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Fabrication And Characterization Of AA7075 With Si-C/Fly Ash Metal Matrix Composite Material Using Stir Casting Method.)

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Abstract: There has been an increasing Interest in composites containing low density and low cost reinforcements. Among various discontinuous dispersions used, fly ash in one of the most inexpensive and low density reinforcement available in large quantities as solid waste by product during combustion of coal in thermal power plant. The study conducted investigates the impact of incorporating varying proportions (ranging from 0% to 9%) of silicon carbide (SiC) and fly ash (FA) into AA7075 aluminum alloy composites. These composites were fabricated using the stir casting method, a widely used technique in composite material synthesis. Notably, the study employed equal proportions of SiC and FA in the composite fabrication process, ensuring a balanced distribution of both reinforcements. The mechanical properties of the prepared composites were extensively evaluated. Specifically, three key mechanical properties were examined: Young's modulus, impact strength, and flexural strength. Young's modulus indicates the stiffness of a material, impact strength measures its ability to withstand sudden loads or shocks, and flexural strength gauges its resistance to bending. This research provides valuable insights into the optimization of composite materials through the incorporation of SiC and FA, thereby paving the way for the development of high-performance materials with enhanced mechanical properties, suitable for a wide range of engineering applications.

Keywords --- Aluminium Alloy, Reinforcement, Metal Matrix Composites, Silicon Carbide, Fly Ash, Mechanical Properties.

I. INTRODUCTION

These days, Composites using Metal Matrix (MMCs) based on aluminium are the subject of extensive research. Stiffness plus their high weight-to-strength relation, hardness, opposition to wear, extreme temperature resistance, and other properties, the automotive, aerospace, defence, and marine engineering industries all use these composites in a variety of ways. Metal matrix composites has more extensive properties. The aluminium metal matrix composite(AMMC) attract the most response owing to their high strength, suitable temperature for casting, light weight and other features. Composite material consist of two or more materials. One of these materials is called reinforcement and other is called matrix. Reinforcement metal used in metal matrix affects the strength and durability of the material in comparison to their constituent parent materials. Fly ash is one of the most inexpensive and commonly used reinforcement. It offers low density and available in large quantities in solid state. Silicon carbide (SiC), aluminium oxide (Al_2O_3) and boron carbide (B_4C) are commonly used reinforcements. So this paper deals with the aluminium metal matrix composite in which fly ash and SiC are used as reinforcements materials.

In [1] the researchers conduct an experiment on aluminium alloy AA6061 and AA7075 reinforced with fly ash and Sic. The stir casting method is adopted to create aluminium based MMC samples. These samples were tested to compute the parameters like yield strength, wear rate, impact strength, hardness and ultimate tensile strength. They mix the reinforcements in range of (0-15wt%) with aluminium. The hardness of AA7075 composite is high compared to the AA6061 but the impact strength is same for the both composites. Yield strength and ultimate tensile strength are rises with the increase in reinforcement weight percentage. Elongation decreases with the increase in wt% of reinforcement. They concluded that the properties were increasing as reinforcement weight percentage increases.

Vipin k sharma et. at.[2] Their work deals with the tribological behaviour of aluminium metal matrix composite. Aluminium fly ash composites were prepared by using stir casting process with different weight % (2, 4 and 6%) of reinforcement particles i.e fly ash. The wear resistance of the fabricated composites increases with the increase in the fly ash contents. The composites with high fly ash contents resulted in 13.6% less wear as compared to low fly ash content composites.

Pavitra ajagol et.al.[3] The effect of Sic reinforcement on mechanical properties of aluminium metal matrix composite fabricated by stir casting method with different proportions of SiC (5,10,15%) and performed. The samples were tested for parameters like hardness and tensile strength. The best results has been obtained for composite reinforcement with 15% weight fraction of SiC particle, maximum hardness achieved was 47HV and maximum ultimate tensile strength was 130Mpa.

