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Fabrication of Aluminium Alloy (Al 7075) Hybrid Composite and Effect of Reinforced Particles on Physical and Mechanical Properties

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ABSTRACT

In the recent years, among the major developments in the field of composites, aluminium alloy hybrid composites are one of the most dominant for different areas such as aerospace industries, automobiles and other heavy duty applications due to their high strength to weight ratio. This paper work presents the fabrication of aluminium alloy (Al 7075) hybrid composite reinforced with silicon carbide (SiC) and zirconium dioxide (ZrO_2), through step – wise stir casting technique. The particle size of the reinforcements used was 25 µm. Density test (Archimedes' Principle) and Charpy Impact test has been carried out to study the effect of change in weight percentage of the reinforcements on the density and toughness and void contents has been calculated.

Keywords: Aluminium alloy (Al 7075), Charpy impact test, Density test, Hybrid composite, Void contents

I.INTRODUCTION

A composite material is generally defined as a fusion of two or more materials that results in better properties than those of the individual materials used. The composite mainly consists of two different components, primary component is known as matrix and the secondary component is known as reinforcement [1]. The reinforcements are used in order to enhance the overall property of the fabricated composite as desired.

For the last few years, it has been found that the application of aluminium alloys has been increased rapidly in different areas due to low weight, density, better mechanical properties. Aluminium alloys and aluminium based metal matrix hybrid composites have been utilized in the fabrication of various automotive parts and aerospace industries [2].

II. LITERATURE SURVEY

The purpose of this literature survey is to study the latest developments in the field of aluminium alloy hybrid composites and analysing the behaviour of different types of reinforced particles on the physical and mechanical properties. The table below shows various grades of aluminium alloys used as matrix materials ingrained with different classes of reinforcements, fabrication techniques used and their effect on physical and mechanical properties are studied.

Table 1: Effect of reinforcements on the physical and mechanical properties of the fabricated composite

S.No.	*Matrix*	*Reinforcement*	*Wt. %*	*Fabrication technique*	*Effect on physical and mechanical properties*	*Ref. No.*
1	LM6	B_4C	2.5, 5, 7.5	Stir casting	Increase in the wt. % of B_4C, decreases the density of the composite and increases hardness	3
2	A384	SiC	10	Stir casting	Higher stirring time with high speed increases mixing of reinforced particles thus reduces voids and increases mechanical strength	4
3	Pure Al	SiC (300 and 400 mesh size)	10, 15	Powder metallurgy	Density and hardness is increased with increase in wt.% of SiC but increase in particle size of SiC decreases the hardness	5
4	AA7068	ZrO_2	0, 2, 4, 6, 8	Stir casting	Increase in wt.% of ZrO_2 increases the tensile strength as well as hardness	6

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III. MATERIALS AND METHOD OF FABRICATION

3.1 Matrix Material –

Aluminium alloy (Al 7075) was found to be the most suitable matrix material due to low density, high strength and generally used for highly stressed structural parts[7]. The density of Al7075 is 2.81 gm/cm³. The table 2 below shows composition of Al 7075. The fig. 1(a) below shows Al 7075

Table 2: Chemical Composition of Al 7075 [8]

Al %	*Zn %*	*Mg %*	*Cu %*	*Cr %*	*Fe %*	*Si %*	*Mn %*	*Ti %*
87.1–91.4	5.1 – 6.1	2.1 – 2.9	1.2 – 2	0.18 – 0.28	Max 0.5	Max 0.4	Max 0.3	Max 0.2

3.2. Reinforcement Material:–

3.2.1. Silicon Carbide (SiC) –Silicon carbide is very hard ceramic particles that are used as a reinforcing particle within the matrix material in order to enhance overall mechanical properties of fabricated composite. The density of SiC is 3.16 gm/cm³ and particle size is 25 µm. The fig. 1(b) below shows silicon carbide micro powder.

3.2.2. Zirconium Dioxide (ZrO_2) – ZrO_2 adopts a monoclinic crystal structure at room temperature. The density of ZrO_2 is 5.7 gm/cm³ and particle size is 25 µm as shown in fig 1(c).

(a). Al 7075   (b). Silicon carbidepowder   (c). Zirconium dioxide powder

Fig 1: (a), (b) & (c) shows matrix and reinforcement materials required for fabrication of composite

3.3. Chemical Composition of fabricated composite

Aluminium alloy hybrid composite is fabricated in three different compositions and then comparison between the pure aluminium alloy and different compositions of composite has been done.

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Table 3: Chemical composition of Al7075 metal alloy hybrid composite

Designation	*Al 7075 (wt. %)*	*Silicon Carbide (wt. %)*	*Zirconium Dioxide (wt. %)*
ASiZr – 0	100	0	0
ASiZr – 1	95	3	2
ASiZr – 2	90	6	4
ASiZr – 3	85	9	6

3.4. Stir Casting Fabrication Technique

Step 1:Melting of aluminium alloy (Al 7075)

Al7075 was melt under the temperature controlled electric furnace. Graphite crucible was used for melting Al7075. The crucible was placed within the furnace until the Al7075 melts. The melting temperature of Al7075 is 477 °C to 655 ° C but in order to avoid solidification during pouring the temperature is kept higher. The fig.2 below shows furnace used for melting Al 7075.

