A Study on Mechanical and Tribological Properties of Aluminium Alloy (7075) Reinforced with Nano Silicon Carbide and Fly Ash

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Abstract— A composite material is a combination of two or more chemically distinct and insoluble phases. Metals and ceramics, as well, can be embedded with particles or fibers, to improve their properties; these combinations are known as Metal-Matrix composites. Aluminum 7075 alloy constitutes a very important engineering material widely employed in the aircraft and aerospace industry for the manufacturing of different parts and components. It is due to its high strength to density ratio that it a sought after metal matrix composite. The present study deals with the behaviour of Al 7075 alloy based composites, reinforced with nano particulate Sic(particle size of 50 nm) and Fly Ash. The nano-particles can improve the base material in terms of wear resistance, damping properties and mechanical strength. To achieve this objective stir casting technique can be adopted and then studying its mechanical and tribological properties such as tensile strength, impact strength and wear behavior of produced test specimen. Experiment has been conducted by varying weight fraction of Fly Ash (2%,4% and 6%)while keeping SiC constant (0.1% and 0.2%). It was found that the tensile strength and hardness of Al alloy 7075 composites increases with the increase in %wt of Fly Ash upto certain limit. In addition of more amount of reinforcement the Tensile strength decreases due to poor wettability of the reinforcement material with metal aluminium matrix. The result shown that increase in addition of fly ash increases impact strength and wear resistance of the specimen and decreases the percentage of elongation.

Key words: Nano Sic, Fly Ash, metal matrix composites, Al 7075 alloy, Mechanical and Tribological properties and Stirr casting

I. INTRODUCTION

There are more than 50,000 materials available to engineers for the design and manufacturing products for various applications. These materials range from copper, cast iron, brass, which have been available for so many years, to the more recently developed advanced materials such as composites, ceramics and high- performance steels. Due to wide choice of materials, today's engineers are posed with a big challenge for the right selection of material and manufacturing processes for an application. These materials depending on their major characteristics like stiffness, strength, density and melting temperature, can be classified into four categories. They are (1) Metals (2) Plastics (3) Ceramics and (4) Composites.

Aluminium is the most abundant metal and the third most abundant chemical element in the earth's crust comprising over 8% of its weight. Only oxygen and silicon are more prevalent. Yet until about 150 years ago aluminium in its metallic form was unknown to man, the reason for this is that aluminium, unlike iron or copper, does not exist as a metal in nature. Because of its affinity for oxygen, aluminium is always found combined with other elements mainly as aluminium oxide. As such it is found in nearly all clays and many minerals.

The properties of aluminium that make this metal and its alloys the most economical and attractive for a wide Variety of uses are appearance, light weight, excellent fabricability, good physical properties, better mechanical properties, and good corrosion resistance. Aluminium is often selected for its electrical conductivity, which is nearly twice that of copper on an equivalent weight basis. The thermal conductivity of aluminium alloys, about 50 to 60% that of copper, is advantageous in heat exchangers, evaporators, electrically heated appliances and utensils, and automotive cylinder heads and radiators. Aluminium is non-ferromagnetic, a property of importance in the electrical and electronics industries. It is non-pyrophoric, which is important in applications involving inflammable or explosive-materials handling or exposure. Aluminium is also non-toxic and is routinely used in containers for foods and beverages. It has an attractive appearance in its natural finish, which can be soft and lustrous or bright and shiny. Aluminium has a density of only 2.7g/cm^3, approximately one-third as much as steel (7.83g/cm^3), copper (8.93g/cm^3), or brass (8.53g/cm^3).

Composite materials are defined as "a material systems consisting of mixture of or combination of two or more micro constituents insoluble in each other and differing in form and or material composition". Composites are generally prepared by adding dissimilar materials together to work as a single mechanical unit and the properties of such materials are different in scale and kind from those of any of its individual constituent. Composites can offer a combination of properties and a diversity of applications unobtainable with metals, ceramics, or polymers when used alone.

