Mechanical Behaviour of Silicon Carbide(Sic) / Fly Ashparticles Reinforced Aluminium-7075 Based Metal Matrix Composite Fabricated By Stir Casting Method

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Abstract- *The main intentions of this experiment work is to lesson about the microstructures, mechanical properties and wear characteristics of Aluminum-zinc alloy (Al-7075) reinforced with silica carbide & Fly ash. Aluminum metal matrix composites are used in varies applications like aerospace, defense, automobile, sports equipment and electronics due to their complimentary properties viz. light weight, high strength and coefficient of thermal expansion. The commercial Al 7075 alloy is used broadly in the aerospace engineering for the invention of structural components. In this experiment work, Al 7075 Reinforced with 2, 4 & 6 (%) weight of Silica Carbide & 2 (%) weight of Fly Ash are manufactured using stir casting technique. Sample Specimens are prepared as per the international standards for tensile, hardness, impact, wear tests are conducted. It was concluded that Fly ash and cast iron powder up to 6% can be added to Aluminum successfully by stir casting method route to fabricate a hybrid composite. The hardness and tensile strength increased with the increase in concentration of silica carbide powder. The wear and frictional force decreased with the increase in concentration of cast iron powder in the aluminum matrix. Impact strength variation is marginal with the increase in wt% of Silica Carbide. Porosities were observed in microstructures and increased with increasing wt. % of Silicon carbide (SiC) reinforcements in aluminum matrix composites. Pin-on-disc wear test indicated that reinforcing Al matrix with Silicon carbide (SiC) particles increased wear resistance.*

Keywords- Metal Matrix Composite, Stir Casting, Hardness Test, Tensile Test, Impact Test, Wear

I. INTRODUCTION

1.1 Introduction about Composite Material

A Composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, the new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials. More recently, researchers have also begun to actively include sensing, actuation, computation and communication into composites, which are known as Robotic Materials.

1.2 General Classification of Composite Materials

Composite materials are generally used for buildings, bridges, and structures such as boat hulls, swimming pool panels, race car bodies, shower stalls, bath tubs, storage tanks, imitation granite and cultured marble sinks and countertops. The most advanced examples perform routinely on spacecraft and aircraft in demanding environments.

1.3 Significance of Composite Material

Fiber-reinforced composite materials have gained popularity (despite their generally high cost) in high-performance products that need to be lightweight, yet strong enough to take harsh loading conditions such as aerospace components (tails, wings, fuselages, propellers), boat and scull hulls, bicycle frames and racing car bodies. Other uses include fishing rods, storage tanks, swimming pool panels, and baseball bats. The new Boeing 787 structure including the wings and fuselage is composed largely of composites. Composite materials are also becoming more common in the realm of orthopedic surgery. And it is the most common hockey stick material. Carbon composite is a key material in today's launch vehicles and heat shields for the re-entry phase of spacecraft. It is widely used in solar panel substrates, antenna reflectors and yokes of spacecraft. It is also used in payload adapters, inter-stage structures and heat shields of launch vehicles. Furthermore, disk brake systems of airplanes and racing cars are using carbon material, and the composite material with carbon fibers and silicon carbide matrix has been introduced in luxury vehicles and sports cars. Pipes and fittings for various purposes like transportation of potable water, fire-fighting, irrigation, seawater, desalinated water, chemical and industrial waste, and sewage are now manufactured in glass reinforced plastics.

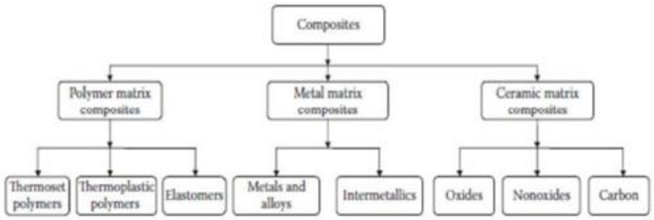


Figure 1 Classification of Composites based on Matrix Material

1.4 Metal matrix composite

The intend convoluted in designing metal matrix composite materials is to combine the desirable attributes of metals and ceramics. The addition of high strength, a high modulus refractory particle to a ductile metal matrix produces a material whose mechanical properties are midway between the matrix alloy and the ceramic reinforcement. Metals have a useful combination of properties such as high strength, ductility and high temperature resistance, but sometimes have low stiffness, whereas ceramics are stiff and strong, though brittle. Aluminum and silicon carbide, for example, have very different mechanical properties: Young's modules of 70 and 400 GPa, coefficients of thermal expansion of 24 × 10−6 and 4 × 10−6/°C, and yield strengths of 35 and 600 MPa, respectively. By combine these materials, e.g. A6061/SiC/17p (T6 condition), an metal matrix composite with a Young's modulus of 96.6 GPa and a yield strength of 510 MPa can be produced. By carefully controlling the relative amount and distribution of the ingredients of a composite as well as the processing conditions, these properties can be further improved.

