Experimental Investigation on Mechanical Properties & Wear Behaviour of Fly Ash & Rice Husk Ash Reinforced Aluminum Alloy (Al 7075) Hybrid Metal Matrix Composites

A project report submitted in partial fulfilment of the requirement for

the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

BY

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CERTIFICATE

This is to certify that the Project Report entitled **"EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES AND WEAR BEHAVIOUR OF FLY ASH AND RICE HUSK ASH REINFORCED ALUMINUM ALLOY (AL 7075) HYBRID METAL MATRIX COMPOSITES"** being submitted by AMPOLU RAVI KUMAR (318126520L37), AKKIREDDY TIRUMULU (318126520L53), THANDI LEELA SAI VENKAT (317126520226), KARIPALLI EPHRAIM (318126520L40), VADDI NAVEEN ABHISHEK (317126520228) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING, ANITS**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.A.P.S.V.R. SUBRAHMANYAM**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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We, the undersigned, hereby declare that this "**Thesis**" under the title of **"Experimental Investigation On Mechanical Properties & Wear Behaviour of Fly Ash & Rice Husk Ash Reinforced Aluminum Alloy (Al 7075) Hybrid Metal Matrix Composites"** submitted by me for the award of Degree of "Bachelor of Technology" in Mechanical Engineering at ANIL NEERUKONDA INSTITUTE OF TECHNOLOGY & SCIENCES (A), Visakhapatnam, is a record of original research work carried out by us. This work has not been submitted to any University or Institution in India or abroad, for the award of any degree.

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CONTENTS

ABSTRACT

Aluminum-based Hybrid metal matrix composites (HMMCs) are considered in several technological applications due to their enhanced mechanical properties compared with other metals. Since Aluminum-based HMMCs are used extensively in automobile, naval and aviation sectors, where the demand for lightweight, high strength and wear resistance material is very much required. In the present work, varied compositions of the Rice Husk Ash (RHA) and Fly Ash (FA) reinforcements particles in 15:5, 5:15, and 10:10 wt% respectively were added to AL7075 alloy through stir casting method. The experimental study aimed at experimental investigations of Mechanical properties (Tensile Strength & hardness) and Tribological (Wear rate) behavior of the composite formed through stir casting.

We found that the HMMCs showed better mechanical and tribological properties than pure alloy. The reinforcements in equal proportions, 10% each wt%, resulted in superior mechanical properties. Notably, RHA at a higher proportion (15%) increased hardness and thereby wear resistance. If we increase beyond these limits, there is a slight decrease in the mechanical properties of the composite. The fly ash content beyond 10%, showing a negative effect on the properties of hybrid composite.

Key words: AL7075, Rice Husk Ash, Fly Ash, Stir Casting, Tensile test, Hardness test, wear test

CHAPTER-I

1.INTRODUCTION

Manufacturing industries worldwide are striving towards the development of lightweight and high-strength materials with lower production costs to meet the modern-day applications in the aerospace, defense, and automotive sectors. This can be achieved by processing Aluminum matrix composite (AMC) materials having desired properties at low cost by the proper selection of material composition, manufacturing methods.

The concept of maximum possible optimization is applied in the manufacture of these advanced materials. Recently, hybrid MMC is being developed for better physical, mechanical and tribological properties with a different combination of reinforcements. The industries are focusing on the concept of sustainability considering the economic, environmental and social aspects when developing new materials; and are known as sustainable composites.

Recent studies show the utilization of freely available agro/industrial waste products like fly ash, rice husk, red mud, bagasse ash, eggshells as complementary reinforcement particles in the hybrid composite for advanced engineering applications.

1.1 Composite material

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics other than the individual components. The individual constituents remain separate and distinct within the finished structure. The new material may be preferred for many reasons; typical examples include more potent, lighter, or less expensive materials than traditional materials.

The composite material can be defined as the system of material consisting of a mixture of combination of two or more micro constituents insoluble in each other and differing in form and or in material composition. These materials can be prepared by putting two or more dissimilar materials in such a way that they function mechanically as a single unit. The properties of such materials differ from those of their constituents.

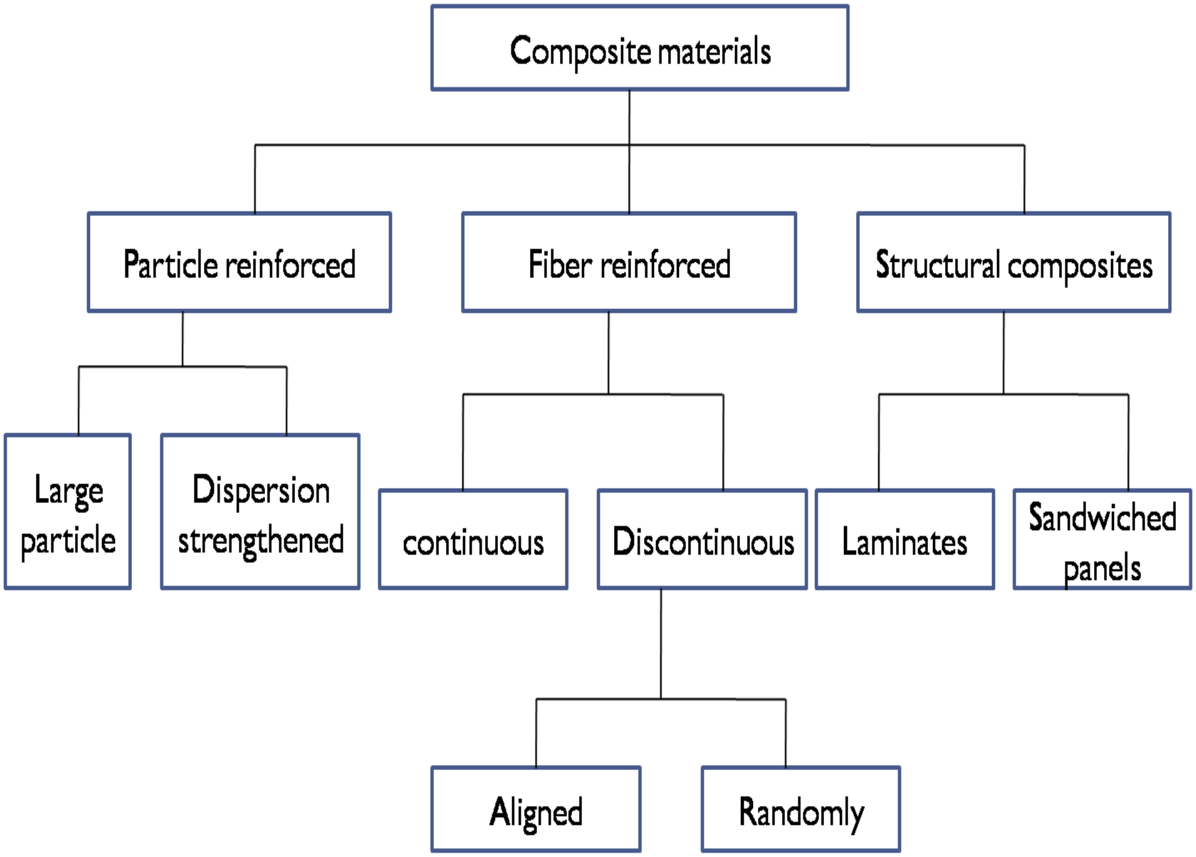

Fig.1 classification of composite materials

1.2 Matrix

The matrix binds the fiber reinforcement, transfers loads between fibers, gives the composite component its net shape and determine its surface quality. A composite matrix may be a polymer, ceramic, metal, or carbon.