R. Devanathan et.al.[4] studied and looked at hybrid metal matrix composite (HMMC) with silicon carbide, fly ash and coconut shell ash as reinforcements. They made samples and named as a, b, c, d with different weight percentage of fly ash, sic and coconut shell ash. The fly ash percentage (10%,12.5%,15%,20%) and the sic was taken at constant percentage (10%) and the coconut shell ash as (0%,2%,5%,10%). The test they carried out were hardness, tensile and microstructure. The sample d has more hardness value and tensile strength compared to the other samples.

Balasubramani SUBRAMANIAN et. al. [5] review on properties of aluminium metal matrix composite with reinforcements like SiC, B_4C, Mgo, aluminium oxide. They conducted tests like tensile strength, yield strength, elongation on the fabricated samples. There is a drop of density in the composite and also increases the hardness of the metal matrix composite. The wear rate of the composite is increased when load and speed are increased. It also has high elastic modulus and tensile strength. And also they found that lowering particle size helps to achieve uniform mixing in the hybrid composite.

B. Madharao et. al.[6] studied the tribological behaviour of aluminium alloy (AA7075) reinforced with silicon carbide of different weight proportions (10%,15%) fabricated by stir casting method. Looked about wear and frictional properties of metal matrix composite by performing dry sliding wear test. They predicted that sliding distance and applied load have the highest influence on wear rate in composites.

B. Ramgopal Reddy et. al. [7] studied the characterization of silicon carbide and fly ash reinforced aluminium metal matrix hybrid composite. Al6082 is reinforced with silicon carbide and fly ash are fabricated by stir casting method. The composite are made at three different weight fractions (2.5%,5%,7.5%) for study of microstructure, ultimate tensile strength, hardness and wear testing. The hardness, wear resistance and ultimate tensile strength increases as the weight fraction reinforcement increases. The increase in mechanical and wear resistance properties are fairly high at higher weight fractions of reinforcement.

In[8] the researchers studied the microstructure and mechanical behaviour of aluminium metal matrix composite. Al7075 is reinforced with silicon carbide and fly ash are fabricated by stir casting process. The composite are made at two different weight fractions (5% & 10%) for study of EDS analysis, Rd analysis, density and hardness and tensile. The hardness was increased and the tensile properties like yield ultimate and elastic modulus are enhanced to the composites when compared to the base alloy. The density of the composite decreases as reinforcement increases.

In[9] aluminium matrix reinforced with silicon carbide particles. In this they studied the effect of sic on mechanical properties and compressive failure mechanism of al/sic composite with constant mass fraction. The static and dynamic compressive tests with higher rates were carried out to analyse the variation of yield strength with strain rate. For the composite with smaller average size of sic particles, sic particles play a real role of reinforcement subjected to loading fractured.

Uppada Rama Kanth et. al.[10] studied the mechanical behaviour of fly ash/sic particle reinforced Al-Zn alloy based metal matrix composite and concluded that incorporation of fly ash particles enhanced the hardness and tensile properties like ultimate tensile and yield strengths were improved by the addition of SiC particle. Densities for composites were found decreased when related to the base alloy

II. Materials

Aluminium alloy (AA7075) was used as matrix material. AA7075 is employed in applications where a high strength-to-weight ratio is crucial, such as in military and aerospace technologies. Used extensively in the aerospace industry for aircraft frames, wings, and fuselage components. The chemical composition of AA7075 is shown in the table(1). The matrix was reinforced with fly ash and SiC, the fly ash is collected form the simhadri power plant also known as NTPC Visakhapatnam, Andhrapradesh. Sic will increase the hardness and toughness of the composite.

The chemical composition of class F fly ash (SiO_2+Al_2O_2+Fe_2O, ≥ 70%)

Chemical Composition

AA7075	Al	Zn	Mg	Cu	Fe	Si	Cr	Ti	Mn
	Bal	5.11	2.04	1.11	0.61	0.33	0.299	0.027	0.014

Table-1 AA7075chemical composition

III. Experimentation

Metal matrix composites (MMCs) were fabricated using the stir casting method, which involves melting the material while continuously stirring and promptly pouring the molten mixture into a preformed cavity. Subsequently, the mixture is cooled, allowing it to solidify. During the stir casting process, particles frequently aggregate, necessitating vigorous stirring at elevated temperatures to disperse them evenly. The stir casting set up consists of a furnace, crucible and a rotor attached to the motor. For preparing the Al-fly ash metal matrix composite by stir casting, the fly ash particles were pre- heated at a temperature of 300^{o} C for three hours to remove moisture. The aluminium alloy 7075 is melted in a crucible. About (1-2%) by weight of magnesium is then added to the melt. The purpose of adding the magnesium is to increase the wettability of the fly ash particles by liquid aluminium.

