Investigation on Mechanical Properties of Aluminium Hybrid Metal Matrix Composites- AL7075 with SiC and Coconut Shell Fly Ash

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Abstract— Aluminium has been widely used in the present period in engineering applications owing to its light weight, less corrosion properties and its abundance. Out of various series of aluminium, Al 7075 has a huge number of applications especially in the aerospace and defense industries all over the world. The fabrication of composite material by liquid metallurgy technique of stir casting process and experimentally investigating its various mechanical properties is the main focus area of the project. The Base material used for the fabrication of composite is Al7075 and reinforcements such as silicon carbide and coconut shell fly ash powders. The proportions of silicon carbide vary from 3, 6, 9 and 12% and constant proportion of fly ash powder at 3%. The melted composites are poured into rectangular dies.

Keywords: Mechanical Properties, Aluminium Hybrid Metal Matrix Composites, SiC, Coconut

I. Introduction

Nowadays aluminium has been the material of choice for engineering applications due to its less weight, high corrosion resistance. Aluminium is a non- ferrous metal and is the third most abundant element in the earth's crust next to silicon and oxygen. Its role in the aircraft industry for the development of structurally reliable, strong and fracture resistant parts of aircraft frames [28]. It is largest metal consumed after iron due to its abundance. Aluminium is known for its versatility because the range of physical and mechanical properties developed from pure aluminium to alloys are remarkable [22].

Aluminium metal is also used in commercial applications such as automobiles, trucks, railway cars, marine vessels and spacecraft. It widely replaces iron in the construction sector such as in roofing's, doors and windows [7].

Aluminium is always alloyed which improves its mechanical properties [14]. Various alloying elements such as copper, zinc, magnesium, manganese and silicon are added to pure aluminium metal at different weight percentage. Strength and durability of aluminium alloys vary widely not only because of presence of alloying agents but also as result of heat treatments and manufacturing processes [1]. More than three hundred alloy compositions are commonly recognized. The properties of aluminium that make this metal and its alloys the most economical and attractive for a wide variety of uses are Light weight, excellent specific strength, high thermal and electrical conductivities, high reflectivity, good corrosion resistance, excellent workability, and attractive appearance [17].Here, AL 7075 is used as base metal to which SiC and Coconut Shell fly ash are added as reinforcing elements by using stir casting method

II. Materials and Methods:

A. Materials

Elements	Zn	Mg	Cu	Cr	Fe+Zr+Ti	Si+Mn	Al
%composition	5.1-6.1	2.1-2.9	1.1-2.0	0.18-0.28	<=0.75	<=0.40	Remaining

Table 1: (Composition of Aluminium 7075 alloys)

B. Preparation of coconut Shell Fly Ash

Fly ash is the byproduct obtained from the combustion of coal and other carbon material. They are waste products obtained from industries which can be used as replacements and reinforcements [10]. Coconut as an agricultural commodity is also beneficial to the economic improvement of the society, wastes such as coconut shell are beneficial to material science. Coconut shell fly ash is a silica compound SiO_2 obtained from heating at a temperature between 500^0C and 700^0C lower than conventional cement heating process until the fiber becomes ashes after through the process of carbonating at a certain temperature [6]. Composition of coconut shell fly ash are majorly silica (SiO_2) compounds amounting to 67.55%.

Properties of the coconut shell fly ash are high strength, low specific weight, good durability, abrasion resistance characteristics [12]. Addition of fly ash powder in the metal matrix gives it light weight, less density [17]. Coconut shell fly ash has been used as reinforcement in metal matrix composite to reduce its weight [19].

