Evaluation of Mechanical Properties of Aluminium Cast Alloy LM24 Reinforced With Rice Husk Ash And Tio_2 Particles

Chandrappa S[1], Dr. H K Shivanand[2], Poornima Y H[3]
[1, 2, 3] Dept of Mechanical Engineering
[1, 2, 3] University Visvesvaraya College of Engineering, K.R.Circle, Bengaluru – 560001, Karnataka, India

Abstract- *In this study, aluminium LM24 hybrid composites were fabricated by reinforcing eco-friendly rice husk ash and Titanium oxide powder. The casting method was adopted is stir casting process method. Titanium oxide and rice husk ash were added in different ratios in percentage by weight. The ratios of these are 2:1, 2:3, 2:5, 4:1, 4:3, 4:5, 6:1, 6:3 and 6:5 defined for study purpose. The behaviour of aluminium LM24 against these weight ratios were studied on mechanical properties namely Tensile strength, Percentage of elongation and Hardness and the results were compared. The fracture mechanism of tensile specimens were studied by Universal Testing machine. The tensile strength and hardness Increasing rice husk ash particles in hybrid composites decreases the tensile strength and hardness. Brittle fractures in the form of cracks, and particle fractures were formed due to the solid interfacial bonding between the reinforcements and alloy. Ductile fractures are the reason for high impact strength and are characterised by dimples and voids. The eco-friendly rice husk ash has the potential to serve as reinforcement for the development of hybrid composites.*

Keywords- Hybrid Aluminium metal matrix, stir casting, Titanium Oxide, Rice Husk Ash, Mechanical Properties.

I. INTRODUCTION

Many of the engineering applications in the world today require materials with unusual combination of properties that cannot be met by the conventional metal alloys, ceramics or polymers. This is especially true for the materials that are needed for aerospace, Naval and transportation applications. For example aircraft engineers are request for structural materials that have low densities yet strong, hard yet impact resistant, and so on. Frequently, materials having high strength have relatively high density, also increasing the strength or stiffness results in a decrease in impact strength. Engineers around the world have always been in search of better combination of properties in materials.

Metal matrix composites are composed of a metallic matrix (aluminium, magnesium, iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase. Metal matrix composites, at present though generating a wide interest in research fraternity, are not as widely in use as their plastic counterparts. High strength, fracture toughness and stiffness are offered by metal matrices than those offered by their polymer counterparts. They can withstand elevated temperature in corrosive environment than polymer composites. Most metals and alloys could be used as matrices and they require reinforcement materials which need to be stable over a range of temperature and non-reactive too. However, the guiding aspect for the choice depends essentially on the matrix material. Light metals form the matrix for temperature application and the reinforcements in addition to the aforementioned reasons are characterized by high module.

Most metals and alloys make good matrices. However, practically, the choices for low temperature applications are not many. Only light metals are responsive, with their low density proving an advantage. Titanium, Aluminium and magnesium are the popular matrix metals currently in vogue, which are particularly useful for aircraft applications. If metallic matrix materials have to offer high strength, they require high modulus reinforcements. The strength-to- weight ratios of resulting composites can be higher than most alloys. The melting point, physical and mechanical properties of the composite at various temperatures determine the service temperature of composites.