The aluminum 7075 alloy, zinc is the primary alloying element. It is strong, with a strength comparable to many steels, and has good fatigue strength and average machinability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable. Alloy 7075, a cold finished aluminum wrought product, has the highest strength of all aluminum screw machine alloys.

Silicon carbide(Sic),also known as carborundum. Silicon carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties.It is used in abrasives, refractory ceramic and numerous high performance applications. The material can also be made an electrical conductor and has application in resistance heating, flame igniters and electronic components.

Fly Ash is a material separated from exhaust gases of power plants with suspension – fired furnace in which pulverized coal is used as fuel. It is collected from fuel gases using electrostatic, mechanical precipitator or bag houses.The major components of fly ash reported in oxide form are silica (SiO_2), alumina (Al_2O_3), and oxides of calcium and iron.. Its density ranges between 1.3 g/cm^3 to 4.8 g/cm^3.

The challenges and opportunities of aluminium matrix composites have been reported much better to that of its unreinforced counterpart. The addition of reinforcing phase significantly improves the Tribological properties of aluminum and its alloy system. The thinking behind the development of hybrid metal matrix composites is to combine the desirable properties of aluminium, nano Silicon Carbide and Fly Ash. Aluminium have useful properties such as high strength, ductility, high thermal and electrical conductivity but have low stiffness.[1,2]

In this study an attempt has been made to fabricate a Hybrid composite from commercial silicon carbide and fly ash. Aluminium alloy (7075) is used as matrix material for the fabrication of Al7075-Sic-Fly ash hybrid composite material. Methods available for the production of Hybrid composites are powder metallurgy, spray deposition, liquid metal infilteration, squeeze-casting, stirrcasting. Though various processing techniques available for particulate or discontinuous reinforced metal matrix technique is most suitable due to its simplicity, flexibility and ease of production for large sized components. Hence stirr casting methodis used in this study.[1]

The objective of present work is to produce hybrid composites of Al7075/nano Sic/Fly ash by stir casting method and determine the effect of addition of Fly ash on mechanical and tribological properties of Al7075-Silicon carbide MMCs.[2]

II. Materials and Methods

A. Materials

The materials used in the present investigation are Al 7075, nano Sic and Fly Ash. Here the grain size of the Sic is 50nm and Fly Ash is 50µm. Chemical composition of Al7075 with Fly Ash is shown in table 1,2 and 3.

B. Experimental Methodology

The Alminium metal matrix composite material has been prepared by stir casting method in an induction furnace(fig1.1). The weighed quantityof Al 7075 metal in the form of flakes has been taken in the crucible and then melted upto 800ºC temperature been maintained. To this pre heated (at 350ºC in muffle furnace) Sic and Fly Ash has been added at a proper weight %. The contents are stirred (at 400 rpm, about 3 to 4 minutes) to create fine vortex for proper mixing of the matrix and phases. A small amount of (1%) Magnesium is added to improve the wettability of the phases in the matrix. After mixing the melt is poured into the pre heated (about 200ºC) CI Metal die for specimen preparation.

III. Specimen Preparation

The die mold produced cylindrical rod with diameter of 15mm and height of 250mm. The test specimens were prepared by machining the cylindrical rod. For tensile test the specimens with 12mm dia X 100mm guage length, for impact test the specimen with 10mm X 55mm length with 2mm V- notch at the centre and for wear test the specimen with 8mm dia X 22mm length were produced.

IV. Results and Discussion

A. Tensile Testing

Tensile test was carried out at room temperature using a universal testing machine. Tensile test is a fundamental mechanical test where a carefully prepared specimen is loaded in a very controlled manner while measuring the applied load and the elongation of the specimen over some distance. The composite and matrix alloy rods were machined. Tensile tests were performed on the composites produced in accordance with the specifications of ASTM (A370) standard. The test was carried out at room temperature using an Instron universal testing machine. Al7075 + 0.2% nano Sic + 4% Fly Ash composite resulted in higher tensile strength.

