ANALYSIS OF TRIBOLOGICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITE FABRICATED BY STIR CASTING METHOD

A DISSERTATION

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IN

[**PRODUCTION ENGINEERING**]

Submitted by

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CANDIDATE'S DECLARATION

I FAIM KHAN, Roll No 2K17/PIE/05 students of M. Tech (Production Engineering), hereby declare that the project dissertation titled, **"ANALYSIS OF TRIBOLOGICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITE FABRICATED BY STIR CASTING METHOD"** which is submitted by me to the department of Mechanical Engineering ,Delhi Technological University ,Delhi in partial fulfillment of the requirements for the award of degree of **Master of Technology ,** is original and not copied from any source without proper citation . The work has not previously formed the basis for the award of Degree, Diploma Associateship, Fellowship or other similar title or recognition.

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CERTIFICATE

I hereby certify that the project Dissertation titled **"ANALYSIS OF TRIBOLOGICAL PROPERTIES OF ALUMINIUM METAL MATRIX COMPOSITE FABRICATED BY STIR CASTING METHOD"** which is submitted by Faim khan, Roll no 2K17/PIE/05, Mechanical Engineering Department, Delhi Technological university, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology, is a record of the project work carried out by the student under my supervision. To the best of my knowledge this work has not been submitted in part or full for any Degree or Diploma to this university or elsewhere.

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Date:

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ABSTRACT:

The composite material has been fabricated using mechanical stir casting method. For which Al6063 alloy was selected as a metal matrix and yttrium oxide (Y_2O_3) in 25 micrometer as a reinforcement powder and three sample of casting were made. One as casted, second with 2% reinforcement by (weight), and third with 4% reinforcement by (weight). The die used was of mild steel. And the parameter selected for this fabrication are melting temperature of alloy 900°C, melting time of alloy 90 min. stir rpm 200, stir time 15 min. preheating of reinforcement for 30 min. at 300°C in muffle furnace and then wear test and Micro-Hardness test were performed. Wear test was performed at three different load (20 N. 40 N, 60 N) first at 1 m/s sliding velocity and then at 2 m/s sliding velocity in the specimens (pin) of all three casting sample at a fix sliding distance of 2000 m. The time taken for wear test was 33.33 min. at 1 m/s sliding velocity and 16.66 min. at 2 m/s sliding velocity. Wear test was performed in dry condition at room temperature. The material of disc used for wear test is EN24 steel with hardness value of 58HRC. The result obtained of wear test shows that the casting sample with 4% yttrium oxide (Y_2O_3) at 1 m/s sliding velocity has good wear resistance and low wear rate and less weight loss in (gm.) after wear at all three load (20 N, 40 N, 60 N). and the result of Micro-Hardness test shows that the casting sample with 4% yttrium oxide (Y_2O_3) has more hardness value compare to as casted sample and sample with 2% yttrium oxide. For inspection of microstructure optical microscopy techniques was used.

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ABBREVIATIONS

SEM	Scaning electron microscopy
XRD	X ray diffraction
AA	Aluminium Alloy
MMC	Metal Matrix Composite
AMMC	Aluminium metal matrix composite
LLCCT	Liquid-Liquid compound casting technique
SCM	Stir casting method
SQCT	Stir-squeeze casting techniques
DSCT	Direct squeeze casting techniques
USSCP	Ultrasonic assisted stir casting process
USSC	Ultrasonic assisted stir casting
UTS	Ultimate tensile strength
USSCT	Ultrasonic assisted stir casting technique
USSCM	Ultrasonic assisted stir casting method
USCM	Ultrasonic squeeze casting method
SCCM	Semi-continuous casting method
MM	Metal matrix

CHAPTER-1

INTRODUCTION

1.1 Composite:

A composite is generally defined as a multiphase system that consists of two different groups of materials one is matrix and another is reinforcement which are chemically and physically distinct and separated by interfaces. [1]

The two materials produced a composite material of unique properties by mixing together properly.

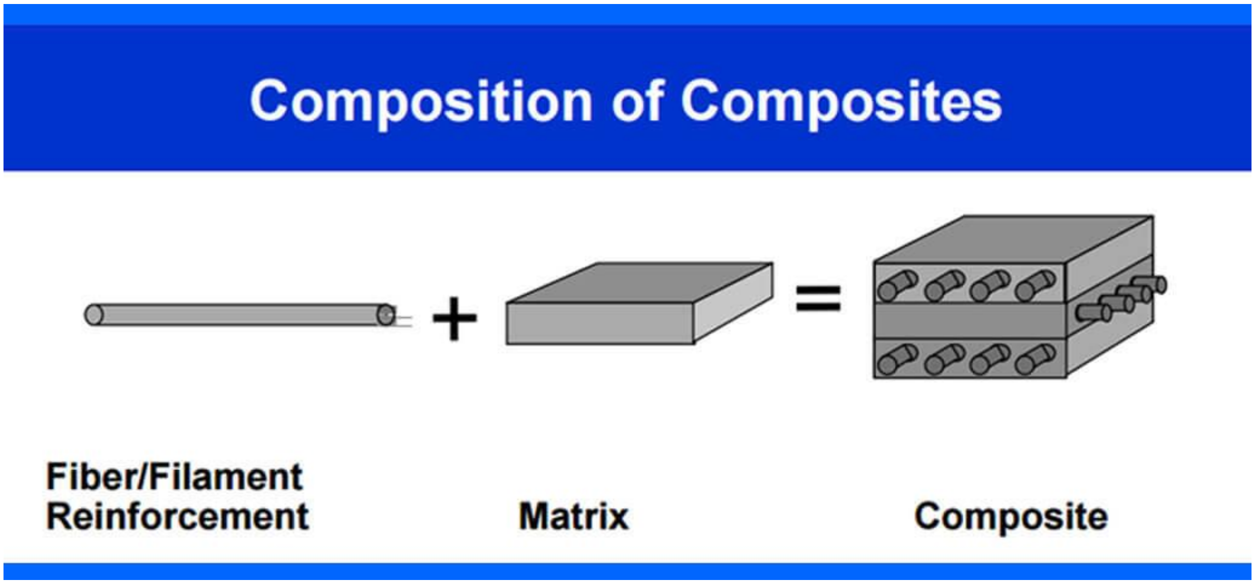

Figure 1.1 Formation of composite

1.2 Various kinds of composite materials:

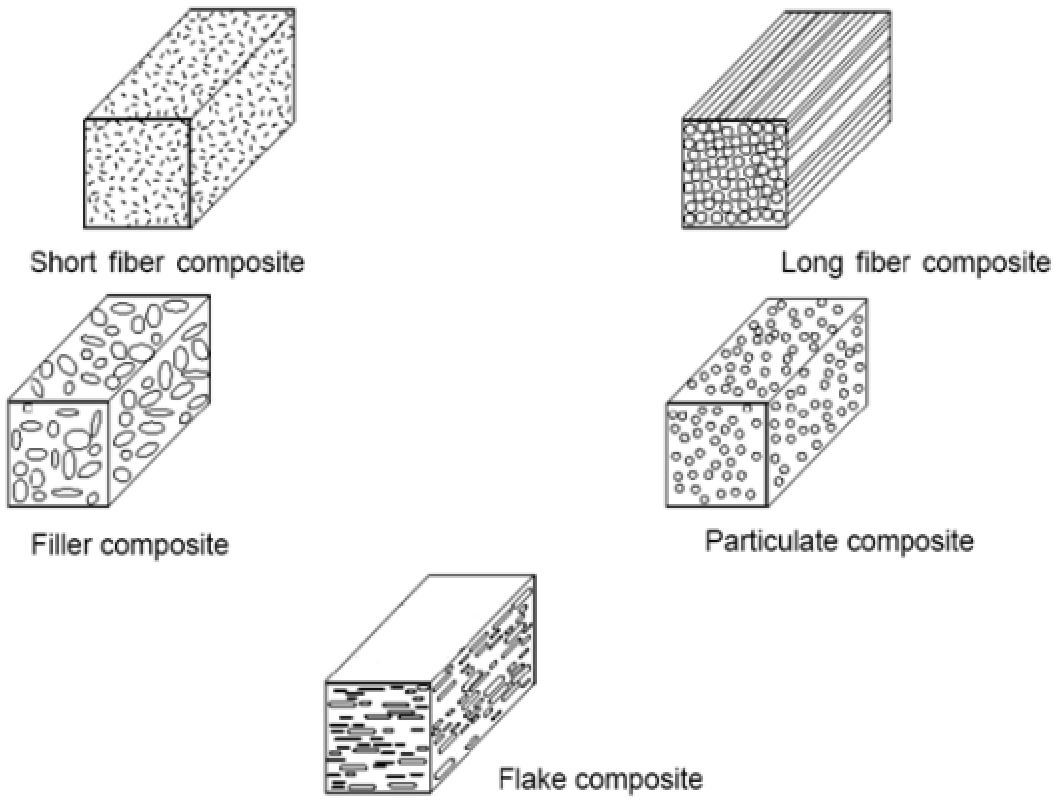

Figure 1.2 Various kinds of composite

1.2.1 Natural composites:

The bone in human body is also a composite. Collagen is also exit in finger nails and hair.

1.2.2 Early composites:

Composites have been making for many thousands of years by the people. Mud brick is very early example. “Because of having god compressive strength mud brick is very strong but oppon bending it breaks easily because mud brick have low tensile strength. Straw is very strong in case of streaching. Brick are made by mixing straw and mud together which have good resistant property against tearing and squeezing”.

Concrete is Another modern composite.

1.2.3 Modern examples:

The fiber glass was the first modern composite material. “It is widely used in many car bodies, building panels, sports equipment etc. in this composite the matrix is plastics and reinforcement is glass. The plastics matrix have two purpose here. It holds glass fibers and together together as well as it protects glass fibers from damage”.

1.3 Matrix:

Matrix is a basically monolithic and homogeneous materials in a fibers system of a composite is embedded. “Matrix is completely continuous. The matrix in to a solid provides a medium, together for binding and holding a reinforcement. Matrix also protects the reinforcement from any environmental and any mechanical damage. The primary functions of matrix are to transfer stress between reinforcement fibers. Matrix also provides finish, texture, color, functionality and durability”.