MMCs are mostly fabricated by adding ceramic particles as reinforcement due to the ease of processing, low thermal shock and relatively inexpensive. The matrix phase can be selected based on their melting temperature of the alloy, corrosive resistance, oxidation, bonding nature and castability of metals [1]. AMCs are widely used due to their inherent properties of low density, high strength–weight ratio, wettability, fluid flow and ease of availability. The strength of AMCs depends on the composition of metals and ceramics, fabrication process, materials selection and grain size of the reinforcements [2]. P.K. Rohatgi et al., [3] investigated the mechanical properties like compressive strength, ductility, and hardness by using aluminium fly ash composites. By increasing the weight fraction of the fly ash particles the above mentioned properties gets improved. Different composition needed to be added in the fly ash composites to enhance their properties further. R.L. Deuis et al., [4] have fabricated the aluminium fly ash composite by stir casting process. The addition of fly ash acts as a barrier to the movement of dislocations and there by increases the hardness of the composite. And also by adding fly ash to the aluminium in molten state increases the abrasive wear resistance. This strengthening of the composite is because of the solid solution strengthening, dispersion strengthening and particle reinforcement. M. Mares et al., [5] have prepared a composite by using aluminium 6061 as the matrix and SiC, fly ash as the matrix material. The composite is produced by stir casting technique in which the weight fraction of the silicon carbide is varied (from 2.5%, 5%, 7.5%. 10%) by fixing the fly ash weight fraction (5%). From the analysis it is clear that by increasing the weight fraction of SiC the tensile strength and hardness of the composite gets improved. M. K. Surappa et al., [6] have investigated the mechanical properties of hardness and wear rate by using different casting techniques .In this, al –fly ash with 7.5% weight fraction has high hardness and wear rate when compared to the aluminium alloy produced by squeeze casting and gravity casting. And also the sample produced in this gravity casting has low hardness and high wear rate. MahendraBoopathi et al., [7] have used eutectic -Al -Si -alloy as a matrix material with increasing fly ash (in wt. %) as a reinforcement and prepared a composite using squeeze casting by applying pressure .By increasing theweight percentage of fly ash the sliding wear resistance of the composite gets improved. And also by employing squeeze casting the porosity in composite has been removed. Ganesh Pandi et al., [8] have produced al/fly ash/graphite metal matrix composite using stir casting by fixing wt % of graphite (3%) and varying the composition of fly ash (3 to 9%). It has been observed that the sliding wear rate depends on the load. And also the hardness of the hybrid metal matrix composite is more when compared to Al 6061. S. Rama rao et al., [9] fabricated the metal matrix composite by using al-4.5% cu as the matrix material and fly ash with varying weight fraction (5 to 15%) as the reinforcement material. The composite is produced by stir casting method in which the impact strength, compressive strength, tensile strength and hardness increases with increase in fly ash content. But the density and corrosion resistance decreases. E. Mohammad Sharifi et al., [10] investigated the pitting corrosion behaviour and corrosion kinetics of Al alloy. In this method, they have used AK12 as the matrix material and fly ash as the reinforcement to produce the composite by gravity casting and squeeze casting. Fly ash particles lead to an enhanced pitting corrosion of the AK12/9% fly ash composite in comparison with unreinforced matrix. Cui Y Geng et al., [11] have used LM25 aluminium alloy as the matrix material and constant weight fraction of fly ash (3%) with varying weight fraction of aluminium oxide (5%,10%,15%) as the reinforcement to produce the composite by stir casting. By analysing this sample, the tensile strength and hardness gets increased with increase in % wt of aluminium oxide. But the major issue is the ductility and impact strength gets reduced. Bhandakkar A et al., [12] have chosen al6061 alloy as the matrix material and 2 to 8wt% of fly ash with 2 and 6wt% of e-glass fibre as the reinforcement to produce the composite by stir casting. The hardness, tensile strength and compressive strength increases as the wt % of fly ash increases. And also the samples were tested using ultrasonic flow detector to identify the defects. Madhu Kumar Y C et al., [13] have opted Al6061 alloy as the matrix and bottom ash as the reinforcement to produce the composite by stir casting. Micro hardness and tensile strength of the composite increases with increase in wt% of bottom ash particles. But the problem is, after 9% wt of bottom ash the tensile strength and micro hardness decreases. B.S. Unlu et al., [14] have used aluminium alloy 6351 as the matrix material and fly ash with weight percentage (5 to 15%) as the reinforcement to produce the composite by stir casting. From the result it is clear that the composite does not wear at low loads. And the result shows that the applied load has the greatest effect on dry sliding wear. Shyong J.H. et al., [15] have utilized eutectic Al-Si-alloy LM6 containing 12.2491% Si as the matrix and the cenosphere of two different types (fly ash type- A and type -B) as the reinforcement to produce the composite by stir casting. The micro hardness, tensile strength, impact strength and hardness were higher for type-B fly ash because of its micro structural differences and presence of small amount of carbon. H.C. Anilkumar et al., [16] observed that in the case of Aluminium 6061 metal matrix composites, density of the composites increased with increasing weight percentage of the reinforcements. The wettability and the bonding force between aluminium alloy and reinforcement particles were improved by the applied pressure after pouring and porosity also decreased because of this pressure. The tensile strength and hardness of MMCs increased while the elongation of composites decreased with decreasing size and increasing weight percentage of the particles in stir casting method.