B. Impact Testing

Impact tests are designed to measure the resistance to failure of a material to a suddenly applied force. The test measures the impact energy, or the energy absorbed prior to fracture.The most common methods of measuring impact energy are the Charpy test and Izod test. A standardized high strain- rate test which determines the amount of energy absorbed by material during fracture, is called the Charpy Impact test also known as Charpy V- notch test. In this paper Charpy test specimens measure 55x10x10mm and have a notch machined across one of the larger faces. V-shaped notch, 2mm deep, with 45° angle. Impact test was carried out at room temperature. The reading was taken by breaking specimen due to the impact of the pendulum. Al7075 + 0.2% nanoSiC + 4%Flyash resulted in higher impact strength.

C. Wear Test

The prepared Al7075 with varying percentages of (Sic & Fly ash) were subjected to wear test under dry sliding conditions. The specimen size of 8mm dia and 22mm in length were tested against a rotating EN- 32 steel disc.For each type of material, test were conducted at 60mm track dia, load in a multiple of 0.5kg (for specimen F1 it is 1.5kg) and the sliding speed in a multiple of 100rpm (for speciemen F2 it is 300rpm), wear tests were carried out at room temperature without lubrication for 6mins. The result of Wear and Friction force shown in table-5. Wear resistance is increased by increase in addition of Fly Ash in Al7075-Sic hybrid composite.

D. X-Ray Diffraction

X-Ray powder diffraction(XRD) is a rapid analytical technique primarily used for phase identification of crystalline material and can provide information on unit cell dimensions. Analyzed material is finely ground, homogenized and average bulk composition is determined. Graph 11 and 12 shows the XRD pattern of nano Silicon Carbide powder and Fly Ash powder.

