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RESEARCH ARTICLE

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Fabrication, Characterization and Deformation studies on Aluminum Alloy 7075/FA/SIC with Silicon carbide and Fly-ash Composites

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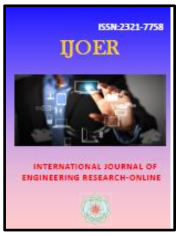

ABSTRACT

Within the last few years there has been a rapid increase in the utilization of aluminum alloys, particularly in the automobile industries. The study of the Mechanical and micro structural behavior of these materials (aluminum alloys) is of utmost importance, since the components which are made of these materials are subjected to different working conditions (like high speed, high temperatures, varying load, high thermal stresses etc.). Therefore the mechanical and micro structural behavior of the specimens made of Aluminum alloys with different improvement methods like reinforcement of fly ash and sic particles were studied.

Key words: Microstructural behavior, Aluminium Alloys, Tribology, Flyash

I. INTRODUCTION

ALUMINUM ALLOYS: In recent years aluminum alloys are widely used in automotive industries. This is particularly due to the real need to weight saving for more reduction of fuel consumption. Aluminum alloys are alloys in which aluminum (AL) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon and zinc. Apart from steel and cast iron, aluminum is one of the most widely used metals owing to its characteristics of lightweight, good thermal and electrical conductivities. Despite these characteristics, however, pure aluminum is rarely used because it lacks strength. Thus for industrial applications, aluminum is mostly used in the form of alloys. There are a number of elements that are added to aluminum in order to produce alloys with increased strength and improved foundry or working properties. In addition to alloying aluminum with other elements, the mechanical properties can also be enhanced by heat treatment. Generally, aluminum alloys can be classified into two main categories: cast alloys and wrought alloys.

The objectives of this project:

1. There has been an increasing interest in composites containing low density and low cost reinforcements.
2. So far most of the research work has been carried out by incorporating hard ceramic particles such as Al_2O_3, and graphite particles to soft matrix like pure aluminum, A2024, A6061 and many more alloys.
3. In the current work, an attempt has been made by Fly-ash an industrial waste from thermal power plant which significantly improves the mechanical properties and Wear studies on as matrix.

Aluminum a silvery white and ductile member of the boron group of chemical elements. The chemical symbol of aluminum is Al; its atomic number is 13. The following table illustrates the properties of Aluminum.

TRIBOLOGY: Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear.

WEAR MECHANISMS: Wear, corrosion and the specific degradation of polymers under ultraviolet light are the main modes of material degradation.

Wear typically induces some degree of material loss. Several methods can be used to quantify wear, such as:

1. Weighing of samples once the tests have been performed.
2. Friction force (N)
3. Applied force (N)
4. Quantifying the volume of removed material through the use of 3D tactile or Optical profilometers.
5. Filtration and analysis of the oils and wear debris found in lubricants;
6. Surface activation which consists of marking it with radio tracer isotopes and monitoring the wear through analysis of the radioactive signal emitted, provided it has been properly calibrated, the intensity of this signal can yield the depth of wear.

Adhesive wear: Adhesive wear is characterized by the appearance of junctions between the surfaces that are subject to friction. When these junctions are weak, shear occurs at the interface of the two surfaces and there is no wear. However, when junctions are strong, the softer material is subject to shearing and, as a consequence, is transferred onto the harder material.

FLY ASH: Fly ash, also known as "pulverized fuel ash" in the United Kingdom, is one of the coal combustion products, composed of the fine particles that are driven out of the boiler with the flue gases. Ash that falls in the bottom of the boiler is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitates or other particle filtration equipment before the flue gases reach the chimneys. In the past, fly ash was generally released into the atmosphere, but air pollution control standards now require that it be captured pri`or to 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,[3] often used as a pozzolan to produce hydraulic cement or hydraulic plaster and a replacement or partial replacement for Portland cement in concrete production. Pozzolans ensure the setting of concrete and plaster and provide concrete with more protection from wet conditions and chemical attack.