II. EXPERIMENTAL PROCEDURE

Materials

From critical literature review, LM 24 Aluminium Alloy is selected as matrix material and the need is fulfilled by "Fenfee metallurgical Pvt. Ltd. Bengaluru", so as the research requirement is to form a hybrid type composite, materials selected as reinforcement are Rice Husk Ash and TiO2. Rice Husk Ash was may be obtained from Chamundeshwari Rice Mill, Maddur and TiO2 was mat be obtained from Snam Abrasives. Detail information regarding these materials is as follows.

Matrix Alloy - LM24 Aluminium alloy

Figure – 1: LM24 Aluminium Ingots

Table-1 : Mechanical Properties of LM24 aluminium alloy

	Chill Cast	Die Cast
0.2% Proof Stress (N/mm^2)	100-120	150
Tensile Strength (N/mm^2)	180	350
Elongation (%)	1.5-4	1-3
Impact resistance Izod (Nm)	-	3.4
Brinell Hardness	85	85
Modulus of Elasticity ($x10^3$ N/mm^2)	71	74
Shear Strength (N/mm^2)	-	185

Table-2 : Chemical Composition of LM24 aluminium alloy

Copper	3.0 – 4.0
Magnesium	0.3 max
Silicon	7.5 – 9.5
Iron	1.3 max
Manganese	0.5 max
Nickel	0.5 max
Zinc	3 max
Lead	0.3 max
Tin	0.2 max
Titanium	0.2 max
Aluminium	Remaining

Reinforcement - Titanium Oxide

Figure – 2: Titanium Oxide particles

Table-3 : Physical Properties of Titanium **Oxide**

Molar mass $g\text{-}mol^{-1}$	79.8658
Refractive index	2.76-2.55
Mohs Hardness	5.5-6
Capacitance ratio	114 to 31
Coefficient of linear expansion	25
Thermal conductivity	1.809 to 10.3
Oil absorption	16-48
Particle size	0.2-0.3

Table-4 : Characteristics of Titanium Oxide

Property	Minimum	Maximum
Atomic Volume m3/kmol	0.0057	0.007
Density(Mg/m3)	3.97	4.05
Energy content (MJ/kg)	100	150
Bulk Modulus (GPa)	209.1	218.1
Compressive strength (MPa)	660	3675
Ductility	0	0
Elastic Limit (MPa)	333.3	367.5
Endurance Limit (MPa)	283.5	330.7
Fracture Toughness ($MPa.m^{1/2}$)	2.4	3.3
Hardness (MPa)	9330	10290
Loss Coefficient	5e-0005	8e-005
Modulus of Rupture (MPa)	140	441.2
Poisson's Ratio	0.27	0.29
Shear Modulus	90	112.5
Tensile Strength (MPa)	333.3	367.5
Young's Modulus (GPa)	230	288
Latent Heat of Fusion (kJ/kg)	820	930
Maximum Service Temperature (°K)	1840	1910
Melting Point (°K)	2103	2123
Minimum Service Temperature (°K)	0	
Specific Heat (J/kg.°K)	683	697
Thermal Conductivity (W/m.k)	4.8	11.8
Thermal Expansion (10^{-6}/°K)	8.4	11.8
Breakdown Potential (MV/m)	2	12
Dielectric Constant	10	85
Resistivity (10^{-8}ohm.m)	1e+019	1e+024

Reinforcement – Rice Husk Ash (RHA)

Figure – 3: Rice Husk

Rice Husk is the outermost layer of protection encasing a rice grain. It is a yellowish colour and has a convex shape. It is slightly larger than a grain of rice with typical dimensions 4mm by 6mm. It is light weight, available in plenty having bulk density of 340kg/m^3 to 400kg/m^3.