V. FIGURES AND TABLES

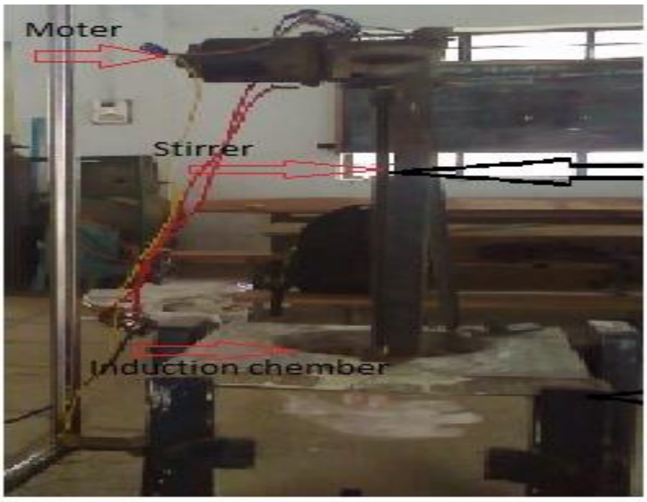

Fig.1: Shows Stirr Casting setup

Fig.2: Induction Furnace

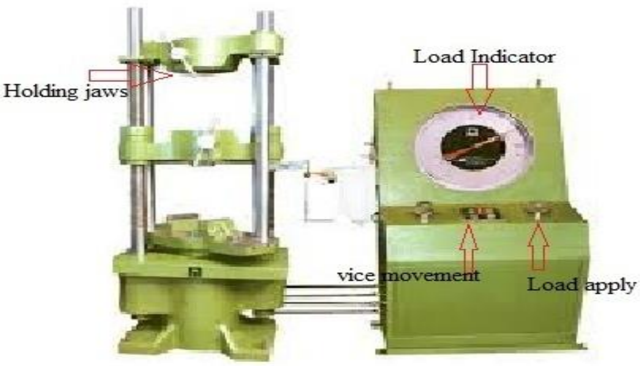

Fig. 3: Universal Testing Machine for Tensile Test

Fig. 4: Tensile Test Specimen after Machining

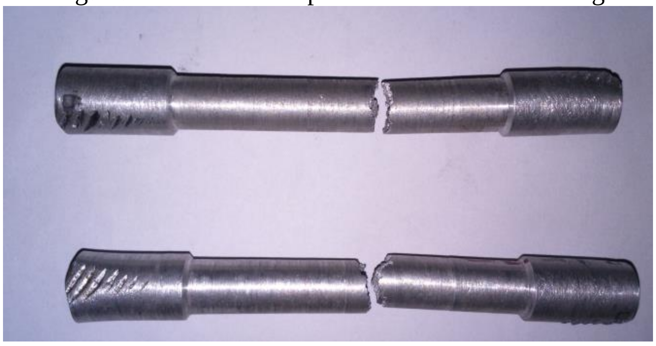

Fig. 5: Tensile Test Specimen after Testing

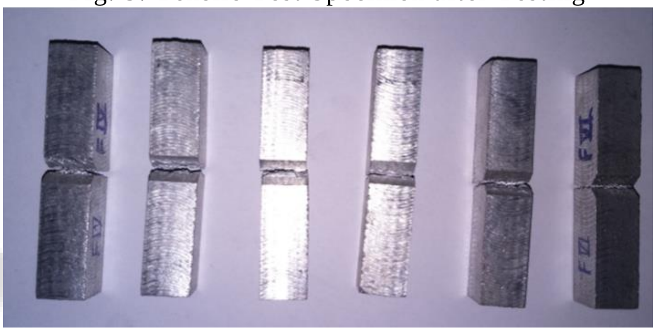

Fig. 6: Impact Test Specimen after Testing

Fig. 7: Wear Test Specimen after Testing

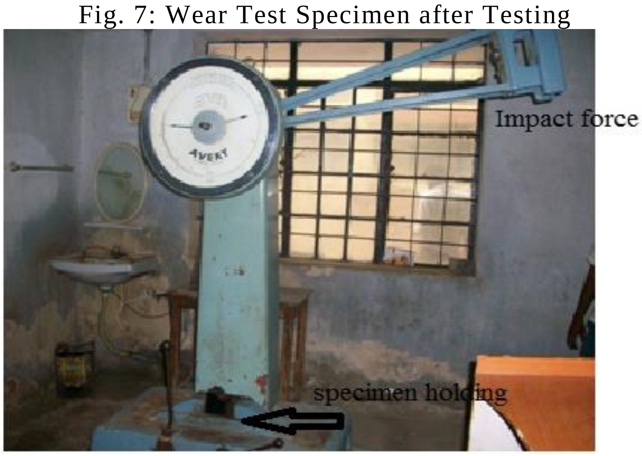

Fig. 8: Charpy Machine for Impact Test

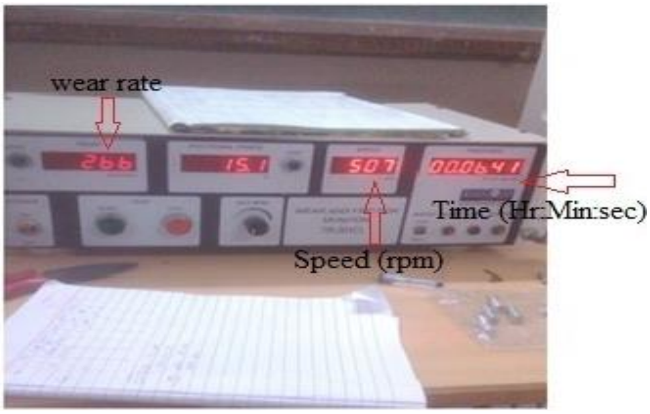

Fig. 9:

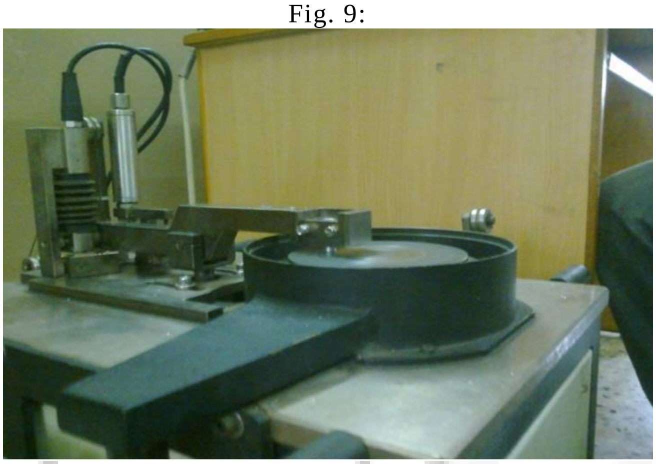

Fig. 10: shows pin-on-disc wear testing machine

Component	Wt.%
Zn	5.10-6.10
Mg	2.10-2.90
Cu	1.20-2.00
Cr	0.18-0.28
Fe	0.50(Max)
Si	0.40(Max)
Mn	0.30(Max)
Ti	0.20(Max)
Reminder	Aluminium

Table 1: Chemical composition of

Components	Weight %
SiO_2	44.8
Al_2O_3	22.2
Fe_2O_3	24
MgO	0.9
CaO	1.8
TiO_2	0.8
K_2O	2.4
Na_2O	0.9
SO_3	1.4
Balance = Oxides of other trace element	

Table 2: chemical composition of Fly Ash Aluminium 7075

Sample	Composition	Tensile Strength N/mm²	% Elongation
Pure Aluminim 7075	Al 7075	146.979	2.84
F1	Al7075 + 0.1% nano Sic + 2% Fly Ash	92.160	0.80
F2	Al7075 + 0.1% nano Sic + 4% Fly Ash	82.957	0.66
F3	Al7075 + 0.1% nano Sic + 6% Fly Ash	92.391	2.18
F4	Al7075 + 0.2% nano Sic + 2% Fly Ash	105.944	0.86
F5	Al7075 + 0.2% nano Sic + 4% Fly Ash	150.777	1.90
F6	Al7075 + 0.2% nano Sic + 6% Fly Ash	130.188	1.46

Table 3: Results of Tensile Test

Sample	Composition	Energy Absorbed N-m
Pure Aluminim	Al 7075	6
F1	Al7075 + 0.1% nano Sic + 2% Fly Ash	6
F2	Al7075 + 0.1% nano Sic + 4% Fly Ash	5
F3	Al7075 + 0.1% nano Sic + 6% Fly Ash	4
F4	Al7075 + 0.2% nano Sic + 2% Fly Ash	5
F5	Al7075 + 0.2% nano sic + 4% Fly Ash	6
F6	Al7075 + 0.2% nano sic + 6% Fly Ash	5

Table 4 – Result of Charpy Impact Test

Sample	Wear in (μm)	Frictional Force in (N)	Speed in (rpm)	Load in (kg)
Pure Aluminim	899.69	22.60	300	1.5
F1	29.33	5.38	400	2.0
F2	139.91	5.79	500	2.5
F3	82.78	8.48	600	3.0
F4	276.65	11.78	700	3.5
F5	162.64	7.82	800	4.0
F6	800.10	17.31	900	4.5