1.4 Types of matrix materials:

There are three types of matrix materials used in composite.

- Ceramic matrix
- Metal matrix
- Polymer matrix

My work is on metal matrix composite.

1.5 AMMC:

The demand of aluminum metal matrix composite has been increased because of their lightweight, energy saving, materials, in the transportation industries”.

Because of improved tribological and mechanical properties the composite materials of aluminium “metal matrix with discontinuous reinforcements has large application in automotive and aerospace industries. Because of enhanced tribological properties Aluminium Matrix Composites have importance in many application areas. Due to better resistance to wear properties it has large importance. [2]

I selected Al6063 alloy as a metal matrix”.

1.6 Al6063:

Al6063 is an aluminum alloy in which silicon and magnesium are mixed as a alloying elements. the mechanical properties of Al6063 alloy are good and these alloy also have good heat treatable properties and welding properties.

Al6063 alloy is the most common alloy which is used generally for extrusion of aluminum. "Very high complex shape product can be easily formed by using Al6063 alloy and these alloy also gives very smooth surface finish. Al6063 alloy can also be easily anodize hence because of this good anodizing properties of Al6063 alloy this is also much useful for the architectural applications such as sign frames, roofs, and window frames".

1.7 Reinforcements:

the reinforcement in a composite material increase the mechanical properties of the system. All different fibers have different properties hence affects the properties of composite in different ways.

1.8 Types of fibers (reinforcement):

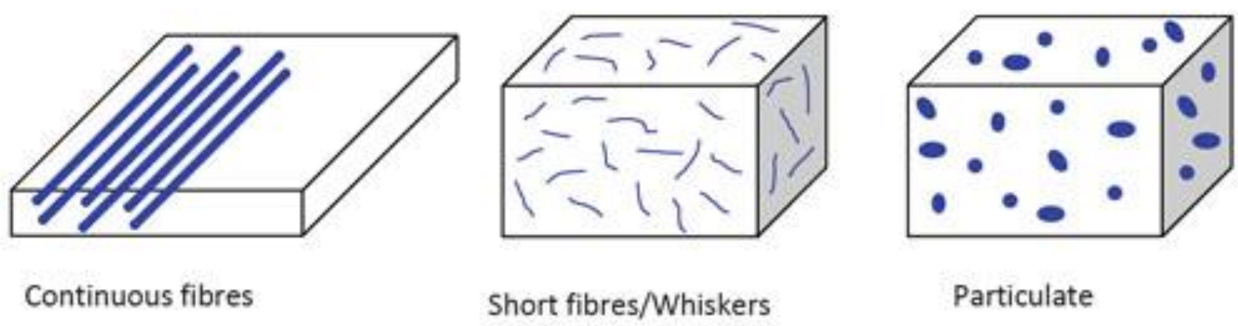

Figure 1.3 Different types of fibers

I selected yttrium oxide (Y2O3) as a reinforcement particles.

1.9 Yttrium oxide (Y_2O_3):

Yttrium oxide is a white solid and an air-stable substance. Yttrium oxide also knowns as yttria. The chemical formula of yttrium oxide is Y_2O_3. Yttrium oxide is used for both inorganic compounds and materials science as a common starting material.

The thermal conductivity of yttrium oxide is 27 W/(m·K).

yttrium oxide Y_2O_3 widely used in the field of materials science. It used in the picture tubes of television to imparting color.

Some of the other applications of yttrium oxide include additives in steel, non-ferrous alloys and iron.

1.10 Processing of (MMCS):

1.10.1 Stir casting method:

Stir casting is a method of fabrication of composite material in a liquid state. In this method a dispersd phase reinforcement (shorts fibers, ceramic particles) is mixed with the help of mechanical stirrer by stirring them at certain RPM in a molten metal matrix.

Stir casting is cost effective and the simplest method of fabrication of composite material in liquid state.

In stir casting method the amount of disprd phase reinforcement powder should not be more than 30% of volume. “In stir casting method the distribution reinforcement powder not perfactely homogeneous throughout in the matrix. During the mixing of reinforcement a local cloud are formed of the reinforcement in the liquid metals. Distribution of reinforcement powder in the metal matrix in liquid state may be improved if reinforcement powder is mixed in the metal matrix in semi solid condition. If semi solid matrix of metal has high viscosity then it help for the better mixing of reinforcement powder . the stir casting technology is cost effective and simple compare to other technology”.

CHAPTER-2

LITERATURE REVIEW

2.1 Past Study:

- Gang Chena, et al [3] in 2019 "study the composite material fabricated by ultrasonic assisted squeeze casting method of a wrought aluminum alloy" and the materials selected for this study are, Metal matrix- "2024 alloy" and the parameters used for this study are, Melting temperature-(730 °C), ultrasonic frequency-(20 kHz), power-(1.8 kW) and techniques used for analysis are, SEM and XRD And the result obtained are. that Al 2024 alloy part can be fabricated by the ultrasonic assisted squeeze casting method. with a good surface quality and complex shape at a increasing ultrasonic power. The microstructures of the composite produced by ultrasonic casting were refined clearly.
- Z.Y. Dou, at al, [4] in 2018 "study the compressive behavior of a beryllium-aluminum metal matrix composites fabricated by stir casting techniques" and the materials selected for this study are, Metal Matrix-(aluminum alloy), reinforcement material-(beryllium) and the parameters used for this study are, melting temperature in furnace-(650.8 C.) and techniques used for analysis are, Differential scanning Calorimetry (DSC) for the melting behavior and SEM for fracture surface of composites. And the result obtained are, The load bearing capacity and flowability of aluminum and the compatible plastic Deformation of the alloy is influence by The temperature. The work hardening and The And the peak stresses. Are influence by the strain rate.
- Zailiang Jiang, et al, [5] in 2018 "study the effect of LLCCT on the properties of properties of Mg/Al bimetal MMC. and the materials selected for this study are, Metal Matrix –(AZ91D magnesium alloy and A356 aluminum alloy) by using parameter like, preheating temperature of reinforcement-(300°C,), and techniques used for analysis are Extended depth-of field microscope for macroscopic characteristic and SEM for interfacial microstructures and EDS for chemical compositions at the interface, XRD for phase constitutions. And the result obtained are, that The inclusion of the Zn interlayer also controlled the generation of Mg-Al inter metallic.

- Jie Xia, Hui Jin et al [6] in 2018 Analysis the residual stresses and variation mechanism in dissimilar girth welded joints between tubular structures and steel castings fabricated by stir casting techniques.
- Wenming Jiang, et al, [7] in 2018 “study the Effect of CCT on aluminum/steel bimetal MMC. and the materials selected for this study are, Metal Matrix –(ZL114A aluminum alloy) and the parameters used for this study are, preheating temperature of reinforcement-(300 °C,), time of preheating-(5 min), melting temperature in furnace-(740℃.), and techniques used for analysis are, SEM for the micrographs of the interface of the composites. And the result obtained are, that at interface there is no gaps defects can be notice
- Amir Pakdela, et al, [8] in 2018 “analysis the extrusion behavior, microstructural evolution, and mechanical properties of 6063 Al–B4C composites fabricated by semisolid stir casting In extrusion process” .for this study of composity they selected materials as like, Metal Matrix –(6063 aluminum alloy), reinforcement material-(boron carbide(B4C) and the parameters used for this study are, melting temperature in furnace-(950 K), stirred rpm-(600), stirred time-(5 min), reinforcement particles feed rate-(100 K/min), and techniques used for analysis are, Extensive electron microscopy for interdependency of microstructural evolution and tensile test mechanical properties And the result obtained are, that At higher temperatures large reduction in area achieved in composites fabricated by semisolid stir casting.
- Uppada et al [9] in 2018 “investigate the behavior of Al-Zn with(SiC) particles using SCM. and the materials selected for this study are, Metal Matrix –(Al-Zn alloy (A7075)), reinforcement material-(fly ash and SiC), by using parameter like, preheating temperature of reinforcement-(100◦C), time of preheating-(24 h), stirred rpm-(450), and techniques used for analysis are, Optical microscope, SEM, Electron back scattered diffraction(EBSD) and tensile test for microstructure and mechanical properties of prepared composites. And the result obtained are, that The hardness of metal matrix composites enlarge by adding the fly ash particles.
- K.N.P. Prasad, et al [10] in 2018 work on the LM6 and Al-fly ash MMC by using SSCT. ” and the materials selected for this study are, Metal Matrix –(LM6 aluminum alloy), reinforcement material-(fly ash), carbide(B4C) and the parameters used for this study

are, preheating temperature of reinforcement-(300°C), melting temperature in furnace-(800oC), stirred rpm-(200 to 400 RPM), reinforcement particles feed rate-(300 to 400 gms/min), and techniques used for analysis are, SEM for distribution of fly ash particles And the result obtained are, that The obtained Composites which is fabricated by squeeze casting Method has superior wear resistance compare to that of the base alloy.

