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CHAPTER 1

INTRODUCTION

Our current society is dependent on different types of metal usage and the demand is growing every day. To meet this demand, we need to produce the right amount of product which is dependent on several criteria. Some of the criteria are, proper supply of the raw materials, produce and meet the demand, effective cost management and the quality of the products.

The main challenges in material productions are, preparing raw materials, production environment (such as, temperature), material testing which are costly process that increase the cost of the final product. To reduce the cost, scientists have proposed many solutions, which includes mixing of other materials, such as, zinc, silicon, magnesium, carbide, tin etc. However, those materials also need the same process of production, thus cannot minimize the cost significantly.

Besides adding materials to other materials, scientists have also proposed to mix bio products which are easily available and cheap in terms of other materials. This hybrid solution has created a new way of making metal in a cost-effective manner, that serves the same purpose (e.g., strength).

The main aim of this report is to mix some bio-ash reinforcements separately, such as, rice husk, cow dung and jute stick with aluminium alloy and to test their hardness, tensile strength and double shear strength. This report not only shows the result of testing but also compare those three tests by blending the materials, like, alloy with rice husk, cow dung and jute stick ash mix. The purpose of mixing all bio elements with alloy is to re-verify the strength of newly produced alloy.

During the past few years, material design has changed prominence to pursue light weight, environment friendliness, low cost, quality, higher service temperature, higher elastic modulus, improved wear resistance and performance. Straight monolithic materials have limitations in achieving the above decisive factors. To overcome these limitations and to convince the ever-increasing demand of modern-day technology, attention has been shifted towards Metal Matrix Composites (MMC). Stir casting route is most hopeful for synthesizing discontinuous reinforcement Aluminium matrix composites because of its relative simplicity and easy adaptability with all shape casting process used in metal casting industry. Hybridization of metal matrix composites is the introduction of more than one type, size and shape of reinforcement during processing of composites. It is carried out to obtain synergistic properties of different reinforcements and matrix used, which may not be realized in monolithic alloy or in conventional mono-composites.

Composites are materials made from two or more constituent materials of significant properties, both physical and chemical that, when combined, produce a material with a whole new characteristic better than the individual characteristics of each constituents. These constituents along with the interface determine the characteristics of a composite [1]. However, within the composite the different materials can be identified easily as they do not dissolve or blend into each other. The constituents must be chemically dissimilar and separated by a distinct interface [2]. The most important advantage associated with composites is their high strength, hardness and stiffness along with low weight [3]. A typical composite has two parts: a strong, stiff reinforcement, that provides the strength and rigidity which is distributed in a second material, called the matrix, which serves to bind and protect the reinforcements [4]. Composites can be classified as dispersion strengthened, fiber reinforced, and particulate reinforced composites based on the reinforcement type and as metal matrix [5]. The MMCs are lightweight and resist wear and thermal distortion better than their metal counterparts, so it is mainly used in the automobile industry since here the emphasis is reduction and engine efficiency to improve fuel economy [6].

Aluminium is popular as a matrix due to its high strength to weight ratio, ductility and malleability, machinability and durability. Rice husk, Cow Dung and Jute Stick are low cost and low-density materials, exhibits superior physical and mechanical properties. Thus, Rice Husk Ash (RHA), Cow Dung Ash (CDA) and Jute Stick Ash can be utilized more effectively in the development of composite materials for various applications [7, 11]. Presence of silica is an additional advantage in comparison to other byproduct materials which makes RHA, CDA and JSA important material for a wide range of manufacturing and application-oriented processes [8, 12]. MMCs can be processed in either solid state or liquid state methods [9]. Stir casting technique is currently the most common and cost-effective commercial method for composite making. Mechanical mixing of the reinforcement particulate into a molten metal bath is the basic principle of this technique. The molten metal matrix is stirred vigorously to form a vortex at the surface of the melt and the reinforcement material is introduced at the side of the vortex. The stirring is continued for a few minutes before the slurry is cast. During stir casting for the synthesis of composites, stirring helps in transferring particles into the liquid metal and maintaining the particles in a state of suspension [10]. In this work RHA, CDA, JSA was used as the reinforcement. The main idea was to utilize the agro industrial waste to reduce its negative environmental impact and at the same time to develop a composite material economically with superior properties.

