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Mechanical Properties of Composite Aluminum Matrix Reinforced with Tungsten Carbide and Molybdenum Disulphide Hybrid Composite

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Abstract— ***Metal matrix composites are formed by combination of two or more materials having dissimilar characteristics. In the present investigation, Aluminium (7075) is taken as base matrix metal, Tungsten Carbide particulate and Molybdenum Disulphide (MoS2) as reinforcements. The metal matrix composites are fabricated by stir-casting process. The Tungsten Carbide particulate was added in proportions of 1%, 1.5% and 2% and Molybdenum Disulphide was added in constant proportion of 1%, 1.5% and 2% on mass fraction basis to the molten metal. The different combination sets of composites were prepared. The different combination sets of composites were prepared. Mechanical properties like hardness and tensile strength were studied for both reinforced and unreinforced Al7075 samples. From the results, it was found that the hardness and tensile strength of the prepared metal matrix composites increases with increasing weight percentage of Tungsten Carbide***

Keywords: Aluminum 7075, MoS2, Hybrid Composite, Stir-Casting Process

I. INTRODUCTION

There have been continuous efforts to develop new manufacturing processes using Aluminum based alloy materials for such as automotive engine components, wear resistance components, and also heavy applications [1]. As the automotive engine components play an important role by transferring the explosive impact from the explosion chamber to the connecting rod, high thermal resistance and great structural strength is required to endure extremely high temperature and pressure [2]. Gravity die-casting, squeeze casting, hot forging, powder forging, stir casting processes have been generally used for the manufacturing of aluminum materials [3]. Among them, application of the stir casting process is dominant enough to occupy over 90% of composites manufacturing in the modern industry. However, as feed materials of the stir casting process are handled at the completely molten state. Its final product undergoes inhomogeneous solidification, which damages the integrity [4]. Moreover, they have dendrite microstructures, which lower the strength of material. Recently, the challenged hot forging process is suitable for high strength products, because the work piece experiences a significant amount of work hardening [5]. However, its requirement for large forming load and the poor generosity on the product geometry could not be overlooked. This project deals with the selection of better material for the process of more hardness and temperature resistance, in that Aluminum hybrid composite are produced by AL 7075 as matrix material and fly ash and activated carbon as reinforcement in different composition [6]. Different sample are produced by using stir casting methods. Various tests have been conducted to evaluate the different properties of Aluminum composites and they are compared with commercial Aluminum alloy [7]. Composite materials are engineering materials made from two or more constituent materials that remain separate and distinct on a macroscopic level while forming a single component. There are two categories of constituent materials: matrix and reinforcement. At least one portion of each type is required [9]. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their special mechanical and physical properties to enhance the matrix properties [10]. A synergism produces material properties unavailable from the individual constituent materials. Due to the wide variety of matrix and reinforcement materials available, the design potentials are incredible [11].The physical properties of composite materials are generally not isotropic in nature. For instance, the stiffness of a composite panel will often depend upon the directional orientation of the applied forces or moments. In contrast, an isotropic material has the same stiffness regardless of the directional orientation of the applied forces or moments. The relationship between forces/moments and strains/curvatures for an isotropic material can be described with the following material properties like Young's Modulus, the Shear Modulus and Poisson's Ratio.Composite materials are made from two or more constituent materials with significantly different physical or chemical properties. Metal Matrix Composites (MMCs) are the forerunners amongst different classes of composites. Over the past two decades Metal Matrix Composites (MMCs) have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance. Metal Matrix Composite consists of a metallic matrix combined with a reinforcing material [12]. The matrix materials are Aluminium, Magnesium, and Titanium etc. The reinforcing materials can be Silicon Carbide, Flyash, Alumina, and Graphite. MMCs offer a unique balance of physical and mechanical properties. Aluminium based MMCs have received increasing attention in recent decades as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance.

II. LITERATURE REVIEW

Salmaan et al. were conducted An Experimental investigation of Mechanical behavior of Aluminum by adding SiC and Alumina. This work was focused to study the change in behavior of aluminum by adding different percentage age amount of 'Sic' and 'Al2O3' composite and it is concluded that as the weight percentage of reinforcement goes on increasing the mechanical properties such as hardness, yield strength, ultimate strength also increases. But at the same time elongation decreases and the behavior of material changes from ductile to brittle [13]. Raj et al. were conducted the mechanical properties of fly ash reinforced Aluminium Alloy (Al6061) Composites and found that the tensile strength, compressive strength and hardness of the aluminium alloy (Al 6061) composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles increases the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite [14]. Tirumani Srilakshmi et al. were done a Comparative Investigation of Mechanical Properties of Aluminium Based Hybrid Metal Matrix Composites. The result indicated that the there is an increase in the value of tensile strength, ultimate tensile strength, hardness value and flexural strength of newly developed composite having SiC and B4C particulates in comparison to the SiC, graphite reinforced composite [15]. Umanath et al. were conducted the Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites and aimed to present the experimental results of the studies conducted regarding hardness, tensile strength and wear resistance properties of Al6061-SiC and Al7075-Al2O3 composites. The SiC and Al2O3 resulted in improving the hardness and density of their respective composites [16]. Manda et al. were investigated about the development of Aluminium Based Hybrid Metal Matrix Composites for Heavy Duty Applications and investigated the dry sliding wear behavior of aluminium alloy-based composites, reinforced with silicon carbide particles and solid lubricants such as graphite/antimony tri sulphide (Sb2S3). The aluminum composite materials can be easily prepared by stir casting method, and microstructure study shows the near uniformly distributed phases in the metal matrix. The mechanical properties like Tensile strength and Hardness increases with increase in %wt addition of Al2O3.While at the other end ductility and impact strength will gets reduced [17]. The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement, due to this problem the strength decreases after certain limit. From this problem we can overcome by adding small amount of Magnesium and by pre heating the composites and the die