SILICON CARBIDE: Silicon carbide (SiC), also known as carborundum is a compound of silicon and carbon with chemical formula SiC. It occurs in nature as the extremely rare mineral moissanite. Synthetic silicon carbide powder has been mass-produced since 1893 for use as an abrasive. Grains of silicon carbide can be bonded together by sintering to form very hard ceramics that are widely used in applications requiring high endurance, such as car brakes, car clutches and ceramic plates in bulletproof vests. Electronic applications of silicon carbide such as light-emitting diodes (LEDs) and detectors in early radios were first demonstrated around 1907. SiC is used in semiconductor electronics devices that operate at high temperatures or high voltages, or both. Large single crystals of silicon carbide can be grown by the Lyle method; they can be cut into gems known as synthetic moissanite. Silicon carbide with high surface area can be produced from SiO_2 contained in plant material.

METAL MATRIX COMPOSITES: Metal Matrix composites (MMCs) are becoming attractive materials for advanced aerospace and automobile structures because of their properties can be tailored through the addition of selected reinforcements. In particular particle reinforced MMCs have found special interest because of their high specific strength and specific stiffness at room or elevated temperature.

II. DESIGN: The Aluminum-5%Zinc-3%Magnesium alloys were prepared by adding (SiC& FA) particles with percentage of 2% hybrid MMC by stir casting route. Samples of different dimensions were cut for different tests. Their composition was analyzed with the help of an optical emission spectrometer. Wear behavior of different composition samples were studied by conducting several wear tests on computerized friction and wear monitor pin on-disc wear test machine. The micro structures of the samples and of the worn surfaces were observed under a scanning electron microscope. The hardness was measured with the Brinell hardness, vicker's hardness testing machine and tensile test was conducted.

MATERIALS AND METHODS

- Preparation of Matrix Material (A 7075)
- Fabrication of Hybrid Composites by reinforcing with A 7075/5% Sic + FA particulates with wt. % fractions varying between 0 & 5%.

- Characterization of composites
    - Metallographic Studies (SEM)
    - Mechanical properties (Hardness, Density and Tensile studies)
    - Wear Studies

DENSITY: The average theoretical and measured density values of the A 7075 alloy and its respective composites were given in table. It was observed that the addition of 5% Sic + FA particles into the A7075 alloy matrix significantly decreases the density of the resultant composites in compare to the base alloy.

PREPARATION OF SPECIMENS: The A7075 MMC with varying composition were prepared by melting exact amounts of A7075 alloy in a graphite crucible in a melting furnace at a temperature of 800°Cin order to attain homogeneous composition. In this preparation Alloy is prepared from A7075 alloy and named as an as cast alloy. After preparation of specimen first, adding 5% of Sic & FA particles with 2.5% Sic + 2.5% FA to the A7075 alloy by stir casting method and named as a hybrid MMC specimen.

Fig 3.1: Shows A7075 alloy and Sic/FA

The electric furnace, crucible and the mould used for the purpose of preparation of the specimens is shown in fig 3.2

Fig3.2: Melting Furnace

Fig3.3: Stir casting

Mixing of Composites: It is a liquid state method of metal matrix composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers and fly ash) is mixed with a molten matrix metal by means of mechanical stirring.

Fig3.4: Stir Casting Process

Fig 3.5: Cast Iron Die Fig3.6: A7075 As cast Alloy

Fig3.7: A7075/ 5% Sic + FA Hybrid MMC

Impingement of Sic and FA particles: Melting furnace was to taken to melt required quantity of Al alloy was charged into the crucible and heated up to 850°C (above the alloy liquid us temperature) for melting. Required grams of mixture is taken and melted in the furnace at optimum temperature After that liquid solution is formed in that there is a formation of slag by adding coverall powder after removing Slag Hybrid 5% Sic + FA particles are reinforced to that mixture with help of stirring at speed of 1100rpm after stirring molten metal is poured in to the mould and cast object is taken from mould. Required Specimen with impingement of Hybrid A7075/5% Sic + FA is obtained.

