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Investigation on Tribological Behavior of Metal Matrix Composites (Al6063-TiO2)

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Abstract: Metal matrix composites are gaining widespread importance & popularity in several technological fields owing to their high strength, low density, better wear and corrosion resistance coupled with good strength. Currently these composites are produced by several techniques viz, powder metallurgy, liquid metallurgy, infiltration techniques, spray deposition, squeeze casting etc. Each of these techniques has several limitations, particularly in achieving a clean interface between the reinforcement & the matrix.

This factor is the most important one which dictates to a great extent the final mechanical properties of the developed metal matrix composites. However this limitation is overcome by producing MMCs by triggering liquid metallurgy route.

Of all the aluminium alloys 6063 is a quite a popular choice as a matrix material to prepare MMCs owing to its better formability characteristics and option of modification of the strength of composites by adding reinforcements. From the literature, it is quite evident that the focus has been centered on processing of MMCs and characterization of mechanical properties of MMCs.

TiO_2 ceramic particles posses excellent hardness with good wear resistance & better anti-friction characteristics. It has been well established that dispersion of TiO_2 in the matrix alloy by conventional route has resulted in drastic improvement in mechanical properties.

In the light of the above, the present investigation deals with development of TiO_2 reinforced Al 6063 composites by liquid metallurgy route. The extent of incorporation of TiO_2 particles in the composite will be varied from 2-8 wt% in steps of 2. Microstructure studies, wear properties, hardness of as cast Al 6063 alloy and Al 6063- TiO_2 composites will be evaluated further, and SEM study of fractured surfaces conducted and analyzed using Taguchi and Anova method.

Introduction

Material Science

Material science is the field of applying the properties of material of different ranges of science and Engineering. This logical field of Engineering examines the connection between the structure of materials at sub-atomic scales and their plainly visible qualities. It fuses parts of material science and science. With important media thought focused on nano science and nanotechnology starting late, materials science has been moved to the forefront at various colleges. It is also a fundamental bit of logical outlining and disappointment examination. Materials science also oversees key properties and characteristics of materials.

The material of choice of a given time is much of the time a describing point. Expressions, for instance, Stone Age, Bronze Age and Steel Age are incredible cases. At first getting from the make of earthenware production generation and its putative auxiliary metallurgy, materials science is one of the most seasoned sorts of building and connected science. In Present day materials science grew direct from metallurgy, which itself progressed from mining and (likely) pottery generation and the use of flame. An important jump forward in the understanding of materials occurred in the late nineteenth century, when the American researcher Josiah Willard Gibbs exhibited that the thermodynamic properties identified with nuclear structure in various stages are related to the physical properties of a material. Fundamental segments of present day materials science are an after the effect of the space race: the appreciation and planning of the materials blends, and silica and carbon materials, used as a piece of the advancement of space vehicles engaging the examination of space. Materials science has driven, and been driven by, the change of dynamic headways, for instance, plastics, semiconductors, and biomaterials.

Before the 1960s (and now and again decades after), various materials science workplaces were named metallurgy workplaces, from a nineteenth and mid twentieth century complement on metals. The field has since enlarged to join each class of materials, including stoneware creation, polymers, semiconductors, appealing materials, therapeutic install materials and natural materials(materiomics).

Metal Matrix

A metal network composite will be composite material with no less than two constituent parts, one being a metal. The other material may be a substitute metal or another material, for instance a clay or natural compound. At the point when no less than 3 materials are there, at that point it is called as a half breed composite. A MMC is correlative to a cermet[1].

MMCs are made by scrambling a strengthening material into a metal grid. The fortification surface can be covered to keep a synthetic response with the grid. For instance, carbon filaments are generally utilized as a part of an Aluminum framework to join composites demonstrating low thickness and high quality. Be that as it may, carbon reacts with aluminum to deliver a fragile and water-solvent compound Al_4C_3 on the surface of the fiber. To control this response, the carbon strands are covered with nickel or titanium boride.

Reinforcement

The fortification material is connected into the framework. The support does not generally serve a simply auxiliary assignment (strengthening the compound), yet it is additionally used to change physical properties, for example, wear resistance, erosion coefficient or warm conductivity. The support can be either consistent or intermittent. Broken Metal grid composites can be isotropic and can be worked with standard metal working condition, for example, expulsion, producing and rolling. What's more, they might be machined utilizing customary techniques, however generally would require the usage of polycrystalline jewel tooling (PCD).

Consistent fortification uses monofilament wires or filaments, for instance, carbon fiber or silicon carbide. Since the strands are connected into the framework in a specific heading, the outcome is an anisotropic structure in which the course of action of the material impacts its quality. One of the essential MMCs used in boron fiber as support. Intermittent support utilizes "hairs", short strands, or particles. The most generally perceived fortifying materials in this class are alumina and silicon carbide.

Aluminum Matrix Composites (AMCs)

Aluminum metal grid composites incorporates the class of light weight, superior aluminum driven material frameworks. The support in AMCs could be as persistent or intermittent strands, bristle or particulates, in volume portions running from some percent to 70%. Properties of AMCs can be redone to the requests of different present day applications by suitable blends of network and support. By and by a few sorts of composites are created by different sorts. Three numerous times of research have given an abundance of new logical learning on the intrinsic and outward effect of clay support, for example, physical, mechanical, thermo-mechanical and tribological properties of AMCs.AMCs have been utilized as a part of basic and practical applications including avionics, resistance, car, and warm administration ranges and also in diversions and amusement[2].

Introduction about the Project work

My project work is mainly based on metal matrix composites. I choose Al6063 as a matrix material and TiO_2 as a reinforcement material.Al 6063 is a flexible material with medium to high quality abilities.TiO_2 is a naturally available oxide of titanium. I prepare the composites by liquid metallurgy route. Composites are prepared with TiO_2 varying from 2 to 8% in steps of 2.Tests are performed like wear, density, porosity and Hardness. And it is analyzed by Taguchi, Anova and Edax method.

Composite Materials

Composites

A composite is an essential material that includes no less than at least two consolidated constitutions that are joined at a naturally visible level and are not dissolvable in each other.

Matrix Phase

The one in which it is mixed into reinforcements is called the matrix. The grid stages are for the most part consistent. Cases of composite materials contain concrete fortified with steel and epoxy strengthened with graphite filaments and so on [1].

Reinforcing notch

The second phase is mixed in the matrix in a discontinuous way. This secondary phase is called dispersed phase. Dispersed phase is stronger than the matrix; therefore it is called as reinforcing phase.

Composite materials are likewise characterized as material arrangement or blending of at least two small scale constituents insoluble in each other and contrasting in frame.

Composites are delivered by adding not at all like materials together to fill in as a solitary mechanical unit and properties of such materials are distinctive in scale and kind from those of any of its constituent. These materials may have a hard stage in delicate grid and other path around. In a large portion of the cases a hard stage is blended in a delicate lattice and it fabricates modulus or quality of the framework [3, 4]. A delicate stage embedded in hard network constructs the stun resistance of the metals [5, 6].
The properties that can be enhanced by utilizing composite materials are [7]

1. Quality
2. Stiffness
3. Corrosion and Wear resistance
4. Reduction of weight
5. Thermal properties.

Classification of composites

These composites can be classified into 2 types. One is Material and another one is depend on matrix material like polymer, metal & ceramic.

Types of Composites (Based on classification of matrix)

Metal Matrix Composites

Metal grid composites (MMCs) as the name surmises, have a metal network. Sorts of lattices in such composites incorporate aluminum, magnesium, and titanium. Regular strands consolidate C & SiC. Metals are fortified to increment or diminishing their properties to suit the requirements of outline. For instance, the flexible solidness and quality of metals can be expanded and vast coefficients of warm development and warm and electric conductivities of metals can be limited, by the expansion of filaments, for example, silicon carbide and so forth.

Ceramic Matrix composites

Artistic grid composites (CMCs) are a subgroup of composite materials and moreover subgroup of particular earthenware production. They include earthenware filaments blended in a clay lattice, thusly delivering an artistic fiber strengthened fired (CFRC) material. The lattice and filaments involve any clay materials, whereby carbon and carbon strands can likewise be seen as fired materials.

Polymer-matrix composites

The most widely used matrix materials for composites are polymeric. Polyester and vinyl esters are the most broadly utilized and cost is least expensive polymer resins. These matrix materials are essentially utilized for fiber glass reinforced composites. For mutations of a immense number of resins give a broad range of properties for these materials. The epoxies are more costly and in addition to large range of commercials applications, and also find use in PMCs for aviation applications. The constraints of PMCs are their low most extreme working temperature, high coefficients of warm extension and consequently affectability to radiation and dampness. The quality and firmness are low contrasted with metals and earthenware production [7,8].

Classification of composites (Type of reinforcement)

Particulate Composite

Particulate fortifications have measurements that are practically equivalent every which way. The state of the strengthening particles might be circular, cubic, normal or unpredictable geometry. These composite can ordered into 2 sorts (i) Large molecule composites (ii) Dispersion fortified composites.

Fiber Reinforced Composites

A stringy fortification is indicated by its length being considerably more prominent than its cross sectional estimation. However the extent of length to the cross sectional measurement knows as the angle extent can change essentially. In single layer composite long strands with high angle extents give that are called consistent fiber strengthened composites while irregular fiber fortified composites are made utilizing short filaments might be arbitrary or favored[3].

Laminated composite material

Laminate composites comprise of layers with various anisotropic orientation or of a grid fortified with a scattered stage in type of sheets. The framework is persistent and encompasses, the other stage, these are regularly called as a scattered stage. The properties of composites depend basically on the sum, geometry and properties of scattered stage. The geometry of scattered stage fuses its molecule estimate, angle extent and size introduction.

Fabrication of MMCs

MMC manufacturing can be broken into three fundamental sorts: strong, fluid, and vapor.

Solid State Methods

Powder metallurgy: Powder metallurgy is the path toward blending of fine powdered materials, crushing them into a required shape or compacting, and after that warming the packed parts in a controlled air to bond the material is called as sintering. The powder metallurgy handle for the most part contains four basic strides: (1) powder making, (2) powder blending, (3) compacting (4) sintering. Compacting is by and large completed in room temperature, and the raised – temperature method of sintering is ordinarily directed at environmental weight.

Two principle systems used to shape and cement the powder are sintering and metal infusion forming. Late advancements have made it conceivable to use quick assembling procedures which use the metal powder for the segments. Since with this method the powder is softened and not sintered, better mechanical quality can be delivered.

There are a few sorts of hardware utilized as a part of Powder Compacting. It is the shape, which is adaptable, a weight form that the shape is in. There are additionally controlling devices to control the measure of weight and to what degree the weight is held for. The machines need to apply somewhere in the range of 15,000 psi to 40,000 psi for metal.

Powders of the segments like titanium, vanadium, thorium, niobium, tantalum, calcium, and uranium have been delivered by high – temperature decrease of the comparing nitrides and carbides. Press, nickel, uranium, and beryllium sub micrometer powders are created by lessening metallic oxalates.

Another powder-make system incorporates a thin fly of liquid metal met by rapid floods of atomized water which break the stream into drops and cool the powder before it achieves the base of the receptacle. In resulting operations the powder is dried. This is called water atomization. The preferred standpoint is that metal cements quicker than by gas atomization since warm conductivity of water is a few extents higher. Since the hardening rate is contrarily relative to the molecule estimate littler particles can be made utilizing water atomization. The littler the particles, the more homogeneous the small scale structure will be. Particles will have a more unpredictable shape. Powder can be decreased by some sort of pre-union treatment as tempering.

Liquid state methods:

Electroplating: Electroplating is a plating procedure in which metal particles in an answer are moved by an electric field to coat an anode. The procedure uses electrical current to limit cations of a required material from an answer and coat a conductive question with a thin layer of the material, for instance, a metal. Electroplating is essentially used for storing a layer of material to exhibit a coveted property to a surface that generally does not have that property. The strategy utilized as a piece of electroplating is called electro testimony. The part to be plated is the cathode of the circuit. In one system, the anode is made of the metal to be plated on the part. Both segments are submerged in an answer called an electrolyte containing at least one broke up metal salts and different particles that allow the stream of power. A power supply supplies an immediate current to the anode, oxidizing the metal molecule that contains it and empowering them to break up in the arrangement. At the cathode, the broke up metal particles in the electrolyte arrangement are limited at the interface between the arrangement and the cathode, with the end goal that they "plate out" onto the cathode. The rate at which the anode is broken down is equivalent to the rate at which the cathode is plated, versus the present moving through the circuit. Along these lines, the particles in the electrolyte shower are ceaselessly renewed by the anode.

Other electroplating technique may use a non-consumable anode, for instance, lead. In this methodology, particles of the metal to be plated must be intermittently renewed in the shower as they are drawn out of the arrangement.

Stir Casting: Mix Casting is a fluid stage method of composite materials manufacture, in which a scattered stage (fired particles, short strands) is fortified with a liquid framework metal by methods for mechanical blending. Mix Casting is the most straightforward and it is the financially savvy strategy for fluid state creation.