OBJECTIVES

The main objectives of this study are as follows:

Composite Processing

- *Processing of Aluminum Alloy 6061 and Rice Husk Ash (RHA).*
- *Processing of Aluminum Alloy 6061 and Cow Dung Ash (CDA).*
- *Processing of Aluminum Alloy 6061 and Jute Stick Ash (JSA).*
- *Processing of Aluminum Alloy 6061 with RHA, CDA and JSA.*

Material Testing

- *Hardness*
- *Tensile Strength*
- *Double Shear Strength*

Composite Processing Method*(discussed in chapter 4)*

- *Stir casting method (Properties of Stir Casting Method are in Appendix)*

LITERATURE REVIEW

The area of Aluminium Alloy is investigated quite a lot since this popular metal is used in many sectors from daily life to mass production in the industries. The reinforced composites considered in this project are also popular in terms of their availability, less costly and environment friendly. Following is a description of related projects those matches closely to this our work.

The concept of improved performance is broad and includes increased strength or reinforcement of one material by the addition of another material [13]. In recent years there has been an incredible interest in composites containing low density and low-cost reinforcements. The current research trend in composite materials can be traced in the development aluminum alloy which is easily available and less costly. The reduced weight and improved strength and stiffness of the MMCs are achieved with various monolithic matrix materials [14].

Our interest is mainly to make a metal matrix composite made of Al-6061 alloy with RHA, CDA and JSA. It should also be noted that, Aluminum based matrices also have the advantage that they are the cheapest among other competing matrix materials (Copper, Titanium, Magnesium) for metal matrix composites (MMCs) development; and, are amenable to processing using techniques [15]. Also, it conventionally suited to produce metals and alloys [16-17]. Al-6061 alloy or its similar alloy is used as a matrix for obtaining composites according to [15-16], which have an enhanced wear resistance, favorable mechanical properties at room temperature and enhanced mechanical properties at elevated temperatures. The results of preliminary mechanical tests on the obtained composite were compared with the known values of mechanical properties of a commercial modified heat treated A6061alloy [18]. Aluminium matrix composites (AMCs) are noted for their unique combination of mechanical, physical and chemical properties which are scarcely attainable with the use of monolithic materials [18, 20].

In terms of Jute Stick Ash with alloy, there are plenty of work accomplished in the area of material manufacturing and testing. As such, Vinod et. al. mentioned the purpose of supposition is important to reuse and dispose wastage materials into raw materials is especially beneficial not only for the environment but also reduce the production cost in automotive sectors that require large volumes of materials in structural applications [21]. On the other hand, in terms of tensile performance Issar et.al. mentioned, casted Aluminium exhibited increased tensile strength up to 181MPa and tensile strength increased to 175 MPa when fabricated with JSA particles compared to 139 MPa for the parent metal [22-23].

MATERIALS AND METHODOLOGIES

4.1 Materials selection:

The matrix material used in this study was commercially Aluminium of 98.2% purity. The chemical composition of Al 6061 after Spectro analysis is given in the following tables.

TABLE 1: Chemical Composition of Aluminium Ingot

AL	Cu	Mn	Cr	Mg	Zn	Fe
99.33	0.31	.08	0.16	0.99	.01	0.25

TABLE 2: Mechanical Properties:

0.2% Yield strength (MPa)	Ultimate tensile strength (MPa)	Elongation (%)
275	310	12

The reinforcement material was RHA, CDA and JSA prepared from the Rice Husks, Cow Dung and Jute Stick. These raw materials were collected from a village called 'Mohadanga' of Chapainawabganj district, which is the north-west part of Bangladesh. Magnesium at about 1% of the weight of the matrix was used as the wetting agent for the better adhesion of the reinforcements with the matrix. Mg addition reduces the casting fluidity at the same time it reduces the surface tension of the Aluminium [11]. The Mg addition was limited to 1% as increasing the content above 1% of the matrix weight increases the viscosity of the slurry to the detriment of particle distribution [12].

4.2 RHA, CDA and JSA preparation:

The rice husk (RH), jute stick (JS) and cow dung (CD) were washed thoroughly with water to remove the dusts, clay and dried at room temperature for 24 hours. They were then burnt at open atmosphere to remove the moisture and organic constituents. The color of the husk, Dung and Stick changed from yellowish to black at this stage due to charring of the organic matter. This was followed by heating the natural elements at 650^{o}C in a heat treatment furnace

(Model: SPX Blue M Hi-street)for two hours to remove the carbonaceous constituents leaving the grayish which silica rich husk ash, cow dung ash, jute stick ash to be used as the reinforcement of the composite.