Metal Matrix	Reinforced materials	Advantages	Limitations	Tribological behavior
AA 6082	Tungsten Carbide	The hardness of the materials is increases with the level of tungsten carbide. The tensile strength is high at certain proposition.	Strength of the material is decreases. Cracks were formed in the material.	For 2% Tungsten carbide, Density = 2.65 g/cm³, tensile strength = 170 N/mm² and elongation = 5 %.
Al-Mg-Si alloy	Alumina, rice husk ash (RHA) and graphite	The tensile strength of the material is high.	Hardness decreases with the increasing proposition of the RHA and graphite composition. Wear resistance decreases with the increases of the graphite.	Toughness = 8 J/m³, Tensile strength = 140 MPa, and Vickers hardness = 80 VHN.
Al6061	SiC/WC	The reinforcement particles were uniformly distributed without clustering of the particles. Hardness of the materials is increased. The compressive, tensile and wear resistance is increased.	Cracks, broken particles and grooves were found in the material.	Hardness = 78 HV, UTS = 140 N/mm³, and Compression strength = 300 N/mm³.

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Metal Matrix	Reinforced materials	Advantages	Limitations	Tribological behavior
Al6061	Graphite and Tungsten carbide	Optimal tribological characteristics is provided.	Strength and hardness of the materials is need to be evaluated.	Wear rate = 3 m/s.
ZA27	Nano-sized graphite (Gr) and boron carbide (B4C)	Density is decreased.	Tensile strength is decreased.	Density = 4,72 g/cm³ and UTS = 98 MPa.
AA6351	Graphite and alumina particulates reinforced.	Tribological characteristics were improved.	Reinforcement is not uniform.	Density = 2.6761 g/cm³.
AA 5052	Tungsten carbide and graphite	Surface roughness is low.	Strength and hardness is need to be evaluate.	Surface roughness = 0.0408 µm.
Al 6082	Zirconium oxide and coconut shell ash particles	Strength of the material is high. Hardness is increased.	Cracks were found and this affects the fatigue of the material.	Density = 2.62 g/cc, Hardness = 43 BHN, Tensile strength = 168 N/mm² and flexural strength = 88 N/mm².
AALM4	Tungsten carbide (WC)	The particles were uniformly distributed. The hardness, impact strength and tensile strength is increases with the increases in the reinforcement.	Cracks were found in the developed materials.	Hardness = 90 VHN, Tensile strength = 132 MPa, and impact strength = 2.5 MPa.
Al7075	Tungsten carbide, and cobalt.	Reinforced particles were uniformly distributed in the metal matrix.	Strength and hardness of the materials is need to be evaluated.	

III. EXPERIMENTAL METHODOLOGY

Experimental Procedure for Stir Casting:

The conventional experimental setup of stir casting essentially consists of an electric furnace and a mechanical stirrer. The electric furnace carries a crucible of capacity 2kg. The maximum operating temperature of the furnace is 1900ºC. The current rating of furnace is single phase 230V AC, 50Hz. The aluminium alloy (7075) is made in the form of fine scraps using shaping machine. It amounts to about 1150 gm. The metal scraps are poured into the furnace and heated to a temperature just above its liquidus temperature to make it in the form of semi liquid state (around 650ºC). The mixing of aluminium alloy is done manually for uniformity. Then the reinforcement powder that is preheated to a temperature of 600°C is added to semi liquid aluminium alloy in the furnace. Again reheating of the aluminum matrix composite is done until it reaches complete liquid state. Mean while argon gas is introduced into the furnace through a provision in it for few minutes. During this reheating process stirring is done by means of a mechanical stirrer which rotates at a speed of 60 rpm. The aluminium composite material reaches completely liquid state at the temperature of about 950°C as the melting point of aluminium is 700ºC. Thus the completely melted aluminium metal matrix composite is poured into the permanent moulds and subjected to compaction to produce the required specimen.