The Ash was obtained by burning Rice Husk in a steel vessel. This was thoroughly washed with water to remove dust particles and dried at room temperature for 24 hrs. The washed Rice Husk Ash was then heated to 100°C for 2hrs in order to remove the moisture and organic matter. Finally the RHA was again heated in furnace (Owen) to 500°C for 12hrs. The chemical composition of RHA is listed in table-5.

Table-5: Chemical Composition of Rice Husk Ash

Silicon Dioxide	86.94%
Aluminium Oxide	0.2%
Iron Oxide	0.1%
Calcium Oxide	0.3- 2.25%
Magnesium Oxide	0.2-0.6%
Sodium Oxide	0.1-0.8%
Potassium Oxide	2.15-2.3%

Figure – 4: Rice Husk Ash

Specimen Preparation

The liquid processing route utilizing the technology of stir casting has been selected for current work. In this technique, initially the selected matrix material is heated until it reaches its melting point i.e. material is allowed to melt inside an incubation chamber. Also the material selected as reinforcement is also added after a saturation point is reached inside the chamber and material is in molten state. After adding the reinforcement material stirring is carried out by a stirrer arrangement provided on equipment. This is most efficient method usually followed and also followed in this research. During operation, mold which is of same shape as that of required dimension is placed properly to carry the final mixture. After thorough stirring, the mixture is poured in to the mold cavity and final casting is obtained once a directional solidification is accomplished.

The synthesis of the composite material in the present study is carried out by stir casting technique. The Aluminium LM24 Alloy in the form of ingots were placed in the Graphite Crucible and heated to 850° C till the entire Alloy in crucible is melted. The reinforcement particles RHA and TiO2 are pre heated to 400°C for 2hrs before incorporating into the Graphite Crucible containing Aluminium LM24 melt. Degassers tablet like HexaChloro Methane and 1% of Magnesium was added before reinforcing the TiO2 and RHA particles. Degasser reduces the blow holes and porosity during the cast preparation. While Magnesium is added to get wet ability property for the formation of the composite.

A mechanical stainless stirrer was lowered for mixing of matrix and reinforcement material thorough at a speed of 600 rpm. The reinforcement of 2% wt of Tio2 and 1% wt RHA was added into the melt and stirred for constant speed for 15minsfor proper mixing. Finally the combined mixture is poured into the mould which is preheated to 400° C for 20mins for proper solidification of the molten mixture. The above steps are repeated for the other weight volume fraction of 4% of Tio2 and 1% of RHA , 6% of Tio2 and 1% of RHA, 2% of Tio2 and 3% of RHA, 4% of Tio2 and 3% of RHA, 6% of Tio2 and 3% of RHA, 2% of Tio2 and 5% of RHA, 4% of Tio2 and 5% of RHA, 6% of Tio2 and 5% of RHA and necessary post finishing operations are carried out for respective tests to be conducted in later stages.