4.3 Composite preparation

The composite was made by stir casting method. Initially 4.8 kg of Al was charged into a graphite crucible and melted to 810^{o}C in a pit furnace. As the metal melted, about 60gm of magnesium was added to the melt as a wetting agent between matrix and reinforcement since it reduces the casting fluidity as well as the surface tension of the molten Al. The Fabrication and Evaluation of Aluminium Rice Husk, Cow Dung and Jute Stick Ash composite prepared step by step using Stir Casting Method shown in figure 1 (Fig1).

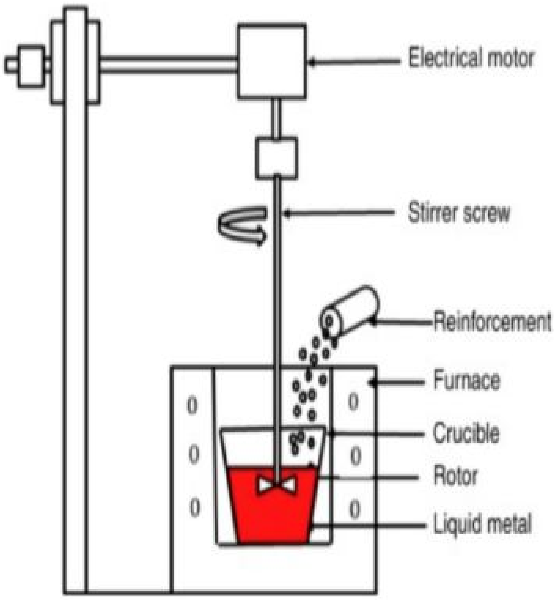


Fig 1: Schematic view of stir casting setup

Molten Al was then transferred to the holding furnace of the stir casting apparatus. RHA particles were preheated to 700^{o}C for 1hour so that the silica content remained amorphous below 800^{o}C. The graphite stirrer was lowered into the melt and stirring was commenced at 500rpm to create a vortex. The preheated RHA (~105-420μm) was added slowly into the melt at the side of the vortex to ensure a uniform distribution. The stirring was continued for another 7-8 minutes after adding the reinforcement so that the particle distribution and the mixing is done properly. The mixture was poured at a temperature of 732^{o}C into a mild steel permanent mold that was preheated earlier to obtain uniform solidification of the casting. Table 3 shows the percentage of reinforcements with aluminium.

TABLE 3: Percentage of reinforcements:

Elements	Percentage
Al	93%
Rice Husk Ash	7%
Cow Dung Ash	7%
Jute Stick Ash	7%

This process was also applicable for Cow Dung Ash and Jute Stick Ash (In 2nd& 3rd stage separately) In this process Al-RHA, Al-CDA and Al-JSA reinforced Al matrix composites were prepared. Later, the other composite was also prepared by mixing RHA, CDA and JSA in a cohesive way with aluminium in specific composition which is mentioned in table 4.

TABLE 4: Percentage of reinforcements

Elements	Percentage
Al	90%
Rice Husk Ash	4%
Cow Dung Ash	3%
Jute Stick Ash	3%

(a1) Raw Rice Husk

(a2) Carbonize Rice Husk Ash

(b1) Raw Cow Dung

(b2) Cow Dung Ash

(c1) Raw Jute Stick

(c2) Carbonize Jute Stick Ash

Fig 2: Each element before and after preparation

4.4 Raw material analysis

4.5 kg of rice husk was burnt that produced 948gm of ash which was approximately 21% of the rice husk taken initially. The loss of ignition was calculated as 30gm of ash was heated in the Blue M furnace for two hours and after the removal of carbonaceous matters, 21.804gm ash content was left. Hence the loss of ignition was (3021.804) gm or 8.196gm or 27.32%. Similar procedure was applicable for CDA and JSA which is showed in form of table 5.

TABLE 5: RAW materials analysis of RHA, CDA, JSA in the following table by following above process.