- G.N.Lokesh, et al. [11] in 2018. "Study the Mechanical and dry sliding wear behavior of hot rolled hybrid Al-Cu/fly ash/SiC MMC with SiC and fly ash by using DSCT. and the materials selected for this study are, Metal Matrix –(Al–4.5Cu alloy), reinforcement material-(fly ash, SiC), by using parameter like, melting temperature in furnace-(750ºC), stirred rpm-(400), and techniques used for analysis are, SEM for percentage of particulate on the wear behavior of the MMCs. And the result obtained are, that The composites fabricated by direct squeeze casting method reveals upgraded hardness and tensile strength and at for higher percentage of reinforcement with increase in pull out of rolling the Wear resistance is superior. At higher depletion during rolling produce shrinkage cavities and particle cracking in case of Higher weight percentage of reinforcement mixed in base metal.
- V. Mohanavel, et al, [12] in 2018. Study the Mechanical and tribological characteristics of Al- SiC MMC with SiC for this study of composity they selected matterialsals as like, Metal Matrix –(Al6351 aluminum alloy), reinforcement material-(SiC), and the parameters used for this study are, preheating temperature of reinforcement-(500oC), melting temperature in furnace-(800oC), and techniques used for analysis are, SEM for microstructure of manufactured composite and the plain alloy. And the result obtained are, that "By increasing the SiC particles The hardness of composites increase.
- Ashok Kumar. et al, [13] in 2018. "Investigations of Mechanical and Tribological Properties of Extruded AA A356 – AL2O3 MMC with AL2O3 by using SCM. and the materials selected for this study are, Metal Matrix –(Aluminum A356),reinforcement material- (AL2O3), and the parameters used for this study are, stirred rpm-(2000) and techniques used for analysis are, SEM for the image of composite material.
- C.Magaacibhi, et al, [14] in 2018. "Study of Mechanical and Adhesive Wear properties of Al LM25/TiC by using ASCM. and the materials selected for this study are, Metal Matrix –(LM25 alloy), reinforcement material-(TiC), by using parameter like,

preheating temperature of reinforcement-(350ºC), time of preheating-(25 minutes), melting temperature in furnace-(700°C), stirred rpm-(310), stirred time-(10 minutes), squeeze pressure-(125 Mpa). And techniques used for analysis are, SEM for Worn surfaces of metal matrix composites. And the result obtained are, that The results Shows that by increasing the applied load the wear rate increases.

- P. Vijaya Kumar Raju et al [15] in 2018 . "To investigate Tribological behavior of an Al-Cu with Cu powder by using SCM. and the materials selected for this study are, Metal Matrix –(Al- Cu alloy and Al–Cu alloy), reinforcement material-(Cu powder), and the parameters used for this study are, preheating temperature of reinforcement-(2000C), time of preheating-(30 minutes), melting temperature in furnace-(7500C), stirred rpm-(200), stirred time-(5 to 10 minutes), and techniques used for analysis are, SEM and EDAX formorphology changes in composites.
- V. Mohanavel, et al, [16] in 2018 "Study the mechanical properties of graphite particulates reinforce As a mass fraction, with aluminum matrix based composite fabricated by stir casting technique" and the materials selected for this study are, Metal Matrix –(aluminum alloy 6351.), reinforcement material-(graphite (Gr)) by using parameter like, preheating temperature of reinforcement-(500oC), melting temperature in furnace-(850oC), stirred rpm-(400rpm), stirred time-(30minutes),), and techniques used for analysis are, SEM for microstructures of the composites And the result obtained are, that By increasing the the mass fraction of graphite particle the mechanical properties of the composite decrease.
- K.N.P. Prasad, et al, [17] in 2018 "study the influence of LM6 Al-fly ash effect by using SCM. and the materials selected for this study are, Metal Matrix –(LM6 Al alloy), reinforcement material-(fly ash), by using parameter like, preheating temperature of reinforcement-(300°C), melting temperature in furnace-(800oC), stirred rpm-(600), reinforcement particles feed rate-(300 to 400 gms/min), and techniques used for analysis are, SEM for distribution of fly ash particles And the result obtained are, that very much superior wear resistance achieved of the composites fabricated by squeeze casting Method compare to the base alloy.
- P. Vijay Kumar Raju, et al, [18] in 2018, "study effect of Al–Cu alloy with Cu powder using SCM. for this study of composity they selected materials as like, Metal Matrix –(

Al–Cu alloy and Al–Cu alloy), reinforcement material-(Cu powder), and the parameters used for this study are, preheating temperature of reinforcement-(200°C), melting temperature in furnace-(670°C to 850°C), homogenized temperature-(100°C), time of homogenized-(24 h), And the result obtained are stresses increases and less compressive As compared to both the alloys.

- B. Ramgopal Reddy, et al, [19] in 2018. "Study the fabrication and the characterization of 6082 Aluminum matrix hybrid composites fabricated by Stir casting method with Silicon Carbide (SiC) and Fly Ash in equal Proportions both as a reinforcements" .for this study of composite they selected materials as like, Metal Matrix –(Al6082), reinforcement material-(Silicon Carbide and Fly Ash), and the parameters used for this study are, melting temperature in furnace-(750 ºC,), stirred rpm-(600), stirred time-(15 minutes), and techniques used for analysis are, SEM for microstructural characteristics of composites. And the result obtained are, that By increasing the weight fraction of SiC and Fly Ash AMMC shows good improvement in UTS.
- Rajesh Purohit et al [20] in 2018 Study of tribological properties of Al-Al2O3 nano composites fabricated using UASCP. and the materials selected for this study are, Metal matrix-(Al6061), reinforcement-(nanoAl2O3) and the parameters used for this study are, Melting temperature-(700°C), stir rpm-(150 rpm), stir time-(15 minutes.), ultrasonic probe time-(30 second) and author found result that The wear resistance of the composite is much more than that of the matrix alloy and got larger with increasing Al2O3 particle content.
- R. Raghu, et al, [21] in 2018 "study the mechanical properties of composite material of MgAl2O4 particles and Al-Mg alloy produced by ultrasonic casting method" and the materials selected for this study are, Metal matrix-(Al-4Mg alloy), reinforcement-(MgAl2O4 particles) and the parameters used for this study are, Melting temperature-(750 °C), power-(1.6 kW). and techniques used for analysis are, SEM and EDS for synthesized composites. And the result obtained are, that the grain refinement of composite enhance by the reaction of H3BO3 which resulte increase in the density of MgAl2O4 particles.
- Shulin Lü, et al [22] in (2018) "investigate the effect of AMMC with nano-SiCp using ASCM. For this fabrication of composite they selected materials as like, Metal matrix-(

A356 alloy), reinforcement-(nano SiC particles) and the parameters used for this study are, Melting temperature-(720◦C), stir rpm-(240 rpm to 300 rpm), stir time-(20 min), ultrasonic probe time-(), ultrasonic frequency-(20 kHz), ultrasonic power-(1.8 kW), squeeze pressure-(200 Mpa), pressure time-(30 s) and techniques used for analysis are SEM for Microstructure of composite granules, XRD and EDS for composite granules And the result obtained are, that the nano-SiC particles are uniformly distributed in the nano-SiCp/Al composite granules, this shown in results.

- Jayakrishnan Nampoothiri, et al [23] in (2018) investigate the effect of Sr modified A356 Al alloy on mechanical properties using SCM. and the materials selected for this study are, Metal matrix-(A356 Al alloy), reinforcement-(strontium (Sr)) by using parameter like, Melting temperature-(720 °C.), stir rpm-(), stir time-(), ultrasonic probe time-(), ultrasonic frequency-(20.1 kHz), mould pre-heated temperature-(300 °C.), ultrasonic power-(1.75 kW,) and techniques used for analysis are, SEM for microstructural and fractography And the result obtained are, that the length of eutectic Si decrease from 15.6 μm to 0.65 μm by the inclusion of Sr in trace amount (500 ppm) to A356 alloy and porosity increase from 0.84% to 3.59%.
- Y. Pazhouhanfar, et al, [24] in 6 November 2017 study of TiB2 with Al6061 MMC on mechanical properties using SCM. and the materials selected for this study are, Metal Matrix –(Al6061 alloy), reinforcement material-(TiB2) by using parameter like, preheating temperature of reinforcement-(250 °C), time of preheating-(2 h), melting temperature in furnace-(700 °C), stirred rpm-(350), stirred time-(15 min), weight fraction of reinforcement-(3, 6 and 9 wt.%)), and techniques used for analysis are SEM. And the result obtained are, that by increasing TiB2 UTS was upgraded.
- N. V. Murthy, et al [25] in (2017) "study the Al 2219 AA using UASCT. and the materials selected for this study are, Metal matrix-(Al 2219), reinforcement-(Nano particles Al2O3) and the parameters used for this study are, Melting temperature-(760°C.), stir rpm-(600 rpm.), stir time-(15 minutes), ultrasonic probe time-(15 to 9 minutes), ultrasonic frequency-(20Khz), mould pre-heated temperature-(780°C) and techniques used for analysis are, XRD for the phases of the particles, and author found result that UTS of AA 2219 alloy increased than the base alloy. and grain boundary area. also increased because of the grain refinement and degasification.

- Yang ZHANG, et al [26] in (2016) study the consequence of applied pressure on Al−Cu alloy using SCM. and the materials selected for this study are, Metal matrix-(Al−Cu alloy), and the parameters used for this study are, Melting temperature-(983 K.), stir rpm-(), stir time-(), ultrasonic probe time-(), ultrasonic frequency-(20 kHz), ultrasonic power-(1 kW), squeeze pressure-(50 Mpa) and techniques used for analysis are, SEM and EDX for average compositions of the phases. And author found result that the homogeneous distribution of α(Al) and θ(Al2Cu) refined microstructures, enhance microhardness can be obtained when squeeze pressure or power ultrasonic is applied individually. Compared with the conventional casting.
- Dinesh Kumar Kolia, et al [27] in (2015) Investigate the consequence of UASCM on properties of Al6061 AA with Al2O3. and the materials selected for this study are, Metal matrix-(Al6061), reinforcement-(nano Al2O3) and the parameters used for this study are, Melting temperature-(760 °C,), stir rpm-(), stir time-(10-15 minutes), ultrasonic probe time-(), ultrasonic frequency-(20.20 Khz), horn temperature-(600-8000C.) and author found result that The result shown That the mechanical properties were enlarged using UASCM.
- Mayuresh singh, et al [28] in (2015) prepare the MMC with 6061 Al AA and Al2O3 by using SCM. For this fabrication of composity they selected materials as like, Metal matrix-(Al 6061), reinforcement-(nano Al2O3) by using parameter like, Melting temperature-(800°C), stir rpm-(80 to 900 rpm), stir time-(10 min.), ultrasonic probe time-(), ultrasonic frequency-(20.40 KHz), Preheating temperature of reinforcement-(300°C) And the result obtained are, that the by using SCM mechanical properties increased.
- Dinesh Kumar Kolia, et al [29] in (2015) Study the effect of UASCM on Al6061-nano with Al2O3 MMC. and the materials selected for this study are, Metal matrix-(Al6061aluminium alloy), reinforcement-(Nano Al2O) using the parameter like, Melting temperature-(760°C), stir rpm-(), stir time-(2-3 minutes), ultrasonic probe time-(), ultrasonic frequency-(20.20 KHz), power-(1200 Watt) and author found result that the results shows that the properties increased with UASCM by adding Al2O3.
- Shulin Lü, et al [30] in (2012) investigate the effect of USCM on A356 AA. and the materials selected for this study are, Metal matrix-(A356 Al alloy), using the parameter,

Melting temperature-(720–730 ◦C,), stir rpm-(), stir time-(), ultrasonic probe time-(), ultrasonic frequency-(20 kHz), ultrasonic power-(2.6 kW),), mould pre-heated temperature-(570 ◦C), squeeze pressure-(25 to 100 Mpa), die preheating temperature-(300 ◦C) . an author found result that The results show that the properties of MMC upgraded using USCM.