Step 2: Addition of reinforcement

After melting of Al7075, the reinforcements were added to the molten Al7075 as per the designations given in the table 3. Electronic weighing machine was used for weighing reinforcements as shown in fig. 3 below.

Step 3: Stirring of reinforcement

After weighing the reinforcements (i.e. SiC and ZrO_2), the reinforcements were mixed with the molten Al 7075 with the help of a mechanical stirrer made of hardened steel for 5 – 7 minutes and heated again in furnace. Then crucible is taken out of the furnace and stirred again for 5 – 7 minutes and then poured into the die.

Step 4: Pouring of the mixture (SiC + ZrO_2 mixed with the molten Al 7075)

The mixture of Al 7075 + SiC +ZrO was then poured in a die made of hardened steel having dimension 140 x 90 x 10 mm. The mixture was then allowed to solidify for 2 – 3 minutes and then after taking out from the die, the solidified plate of composite was suddenly quenched into cold water in order to improve its surface property.

Fig 2: Electric Furnace Machine

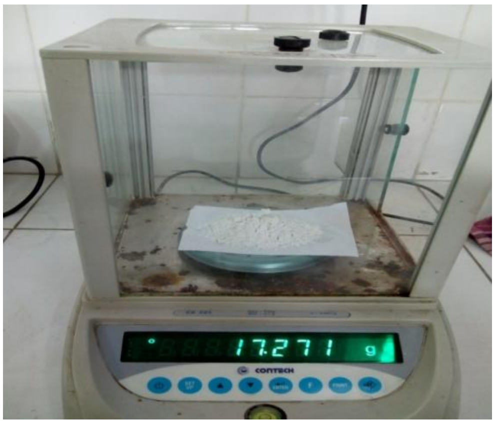

Fig 3: Electronic Weighing Machine

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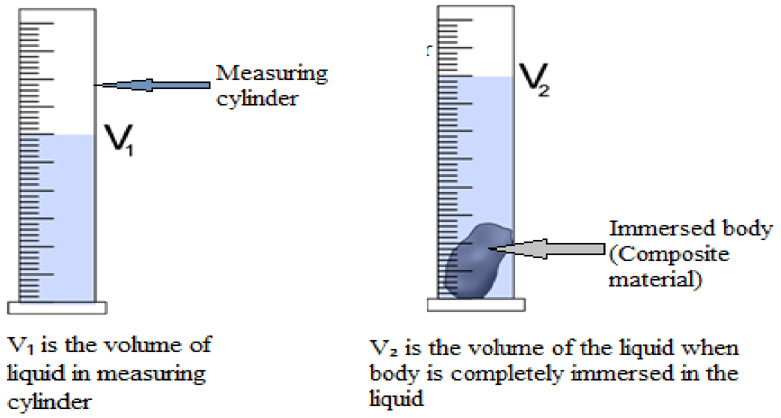
IV. RESULTS AND DISCUSSION

4.1 Density Measurement

Density is a physical quantity defined as mass per unit volume. Actual density or experimental density of the composite is calculated by using Archimedes' principle [9, 10]. According to this principle "when a body is immersed in a liquid then the liquid displaced by the immersed body is equal to its volume".



$$Volume\ of\ the\ Composite\ material\ (V) = Volume\ of\ Liquid\ displaced\ (V_2 - V_1)$$

Fig 4: Determination of volume by liquid displacement method (Archimedes' Principle)

Theoretical density of a composite (Al7075 :SiC : ZrO_2) is calculated by formula given below [9]: -

$$\rho_{tc} = \frac{1}{\frac{w_{Al7075}}{\rho_{Al7075}} + \frac{w_{SiC}}{\rho_{SiC}} + \frac{w_{ZrO_2}}{\rho_{ZrO_2}}} \quad \dots\dots\dots\dots (1)$$

Where, w_{Al7075} is wt. % of Al 7075 alloy

w_{SiC} is wt. % of Silicon Carbide micro powder

w_{ZrO_2} is wt. % of Zirconium dioxide micro powder

ρ_{Al7075} is density of Al 7075 alloy

ρ_{SiC} is density of Silicon Carbide micro powder

ρ_{ZrO_2} is density of Zirconium dioxide micro powder

4.2 Void Contents

Void contents can be minimized by using temperature controlled vacuum furnace, centrifugal casting or some external pressure over the mould but cannot be completely eliminated. The void contents can be calculated theoretically by the formula as given below [9, 10]:-

$$Void\ Contents = \frac{Theoretical\ density\ (\rho_{tc}) - Experimental\ density\ (\rho_{ec})}{Theoretical\ density\ (\rho_{tc})} \quad \dots\dots\dots\dots (2)$$

Where, ρ_{tc} is theoretical density of the composite and

ρ_{ec} is experimental density of the composite

Table 4: Theoretical density, experimental density and percentage increase in void contents in different compositions

Designation	*Composition wt. % ($Al7075 : SiC : ZrO_2$)*	*Theoretical Density (gm/cc)*	*Experimental Density (gm/cc)*	*Void Contents (%)*
ASiZr – 0	100 : 0 : 0	2.810	2.766	1.565
ASiZr – 1	95 : 3 : 2	2.820	2.769	1.808
ASiZr – 2	90 : 6 : 4	2.888	2.813	2.596
ASiZr – 3	85 : 9 : 6	2.928	2.832	3.278

4.3 Impact strength

Impact tests are performed to assess the shock absorbing capacity of the material under impact or sudden loads. The stresses produced in the components during impact loading are many times more than the stresses produced by the gradual loading. Therefore impact strength of a material is defined as the ability of a material to withstand impact or sudden load per unit cross – sectional area.