Name of the element	Weight of element before burnt (kg)	Weight of element after burnt (gm)	Weight of element after Burnt in percentage (%)	Loss in ignition of Ash before heated (gm)	Loss of ash content left after heated (gm)	Loss of ignition (gm)
RHA	4.5	0.948	21	30	21.804	8.196
CDA	4.5	0.854	19	38	26.314	11.686
JSA	4.5	1.464	32	25	19.302	5.70

EXPERIMENT AND ANALYSIS

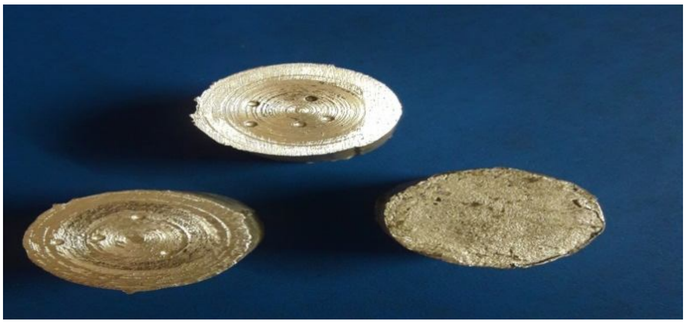
5.1 Hardness tests

The hardness of the samples was evaluated using Rockwell Hardness Testing Machine. The samples were machined and tested for hardness in B scale; with 100kg force and 1.58 mm diameter steel ball indenter for 30 seconds. Three indentations were taken on the surface at room temperature and the average value was calculated which shown on the table 06.

TABLE 6: Hardness test result for each composite.

Composite	Value taken (HRB)	Average value (HRB)
Raw Aluminium Alloy(6061)	35	34.33
	34	
	34	
Aluminium with Rice Husk Ash (93% Al+7% RAH)	42	43.33
	46	
	42	
Aluminium with Cow Dung Ash (93% Al+7% CDA)	40	41.33
	42	
	42	
Aluminium with Jute Stick Ash (93% Al+7% JSA)	46	46.67
	48	
	46	
Aluminium with RHA, CDA,JSA (90%Al+4%RHA+3%CDA+3%JSA)	41	43
	44	
	44	

(a) Hardness test sample of Al-RHA and Al-CDA



(b) Hardness Test Sample of Al-JSA and Al+RHA+CDA+JSA

Fig 3: Hardness test samples of Al with RH, CD, JS ash separately and all together

5. 2 Tensile tests

The tensile test was performed using universal testing machine. Two specimens were prepared for each composite using electrical discharge machining as per the ASTM: E08 standard for each composition as shown in figure 4 (Fig. 4). The average value of ultimate tensile strength was calculated.

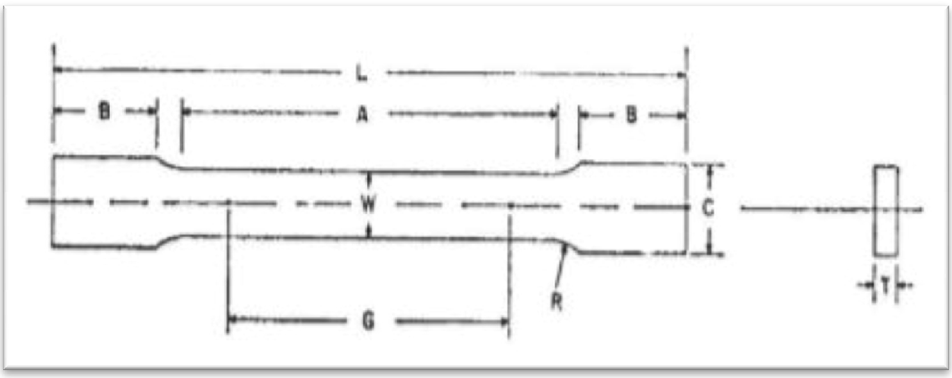


Fig 4: ASTM: E08 tensile strength test specimen.

TABLE 7: Tensile test result for each composite.

Composite	Test value (MPa)
Raw Aluminium Alloy(6061)	240.60
Aluminium with Rice Husk Ash (93% Al+7% RAH)	184.46
Aluminium with Cow Dung Ash (93% Al+7% CDA)	252.63
Aluminium with Jute Stick Ash (93% Al+7% JSA)	200.50
Aluminium with RHA,CDA,JSA (90%Al+4%RHA+3%CWDA+3%JSA)	192.48

TABLE 8: Dimensional Specifications of ASTM E8/E8m Sub size Tensile Sample.

Dimension	Range(mm)
Outer diameter	17.6
Inner diameter	12.6
Gage length, G	25
Width, W	6
Thickness, T	5
Overall length, L	100
Length of reduced section-A	32
Length of grip section-B	30
Width of grip section-C	10

(a)Tensile test sample of Al+RHA

(b)Tensile test sample of Al+CDA

(c)Tensile test Sample of Al+JSA

(d) Test Sample of Al+RHA+CDA+JSA

Fig 5: Tensile test samples of Al with RH, CD, JS ash separately and all together.

