A COMPARATIVE INVESTIGATION ON PHYSICAL AND MECHANICAL PROPERTIES OF MMC REINFORCED WITH WASTE MATERIALS

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Abstract

Abstract— Aluminium alloy based metal matrix composites (MMC) are produced with agro waste Rice Husk Ash (RHA) and industrial waste Fly Ash as reinforcement. By the continuous stir casting method the MMCs were fabricated in a bottom pouring furnace at 7000C. A rectangular metal mould was used to prepare the casting having dimension 300x50x20 mm3. The effect of adding the different reinforcement were realized through various mechanical behaviour tests. Based upon the standards in the mechanical workshop samples were prepared for measuring mechanical properties such as Impact strength, Compression strength, Tensile strength, Brinell hardness and Density test of both the MMCs. The Fly Ash and Rice Husk distributions in the MMCs were confirmed through the examinations conducted of the microstructure on image analyzer and scanning electron micrographs. Results thus found revealed that there is a great effect of reinforcing Flyash and Rice Husk in aluminium alloy matrix composites. Fly ash gave more enhanced mechanical properties as compared to Rice Husk. Thus selection of waste material from industry based and agro based for reinforcement was found one of the most important criteria for fabricating aluminium matrix composites.

Keywords: *Metal Matrix Composites (MMCs), Flyash, Rice Husk Ash (RHA), Mechanical Properties, Physical property.*

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1. INTRODUCTION

A metal matrix composite (MMC) can be defined as the composite material with at least two constituent parts such as different metals or a ceramic or organic compound. Metal matrix composites (MMCs) generally consist of lightweight metal alloys of magnesium, aluminum, or titanium, reinforced with ceramic particulate, whiskers, or fibers. As it determines different mechanical properties, cost, and performance of the given composite, so the reinforcement is very important. Metal-matrix composite structure can be termed as metal alloy of the matrix and the material in the form of strengthening. The matrix is penetrating the soft part generally having excellent tensile strength, hardness, ductility and thermal conductivity [1,2]. For the development of metal-matrix, light metal composite materials combined with light metal alloys are applied as matrix materials. Now a days designers are looking for the MMCs to provide the extra strength, stiffness, and higher temperature capabilities required for their advanced applications [3,4]. Since last 20years metal matrix composite has become a significant topic for the research and its commercial application [5]. It gives a distinctive physical and mechanical properties.

Aluminium metal matrix composites (MMCs) have gained importance in various industries because of their good Mechanical properties. Al-alloy is used as a matrix due to its good casting abilities, high corrosion resistance and low density [6]. In our experiment we are using Stir casting method as it improves the wettability between matrix and reinforced particles.

Composites produced by using the waste as reinforcements helps not only clearing environmental issues but also helps in increasing mechanical properties of the composites. Due to the increase in population, a large amount of waste materials are generated from mining, industrial and agricultural activities by the technology development. As the waste materials are hard to disposal, so by recycling the waste material we can use them in automobile, aerospace and construction industries [7-8].

By utilizing fly ash as reinforcement we can improve the hardness of metal matrix composites due to the ceramic reinforcements which are so hard [9]. Fly ash particles are discontinuous dispersions in form of hollow spherical shape used in MMCs. As MMCs are of low density and low cost reinforcement which are available in large quantities as a waste at thermal power plants, so the fabrication of MMCs can be done with relatively low cost [10].

Rice husk is an agro based waste material which is most abundantly available in rice producing countries like India. It is also a good additive for composite material. Use of the Agro-industrial waste not only solve but also their storage and handling as a threat to the environment [11]. By using these waste materials we can convert industrial wastes to industrial wealth.

In this paper we are comparing the different physical and mechanical properties of fly ash and rice husk metal matrix composites.

2. REVIEW OF LITERATURE

A.K.Senapati et al.(2014) found that by adding fly ash to Al-Si metal matrix composite we can improve the micro hardness, impact strength and compressive strength of LM-6 MMC [12]. Chittaranjan. V et al.(2014) found that by adding fly ash ultimate strength, hardness of commercially pure aluminum is increased from 58BHN to 86BHN [13]. Mahendra et al. investigated the properties of Al-4.5% Cu alloy composite with the fly ash as a reinforcement. They reported that the increase in tensile strength, hardness, impact strength and compression strength with increase in the fly ash content [14]. AnkushSachdeva et al. showed the effect on mechanical properties of Al5052 alloy Composites when reinforced and fabricated by stir casting method. The reinforcement consisted of 8% Sic+8%Fly Ash+4% Graphite by weight percentage which showed improvement in Mechanical properties such as hardness and ultimate tensile strength. [15]. The increase of wear resistance of Al MMC in the presence of SiO2 in fly ash by the sliding wear test found by Dr. Selvi.S et al. The hardness of the AL MMC composites increases as the fly ash content increases. It is observed that as the time increases the weight loss due to erosion increased for both Aluminum as well as ALMMC composites. However, the weight loss was minimum for the AL MMC composites [16].