Table3.1: Test Specimens Designation

S.NO	SPECIMEN NAME	ALLOY DESIGNATION
1.	A7075 alloy	A 7075/As cast alloy
2.	A7075-.5% Sic+2.5%FA MMC	A 7075/5% Sic + FA Hybrid

HARDNESS: Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness.

Brinell Scale: The Brinell scale characterizes the indentation hardness of materials through the scale of penetration of an indenter, loaded on a material test-piece. It was the first widely used and standardized hardness test in engineering and metallurgy. The large size of indentation and possible damage to test-piece limits its usefulness.

Fig 3.8: Brinell Testing Machine

The typical test uses a 10 millimeters (0.39 in) diameter steel ball as an indenter with a 250 kgf (29 KN; 6,600 lbf) force. For softer materials, a smaller force is used; for harder materials, a tungsten carbide ball is substituted for the steel ball.

Micro hardness test: The term "micro hardness" has been widely employed in the literature to describe the hardness testing of materials with low applied loads. A more precise term is "micro indentation hardness testing". In micro indentation hardness testing, a diamond indenter of specific geometry is impressed into the surface of the test specimen using a known applied force (commonly called a "load" or "test load") of 0.5 to 1 kg. Micro indentation tests typically have forces of 2 N and produce indentations of about 50 µm. Due to their specificity, micro hardness testing can be used to observe changes in hardness on the microscopic scale. Unfortunately, it is difficult to standardize micro hardness measurements; it has been found that the micro hardness of almost any material is higher than its macro hardness. Additionally, micro hardness values vary with load and work-hardening effects of materials. The Vickers micro indentation test is carried out in a similar manner to the Vickers micro indentation tests, using the same pyramid.

Fig 3.9: Vicker's Hardness Tester

TENSILE TEST: Tensile or tension test is widely used to find the behavior of material subjected to a slowly applied tensile load. It is conducted on Universal Testing Machine (UTM) in which load is increased gradually up to fracture and stress-strain diagram is obtained automatically with the aid of instrument attached to machine.

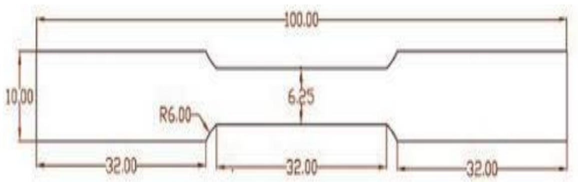

Fig3.10: Universal Testing Machine

TRIBOMETER : A simple tribometer is described by a hanging mass and a mass resting on a horizontal surface, connected to each other via a string and pulley as shown in figure 3.11. The coefficient of friction, μ, when the system is stationary, is determined by increasing the hanging mass until the moment that the resting mass begins to slide.

Then using the general equation for friction force:

$$F = \mu \mathbb{N}$$

Where *N*, the normal force, is equal to the weight (mass x gravity) of the sitting mass (m_T) and *F*, the loading force, is equal to the weight (mass x gravity) of the hanging mass (m_H).

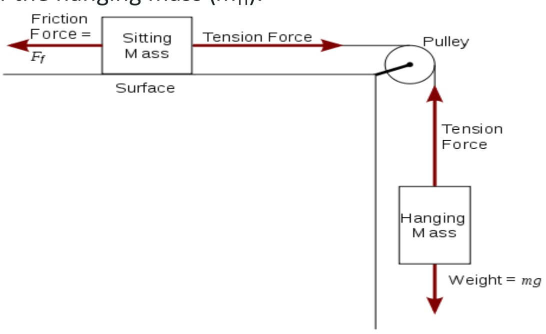

Fig3.11: Simple Tribometer

Pin on Disc Type Tribometer (Wear & Friction Monitor): The Tribotech Tribometer uses a pin-on-disk system to measure wear. The unit consists of a gimbaled arm to which the pin is attached, a fixture which accommodates disks up to 100 mm in diameter & an electronic force sensor for measuring the friction force, and a computer software for displaying the parameters, printing, or storing data for analysis. The motor driven turntable produces up to 3000 rpm. Wear is quantified by measuring the wear groove with a weight measuring machine, the amount of material removed. Users simply specify the turntable speed, the load, and any other desired test variables such as friction limit and number of rotations.

