INVESTIGATIONS ON THE MECHANICAL PROPERTIES OF TUNGSTEN CARBIDE REINFORCED ALUMINIUM AND FLY ASH METAL MATRIX COMPOSITES BY STIR CASTING.

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Abstract.

In the present world, metals play a pivotal role in manufacturing industries. The requirements for various metals have been growing exponentially over the last few centuries resulting in the exploitation of natural resources. As the applications and technical specifications of metals are different and very large. There is an urgent need to develop methods to suit the specific requirements of the metals and the combination of metals. Also, various techniques have been developed over the year and metal matrix composites are one of them.

It has an inherent advantage that all the constituents need not be processed to their melting points instead they are processed to the lowest melting temperatures of their constituents thereby ensuring better bonding and structural stability

The main objective of this work is to employ aluminium alloy-fly ash–tungsten carbide metal matrix composites as they possess light-in-weight characteristics with improved corrosion and hardness properties. The workpieces shall be manufactured by stir casting and corresponding mechanical properties are determined. This work deals with the investigation of the effects of fly ash and tungsten carbide as reinforcements in aluminium alloy metal matrix composite. Theresults of the impact test shall be compared with other composite materials. Tensile strength and Hardness tests were performed on the samples under the stir casting process. Morphological analysis is carried out to find the internal structure of the tested specimens.

Index Terms – Mechanical properties like Impact, Hardness, Corrosion and Wear.

I. INTRODUCTION

The majority of composite materials, including metal matrix composites (MMCs), offer improved qualities in comparison to monolithic materials. These improvements include increased strength, stiffness, and hardness, as well as a reduction in weight. Aluminum-based metal matrix composites are becoming increasingly important in the engineering industry. This is due to the fact that these composites belong to a class of lightweight and high-performance aluminum-centric materials system. Al6061 is a type of aluminium alloy that is typically used in aerospace applications, maritime applications, cycling and automotive applications, and for the production of gas cylinders. Magnesium and silicon play a significant role in the alloying process of Al6061. It is possible to heat treat Al6061, and it has extremely strong corrosion resistance and finishing properties. Additionally, it can be easily welded. It possesses a strength and a hardness that are around average.

Stir casting is the most popular choice among the several processing techniques that are available for fabricating composites. This is due to the fact that stir casting is the most straightforward and economical form. sources. According to the references, tungsten carbide can be found as a

ISSN: 2278-4632
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reinforcement material in Al6061 matrix composites of various weight percentages. Stir casting is a technique used to fabricate the object. The mechanical properties of the matrix material, such as its hardness and tensile strength, were shown to significantly improve when the amount of WC inside the matrix material was increased. The amount of tungsten carbide increases along with density, according to the reference. The reference claims that higher WC concentrations result in higher levels of wear resistance.

References provide information on the use of fly ash as a reinforcing ingredient in aluminium composites. The fabrication process employs the stir-casting technique. Casting and powder metallurgy are the procedures that are utilised in the production of MMCs more frequently than any other processes. Powder metallurgy is a highly developed way of making reliable net shaped components by mixing together elements or pre-alloyed powders, compacting this blend in die, and then sintering in a controlled furnace atmosphere to bind particles. This process is known as "powder metallurgy.

LITERATURE REVIEW

V. V. Kondaiaha, P. Pavanteja, P. A. Khan, S. A. Kumar, R. Dumpala, and B. R. Sunil, "Microstructure, hardness and wear behavior of AZ31 Mg alloy – fly ash composites produced by friction stir processing," Materials Today: Proceedings, vol. 4, no. 6, pp. 6671–6677, 2017, recent research has demonstrated that improving a material's ductility and mechanical qualities by adding reinforcements such SiC, Al2O3, MgO, and ZrO2 can have a positive impact. Fly ash is the most easily available and inexpensive substance, and if it is used correctly, it can help minimise the 'mount of pollution that is caused to the land. It has a significant impact on the environmental effect of thermal power plants and other combustion processes that are used by enterprises that use coal as fuel.