Impact test are conducted with two types of specimen i.e. Charpy test specimen and Izod test specimen. In both the tests, a notched beam specimen is used. For this research work Charpy impact test was used. In Charpy test, the specimen is placed as simply supported beam. The impact load is applied to the centre and behind the notch. The standard size of the specimen and notch shape and size is as shown in fig. 5 below. The specimen has standard V – shape notch with included angle of 45°.Size of specimen is according to ASTM E 23 for Charpy test = (55 X 10 X 10) mm size of notch = t/5 to t/3 [11].

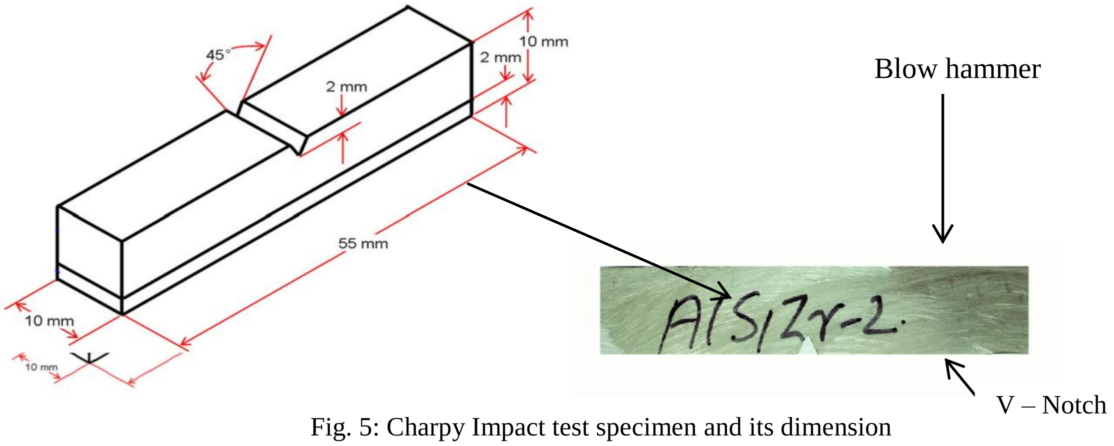


Fig. 5: Charpy Impact test specimen and its dimension

The table 5 below show the experimentally calculated value of impact strength for each composition. To perform the Charpy impact test, two samples were prepared of each composition, impact strength was determined i.e. energy absorbed per unit area and then average value of the two samples was taken as its impact strength.

$$Energy\ absorbed\ (U) = Energy\ before\ fracture\ (U_i) - Energy\ after\ fracture\ (U_f) \quad \ldots\ldots\ldots\ldots (3)$$

Table 5: Experimentally calculated value of impact strength for different compositions

Designation	*Composition wt. %* *Al7075 : SiC : ZrO_2*	*Impact Strength* $\left(^{KJ}/_{m^2}\right)$
ASiZr – 0	100 : 0 : 0	312.50
ASiZr – 1	95 : 3 : 2	353.12
ASiZr – 2	90 : 6 : 4	371.87
ASiZr – 3	85 : 9 : 6	350

V. CONCLUSION

This paper presents different type of composite i.e. aluminium alloy (Al 7075) hybrid composite reinforced with silicon carbide and zirconium dioxide. These reinforced particles experimentally prove that there is an increase in the physical and mechanical property of the composite when compared with the monolithic material. Hence this composite can be used for different applications in a much better way such as automobiles, aerospace and structural applications. This research work describes the density, void contents and impact strength as listed below: –

- Aluminium alloy hybrid composite has been fabricated using stir casting technique. Stir casting technique is the most economical and conventional method of casting composites.
- With increase in the weight percentage of the reinforcements, experimental density is increased but there is an increase in the percentage of void contents also.
- Experimentally it is also found that, with increase in the weight percentage of reinforcements there is an increase in the impact strength of the composite up to 10 % (i.e. 6 % SiC + 4 % ZrO_2).

VI. FUTURE SCOPE

- The fabrication technique performs major role in the fabrication of composites. This work presents composite fabrication through stir casting technique only. Therefore, other different casting techniques could be also tried, so that observations can be done more satisfactorily.
- Other reinforcements such as alumina (Al_2O_3), graphite (Gr), titanium carbide (TiC) etc. can also be used with aluminium alloys in order to enhance its property and use it for different applications.

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