1.2.1 classification of Matrix Material

The matrix material is classified into three types. There are

1.2.1.1 Polymer Matrix Composites (PMC.)

1.2.1.2 Metal Matrix Composites (MMC)

1.2.1.3 Ceramic Matrix Composites (CMC.)

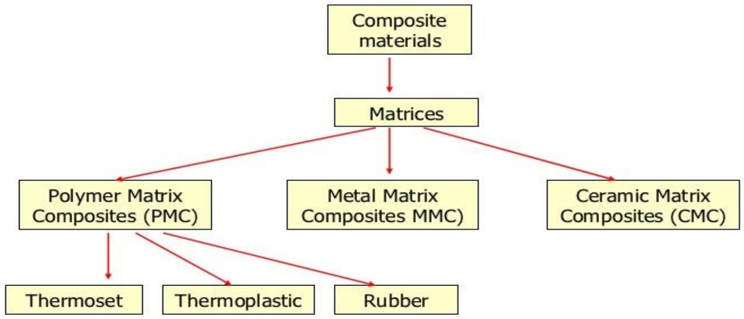

Fig.2 classification of Matrix materials

1.2.1.1 Polymer Matrix Composites (PMC.)

The most material matrix materials for composites are polymeric. Polyester and vinyl esters are the most widely used and least expensive polymer resins. These matrix materials are basically used for fiberglass-reinforced composites. For mutations of a large number, resin provides a wide range of properties for these materials. The epoxies are more expensive and in addition to a wide range of ranging commercials, applications also find use in PMCs for aerospace applications. The main advantages of PMCs are their low maximum working temperature, high coefficients of thermal expansion, and hence dimensional instability and sensitivity to radiation and moisture. The strength and stiffness are low compared with metals and ceramics.

1.2.1.2 Metal Matrix Composites (MMC)

The matrix in these composites is a ductile metal. These composites can be used at higher service temperatures than their base metal counterparts. These reinforcements in these materials may improve specific strength, abrasion resistance, creep resistance and dimensional stability. The MMCs are light in weight and resist wear and thermal distortion, mainly used in the automobile industry. Metal matrix composites are much more expensive than those PMCs.

1.2.1.3 Ceramic Matrix Composites (CMC.)

One of the main objectives in producing CMCs is to increase the toughness. Ceramics materials are inherently resistant to oxidation and deterioration at elevated temperatures were it not for their disposition to brittle fracture. Some of these materials would be ideal candidates for use in higher temperature and serve stress applications, specifically for components in automobiles and aircraft gas turbine engines. The developments of CMCs has lagged mostly for remain reason, and most processing routes involves higher temperature reinforcements.

1.3 Reinforcement

Reinforcement is the material, which is added to improve the various properties of the matrix material. The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity.

1.3.1 Classification of reinforcement

The reinforcement can be either continuous or discontinuous. Discontinuous MMCs can be isotropic and can be worked with standard metalworking techniques, such as extrusion, forging, or rolling. In addition, they may be machined using conventional methods but commonly would need the use of polycrystalline diamond tooling (PCD).

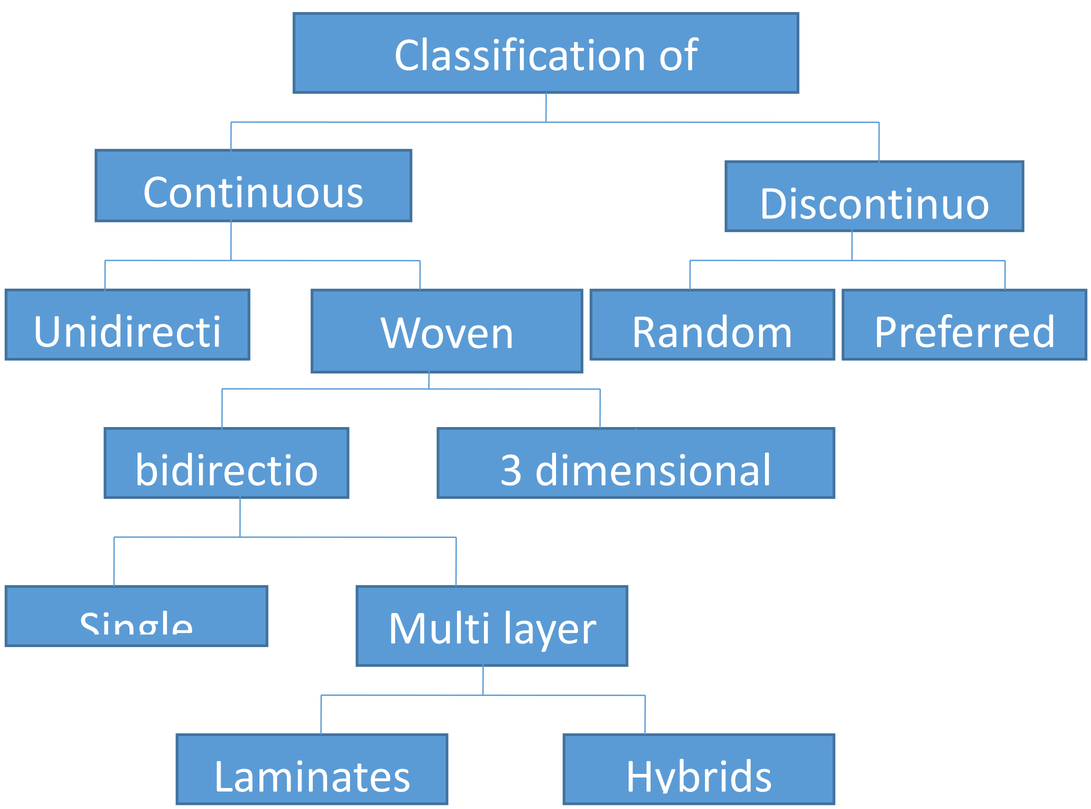

Fig.3 classification of reinforcements

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. The fibers are get embedded into the matrix in a specific direction. The result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses "whiskers", short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

1.3.2 Particle Reinforced Aluminum Matrix Composites (P.A.M.M.C.s)

PAMMCs contain equiaxed reinforcements with an aspect ratio of less than five. These reinforcements are basically ceramic materials like SiC or Al2O3 or TiB_2. PAMMCs are manufactured using powder metallurgy techniques or liquid state (stir casting, infiltration and in-situ) processes. Particulate composites are isotropic and can be subjected to a range of secondary forming operations like extrusion, rolling and forging. PAMMCs are less expensive compared to other classes of AMMCs.

1.3.3 Short Fibre and Whisker-reinforced Aluminum Matrix Composites (SFAMMCs)

SFAMMCs contain reinforcements with an aspect ratio greater than five but are not continuous. Mechanical properties of whisker-reinforced composites are better than particle or short fiber-reinforced composites. Nevertheless, the usage of whiskers as reinforcements in AMMCs is declining due to alleged health hazards.

1.3.4 Continuous Fibre-Reinforced Aluminum Metal Matrix Composites (CFAMMCs)

CFAMMCs have reinforcements in the shape of continuous fibers (of Al2O3, SiC or carbon) with a diameter less than 20 µm. The fibers can be either parallel or pre-woven, braided prior to manufacture the composite. These composites are produced by pressure infiltration route. These have better mechanical characteristics but are expensive than other SFAMMC and PAMMCs.

1.3.5 Monofilament Fibre Reinforced Aluminum Metal Matrix Composites (MFAMMCs)

MFAMMCs have reinforcements as monofilaments of large diameter (100 to 150 µm). These composites are produced by diffusion bonding techniques and are limited to superplastic forming Aluminum alloy matrix.