1.5 Aluminum based Metal matrix composite

Aluminium and its alloys have continued to maintain their mark as the matrix material most in demand for the development of Metal Matrix Composites (MMCs). This is primarily due to the broad spectrum of unique properties it offers at comparatively low processing cost, and. Some of the attractive property combinations Aluminum metal matrix composites are: high specific stiffness and strength, better high temperature properties (in comparison with its monolithic alloy), thermal conductivity, and low thermal expansion. The multifunctional nature of Aluminum metal matrix composites has seen its application in aerospace engineering, electronic heat sinks, solar panel substrates and antenna reflectors, automotive drive shaft fins, and explosion engine components, among others. Most work reported in literature has been devoted to aluminum alloy-based composites, such as A357, A359, 2618, 2214, 6061 and 7075. Composition of Al 7075 alloy by spectrometric analysis is shown in Table 1. The potential for developing high performance and low-cost waste by-product reinforced Aluminum metal matrix composites using Al7075 alloy as a matrix has formed the thrust of this research work.

1.6 Composites Application - The composite materials application is increasing day to day in modern world due to the high tensile strength and with less weight. And Most widely used in Aerospace industry, defense industry, sport goods, marine application etc… and below figure shows the initial to high volume production of goods from a past decades.

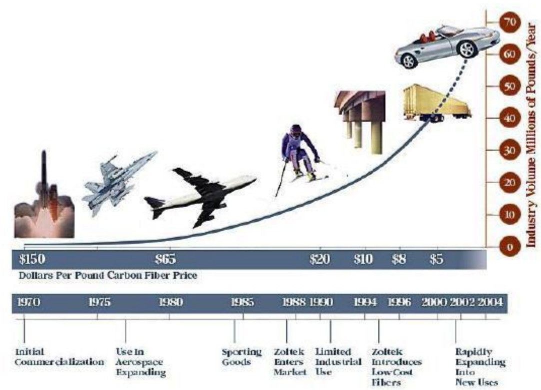


Figure 2 Increase in usage of Composite material in different applications

II. LITERATURE SURVEY

- ***Prasad***[1] have investigated the mechanical properties of hardness and wear rate by using different casting techniques .In this, al –fly ash with 7.5% weight fraction has high hardness and wear rate when compared to the aluminium alloy produced by squeeze casting and gravity casting. And also the sample produced in this gravity casting has low hardness and high wear rate.
- **Anil** [2] investigated the mechanical properties like compressive strength, ductility, and hardness by using aluminium fly ash composites. By increasing the weight fraction of the fly ash particles the above mentioned properties gets improved. Different composition needed to be added in the fly ash composites to enhance their properties further.
- **Vivekanandan**[3] have fabricated the aluminium fly ash composite by stir casting process. The addition of fly ash acts as a barrier to the movement of dislocations and there by increases the hardness of the composite. And also by adding fly ash to the aluminium in molten state increases the abrasive wear resistance. This strengthening of the

composite is because of the solid solution strengthening, dispersion strengthening and particle reinforcement

- **Vipin K. Sharma** [4] have investigated effect of fly ash particles on the wear of aluminum metal matrix composite. Stir casting method was used to fabricate the MMC with 2, 4 & 6% weight of fly ash contents in aluminum. The wear resistance of the fabricated composites increases with the increase in the fly ash contents. The composites with 6% fly ash contents resulted in 13.6% less wear as compared to 2%fly ash content composites. The sample with fly ash content 4% resulted in the lowest average coefficient of friction (0.12) and sample with high fly ash contents 6% shows the maximum average coefficient of friction (0.161).
- **Sumit Kumar Tiwari** [5] studied effect of heat treatment on mechanical properties of aluminum alloy-fly ash metal matrix composite. This study reveals that, there is an improvement in tensile strength, compressive strength, hardness as we increases the weight percentage of fly ash & there is an decrease in ductility with increase percentage. Also it is concluded that the tensile strength, compressive strength & hardness decreases with increase in particle size of fly ash. Heat treatment and ageing further improves these properties.