The pre-heated fly ash particles and silicon carbide are then added to the melt and it is stirred continuously at a speed of 100 rpm to 600 rpm. Different specimens were prepared by varying the percentage of fly ash and silicon carbide. Specimens with (0-9%) fly ash and silicon are prepared and also a standard aluminium specimen is prepared.

After the fly ash and silicon carbide has been mixed with the molten melt. The molten mixture of aluminium with fly ash and silicon carbide was poured in a predefined cavity with required dimensions. After subsequent cooling and secondary machining processes, different specimens were made for testing of tensile, impact, and flexural.

Fig-1 Stir casting

Fig-2 casting specimens

S.No	Specimen	Al7075 In gms	Fly ash In gms	silicon carbide (sic) in gms
1	Pure	100% (600gms)	------	------
2	3%	97% (582gms)	1.5% (9gms)	1.5% (9gms)
3	6%	94% (564gms)	3% (18gms)	3% (18gms)
4	9%	91% (546gms)	4.5% (27gms)	4.5% (27gms)

Table-2 Expermental samples for study

Tensile test:

The metal matrix composite underwent tensile testing using a Universal Testing Machine. Standard specimens were employed to assess both the ultimate tensile strength and young's modulus. The tensile test, a fundamental mechanical test, involves loading a meticulously prepared specimen under precise conditions while monitoring the applied load and the specimen's elongation over a specific distance. All test specimens were prepared according to reference standards.

Young's modulus is obtained by using the formula:

$$E=\frac{Tensile\ stress}{Tensile\ strain}$$

Where E is young's modulus

Flexural test:

Flexural testing for metal matrix composites involves subjecting the material to a bending load to evaluate its mechanical properties, such as modulus of elasticity, flexural strength, and fracture toughness. This test typically employs a three-point or four-point bending setup, wherea specimen is supported at two points while a load is applied at a specified rate to induce bending. The resulting deformation and load data are then analyzed to determine the material's performance under bending stress. All test specimens were prepared according to reference standards ASTME855.

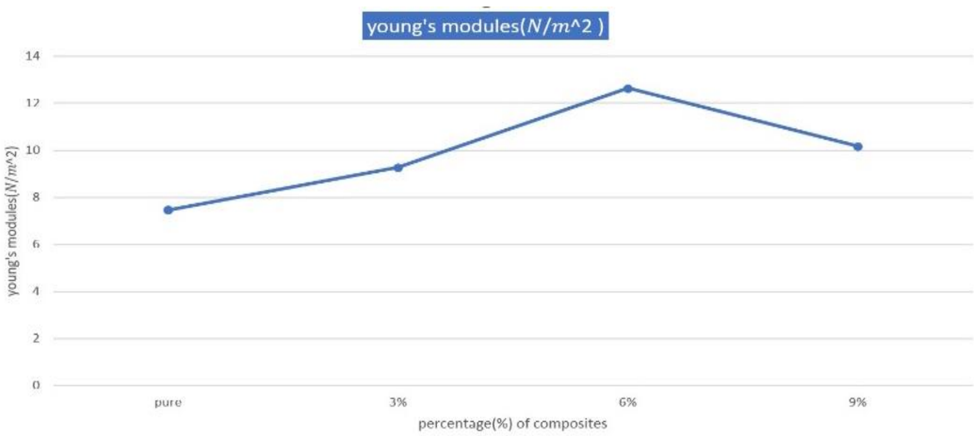
Impact test:

The Charpy impact test is a widely used method for determining the impact resistance or toughness of materials, particularly metals. It's governed by ASTM standard E23 for metallic materials. In this test, a notched specimen is clamped and then struck by a swinging pendulum. The amount of energy absorbed by the specimen during fracture is measured. This test helps assess a material's ability to absorb energy and resist fracture under sudden loading conditions.