Table-6 : Percentage of Reinforcements

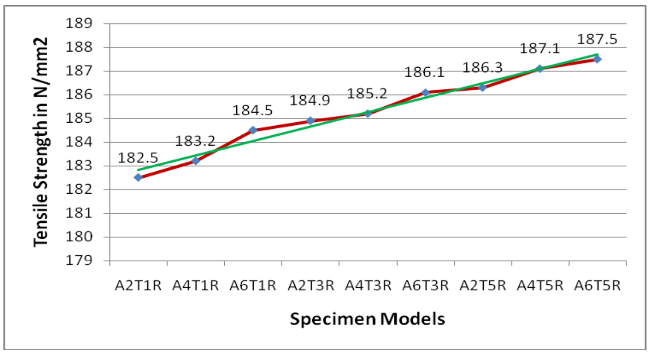
Models	Reinforcements		
	LM24 in %	TiO_2 in %	RHA in %
A2T1R	97	2	1
A4T1R	95	4	1
A6T1R	93	6	1
A2T3R	95	2	3
A4T3R	93	4	3
A6T3R	91	6	3
A2T5R	93	2	5
A4T5R	91	4	5
A6T5R	89	6	5

III. RESULTS AND DISCUSSION

Evaluation of Mechanical Properties

(a) Tensile property analysis for the specimen.

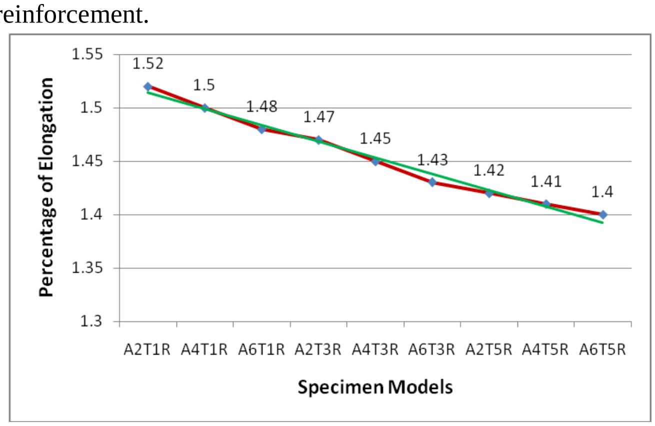
Specimens were processed according to the ASTM The relation between tensile strength of the fabricated specimen with different weight fraction of TiO2 and RHA is shown in Graph – 1. From the figure it can be said that for increasing volume fraction of reinforcement, the tensile strength is increases with increasing load is distributed among the reinforcement, Hence for higher volume fraction of reinforcement greater resistance to external load is observed. The green line in the graoh shows the linear property of the relation.



Graph – 1: Tensile strength of Specimens

(b) Percentage of elongation property analysis for the specimen.

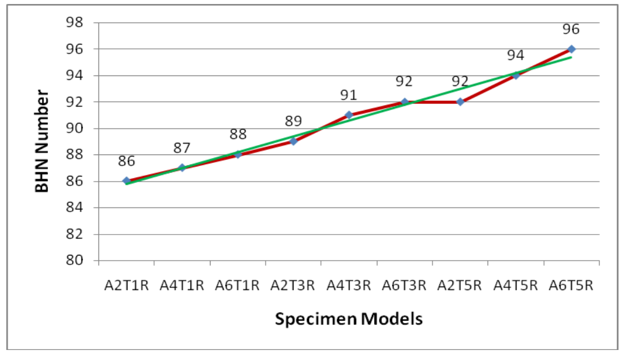
Specimens were tested along with tensile test for the property of Percentagae of elongation. The relation between Percentage of elongation of the fabricated specimen with different weight fraction of TiO2 and RHA is shown in Graph – 2. From the figure it can be said that for increasing volume fraction of reinforcement, the Percentage of elongation is decreases with increasing load is distributed among the reinforcement.



Graph – 2: Percentage of elongation of Specimens

(c) Hardness property analysis for the specimen.

Specimens were tested for the property of Hardness. The relation between Hardness of the fabricated specimen with different weight fraction of TiO2 and RHA is shown in Graph – 3. From the figure it can be said that for increasing volume fraction of reinforcement, the Hardness is decreases with increasingthe addition of RHA, consequently the presence of TiO2 particles increases the hardness property.