III. EXPERIMENTAL SET UP & MATERIALS USED

This chapter contains the details about materials and the experimental procedure that were considered for the fabrication of composite and the test procedure followed for testing the characterization of composites, respectively.***The composites used in this study are produced by stir casting method. The matrix materials used in the present work is Al 7075 and the reinforcement materials are Silica Carbide and Fly ash particulates of grain size 200 mesh***.

The raw materials used for fabrication are

- *Aluminum Matrix Material*
- *Silicon Carbide (SiC)*
- *Fly ash*

(a)- Aluminum Metal

(b)- Silicon carbide

(c) – Fly ash powder

3.1 Materials used -*Al was used as matrix material and Silica Carbide (SiC) particles were added as reinforcements to prepare composites in this lesson*. The chemical composition of Al used as matrix material is given in table 1. To increase the wet ability of Silica Carbide (SiC) particles in the molten Al, 1 wt. % of magnesium (Mg) was added to molten aluminum during casting [5]. Silica Carbide (SiC) particles of mesh size -200/+270 (particle size is below 70µm and above 56µm) and ribbon shaped Mg were used.

Table 1 Composition of Al 7075 alloy by spectrometric analysis

Al	Cr	Cu	Fe	Mg	Zn	Si	Mn	Ti
89.8	0.08	1.35	0.3	2.21	5.67	0.4	0.08	0.06

3.2 Stir casting method

Stir Casting is a liquid state method of composite materials manufacture, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring. The liquid composite material is then cast by conventional casting methods and may also be processed by conventional Metal forming technologies. Stir Casting is characterized by the following features: Content of dispersed phase is limited (usually not more than 30 vol. %). Distribution of dispersed phase throughout the matrix is not perfectly homogeneous: There are local clouds (clusters) of the dispersed particles (fibers). There may be gravity segregation of the dispersed phase due to a difference in the densities of the dispersed and matrix phase. Figure 1 shows

Mechanical stirrer of the stir casting setup. The technology is relatively simple and low cost

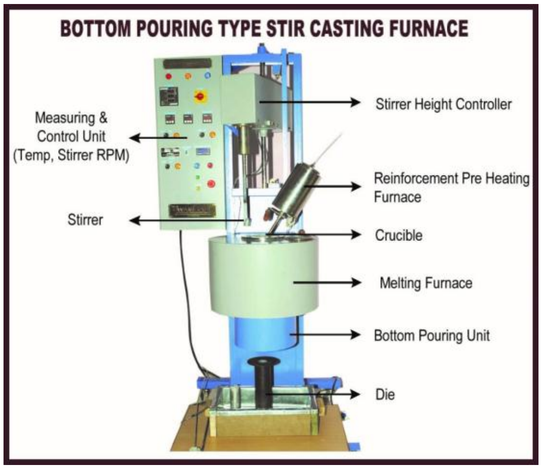


Figure 3 Stir Casting Furnace

3.3 Characterization of Mechanical Properties of Specimens - After fabrication, the characterization mechanical properties of each specimen subjected to the following mechanical tests as per the workshop equipments are listed in the below tabular column as follows:

Table 2 Below Table Shows Type of Test Performed and Type of Machine Setup used

NAME OF THE TEST	NAME OF MACHINE USED FOR TESTING
Pin on disc Method	Wear test
Hardness test	Vickers's Hardness Testing Machine
Tensile Test	Computerized Tensometer
Microstructure	Trinocular inverted metallurgical microscope
Impact Test	Izod Impact Test

3.3.1 Wear test

The wear testing was carried out in Pin on Disc wear test rig shown in below figure (4) at a constant speed of 800 rpm with normal loads of 3kg. A cylindrical pin of size around 6mm diameter and 25mm length prepared from composite casting was loaded through a vertical specimen holder against horizontal rotating disc. Before testing, the flat surface of the specimens was abraded by using grit paper. The rotating disc was made of carbon steel. Wear tests were carried out at room temperature without lubrication for 10 min. The principal objective of investigation was to study the wear rate.