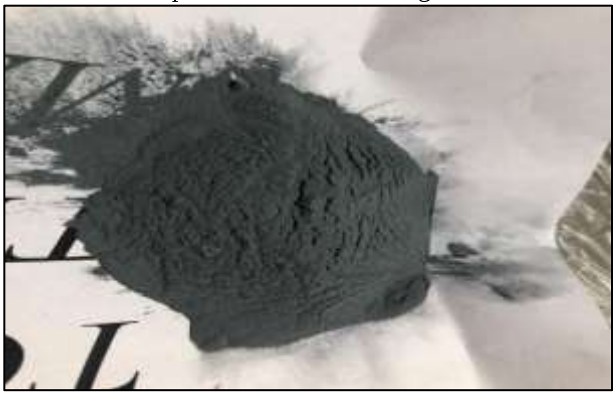

Fig. 1: Coconut shell fly Ash

C. Stir Casting Method

Here, Stir Casting – A Liquid metallurgy technique is used which is generally accepted as a promising route, also currently practiced commercially due to its advantages like simplicity, flexibility and applicability to large quantity production with cost advantage. It is the most preferred and economical method for the fabrication of aluminium metal matrix composites. It is used to produce discontinuous particle reinforced composites due to its simplicity, flexibility, low cost and large quantity production. Process parameters in the casting process affect the mechanical properties and microstructure of the hybrid composites. Stirring action of the stirrer promotes uniform distribution of the particles in the matrix. It consists of high temperature electric furnace, stirrer arrangement, stainless steel pot for melting with bottom pouring. It also comprises controls for preheating temperature, casting temperature and electronic controls for the operation of stirrer.

In this investigation, the combination added for stir casting is as follows.

Sample	Al(%wt.)	SiC(wt.)	Fly ash(%wt.)
AMMC-I	100	0	0
AMMC-II	97.0	0	3
AMMC-III	94.0	3.0	3
AMMC-IV	91.0	6.0	3
AMMC-V	88.0	9.0	3
AMMC-VI	85.0	12.0	3

Table 2: Combinations of AMMC's Stir casted for conducting tests

Fig. 2: Stir casting setup

Fig. 3: Stir casted AL7075 MMC

D. Mechanical Properties

The effect of changes in the reinforcement particles in different weight percentage of SiC and CSFA with Al7075 composites were analyzed by determining the mechanical properties of the specimens viz hardness, tensile strength and impact energy [6]. The hardness test was performed as per ASTM E10-07 standards using Brinell hardness testing machine with 10 mm ball indenter and 500 kg load [23].

The hardness was measured using a test specimen of 40 mm × 40 mm × 10 mm. The hardness values were measured in three different places in each specimen and the average value of the hardness is presented in the paper. The composite specimens for determining the tensile strength were prepared according to the ASTM E8-M04 standard [27]. The standard dimensions of tensile test specimen (6 mm of thickness, 12 mm of width, 40 mm of the gauge length with 30 mm gripping surface length) are shown above. The tensile strength was measured using a computerized universal testing machine HITECH TUE-C-1000 [14].

III. LITERATURE REVIEW

M.S. Aldrin Sugin et al made an Investigation on (Fabrication and Characterization of Aluminium 7075 - fly ash Metal Matrix Composite with Analytical Verification on Application to Aircraft Wings) in which requirement for high quality and lightweight materials is the need of the day in all fields of applied sciences [12]. This exploration work focuses on the creation of a light weight material by adding fly ash to Aluminium 7075, in this manner shaping a metal lattice composite. Utilizing Aluminium fly ash metal network composite an unmanned ethereal vehicle wing is demonstrated and dissected. The thickness of the composites lessens with increment in fly debris content for fortification. So Aluminium-fly debris Metal grid composites can be used in applications where weight decreases are required. Rigidity, sway quality and hardness were decided for the examples created. Expanding fly debris content up to 15% brought about increment in the rigidity of the Al. Additionally hardness of the composites was additionally found to increment with expanded fly debris content [12].