BasavarajMathpathi and Bharat S Kodli used liquid metallurgical (stir casting) method to fabricate MMC of pure aluminium reinforced with Silicon Carbide (SiC) and Rice Husk (RHA) ash to study its mechanical behavior. The reinforcement silicon carbide and RHA were added in varying weight percentages of (3%-6%). It showed higher tensile strength with the increase in rice husk content and vice versa. Higher impact strength & hardness with increased SiC content while it slightly decreases with increase in rice husk content [17]. Ankit Mittal and Ramnarayan Muni experimented on aluminium alloy with rice husk ash and copper as reinforcements to study the mechanical behavior of the composite. Magnesium was used to increase the wettability between the metal matrix and reinforcing particles. Varying weight percentage of rice husk ash (8%, 16%, 24%, 32%) and copper (3%) were added to the molten metal. With this it was observed that the specimens containing copper showed improved values for hardness than those specimens containing only rice husk. The hardness of prepared composites are increased by increasing rice husk ash and copper content [18]. PallaviDeshmukh et al. focused on the changes in the mechanical properties of the Al based MMC composites which were synthesized by reinforcing amorphous nano sized (32-56nm) rice husk SiO_2 particles and metallurgical grade SiO_2 particles (10 µm) in Al-Mg alloy by liquid metallurgical route (stir casting) with varying percentage of Mg. Improved mechanical properties was observed in the composite synthesized by the use of Rice Husk, silica in comparison to metallurgical grade silica. The micro hardness of the Al-Mg- SiO_2 was found to be maximum for 2.5% of Mg and by using rice husk SiO_2 of nano structure dimension as reinforcement [19].

The literature review on the topics cited that although research has been done on individual MMC's taking different agro based and industrial based waste materials but none of them has done work on comparison of properties among the MMC's taking different agro based and industrial based waste products as reinforcement and compared their physical and mechanical properties. Very few researchers have discussed the effect of morphology of reinforcement on mechanical and physical property on agro waste reinforced MMC's. Therefore, in this investigation an attempt was made to use two different types of reinforcement like fly ash and rice husk to fabricate the AMCs and a comparative analysis is done in terms of their physical and mechanical properties. The details of experiment and results are discussed in the subsequent sections below.

3. MATERIALS AND METHOD

Composite materials are formed when two or more dissimilar materials are intimately bonded to form an integrated structure. Composite material has two part one is continuous i.e matrix and the other one is discontinuous i.e reinforcement. Solid state and liquid state processing are the processing techniques used for the production of composite materials. Mainly the processing technique is selected on the basis of the application and the state of the matrix as well as depends upon reinforcement materials. Here the manufacturing of the composite material is done with the liquid state processing. Stir casting, infiltration, spray deposition, etc. are several methods which are available for the liquid state processing. In the process the stir casting is preferred.

3.1 Materials Used

In this experiment we have used Eutectic Al-Si alloy LM6 which contained 12.249% of Si. In the table I the chemical compositions of the LM6 alloy are given. Here fly ash and rice husk ash were used as a reinforcement material. The chemical compositions of fly ash and rice husk ash are mentioned in the Table 2 and Table 3 respectively.

Table-1:Chemical Composition of Al-Si Alloy [Wt. %] Designated as Base Alloy

Compound	Wt %	Compound	Wt %
Si	12.2491	Ti	0.0672
Co	0.0174	Zn	0.0944
Fe	0.4353	Ni	0.0264
Cu	0.0800	Sn	0.0632
Mn	0.1601	Cr	0.0199
Ca	0.0802	V	0.0146
Al	86.754		

Table-2: Chemical Composition of Flyash

Compound	Wt %
SiO2	63.34
Al2O3	23.60
Fe2O3	4.97
CaO	1.23
MgO	0.56
Na2O	0.11
K2O	0.64

Table-3: Chemical Composition of Rice Husk Ash

Composition	Wt %
SiO2	93.42
Al2O3	0.238
Fe2O3	0.167
CaO	0.823
MgO	0.53
Na2O	0.25
K2O	1.94
LOI	2.632

