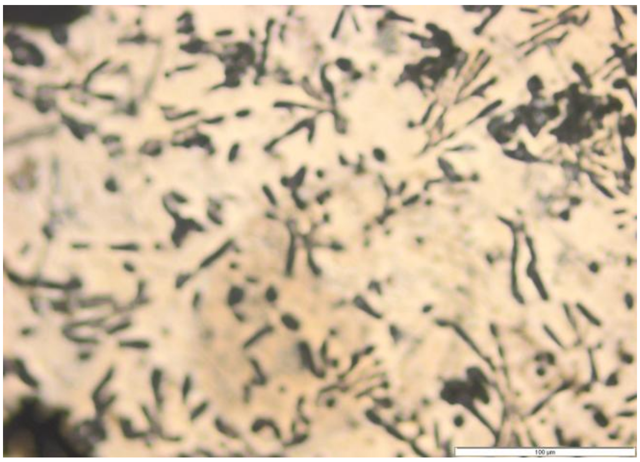

Fig 3: Microstructure of MMC

### *B. Tensile test*

Tensile test samples were collected as per ASTM-E8M Standard (fig 3) for Al-3%Mg alloy and Al-3%Mg-10%SiC MMC .The tensile test was conducted using an Instron 8801 as per procedure IS-1608 with strain rate 0.5 mm/min .The results are tabulated in Table-4[18]. Yield Strength, UTS and elastic modulus increased by 49%, 31% and 24% respectively as compared to matrix material. The % of elongation of MMC was decreased by 68% but still showing appreciable value of 6%. The yield strength and UTS are comparable to properties of cast composites of similar composition as reported by Alman (ref 21) .

However the ductility is much higher. This is probably due to the finer grain size, obtained by the oxides present as detected by the x-ray diffraction studies. Such refinement is observed by Panigrahi and Banerjee (ref 22) and Bansal et al (ref 23).Sarkar and Panigrahi (Ref 24) have also reported increased ductility in composites and attributed this to finer grains.

**Table 4** Mechanical properties of Al-3%Mg alloys and Al-3%Mg-10%SiC MMC

| Material | Yield Strength (MPa) | Tensile Strength(MPa) | Elastic Modulus(GPa) | % of Elongation |
|---|---|---|---|---|
| Al-3%Mg | 91 | 224 | 62 | 21.25 |
| Al-3%Mg-10%SiC | 136 | 293 | 77 | 6.7 |

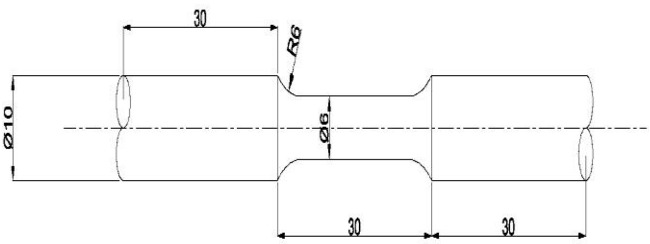


**Fig 4: Tensile test specimen for alloy and MMC**
(All dimensions are in mm)

## IV. Conclusion

The modified stir casting process can address some of the problems of producing cast metal matrix composites. The method is suitable for eliminating the fading effect of inoculation and simultaneous addition of alloying element and reinforcement. Yield Strength, UTS and elastic modulus increased by 49%,31% and 24% respectively as compared to matrix material. The % of elongation of MMC was decreased by 68% but still showing appreciable value of 3.7%. Higher ductility is possibly due to the finer grains made possible by the presence of oxides. The process can be easily adopted for production in industrial scale.

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