Vitala H R et al has said that this exploration is chiefly expected to assess the impact of nitriding on the wear conduct of Al_2O_3 strengthened aluminum-7075 metal framework composite materials. The measure of Al_2O_3 in these composites was fluctuated from 3% to 7% (by weight) in steps of 2%. The compaction load was streamlined to get an equivalent thickness as base specimens, then the compacted examples were sintered at 5400 C which is 80% of liquefying temperature aluminium base amalgam [5]. The sintered materials were nitrided with a temperature of 520°C for 72hrs. Natural X-Ray Diffraction procedure (XRD) was utilized to guarantee the dispersion of nitrogen to the outside of composites. After all the standard tests it was seen that the nitrided composites have demonstrated preferred wear opposition over the non-nitrided composites. Expansion of Al_2O_3 fortification to the aluminium alloy matrix enhances the wear opposition property of the composites. Nitriding surface treatment process incredibly improves the wear protection from a next level. Results uncovered that, hardness and thickness expanded with increment in joining of Al_2O_3. Accordingly, maintaining a strategic distance from substantial materials, consequently CO_2 will be diminished particularly for autos and moving components [16].

G. B. Veeresh Kumar et al has said that the exploratory consequences of the investigations directed with respect to hardness, rigidity and wear opposition properties of Al6061-SiC what's more, Al7075-Al2O3 composites [20]. The composites are readied utilizing the fluid metallurgy system, in which 2-6 wt. %age of particulates were scattered in the base network in steps of 2. The acquired cast composites of Al6061-SiC and Al7075-Al2O3 and the castings of the base combinations were painstakingly machined to set up the test examples for thickness, hardness, mechanical, tribological tests and just as for microstructural considers according to ASTM measures. Microhardness of the composites found expanded with expanded filler content and the increment in hardness of Al6061-SiC and Al7075-Al2O3 composites are seen as 60- 97VHN and 80-109VHN individually. The rigidity properties of the composites are discovered higher than that of base framework and Al6061-SiC composites prevalent elasticity properties than that of Al7075-Al2O3 composites [18]. The wear opposition of the composites are higher, further the SiC contributed fundamentally in improving the wear obstruction of Al6061-SiC composites.

Arun Babu Nallabelli et al made an examination on (Evaluation of Mechanical Properties of Al 7075 Reinforced with WC Metal Matrix Composites) the Al 7075 was broadly applied in airplane motor and wings [9]. Due to their higher hardness, higher quality, astounding wear opposition, and high-temperature. Tungsten carbide is appealing as support since it has high hardness, high modulus of flexibility and astounding warm solidness. The advancement of Al7075 composite based metal lattice fortified with fluctuating strides of tungsten carbide by 1.5wt%, 3wt%, 4.5 wt%, 6 wt% and furthermore test study was completed to explore the mechanical properties, for example, hardness, elasticity, sway quality. The smaller scale hardness of the composites was Enhancing from 83 HV to 121 HV with expanding weight level of WC particles. The WC support has improved the elasticity of Aluminium Matrix Composites (AMCs) from 217 MPa to 298 MPa. The Wt% Of WC support has Increased the effect quality of Aluminium Matrix Composites (AMCs) Reduced from 6 J to 2 J [19].

Rohith Nagabhyrava et al made an examination on (Investigation of Mechanical Properties of Al 7075/Sic/Gr Hybrid Metal Matrix Composites) to contemplate the mechanical properties of Aluminium Hybrid Matrix Composites (AHMCs) strengthened with silicon carbide (SiC) also, graphite (Gr) particles [4]. Aluminium 7075 amalgam is utilized as the grid material with support of SiC particles from 4 to 12 wt% in steps of 4 wt% and fixed amount of 3 wt% of graphite. The Al 7075-SiC-Gr half and half composite by utilizing Stir Casting with legitimate circulation conveyance of fortification particles. The hardness of composites expanded essentially with expansion of SiC particles, while most extreme hardness was gotten for 12% of SiC and 3% Graphite fortification. The Ultimate rigidity expanded with an expansion in wt% of fortification in the half breed composite [14]. The expansion of fortifications to Al7075 leads to diminish in rate prolongation.