Fig3.12: Wear and Friction Monitor

Principle: A pin on disc tribometer consists of a stationary "pin" under an applied load in contact with a rotating disc. The pin can have any shape to simulate a specific contact, but spherical tips are often used to simplify the contact geometry. Coefficient of friction is determined by the ratio of the frictional force to the loading force on the pin.

RESULTS: The test results of A7075 As cast alloy and A7075/2.5% Sic+2.5% FA hybrid MMC. Different tests like wear test, hardness test and tensile test were carried out on the A7075as cast alloy and A7075/2.5%Sic+2.5%FA hybrid MMC specimens. The results obtained from these tests are reported.

HARDNESS TEST: The macro hardness tests of all the samples were conducted using a Brinell hardness testing machine with a dwell time of 15 s and applied load of 250 kgf (P) during the test and micro hardness test was conducted using a digital vicker's micro hardness testing machine with a load of 1 kg.

Fig 4.1: Brinell hardness tester

Fig 4.2: Indentation Marks

The following table shows the Brinell hardness and micro hardness values for each specimen. **TENSILE TEST:**

Fig 4.3: Tensile test specimens

Table4.3: Tensile Test values

S.NO	DESIGNATION	DIAMETER (mm)	AREA (mm^2)	ULTIMATE TENSILE LOAD (N)	TENSILE STRENGTH (N/mm^2)
1.	A7075/As cast alloy	6.25	29.70	840	28.28
2.	A7075/5% Sic + FA	6.11	29.32	960	32.74

WEAR TEST: The wear test on the specimens is carried out by means wear and friction monitor. The specimen which is pin(or) hem spherical shaped is fixed above the disc of a Pin on Disc Tribometer and the speed of the disc is initially set to speed 200rpm and apply the load 20N for 30 muns. Now the disc starts to rotate at the desired speed and the pin which is fixed above the disc undergoes wear due to the rotation of disc. The Initial and Final weights of the specimens i.e. AL 7075/As cast alloy and AL 7075/5% Sic + FA are also noted down to obtain the wear rate.

Fig 4.4: Wear test specimens

Table4.4: Wear Test Values

S.NO	**DESIGNATION**	**LOAD (Kg)**	**Time (Min)**	**Wear (Microns)**	**Friction factor (N)**	**Runs**
1	**AL 7075/As cast alloy**	**0.5**	**5**	**170**	**0.9**	**1**
2	**AL 7075/As cast alloy**	**1**	**10**	**185**	**0.5**	**2**
3	**AL 7075/As cast alloy**	**2**	**15**	**200**	**0.8**	**3**
4	**AL 7075/5% Sic + FA**	**0.5**	**5**	**110**	**0.7**	**1**
5	**AL 7075/5% Sic + FA**	**1**	**10**	**140**	**0.2**	**2**
6	**AL 7075/5% Sic + FA**	**2**	**15**	**175**	**0.1**	**3**

DRY SLIDING WEAR BEHAVIOR OF COMPOSITES: Standard specimens of 30 mm length and 4 mm ø were prepared wire cut EDM process from Alloy and composites.

Fig 4.5 Samples wear test

DISCUSSION: Wear test, hardness test and tensile test were carried out on the A7075/as cast alloy and A7075/5% Sic + FA. The results obtained from these tests are reported, analyzed and discussed in this chapter.

MATERIAL CHARACTERIZATION: The SEM Photograph of A7075 alloy is shown in Fig 5.1. It is observed that the particles are of nearly Spherical or irregular hexagonal shape. The Size of the particles varies from 10 to 100 micro meters.