5. 3 Double Shear test

In Direct Shear Test, the shearing stress is considered as uniformly distributed over the entire cross section. The shear force is applied by a suitable test rig, two different cases of shearing may arise; i.e., single shear and double shear. In single shear shearing occurs across a single surface and in double shear shearing occurs across two surfaces. Knowledge of shear failure is important while designing any structures or machine components. Shear force causes the surface to go out of the alignment with each other and thus the material fails.

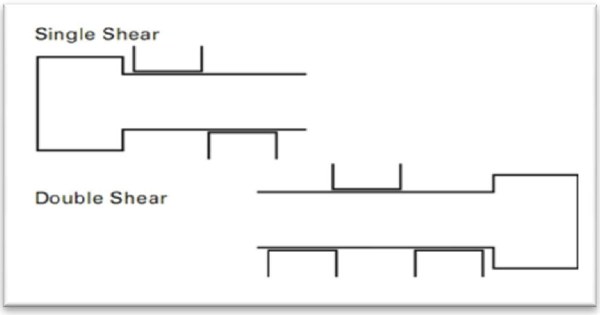


Fig 6: Direct shear strength test specimen.

The shearing force P in each section is P = F/2, it can be concluded that the average shearing stress is the maximum load divided by the combined cross-sectional area of the two planes This shall be calculated from the follow

$$\text{Double shear strength} = \frac{P}{A} = \frac{\frac{F}{2}}{A} = \frac{F}{2 \times A}$$

Shear strength of the specimen is determined by inserting a cylindrical specimen through round holes in three hardened steel blocks, the center of which shall be pulled (or pushed) between the other two to shear the specimen on two planes. In this test a suitable length of cylindrical specimen is subjected to double shear loading using a suitable test rig in a testing machine under a compressive load or tensile pull and recording the maximum load P to fracture. The speed of testing or the rate of separation of the cross-heads, at any moment during the test, shall not be greater than 10 mm/min.

5.3.1 Shear stress:

It is produced in a body when it is subjected to two equal and opposite forces spaced at an infinite decimal distance or tangentially across the resisting section.

$$\text{Shear stress, Ss} = \frac{\text{Shearing force}}{\text{Area of resisting section}}$$

Generally, it is difficult to produce conditions of pure shear as some bending effect is likely to occur due to shearing load resulting in equal and opposite forces at a small finite distance.

5.3.2 Test specimen:

The double shear test was performed using universal testing machine. Two specimens were prepared for each composition using electrical discharge machining as per the ASTM: E08 standard for each composition as shown in figure 7 (Fig. 7). The average value of Double Shear strength was calculated.

TABLE 9: Double shear strength test result for each composite.

Composite	Test value (MPa)
Raw Aluminium Alloy(6061)	105.95
Aluminium with Rice Husk Ash (93% Al+7% RAH)	130.87
Aluminium with Cow Dung Ash (93% Al+7% CDA)	122.15
Aluminium with Jute Stick Ash (93% Al+7% JSA)	117.16
Aluminium with RHA, CDA,JSA (90%Al+4%RHA+3%CDA+3%JSA)	123.40

Fig 7: Double shear strength test specimen

TABLE 10: Dimensional Specifications of Double shear strength Sample

Dimension	Range
Length L	150mm
Diameter D	22.6mm
Area A	401.15mm^2

(a) Double shear strength test sample of Al+RHA

(b)Double shear strength test sample of Al+CDA

(c) Double shear strength test sample of Al+JSA

(d) Double shear strength test sample of Al+RHA+CDA+JSA

Fig 8: Double shear strength test samples of Al with RH, CD, JS ash separately and all together

RESULTS AND DISCUSSIONS

Mechanical properties of Aluminium Alloy hybrid composites increase in addition of RHA, CDA and JSA particles. Figure 9 (Fig. 9) shows the graphical representation on the effect of reinforcements on hardness. From the results it is found that, the hardness for any kind of mixes was increased. To be more specific, Al with JSA has achieved the highest value, meaning that, it gained the maximum hardness for the composites we have chosen. However, the other mix shows a very close hardness values, that indicates, we can also use the other materials in case of cost saving and environmental factors (such as, decompositions). The decrease in hardness may be due to density difference between CDA and aluminium matrix. CDA is a soft and a low density particle which tends to stay on the surface in the melt during casting process leading to non-homogeneous distribution in the matrix. This causes weak interfacial bonding between CDA and matrix which reduces hardness.