B. Vijay Kiran et al (Investigation on mechanical properties of AL 7075 with magnesium oxide nano powder mmc) have investigated by preparing a matrix composite reinforced with magnesium oxide using stir casting technique [28]. They have varied the wight percentage of the particles at 5% & 10 % and have found that tensile properties and hardness and values after reinforcing has increased many-folds than non-reinforced nano particles. Also, it is experimentally proven that stir casting was the best method for their fabrication as it resulted in even-spreading of nano particles throughout the specimen. They experimentally found that at 100% Al the ultimate load is 5.220KN & Ultimate tensile strength is 50.887N/mm2, hardness value is 96.83. At 95% Al and 5% of MgO, Ultimate load is 13.500KN, Ultimate tensile strength is 137.042N/mm2, hardness value is 92.07. At 90% Al and 10% MgO, Ultimate load is 19.800KN, Ultimate tensile strength is 197.211N/mm2, hardness value is 100 [28].

Santhosh Kumar B M et al has said that Endeavours are made to contemplate the Wear pace of as-cast Tungsten carbide particulates and Short E-glass filaments fortified AL7075 Hybrid Composites. The vortex technique for mix throwing was utilized, in which the fortifications were brought into the vortex made by the liquid metal by methods for the mechanical stirrer [19]. Castings were machined to the ASTM norms on an exceptionally advance. Level of progress of Wear qualities of MMCs is firmly subject to the sort of support. An improved Wear The coefficient of erosion of Al7075 amalgam and its crossover composites reduces with Addition optional fortifications. A tremendous decrease in coefficient of grating is seen with double fortification. Warmth treated amalgam and its cross-breed composites have appeared marginally diminished coefficient of erosion when assessed with unreinforced aluminium amalgam and its cross-breed composites. Further, Heat treatment has brought about least wear pace of network material and half-breed composite under indistinguishable test conditions [19]. An exceptional change in wear instrument is seen in half and half composites contrasted and unreinforced Al7075 amalgam.

Rupa Dasgupta made an Investigation on (Aluminium Alloy-Based Metal Matrix Composites: A Potential Material for Wear Resistant Applications) in which Aluminum amalgam-based metal grid composites (AMMCs) have been at this point set up themselves as a reasonable wear safe material particularly for sliding wear applications [9]. An endeavour has been made in the present to improve feature the impact of scattering SiC base amalgam embracing the fluid metallurgy course on various wear modes like sliding, scraped area, disintegration, and blends of wear modes like cavitation disintegration, disintegration scraped area, sliding scraped area, and the outcomes acquired contrasted and the base composite [9]. At the point when the topic of suitability emerged, from the extraordinary strategies embraced for making AMMCs the fluid metallurgy course remained ahead because of its simplicity of manufacture; in spite of the fact that different courses were progressively proficient with respect to property accomplishment and microstructural highlights, still the simplicity of manufacture added to the cost financial aspects made the fluid metallurgy highway an aggressive and reasonable strategy.

B. S. Motgi et al has said that Aluminum combinations are broadly utilized in aviation vehicle businesses because of their low thickness and great mechanical properties, better erosion opposition and wear, low warm coefficient of extension when contrasted with show metals and compounds [17]. The fundamental point associated with the present work is centred around investigation of mechanical properties of Al7075 compound composite having changing weight rates of 3% - 6% of Silicon Carbide, fly debris and Red mud were created by fluid metallurgy (Stir Casting) technique. The thrown composite examples were machined according to BS: 18: 1962 test principles. The outcome got uncovers that ductile quality, sway quality and wear opposition are higher in Al7075-SiC-Redmud tests when contrasted with Al7075-SiC-fly ash tests [17].