M.Viswanath, H. Dieringa, K. K. Ajith Kumar, U. T. S. Pillai, and B. C. Pai, "Investigation on mechanical properties and creep behavior of stir cast AZ91-SiCp composites," Journal of Magnesium and Alloys, vol. 3, no. 1, pp. 16–22, 2015, a friction stir procedure was used by Kondaiah et al. to create AZ31/fly ash composites, and they reported that the composites had enhanced hardness and superior wear properties. Stir casting was 75tilized by Viswanath et al. in the development of AZ91/SiC composites with weight percentages of 5, 10, 20, and 25% respectively. They found that composites containing 15, 20, and 25 weight percent of SiC had enhanced creep resistance. Stir casting was 75tilized by Matina et al. in order to create pure magnesium/SiC and AZ80/SiC composites.

M. Hassan, A. T. Mayyas, A. Alrashdan, and M. T. Hayajneh, "Wear behavior of Al-Cu and Al-Cu/SiC components produced by powder metallurgy," Journal of Materials Science, vol. 43, no. 15, pp. 5368–5375, 2008, die casting was the process that Lim et al. used to develop their AZ91/D-fly ash composites. According to what they found, the composite density declined as the amount of fly ash grew, and the maximum tensile strength was reached in composites that had 5 weight percent of reinforced fly ash . Hassan and colleagues looked into the wear behaviour of composites that were reinforced with magnesium and silicon carbide. They were able to demonstrate that the composites' outstanding load-bearing capacity led to an increase in wear resistance of between 15 and 30 percent.

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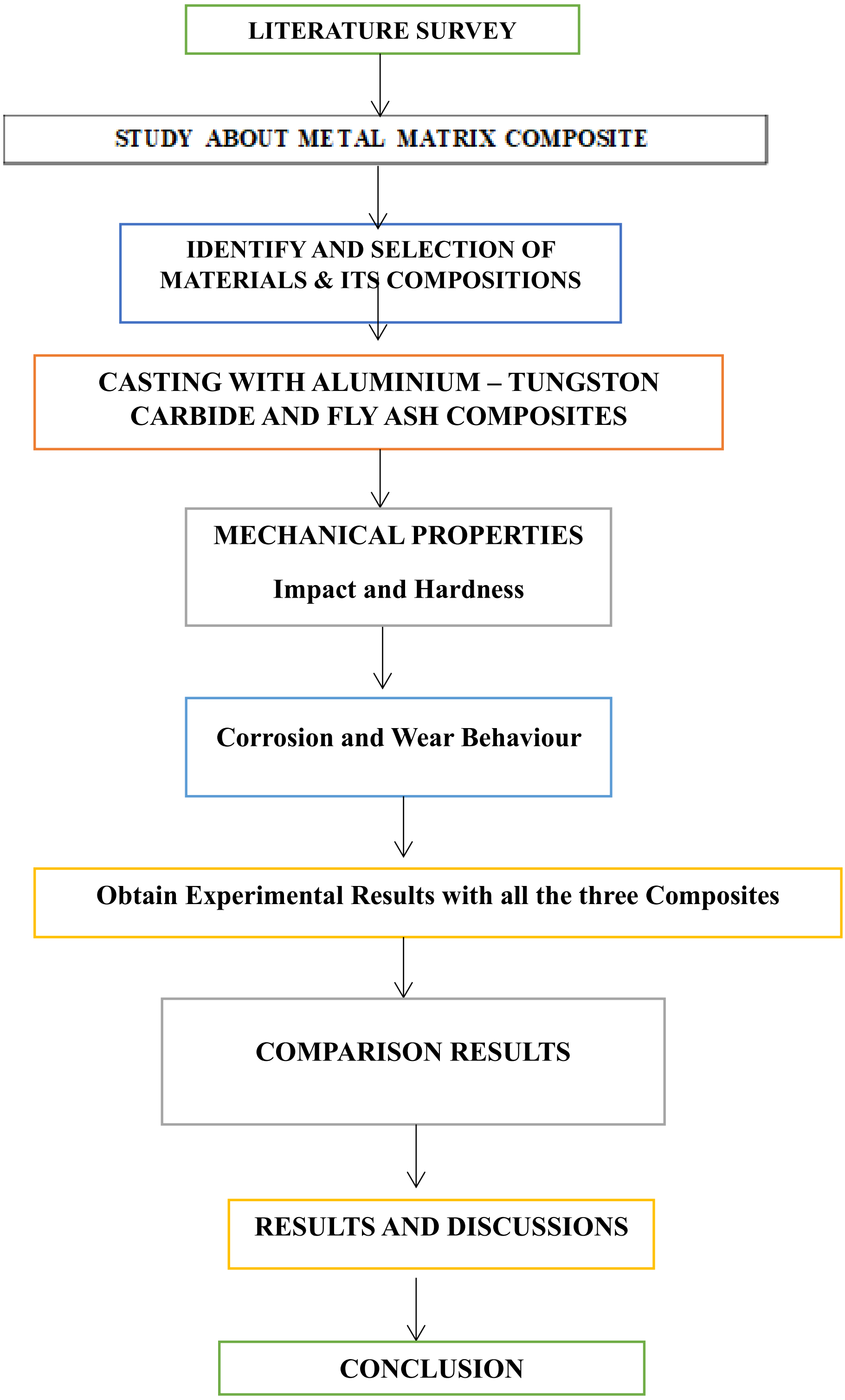
METHODOLOGY