- ZHANG Zhi-qiang, et al [31] in (2010) "analysis of consequence of SCCM on AZ80 Mg alloy. and the parameters used for this study are, Melting temperature-(650 °C,), stir rpm-(), stir time-(), ultrasonic probe time-(), ultrasonic frequency-(18 to 20 kHz), Ultrasonic power-(0 to 2 kW) and techniques used for analysis are, stereoscopic microscope and optimal microscope for center region of billets.
- R divakar et al [32] in 2010 "Fabricate and test the properties of AMMC Al with Graphene and Y2O3. and the materials selected for this study are, Metal matrix -(Al-Mg alloy), reinforcement-(Graphene and Yttrium Oxide Y2O3). and the parameters used for this study are, Furnace temperature-(6000C), heating time-(1 h), stir time-(15 min), Mold preheating temperature-(2000C) and techniques used for analysis are SEM for micro structure and the result obtained are, that the UTS of alloy increased by the addition of Gr and Y2O3.

CHAPTER-3

EXPERIMENTAL PROCEDUREM

3.1 Materials:

To fabricated composite material using mechanical stir casting method Al6063 has been selected as a metal matrix and yttrium oxide (Y_2O_3) in 25 micrometer as a reinforcement powder .

3.1.1 Aluminium 6063:

Al6063 is an aluminum alloy in which silicon and magnesium are mixed as a alloying elements the mechanical properties of Al6063 alloy are good and these alloy also have good heat treatable properties and welding properties.

Al6063 alloy is the most common alloy which is used generally for extrusion of aluminum. very complex shape product can be easily formed by using Al6063 alloy and these alloy also gives very smooth surface finish. Al6063 alloy can also be easily anodize hence because of this good anodizing properties the alloy also much useful for the architectural applications such as sign frames, roofs, and window frames.

3.1.1.1 composition of Al6063 alloy:

Silicon	0.2% to 0.6% by weight
Iron	up to 0.35% by weight
Copper	up to 0.10%. by weight
Manganese	maximum 0.10%. by weight
Magnesium	0.45%, to 0.9%. by weight
Chromium	up to 0.10% by weight
Zinc	maximum 0.10% . by weight
Titanium	up to 0.10% by weight

Remainder is Aluminum.

3.1.1.2 Application of Al6063:

Al6063 generally gives good anodizing properties hence because of this properties these alloy generally used for architectural application such as pipe and tubing, and aluminium, furniture, window and door frames.

3.1.2 Yttrium oxide:

Yttrium oxide is a white solid and an air-stable substance. Yttrium oxide also known as yttria. The chemical formula of yttrium oxide is Y2O3. Yttrium oxide is used for both inorganic compounds and materials science as a common starting material.

3.1.2.1 Properties of yttrium oxide:

Chemical formula	Y2O3
Appearance	White solid
Molar mass	225.81 g/mol
Melting point	2,425 °C (4,397 °F; 2,698 K
Boiling point	4,300 °C (7,770 °F; 4,570 K)
Density	5.010 g/cm3, solid
Solubility in alcohol acid	soluble
Solubility in water	insoluble

3.1.2.2 application of yttrium oxide:

- Given below are some of the chief applications of yttrium oxide nanoparticles.
- Yttrium oxide Y2O3 widely used in the field of materials science. It used in the picture tubes of television to imparting colour.
- Yttrium oxide also used in the synthesis of inorganic compounds, the red light emission property of yttrium oxide is used to making fluorescent lamps.

- Yttrium oxide Y2O3 also used to protect against UV degradation in high-temperature applications, paints and plastics as a additives for the coating.
- Yttrium oxide is used in g-ray and x-rays In ultrafast sensors.

3.2 Procedure:

3.2.1 Process parameters:

Based on the literature review the following parameters were selected.

The parameters selected in mechanical stir casting method are.

- Melting temperature 900°C
- Melting time of alloy 90 min.
- Stir rpm 200
- Stir time 15 min.
- Preheating temperature of reinforcement 300°C
- Time for preheating 30 min.

First solid (Al6063) alloy was kept inside the furnace of stir casting machine for melting purpose And then furnace temperature was set at 900°C for melting and time for melting was selected 90 min. at 900°C. Simultaneously yttrium oxide (Y2O3) powder in 25 micrometer preheated at 300°C for 30 min. in muffle furnace. The cup used for preheating the reinforcement powder in which the reinforcement powder kept was of galvanizing iron sheet. And the shape of cup was square and this cup has been prepared in sheet metal shop.

After completing 90 min. of melting of Al6063 alloy the reinforcement powder poured into the liquid metal in the furnace and stirrer started at 200 stir rpm for mixing the yttrium oxide Y2O3 stir time selected was 15 min. after proper mixing of reinforcement powder this liquid mixture of Al6063 alloy and reinforcement powder poured in to the die and then casting is allow to cool in the die at room temperature for approx. 30 min. the die used was of permanent type and The die material selected was mild steel and after cooling the casting the casting removed from the die. The casting made were in cylindrical shape and the dimension of casting was 80 mm in diameters and approx. 60 mm length. after removing the casting from the die the machining process has been carried out on lathe machine to make surface of casting smooth and better in finishing. The turning and facing operation has been performed on the casting.

- Three casting sample has been made one as casted and second with 2% yttrium oxide (Y_2O_3) powder by weight and third with 4% yttrium oxide (Y_2O_3) powder by weight.

Table 3.1 Casting Sample composition:

Casting Sample	Al6063 Alloy (%)	Yttrium oxide (%)
Sample 1	100	0
Sample 2	98	2
Sample 3	96	4

- The procedure and parameteres used are same in casting sample with 2% yttrium oxide and 4% yttrium oxide. The difference is only quantity of yttrium oxide used.
- The parameter’s used in as casted casting are melting temperature 900°C and melting time 90 min. only and procedure was same.

Figure 3.1 Permanent die

Figure 3.2 Stir casting machine setup

3.3 Wear test:

Pin disc Wear test has been performed in the composite fabricated with Al6063 alloy as a metal matrix and yttrium oxide (Y2O3) reinforcement powder. For performing wear test, the cylindrical shape specimens (pin) with 10 mm diameter and 40 mm length were used as shown in Figure 3.3. This specimens were cut from all three casting sample by using wire EDM (electric discharge machining) process. Total number of pin used for wear test are 15. Six (6) pin were used from casting sample 3 and Six (6) pin from casting sample 2 and Three (3) pin were used from casting sample 1. For performing wear test disc also were made as shown in Figure 3.4. For disc EN24 steel material was selected. First disc were made on lathe machine and then drilling was carried out to make three holes at pitch circle diameter at equal distance between each hole. The hole was made for tightening the disc in the machine by using nut. After machining process and drilling process the heat treatment process has been carried out on disc to make it hard and the hardening achieve was 58 HRC. The dimension of disc were 100 mm in diameter and 8 mm in thickness. Wear test was performed at three different load 20N ,40N 60N with three different track diameter (40 mm, 50 mm. 60 mm) respectively and rpm were calculated according to diameter.

The sliding distance for wear test was selected 2000 m which kept fix in both case (1 m/s and 2 m/s) sliding velocity. The test was performed in dry condition and at room temperature that is temperature did not vary during the experiment.

The parameter selected for wear test are given in the table below.

Table 3.2 : parameters used in wear test at 1 m/s sliding velocity.

Sl no.	Load (N)	Sliding distance (m)	Speed (m/s)	Time (minute)	Track diameter (mm)	RPM
1.	20	2000	1	33.33	40	478
2.	40	2000	1	33.33	50	382
3.	60	2000	1	33.33	60	318

Tables 3.3 : parameters used in wear test at 2 m/s sliding velocity.

Sl no.	Load (N)	Sliding distance (m)	Speed (m/s)	Time (minute)	Track diameter (mm)	RPM
1.	20	2000	2	16.66	40	478
2.	40	2000	2	16.66	50	382
3.	60	2000	2	33.33	60	318

Wear test was performed at two different sliding velocity (1 m/s and 2 m/s).

First wear test was performed at 1 m/s sliding velocity in the specimens of all three casting sample At three different load 20 N ,40 N 60 N with three different track diameter (40 mm, 50 mm. 60 mm) respectively. Again wear test was performed at 2m/s sliding velocity in the specimens of all three casting sample At three different load 20 N ,40 N 60 N with three different track diameter (40 mm, 50 mm. 60 mm) respectively similarly like 1 m/s sliding velocity. sliding distance was kept fix that is 2000 meter in both case at 1 m/s and 2 m/s sliding velocity. Before performing wear test the weight of all specimen (pin) were measured in digital weighing machine and after performing wear test again weight was measured of all specimen (pin) for calculating loss in weight. The time taken for wear test was 33.33 min at sliding velocity 1 m/s and 16.66 min at sliding velocity 2 m/s. which were kept fix at all three load. And these time were calculated with the help of sliding velocity and sliding distance In both case that is at 1 m/s sliding velocity and at 2 m/s sliding velocity.

Wear rate calculation:

Wear rate has been calculated by subtracting initial wear from the wear at 2000 m and than dividing these value by time (by 33.33 min. at 1 m/s sliding velocity and by 16.66 min. at 2 m/s sliding velocity).

Let

w1 = initial wear in (μm)

w2 = wear at 2000 m, in (μm)

W = wear rate in (μm/min.)

T -= time in (min.)

