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# Preparation of 7075Al-Al4C3 MMC's by Stir Casting and Evaluation of Mechanical and Wear Properties

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***Abstract:*** *Aluminum MMCs are preferred to other conventional materials in the fields of aerospace, automotive and marine applications owing to their improved properties like high strength to weight ratio, good wear resistance etc. In the present work an attempt has been made to synthesize metal matrix composite using 7075Al as matrix material reinforced with ceramic Al4C3 particulates using liquid metallurgy route in particular stir casting technique. The addition level of reinforcement is being varied from 2 - 10wt% in steps of 2wt%. For each composite, reinforcement particles were preheated to a temperature of $200^0$C and then dispersed in steps of two into the vortex of molten Al7075 alloy to improve wettability and distribution. Microstructural characterization was carried out for the above prepared composites by taking specimens from central portion of the casting to ensure homogeneous distribution of particles. Hardness and tensile properties of the prepared composite were determined before and after addition of Al4C3 particulates to note the extent of improvement. Microstructural characterization of the composites has revealed fairly uniform distribution and some amount of grain refinement in the specimens. Further, the hardness and tensile properties are higher in case of composites when compared to unreinforced 7075Al matrix, also increasing addition level of reinforcement has resulted in further increase in both hardness and tensile strength.*
***Keywords:*** *MMC's, Al4C3 particulates, 7075Al, stir-casting*

## I. Introduction

Now a day the modern automotive and aerospace industries are looking towards light weighted and high strength materials to increase their overall efficiency. As in present scenario the Aluminum metal matrix composites will secure the requirements of such industries, due to their low weight, high strength, thermal resistant, and corrosion resistance properties.[1-2].Aluminum alloy 7075 possesses very high strength, higher toughness and are preferred in aerospace and automobile sector [3].

The literature survey regarding the above alloy systems and their composites are as follows. [4]Investigated the mechanical properties like hardness and tensile strength and the wear resistance properties of Al6061/Sic andAl7075/Al2O3 composites prepared by using the liquid metallurgy technique. Reinforcement of the Sic and Al2O3 resulted in improving the hardness and density of their respective composites. Y. Reda et. al. [5] and R. Clark et. al. [6], in their studies on Al7075 reported that, pre-aging at various retrogression temperatures improves the hardness, tensile properties and electrical resistivity. The literature reveals that the little research is done on the mechanicalbehavior and wear behavior of Al4C3 reinforced aluminummetal matrix composites.

Hence, the present research is focused on experimental investigation to study the wear behavior and mechanical behavior of Al7075/ Al4C3AMMCs.

## II. Experimental Details

The aluminum alloys Al7075 are used as the matrix metal for the fabrication of the composites that has been reinforced with 2 wt. %, 4 wt. %, 6wt. %, 8 wt. % and 10 wt. %of Al4C3 of average 45 μm size. The chemical composition, mechanical and thermo physical properties of the matrix material (Al7075) and reinforcement material (Al4C3) are given in Tables 1 and 2. The composite was fabricated by the stir casting technique. The melting was carried in a stir casting furnace in a range of 750±200C. A schematic view of the stir casting set up and metallic mold is shown in Fig.1. The melt has mechanically stirred by using a graphite stirrer with motor, during this the pre-heated aluminum carbide particles (about $800^0$C to make their surfaces oxidized) and 1% of magnesium as a wetting agent (to reduce the surface tension of aluminum and to increase the wetting property between matrix and reinforcement material) were added gradually into the molten metal. The stirring process is carried out at a temperature of $750^0$C with a stirring speed 600 rpm and time of 10min. One K-type thermocouple has inserted into the graphite crucible to measure the temperature variation of the molten metal. Finally, the mechanical properties Al7075/ Al4C3 composites are compared with the unreinforced Al7075 matrix alloys. The micro structural characteristics, tensile strength, hardness and wear behavior of the composites are evaluated.

**Figure.1** Experimental Setup

**Table1.** Chemical Composition of Al7075 by Weight percentage

| Elements | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Al |
|---|---|---|---|---|---|---|---|---|---|
| Al7075 | 0.4 | 0.5 | 1.6 | 0.3 | 2.5 | 0.15 | 5.5 | 0.2 | Balance |

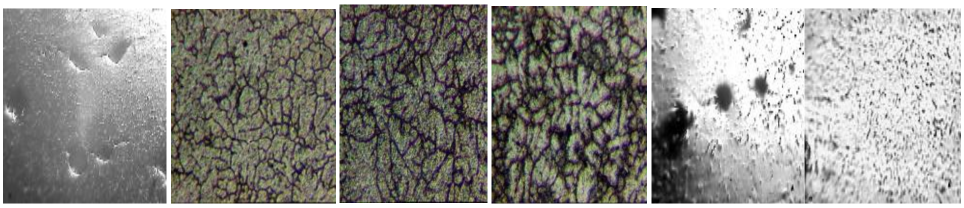
**Table2.** Mechanical and thermo physical properties of Al7075 and Al4C3

| **Properties** | **Al7075** | **Al4C3** |
|---|---|---|
| Elastic Modulus (Gpa) | 70-80 | - |
| Density (g/cc) | 2.81 | 2.36 |
| Poisson's Ratio | 0.33 | - |
| Hardness (HB500) | 60 | - |
| Tensile strength(T)/Compressive Strength (c) (Mpa) | 220(T) | - |
| Liquids temperature ($^0$C) | | 2100$^0$C |