3.2. Stir Casting

After Al-Si ingot is cleaned, it was cut into desired proper sizes, was weighed in essential quantities and then subjected into a vertically aligned pit type bottom poured melting furnace shown in Fig.1. Before pouring the fly ashes in to the melt of Aluminiun-Silicon Alloy it was preheated to 650^0C±5^0C. It was done so as to remove any residual moisture as well as to improve wettability. With the help of BN coated stainless steel rotor the molten metal was stirred at a speed of 600-650 rpm. Due to the stirring a vortex was created in the melt where the preheated fly ash was poured centrally into the vortex. Slowly the rotor was moved down, from top to bottom by maintaining a clearance of 12mm from bottom. After stirring the rotor was slowly pushed back to its initial position. The temperature of pouring of the liquid was kept around 700^0C. Casting was done in rectangular metal mould of dimension 300x50x20 mm3. The desired characteristics was compared by fabricating the AMCs with the two reinforcements i.e. Fly Ash and Rice Husk respectively.

Fig-1: Real photo of used vertically aligned pit type bottom poured melting furnace

3.3. Impact Strength Test

Impact Strength tests were performed by Charpy V Notch pendulum impact testing machine. Just as simply supported beams the square bar test specimens was placed. Specimens were prepared from Fly Ash and Rice Husk AMCs by square cross section 10 mm x 10mm and 55mm in length with 45-degree V Notch at the center as shown in Fig. 3. At the mid span of the specimen there was a single blow of hammer given. The blow was sufficient to bend or break the specimen at the center. The striking energy was measured.

Fig-2: Impact testing machine

Fig-3: Specimen before test **Fig-4:** Specimen after test

3.4. Compression Strength Test

Compression test is done in the Universal Testing Machine (UTM). The cylindrical test specimen is mounted on the base plate of the UTM. The specimen used has an equal diameter as that of height of the specimen. The load is applied gradually on the specimen until it is compressed by 50 %(height). With the increase of application of loads displacement also increases upto certain range and then reduces all of sudden until a certain height after which it cannot be compressed anymore. The real photo of used UTM and test specimens is shown in Fig. 6

Fig-5: Universal Testing Machine (UTM)

Fig-6: Specimen before testing

Fig-7: Specimen after testing

3.5. Tensile Strength Test

The tensile strength of the AMC specimens was measured through an electronic tensometer as shown in Fig.7.The specimens were made as per the standards. The specimens for tensometer test were loaded between two grips and were adjusted manually. By the means of electronic control a constantly increasing force was applied to the specimen. The load and elongation were continuously recorded. Then the UTS and percentage elongation was calculated.

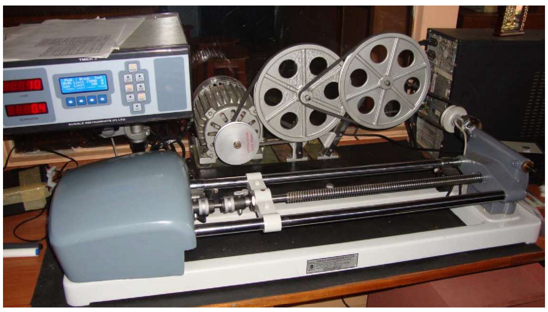

Fig-8: Electronic Tensometer

Fig-9: Specimen before test

Fig-10: Specimen after test

3.6. Micro Hardness Test

Hardness test was carried out using Brinnell cum Rockwell hardness tester. The samples were prepared and polished to provide a scratch free test surface. Tungsten Carbide ball indenter of 20mm with 3mm tip was used for Brinnell Hardness Test**.**

Fig-11: Brinnell cum Rockwell Hardness tester

3.7. Density Test

There are no. of ways to calculate density of a material but here we used two method to determine the density of the specimen, they are direct measurement of volume using vernier calliper and measurement of volume using Archimedes' principle. The deviation in the result from both the methods were compared to get the accurate value.