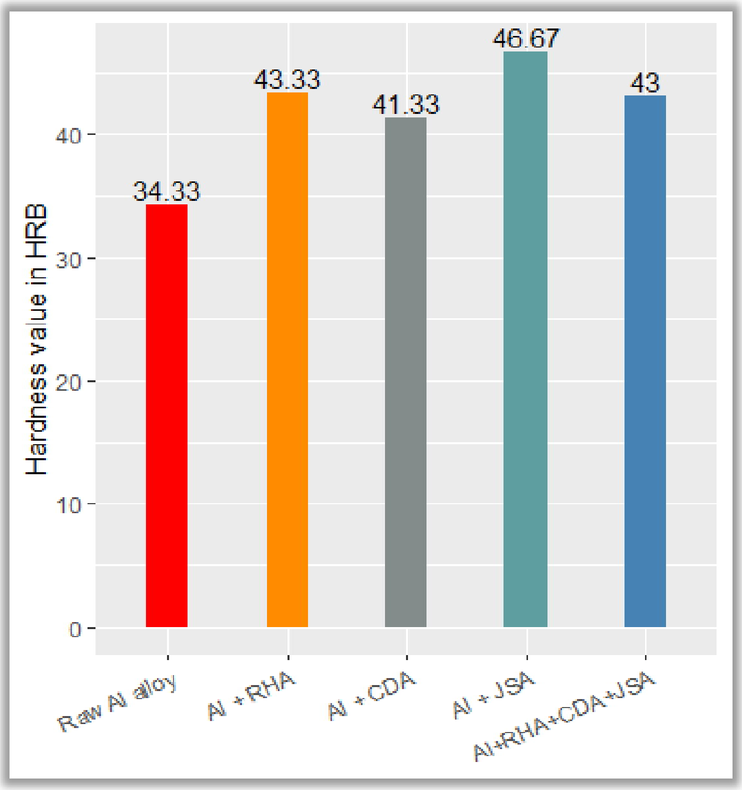


Fig 9: Hardness results on fabricated specimens

The resistance against indentation on the reinforcements was identified by Rockwell hardness B scale value. The average hardness values are found to be 34.33,43.33,41.33,46.67 and 43 HRB for Al, Al with RHA, Al with CDA, Al with JSA and Al with RHA, CDA, JSA samples respectively. The highest value was found in sample Al with JSA when compared to base Al alloy.

