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Microstructural and Mechanical Characterization of AA7075/(SiC+Al2O3) Hybrid Composites

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Abstract – **This paper presents the behaviour of hybrid composites with aluminium matrix AA7075 alloy, reinforced with silicon carbide (SiC) andAl2O3 .Newly formed AA7075/FA/SiC hybrid composites are the combination of the two different hybrid materials. Material obtained on combining, when two or more materials possessing significantly distinct physical or chemical characteristics, produce a material with properties different from the individual one is known as composite material .These materials are magnificent materials with high strength to weight ratio, highly resistant against corrosion and wear, good stiffness properties etc.**

Keywords **– Hybrid Composites Material, AA7075, Metal-Matrix Composites, Silicon Carbide.**

I. INTRODUCTION

Composite materials combine the desirable properties of the constituent materials and provide enhanced physical and mechanical properties. Composite materials possess applications in almost all industries today. The automobile and aerospace industries are constantly in search of composites that inhibit higher strength and are lighter in weight for structural applications. Aluminium is preferred as a structural material in these areas because of its light weight. Ceramic particulates are added to the aluminium base matrix as a reinforcement to fabricate aluminium metal-matrix composites (AMMCs), which provide improved strength. Among the aluminium alloy series, the aluminium 7075 alloy has many favourable properties, like higher strength, good wear resistance, higher toughness and stiffness. The ceramic reinforcements added to the aluminium matrix also give further improvement to the endurance at higher operating temperatures. Most industries prefer metal-matrix composites with aluminium to take advantage of its ease of fabrication. Though many casting methods are available, stir casting is considered for manufacturing AMMCs, as the technique is simple, economical and because of its capability for large volume production.

The tensile strength and fatigue strengths of a SiC-whisker-reinforced AA7075 specimen produced by the powder metallurgy method was tested by Komai et al.1 in normal atmospheric and water environments. It was observed in the report that all the mechanical properties showed enhanced values, except the elongation to failure. The pattern of propagation of a crack for fatigue failure was also studied. The water environment was found to give a shorter fatigue life due to the effect of corrosion. Azim et al.2 produced a MMC with Al2024 base material and Al2O3 as the ceramic reinforcement to study the change in the mechanical properties. The observations revealed that the increments in the volume percentage of Al2O3 caused an increase in the ultimate tensile strength and a decrease in the ductility.

Advantages of composite materials

1. As moulded dimensional accuracy. Tight tolerance, repeatable mouldings. ...
2. Chemical Resistance.
3. Consolidated Parts and Function.
4. Corrosion Resistance.
5. Design Flexibility.
6. Durable.
7. High Flexural Modulus to Carry Demanding Load.
8. High Impact Strength.
9. High Performance at Elevated Temperatures.

II. LITERATURE REVIEW

Nagaraj Ashok, Palaniswamy Shanmughasundaram (2016) Aluminium metal-matrix composites are being used as materials for automobile and aerospace applications. Aluminium- and magnesium-based Metal-Matrix Composites (MMCs) are an important class of high-potential engineering materials.1 Aluminium alloy reinforced with silicon carbide displays better mechanical and tribological properties than the unreinforced alloy because of their high strength-to-weight ratio. Silicon carbide is often the preferred reinforcement in the production of aluminium powder composites.2 Stir casting can be used to fabricate the composites for a better homogenous distribution of reinforcement particles in the matrix. P. Shanmughasundaram et al.3 investigated the effect of the addition of fly ash on the mechanical and wear behaviour of Aluminium–fly ash composites. The composites were prepared with the varying weight percentage of fly ash (5, 10, 15, 20 and 25) by a two-step stir casting method. They concluded that hardness, tensile strength and compressive strength of the composites increases up to the addition of 15 % of mass fractions of fly ash [1].

N Tulasiram, k.manikanta (2018) This paper presents the deformation behaviour of hybrid composites with aluminium matrix AA7075 alloy, reinforced with silicon carbide (SiC) and Fly ash. Newly formed AA7075/FA/SiC hybrid composites are the combination of the two different hybrid materials. Cold upsetting experiments were carried out on as cast and homogenized hybrid composite billets. Optical and scanning electron micrographic examination of the samples was also undertaken. Hardness measurements were carried out to observe changes, if any, before and after the forging. Specimens were deformed in compression between two flat platens to predict the metal flow at room temperature. The circumferential stress component $\sigma\theta$ increasingly becomes tensile with continued deformation. On the other hand the axial stress, σz increased in the very initial stages of deformation but started becoming less compressive immediately as barreling develops. FEM simulation analysis of the forging of composite cylinders was then undertaken using Ansys software with a specified diameter-to-height ratio. Detailed comparisons of the experimental variables with the finite element method (FEM) results were carried out to ascertain the accuracy with which the deformation process can be modelled. Predictions from the simulation results were found to be in good agreement with the actual experimentation [2].