1.4 Advantages of Composite materials

a) Light Weight

Composites are light in weight compared to most woods and metals. For example, their lightness is important in automobiles and aircraft, where less weight means better fuel efficiency.

b) High Strength

Composites can be designed to be far stronger than aluminum or steel. Metals are equally strong in all directions. But composites can be engineered and designed to be strong in a specific direction Strength Related to Weight - Strength-to-weight ratio is the strength of a material to how much it weighs.

c) Corrosion Resistance

Composites resist damage from the weather and from harsh chemicals that can eat away at other materials. Composites are good choices where chemicals are handled or stored. High-Impact Strength - Composites can be made to absorb the sudden force of a bullet, for instance, or the blast from an explosion.

d) Design Flexibility

Composites can be molded into complicated shapes more quickly than most other materials. This gives designers the freedom to create almost any shape or form.

e) Part Consolidation

A single piece made of composite materials can replace an entire assembly of metal parts. Reducing the number of elements in a machine or a structure saves time and cuts down on the maintenance needed over the item's life.

f) Dimensional Stability

Composites retain their shape and size when they are hot or cool, wet or dry. Wood, on the other hand, swells and shrinks as the humidity changes.

g) Nonconductive

Composites are nonconductive, meaning they do not conduct electricity. This property makes them suitable for such items as electrical utility poles and circuit boards in electronics.

h) Nonmagnetic

Composites are used in both the equipment housing and table. In addition, the construction of the room uses composites rebar to reinforced the concrete walls and floors in the hospital.

i) Low Thermal Conductivity

Composites are good insulators. They do not efficiently conduct heat or cold. They are used in buildings for doors and windows where extra protection is needed from severe weather.

1.5 Disadvantages

- Composite materials don't break easily, but that makes it hard to tell if the interior structure has been damaged at all. In contrast, aluminum bends and dents quickly, making it easy to detect structural damage; the same damage is harder to detect with composite structures. Repairs can also be more difficult when a composite surface is damaged.
- The resin used in composite material weakens at temperatures as low as 150 degrees, making it essential for these aircraft to avoid fires.
- Fires involved with composite materials can release toxic fumes and microparticles into the air. Temperatures above 300 degrees can cause structural failure.
- Finally, composite materials can be expensive, but long-term cost savings typically offset the high initial costs

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1.6 Hybrid Aluminum MMC(HMMC.)

Hybrid metal matrix composites are advanced materials for lightweight, high-strength applications in the aerospace and automobile sectors. Aluminum metal matrix composites are potential materials for various applications due to their excellent physical and mechanical properties. Hybrid composites primarily consist of one matrix and two or more reinforcement. In the present study, the weight proportions of the matrix and reinforcements used to prepare HMMCs are given in Table1.

Table.1 HMMC Composition

	Rice husk ash	**Fly ash**	**AL7075**
1.	0%	0%	100%
2.	5%	15%	80%
3.	10%	10%	80%
4.	15%	5%	80%

CHAPTER-II

2. LITERATURE REVIEW

U. S. Ramakanth and putti. Srinivasa rao [1] had studied the influence of sic and fly ash on the wear behavior of aluminum7075 and the weight percentage of the hybrid complex. Aluminum alloy 7075 strengthened with sic-fly ash was examined. The effectiveness of the integration of SiC in the composite for obtaining wear reduction was investigated in this study.

Sweety Mahanta, M Chandrasekaran et al. [2] had studied the hybrid metal matrix nanocomposites(MMNC) having AL7075 matrix alloy reinforced with B_4C (1.5 wt%) and fly ash (0.5, 1.0 and 1.5 wt%) nanoparticles were produced by ultrasonic stir casting method. A good enhancement in the wear properties of all combinations of reinforcements in AL7075 hybrid nanocomposites is observed. The hybrid nanocomposites having 1.5 wt% of B_4C and 1.5 wt% of fly ash exhibited the maximum wear resistance.

Balasubramani Subramaniam, Balaji Natarajan, et al. [3] study involves dry sliding wear behavior of AL7075 hybrid composites by pin-on-disc wear tester. The experimental research work is carried out in material of AL7075 hybrid composite manufactured through stir casting. Wear specimen of AL7075 alloy hybrid composites are manufactured with varying weight percentage of (0, 3, 6, 9 and 12 wt%) B_4C with 3 wt% FA composite. These experimental results exposed that the addition of hard reinforcements such as B_4C and agro-based waste material as a reinforcement of CSFA particles have greater improvement in wear resistance.

M. H. Faisal and S. Prabagaran [4] performed mechanical and wear tests on AL7075/B4C, AL7075/ B_4C /Gr and AL7075/B4C/Fly ash composites. By adding boron carbide and Fly ash in the AL7075 Aluminum matrix, the hardness of the produced composites gets raised. In the case of tribological properties like wear, coefficient of friction and frictional force, a decline was observed with the addition of boron carbide and Fly ash.

SD.Saravanan, M.Senthil Kumar et al.[5] studied the properties of the AlSi10Mg alloy with RHA reinforcements and found that the tensile Strength and compressive Strength increased with an increase in the weight percentage of rice husk ash. Hardness of the composite linearly increasing with the increase in weight fraction of the rice husk ash particles.

P. Anitha, U. Shrinivas Balraj et al. [6] studied the dry sliding wear performance of Alumina- Al2O3 and graphite-Gr particles reinforced with AL7075 (aluminum alloy 7075) hybrid metal matrix composites is studied using a pin-on-disc tribometer. Wear decreases with the increase of Al_2O_3% reinforcement and increases with the increase of applied load. Whereas, coefficient of friction is mainly influenced by Gr% reinforcement and the applied load. Applied load significantly affects both wear and coefficient of friction, whereas sliding distance has an insignificant effect on both.

N. Sathish Kumar [7] studied the fabrication and characterization of high-performance Aluminum composite material with agro-waste reinforcements. The base material selected for the composite development is Aluminum 7075, whereas rice husk ash (RHA) and mica is preferred as reinforcement and fabricated by squeeze casting. The manufactured composite is economical and harder than the base material and it posses high toughness and tensile strength.

Ashiwani Kumar [8] studied the mechanical and dry sliding behavior of AL7075- B_4C - rice husk ash (RHA) hybrid alloy composite. The specimens of AL7075 with 0, 2, 4, 6, 8 wt% of B4C mixed with 0, 2, 4, 6 and 8 wt% rice husk ash (RHA) are prepared using high vacuum casting machining. The addition of 8 wt% B4C – 8 wt% of RHA has reduced wear rate of composite greatly even with increasing sliding velocity and the applied load. Thus, the wear resistance of composite improves at 8 wt% B4C – 8 wt% of RHA.

Satish D [9] assessed concrete strength using Fly ash and Rice husk ash. When burned, it was found that rice husk produced an amount of silica (more than 80%). For this reason, it provides excellent thermal insulation. The workability of RHA concrete has been found to decrease, but FA increases the workability of concrete. Compressive strength increases with the increase in the percentage of Fly ash and Rice Husk Ash up to replacement.

D.Siva Prasad, Dr.A.Rama Krishna [10] concluded the hardness of A356.2/RHA composites increases with an increase in rice husk ash content. Incorporating rice husk ash particles in Aluminum matrix can lead to the production of low-cost Aluminum composites with improved hardness and strength.

H.C. Anilkumar, H.S. Hebbar et al. [11] found that the stir casting method used to prepare the composites could produce a uniform distribution of the reinforced fly ash particles. The Tensile Strength, Compression Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with an increase in particle size of the fly ash.