## III. Results And Discussion

### 3.1 Microstructural studies

The mechanical properties and wear properties of AMMCs are majorly influenced by the type of reinforcing particles and its distribution. It is necessary to distribute particles uniformly throughout the AMMC casting. The variable that directs the distribution of particles are solidification rate, fluidity, type of reinforcement and the method of casting process. The microstructures of the samples, cut from the casting at different locations are observed using optical microscope to study the particle distribution. The obtained optical micrograph (Fig.2) shows the uniform distribution of reinforcing particles. The particle distribution strongly influences the physical and mechanical properties of the composites.



0%Al4C3 2%Al4C3 4%Al4C3 6%Al4C3 8%Al4C3 10%Al4C3

**Figure.2** Optical micrographs of Al7075 with 0 - 10% Al2O3

### 3.2 Hardness measurements

Hardness is one of the important mechanical properties in case of composite material as the hardness of matrix metal is very low, which limits its wide application. The hardness of matrix metal enhances due to reinforcement of Al4C3 particles with it. Hardness test has conducted on each AMMC specimen using ASTM E10-12 standards. These experimental values are compared with theoretical values of hardness obtained by the Eq.1 and shown in Table.3.

$$\text{BHN} = \frac{2F}{\pi D\,(D-\sqrt{D2-d2})} \qquad (1)$$

Where, F is load, D is ball diameter and d is hole diameter. From Table 3 and Fig. 3, the hardness value increases with the increase of weight percentage of Al4C3 particles. The maximum hardness value obtained at 10 wt. % of Al4C3.

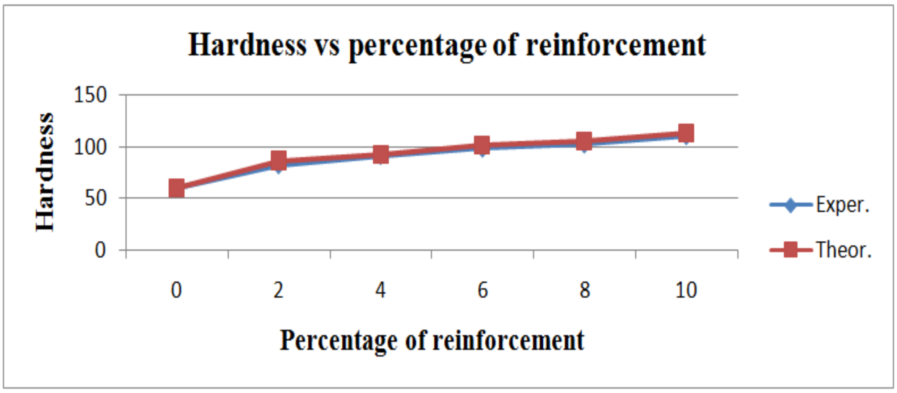



**Fig.3**Hardness vs. percentage of reinforcement

### 3.3 Tensile Strength

Theoretical values of tensile strength are obtained by Rule of Mixture (Eq.2) and experimental values are obtained by conducting experiments using the computer interfaced universal testing machine on AMMC samples which are machined as per ASTM D 3039-76 specifications (Fig.4). From the Table 3and Fig.5 the experimental result shows that the tensile strength of the produced AMMCs is somewhat higher than that of the non-reinforcedAluminum alloys. It can be noted that the addition of aluminum carbide particles (Al4C3) enhanced the tensile strength of the composites. It is apparent that an increase in the weight percentage of aluminum carbide particle results in an increase in the tensile strength. The tensile strength of Al 7075 in non-reinforced condition is 220Mpa and this value increases to a maximum of 229.92.1 Mpa for Al 7075/Al4C3/10 wt. %.

$\sigma_c = \sigma_f v_f + \sigma_m v_m$ (2)

Where $\sigma_C$, $\sigma_f$ and $\sigma_m$ are the tensile strength of composite, reinforcement and matrix materials and $V_f$ and $V_m$ are volume fractions of reinforcement and matrix materials.