PRADYUMNA VISWAKARMA, SANJAY SONI & P M MISHRA (2018) AA7075 is a combination with zinc as an essential alloying component. When contrasted with numerous different steels its quality is very similar. It has greater fatigue strength, however less protection from corrosion than numerous other Al alloy. This paper investigates the possibility of growing elite composites with low cast, for different applications like aviation and automobile. The impact of different reinforcements on the AA7075 based composite has been investigated. The mechanical properties, have been seen to be either practically identical or better after heat treatment to the as cast composites. It has been found from the past research that the nearness of the hard ceramic stage, for example, SiC, TiB2, B4C, Al2O3 effects direct strengthening of the composites. In view of the information from the previous research, the application region of AA7075 AMCs has been shown in the present review. It has been gathered that the hybrid composites give greater reliability and flexibility in the design of components depending upon the reinforcement and matrix material .[3].

Shashi Prakash Dwivedi, Satpal Sharma, (2014) The mechanical properties of MMCs are sensitive to the processing technique used to fabricate the materials. Considerable improvements may be achieved by applying science-based modelling techniques to optimize the processing procedure. Several techniques have been employed to prepare the composites including powder metallurgy, melt techniques, and squeeze casting [7–10]. Investigation of mechanical behaviour of aluminium alloys reinforced by hard particles such as Silicon Carbide is an interesting area of research. Therefore, the aim of the present work is to investigate the effects of different factors such as: (i) weight percentage of the SiC particles (ii) type of fabrication process (mechanical stir and electromagnetic stir casting) on the microstructure, mechanical properties and wear behaviour of the metal matrix composites [11, 12].

On the basis of literature review, the compositions of reinforcement selected in a multiplication of 5 and the percentage of reinforcements are varied from 0 to 15% weight fraction in metal matrix. If the weight percentage of reinforcement's increases more than 15% there is no more effect occurring in physical and chemical properties of metal matrix composite. This work aims to compare the result of aluminium matrix composite material reinforced by (0, 5, 10, and 15 wt.%) silicon carbide particles using electromagnetic stir casting method and mechanical stir casting method.[4]

Mehdi Rahimianet (2009) Investigated the effect of Al2O3 particle size, sintering time and sintering temperature on the properties of Al–Al2O3 MMCs made by powder metallurgy. In this study, The average particle size of alumina were taken as 3, 12 and 48 μm and 10 wt.% of Al2O3 is mixed with aluminium. The sintering temperature were taken as 500, 550 and 600 ◦C and sintering time was in the range of 30-90 min. From this study they observed that the relative density of Al–Al2O3 composite was higher in samples containing fine particle sizes.

The highest relative density of 99.95% was observed in specimens sintered at 600 ◦C. The grain size of samples having fine Al2O3 particles is smaller and increasing the sintering time to 90 min leads to grain coarsening and the highest hardness was 76 HB in specimens having average particle size of 3 μm sintered at 600 ◦C for 45 min. Further increase in sintering time from 45 to 90 min results in a reduction of hardness to 59 HB. [5]

III. PROBLEM FORMULATION

Going through the research,it is observed that work has been done to a lesser degree on the composite of SiC and Al2O3.For the achievement of this purpose an experimental set up is made with all relevant equipments available then we manufactured three composites after considering varying amount of combined reinforcement as located below:

1. Al 7075 + 5% (SiC+ Al2O3)
2. Al 7075 + 10 % (SiC+ Al2O3)
3. Al 7075 + 15% (SiC + Al2O3)

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Several manufacturing processes are available to manufacture AMC's but the stir casting approach seems to be quite economical to follow.

IV. EXPERIMENTAL SETUP

4.1 Matrix Material (something within or from which something else originates)

Here we have taken AA7075 as base material and (SiC+ Al2O3) as reinforcement material to study.