The ductility of the composite decreased with an increase in the weight fraction of reinforced fly ash and decreased with an increase in particle size of the fly ash. The enhancement in the mechanical properties can be well attributed to the high dislocation density.

Namdev A. Patil et al. [12] used friction stir processing (FSP) to fabricate rice husk ash (RHA) reinforced aluminum 7075 alloy (AL7075) surface composites (SCs). The deposition method of RHA into AL7075 substrate has been taken as a variable and its effects on microstructure, microhardness and tensile properties of resultant SCs were analyzed.

Kenneth Kanayo Alaneme et al. [13] in their study, mechanical and wear behavior of Aluminum matrix hybrid composites reinforced with alumina, rice husk ash (RHA) and graphite were investigated. Alumina, RHA and graphite mixed in varied weight ratios were utilized to prepare 10 wt% reinforced with Al-Mg-Si alloy to make hybrid metal matrix composites using two-step stir casting. The hardness decreases with an increase in the weight ratio of RHA and graphite in the composites, and with RHA content greater than 50%, the effect of graphite on the hardness becomes less significant. The tensile strength for the composites containing o.5wt% graphite and up to 50% RHA was observed to be higher than that of the composites without graphite.

Nishant Verma [14] had studied the mechanical behavior of AA 7075-B4C -Rice Husk Ash (RHA) hybrid composite. The samples AA 7075 and 5 wt% of B4C and 3, 5 wt % of RHA are prepared using the Stir Casting technique. The highest hardness is 121 HV at 5 wt% of B4C and 5 wt% of RHA. The highest tensile strength is 260 MPa at 5 wt% of B4C.

From the literature review, it is evident that a considerable quantity of studies has been carried out in aluminum metal matrix composites (AMMCs) and its manufacturing techniques to attain different mechanical and wear properties. The properties of AMMCs can be enhanced by choosing the appropriate combination of reinforcement, its volume fraction, size, and manufacturing technique.

AMMCs are used for various components in aircraft, spacecraft, satellites and automobiles. A significant amount of research has been done on AMMCs and mechanical properties. The machining characteristics of AMMCs reinforced with different reinforcements (SiC, Al2O3, Fly ash, Rice Husk ash, etc.) have been investigated by various researchers. However, various alloys of aluminum have been used as matrix materials and Rice husk ash and fly ash have been used as reinforcements; Al7075/Fly ash/Rice Husk ash hybrid composite has not been studied in detail.

In the present study, an attempt has been made to fabricate AL7075/Fly ash/Rice Husk ash hybrid metal matrix composite with different weight percentages of reinforcements. Hybrid metal matrix composites are to be produced with fly ash and rice Husk ash as reinforcements to develop better tensile strength, hardness and wear resistance. We have studied the mechanical properties of the hybrid composite with different weight fractions of the reinforcements.

CHAPTER-III

3.MATERIALS AND METHODS

3.1Materials

Aluminum:

Aluminum is a lightweight, silvery metal familiar to every household in pots and pans, beverage cans, and aluminum foil. It is attractive, non-toxic, corrosion-resistant, nonmagnetic, and easy to form, cast, or machine into various shapes. It has a melting point of 660°C (1,220°F) and a boiling point of 2,519°C (4,566°F).

3.1.1 Matrix Material

Aluminum Alloy 7075:

7075 Aluminum alloy (AL7075) is an Aluminum alloy, with zinc as the primary alloying element. It has excellent mechanical properties and exhibits good ductility, high strength, toughness, and good fatigue resistance.

It is more susceptible to embrittlement than many other Aluminum alloys because of microsegregation. But it has significantly better corrosion resistance than the alloys from the 2000 series. It is one of the most commonly used Aluminum alloys for highly stressed structural applications and has been extensively utilized in aircraft structural parts.

3.1.1.1 Chemical Composition of AL7075

Table.2 Chemical composition

Elements	Chemical composition (wt%)
Zn	5.6
Mg	2.5
Cu	1.5
Mn	0.04
Fe	0.3
Si	0.08
Al	bal.

3.1.1.2 Properties of AL7075

- Density (ρ) : 2.81g/cc
- Young's modulus (E) : 71.7 GPa
- Poisson's ratio (v) : .33
- Melting temperature (T_m) : 477 ^{0}C
- Thermal conductivity (k) : 196 W/m ^{0}K
- Linear thermal expansion coefficient : $2.36*10^{-5}$ K^{-1}
- Specific heat capacity (c) : 714.8 J/Kg ^{0}K

3.1.1.3 Advantages

- Higher temperature capability
- Fire resistance
- Higher transverse stiffness and strength
- No moisture absorption
- Higher electrical and thermal conductivities
- Better radiation resistance

3.1.1.4 Disadvantages

- Higher cost of material systems
- Limited service experience

3.1.1.5 Applications of AL7075

1. Aircraft fittings
2. Gears and shafts
3. Missile parts
4. Regulating valve parts
5. Worm gears
6. Aerospace/defense applications
7. Automotive

3.1.2 Reinforcements

Reinforcement is the material, which is added to improve the various properties of the matrix material. For example, in Aluminum matrix composites, hard reinforcement such as rice husk ash and fly ash strengthens the matrix extrinsically through improved load transfer intrinsically by increasing the density.

In the present study, both hard reinforcements rice husk ash and fly ash had been used to produce composites. A significant enhancement in composite properties, such as stiffness, strength and fracture toughness, as well as low reactivity and the low cost make this reinforcement ideal for the manufacture of cast metal matrix composites requiring excellent wear resistance.

3.1.2.1 Rice Husk Ash

India has a major agribusiness sector that has achieved remarkable successes over the last three and a half decades. Agricultural waste or residue is made up of organic compounds from organic sources such as rice straw, oil palm empty fruit bunch, sugar cane bagasse, coconut shell, etc. Rice husk from paddy is one example of alternative material that has great potential. Rice husk, a major by-product of the rice milling industry, is one of the most commonly available lignocellulosic materials that can be converted to different types of fuels and chemical feedstocks through various thermochemical conversion processes.

Fig.4 Rice Husk

Rice husk is an agricultural residue abundantly available in rice-producing countries. The husk surrounds the paddy grain. During milling of paddy, about 78 % of the weight is received as rice, broken rice and bran. Rest 22 % of the weight of paddy is received as a husk. This husk is used as fuel in the rice mills to generate steam for the parboiling process. This husk contains about 75 % volatile organic matter and the balance 25 % of the weight of this husk is converted into ash during the firing process, known as rice husk ash. This RHA, in turn, contains around 85 % - 90 % amorphous silica. The moisture content ranged from 8·68 to 10·44%, and the bulk density ranged from 86 to 114 kg/ m^3.

Rice husk is unusually high in ash, 92 to 95% silica, highly porous and lightweight, with a very high external surface area. Its absorbent and insulating properties are helpful in many industrial applications, such as strengthening agents in building materials. Rice husks are processed into rectangular-shaped particle boards.

The annual rice husk produces in India amounts is generally approximately 120 million tons. Rice husk is generally not recommended as cattle feed since its cellulose and other sugar contents are low. Instead, Furfural and rice bran oil are extracted from rice husk. power generation.

Gray colour rice husk ash

Pulverized gray colour Rice Husk Ash

Fig.5 Rice Husk Ash

Rice husk is an agricultural residue that accounts for 20% of the 649.7 million tons of rice produced annually worldwide. Burning the husk under a controlled temperature below 800 °C can produce ash with silica mainly in amorphous form. The procedure adopted is in accordance with Aluminates (Al). It involves the use of a simple metallic drum with perforations as a burner for the rice husk. Dry rice husks placed inside the drum were ignited with the help of charcoal. The husk was allowed to burn completely and the ashes were removed 24 hours later. The ash was then heat-treated at a temperature of 650^0 c for 180 minutes to reduce its carbonaceous and volatile constituents. Sieving of the bamboo leaf ash was then performed using a sieve shaker to obtain ashes with mesh size under 50μm. Chemical compositions of RHA are affected due to the burning process and temperature. Silica content in the ash increases with higher the burning temperature.