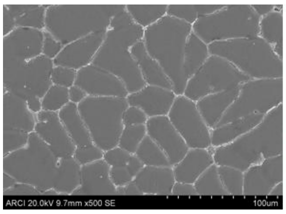

Fig 5.1: Characterization of A7075 alloy　Fig 5.2: Samples for SEM

MICRO STRUCTURAL OBSERVATION

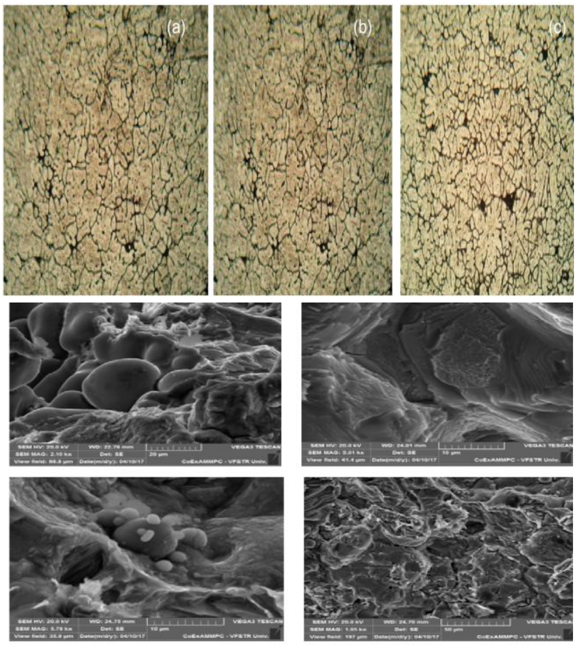

Figure 5.1 (a, b) SEM Micrograph of A7075 fractured specimens (c) AA7075 –5% FA/SiC composite (d) AA7075 -10% FA/SiC composite

Fig (a) shows alloy A7075/As cast alloy by SEM and (a) Shows alloy A7075/As cast alloy by optical Microscope (c) shows alloy A7075/5% Sic + FA by SEM and fig (c) shows alloy AL 7075/ 5% Sic + FA by optical microscope.

5.4 WEAR TEST:

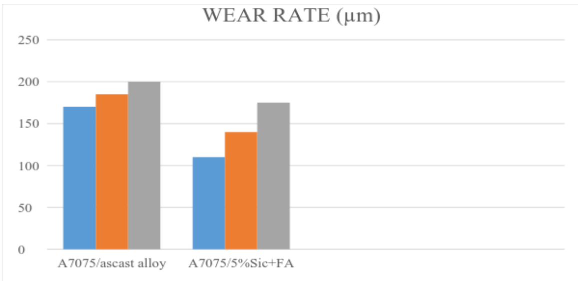

Fig 5.4: Wear Rate

The Wear rate of A7075/as cast alloy and A7075/5%Sic+FA were shown in Fig 5.4. It is observed that A7075/as cast alloy showed higher wear resistance when compared to A7075/5%Sic+FA alloy. There is a decrement in wear rate value 23.46% between A7075/as cat alloy and A7075/5%Sic+FA alloy.

FRICTION FACTOR: The friction factor of A7075/as cast alloy and A7075/5%Sic+FA were shown in Fig 5.5. It is observed that A7075/as cast alloy showed higher friction factor when compared to A7075/5%Sic+FA alloy. There is a decrement in wear rate value 54.57% between A7075/as cat alloy and A7075/5%Sic+FA alloy.