IV.Results and discussions:

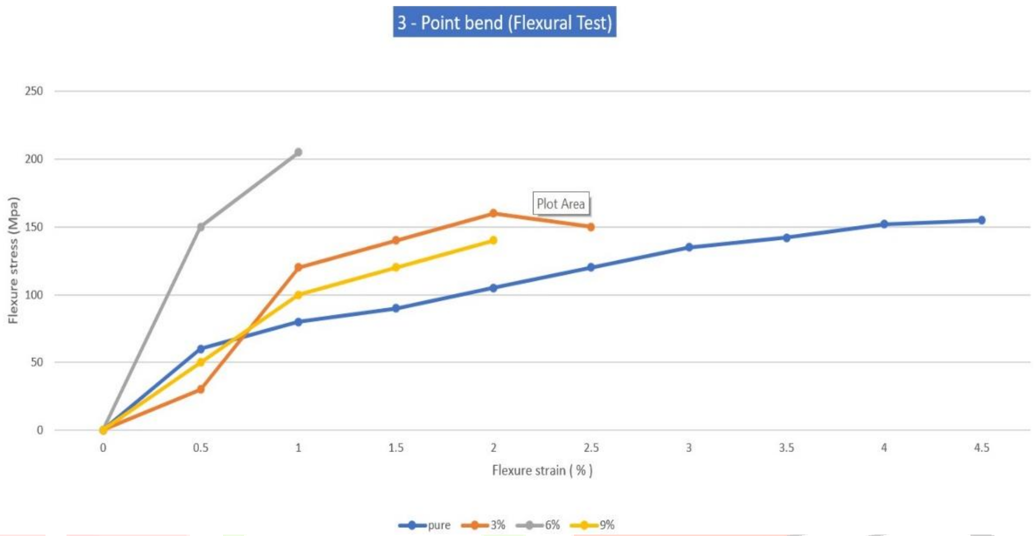
Tensile test:

The graph of the experimental young's modulus of the composites according to the sic, fly ash and their mixtures is shown in figure. In X-axis we are representing the different percentage of compositions and in Y-axis we are representing the young's modulus, young's modulus $\left(\frac{N}{m^2}\right)$ is a measure of ratio of tensile stress to the tensile strain .Results show that the young's modules of the composites is higher than that obtained for the pure Al7075. pure Al7075 having young's modulus $7.47\text{x}10^9\ \frac{N}{m^2}$, and for 3% the young's modulus increase to $9.271 \times 10^9\ \frac{N}{m^2}$, and for 6% the young's modulus increase to $1.264\times 10^{10}\ \frac{N}{m^2}$, and finely for 9the young's modulus we get $1.016\times 10^{10}\ \frac{N}{m^2}$. At 6% we get the best young's modules value when comparing to the other percentages.



Graph shows young's modulus at different percentages

Flexural test:

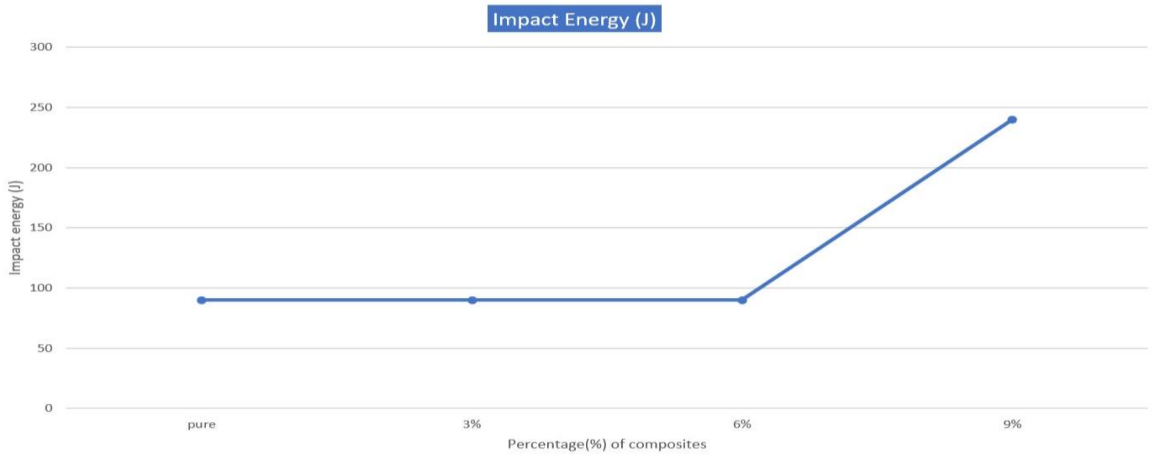


Graph shows the Flexural strength for different compositions of the specimens

In the figure, we observe the experimental Flexural strength of composites containing SIC, fly ash, and their mixtures in the compositions of pure,3%,6%,9%. Notably, the Flexural strength of these composites surpasses that of the unreinforced aluminium (Al7075). In X-axis, we are representing the Flexural strain percentages (pure,3%,6%,9%) and on Y-axis we are representing the Flexural stress in Mpa. As we can see in the graph pure Al7075 is having much greater strain value when comparing with the composite mixture of Al7075, sic, fly ash. It is clearly observed that the flexural strength value increase with increasing the fly ash and sic in Al7075, At 3% we are getting more flexural strength value when comparing with the pure al7075 and 6% we are getting more flexural strength then the 3%,and at the 9% we can observe decrease in flexural strength when comparing with the 6% but it's value is greater than the pure,3% .finally we can conclude that at 6% we are getting higher Flexural strength value when comparing compared the pure,3%,9%.

Impact test:

In the figure, we observe the experimental impact energy of composites containing SIC, fly ash, and their mixtures. Notably, the Flexural strength of these composites surpasses that of the unreinforced aluminium (Al7075). In X-axis, we are representing the different composite percentage (%) and on Y-axis we are representing the impact energy in Joules. It is clearly observed that the pure Al7075, 3% , 6% are having the same impact energy of 90 Joules .but at the 9% we are getting more impact energy of 240 Joules ,which is very high when compared with the other composite percentages.



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Conclusion:

The following conclusions were made based on the study of Mechanical Properties of Aluminium metal matrix hybrid composites reinforced with SiC and Fly Ash are fabricated by stir casting route. Adoption of stir casting technique was successful in fabricating aluminum-silicon carbide composites.

Aluminium based metal matrix composite up to 9% silicon carbide and fly ash have been successfully fabricated by stir casting technique with fairly uniform distribution of Silicon Carbide & Fly Ash.

The composites are made at four different weight fractions of reinforcements for, tensile testing, Flexural testing and Impact test.

Sample 6% shows the young's modules value of E≈ $1.264\times 10^{10} \frac{N}{m^2}$, with 3% sic, and 3% fly ash was added in the matrix which is significantly higher when compared to pure,3%,9%. The overall Young's modulus of the composite will depend on the volume fraction of each material in the mixture and their respective Young's moduli. Typically, adding stiffer materials like SIC will increase the overall Young's modulus of the composite, while adding less stiff materials like fly ash may decrease it.

The flexural strength of the fabricated composite materials was tested, and it was found that the 6% composite has more flexural strength compared to the pure, 3%, and 9% composites. This is due to the addition of silicon particles to the composite; adding silicon particles can increase the strength of the composite due to its inherent strength properties.

The impact strength of the composite with 9% (sic + fly ash) is higher compared to the pure, 3%, and 6%. It is due to the presence of sic particles in the composite. Both SiC and fly ash act as reinforcement fillers in the aluminum matrix. SiC particles are known for their high strength and hardness, while fly ash provides additional toughness. When dispersed uniformly within the aluminum matrix, these particles help to resist sudden load.

From the above results, we can conclude that the aluminum metal matrix composite shows better mechanical properties than that of the base alloy.

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