Table 5: Results of Wear Test

A. Tensile Test Results

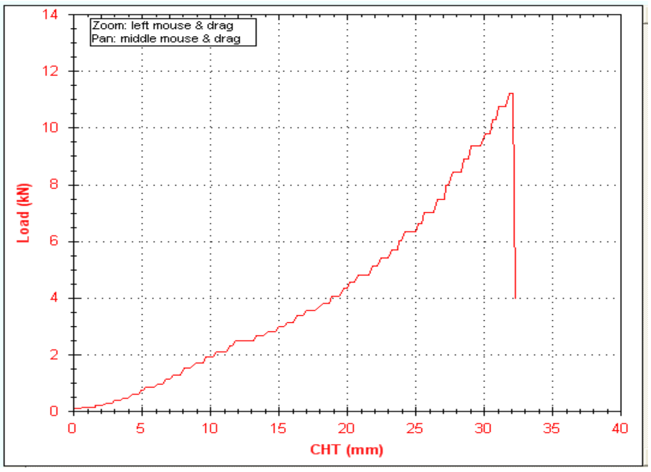

Fig. 11: Graph 1 Shows Tensile Test Result For Pure Ailuminium

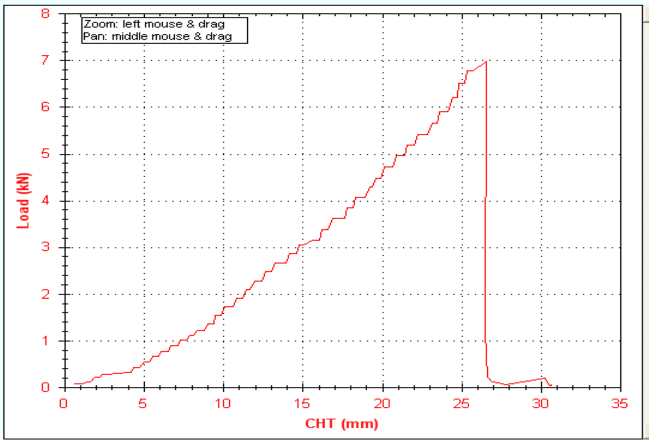

Fig. 12: Graph 2. Shows Tensile Test Result For Sample1 (F1)

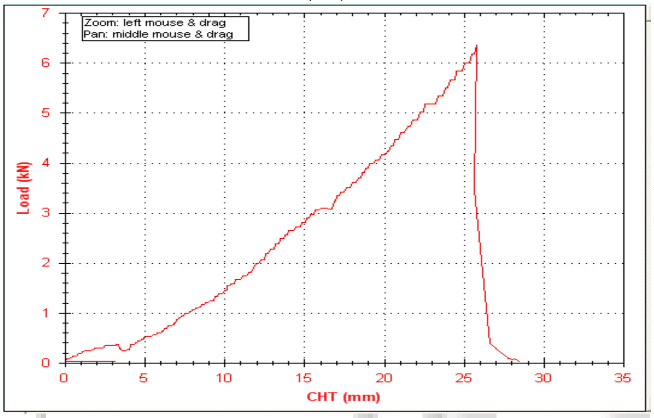

Fig. 13: Graph 3.Shows Tensile Test Result For Sample 2 (F2)

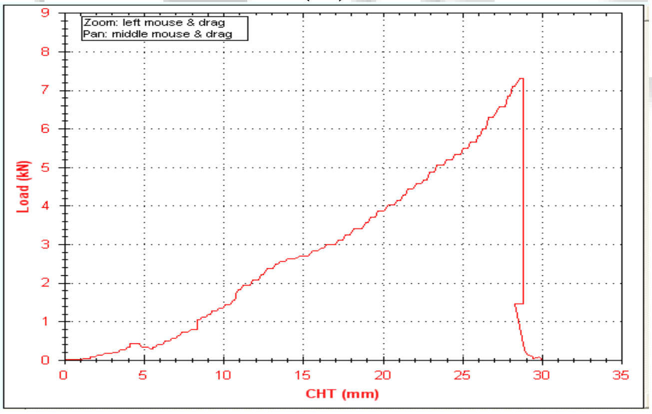

Fig. 14: Graph 4. Shows Tensile Test Result For Sample 3 (F3)