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MATERIAL'S COMPOSITIONS & METHODS

The following composition was chosen for characterization:
Compistion-1: 94% Aluminium Alloy – 3% Tungsten Carbide – 3% Fly Ash
Compistion-2: 94% Aluminium Alloy – 2% Tungsten Carbide – 2% Fly Ash
Compistion-3: 94% Aluminium Alloy – 1% Tungsten Carbide – 1% Fly Ash

ALUMINIUM ALLOY

Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying element are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat-treatable and non-heat-treatable. . The most important cast aluminium alloy system isAl–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. 6111 aluminium and 2008 aluminium alloy are extensively used for external automotive body panels, with5083 and 5754 used for inner body panels. Hoods have been manufactured from 2036, 6016, and 6111 alloys. Truck and trailer body panels have used 5456 aluminum. Automobile frames often use 5182 aluminium or 5754 aluminium formed sheets, 6061 or 6063 extrusions.

TUNGSTEN CARBIDE

Tungsten carbide (chemical formula: WC) is a chemical compound (specifically, a carbide) containing equal parts of tungsten andcarbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use inindustrial machinery, cutting tools, abrasives, armor-piercing rounds, other tools and instruments, and jewelry. Tungsten carbide is approximately two times stiffer than steel, with a Young's modulus of approximately 530–700 GPa (77,000 to 102,000 ksi), and is double the density of steel—nearly midway between that of lead and gold.

Tungsten carbide has a high melting point at 2,870 °C (5,200 °F), a boiling point of 6,000 °C (10,830 °F) when under a pressure equivalent to 1 standard atmosphere (100 kPa), a thermal conductivity of 110 $W\cdot m^{-1}\cdot K^{-1}$, and a coefficient of thermal expansion of 5.5 $\mu m\cdot m^{-1}\cdot K^{-1}$. Tungsten carbide is extremely hard, ranking about 9 on Mohs scale, and with a Vickers number of around 2600. It has a Young's modulus of approximately 530–700 GPa, a bulk modulus of 630–655 GPa, and a shear modulus of 274 GPa.[16] It has an ultimate tensile strength of 344 MPa, an ultimate compression strength of about 2.7 GPa and a Poisson's ratio of 0.31.

FLY ASH

Fly ash, also known as flue-ash, is one of the residues generated in combustion, and comprises the fine particles that rise with the flue gases. Ash which does not rise is termed bottom ash. In an industrial context, fly ash usually refers to ash produced during combustion of coal. Fly ash is generally captured byelectrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys ofcoal-fired power plants, and together with bottom ashremoved from the bottom of the furnace is in this case jointly known as coal ash. Since the particles solidify rapidly while suspended in the exhaust gases, fly ash particles are generally spherical in shape and range in size from 0.5 µm to 300 µm.