Figure 4 Pin- on- disc wear test rig

Specimen used for wear test

3.3.2 Hardness test

The hardness test on the specimens is carried out on a Vickers Hardness testing machine (VHTM) shown in below figure 5. The hardness test specimens shown in figure 3 are prepared as per the ASTM standards (ϕ18x15mm). The specimens are fine turned and then polished to eradicate any burrs or irregularities on the surface. For indentation a 136° pyramidal diamond indenter is used.

Figure 5 Vicker's Hardness Testing Machine

The specimens are loaded onto the machine and the test is carried on as follows:

- The indenter is pressed into the sample by an accurately controlled test force.
- The force of 200g is maintained for a specific dwell time, normally 10 – 15 s [11].
- After the dwell time is complete, the indenter is removed leaving an indent in the sample that appears square shaped on the surface
- The size of the indent is determined optically by measuring the two diagonals of the square indent.
- The Vickers hardness number is a function of the test force divided by the surface area of the indent. The average of the two diagonals is used in the following formula to calculate the Vickers hardness.
- HV = Constant X test force / (indent diagonal) * 2

Specimen used for Vicker's Hardness Test

3.3.3 Tensile test

The tensile test specimens are prepared with dimensions according to the ASTM standards. The tensile test specimen is as shown in the figure 8. The tensile test is carried out in the computerized tensometer shown in figure 7.

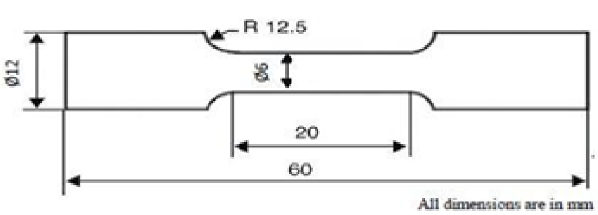


Figure 6 Tensile Test specimen dimensions according to ASTM standards

Figure 7 Computerized Tensometer

The specimen shown in figure is gripped by the holding jaws. The grips are two small round shape hollow structures in which the specimen can be held in between with the help of a ring over it. There are two grips which hold the specimen from both the sides and are in turn attached to specimen holder. On fixing the specimen and ensuring that all the electrical connections are made on the tensometer, the computer that controls the system is switched on. Software controls all the operations. All the data regarding the specimen is fed in the system. After the data fed is rechecked for any errors if any, the command for "Test" is given. The readings are recorded for every displacement of 0.01mm. The tensometer stretches the specimen by incrementing the force it applies until the specimen breaks. After the specimen breaks, a message of termination of the function appears. After the readings have been saved, the specimen is removed from the tensometer and is set to be used for another specimen.

Figure 8 Tensile Test Specimens

3.3.4 Microstructure analysis

The As-cast composites are polished with six different emery papers of 100 to 600 grit in the steps of 100 grit. To obtain mirror like smooth surface, super finishing is carried out on velvet cloth embedded disc polisher using diamond paste. Finally mirrored surfaces are treated with NITAL etchant for preferential chemical attack on the phases. It will expose the grain boundary, secondary phases visible in the microscope at higher magnification. Specimen used for Microstructure analysis is shown in figure 9. ***The procedure***

followed for conducting microstructure study using Trinocular inverted metallurgical microscope shown in below figure is as follows.

Figure 9 Trinocular Inverted Microscope

The specimen is mounted on the stage of the electron microscope with the etched surface facing the objective lens with suitable magnification. Care is taken so that sufficient light falls on the etched surface. The specimen is viewed with the help of the eyepiece. Focus knobs are adjusted as per desired magnification to obtain clear image. In this case a magnification of 200x is used.

3.3.5 Impact test

The specimens shown in fissure for the impact test are prepared on a horizontal shaper machine according to the dimensions shown in figure 10.

Figure 10 Izod Impact pendulum machine

Izod impact test is performed on the specimen as shown in figure 10 as per ASTM standard. for determining the impact resistance of materials using an Izod impact testing machine. An arm held at a specific height (constant potential energy) is released. The arm hits the sample and breaks it. From the energy absorbed by the sample, its impact energy is determined. A notched sample is generally used to determine impact energy and notch sensitivity.