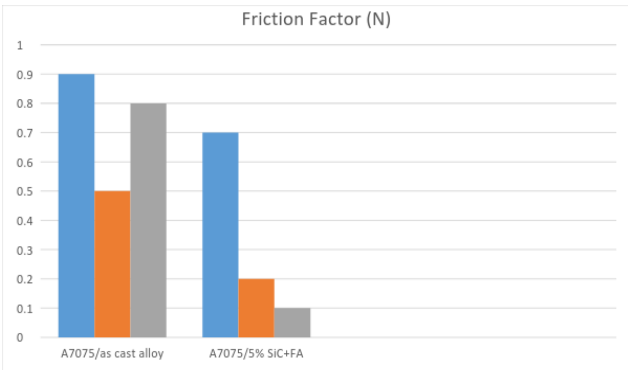

Fig 5.5: Friction Factor

HARDNESS TEST

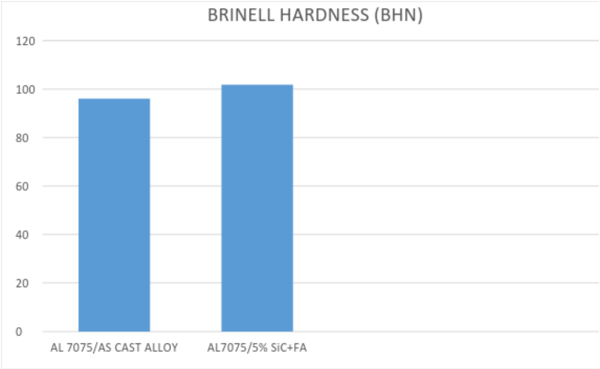

Fig 5.6: Macro Hardness Value

The Macro Hardness of A7075/as cast alloy and A7075/ 5% Sic +FA hybrid MMC were shown in Fig 5.6. A7075/ 5% Sic +FA hybrid MMC shows better hardness value when compared to A7075/as cast alloy and %of increment between A7075/as cast alloy and A7075/ 5% Sic +FA is 5.62%

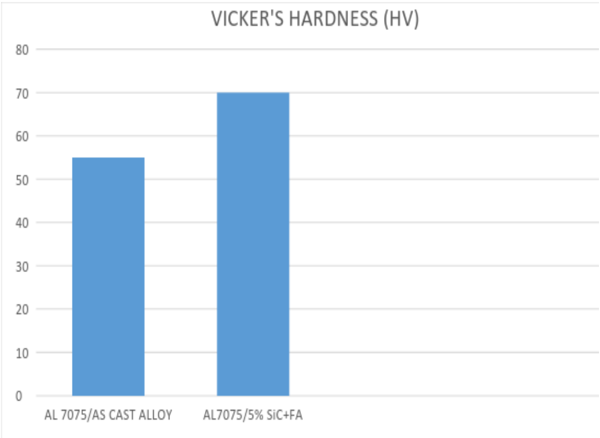

Fig 5.7: Micro Hardness Value

The Micro Hardness A7075/as cast alloy and A7075/ 5% Sic +FA hybrid MMC were shown in Fig 5.7. A7075/as cast alloy shows better micro hardness value when compared to A7075/ 5% Sic +FA hybrid MMC and actual alloy %of increment observed between A7075/as cast alloy and A7075/ 5% Sic +FA hybrid MMC alloy is 21.4%.

ENSILE TEST: Tensile Test of A7075/as cast alloy and A7075/ 5% Sic+FA were shown in Fig 5.8 it observed that exhibits better A7075/5% Sic+ FA tensile strength compared to A7075 /as cast alloy.

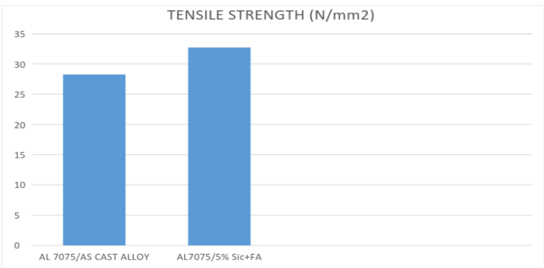

Fig. 5.8: Tensile strength value

A7075/ 5% Sic +FA hybrid MMC and actual alloy %of increment observed between A7075/as cast alloy and A7075/ 5% Sic +FA hybrid MMC alloy is 13.62%.

CONCLUSION

The A7075/ AA7075 composites were produced by stir casting route successfully. There was a uniform distribution of AA7075 particles in the matrix phase. From the SEM figures, it clearly shows that there were no voids and discontinuities in the composites; there was a good interracial bonding between the AA7075 particles and matrix phase. The density of the composites decreases with increasing the percentages of AA7075 particulates compared to the density of the alloy. The measured densities were lower than that obtained from theoretical calculations. The extent of deviation increases with increasing AA7075 content. The hardness of the composites increased with increasing the amount of AA7075 than the base alloy. The tensile strength of the composites increased with increasing amount of AA7075 alloy.

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