Table.3 Composition of rice Husk Ash

Constituent	SiO2	Al2O3	C	CaO	MgO	KaO	Fe2O3
(%)	90.23	3.54	1.23	1.58	0.53	0.39	0.21

3.1.2.1.1 Applications of Rice Husk Ash:

- Rice husk ash can be put to use as a building material, fertilizer, insulation material, or fuel.
- Rice husk ash uses aggregates and fillers for concrete and board production, economical substitute for micro silica, absorbents for oils and chemicals.
- It can be used in soil ameliorants, as a source of silicon, as insulation powder in steel mills to name a few.

3.1.2.2 Fly Ash

Fly ash, also known as "pulverized fuel ash" in the United Kingdom, is one of the residues generated by coal combustion and is composed of the fine particles driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. Fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys of coal-fired power plants. Together with bottom ash removed from the bottom of the boiler is known as coal ash. Depending upon the source and makeup of the coal being burned, the components of fly ash vary considerably. Still, all fly ash includes substantial amounts of silicon dioxide (SiO_2) (both amorphous and crystalline), Aluminum oxide (Al2O3) and calcium oxide (CaO), the main mineral compounds in coal-bearing rock strata.

Constituents depend upon the specific coal bed makeup but may include one or more of the following elements or substances found in trace concentrations (up to hundreds of ppm): arsenic, beryllium, boron, cadmium, chromium, hexavalent chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, and vanadium, along with minimal concentrations of dioxins and PAH compounds.

Fig.6 Fly Ash

In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured before release by fitting pollution control equipment. In the US, fly ash is generally stored at coal power plants or placed in landfills. About 43% is recycled, often used as a pozzolan to produce hydraulic cement or hydraulic plaster and replace Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attacks. After a lengthy regulatory process, the EPA published a final ruling in December 2014, which establishes that coal fly ash does not have to be classified as hazardous waste under the Resource Conservation and Recovery Act (RCRA).

Table.4 Chemical composition of Fly Ash

Constituent	SiO_2	$Al_2 O_2$	MnO_2	Na_2O	K_2O	CaO	Fe_2O_3	TiO_2	C.F.A.
%	63.95	26.07	0.02	0.02	0.04	2.43	4.88	0.68	1.91

In the case that flies or bottom ash is not produced from coal, for example, when solid waste is used to produce electricity in an incinerator (see waste-to-energy facilities), this kind of ash may contain higher contaminants than coal ash. In that case, the ash produced is often classified as hazardous waste.

3.1.2.2.1 Applications of Fly Ash:

- Stabilization of soft soils
- Road subbase construction
- As Aggregate substitute material (e.g., for brick production)
- Mineral filler in asphaltic concrete
- Agricultural uses soil amendment, fertilizer, cattle feeders, soil stabilization.
- Concrete production, as a substitute material for Portland cement and sand
- Embankments and other structural fills (usually for road construction)
- Waste stabilization and solidification
- Cement clinkers production - (as a substitute material for clay)

3.2 Methods of fabrication

3.2.1Stir Casting

Among all the well-established metal matrix composite fabrication methods, stir casting is the most economical. For that reason, stir casting is currently the most popular commercial method of producing aluminum-based composites.

Among the variety of manufacturing processes available for discontinuous metal matrix composites, stir casting is generally accepted as a particularly promising route, currently practiced commercially. Its advantages lie in its simplicity, Flexibility and applicability to large quantity production.

It is also attractive because, in principle, it allows a conventional metal processing route to be used and hence minimizes the final cost of the product. This liquid metallurgy technique is the most economical of all the available routes for metal matrix composite production and allows very large-sized components to be fabricated.

Fig.7 Stir Casting Setup

The most straightforward and most commercially viable technique is the vortex technique or stir casting technique. The stir casting setup consists of a furnace, an electric motor with a stirrer arrangement and temperature sensors. In this method, ceramic particulates are incorporated into liquid metal melt and the mixture is allowed to solidify. It is essential to create a good wetting between the particulate reinforcement and the liquid metal. The vortex technique requires the introduction of pre-treated ceramic particles into the vortex of the molten matrix created by a rotating impeller. Generally, it is possible to incorporate up to 30% ceramic particles in size range 5 to 100μm in various molten Aluminum alloys.

Fig.8 Stir Casting Machine

CHAPTER - IV

4.EXPERIMENTAL PROCEDURE

4.1 Preparation of matrix material:

The preparation of matrix material mainly consists of six major steps:

1. Collection of AL7075, RHA and FA materials.
2. Melting of AL7075, RHA and FA materials
3. Setting of Dies in Position.
4. Pouring Red Hot molten metal into the Cast Iron Dies.
5. Solidification of the Molten Metal in the die.

4.1.1 Collection of AL7075alloy:

PLUS METALS Ltd, Mumbai, has supplied the AL7075. Initially, the alloy was in brick form. We made it into ingot form by cutting process. The impurities of the alloy were removed during its melting.

Fig.9 AL7075 in ingot form

4.2 Preparation of Reinforcements

4.2.1 Collection and preparation of Rice Husk Ash:

The Rice Husk Ash was bought from Hari Hara Enterprises, Visakhapatnam. We bought 1kg of gray color rice husk ash, then it was pulverized by using ball mills. The impurities in pulverized gray color rice husk ash were removed by using filters.

Initially, we washed with water to remove the dust and dried at room temperature for one day. Washed rice husk is then heated to 200°C for 1 hr to remove the moisture and organic matter. During this operation, the color of the husk is changed from yellowish to black because of changing of organic matter. It is then heated to 600°C for 12 h to remove the carbonaceous material. After this operation, once again, the color is changed from black to grayish-white. The obtained silica-rich ash (RHA) is used as a reinforcement material for the preparation of composites.

Dry rice husk **pulverized gray color rice husk ash**

Fig.10 Preparation of Rice Husk Ash

4.2.2 Collection and preparation of Fly Ash:

The Fly Ash was bought from Hari Hara Enterprises, Simhadri Thermal Power Station, Visakhapatnam. We collected 1kg of Fly Ash at the chimney of the thermal power plant. The impurities in Fly Ash were removed by using filters.

Fig.11 Fly Ash

4.3 Experimental procedure

I. Initially, A7075 Al alloy, 79% by weight, was charged into the graphite crucible and heated to about 750ºC till the entire alloy in the crucible was melted.

II. The reinforcement particles RHA and FA were preheated to 800 ^{0} C for 1 hour before incorporation into the melt.

III. Simultaneously, 1wt % magnesium was added to the melt in order to enhance the wettability between rice husk, fly ash particles and the alloy melt.

IV. The stirrer made up of stainless steel was lowered into the melt slowly to stir the molten metal at the speed of 500 -700 rpm.

V. The preheated RHA and FA particles in 5,10 and 15 % by weight respectively were added into the molten metal at a constant rate during the stirring.

VI. The stirring was continued for another 10 min even after the completion of particle feeding.

VII. The mixture was poured into the mold was cooled to room temperature for one day to obtain uniform solidification. Thus (79% AL7075+1%Mg+5%FA+15%RHA) aluminum hybrid metal matrix composite was prepared.