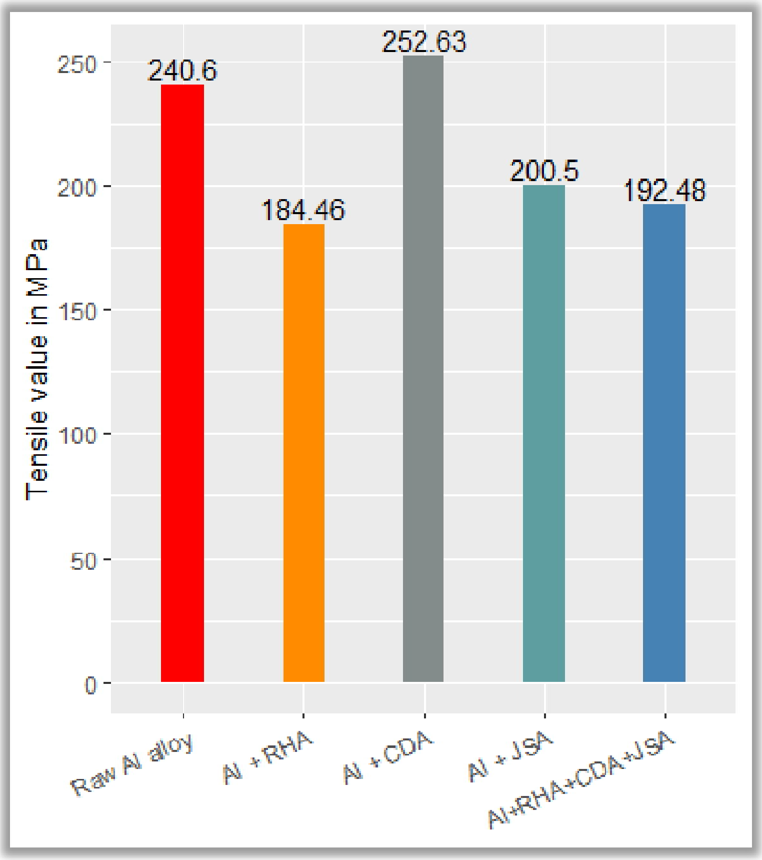


Fig 10: Tensile Strength results on fabricated specimens

The graphical representation of the average tensile strength is shown in figure 10 (Fig. 10). It is observed that the tensile strength has only increased only for the Al with CDA composite samples when compared with the base aluminium alloy. Inclusion of CDA particles increases the tensile strength in the composite samples. Addition of CDA particles causes brittleness in the composites which in turn increases the strength in composite material. However, the other composites tensile strength has decreased at a varying rate than base Aluminium Alloy.

The preheating of reinforcements provokes the generation of thermal stress which may influence the strength in composite materials. The thermal mismatch between reinforcements and matrix is also one of the reasons for increase in tensile strength. The uniform distribution of reinforcements without any defects and flaws may also result in increase of bulk mechanical properties. It is also clear from the result that the composite materials induce high strength to matrix alloy and henceforth increased resistance to tensile stresses which leads to superior ultimate tensile strength.

The resistance against tensile force on the reinforcements can be identified by the ultimate tensile strength value. The average tensile strength values are found to be 240.60, 184.46, 252.63, 200.50 and 192.48MPa for Al, Al with RHA, Al with CDA, Al with JSA and (Al with RHA, CDA, JSA samples respectively. The highest value was found in sample Al with CDA when compared to base alloy.

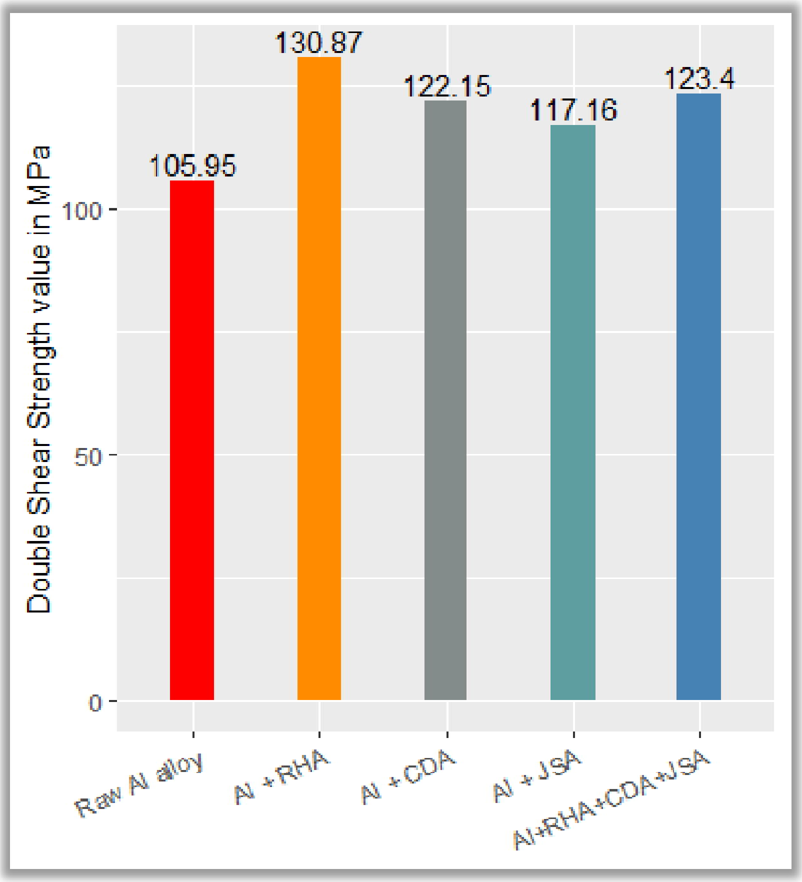


Fig 11: Double Shear Strength results on fabricated specimens

The graphical representation of the average Double Shear Strength is shown in figure 11 (Fig. 11).It is observed that the Double shear strength has increased almost all over the Al with CDA, Al with RHA, Al with JSA composite samples when compared with the base aluminium alloy. Inclusion of those particles increases the Double shear strength in the composite samples. Addition of these particles causes brittleness in the composites which in turn increases the strength in composite material. The average Double shear strength values are found to be 105.95, 130.87, 122.15, 117.16 and 123.40 MPa for Al, Al with RHA, Al with CDA, Al with JSA and Al with RHA, CDA, JSA samples respectively.