Than Wear rate $W = \frac{w2-w1}{T}$

Figure 3.3 Wear test pins (specimen)

Figure 3.4 Wear test disc

Figure 3.5 Pin on disc tribometer

Figure 3.6 High temperature rotary tribometer

3.4 Micro-Hardness test:

Hardness test has been performed on the micro hardness testing machine. Which consist an optical microscope and diamond indenter of pyramid shape. For hardness test, first specimen of 10 mm diameter and 10 mm length in cylindrical shape were cut as shown in Figure 3.7 on wire EDM (electric discharge machine) from all three casting sample (casting sample 1, casting sample 2, casting sample 3).

Before performing hardness test first specimens were prepared, First of all cold mounting has been carried out in al specimen by using Bakelite material than polishing has been carried out using (180, 220, 320, 400, 600, 1000, 1500) no. grit emery paper to make opposite surface perfectly parallel as shown in Figure 3.8 than hardness test was performed. Hardness test was performed with the load of 500 gf for 20 second in the specimen of each casting sample. The diamond indenter was used to measure the hardness value and optical microscope was also used to check the image (indentation) produced by the indenter in the specimens and two diagonal D_1 and D_2 were used to measure the diagonal of indentation produced by pyramid shape diamond indenter for calculating the hardness value.

Figure 3.7 Hardness test specimens before mounting

Figure 3.8 Hardness test specimens after mounting

Figure 3.9 Micro hardness testing machine

3.5 Microstructure test:

Microstructure of casting sample's specimens has been analyzed on optical microscope tester with 100X, 200X, 500X and 1000X image resolution.

Before analysis of microstructure, the specimen were prepared from all three casting sample. First of all cold mounting has been carried out in all specimen as shown in Figure 3.10 by using Bakelite material than polishing has been carried using (180, 220, 320, 400, 600, 1000, 1500) no. grit emery paper in all specimen. after completing polishing again all specimen rubbed with alumina powder and water on polishing machine with a rotating wheel of 300 RPM Than specimens were dried and then etching has been carried out for 20 second in each specimen. Than microstructure has been analyzed.