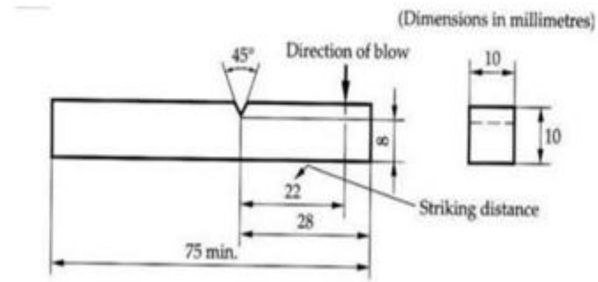


Figure 11 Impact Test Specimen dimensions

Figure12 Impact Test Specimen

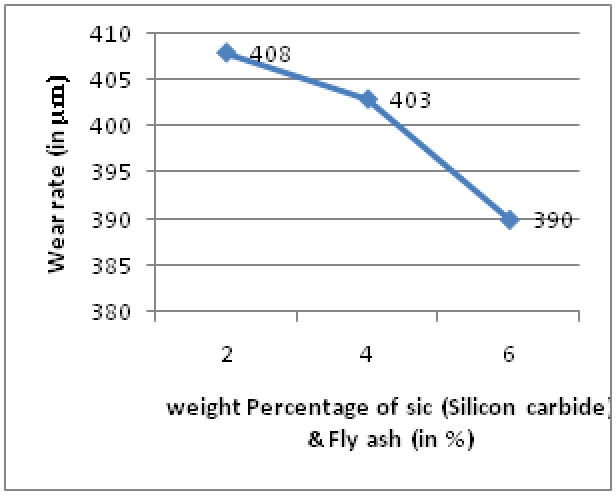
IV. RESULTS AND DISCUSSIONS

Table 3 Results of wear rate, Hardness, Tensile strength, Impact strength valu

S.No.	Composite Specimen based on wt % of Sic &Flyash	Wear Rate (µm)	Tensile strength (Mpa)	Hardness (VHN)	Impact Strength (Joules)
1	2% of Sic + 2% of fly ash	408	181.4	165	3
2	4% of Sic + 2% of fly ash	403	212.9	178	4.3
3	6% of Sic + 2% of fly ash	390	228.6	390	5.6

4.1 wear test

Wear tests on the specimen are performed in pin on disc wear testing machine. It was observed that wear rate decreases with increase in wt% of SiC. This can be attributed to the self-lubricating property of SiC due to the presence of free graphite. The extent of reduction is higher for the lower percentage of SiC in the matrix as shown in the below graph. The conventional values of wear test are listed in the above table (3)



Graph 1 A plot between weight Percentage of sic (Silicon carbide) & Fly ash (in %) Vs wear rate

4.2 Microstructure Analysis

The microstructure shown in below figures 13,14 and 15 at 300X magnification in the optical microscope reveals better dispersion of reinforcement in the matrix. As the wt% of SiC increases in the matrix, the reinforcement particles increases and the inter particle space decreases. There is no indication of agglomeration of reinforcement in the matrix.