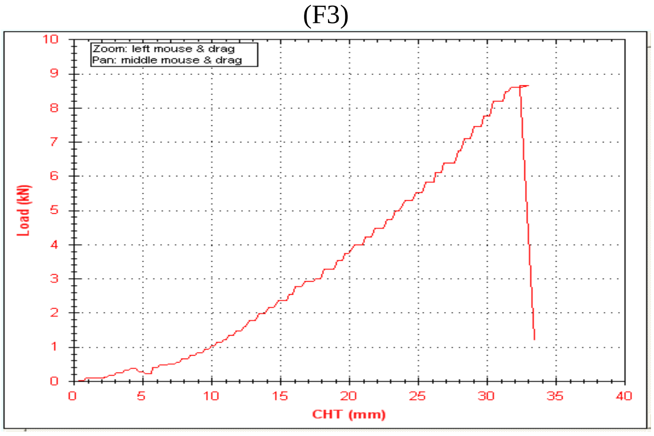

Fig. 15: Graph 5. Shows Tensile Test Result For Sample 4 (F4)

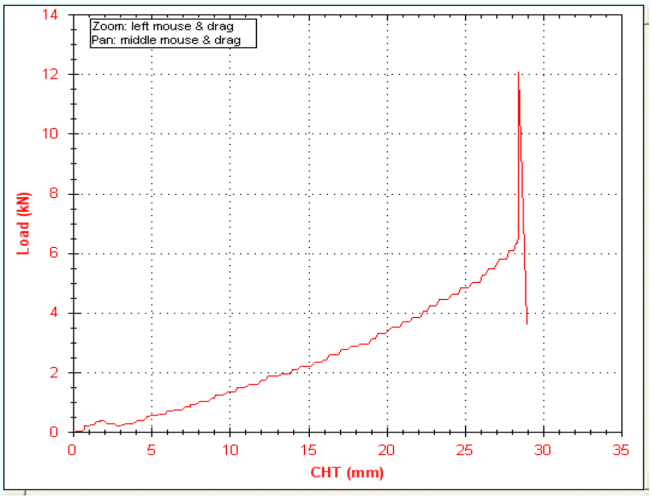

Fig. 16: Graph 6. Shows Tensile Test Result For Sample 5 (F5)

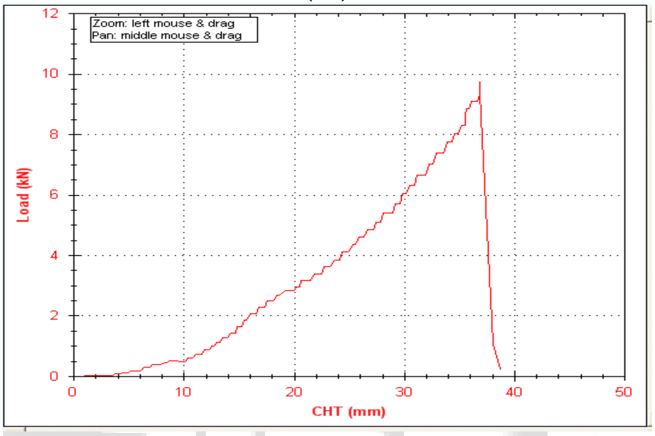

Fig. 17: Graph7. Shows Tensile Test Result For Sample 6 (F6)

B. Impact Test Results

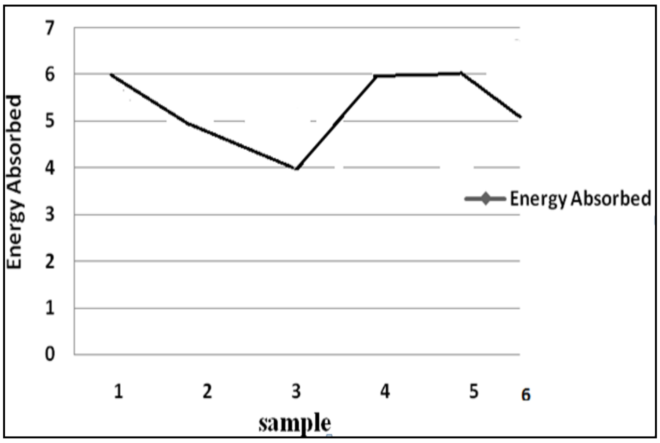

Fig. 18: Graph 8 shows result of charpy impact test.