VIII. By repeating the same procedure, the remaining other compositions were prepared.

IX. AL7075 pure alloy casting was also done

4.4 Plan of Experimental Investigation

Selection of matrix and reinforcement materials

↓

Melting of matrix material (AL7075)

↓

Addition of reinforcements and Stir casting

↓

Preparation of samples for testing

↓

Conducting of mechanical testing

↓

Analysis of Results

↓

Conclusions

Fig.12 Plan of investigation

Fig.13 Moulding

Fig.14 Solidified materials

4.5 Mechanical tests

The different tests are:

1. Tensile Test
2. Hardness test

4.5.1 Tensile Test:

A tensile test, also known as a tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.

A universal testing machine (UTM), also known as a universal tester, materials testing machine, or materials test frame, is used to test the tensile strength and compressive strength of materials.

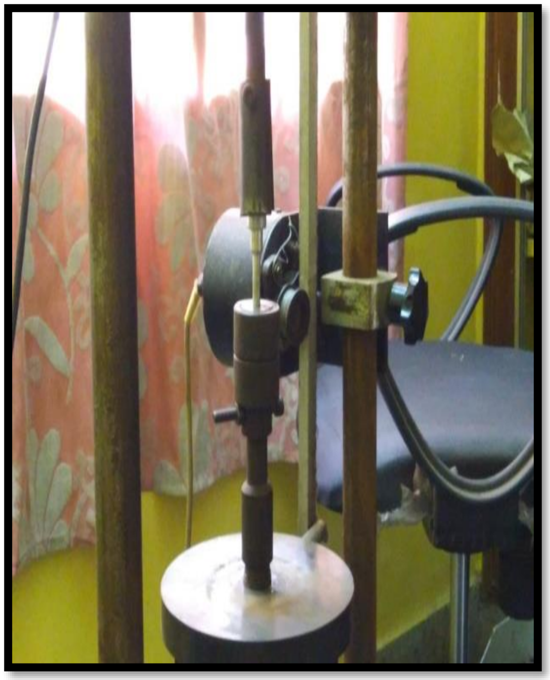

Fig.15 Tensile test machine

Material to be tested must be cut to a specific shape to fit the grips, most usually in the form of a dog-bone shape. If defects are left, the result may be a premature failure from the defect, thus under-estimating tensile strength. We followed ASTM E8 standards.

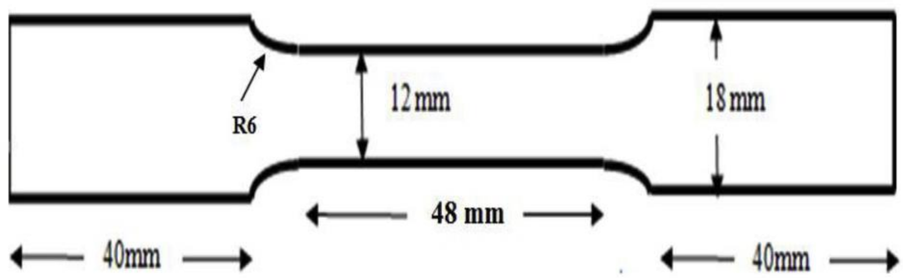

Fig.16 Tensile specimen ASTM E-8

Fig.17 Tensile specimen used

4.5.2 Hardness Test:

Hardness is a characteristic of a material, not a fundamental physical property. It is defined as the resistance to indentation, and it is determined by measuring the permanent depth of the indentation. More simply put, when using a fixed force (load) and a given indenter, the smaller the indentation, the harder the material.

4.5.2.1 Brinell Hardness Test

The Brinell Hardness Test method is the most commonly used hardness measurement technique in the industry. In the Brinell Hardness Testing, the hardness of a metal is determined by measuring the permanent indentation size produced by an indenter. Harder materials will generate shallow indentations, while softer materials will produce deeper indentations.

Fig.18 Brinell Hardness Machine

4.5.2.2 Brinell Hardness Test Procedure

The Brinell Hardness test is performed in a Brinell hardness test unit. In this test method, a predetermined force (F) is applied to a tungsten carbide ball of fixed diameter (D=10mm) and held for a predetermined period, and then removed. The spherical indenter creates an impression (permanent deformation) on the test metal piece. This indentation is measured across two or more diameters and averaged to get the indentation diameter (d). From this indentation size (d), the brinell hardness Number (BHN) is found using a chart or calculated using the Brinell hardness test formula. We followed ASTM E10 standards.

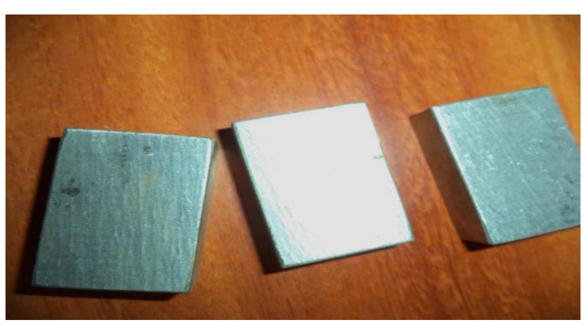

Fig.19 Hardness test Specimen

4.5.2.3 Brinell Hardness Test Formula

Once the average indentation diameter is measured, the Brinell Hardness Number (BHN) can be calculated using the following Brinell hardness test formula:

$$HB = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

where

- HB = Brinell Hardness Number (kgf/mm^2)
- P = applied load in kilogram-force (kgf)
- D = diameter of indenter (mm)
- d = diameter of indentation (mm)

4.5.2 Wear Test

4.5.2.1 Wear

Wear is the damaging, gradual removal or deformation of material at solid surfaces. Causes of wear can be mechanical or chemical. The study of wear and related processes is referred to as tribology.

The wear of metals occurs by plastic displacement of surface and near-surface material and by the detachment of particles that form wear debris. The particle size may vary from millimeters to nanometers. This process may occur by contact with other metals, nonmetallic solids, flowing liquids, solid particles, or liquid droplets entrained in flowing gasses.

4.5.2.2 Types of Wear

Common types of wear include:

a. Adhesive wear
b. Abrasive wear
c. Surface Fatigue
d. Fretting wear
e. Erosive wear

Adhesive wear

Adhesive wear occurs when two bodies slide over or are pressed into each other, which promotes material transfer. This can be described as plastic deformation of tiny fragments within the surface layers.

Abrasive wear

Abrasive wear is commonly classified according to the type of contact and the contact environment. The type of contact determines the mode of abrasive wear. The two modes of abrasive wear are known as two-body and three-body abrasive wear. Two-body wear occurs when the grits or hard particles remove material from the opposite surface. The common analogy is that of material being removed or displaced by a cutting or plowing operation. Three-body wear occurs when the particles are not constrained and are free to roll and slide down a surface.

Surface fatigue

Surface fatigue is a process in which the surface of a material is weakened by cyclic loading, which is one type of general material fatigue. Fatigue wear is produced when the wear particles are detached by cyclic crack growth of microcracks on the surface. These microcracks are either superficial cracks or subsurface cracks.

Fretting wear

Fretting wear is the repeated cyclical rubbing between two surfaces. Over a period of time, fretting will remove material from one or both surfaces in contact. It occurs typically in bearings, although most bearings have their surfaces hardened to resist the problem.

Erosive wear

Erosive wear can be defined as an extremely short sliding motion and is executed within a short time interval. Erosive wear is caused by the impact of particles of solid or liquid against the surface of an object. The impacting particles gradually remove material from the surface through repeated deformations and cutting actions. It is a widely encountered mechanism in the industry. Due to the nature of the conveying process, piping systems are prone to wear when abrasive particles have to be transported.