Table –I: Nominal Compositions of Al Alloy 7075

Aluminium AA7075	97.6%	0.06%	0.03%	0.10%	0.50%	0.35%	0.03%	0.30-0.70%	0.10%
Element	Al	B	Cr	Cu	Fe	Mg	Mn	Si	Zn

Table -II : Various properties of silicon carbide (SiC)

Value	Properties
3.1	Density (g/cm3)
2800	Vickers hardness (Kg/mm²)
4	Thermal expansion Coefficient (10^{-6}/ °C)
120	Transcalency/Thermal conductivity (W/m °K)
0.14	Poisson's ratio
750	Specific heat (J/kg °K)

Table -III: Properties of Aluminum Oxide (Al2O3)

Properties	Value
Compressive Strength (MPa)	2200 – 2600
Melting Point (°C)	2000 +/- 30
Density (g/cm³)	3.9

4.2 Experimental Setup and Instrumentation Detail.

4.2.1 Stir casting

This casting may be defined as Semi- Solid Metal Casting" or "Rheocasting" or "Composting" and is mainly use with the non- ferrous metals.

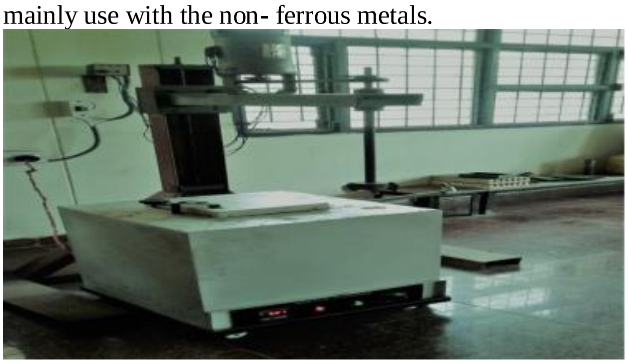

Fig 4.1. Stir casting process.

It is a special case of casting, as it involves different working manner criterion compared to that of conventional process of casting with an improved quality of the outcome or cast product after melting of parent metal into crucible in furnace, other reinforced metal is also heated in powder or liquid form in another crucible, when parent metal is melted then pre heated reinforce metal is mixed with parent metal & for proper mixing electric motor is attached with rotor blade on the shaft. Use different rotational speed of blade and fit blade at different angle to mix it properly. After getting a good mixture of this parent metal plus the reinforced metal ,it is poured into mould to get a specific shape as desired. After this, solidification process take place in the mould on pouring the molten metal due to Peritectic transformation i.e. the solid form reacts with a liquid form and after solidification at a certain temperature transformed into a single solid, here we have ceramic(solid form) and molten metal (liquid form) and obtains a metal alloy.

Fig 4.2. During heating aluminium AA7075.

Fig 4.3. Mechanical molten metal stirrer.

4.4 Preparation of Sample

Composites were fabricated in 4 various composition. i.e

7075 Al (1kg) +0 % (SiC+ Al_2O_3)
7075 Al (1kg) + 5% (SiC+ Al_2O_3)
7075 Al (1kg) + 10% (SiC+ Al_2O_3)
7075 Al (1kg) + 15% (SiC+ Al_2O_3)

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Fig 4.5. Process of pouring molten metal in permanent mould.

Fig 4.6. Cast and mould after casting.

Table V shows various composites manufactured in the present work.

Table -V: Composition of composites

Composite No.	Aluminium (in gram)	Aluminium oxide (in gram)	Silicon Carbide (in gram)	Remarks
1.	1000	0	0	[Al7075 + 0 wt% (SiC + Al_2O_3)]
2.	1000	25	25	[Al7075 + 5 wt% (SiC + Al_2O_3)]
3.	1000	50	50	[Al7075 + 10 wt% (SiC + Al_2O_3)]
4.	1000	75	75	[Al7075 + 15 wt% (SiC + Al_2O_3)]

V. RESULTS AND DISCUSSION

Fig. 5.1 reflects the relation between weight percentages of Silicon Carbide (SiC) and Aluminium Oxide Al2O3,ceramic particulates and micro-hardness of manufactured AMCs and macro-hardness of manufactured AMCs.

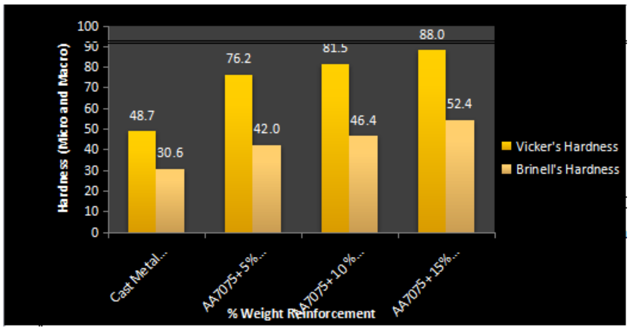

Fig 5.1. Disparity in Micro-Hardness & Macro-Hardness when varied with weight%.