EXPERIMENTAL PROCEDURE OF STIRCASTING

In a stir casting process, the reinforcing phases are distributed into molten matrix by mechanical stirring. Stir casting of metal matrix composites was initiated in 1968, when S. Ray introduced alumina particles into aluminum melt by stirring molten aluminum alloys containing the ceramic powders. Mechanical stirring in the furnace is a key element of this process. The resultant molten alloy, with ceramic particles, can then be used for die casting, permanent mold casting, or sand casting. The matrix that has been used here is Aluminium 6081. The alloy composition and mechanical properties of Aluminium was studied. A micron size of boron carbide was used as the first reinforcement.Two different compositions, taking 2%, 4% and boron carbide as a constant required composites are fabricated.The fabrication of composites are done by stir casting method, Due to its suitability in

ISSN: 2278-4632
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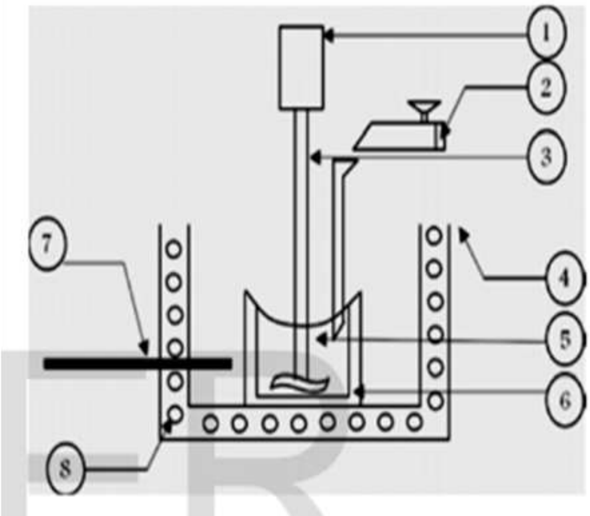
producing uniformly distributed reinforcements. Aluminium was purchased in the form of rods and then were cut into pieces to as per requirement of the crucible.



Schematic View of the Furnace

1. Motor
2. Shaft
3. Molten aluminum
4. Thermocouple
5. Particle injection chamber
6. Insulation hard board
7. Furnace
8. Graphite crucible

TEST RESULTS

Impact Test

The **Charpy impact test**, also known as the **Charpy test**, is a standardized highs train-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's notch toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly. The notch in the sample affects the results of the impact test,[7] thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain.

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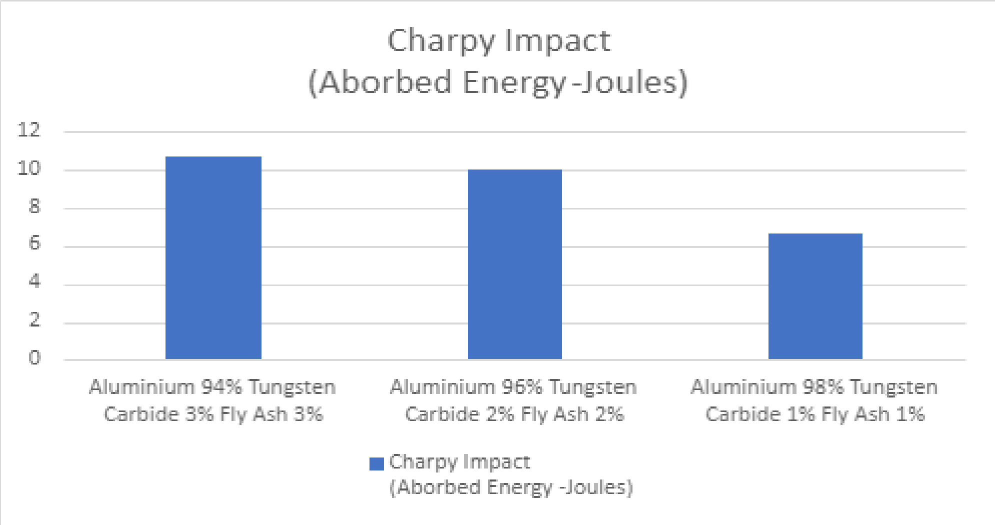
Test Results