4.5.2.3 Methods of wear test

- Abrasive and adhesive test equipment
- Pin-on-disc
- Pin-on-drum abrasive wear test
- Repeated impact wear test
- Rubbing tests
- Block-on-ring test
- Taber test

4.5.2.4 Pin-on-disc test

The pin-on-disk tribometer consists of a flat pin, or sphere, which is attached to a stiff elastic arm that is weighted down onto a test sample with a precisely known weight. The model is rotated at a selected speed. The elastic arm ensures a nearly fixed contact point and a stable position in the friction track formed by the pin on the sample.

The kinetic friction coefficient is determined during the test by measuring the deflection of the elastic arm or by direct measurement of the change in torque by a sensor located at the pivot point of the arm. Wear rates for the pin, and the disk are calculated from the volume or weight of material removed during the test.

The popularity of the method is due to its relative simplicity and abundance of the tribological contacts that can be well described by the simple pin on disk motion.

4.5.2.5 Factors that should be considered when designing pin on disc wear test procedure:

- **Pin shape**. Typically, the pin can be of any form. The ball on disk test uses a ball pin or a lens. Flat pin or chip-shaped pins can also be used.
- **Pin alignment**. If the pin is flat-ended, the alignment should be ensured since otherwise, non-uniform loading occurs, resulting in non-uniform wear and possibly overloaded conditions. The edges of the flat specimens should not be sharp, otherwise chipping may occur.
- **Pin material**. The choice of the pin material is very important. It should be noted that typically, the tribological behavior for the same pair of materials is different depending on

which material is used for the pin and which material is used for the disc. This is specifically true for the case of the contact between 'soft' and 'hard' materials. This difference comes from the fact that the wear occurs mainly on the softer material. If the ball on disc case is considered, if the ball is softer, it will be worn faster and form a flat on flat contact with pressure profile significantly different for the initial one. If the disk is softer, than the groove will form on the disk and plouging wear will occur.

- **Pin location**. It is possible to place a pin on the top of the disk. However, in many cases the pin is pressed against the disk from the bottom. It is typically done to avoid getting the wear particles back into contact once they are formed or to collect the wear particles for further analysis. Due to gravity, the wear particles will be falling down.

Fig.20 Equipment of Pin on disc test

Dimensions if specimen : 40 X 10dia mm

Volume of specimen : 3141.59 mm^3

Density = Mass / Volume

Table.5 Density and Mass of specimen

	1.	2.	3.	4.
Mass	8.83 gm	8.734 gm	8.54 gm	8.16 gm
Density	2.81 gm/cc	2.78 gm/cc	2.72 gm/cc	2.6 gr/cc

CHAPTER – V

5.RESULTS AND DISCUSSIONS

The AL7075/Rice Husk Ash/Fly Ash hybrid composites are fabricated successfully using the stir casting technique. The test specimens are prepared with varying proportions of Rice Husk Ash and Fly Ash. The Results of Various Tests conducted for determining Ultimate Tensile Strength, Hardness and Wear rate are tabulated for all test specimens.

5.1 Tensile test

The test was conducted on the samples according to the standard of ASTM E8 at room temperature, using a universal testing machine. The specimen of diameter 12 mm and the gauge length of 48mm machined from the cast composite as shown in Fig.16,17

Table.6 Tensile test result

Sl. No	Composition	Tensile Strength (Mpa)
1.	AL7075 pure alloy	578
2.	AL7075+FLYASH 15%+RHA5%	597
3.	AL7075+FLYASH 10%+RHA10%	620
4.	AL7075+FLYASH 5%+RHA15%	585

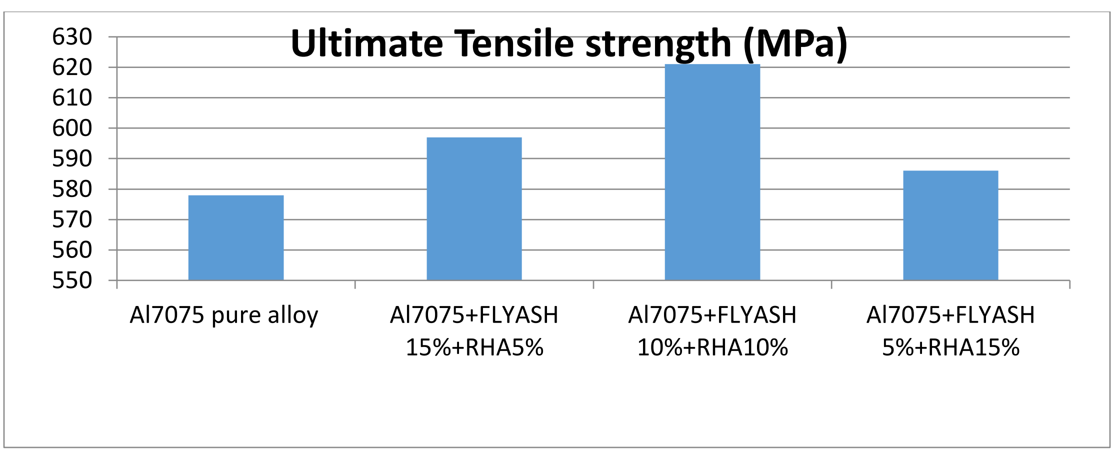

Fig.21 Composition Vs Tensile Strength

From the above fig.21, it was evident that reinforcements in equal proportions boosted the tensile strength of the composite. This was probably due to the uniform distribution of reinforcements in the matrix material, which effectively reduced the hybrid composite porosity by filling the voids and improving the load-bearing capacity. The tensile strength got reduced for Al7075+RHA 5%+ FA 15% hybrid composite due to an increment of FA weight beyond 10%. FA after 10% wt. has shown a negative effect on the tensile strength of the composite.

5.2 Brinell Hardness Test

In this test method, a predetermined force (F) is applied to a carbide ball of fixed diameter (D) and held for a predetermined period, and then removed. The spherical indenter creates an impression on the test metal piece. This indentation is measured across two or more diameters and averaged to get the indentation diameter (d), as per ASTM E10

Table.7 Hardness test results

Sl. No	Composition	Load(Kgf)	B.H.N
1.	AL7075 pure alloy	**500**	148
2.	AL7075+FLYASH 15%+RHA5%	**500**	165
3.	AL7075+FLYASH 10%+RHA10%	**500**	178
4.	AL7075+FLYASH 5%+RHA5%	**500**	189

It was clear from the above graph that the hardness of the hybrid composite linearly increasing with an increase in the weight fraction of the rice husk ash particles. It might be due to the fact that RHA contains hard silica particles in micron and submicron size, which leads to the formation of the hard surface of the hybrid composite. This hard surface offered more resistance to plastic deformation.