4. RESULT AND DISCUSSION

4.1. Mechanical Properties

Table4 and fig-12 representsthe impact strength valuesforthreematerialsi.eAl-Si alloy(Eutectic), MMC with Fly ash and MMC with RHA. The average impact value was recorded and found to be more in MMC with Fly ash and MMC with RHA by 300% and 200% respectively when compared with base alloy and 33.33% more in MMC with Fly ash when compared with MMC with RHA. The compressive properties are listed in Table 5 and fig-13, found that the compression value is increasedin MMC with Fly ash and MMC with RHA by 7.69% and 1.92% when compared with base alloy and 5.67% more in case of MMC with Flyash as compared to MMC with RHA. Table 6 and fig-14 represents the tensile properties of the elements mentioned above. We found that the value is increased in MMC with Fly ash and MMC with RHA by 8.77% and 8.85% respectively as compared to base alloy, 4.4% more in case of composite prepared with fly ash as compared to MMC with RHA. The hardness value from Table 7 and fig-15 shows that there is an increase of 11.32% and 7.85% of MMC with Flyash and MMC with RHA respectively as compared with base alloy, there is an increase of 3.2% hardness value in case of MMC with Flyash as compared to MMC with RHA

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TABLE -4: Impact Strength of Al-Si, MMC (Fly ash) and MMC (RHA)

Sample No.	Sample name	Tensile strength in N/mm^2				Mean
		Trail-1	Trail-2	Trail-3	Trail-4	
01	Al-Si	115	116	113	111	114
02	MMC (Fly ash)	122.2	126.1	125.2	123.1	124.1
03	MMC (RHA)	118	117	120	120	119

TABLE-5: Compression Strength of Al-Si, MMC (Fly ash) andMMC (RHA)

Sample No.	Sample name	Impact strength in joule				Mean
		Trail-1	Trail-2	Trail-3	Trail-4	
01	Al-Si	0.5	0.51	0.49	0.5	0.5
02	MMC (Fly ash)	1.9	2	2	2.1	2
03	MMC (RHA)	1.5	1.48	1.52	1.5	1.5

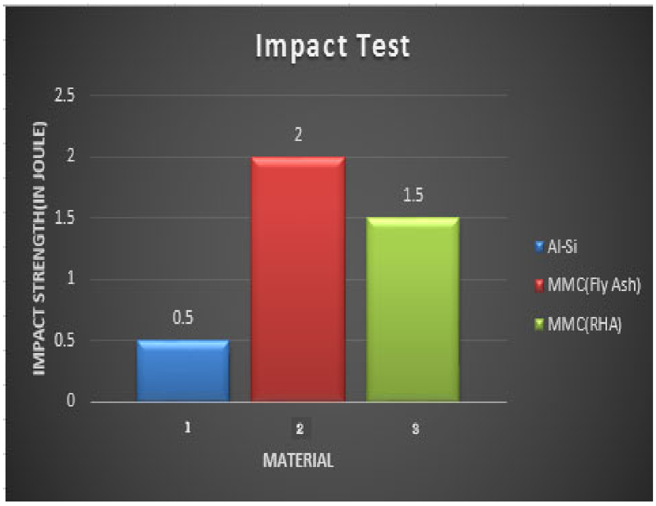

Fig-12: Impact strength

Table-6: Tensile strength of Al-Si, MMC (Fly ash) and MMC (RHA)

Sample No.	Sample name	Compression strength in KN/mm^2				Mean
		Trail-1	Trail-2	Trail-3	Trail-4	
01	Al-Si	0.916	0.779	0.825	0.81	0.832
02	MMC (Fly ash)	0.906	0.902	0.889	0.89	0.896
03	MMC (RHA)	0.840	0.855	0.855	0.845	0.848