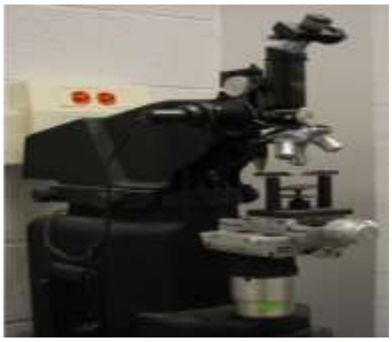
Test Parameters	ID-1	ID-2	ID-3	Charpy Impact (Aborbed Energy -Joules)
Aluminium 94% Tungsten Carbide 3% Fly Ash 3%	12	10	10	10.67
Aluminium 96% Tungsten Carbide 2% Fly Ash 2%	10	12	8	10
Aluminium 98% Tungsten Carbide 1% Fly Ash 1%	8	6	6	6.67

Comparison results of Charpy Impact



Vickers hardness test

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E. Sandland at Vickers Ltd as an alternative to the Brinell method to measure the hardness of materials.[1] The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe the questioned material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness tests.



As a general rule of thumb the sample thickness should be kept greater than 2.5 times the indent diameter. Alternatively indent depth can be calculated according to:

$$h = \frac{d}{2\sqrt{2}\tan\frac{\theta}{2}} \approx \frac{d}{7.0006},$$

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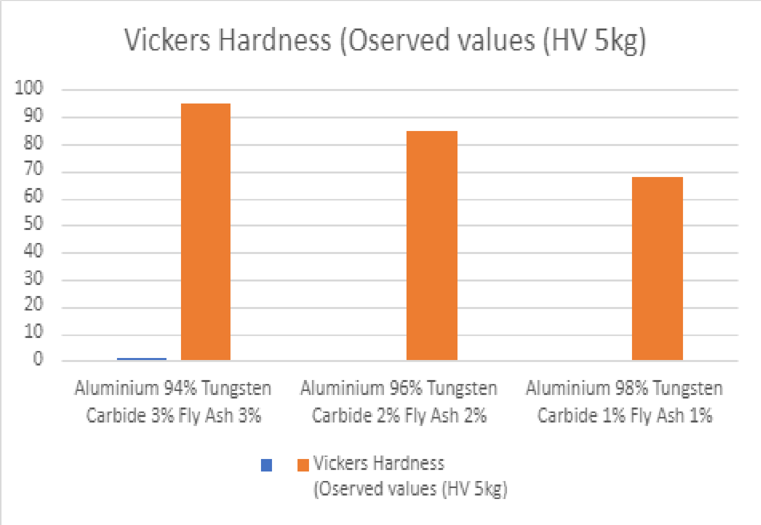
Test Results

Test Parameters		Vickers Hardness (Oserved values (HV 5kg)
Aluminium 94% Tungsten Carbide 3% Fly Ash 3%	94.6,95.3,94.1	94.6
Aluminium 96% Tungsten Carbide 2% Fly Ash 2%	86.3,84.1,84.5	84.9
Aluminium 98% Tungsten Carbide 1% Fly Ash 1%	68.3,67.2,67.7	67.7

Comparison results of Vicker Hardness



SALT SPRAY TEST

The salt spray test is a standardized test method used to check corrosion resistance of coated samples. Coatings provide corrosion resistance to metallic parts made of steel, zinc or brass. Since coatings can provide a high corrosion resistance through the intended life of the part in use, it is necessary to check corrosion resistance by other means. Salt spray test is an accelerated corrosion test that produces a corrosive attack to the coated samples in order to predict its suitability in use as a protective finish. The **salt spray test** is a standardized and popular corrosion **test** method, used to check corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal.