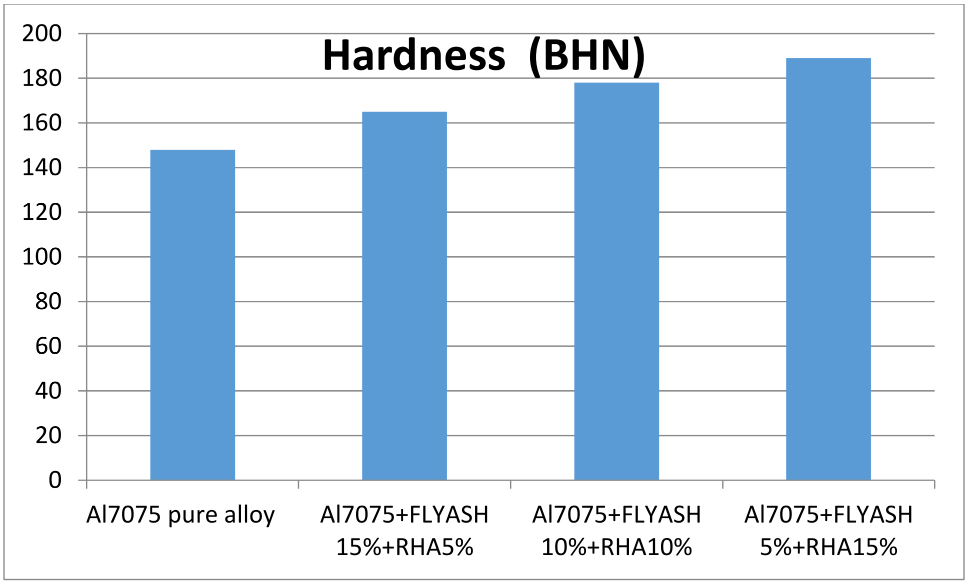

Fig.22 Hardness of various composites

5.4 Wear Test

The sliding wear behavior of AL7075 alloy and AL7075 alloy-FA and RHA particulate composites are shown in table 1.6. As per ASTM G99 30 N of the load has been applied. For a period of 33minutes, the wear test was conducted with a track velocity of 0.5m/sec at the sliding speed of 87 rpm on a steel disc with 110 mm track diameter and the sliding distance is 1000m.

Wear rate = volume lost by specimen / sliding distance

Table.8 Change in volume of specimen after wear test

1.	2.	3.	4.
$V_1 = 280mm^3$	$V_2 = 175mm^3$	$V_3 = 143mm^3$	$V_4 = 110mm^3$

Table.9 Wear test results

Sl. No	Composition	Wear rate (µm)	COF.
1.	AL7075 pure alloy	280.09	0.280
2.	AL7075+FLYASH 15%+RHA5%	175	0.224
3.	AL7075+FLYASH 10%+RHA10%	143	0.180
4.	AL7075+FLYASH 5%+RHA5%	110	0.16

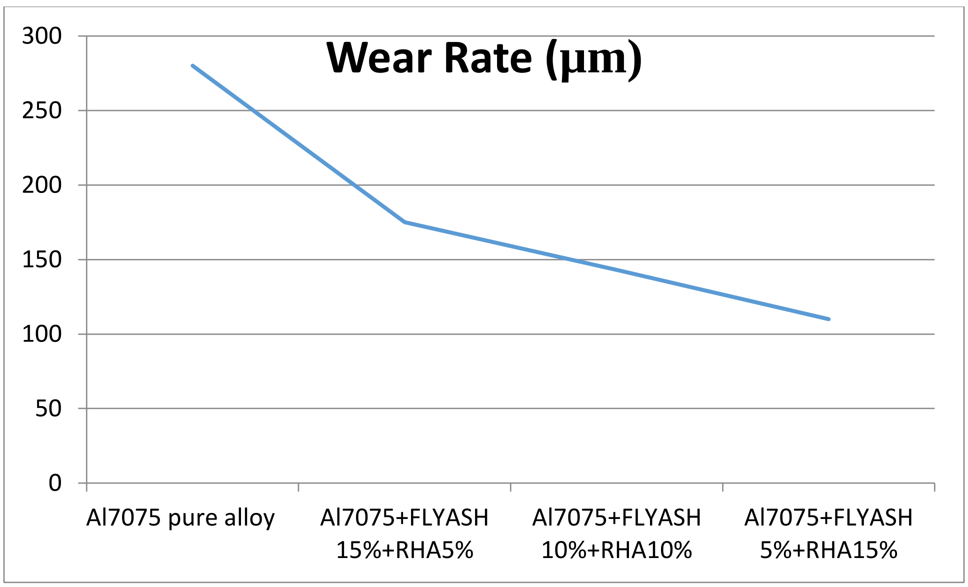

Fig.23 Composition Vs. Wear rate

The wear rate of hybrid composite with RHA 15% and fly ash 5% is less than pure alloy. It was because of the formation of a hard surface on the hybrid composite, which offered more resistance against the delamination of surface layers. It was a known fact that harder surfaces wear less. All the hybrid cases showed a positive effect on the wear behavior of aluminum composites.

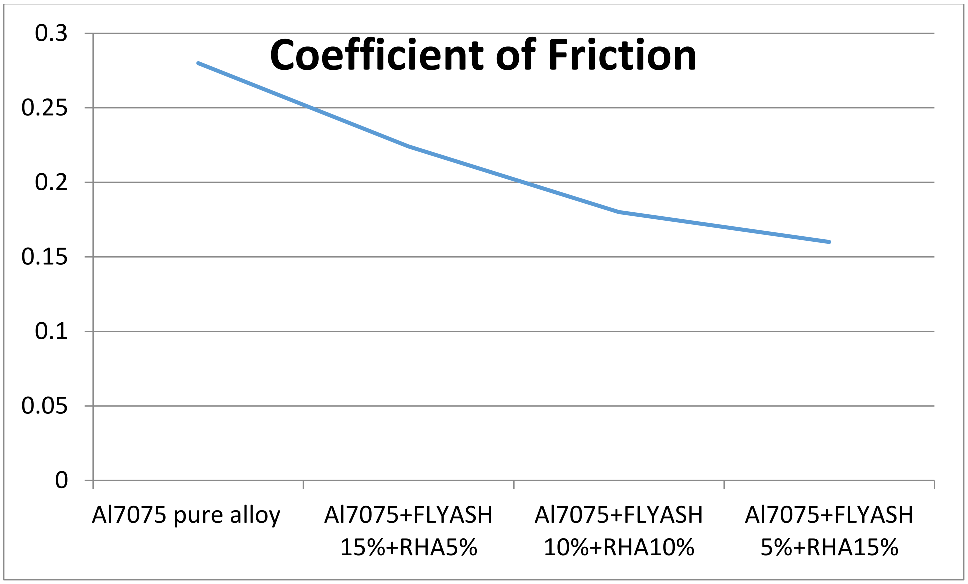

Fig.24 Composition Vs. CoF

The coefficient of friction also decreased with increasing reinforcement RHA. The worn surface will experience a sufficient plastic deformation as the sliding friction increases. The soft materials will undergo higher plastic deformation and because of repeated welding-fracturing process, the coefficient of friction fluctuates more and reaches high values. Whereas harder materials resist this plastic deformation and give the low value of CoF.

CHAPTER – VI

6.CONCLUSIONS AND FUTURE SCOPE

6.1 Conclusions

Based on the results presented above, the following conclusions can be drawn

- Rice husk ash and Fly ash particles were successfully incorporated in AL7075 alloy by using stir casting technique.
- The hardness of AL7075/RHA/FA composites increases with an increase in Rice Husk Ash content.
- The ultimate tensile strength increased with an increase in rice husk ash content up to 10%; beyond that, the tensile strength decreases.
- The wear rate and coefficient of friction decrease with the increase in rice husk ash content.
- All the hybrid cases were having better mechanical properties than pure alloy.
- The poor wettability of the phases in the matrix is the major problem at a higher weight fraction of reinforcement. Due to this problem, the strength decreases after a certain limit. This problem can overcome, by adding a small amount of magnesium and by preheating the composites and the die.

6.2 Future Scope

The scope of present work can be extended by including the following areas for future research work.

- Investigations need to be carried out in different lubrication environments in order to analyze wear behavior of HMMCs in wet conditions.
- Manufacturing and testing real components like piston, connecting rods, gears and other applications , where sliding contact is expected to evaluate the application potential of the hybrid composites.
- The effect of heat treatment on the properties of the composites may possibly be studied.

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