The highest value was found in sample Al with RHA, and almost same data for Al with CDA and Al with RHA, CDA, JSA when compared to base alloy.

CONCLUSIONS

Throughout this study, we have investigated the influence of reinforcing RHA, CDA, JSA individually and a mixture of all these bio-ashes with Al (Al-6061) and reached to certain conclusions.

RHA, CDA, JSA can be successfully be incorporated into Aluminium Alloy matrix to produce composites. This can also solve the problem of storage and disposal of RHA, CDA, JSA and utilization of an agricultural waste. A similar stamen can be made for the mixture of all three bio ashes we used in this study.

The main purpose of this project was to find, whether we can see a different result for combined bio-ashes with Al alloy. We observed that, compared to the ashes individually, the bio-ash mix gives us a decrement in hardness, tensile and double shear cases. But we can also see that, the difference is almost negligible for all three cases. So, we can conclude that, since the bio-ashes we have used in this study, are easily available and less costly, it could be a good idea to produce Al alloy with the individual ashes and we can also use the mix when other materials are not available. One of the strong reasons is, all three elements we have used are environment friendly.

To conclude, we can say that, the comparison in this study would help us to understand what type of materials available and what kind of metal are we want to produce with what kind of test properties (such as, hardness or tensile). This report will also help in a prior cost benefit analysis for material selection with Al alloy in terms of different test took place in this project. A further study would help in finding more results with a different percentage of mix and few other tests such as, impact and bending test.

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APPENDIX

Stir Casting

Stir Casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring.
Stir Casting is the simplest and the most cost-effective method of liquid state fabrication.
The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies.

Stir Casting is characterized by the following features:

- Content of dispersed phase is limited (usually not more than 30 vol.%).
- Distribution of dispersed phase throughout the matrix is not perfectly homogeneous:
  1. There are local clouds (clusters) of the dispersed particles (fibers);
  2. There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase.
- The technology is relatively simple and low cost.

Distribution of dispersed phase may be improved if the matrix is in semi-solid condition.
The method using stirring metal composite materials in semi-solid state is called **Rheocasting**.
High viscosity of the semi-solid matrix material enables better mixing of the dispersed phase.

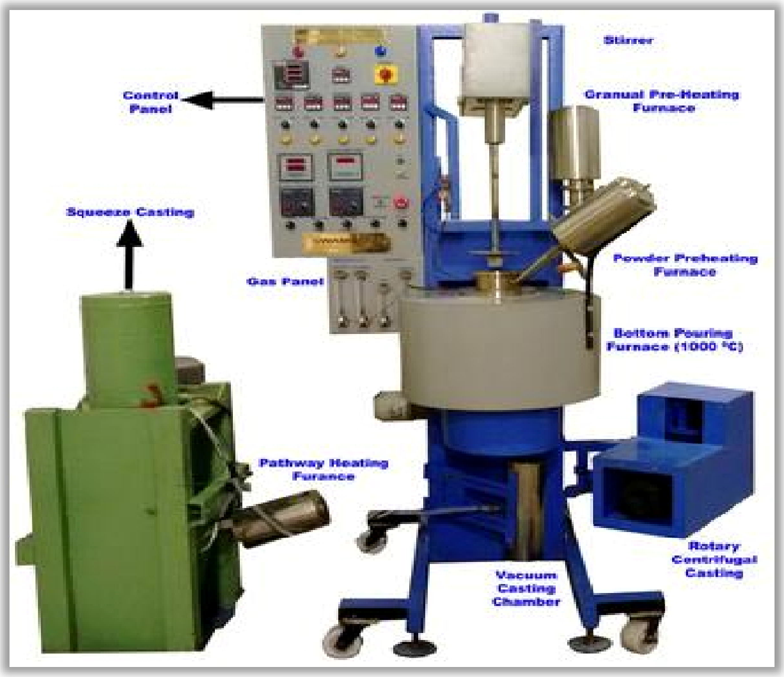

Fig: Stir Casting Machine

***Hardness*:**

- Hardness is a measure of a material Resistance to localized plastic deformation.
- This test is performed on a material to Know its resistance against indentation and abrasion.

Fig: Rockwell Hardness Testing Machine

Tensile Test:

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking. The tensile test is performed on a material to Know its elongation of film.

Double Shear Strength:

The shear to which a member is subject when the shearing stress is along two section planes. The double shear test was performed using universal testing machine.