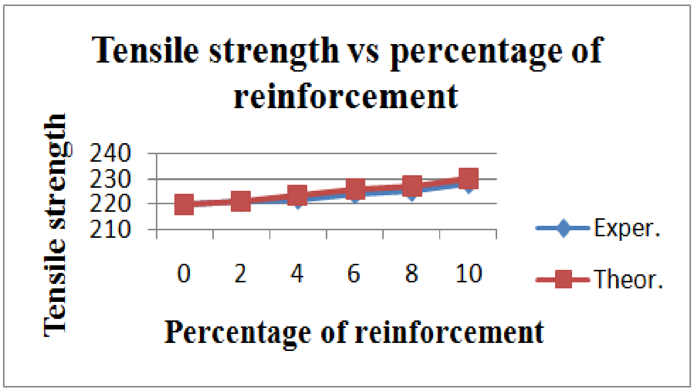



**Fig.4**Tensile tested specimensFig.5 Experimental and theoretical tensile strengthAl7075-Al4C3of Al7075-Al4C3

### 3.4 Wear properties

The dry sliding wear tests were performed on contech-POD-WTM01made pin-on-disc apparatus. Pin-on-disc apparatus is shown in Fig.6 wear tests samples were made of size ϕ10×10mm square pin. The test surface was polished on different grades of abrasive paper to ensure the proper contact with cast iron disc. Each specimen is then weighed using a digital balance having an accuracy of ±0.0001 gm. After that the specimen is mounted on the pin holder of the tribometer ready for wear test. Sliding wear tests were conducted track diameter 80 mm, load 3kg (29.43N), and time 600 sec (10 min) with varying r. p. m 1000, 1500 and 2000 in Fig.8The sliding wear loss was measured. Weight loss of pins was converted into volume loss using density of specimens. The wear rate and wear factor was calculate as

$$\text{Wear rate} = \frac{Vw}{(\pi \times dt \times N \times T)} \quad (3)$$

Where $V_w$ is wear volume, dt is track diameter, N is disc speed, T is time.

$$\text{Wear factor} = \frac{Vw}{FVT} \quad (4)$$

Where $V_w$ is wear volume, V is rubbing velocity and T is time.


**Fig.6** pin-on-disc apparatus **Fig.7** pins for wear test

Fig.Shows pins as the specimens for wear test (1-Al7075, 2-Al7075+2%Al4C3, 3-Al7075+4%Al4C3, 4-Al7075+6%Al4C3, 5- Al7075+8%Al4C3, 6- Al7075+10%Al4C3).

### 3.4.1 Effect of rpm on wear rate

From Fig.3 (a) it is clear that wear rate increases with increase of r. p. m, in sample 1. However, in sample 2,3,4,5 and 6 wear rate decrease with increase of r. p. m (Up to 2000). The addition level wt% of composite material particle size limit based on the wear rate was increase or decrease with increase of r. p. m.

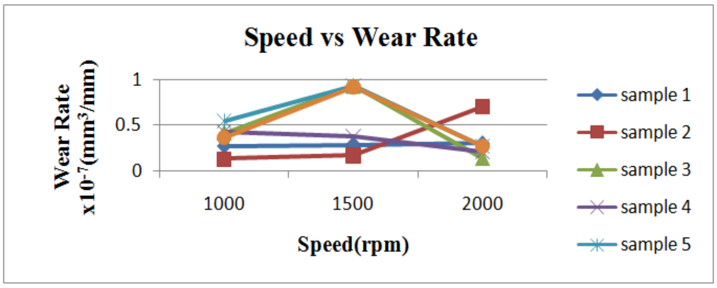



**Fig.8**Effect of rpm on (a) wear rate (b) wear factor

**Table3.** Mechanical properties of Al7075/Al4C3 composites

| Properties | | Al7075 | Al7075/ Al4C3/2p | Al7075/ Al4C3/4p | Al7075/ Al4C3/6p | Al7075/ Al4C3/8p | Al7075/ Al4C3/10p |
|---|---|---|---|---|---|---|---|
| Hardness | Experimental | 60 | 82 | 91 | 98 | 102 | 110 |
| | Theoretical | | 86.43 | 92.66 | 101.23 | 104.94 | 112.89 |
| Tensile | Experimental | 220 | 221 | 222 | 224 | 225 | 228 |
| | Theoretical | | 221.25 | 223.50 | 225.50 | 226.82 | 229.92 |

## IV. Conclusions

1. Liquid metallurgy techniques were successfully adopted in the preparation of Al6061-SiCand Al7075-Al2O3 composites containing the filler contents up to 6 wt %'age.
2. The Microstructural studies revealed the uniform distribution of the particles in the matrix system.
3. Micro hardness of the composites found increased with increased filler content and the increase in hardness of Al7075-Al4C3 composites are found to be 80-112.89BHN respectively.
4. Tensile strength is enhanced with increase of reinforcement percentage in matrix.
5. The wear rate increases with increase of r. p. m in sample 1 and wear rate decrease with increase of r. p. m (sample 2, 3, 4, 5, 6). The addition level wt% of composite material particle size limit based on the wear rate was increase or decrease with increase of r. p. m.

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