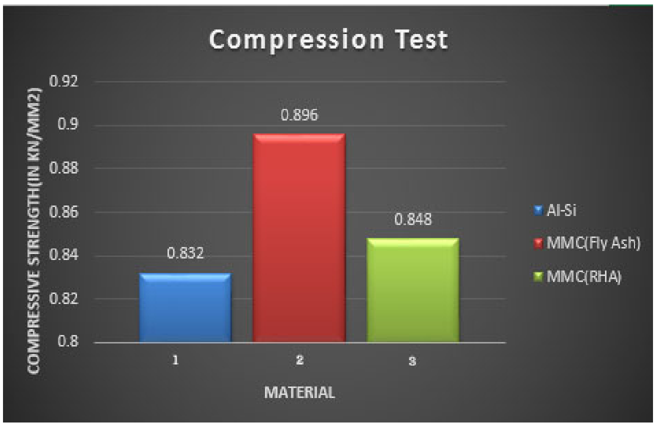

Fig-13: Compression Strength

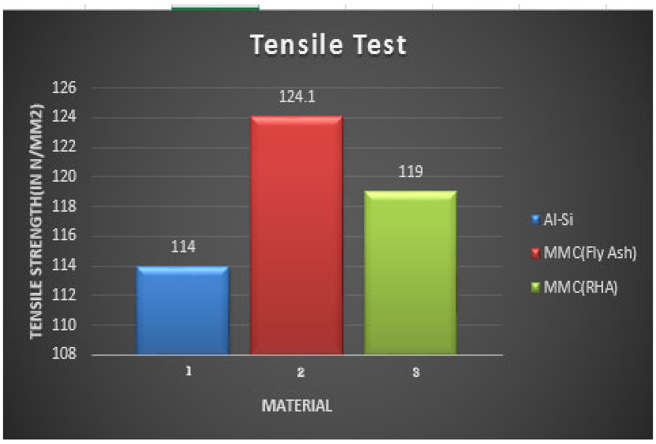

Fig-14: Tensile Strength

TABLE-7: Micro Hardnessof Al-Si, MMC(Fly Ash)And MMC(RHA)

Sample No.	Sample name	Micro Hardness in HV				Mean
		Trail-1	Trail-2	Trail-3	Trail-4	
01	Al-Si	63.52	63.58	63.52	63.58	63.55
02	MMC (Fly ash)	70.72	70.78	70.74	70.76	70.75
03	MMC (RHA)	68.55	68.53	68.54	68.54	68.54

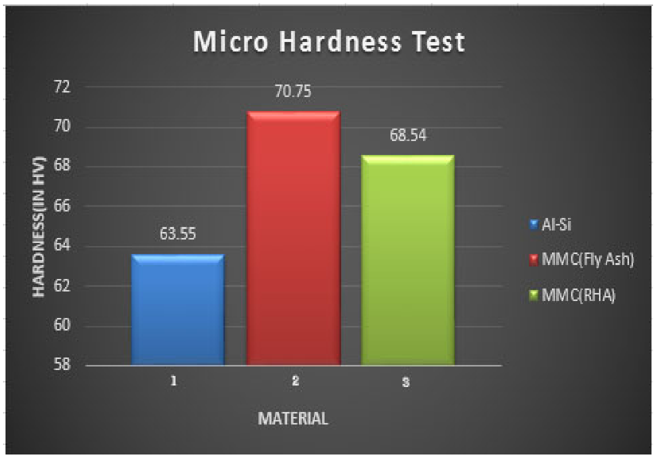

Fig-15: Micro hardness strength

4.2. Physical Properties

From the Table 8and fig-16we found that the density of the MMC with Fly ash and MMC with RHA is increased by 1.15% and 3.61% as compared with base alloy butthe density of MMC with RHA is increased by 2.42% as compared to MMC with fly ash.

TABLE-8: Density of Al-Si, MMC(Fly ash)and MMC(RHA)

Sample No.	Sample name	Density of Kg/m^3				Mean
		Trail-1	Trail-2	Trail-3	Trail-4	
01	Al-Si	2.547	2.551	2.548	2.5	2.549
02	MMC (Fly ash)	2.51	2.53	2.5	2.54	2.52
03	MMC (RHA)	2.44	2.48	2.45	2.47	2.46

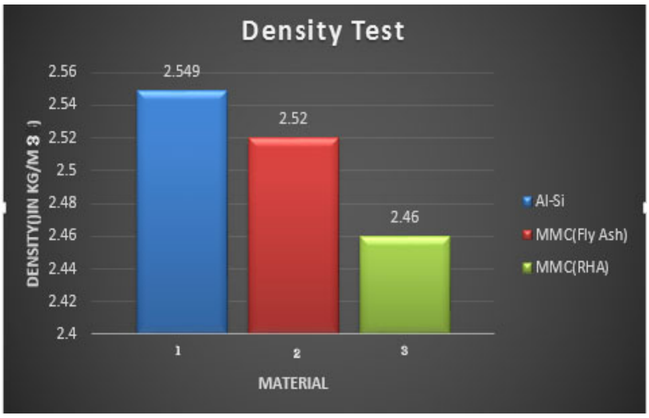

Fig-16: Density

5. CONCLUSIONS

The stir casting method used for the preparation of composites is easy, efficient and most economical method. It also helps in the uniform distribution of reinforced particles (Fly ash and RHA) with the matrix metal. The impact strength, compressive strength, tensile strength and micro hardness test were higher for MMC with fly ash than MMC with RHA. This is because due to the presence of more amount of aluminum oxide and calcium oxide in Fly ash than rice husk ash.But the density is higher in case of MMC with RHA.

The experimented data shows that the selection of reinforced particle when mechanical properties are consider is one of the major aspect for the production of metal matrix composite.

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