Figure 3.10 Microstructure testing specimens

Figure 3.11 Optical microscope testing setup

Figure 3.12 Polishing machine

CHAPTER-4

RESULT AND DISCUSSIONS

4.1 Wear test:

4.1.1 Wear of casting samples 1 at 1 m/s sliding velocity:

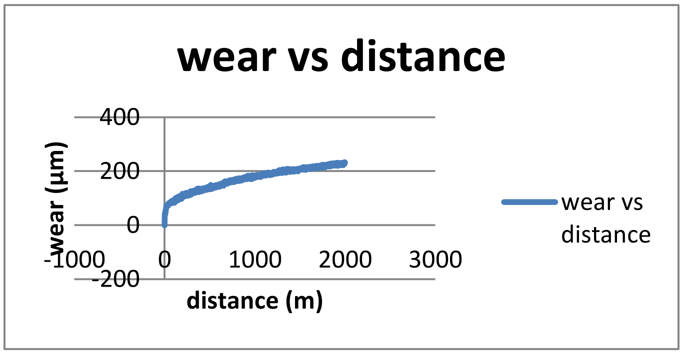

Figure 4.1.1 Wear at 20 N load

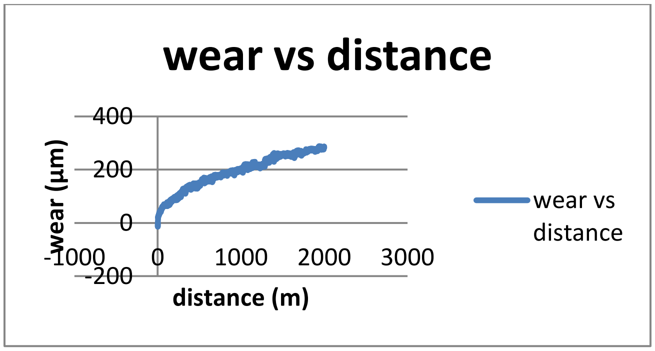

Figure 4.1.2 Wear at 40 N load

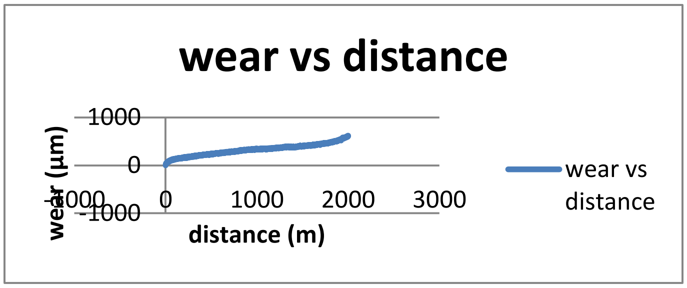

Figure 4.1.3 Wear at 60 N load

4.1.2 Wear of casting samples 1 at 2 m/s sliding velocity:

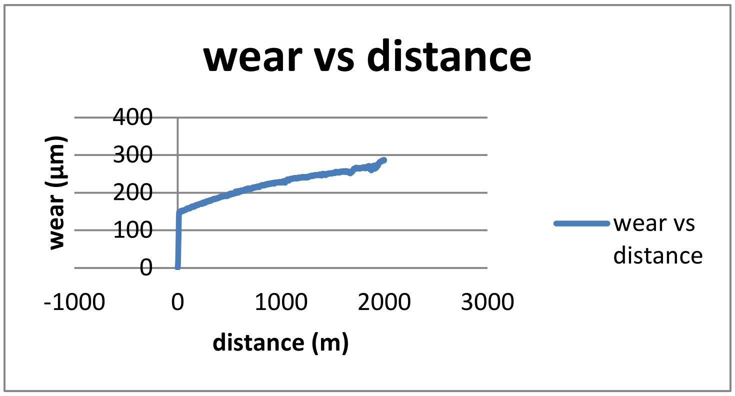

Figure 4.1.4 Wear at 20 N load

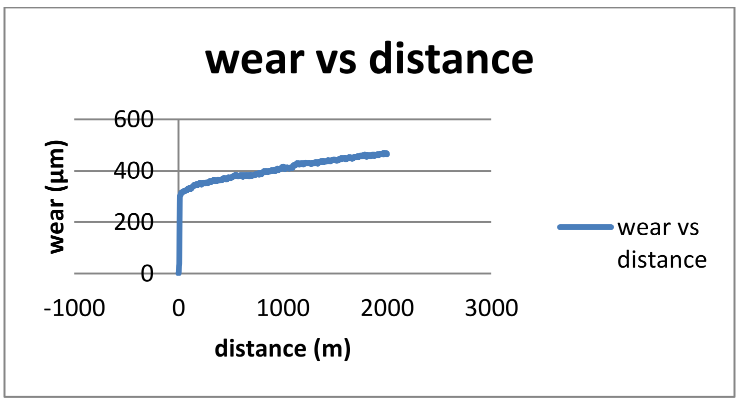

Figure 4.1.5 Wear at 40 N load

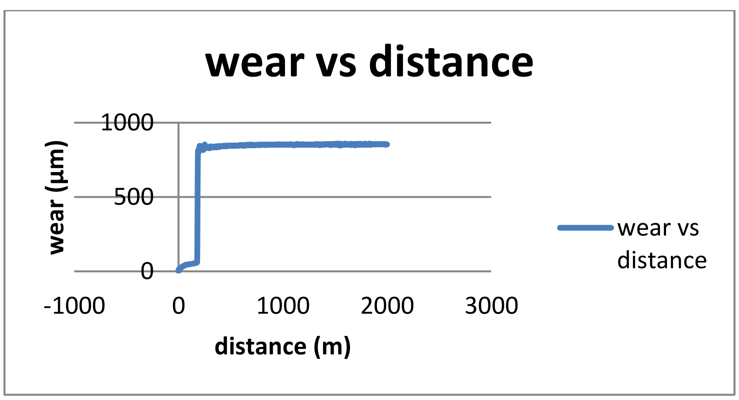

Figure 4.1.6 Wear at 60 N load

4.1.3 Wear of casting samples 2 at 1 m/s sliding velocity:

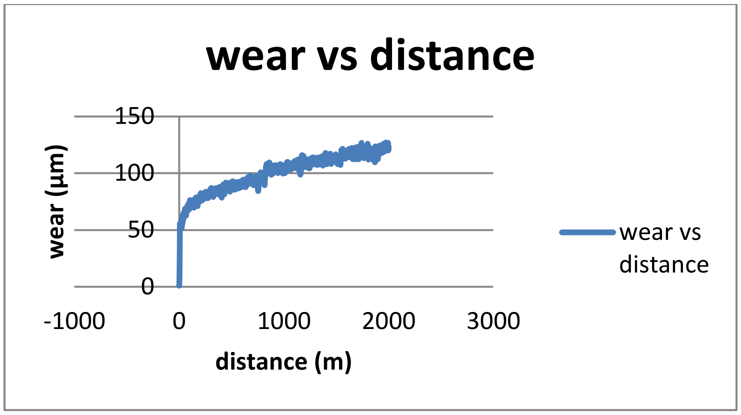

Figure 4.1.7 Wear at 20 N load

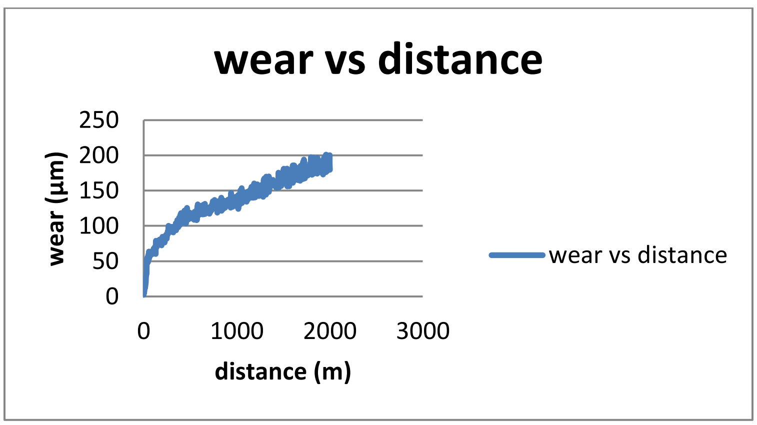

Figure 4.1.8 Wear at 40 N load

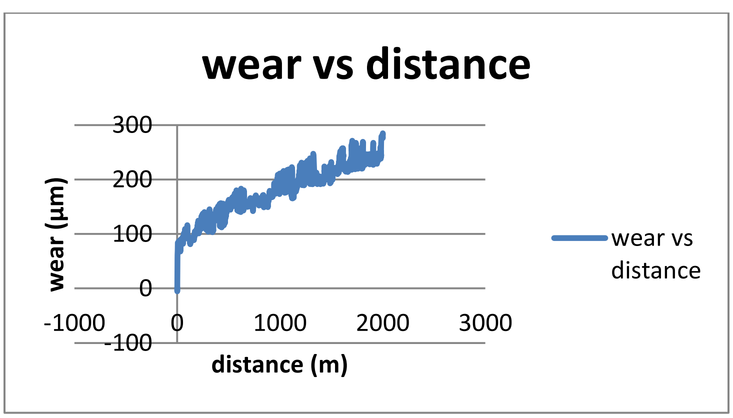

Figure 4.1.9 Wear at 60 N load

4.1.4 Wear of casting sample 2 at 2 m/s sliding velocity:

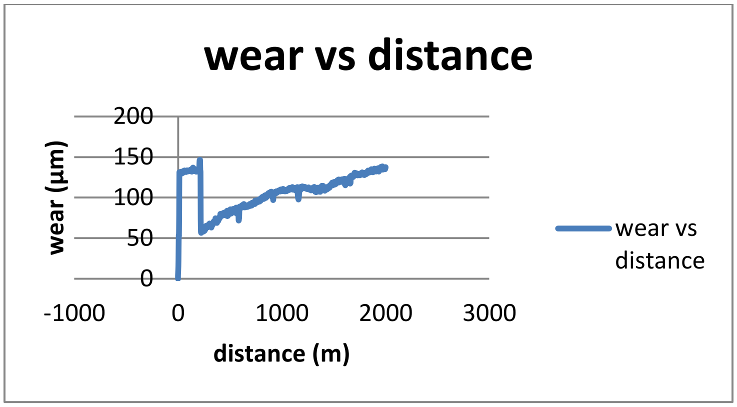

Figure 4.1.10 Wear at 20 N load

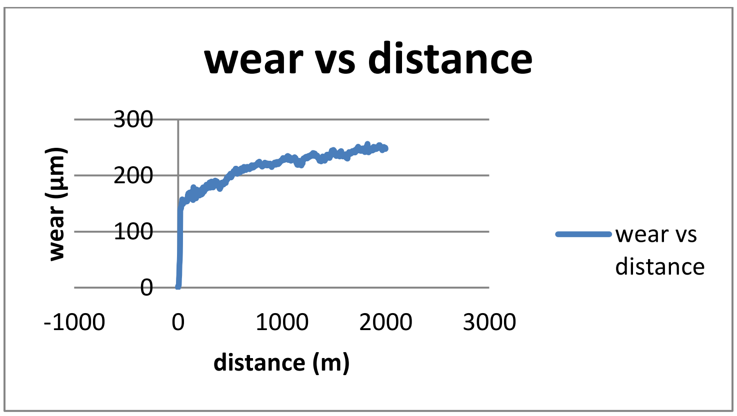

Figure 4.1.11 Wear at 40 N load

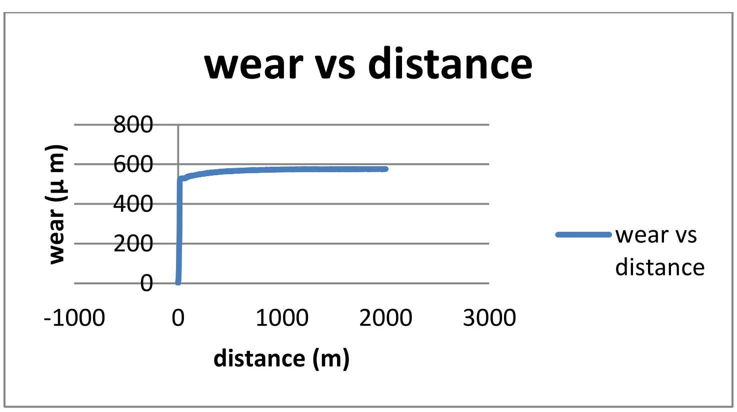

Figure 4.1.12 Wear at 60 N load

4.1.5 Wear of casting sample 3 at 1 m/s sliding velocity:

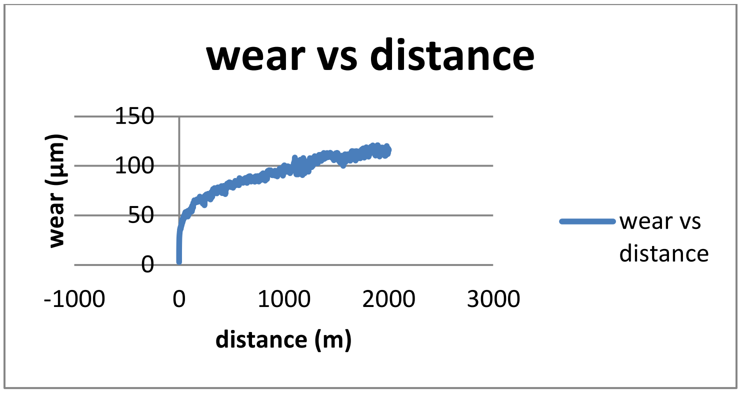

Figure 4.1.13 Wear at 20 N load

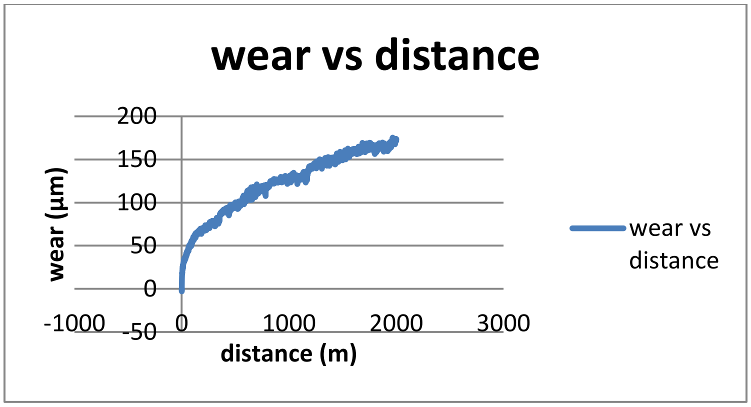

Figure 4.1.14 Wear at 40 N load

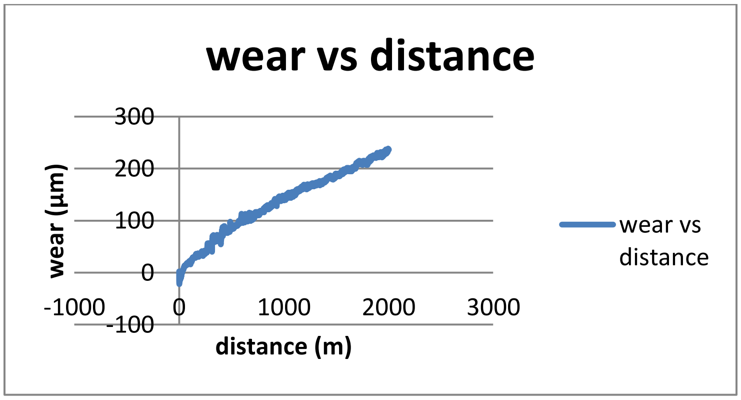

Figure 4.1.15 Wear at 60 N load

4.1.6 Wear of casting sample 3 at 2 m/s sliding velocity:

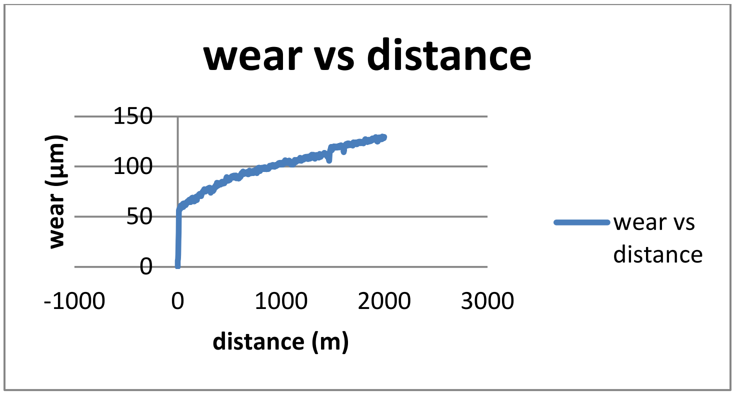

Figure 4.1.16 Wear at 20 N load

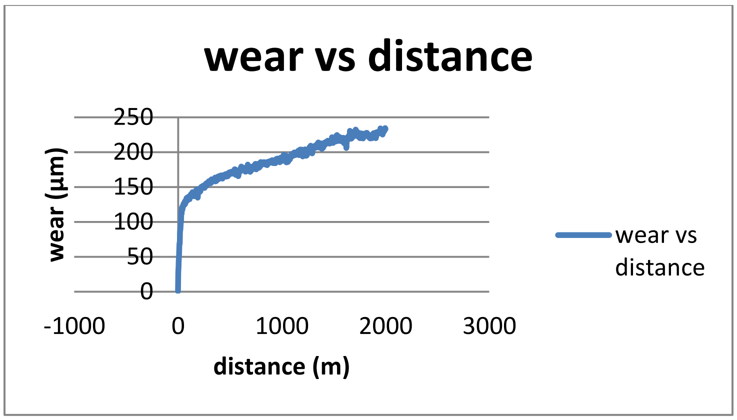

Figure 4.1.17 Wear at 40 N load

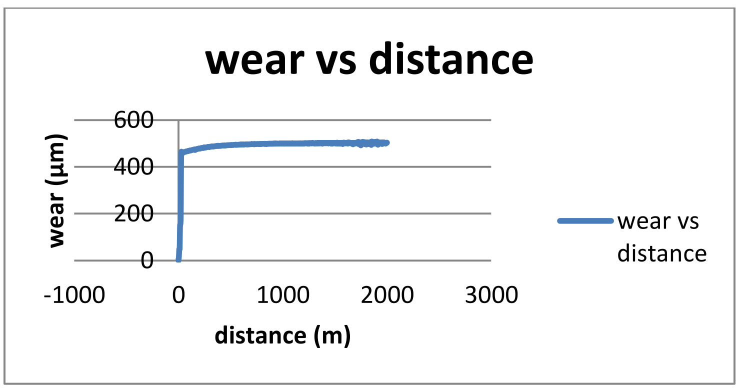

Figure 4.1.18 Wear at 60 N load

4.1.7 Measurement of weight loss:

Table 4.1 Weight loss of casting samples 1 at 1 m/s sliding velocity:

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 1	20 N	4.3588	4.3125	0.0463
Pin 2	40 N	4.3555	4.2990	0.0565
Pin 3	60 N	4.4083	4.2853	0.1230

Table 4.2 Weight loss of casting samples 1 at 2 m/s sliding velocity:

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 1	20 N	4.3125	4.2550	0.0575
Pin 2	40 N	4.2990	4.2063	0.0927
Pin 3	60 N	4.2853	4.1142	0.1705

Table 4.3 Weight loss of casting sample 2 at 1 m/s sliding velocity.