Salt spray cabinet

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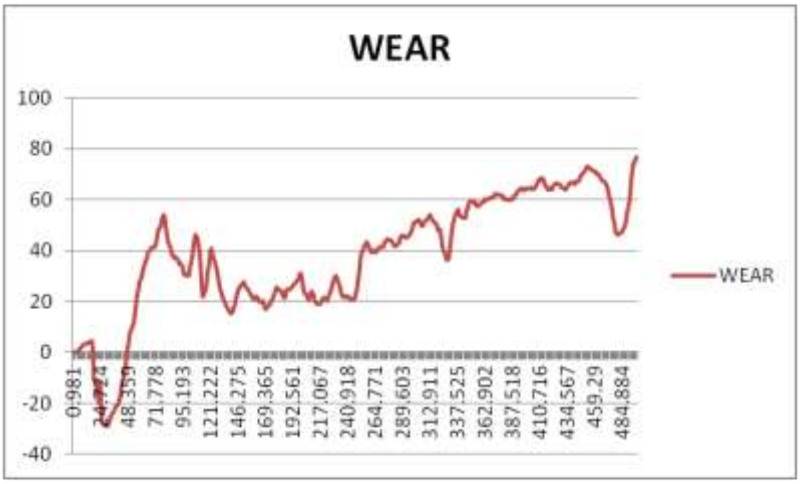
Test Parameters

Test Parameters	Aluminium 94% Tungsten Carbide 3 % Fly Ash 3%	Aluminium 96% Tungsten Carbide 2 % Fly Ash 2%	Aluminium 98% Tungsten Carbide 1% Fly Ash 1%
Test Duration (Hours)	12 Hours	12 Hours	12 Hours
Test Starting date (DD/MM/YY)	15 Dec 2022	15 Dec 2022	15 Dec 2022
Test ending date (DD/MM/YY)	15 Dec 2022	15 Dec 2022	15 Dec 2022
Tower Temperature(*C)	47.2-48.5	47.2-48.5	47.2-48.5
Air Pressure(Psi)	14-18	14-18	14-18
Chamber Temperature (*C)	34.5-35.5	34.5-35.5	34.5-35.5
Components Loading in Chamber Position (Degree Angle)	15-30 degree from vertical	15-30 degree from vertical	15-30 degree from vertical
Concentration of Solution (%)	4.80-5.30 % of Nacl	4.80-5.30 % of Nacl	4.80-5.30 % of Nacl
PH value	6.65-6.85	6.65-6.85	6.65-6.85
Volume of salt solution collected (ml/hr)	1.00-1.50	1.00-1.50	1.00-1.50
Test Oservation)	No white Rust Formation noticed p To 12Hours	No white Rust Formation noticed p To 12Hours	No white Rust Formation noticed p To 12Hours

WEAR TEST

Wear test report
SAMPLE 1 –Al-94%, TC- 3%, Flyash- 3%
Graph:
Time vs wear



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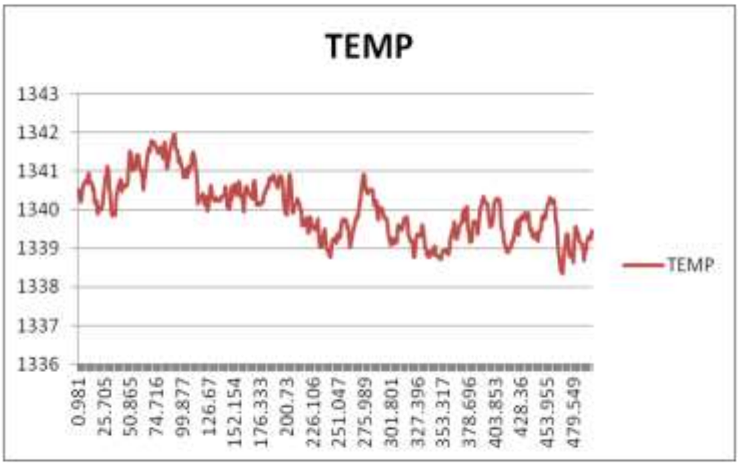
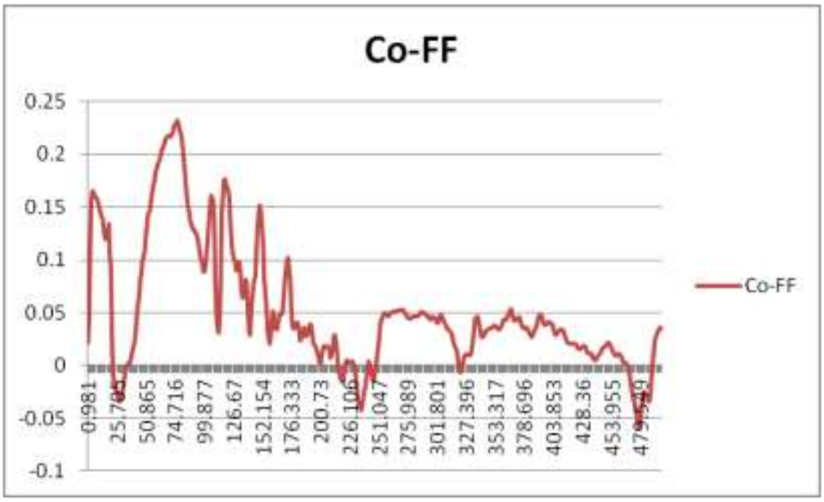
Time vs Frictional Force