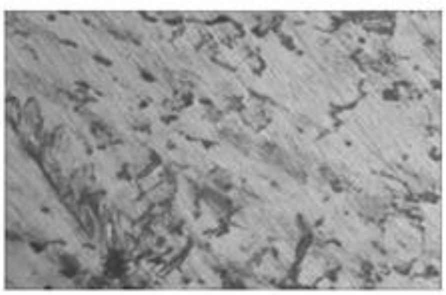


Figure 13 Microstructure of Al 7075 + 2% of Sic + 2% of fly ash

Figure 14 Microstructure of Al 7075 + 4% of Sic + 2% of fly ash

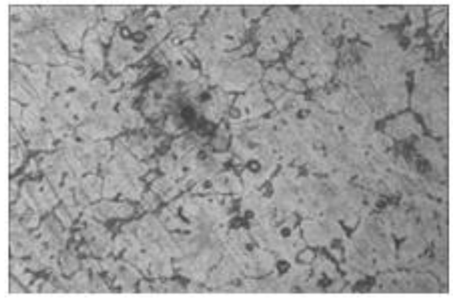
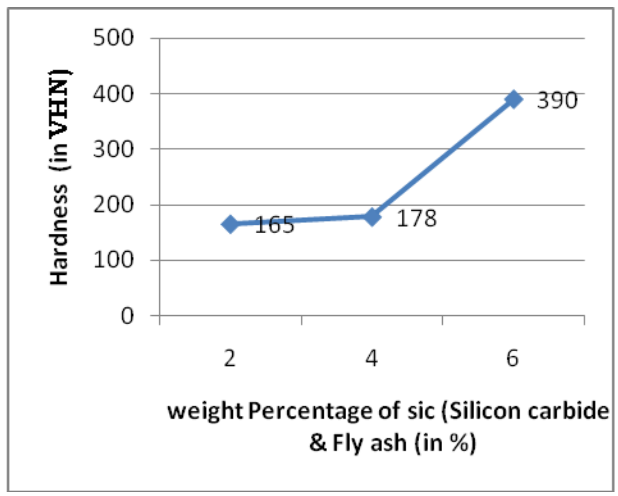


Figure 15 Microstructure of Al 7075 + 6% of Sic + 2% of fly ash

4.3 Hardness Test

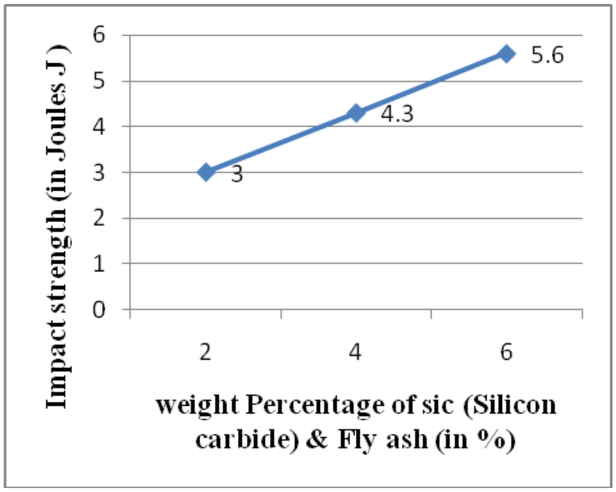
Hardness increases substantially with increase in wt% of SiC in the composite. Increasing trend of hardness from 2-4% SiC by wt is lower compared to 4-6% SiC. This implies the requirement of an optimum wt% of reinforcement in the matrix for better hardness.



Graph 2 A plot between weight Percentage of sic (Silicon carbide) & Fly ash (in %) Vs Hardness

4.3 Impact Test

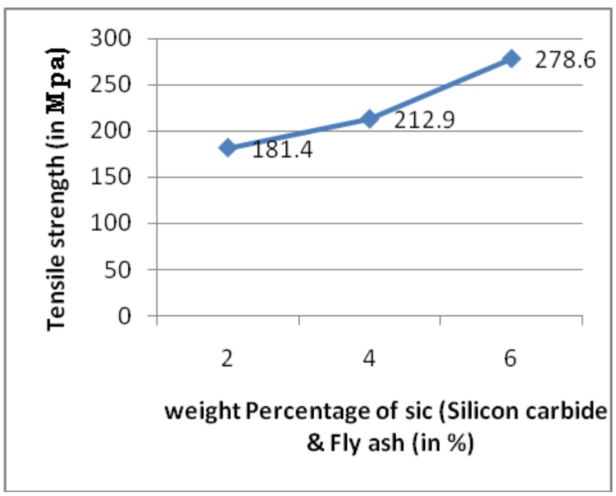
Impact resistance is the measure of toughness. The broken specimen in Izod and tensile tests support the ductile nature of fracture. 6wt% of SiC composite shows good impact strength in the alloy system. Graph(3) shows the variation in toughness of the specimen for different SiCwt% in composites. It implies that the increase in reinforcement increases the toughness of the material.



Graph 3 A plot between weight Percentage of sic (Silicon carbide) & Fly ash (in %) Vs Impact test

4.4 Tensile Test

Tensile tests are performed on a Tensometer for 2, 4 and 6wt% of SiC composite and the readings are tabulated. It was observed that tensile strength increases with the increase in wt% of SiC and fly ash. The extent of increase is higher for the higher percentage of SiC in the matrix as shown in below graph and Table 2 shows the result of all the tests in conventional form



Graph 4 A plot between weight Percentage of sic (Silicon carbide) & Fly ash (in %) Vs Tensile Strength

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