Squeeze casting : Crush Casting Infiltration is a constrained invasion strategy for fluid stage manufacture of MMCs utilizing a portable shape part (slam) for applying weight on the liquid metal and driving it to enter into a performed scattered stage, put into a drag part. Crush throwing strategy is like the Squeeze throwing procedure utilized for metal composites throwing.

Press Casting Infiltration handle has the accompanying fundamental strides:

1. A perform of scattered stage (strands) is set into the drag part.
2. A liquid metal in a foreordained sum is filled the drag some portion of the shape box.
3. The adapt part moves downwards and strengths the fluid metal to invade the perform.
4. The penetrated material sets under the weight.
5. The part is launched out from the form by methods for the ejector stick.

The strategy is utilized for assembling straightforward little parts (car motor cylinders from aluminum combination strengthened by alumina short strands).

Spray deposition: Shower statement is not a powder metallurgical technique inside the strict meaning of that term since metal in real powder shape is excluded. Fluid metal is gas atomized in the run of the mill way and the splash is caused to encroach while still in the fluid or semi-strong state on a strong previous where a layer of thick strong metal of a pre-decided shape is created. The strong consequently created has a structure like that of powder – based material with all the orderly points of interest of fine grain, flexibility from large scale isolation, and so forth.

Physical Vapor Deposition:

The strategy incorporates nonstop section of fiber through an area of high weight of the metal to be kept, where buildup happens in order to create an also thick covering on the fiber. The vapor is created by coordinating a powerful electron shaft onto the finish of a strong bar nourish stock. Composite manufacture is typically finished by amassing the covered strands into a package or cluster. This procedure can be delivered by composites with uniform dissemination of fiber and volume part as high as 80%.

In Situ Fabrication Technique

Controlled unidirectional hardening of an eutectic composite can bring about a two-stage microstructure with one of the stages, display fit as a fiddle or fiber, conveyed in the framework.

Gas – liquid response is moreover used to create Tic fortified aluminum lattice composites. For instance, by gurgling carbonaceous gas like methane into Al-Ti liquefy kept at hoisted temperature it is conceivable to delivered Al-TiCp composites. London and Scandinavian association has created as in – situ technique, which utilities response between blended salts to deliver a scattering of fine TiB2 particles in an aluminum framework. A noteworthy detriment of in–situ strategy is identified with the thermodynamic confinement on the creation and nature of the support stage that can frame in a given framework, and the motor limitations on the shape, size and volume division of the fortification that can be proficient through substance responses under a given arrangement of test condition.

Al6063 alloy

Alloy 6063 is a standout amongst the most broadly used amalgams in the 6000 arrangement. This standard basic composite and warmth treatable compounds, is famous for medium to high quality prerequisites and has great durability attributes.

Composite 6063 has extraordinary consumption imperviousness to environmental conditions and great erosion imperviousness to seawater. This amalgam has likewise offers great completing qualities the most widely recognized anodizing techniques incorporate clear, clear and shading color, and hard coat. Compound 6063 is adequately welded and joined by various business techniques.

Its predominant erosion resistance makes it an appropriate hopeful material for marine auxiliary applications. The interest for lighter weight, decreasing expense and elite materials for use in a range of auxiliary and non-auxillary applications has achieved the manufacture of metal grid composites (MMCs) of various sorts. As of late, the aluminum composite based MMCs have offered originators many included advantages as they are especially suited for applications requiring great quality at high temperatures, great auxiliary inflexibility, dimensional steadiness, light weight and low warm development. The real focal points of AMCs fuses more prominent quality, better firmness, diminished thickness, enhanced high temperature properties, controlled warm and enhanced damping abilities.

Properties of Al6063

Properties of aluminum 6063 incorporate,
1. Medium to high quality
2. Very Good strength

3. Very Good surface wrap up
4. Excellent consumption imperviousness to barometrical conditions
5. Good consumption resistance
6. Can be anodized

Advantages of composite materials:

1. Cost can be reduced
2. Excellent weight/ mechanical strength ratio.
3. Does not corrode.
4. Self- extinguishing, non toxicity of gases.
5. Thermal, electric and phonic insulation.
6. Easy to obtain complex shaped and intricate shapes.
7. Composites have a high specific tensile strength that is approximately 4 to 6 times higher than the other materials such as Aluminium and steel.
8. The weakness continuance constrain is considerably higher than that of steel of aluminum.
9. Corrosion in Composites is much lower compared to steel of Aluminium.
10. Composite materials can dispose of many joint and can be secured by streamlined strategies, along these lines wiping out both basic shortcoming and assembling costs.
11. Environmentally friendly.
12. Easy to clean with a hose.

Disadvantages of Composite materials:

1. High cost of fabrication is the major drawback of composite.
2. Mechanical portrayal of composite structure is more perplexing than that of metal structure.
3. Repair of Composites is a critical issue compared to that of metals.
4. It cannot be used for load – bearing or structural work.
5. Damaged material has to replace.
6. It is temperature delicate and extends and furthermore contracts with temperature change.
7. It is another building material.
8. It's a delicate material and wears effectively. Complex damages such as fibre cracks, matrix cracks, Interface deboning, delamination, micro bucking, etc.

Literature Survey

Literature from Journal Papers

Styles et al.(1998) [9] reported that particulate silicon carbide (SiCP) reinforced aluminum alloys has been observed to posses increased particular quality and firmness over those of comparable solid materials while keeping up great auxiliary formability and isotropic properties. Examinations of short fiber, bristle, or molecule fortified compounds were conducted with the reason for limiting creation cost and getting materials, which are anything but difficult to use and with enhance mechanical properties.

Metal Matrix Composites (MMC's) reinforced with fibres, whiskers, or particulates of silicon carbide have become materials of interest for few years back. These composites are potential competitor materials for a variety of uses in the fields of aviation, automotive, industrial and leisure goods.

Divecha et al.(1981) [10] discussed several processing routes in production of AMCs reinforced with SiCW and SiCP. Casting roots seems to be most attractive out of these methods. Several variants of casting route namely compo casting, liquid pressure forming, spray casting and squeeze casting have been tried successfully to fabricate Al- SiCw, Al-SiCP and Al-SiCf composite.

Buhrmaster et al (1988) [11] developed a new process for producing near – net- shape aluminium and A1/SiC composite components. This process uses an apparatus which is basically a modified gas metal circular segment welding light, where aluminum wire bolster stock is liquefied and can be considered with SiC particles entrained in dormant gas. After striking a shape, the mix of aluminum and SiC cements into composite structures. Mechanical properties obtained in unreinforced materials using this process are similar to those found in conventionally produced version of the same alloys.

David (1991) [12] conducted the tensile and fracture toughness tests on 2014 Al alloy / SiC composite consisting of 15 vol. Percent SiC particulates. Overall tensile elongations values ranged from 1.6 to 2.4 per cent and fracture toughness were controlled by two factors namely; deformation characteristics of the matrix and SiC particles distribution. He discovered that the best method for increasing fracture toughness of composites is dispersing uniformly the particles and by increasing ductility of matrix.

Kim et al. (1991) [13] observed that fracture toughness of Al / SiCp composite decreases from 0.08 to

0.065 per cent as volume fraction increases from 5 per cent to 30 per cent.

Lihe et al. (2002) [14] conducted fracture toughness on 6061 Al alloy reinforced with 15 per cent, fine SiC particles of 0.6□ m & 9.5□ m. He observed that the toughness of fine 0.6□ m SiC particle reinforced composite was 30 per cent more than that of 9.5□ m SiC reinforced composite and it is about one half of the unreinforced 6061 Al alloy. Limits between molecule groups and encompassing grid observed to be in charge of the disappointment component.

V.Bheema (2008) [15] studied the effect of TiO_2 reinforcement on corrosion behavior of Al6063 based composites. He observed that the increase in the percentage of TiO_2 aids in reducing the density and increasing the corrosion resistance significantly.

G.S.Kataiah (2010) [16] studied the mechanical properties and fractography of Al6061 and TiO_2 composites. He observed that with increase in TiO_2 content in Al alloy results in increase in UTS, Hardness, Torsional Strength and impact strength but decrease in ductility.

K.S.Sucitharan (2013) [17] studied the wear behavior of Al6063 and Zicron sand metal matrix composites. He prepared the composites using liquid metallurgy route that is stir casting method. He observed that increasing in the percentage of zircon sand particles will reduce the wear rate of the composites which is having 8wt% of $ZrSio_4$.

V.Danial Jebin (2013) [18] studied the wear behavior of Al6063 and Alumina metal matrix composites. He prepared the composites using stir casting method. wear test carried out on pin on disk machine and he observed that increasing the percentage of Alumina particle will reduce the wear rate of composites.

Scope of present Investigation:

As discussed aluminium amalgam based metal lattice composites are procure across the board acknowledgment in a few applications, for example, cylinder, interfacing poles, microwave channels, vibrators parts, contractual workers and space structures. These composites have an astounding wear resistance not withstanding other prevalent mechanical properties for instance, quality, modulus and hardness when contrasted and ordinary compounds. Of all the aluminium alloys 6063 is a well known selection material as a matrix to produce MMCs attribute by its good formability & also allow modifying the characteristics by applying proper reinforcements. From the writing, it is evident that the concentrate has been fixated on handling of MMCs and portrayal of mechanical properties of MMCs.

The present examination deals with manufacturing of cast Al6063, Al6063-TiO_2 composites by liquid metallurgy path. Further, microstructure, density, porosity, micro hardness and adhesive wear studies will be conducted on both Al6063 alloy and Al6063- TiO_2 composites. The Schematic part of the process plan is as shown in Fig 5.1. And it is analyzed by Taguchi, Anova and Edax method.

Objectives

1. To synthesize Titanium dioxide particle reinforced Aluminium metal matrix composite specimens are prepared using Stir casting method.
2. To study the hardness ofaluminum metal matrix composites at different composition of TiO_2.
3. To study the micro studies ofthe structure, density and porosity of aluminium metal matrix composites at different composition of TiO_2.
4. To study the wear behavior of Aluminium metal matrix compositesat different composition of TiO_2.
5. To study the iron pick up content in Aluminium metal matrix composites at different composition of TiO_2 using EDAXMethod.
6. To study the signal to noise ratio and percentage of contribution of Aluminium metal matrix composites at different composition of TiO_2.

Methodology:

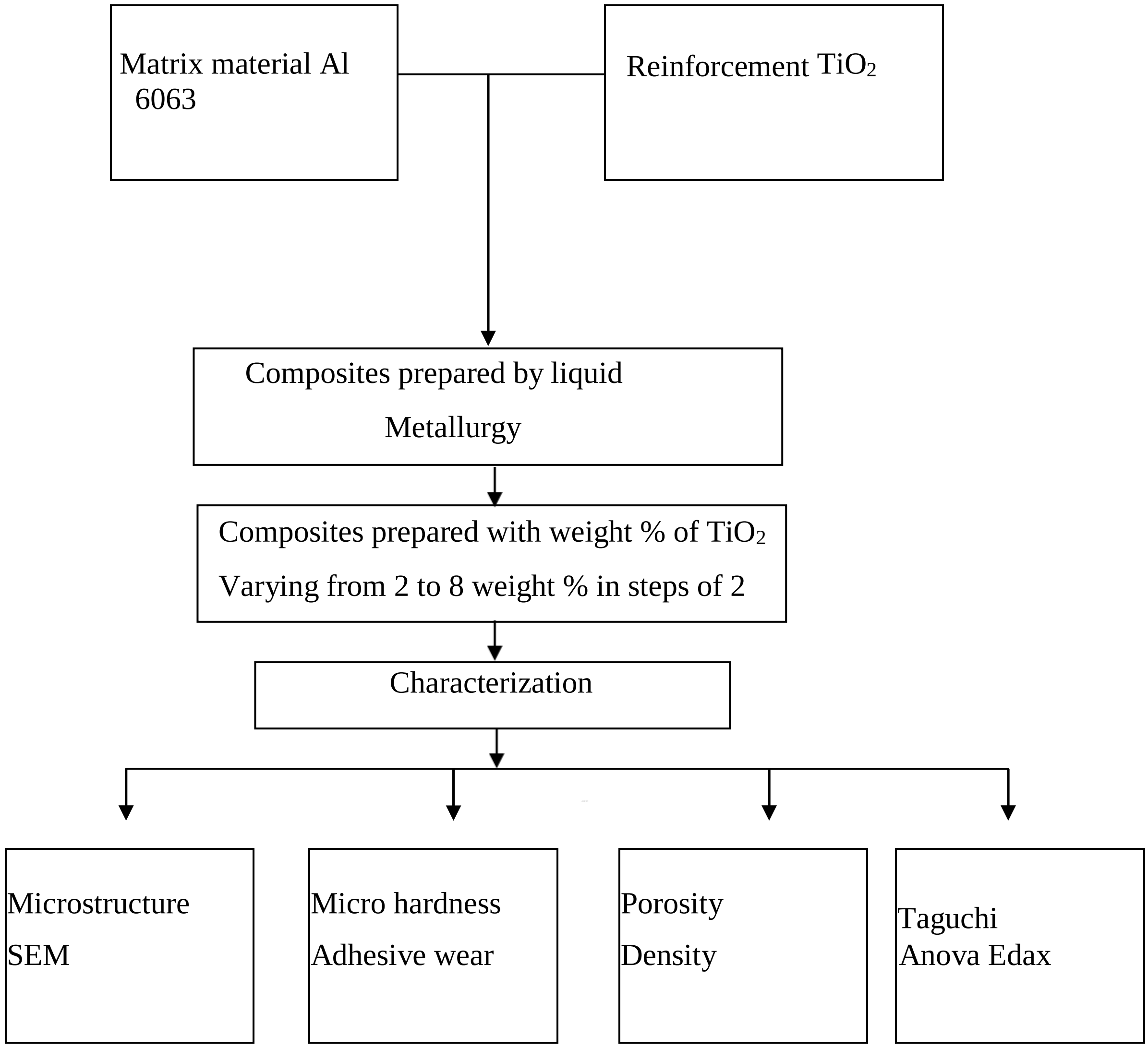


Fig. Process Plan

Aluminium metal matrix composites is reinforced with TiO_2 and composites are prepared using liquid metallurgy technique. Stir casting method is used to prepare the Al6063-TiO_2 composites. Here, composites are prepared with weight% of TiO_2 varying from 2 to 8 weight % in steps of 2.After finishing the casting method; next operation is cutting, grinding and Lathe operation to remove the diameter of the Work piece. Prepared specimens are subjected to SEM analysis to observe the microstructure and analyzed by EDAX method to see the iron pick up in the work piece. Specimen is also subjected to wear test, Density, Porosity, Hardness and it is analyzed by Taguchi and Anova method to find out the signal to noise ratio and Percentage of contribution.

Materials and Experimental Procedure

Selection of Material

Matrix material

For the purpose of using matrix material, Aluminum 6063 was selected. It is a flexible warmth treatable expelled compound with medium to high quality abilities. It contains magnesium (0.8% to 1.2 %) and silicon (0.4% to 0.8%). It is a standout amongst the most widely recognized combinations of aluminum for broadly useful. [37, 38]

Table 6.1: Constituents of Al6063 alloy

Elements	Present % of 6063
Fe	0.0 – 0.35
Mg	0.45 – 0.9
Si	0.2 – 0.6
Ti	0.0 – 0.1
Cr	0.1 – Max
Cu	0.0 - 0.1
Mn	0.0 - 0.1
Zn	0.0 - 0.1
Al	Balance

Reinforcement:

The reinforcement used in titanium dioxide (TiO_2) powder of laboratory grade procured from a authorized chemical shop.Below fig shows the photograph of the procured TiO_2 powder and table 4.2 shows its various properties. It is naturally available oxides of Titanium. TiO2 happens in nature too known minerals rutile, anatase and brookite. A portion of the properties of Titanium dioxide have High gleam, Good whiteness, Extraordinary concealing force and great shading power, Good climate opposing property.

Fig Photograph of Tio2 Powder used as Reinforcement

Table Properties of TiO_2

Density	4.2g/cc
Tensile Strength	300-350 Mpa
Vickers Hardness	980 kgf/mm^2
Compressive Strength	800-1000 MPa
Modulus	240 GPa

Uses

1. It is used in electro ceramics and glass (due to its high stability) and property to absorb UV light)
2. Titanium dioxide is connected to paints, bonds, windows, tiles, or different items for its sanitizing, aerating and hostile to foulingproperties.
3. It's a good reinforcement agent.
4. Improves the corrosion resistance of a material when added to it.

Apparatus

It consists of the furnace, stirrer, mould and the other miscellaneous items.

Furnace specification Electric Resistance Furnace Casting Capacity: 5 kgs. Power Rating: 6 KW Crucible Size: 150 mm dia * 200mm HT Power Supply: 440 V, 50 Hz, 3 phase Max. Temperature: 999^0C
Strrier: 1 HP DC motor, 300 rpm.

Fig Photograph of Electric Resistance Furnace

The above figure shows the image of Electric resistance Furnace. In this furnace, Heat is generated by conductors that offer resistance to the flow of currents. Any temperature unto 3000^*C can be obtained in the furnace chamber. These furnaces are readily mechanized and automated. A resistance furnace may be well sealed

Fig Photograph of Mould box

The above figure shows the image of mould box. This mould box is also called as a core box. It is used in casting and molding process to produce the casting shape of the products. To pour the molten metal into the core box, core box should be preheated.

Fig Photograph of cast specimen

The above figure shows the photograph of cast specimen. The cast specimen is Aluminium matrix reinforced with TiO_2 composites. It should be removed from the core box after cooling.

Miscellaneous items:
Protective Gloves, tongs, crucibles, weighing balance, container for TiO_2, flux etc.,

Casting Process

An approximate 2 kg of aluminium billets were taken and placed in the crucible along with the flux. Fig shows photograph of furnace used. The furnace temperature was set to 700^0C. The furnace door is closed and switched on. The melting of the aluminium may take upto 3 hours. During which five samples of Titanium dioxide corresponding to 2%, 4%, 6%, 8%, were weighed according to the Al6063 billets weights. They were added in different batches. Titanium dioxide heated in the furnace to a temperature of 500^0C. As Aluminium reaches 700^0C the metal moulds were kept ready. The melt was allowed to superheat and soak for a while at 700^0C. Below **Fig** Shows molten Al6063. The preheated Titanium dioxides were added to it quickly so that they do not lose heat. The stirrer was turned on to 300 rpm and care was taken care that splashing did not occur. After stirring for 10 mins the crucible was removed and the melt was poured in the metal moulds. Fig 6.3 shows the mould box. The counter the contraction of the metal during cooling, a little extra melt was added. To prevent porosity, the pouring was done at a uniform rate. The mould was allowed to cool for 15 mins. To avoid entrapment of gasses in the melt, degassing tablets (hexachloroethane) was added and the slag was removed before adding the Titanium dioxide. Fig shows casted sample.

Fig Photograph of molten Al 6063 Microstructure samples

The equipments used for microstructure studies are

1) Lathe
2) Grinding Machine
3) Polishing Machine

The samples with different percentages of Titanium dioxide were removed from the metal mould. The specimen was checked for porosity and a portion of the specimen was selected and was fed into the chuck and tightened using a chuck key. The lathe was switched ON and the speed was set accordingly. The specimen was subjected to turning operation. The samples obtained were of the size 16mm * 18mm. After the hack operation, the specimens were leveled using files. To obtain an excellent surface finish or mirror like finish, the sample were rubbed on sand paper. The specimen is rubbed in a particular direction and was maintained the same throughout the operation. Sand papering operation was first done with a 220 grade followed by 320, 400 and 600. The sample was subsequently subjected to polishing using Brass.

Preparation of microstructure sample

Preparation of the specimen is necessary to study its microstructure in metallurgical microscope, as it involves the principle of reflection of light to obtain the final image of the microstructure. The different steps involved in the preparation of the specimen are as follows.

Selection, cutting, and mounting of the specimen.

The specimen should be selected from the part of the material that should be representing the whole material satisfactorily. A small piece of the specimen is cut from the selected, using cutting tools and the specimen is small it should be mounted in the thermoplastic resin such that the specimen surface is exposed.

Grinding

The specimen is flattened manually using files and emery papers on a grinding machine. Scratches are removed by gently rubbing the specimen against emery paper under running water if possible to remove all the loose particles. Emery papers of different grade (200, 400, 600 etc) are used for this purpose. Each time the specimen is rubbed against each grade of the paper, it is turned by 90^0 and the rubbing action is continued so that the present scratches generated are perpendicular to the previous one. This result in continuous removal of deep scratches and finer scratch will result after the last emery paper.

Polishing

Polishing is a process of obtaining a mirror like finish on the surfaces of the specimen. The specimen held is pressed gently on a rotating disc on which a polishing cloth is fixed. Fig. below shows a typically available polishing machine. The specimen is a rotated on the cloth through a small angular position. A polishing material like Al_2O_3, SiC and MgO or diamond paste is used for this purpose. After achieving scratch free mirror finish of the specimen, the specimen is washed with water or swabbed with alcohol and dried.

Fig Polishing Machine

Etching

Here the polished specimens are exposed to certain chemicals which are referred to as etchants. For aluminium, usually Kellars Etch is recommended. These etchants react selectively with the different phases present in the metal.

Softer phases are attacked more than the harder phases by etchants. Reaction at the grain boundaries is much faster than that at the centre of the grain. As the result of different chemical attack, microstructure show distinctively. Etchants are chosen based on the type of the metal. The specimen is exposed to etchants for a few seconds and then rinsed with running water. After cleaning with alcohol, it is dried using an air blower and stored in a dedicator.

The throwing technique was broke down under the optical magnifying instrument to examine the cast structure. A zone was cut from the castings. It is first belt grained taken after by cleaning with various sorts of emery papers. At that point they were washed and cleaned in garments and after that washed, dried and scratched with Keller's answer and afterward explored however optical magnifying lens.

Scanning Electron Microscope (SEM):

1. An examining electron magnifying instrument (SEM) is a sort of electron magnifying lens that pictures an example by checking it with a light emission. Fig shows photograph of typically available SEM.
2. One of the tools available is an experiment that is a high powered microscope and an emission spectrometer, all in one.
3. This tools, the Scanning Electron Microscope and Energy Dispersive Spectrometer (SEM/EDS) makes possible the quick resolution of tough analytical problems effectively, timely and economically.
4. The SEM is the ultimate tool for:

a. Deposits and Wear Debris Analysis.
b. Particle Sizing and Characterization.
c. Failure Analysis.
d. Contaminant Analysis
e. Metallurgical Studies

5. Back ground.

In 1978 at a Tribology Conference at the Massachusetts Institute of Technology, Douglas Godfrey (a Herguth Research Associate) in a paper on the helpfulness of new surface investigation instrument, he inferred that Scanning Electron Microscope (SEM), alongside Energy Dispersive Spectroscopy (EDS) was the most valuable.

Filtering electron magnifying lens (SEM): Design and capacity:

The surface of an example is brought into the centralization of electron bars. The signs delivered control the splendor of a screen tube with the end goal that a picture of the surface of the example shows up.

Fig. Photograph of SEM

Micro Hardness Test

Hardness is a property of a material, not a key physical property. It is described as the imperviousness to space, and it is controlled by perpetual profundity of space. All the more basically, when utilizing a settled constrain & a given indenter, the littler the profundity of space, the harder the material. Space hardness esteem is acquired by measuring the profundity or zone of space.

Procedure:

1. Sample is placed firmly between two chucks. Fig 6.8 shows photograph of Micro hardness tester.
2. By using 40X microscope set microstructure of sample.
3. By using knob set time of indentation.
4. A load of 100gm is applied on sample.

5. Indentation is viewed by using microscope.
6. Using knob distance of indentation is calculated.
7. Using digital meter hardness is noted
8. Same procedure is repeated for different sample designation and the hardness is determined for each samples.

Fig Micro hardness tester

Adhesive wear (Pin on Disc)

In material science wear is deterioration or sideways uprooting of material from its subordinate and novel position on a solid surface performed by the action of another surface. Fig below shows photograph of Pin on disc apparatus.

Wear is identified with connections amongst surfaces and all the more particularly the evacuation and distortion of material on a surface because of mechanical activity of the inverse surface. The necessity for relative movement between mechanical wear compared to different processes with similar results.

Fig Photograph of pin on disk apparatus

Procedure:

1. Wear tests were inspected in air at surrounding temperature utilizing a stick – on – circle mechanical assembly.
2. The wear test examples had ventured stick geometry with a breadth of 10mm at the rubbing end.
3. The sliding surfaces of test work piece were rubbed on 600 coarseness SiC emery paper to evacuate machining marks and rubbed with acetone to clean the surface.
4. The running time of the disc is 30 minutes. The sliding speed and load were varied. The track radius kept constant at 50 mm.
5. Each trial was rehashed and midpoints of firmly repeatable test esteems were taken.

6. The wear rate was figured utilizing weight reduction strategy.
7. The wear rate and frictional force is note down by seeing the machine after the experiment

Preparation of samples for wear study

The equipments used for microstructure studies are

1. Lathe
2. Polishing machine

Casted specimen is machined to a size of 8mm dia and a height of 20mm. Fig below shows photograph of wear sample.