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 1	20 N	8.0512	8.0263	0.0249
Pin 2	40 N	8.0348	7.9990	0.0358
Pin 3	60 N	7.7673	7.7118	0.0555

Table 4.4 Weight loss of casting sample 2 at 2 m/s sliding velocity:

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 4	20 N	7.8921	7.8646	0.0275
Pin 5	40 N	8.0918	8.0424	0.0494
Pin 6	60 N	8.0449	7.9297	0.1152

Table 4.5 Weight loss of casting sample 3 at 1 m/s sliding velocity:

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 1	20 N	8.0922	8.0690	0.0232
Pin 2	40 N	8.1934	8.1588	0.0346
Pin 3	60 N	8.1230	8.0758	0.0472

Table 4.6 Weight loss of casting sample 3 at 2 m/s sliding velocity:

Pin No.	Load (N)	Weight before wear (gm.)	Weight after wear (gm.)	Weight loss (gm.)
Pin 4	20 N	8.1184	8.0925	0.0259
Pin 5	40 N	8.1446	8.0980	0.0466
Pin 6	60 N	8.1866	8.0860	0.1006

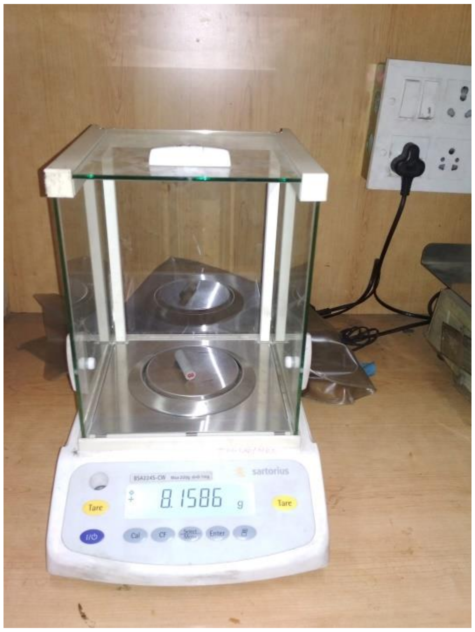

Figure 4.2 Weight measuring machine

4.1.8 Comparison of wear:

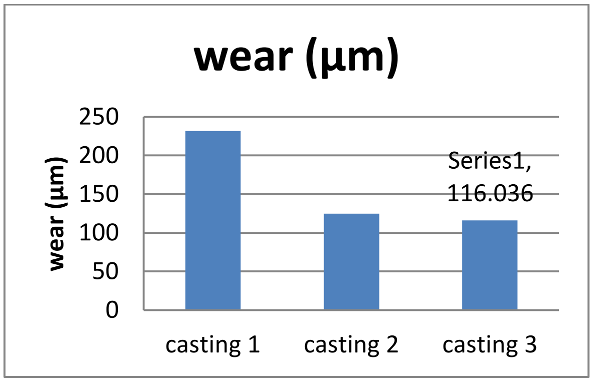

Fig. 4.1.3.1 wear at 1 m/s velocity and 20 N load

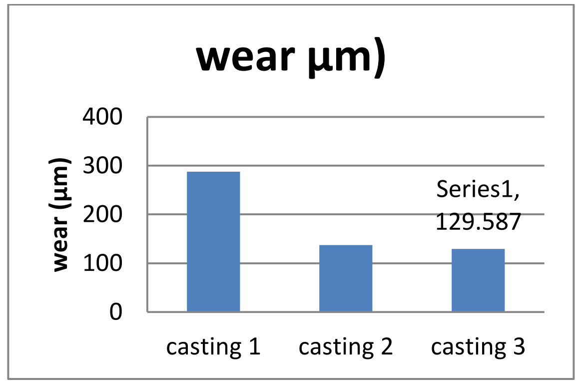

Fig. 4.1.3.4 wear at 2 m/s velocity and 20 N load

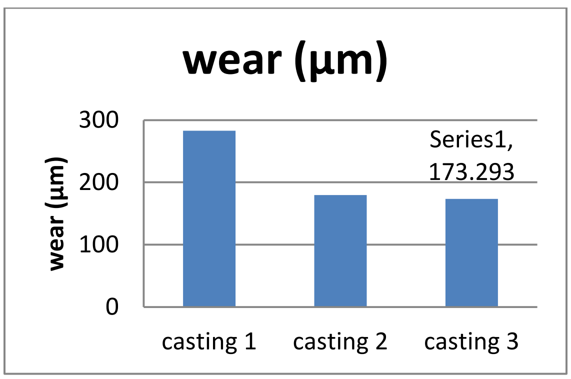

Fig. 4.1.3.2 wear at 1 m/s velocity and 40 N load

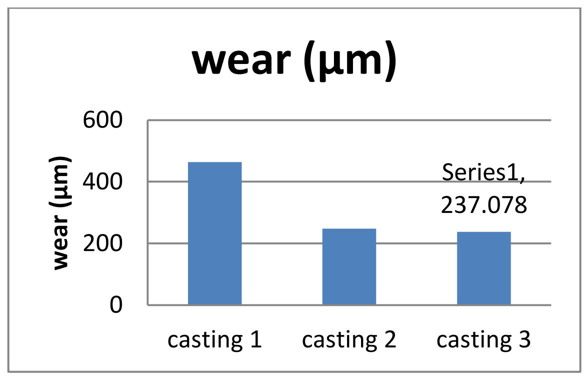

Fig. 4.1.3.5 wear at 2 m/s velocity and 40 N load

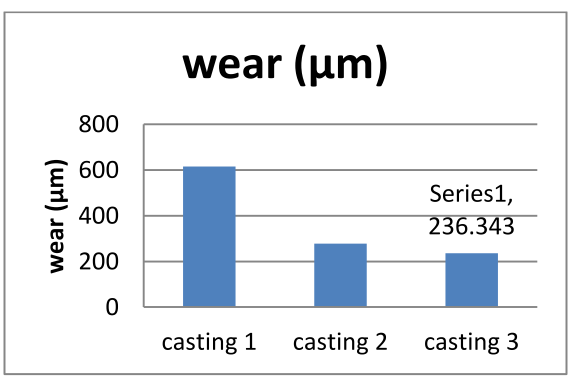

Fig. 4.1.3.3 wear at 1 m/s velocity and 60 N load

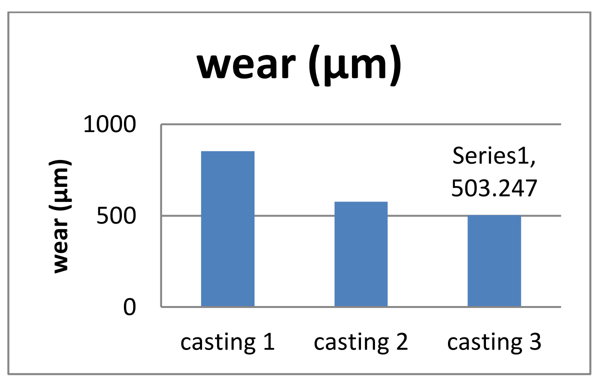

Fig. 4.1.3.6 wear at 2 m/s velocity and 60 N load

4.1.9 Calculation of wear rate:

Table 4.7 Wear rate of casting samples 1 at 1 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (μm/min.)
Pin 1	20	6.9337
Pin 2	40	8.4709
Pin 3	60	18.4489

Table 4.8 Wear rate of casting samples 2 at 1 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (μm/min.)
Pin 1	20	3.740
Pin 2	40	5.3167
Pin 3	60	8.3391

Table 4.9 Wear rate of casting samples 3 at 1 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (μm/min.)
Pin 1	20	3.385
Pin 2	40	5.1901
Pin 3	60	7.0198

Table 4.10 Wear rate of casting samples 1 at 2 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (μm/min.)
Pin 1	20	17.2670
Pin 2	40	27.8410
Pin 3	60	51.1831

Table 4.11 Wear rate of casting samples 2 at 2 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (μm/min.)
Pin 4	20	8.1928
Pin 5	40	14.8465
Pin 6	60	34.5805

Table 4.12 Wear rate of casting samples 3 at 2 m/s sliding velocity:

Pin no.	Load (N)	Wear rate (µm/min.)
Pin 4	20	7.7779
Pin 5	40	14.1896
Pin 6	60	30.20624