Time vs Temperature



Time Vs Coeff. Friction Force



SAMPLE 2 –Al-96%, TC- 2%, Flyash- 2%

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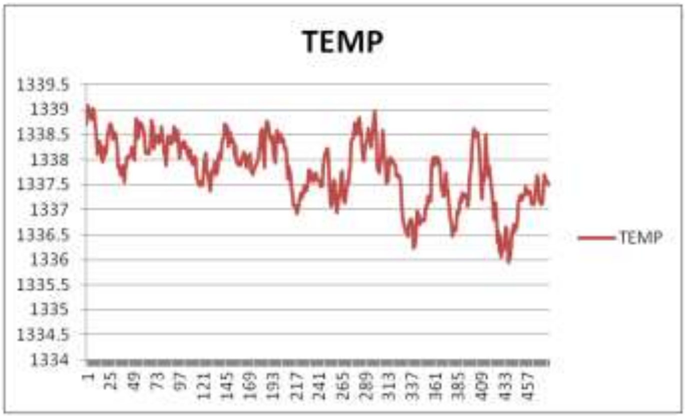
Graph:

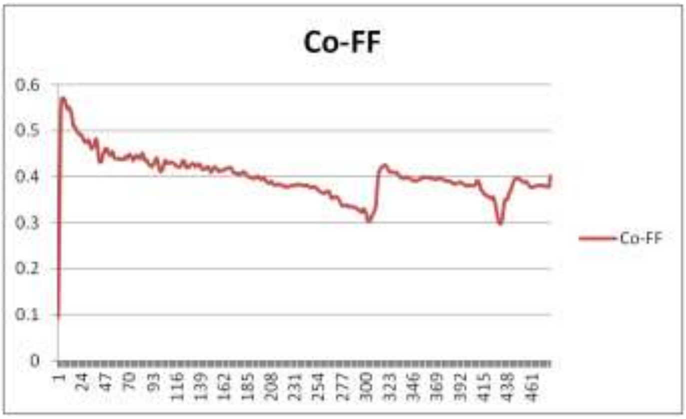
Time vs wear

Time vs Frictional Force

Time vs Temperature



Time vs Coeff-Friction Force



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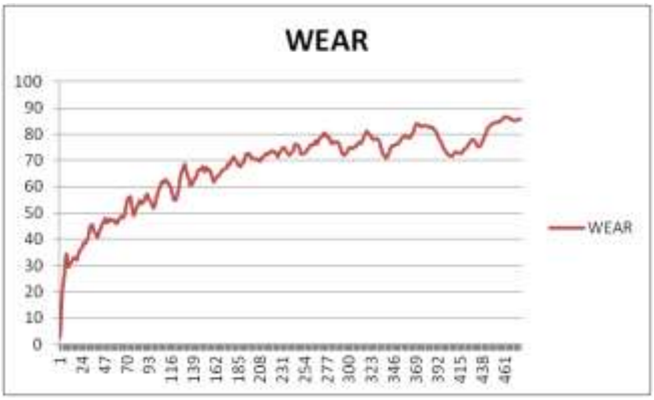
Average for Coefficient of frictional Force = 0.401555