C. Saravanan et al made an examination on (Effect of Particulate Reinforced Aluminium Metal Matrix Composite) in these most of the part used to improve mechanical and tribological properties like quality, firmness, scraped area, sway opposition and wear obstruction [10]. The work has been accounted for to improve the properties of various aluminium based MMC by shaping their composites being fortified with different materials, for example, Al2O3, TiB2, TiO2, SiC, TiC and B4C and so forth. The MMC is manufacture by STIR CASTING. the thickness of the composite increments with the expansion of the hard-artistic fortification into the lattice material. It has been seen that there is an expansion of 30% in hardness and there is an expansion in elasticity that is double the base aluminium combination. an occurrence of Mix throwing, process parameters like mixing rate, blending temperature, pouring temperature and so on., are to be kept up for accomplishing better properties of MMC [10]. For assembling of composite material by mix throwing, information on its working parameters, distinctive creation strategies, for example, strong state forms including powder metallurgy (PM Route), high vitality ball processing, rubbing mix process, dissemination holding and fume affidavit systems are extremely fundamental. On the off chance that the procedure parameters are appropriately controlled, it could prompt the improved properties in composite material.

IV. Results and Discussion:

A. Hardness:

Hardness is the resistance of a material to plastic deformation usually by indentation. However, the term may refer to stiffness or temper or to resistance to scratching, abrasion or cutting. Also, hardness is a measure of resistance to penetration. In another sense, it is the resistance to permanent deformation and is related to the bond in lattice structure.

Hardness of a material depends upon the type of bonding forces between the atoms, ions or molecules and increases, like strength, with the magnitude of these forces. Thus, molecular solids such as plastics are relatively soft, metallic and ionic solids are harder than molecular solids, and covalent solids are the hardest materials known. There is a close connection between the yield strength of metals and their hardness.

Fig. 4: Hardness test specimen.

Sample	Observed HBW(10mm ball/1000kg load)
AMMC-I	107
AMMC-II	114
AMMC-III	122
AMMC-IV	129
AMMC-V	135
AMMC-VI	149

Table 3: Hardness values of the AMMC samples

1) Observation

The hardness values were measured at three locations in each sample and the average of three hardness values for each sample is listed in Table 4. It indicates that hardness of composite material increases with addition of B4C and CSFA reinforcement in aluminium alloy. The increasing wt.% of reinforcement gives increment value of hardness from 107 BHN to 149 BHN. The maximum hardness was 149 BHN by cumulative reinforcement of 15wt.% SiC and CSFA particles in aluminum alloy i.e., (12% SiC + 3% CSFA) Similar results were found in the fly ash particle reinforced composites, which improved hardness of the aluminum matrix composite. Thus, it proves that reinforced samples are showing better mechanical characteristics like hardness comparing with non-reinforced sample. It is also evident that there is gradual increase in hardness with addition of reinforcement materials unlike tensile and impact test results. Therefore, addition of reinforcement helps in achieving higher hardness than that of non-reinforced AL 7075.

B. Tensile strength:

Tensile strength is the ratio of maximum load to original cross-sectional area. It is also known as ultimate tensile strength, in other it refers to the force needed to fracture the material. It is maximum for ductile materials and minimum for brittle materials. It is the measure of strength and ductility of a material. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, such as breaking or permanent deformation. Tensile strength specifies the point when a material goes from elastic to plastic deformation. It is expressed as the minimum tensile stress (force per unit area) needed to split the material apart.

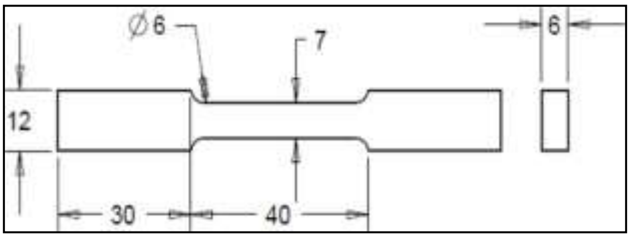

Fig. 5. Tensile test specimen size

Tensile strength testing for metal will determine how much a particular alloy will elongate before hitting ultimate tensile strength and how much load a particular piece of metal can accommodate before it loses structural integrity. Therefore, it is very important in material science. It is also vital for construction safety and personal safety, both during and after the building is completed.