Fig. 19: Graph 9 Shows Wear Comparison Graph of Sample 1-3 with Pure Aluminium (Umair 7)

Fig. 20: Graph10 ShowsWear Comparison Graph of Sample 4-6 with Pure Aluminium

C. *Results of XRD*

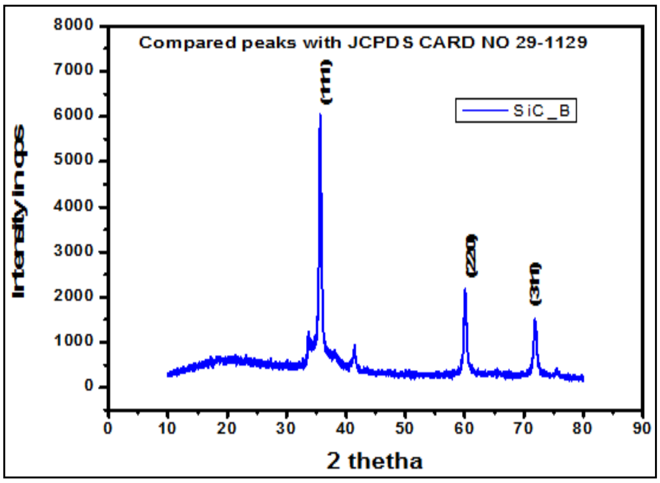

Fig. 21: Graph11 XRD pattern of Nano SiC powder

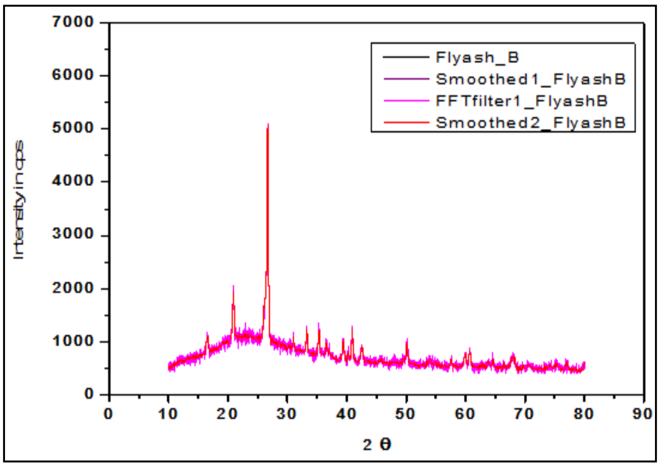

Fig. 22: Graph12. XRD pattern of Fly Ash powder

VI. Conclusion

1) Aluminium based metal matrix composite up to 0.2% silicon carbide and 6% Fly Ash have been successfully fabricated by stir casting technique with fairly uniform distribution of Silicon Carbide & Fly Ash.
2) The Tensile strength and hardness of Metal Matrix Composite increased with increase in SiC content.
3) It appears in this study that Tensile Strength starts increases with increase in weight percentage ofSiC. The best result of tensile strength has been obtained at 0.2% weight percentage of nano SiC & 4% of Fly Ash.
4) It is found that elongation tend to decrease with increasing particles weight percentage which conforms that Silicon Carbide & Fly Ash addition increases brittleness.
5) The impact strength of MMC increases with increase in weight percentage of SiC and it is maximum for sample (0.2% of SiC & 4% of Fly Ash & rest is Aluminium 7075).
6) It found that the wear resistance tends to increase with increase in addition of Fly Ash in Al7075/SiC Hybrid composite.
7) The poor wettability of the phases in the matrix is the major problem at higher weight fraction of reinforcement,due to this problem the strength decreases after certain limit. This problem we can overcome by adding small amount of Magnesium and by pre heating the composites and the die.
8) From this study it is concluded that we can use fly ash for the production of composites and can turn industrial waste into industrial wealth. This can also solve the problem of storage and disposal of fly ash.

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