4.1.10 Comparison of wear rate:

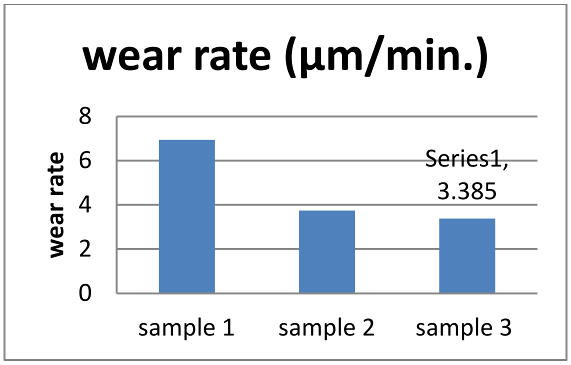

Fig. 4.1.5.1 wear rate at 1 ma/s velocity and 20 N load

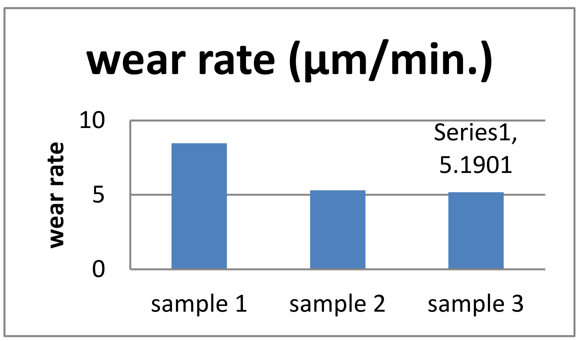

Fig. 4.1.5.2 wear rate at 1 m/s velocity and 40 N load

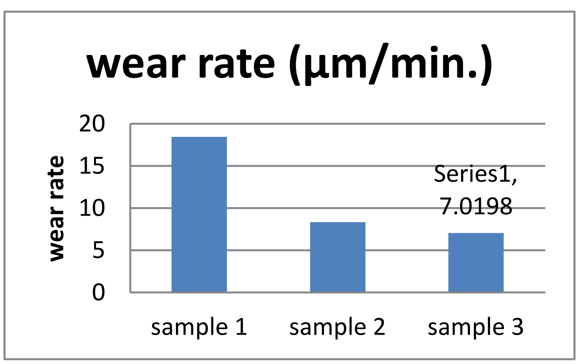

Fig. 4.1.5.3 wear rate at 1 m/s velocity and 60 N load

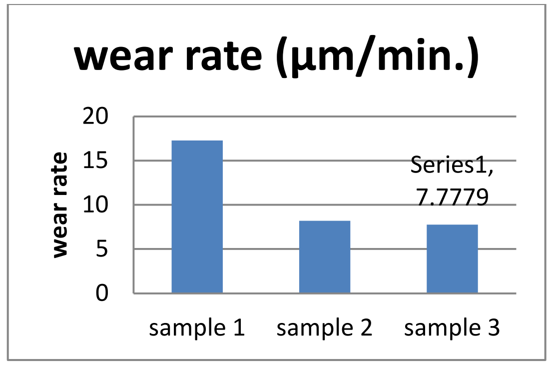

Fig. 4.1.5.4 wear rate at 2 m/s velocity and 20 N load

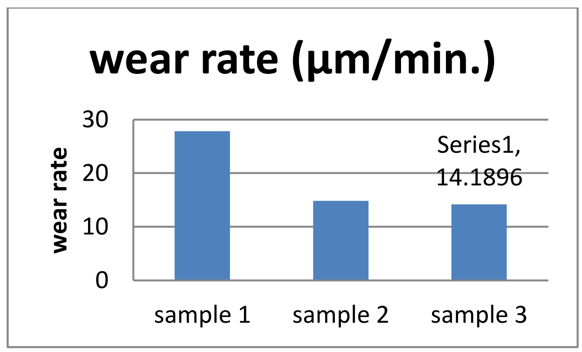

Fig. 4.1.5.5 wear rate at 2 m/s velocity and 40 N load

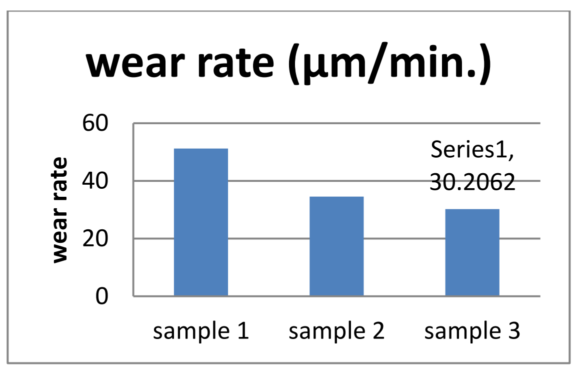

Fig. 4.1.5.6 wear rate at 2 m/s velocity and 60 N load

- The result of pin disc wear test shows that wear resistance increased by increasing the yttrium oxide (Y2O3) reinforcement powder.
- The samples of two casting, sample with 2% yttrium oxide (Y2O3) and 4% yttrium oxide (Y2O3) shows better wear resistance compare to as casted sample at both sliding velocity.
- The graph also shows that wear rate increased by increasing the sliding velocity. Hence at 2 m/s sliding velocity wear rate is more in all three casting sample compare to 1 m/s sliding velocity.
- The casting sample with 4% yttrium oxide (Y2O3) at 1 m/s sliding velocity shows much better wear resistance at all three load (20N, 40N, 60N). And the wear rate is also less in casting sample with 4% yttrium oxide.
- The total wear is less in casting with 4 % yttrium oxide (Y2O3) at 1 m/s sliding velocity at all three different load compare to other casting.
- The loss in weight after wear is less in the casting sample with 4% yttrium oxide (Y2O3) at 1 m/s sliding velocity.

4.2 Micro-Hardness test:

- Experimental result shows that the hardness of casting sample increased by increasing the yttrium oxide (Y2O3) reinforcement powder compare to as casted casting.
- The casting sample with 4% yttrium oxide (Y2O3) has more hardness value compare to other two casting sample.
- The hardness value of casting sample with 4% yttrium oxide (Y2O3) is (67 HV). And the hardness value of other two sample (sample 1 and sample 2) are (62, 64) Respectively.

Table 4.13 Micro-hardness test:

Casting sample	Hardness value (HV)
Sample 1	62
Sample 2	65
Sample 3	67

4.3 Microstructure:

4.3.1 Al6063

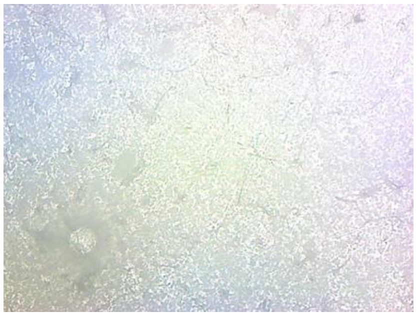

Fig. 4.3.1 OM at 100X of sample 1

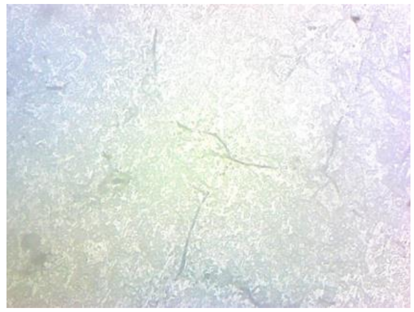

Fig. 4.3.2 OM at 200X of sample 1

4.3.2 Al6063 with 2% yttrium oxide

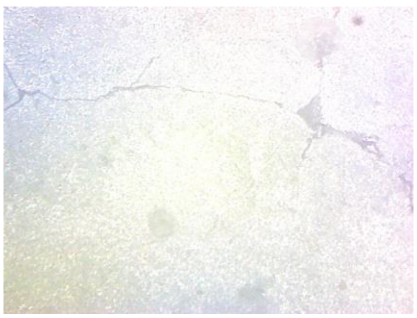

Fig. 4.3.3 OM at 100X of sample 2

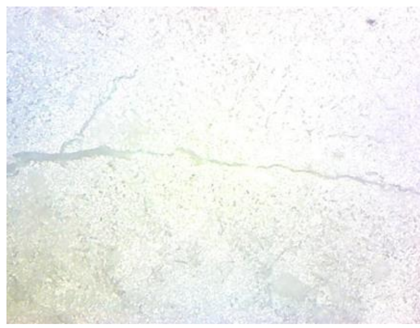

Fig. 4.3.4 OM at 200X of sample 2

4.3.3 Al6063 with 4% yttrium oxide

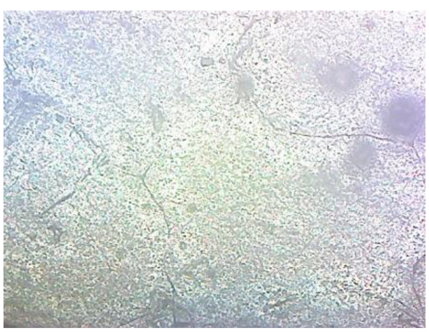

Fig. 4.3.5 OM at 100X of sample 3

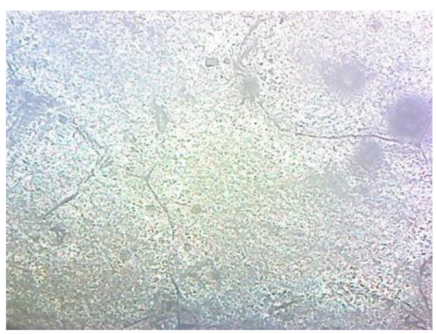

Fig. 4.3.6 OM at 200X of sample 3

CHAPTER-5

CONCLUSION

Al6063 (99% pure) with yttrium oxide reinforcement particle in 25 micrometer was successfully fabricated by using stir casting methodology with minimum defect. Effect of reinforcement on the wear characterstics, microhardness, microstructure of composite produced were analyzed by performing various test on the casting samples specimens.

Following were the major conclusion obtained

- On the basis of result obtained during wear test I concluded that wear resistance increased by increasing the yttrium oxide (Y2O3) powder and wear rate, total wear and weight loss decreased.
- By increasing the sliding velocity wear rate increased and total wear, loss in weight after wear also increased. Hence the casting with 4% yttrium oxide (Y2O3) at 1 m/s sliding velocity shows much better wear resistance.
- Wear rate of casting also decreased by increasing the yttrium oxide powder but by increasing the sliding velocity wear rate increased in same casting.
- Hardness of composite increased by increasing the quantity of yttrium oxide (Y2O3) reinforcement powder.

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