Fig. 6: Tensile test specimen

Sample	Elongation (%)	UTS (N/mm^2)
AMMC-I	13.8	114
AMMC-II	13.5	121
AMMC-III	8.74	131
AMMC-IV	2.6	98
AMMC-V	6.94	110
AMMC-VI	4.91	80

Table 4: Tensile test readings of AMMC samples

1) Observation

It is evident from the test results that impact strength of the composite sample increases with the addition of silicon carbide and attains a maximum value of 1.2 joules. The value is 1.2 for the sample IV (6% SiC + 3% CSFA) and on further addition the value decreases in the samples to 0.75 J and 0.8 J samples V and VI. The impact strength of the sample is maximum and constant at silicon carbide composition of 0% and 6%. This increase in the impact strength also implies that the addition of reinforcement at the composition rate of 6% silicon and 3% coconut shell fly ash is giving significant increase than the sample tested without adding reinforcement materials. Hence it is experimentally visible that the addition of reinforcement at respective values yields increased impact energy hence increased mechanical properties are obtained than non-reinforced AL 7075.

C. Impact strength

Impact strength is a complex characteristic which takes into account both toughness and strength of a material. The capacity of a material to resist or absorb shock energy before it fractures is called its impact strength. Impact strength depends upon the structure of a metal. Coarse grain structure and precipitation of brittle layers at the grain boundaries do not appreciably alter the mechanical properties in static tension, but they substantially reduce the impact strength.

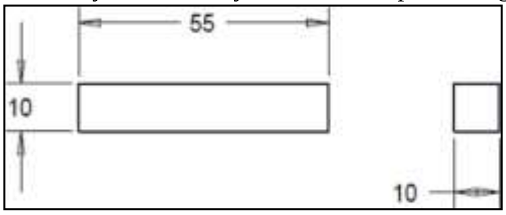

Fig. 7: Impact test specimen size

Impact strength is dependent upon rate of loading and temperature and also upon stress raisers such as notches. Ductile materials have more impact strength when compared brittle materials. It can be found out by subjecting the specimen to Charpy or Izod test.

1) Observation

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Sample	Observed energy (joules)
AMMC-I	0.6
AMMC-II	1.0
AMMC-III	0.6
AMMC-IV	1.2
AMMC-V	0.75
AMMC-VI	0.8

Table 5: Observed values of impact energy

V. CONCLUSION

The results of the tests show that the properties such as tensile strength, hardness and impact strength varying according to the composition of silicon carbide and fly ash. The effect of reinforcements and their composition on the metal matrix composite are studied. The samples of the composites could be tailored for special applications as the samples have a wide range of improvement in properties.

1) Hardness of the material increases with increasing content of reinforcement content in the matrix. The maximum hardness value obtained was 149 for a composition of 12% of silicon carbide and 3% of coconut shell fly ash.
2) AMMC-III with a composition of 3.0% silicon carbide and 3% fly ash shows a better tensile value when compared to other samples. So, it can be incorporated in applications requiring good tensile property.
3) AMMC-IV having composition of 6% silicon carbide and 3% fly ash show good capability of impact energy

absorption of 1.2 joules. Mechanical properties of the aluminium hybrid composites have been investigated and studied.

4) It is also evident that hardness of the specimen is maximum when reinforcement content is high unlike and tensile and impact strength where the maximum values of test result are obtained for moderate addition of reinforcement content.
5) Also, mild cracks where evident in the stir casted component which indicates fracturing while cooling down after pouring into the mould.
6) Considerable increase in mechanical properties are evident from the values obtained above respectively which indicates that the reinforcements can be used as possible alternatives to obtain increased

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