Fig Photograph of wear sample

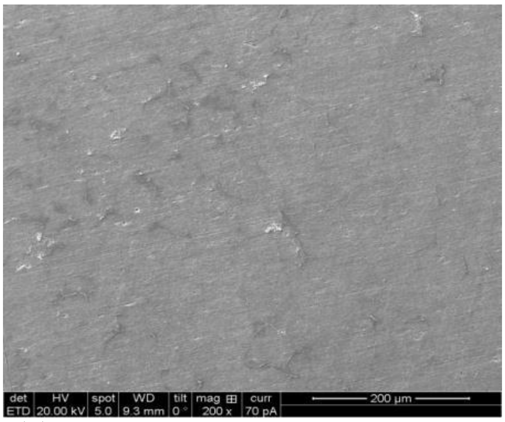
Energy Dispersive X-ray Spectroscopy

Vitality – dispersive X-beam spectroscopy are additionally called as vitality dispersive X-beam examination (EDXA) or vitality dispersive X-beam microanalysis (EDXMA), is an explanatory method used for the essential examination or synthetic portrayal of an example. It relies upon an association of some wellspring of X-beam excitation and an example. Its portrayal capacities are expected in colossal part to the essential rule that every example has a one of a kind nuclear structure permitting a novel arrangement of crests on its electromagnetic outflow range (which is the primary rule of spectroscopy).

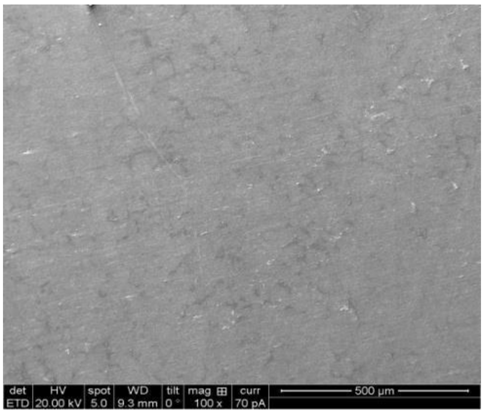
To fortify the emanation of trademark X-beam from a specimen, a high – vitality light emission particles, for example, electrons or protons is engaged into the specimen being examined. Very still, a particle inside the example contains ground state electrons in discrete vitality levels or electron shells bound to the core. The occurrence shaft may energize an electron in an internal shell, catapulting it from the shell while making an electron opening where the electron was. An electron from an external, higher – vitality shell at that point fills the gap, and the distinction in vitality between the higher – vitality shell and the lower vitality shell might be discharged as a X-beam. The number and vitality of the X-beam discharged from an example can be measured by a vitalitdispersive spectrometer.EDS permits the basic arrangement of the specimens to bemeasured.

Results & Discussion

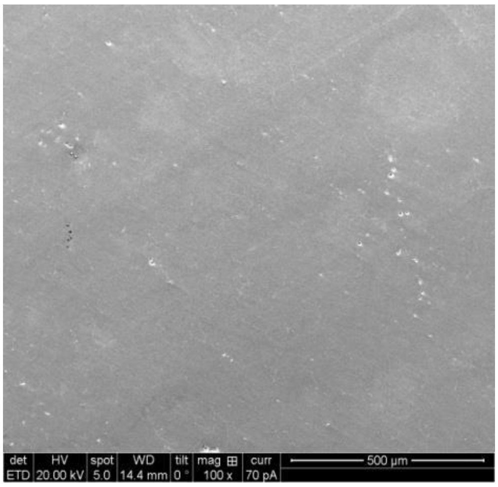
Microstructure (Using SEM)



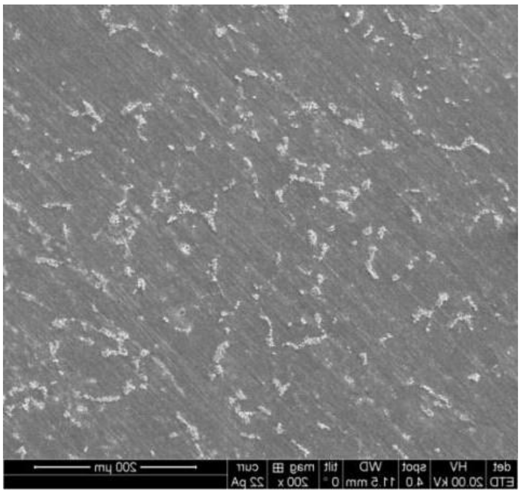
(a)Photograph of Al6063 alloy



(b) Photograph of Al6063-2% TiO_2



(c)Photograph of Al6063-4%TiO2



(d) Photograph of Al6063-6% TiO2

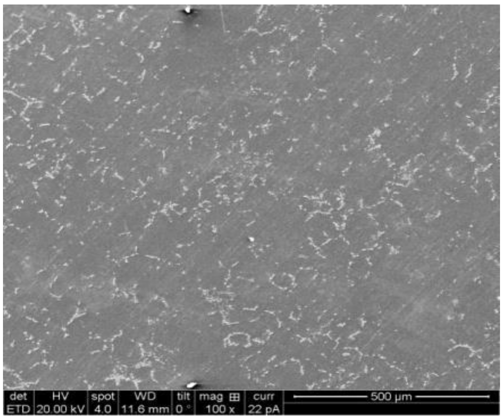


fig 1(a-e) SEM micrographs of Al6063 alloy and Al6063-TiO2 composites

It is seen form figures is that there will be a uniform increase in hardness with the increase in reinforcement. This is because of the presence of hard reinforcement in the forms of TiO_2. This is also attributed to the fact that there is a uniform distribution of TiO_2 present in the microstructure.

Fig 1 (a-e) shows that SEM micrographs of Al6063 and Al6063 - TiO_2 composites. It is observed that TiO_2 reinforcement is uniformly distributed with a fairy maintains bond with matrix & reinforcement. Further, the presence of any surface defects is not notices.

Density:

Table Density of Al6063 alloy and Al6063 – TiO_2 composites

Composites	Density (g/cc)
Al6063 alloy	2.74403
Al6063 -2% wt TiO_2	2.7779
Al6063 -4% wt TiO_2	2.8302
Al6063 -6% wt TiO_2	2.90628
Al6063-8% wt TiO_2	3.14486

Density of composites goes on increasing as we add reinforcement. Density can be calculated by using mass of the specimen divided by volume of the specimen. Density of TiO_2 was found to be 4.2g/cc which is more than density of Al6063 which is around 2.74403g/cc, so density of composites also should lie in the between these two value. So density of Al6063 – 2% wt TiO_2 was found to be 2.7779 g/cc which is slightly higher than Al6063 alloy and density went on increasing till Al6063 – 8% wt TiO_2 which is found to be 3.14886g/cc. Above Table shows density of Al6063 alloy and Al6063 - TiO_2 composites.

Porosity:

Table Porosity of Al6063 alloy and Al6063 – TiO_2 composites

Composites	Porosity (%)
Al6063 alloy	22.02
Al6063 -2% wt TiO_2	20.42
Al6063 -4% wt TiO_2	15.10
Al6063 -6% wt TiO_2	14.23
Al6063-8% wt TiO_2	11.16

Porosity of composites was decreasing as we increase reinforcement in it. For Al6063 alloy porosity was maximum, this because it has so many air voids. As we increase reinforcement air voids will be replaced by TiO_2 hence less porosity. Table 5.2 shows Porosity of Al6063 alloy and Al6063 -TiO_2 composites.

Table above shows that the effect of reinforcement on the porosity of Al6063 alloys. If we increase TiO_2 reinforcement in Al6063 porosity decreases .As decrement in porosity by about 7.26%, 31.42%, 35.37% and 49.3% have been observed for Al6063 -2wt% TiO_2, Al6063 -4wt% TiO_2, Al6063 -6wt% TiO_2 composites respectively when compared with Al6063 alloy.

Micro hardness (VHN):

Table Micro hardness of Al6063 alloy and Al6063 – TiO_2 composites

Composites	Hardness (VHN)
Al6063 alloy	43
Al6063 -2%TiO_2	52
Al6063 -4%TiO_2	57
Al6063 -6% TiO_2	82
Al6063-8%TiO2	90

The samples are then tested for hardness (VHN) values. It is seen from the table and the graph that the hardness values have shown a significant increase. This is because of increase in reinforcement in Al6063 alloy.I got 43 (VHN) for Al6063 alloy and it went on increasing as reinforcement increases. We have maximum value of 90 (VHN) for Al6063 TiO_2 composite. Table 7.3shows Micro hardness of Al6063 alloy and Al6063- TiO_2 composites composites.

Fig. above enlightens that result of reinforcement on the Micro hardness of Al6063 alloys. It is analyzed that there is marginal increase in hardness at micro level of Al6063- TiO_2 by increasing TiO_2 reinforcement in Al6063 alloy. As increase in Micro hardness by about 20.9%, 32.55%, 90.69% and 109.3% have been observed for Al6063 -2wt%, Al6063-4wt% TiO_2, Al6063-6wt% TiO2 and Al6063-8wt% TiO_2 alloy compared against Al6063 alloy. hardness of Al 6063 alloy.

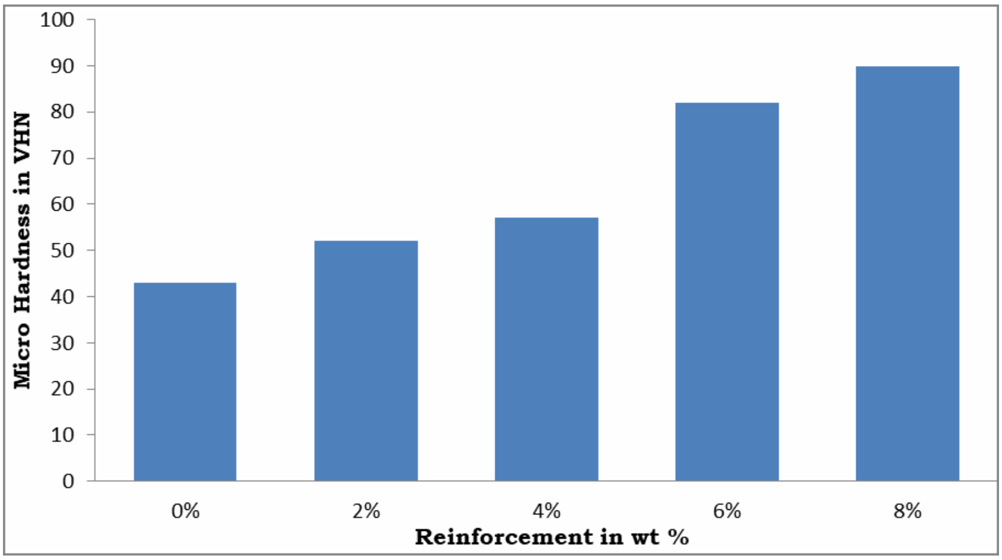


Fig Results of Reinforcement on micro hardness of Al6063-TiO_2 Composites.

Adhesive wears (Pin on Disc):

Effect of reinforcement

It is analyzed the alloy have more wear resistance compared with Al6063 alloy. A marginal improvement of about 6.25%, 18.75%, 37.5%, 43.75, in wear resistance is observed in case of Al6063-2% wt TiO_2, Al6063-4wt% TiO_2,Al6063-6wt% TiO2 and Al6063-8%TiO_2 compared with Al6063 matrix alloy. Al6063-TiO_2 alloy increased wear resistance that can be applied to the following factors. Fig below shows graph of results that wear rate of reinforcement of Al6063 alloy and TiO_2 composites.

1. The small scale hardness of composites can be expanded with the expansion in TiO2 fortification. It is dissected that cement wear relies upon material hardness.

2. The bond between the grid and the support assume a critical part in the wear procedure. As bond strength increase with increase in reinforcement, we can say that wear reduces.
3. There is hardly and presence of any porosity in the developed composites as evidenced in microstructure photographs. Absence of porosity in composite material increases the contact between the sliding surfaces in this way limiting the surface harshness, along these lines it limits the contact weight and diminishes the odds of molecule separation amid sliding. It is additionally broke down that lesser porosity in the composite materials can expand the required length of make spread to fix laugh out loud with different breaks to cause delamination and builds the wear resistance of the composites.
4. Further,, limiting in the wear rate of composites can likewise be credited to higher load bearing limit and crack strength of the TiO2.From the micrograph, it is seen that great security exists between Al6063 compound and TiO2 particles. Along these lines nearness of good bond decreases the likelihood of decohesion or haul out of fortified stage from the lattice combination.