After incorporating (SiC + Al_2O_3) in matrix alloy Al7075 the mechanical properties got improved & this may be ascribed due to an increase in existence of hard ceramic particles and high hardness characteristic of reinforcement.

5.1 Tensile Strength Test

The mechanical behaviour of the composite 1, 2 and 3 is predicted by the tensile test. The trained professionals prepared experimental set up for the tensile test of the given specimens on lathe machine. The ultimate tensile strength of cast metal AA7075 is 160.5MPa and percentage elongation is 8.1. Three tensile test specimens were prepared of each composite (Composite 1, composite 2 and composite 3) and tensile test was performed on each specimen. It means that each result is an average of three readings.

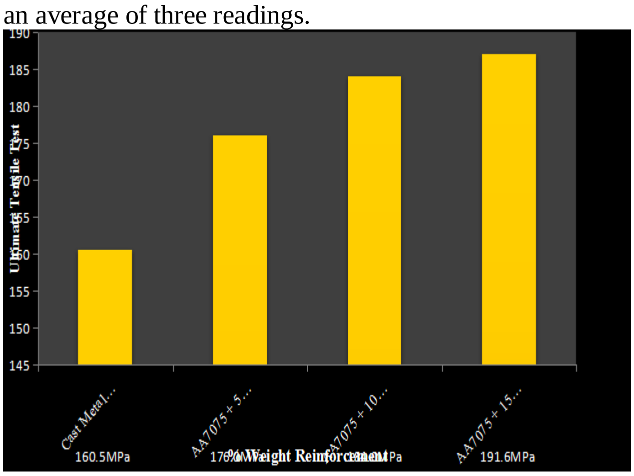

Fig 5.2. Changes observed in Ultimate Tensile Strength of Composite 1, 2 and 3 with AA7075 Cast Metal.

Ultimate tensile strength of the composites & base metal is clearly revealed by the graph above. Particles after being augmented or reinforced get a hike in strength and elastic modulus.More often, it is acknowledged that the composites of aluminium matrix have more tensile and fatigue strength and more improved elastic modulus comparative to monolithic alloys. It was observed that strength of aluminium composites reinforced with

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ceramic particles increases by decreasing the size of reinforcement particles and by increasing the content of ceramic phase in the composite, but the ductility reduced.

5.3 Ductility Test

Hybrid composite structure 1 with 5 wt% ($SiC + Al_2O_3$) is added, the elongation is 7.2 %. That means the ductility is less than the base metal.

On increasing the percentage of reinforcement particles from 5% to 10% the percentage elongation gets reduced to 6.7% & is further reduced to 6.0 % on increasing 15 wt% ($SiC + Al_2O_3$) to metal matrix.

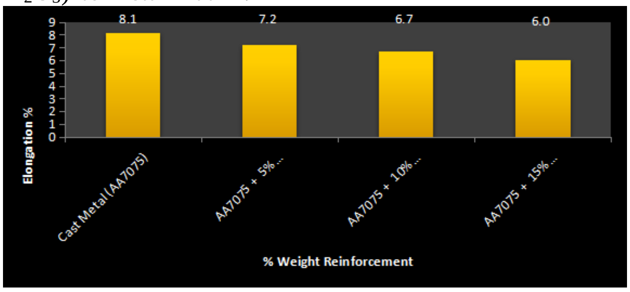

Fig 5.3. Percentage Elongation of Composite 1, 2 and 3 with AA7075 Cast Metal.

On comparing the percentage elongation of composite 1, 2 and 3(with 5%,10% and 15% weight reinforcement respectively) with cast metal AA7075, the ductility of the Base/Cast metal is more than that of composite material(due to the brittle nature of the reinforcement material) .In addition to this the percentage elongation is fallen when the (Silicon carbide + Aluminium oxide) content is increased.

VI. CONCLUSION

Microstructure was more homogeneous at lower weight % (i.e. at 5 % & 10 %) of reinforcement comparative to 15% that was found disorganized too since its porosity increased.

1. It is found from tensile test result, the base metal (AA7075) possess lower tensile strength compared to all manufactured hybrid composites i.e. (160.5 MPa) and composite 3 (AA7075 + 15% ($SiC + Al2O3$)) has the maximum tensile strength (191.6 MPa) respectively.
2. Percentage elongation of the manufactured hybrid composite drops with rise in combined weight percentage of reinforcement & it falls from 8.1 to 6.0.
3. Both micro and macro hardness of hybrid composites increased in comparison with micro and macro hardness of base metal.

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