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Moulded Samples

Mixing Ratio

Table.1 Mixing Ratio of Composition of material (%)

Sample	Al. Alloy 7075 (%)	Tungsten Carbide (%)	Molybdenum Disulphate (%)
A	95	3	1
B	96	1	3
C	97	1.5	1.5

Casting-Process

In this research, the cast iron die prepared as per the standard size as shown in fig.1. Another one is sand casting also known as sand mold casting, is a metal casting process characterized by using sand as the mold material. It is a relatively cheap and sufficient refractory even for steel foundry use. A suitable bonding agent usually clay is mixed or occurs with the sand. The mixture is moistened with water to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The term sand casting can also refer to a casting produced via the sandcasting process. Sand castings are produced in specialized factories called foundries.

In stir casting the reinforcing particulates get distributed into molten matrix by mechanical stirring. Mechanical stirring in the furnace is the key factor in the process. The resultant molten alloy along with ceramic particulates can then be used for die casting, permanent mould casting, or sand casting. For a volume fraction of about 30% stir casting technique is ideal process. Surfacing or settling of Tungsten Carbide is preheated at 1000ºC in the electric pre heater for 20 minutes. Aluminium (is heated at 450ºC for 20 minutes. Die is preheated at 500ºC for 20 minutes. Die is made of high-grade steel material. The slurry can be ensured molten throughout the pouring by this process. Die is preheated in order to attain uniform solidification. If the die is not preheated uneven solidification takes place and crystalline structure and boundary formed will not be as desired.

IV. RESULTS AND DISCUSSION

Table.2 Tensile and Brinell Hardness Test of Aluminum Metal Matrix Composite

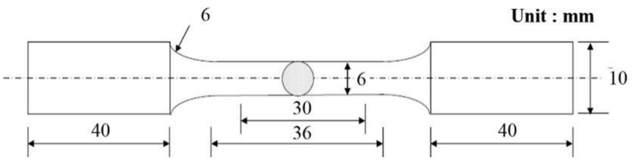
1. Tensile Test:

Test Parameters	Observed Values
Gauge Dia (mm)	12.48
Original Cross Sectional Area (mm^2)	122.33
Ultimate Tensile Load (kN)	4.53
Ultimate Tensile Strength (N/mm^2 or Mpa)	37.00

2. Brinell Hardness Test:

Test Parameters	Observed Values
BHN (10mm Ball / 500 kg Load)	53.8, 53.1, 52.8

ASTM E8M standard tensile testing specimen, all dimensions in mm



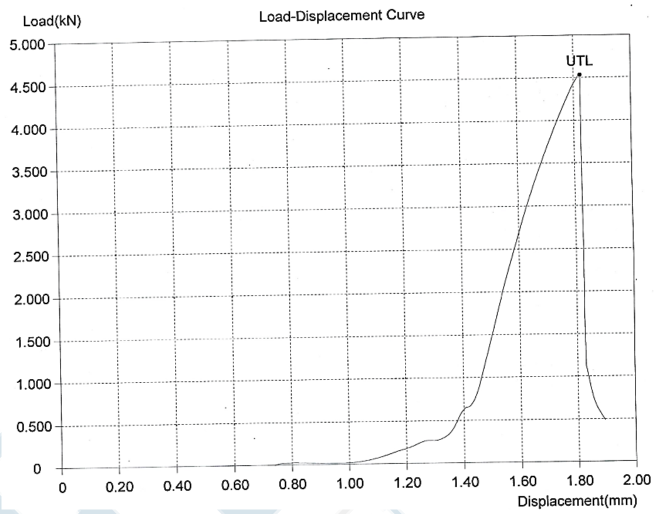


Fig.2 The Load Vs. Displacement of Al-7075 Hybrid Composite

Table:3 Al 7075 Alloy – Compression Test

TOCR NO	8610AT1	Test Date	08-Jun-22
SAMPLE ID	1	Type	Circle
Size (mm)	12.48	Area (mm^2)	122.33
IGL (mm)	50	FGL(mm)	
E(%)	/	FDia(mm)	
RA(%)	/	UTL (kN)	4.530
UTS(Mpa)	37	YL/0.2% PL (kN)	/
YS/0.2% PS(MPa)	/	FL	/

From the proposed material as shown in the **Table.2** Mechanical Properties of Composite Aluminum Matrix Reinforced with Tungsten Carbide and Molybdenum Disulphide Hybrid Composite

Brinell Hardness we could observe that the BH in 500 kg load 53.23%

Ultimate Tensile Load observed 4.53 kN

Ultimate Tensile Strength recorded as 37 Mpa as shown in the figure 2. The load vs. Displacement of the Aluminium Metal Matrix composite recorded 4.54 kN

V. CONCLUSION

A keen exploration of the research performed on the novel material Aluminium + Magnesium + Silicon Carbide + Fly Ash Hybrid Composite material resulted Aluminium composite is successfully fabricated by stir casting technique

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with fairly uniform distribution of WC & MoS2. The Maximum Tensile strength of Aluminium Metal Matrix observed The WC particulate was added in proportions of 1%, 1.5% and 2% and MoS2 was added in constant proportion of 1%, 1.5% and 2% with Brinell Hardness 53.23% under 500 kg load and in further UTS 37 Mpa recorded. This shows that the Tensile and Hardness of the material resulted an excellent outcome.

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