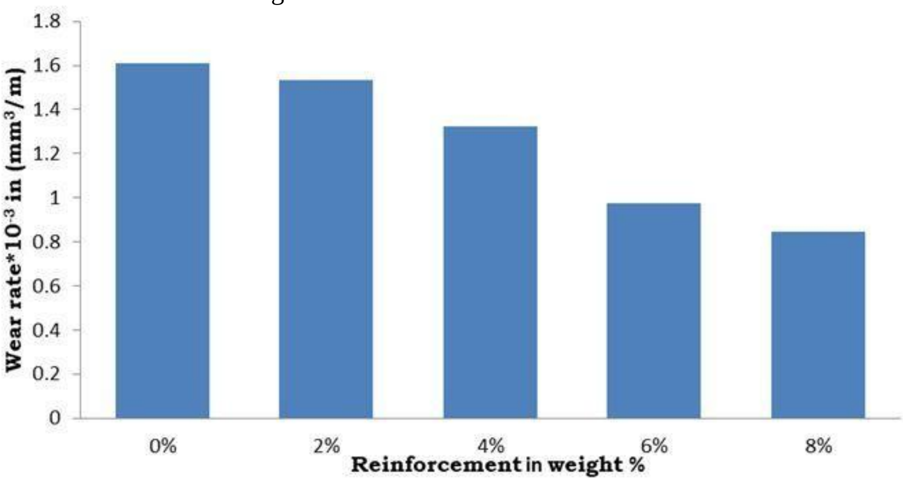


Fig Graph of Reinforcement on Wear rate of Al6063 matrix & TiO_2 Composites.

Effect of Load On Wear Rate:

The impact connected to typical load on the wear rate of Al6063 combination and the composites under sliding speed of 0.3141m/s is delineated in above figure. It is seen that with increment in typical load there is increment in wear rate of both the Al6063 and the Al6063-TiO2composites. Be that as it may, every one of the heaps are contemplated in composites had bring down wear rate when contrasted and the Al6063 combination. Fig below shows Graph of load on wear rate of Al6063 compound and TiO2 composites.

Wear rate can be increments with the expansion in stack in both Al6063 amalgam and Al6063-TiO2 composites can be credited to higher degree of plastic disfigurement, increment in the degree of plastic irregularly higher will be the likelihood of sub surface breaking which prompts colossal material expulsion. The delicate ill tempers in network compound will experience simple twisting under rehashed stacking condition, while the hard ill tempers of the counter surface will cut the delicate surface bringing about a few surface harm, were as on account of composites at first the strengthened particles goes about as load bearing components, as the heap increments, fortified stage experience irregular prompting change in surface attributes.

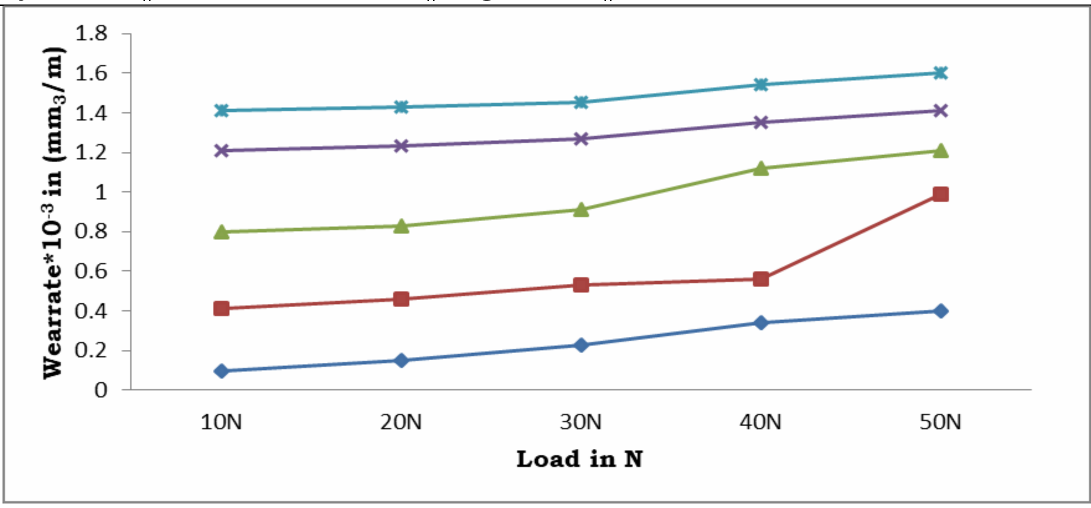


Fig Graph of load on wear rate of Al6063 alloy and TiO2 Composites.

Effect of speed on composites:

Plainly observed that if sliding speed increases there is increment in wear rate of both Al6063 compound and all the created composites. This expansion in wear rate of both the Al6063 combination and the created composites with increment in sliding speed is because of high strain rate subsurface mis shapening. This expanded rate of subsurface twisting increment the contact territories by break and discontinuity as ill tempers. In this way this prompts upgraded delamination adding to improved wear. Fig below shows impact of speed on wear rate of Al6063 amalgam and TiO2 composites.

Further, if sliding velocity increases the wear rate also increases due to the following reasons.

1. At low speeds the wear is due to abrasive action of the wear particles formed at intermediate speeds the wear is due to effect of delamination of the compacted particles and at higher speeds the wear loss is due to melt wear, i.e., plastically deformed material delaminated as flake debris of wear at different sliding velocities.
2. Further, the composites have better wear resistance compare to Al6063 Matrix alloy for sliding velocity.

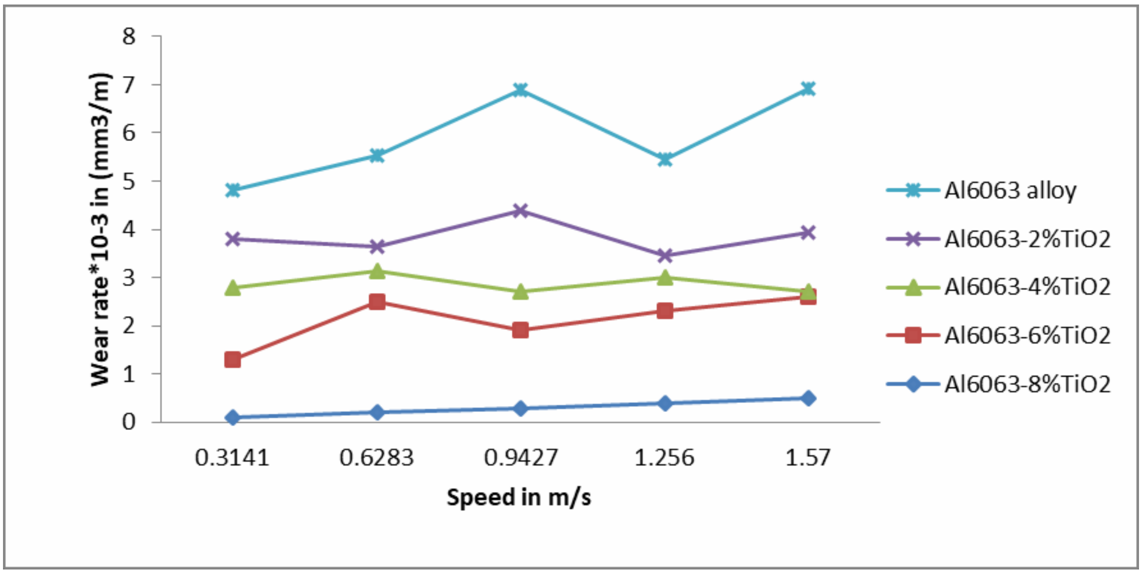
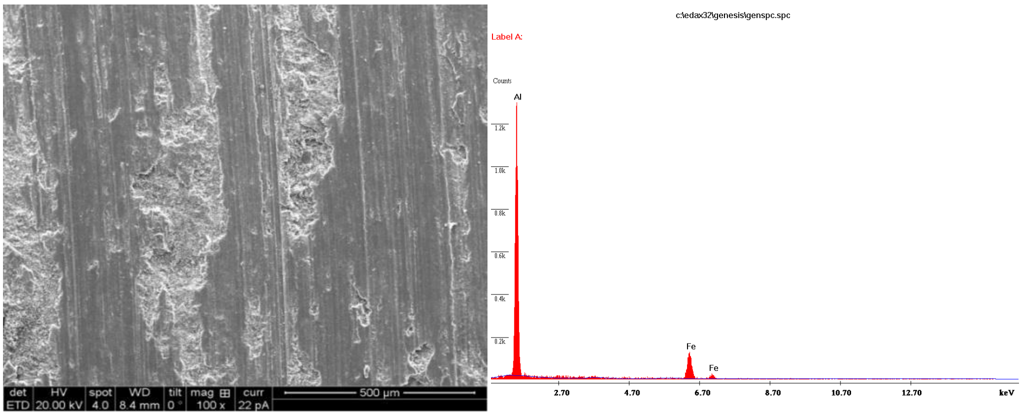


Fig Graph of speed on wear rate of Al6063 alloy and TiO2 Composites

Wear tracks:

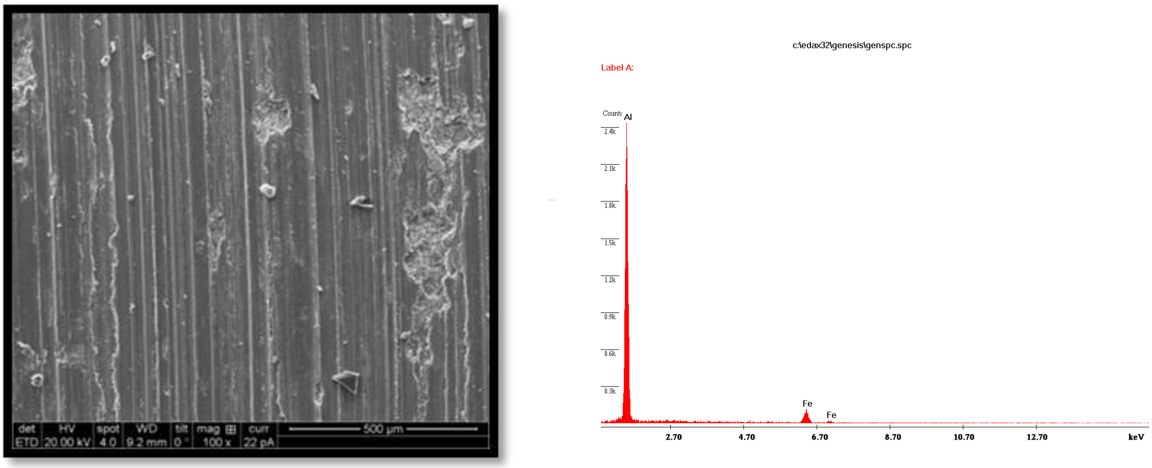
Effect of reinforcement on composites:

The pictures were taken for Al6063-2% wt TiO2, Al6063-4wt% TiO2, Al6063- 6wt% TiO2, and Al6063 -8wt%, TiO2 at 1 kg and 100rpm. As we observed these SEM pictures we can say that depth of groove went on decreasing as we increase in reinforcement, hence resistance to wear goes on increasing as we increase reinforcement. Damage happened to surface of Al6063- TiO_2 is shallower than Al6063 alloy. From EDAX analysis it found that as the content of TiO_2 increases in alloy Iron pick up goes on decreasing. Fig 1.1 (a-e) shows photograph of SEM and EDAX of Al6063 alloy and Al6063- TiO_2 composites.



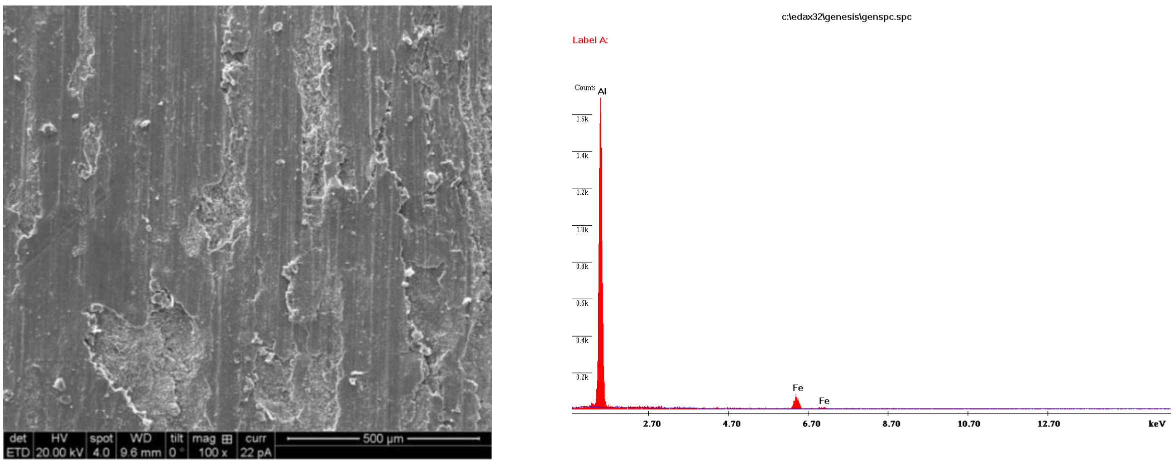
Iron pick up

Fig (a) Photograph of SEM and EDAX of Al6063 Alloy



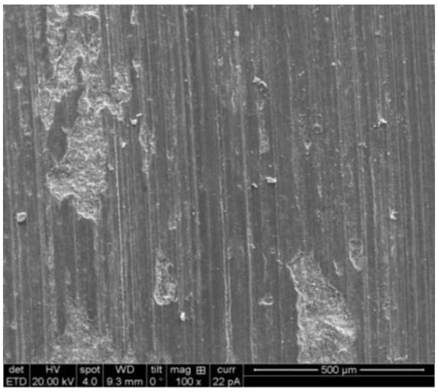
Iron pick up

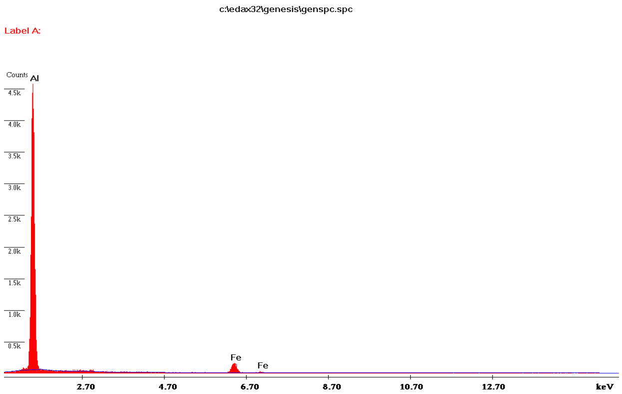
Fig (b) Photograph of SEM and EDAX of Al6063-2%TiO_2 Composites