Graph – 3: Hardness of Specimens

IV. CONCLUSIONS

The conclusions drawn from the present study are discussed below

- A low cost agricultural waste in the form of Rice Husk Ash (RHA) and Titanium Di-oxide was successfully reinforced with Aluminium LM24 alloy by stir casting technique to form a hybrid composite.
- As RHA is available in plenty, it can be utilized as reinforcement with Aluminium alloy.
- The weight fraction of reinforcement increases the tensile property for the specimen due to surface resistance and elongation property of the reinforcement.
- The percentage of elongation is decreases with increasing the weight fraction of TiO2 and RHA reinforcement with the LM24 alloy.
- The hardness of the specimens with different weight fraction increases with increasing weight fraction of TiO2 and RHA reinforcement.

REFERENCES

[1] Zhang P, Li Z, Liu B, Ding W (2017) Tensile properties and deformation behaviours of a new aluminum alloy for high pressure die casting. J Mater SciTechnol 33(4):367–378

[2] Otarawanna S, Dahle AK (2011) Casting of aluminium alloys. In: Fundamentals of aluminium metallurgy. Woodhead Publishing, Oxford, UK, pp 141–154.

[3] P.K. Rohatgi , J.K. Kim, N. Gupta, Simonalaraj, A. Daoud, Compressive characteristics of A356/fly ash cenosphere composites synthesized by pressure infiltration technique, science direct 37(2006) 430- 437
[4] R.L. Deuis, C. Subramanian, J.M. Yellup, Abrasive wear of aluminium composites, a review, Wear 201 (1996) 132–144
[5] M. Mares, Some issues on tailoring possibilities for mechanical properties of particulate reinforced metal matrix composites, Journal of Optoelectronics and Advanced Materials, 3(1), 2001, 119 – 124.
[6] M. K. Surappa, Sudarshan, Synthesis of fly ash particle reinforced A356 Al composites and their characterization, Material Science and Engineering, A, Volume 480, 2008, 117-124.
[7] MahendraBoopathi, M. K.P. Arulshri and N. Iyandurai,” Evaluation of Mechanical Properties of Aluminum alloy 2024 reinforced with Silicon Carbide and fly ash Hybrid Metal matrix Composites”, American Journal of Applied Sciences, 10 (3): 219-229, 2013
[8] Ganesh Pandi, SarvananMathuSwamy,” A review on machining and tribologicalBehavior of aluminum hybrid composites”. Elsevier, Material Science (2012) 1399-1408.
[9] S. Rama rao. G. Padmanabhan, Fabrication and mechanical properties of aluminium-boron carbide composites, international journal of materials and biomaterials applications 2(2012) 15-18
[10] E. Mohammad Sharifi, F. Karimzadeh, M.H. Enayati, Fabrication and evaluation of mechanical and tribological properties of boron carbide reinforced aluminium matrix nanocomposites, Materials and Design 32, 2011 3263–3271.
[11] Bhandakkar A, Prasad RC, Sastry SM. Fracture toughness ofAA2024 aluminum fly ash metal matrix composites. IntJCompos Mater 2014;4(2):108–24.
[12] Madhu Kumar Y C, Uma Shankar, “Evaluation of mechanical properties of aluminum alloy 6061-glass particulates reinforced metal matrix composites”. IJMER, Vol 2 September 2012, PP 3207-3209
[13] B.S. Unlu, investigation of tribological and mechanical properties Al2O3-SiC reinforced Al composites manufactured by casting or P/M method, Materials and Design, 29, 2008, 2002-2008.
[14] Shyong J.H, Materials Science & Engineering A: Structural Materials; properties, Microstructure and processing, Vol.A197, N 1, Jun 30 1995, pp 11-18.
[15] Scolians S, Materials Science & Engineering A: structural Materials; Properties, Microstructure and processing Vol. A210, N1-2, Jun 15 1996, pp.2269-2276H
[16] H.C.Anilkumar, H.S.Hebbar and K.S.Ravishankar, “Mechanical properties of Fly Ash Reinforced Aluminum Alloy (Al6061) Composites”, IJMME, 2011, Vol.6, Issue.1, pp. 41-45.