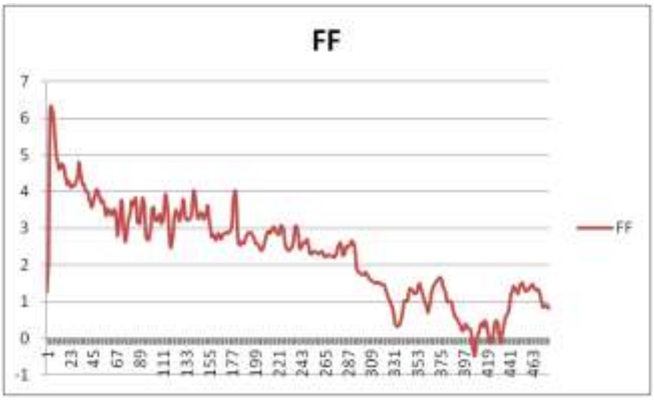
5.4.1.3 SAMPLE 3 –Al-98%, TC- 1%, Flyash- 1%

Graph:

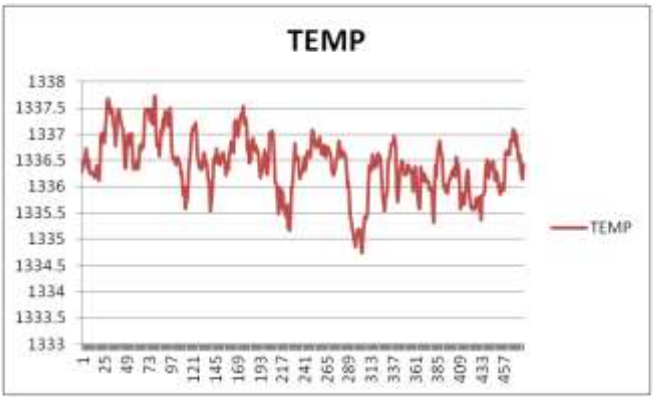
Time vs wear



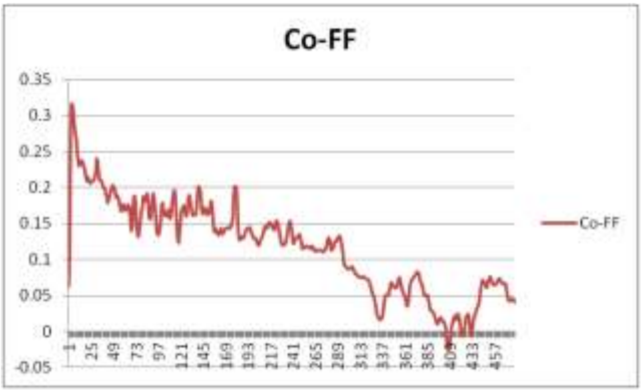
Time vs Frictional Force



Time vs Temperature



Time vs Coeff-Friction Force



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Average for Coefficient of frictional Force = 0.11624

CONCLUSION

- The stir-casting method was used to manufacture Al6061 metal matrix composites, and tungsten carbide and fly ash particles (with varying compositions of volume percentage) were used as reinforcements. The process was simple and cost-effective. The results of the tests on mechanical qualities such as impact and hardness are improved.
- The findings of the impact test showed that the amount of energy in Joules absorbed was proportional to the amount of reinforcement content in the matrix and the weight percentage of the matrix. However, the ductility of the composites decreased as the amount of reinforcement content in the matrix increased.
- When compared to the enhanced effect of fly ash reinforcement, the effect of tungsten carbide reinforcement on mechanical strength and hardness qualities is significantly greater.
- In addition, the results of the corrosion and wear characterisation showed that there was no void formation and that the reinforcing content (tungsten carbide and fly ash particles) was distributed evenly throughout the Al6061 matrix composites. As a result of these experimental investigations, it was observed that the mechanical strength, along with other features such as corrosion and wear resistance, rose when there was a greater quantity of tungsten carbide and flay ash. This was one of the findings that was acquired.

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