Iron pick up

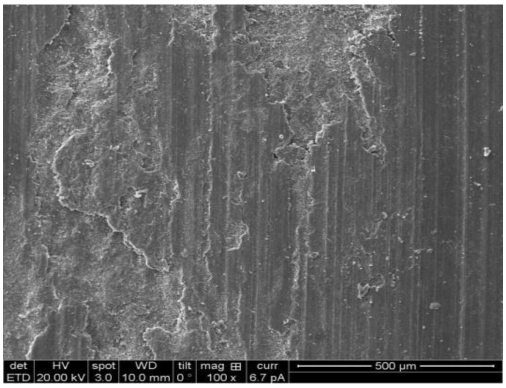
Fig (c) Photograph of SEM and EDAX of Al6063-4%TiO2





Iron pick up

Fig (d) Photograph of SEM and EDAX of Al6063-6%TiO2



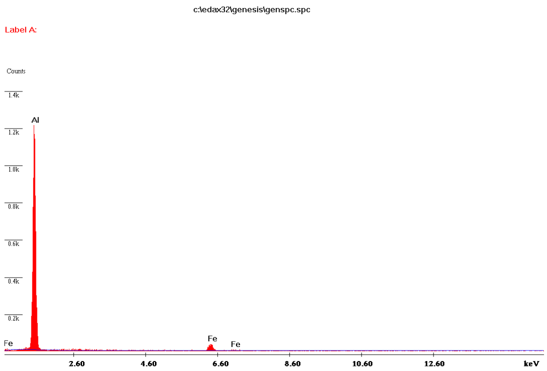
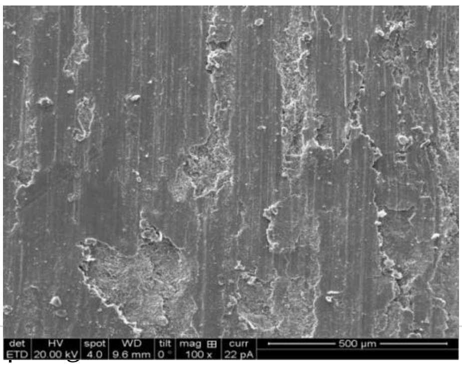


Fig (e) Photograph of SEM and EDAX of Al6063-8%TiO2

Fig1.1 (a-e) Photograph of SEM and EDAX of Al6063 alloy and Al6063-TiO2 Composites.

Effect of load on composites:

The pictures taken from 4% Al6063-TiO2 the Speed kept constant and load is varied 10 Newton to 50 Newton. The groove went deeper and deeper with increase in load. We can see that depth wear track went on decreasing as we increase load. Form EDAX analysis it is found that as the load increases Iron pickup goes on increasing. Fig1.2(a-e) shows photograph of SEM and EDAX of Al6063-alloy and Al6063-4% TiO2, composites at different load.



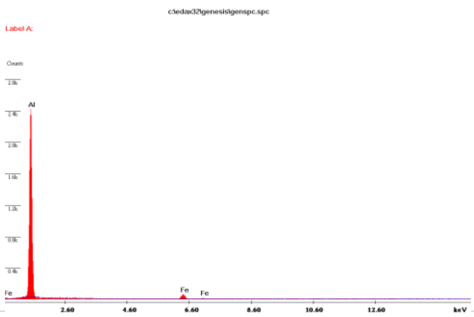


Fig (a) Photograph of SEM and EDAX of Al6063-4% TiO_2 at 1kg Iron pick up

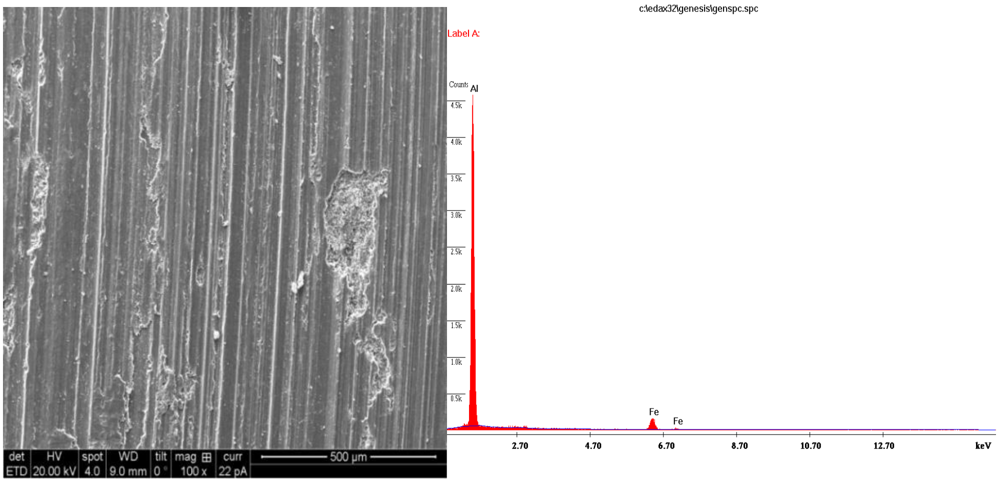
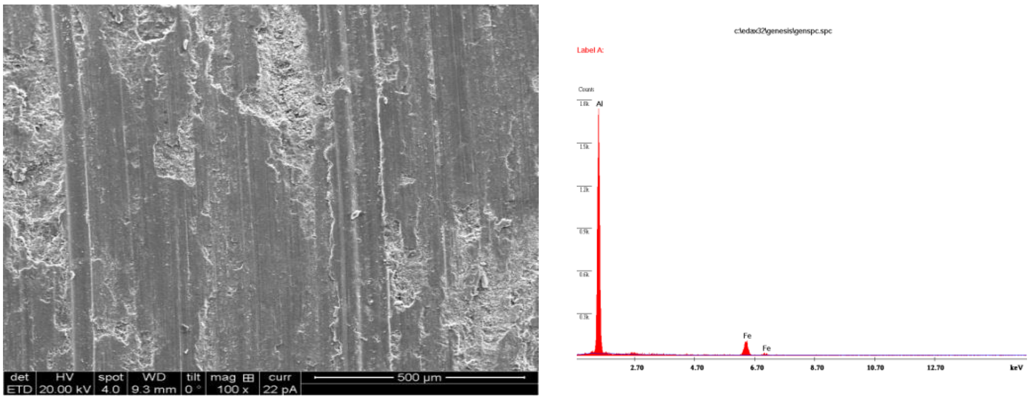


Fig (b) Photograph of SEM and EDAX of Al 6063-4%TiO_2 at 2kg

Iron pick up



Fig(c) Photograph of SEM and EDAX of Al6063-4%TiO_2 at 3kg

Iron pick up

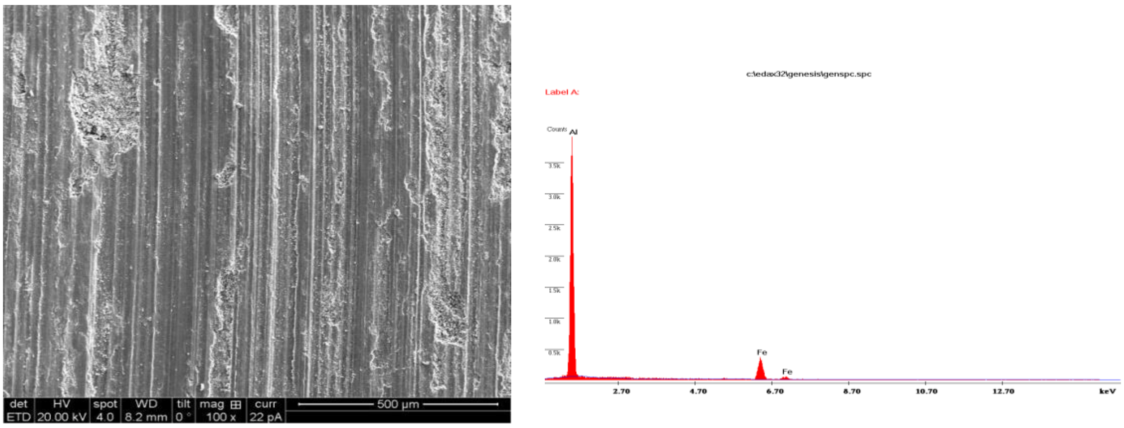
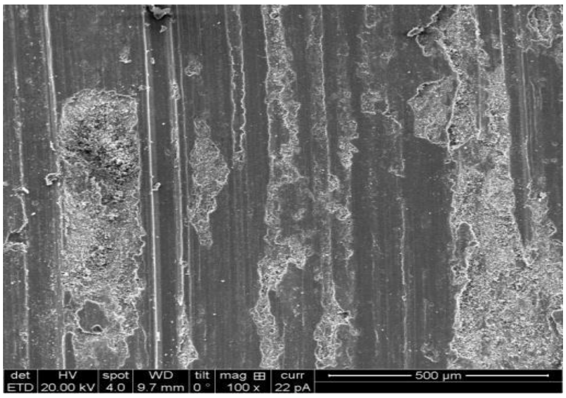
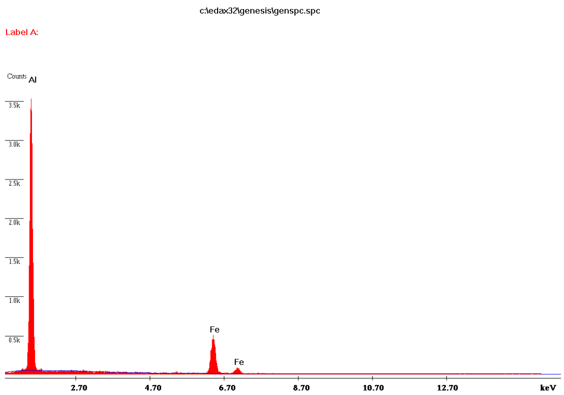


Fig (d): Photograph of SEM and EDAX of Al6063-4% TiO_2 at 4 kg.





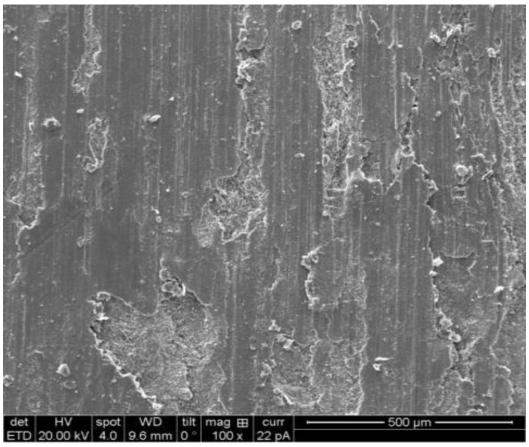
Iron pick up

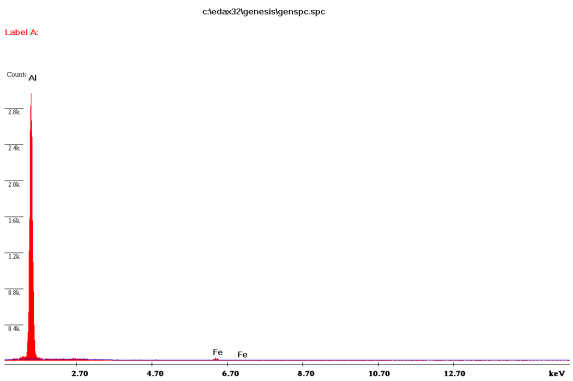
Fig (e) : Photograph of SEM and EDAX of Al6063-4% TiO_2 at 5 kg.

Fig 1.2 (a-e): Photograph of SEM and EDAX of Al6063 alloy and - Al6063 4% TiO_2 composites at different load.

Effect of Speed on composites:

The pictures taken from Al6063-6% TiO_2 the load kept constant and speed is varied from 100rpm to 500rpm. It is observed that as we increase the speed the groove went deeper and deeper. We can see that depth wear track went on decreasing as we increase speed. Form EDAX analysis it is found that as the velocity increases Iron pickup goes on increasing. Fig 1.3(a-e) shows photograph of SEM and EDAX of Al6063-alloy and Al6063-6% TiO_2, composites at different speed.





Iron pick up

Fig (a): Photograph of SEM and EDAX of Al6063-6% TiO_2 at 0.3141 m/s

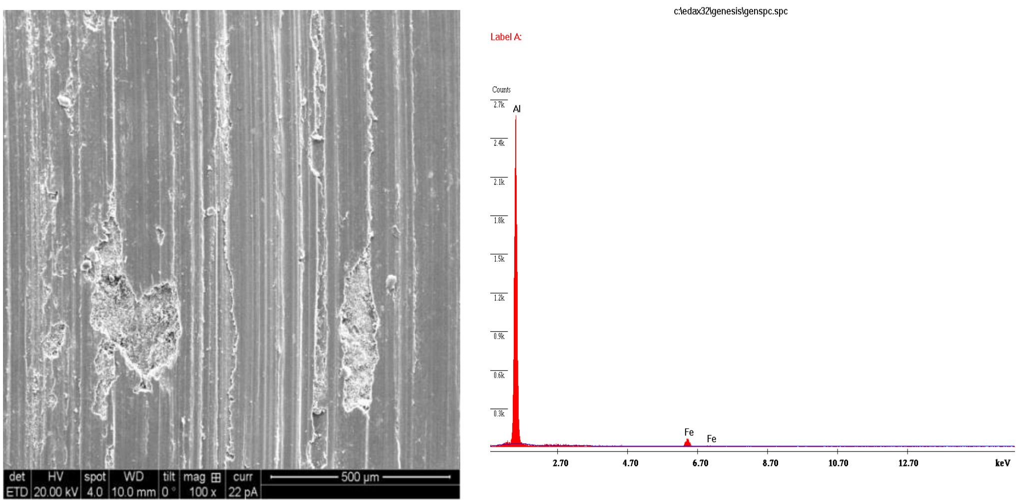
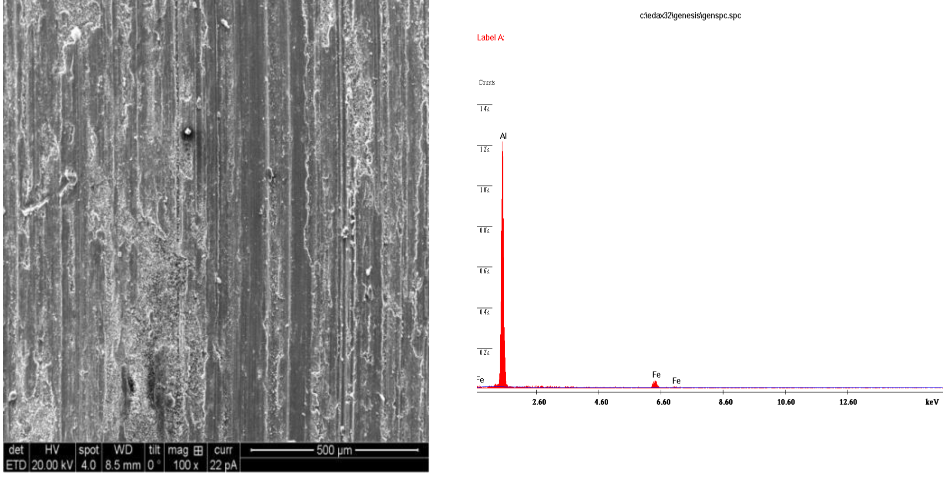


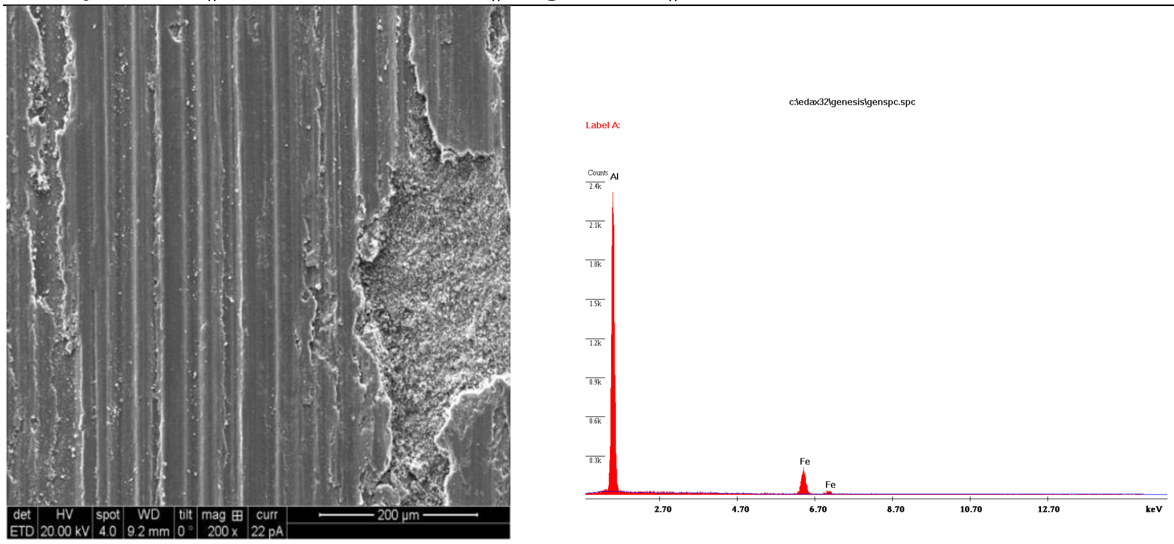
Fig (b): Photograph of SEM and EDAX of Al6063-6% TiO_2 at 0.6283m /s

Iron pick up



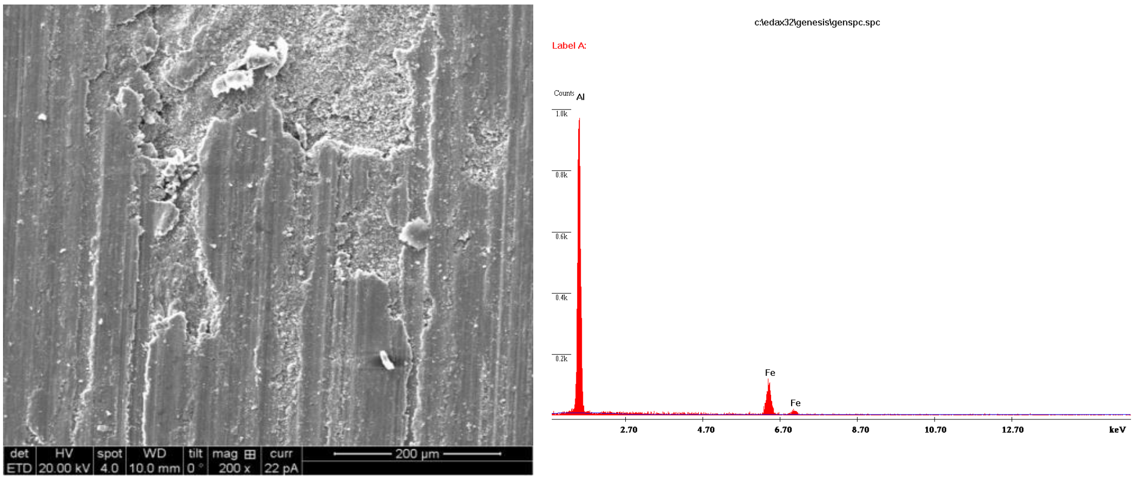
Iron pick up

Fig (c): Photograph of SEM and EDAX of Al6063-6% TiO_2 at 0.9424 m/s



Iron pick up

Fig (d) : Photograph of SEM and EDAX of Al6063-6% TiO_2 at 1.256 m/s



Iron pick up

Fig (e): Photograph of SEM and EDAX of Al6063-6% TiO_2 at 1.57 m/s

Fig 1.3 (a-e): Photograph of SEM and EDAX of Al6063 alloy and Al6063 6% TiO_2 Composites at different speed

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Analyzing Experiments

Wear Test

Analyzing the experiment Taguchi Orthogonal Array method is used. For orthogonal array method degrees of freedom has to set more than the wear parameters, which one of its condition to implement this method. In this experiment, I choose L16 orthogonal array, which contains 5 columns & 16 rows as same as in table 8.1.In this investigation the wear parameters chosen are 1) Load, 2) Speed & 3) Composition as shown in table 8.2.Table 8.3 shows their factors and the levels. The Experiments contains 16 tests.

The 1st column is for Load, 2nd for speed and 3rd for composition. The wear rate values for all factors for all levels obtained and results are summarized in Table 2.1, 2.2 and 2.3.The quality characteristics examined here smaller will be the better one. The objective of experimentation is "smaller the better type" quality characteristics, as wear rate has to be minimum.

L16 orthogonal array

Load (Kg)	Speed (RPM)	Composition (%)	Wear loss (g)	SN Ratio (Wear Loss)
5	100	0	0.011	39.17215
5	200	2	0.0041	47.74432
5	300	4	0.0021	53.55561
5	400	6	0.0046	46.74484
3	200	6	0.0003	70.45757
3	100	4	0.003	50.45757
3	400	2	0.0042	47.53501
3	300	0	0.0031	50.17277
4	300	2	0.002	53.9794
4	400	0	0.0071	42.97483
4	100	6	0.0007	63.09804
4	200	4	0.0023	52.76544
2	400	4	0.0037	48.63597
2	300	6	0.001	60
2	200	0	0.0004	67.9588
2	100	2	0.0016	55.9176

Table 2.1 signal to noise ratio response table

Level	Load (Kg)	Speed(RPM)	Composition (%)
1	58.13	52.16	50.07
2	54.66	59.73	51.29
3	53.20	54.43	51.35
4	46.80	46.47	60.08
Delta	11.32	13.26	10.01
Rank	**2**	**1**	**3**

Table 2.2 Mean response table

Factor	Type	Levels	Values
Load (Kg)	Fixed	4	2, 3, 4, 5
Speed (RPM)	Fixed	4	100, 200, 300, 400
Composition (%)	Fixed	4	0, 2, 4, 6

Table 2.3 Levels of table.

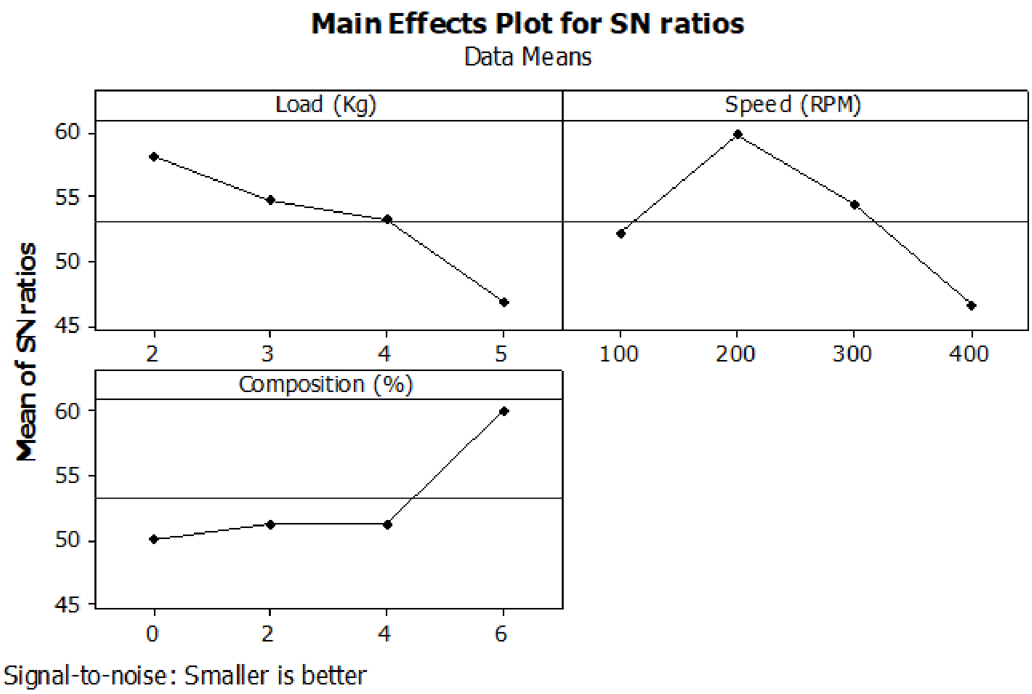


Fig. 2.1 factors on wear loss (SN Ratio)

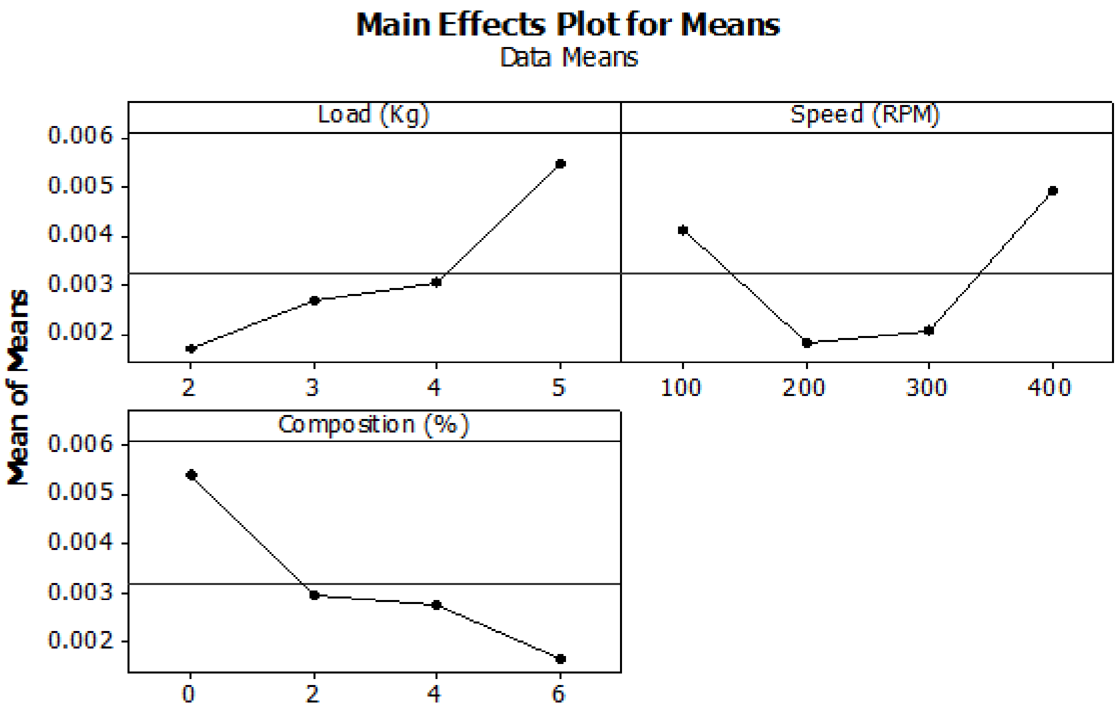


Fig. 2.2 Main control factors on wear loss (Mean)

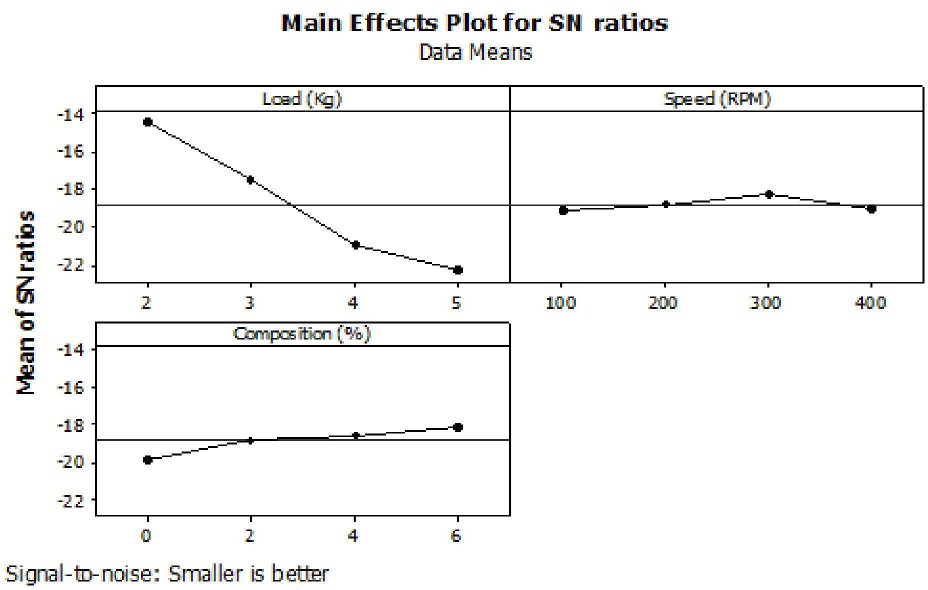
Frictional Force:

Table 2.4 L16 orthogonal array output results

Load (Kg)	Speed (RPM)	Composition (%)	Frictional Force	SNRA1
5	100	0	16.1	-24.1365
5	200	2	11.2	-20.9844
5	300	4	12.8	-22.1442
5	400	6	13	-22.2789
3	200	6	7.8	-17.8419
3	100	4	7.1	-17.0252
3	400	2	7.5	-17.5012
3	300	0	7.6	-17.6163
4	300	2	11.4	-21.1381
4	400	0	12.5	-21.9382
4	100	6	10	-20
4	200	4	10.9	-20.7485
2	400	4	5.3	-14.4855
2	300	6	4.1	-12.2557
2	200	0	6	-15.563
2	100	2	6	-15.563

Table 2.5 Mean Response Table

Levels	Load (Kg)	Speed in rpm	Composition (%)
1	5.350	9.800	10.550
2	7.500	8.975	9.025
3	11.200	8.975	9.025
4	13.275	9.575	8.725
Delta	7.925	0.825	1.825
Rank	**1**	**3**	**2**



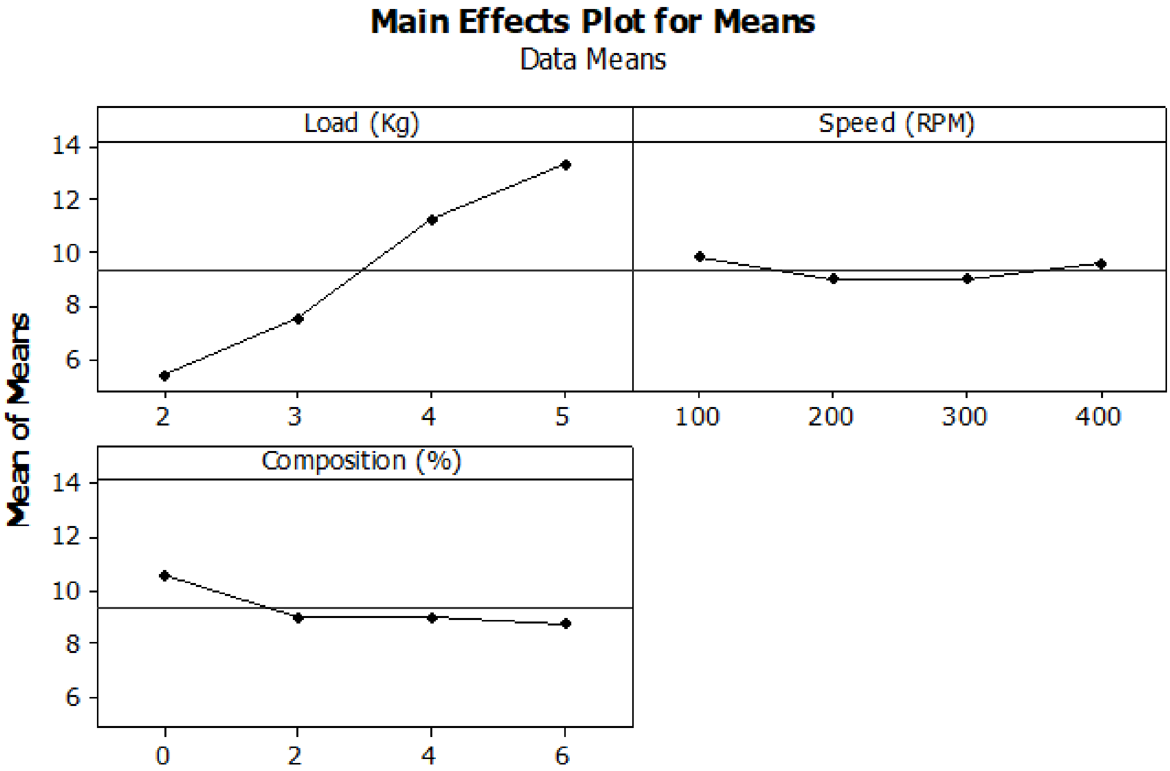


Figure2.4 Main control Factors on Frictional Force (Mean)

S/N (Signal to Noise Ratio)

If S/N ratio is higher than it always acceptable because greater S/N Ratio will results in smaller product variance around the target value. MINTAB R15 is used for analysis with quality characteristic "Smaller the Better" for this experiment.

The control parameters like load (Kg), Speed & Composition on wear of Al 6063 and TiO_2 had been investigated using S/N ratio analysis.

From the **Table 2.1** observed that when S/N ratio is higher when wear rate at column 5 is lower. From the **figure 2.1**, at lower load, the S/N Ratio for 0% is more. When the load is increases S/N ratio is decreases for Al 6063-6% TiO_2.

At lower speed, the S/N Ratio for Al 6063 alloy is medium, when the speed is increases till 200RPM, S/N Ratio is increases, and again it is decreases for increasing speed for Al6063-6% TiO_2.

From the **figure 2.2** at lower load, wear rate for Al 6063 alloy is less. If we increase the load till 5Kgs, wear rate is also increases. If we increase the speed from 100RPM to 400RPM, Wear rate is also increases. For Al6063 alloy, wear rate is more. If we add the reinforcement in matrix till 6%, wear rate is very less when compared to other Al 6063-2% TiO_2, Al 6063-4% TiO_2.

From the **Table 2.4,** we observed that when S/N ratio is lower that is -24.1365 when the frictional force is higher that is 16.1.Similarly when S/N ratio is higher that is - 12 when the frictional force is small that is 6.From the **figure 2.3,** at lower load S/N ratio is larger. It is decreasing till the load 5kgs.At 5kgs S/N ratio is minimum. Similarly in speedS/N ratio is smaller for 100rpm and it is increasing till 300rpm and again it is decreasing till 400rpm.In compositionS/N ratio is smaller for 0% and it is increasing till 6%.From the **Figure 2.4**, at lower load, frictional force is minimum. If the load is increases frictional force is also increases. At 200 and 400rpm, frictional force is same. Similarly in 200 and 300rpm, frictional force is same. At 0%, frictional force is more and t is decreasing till 6%.

ANOVA (Analysis of Variance)

Anova is used to analyze the differences among group means and their associate procedures developed by biologist Ronald Fisher. Using MINTAB R15 in ANOVA variance analysis was carried out with this load; speed & contribution are the main parameters which influences the wear rate. It can be concluded that each term in ANOVA has the significance where they are contributed towards response. The ANOVA was carried out for 5% significance level (which is nothing but the confidence level 95%). Table 6.2 enlightens the analysis which reviles that due to load, composition & speed the wear of composite is influenced. The end column in **table 2.6** is contribution in % (P) of total variation factors which reflects on results.

Anyone can conclude from ANOVA table that speed plays a major role in wear rate as it has 32.59%, load has medium effect i.e. 24.24% & compositions is less influence i.e. 23.09%. In a similar manner from the **table number 2.7** for co efficient of friction, we can see that the Load influences more about 91.17%, Composition is around 3.75% & speed has vey less 1.12%.

Table 2.6 Wear loss table for ANOVA

Sources	DF	Seq. SS	Adj. SS	Adj. MS	F	P	Pr (%)
Load (Kg)	3	269.24	269.24	89.75	2.42	0.165	24.24
Speed (RPM)	3	362.01	362.01	120.67	3.25	0.102	32.59
Composition (%)	3	256.43	256.43	85.48	2.30	0.177	23.09
Error	6	222.86	222.86	37.14			20.06
Total	15	1110.54					100

Table 2.7 Frictional Force for ANOVA table

Sources	DF	Seq. SS	Adj. SS	Adj.MS	F	P	Pr (%)
Load (Kg)	3	151.929	151.929	50.643	46.15	0.000	91.17
Speed (RPM)	3	1.869	1.869	0.623	0.57	0.656	1.12
Composition (%)	3	6.250	6.250	2.083	1.90	0.231	3.75
Error	6	6.584	6.584	1.097			3.95
Total	15	166.632					100

Conclusions

Within the scope of the present investigation the following results are drawn:

1. Al 6063 alloy and Al 6063 - TiO_2 composites are produced using Liquid metallurgy route and are found to be an effective and efficient method in getting the castings.
2. SEM micro photographs confirm a fairly uniform distribution of TiO_2 reinforcement.
3. TiO_2 when used as reinforcement have owed to an increase in the micro hardness (VHN) and Density of the composite.
4. Wear studies also confirms that addition of TiO_2 as reinforcement in Al 6063 alloy have improved the wear resistance.
5. Under identical test conditions if load and sliding velocity increases the wear rate also increases.
6. To obtain wear parameters the ANOVA and Taguchi tool successfully used with S/N ratio.
7. This there by confirms that the current composite developed can be effectively usable in improvement of hardness & wear resistance.

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