TRIBOLOGY OF ALUMINA NANO COMPOSITES

A Thesis Submitted to

National Institute of Technology

Rourkela

In Partial fulfillment of the requirement for the degree of

Bachelor of Technology

in

Mechanical Engineering

By

N.V.S.S.SUBHASH

Department of Mechanical Engineering

National Institute of Technology

Rourkela -769 008 (India)

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CERTIFICATE

This is to certify that the thesis entitled "**TRIBOLOGY OF ALUMINA NANOCOMPOSITES**" submitted to the National Institute of Technology, Rourkela (Deemed University) by **N.V.S.S.SUBHASH**, Roll No. **109ME0194** for the award of the Degree of **Bachelor of Technology** in Mechanical Engineering is a record of bonafide research work carried out by him under my supervision and guidance. The results presented in this thesis has not been, to the best of my knowledge, submitted to any other University or Institute for the award of any degree or diploma.

The thesis, in my opinion, has reached the standards fulfilling the requirement for the award of the degree of **Bachelor of technology** in accordance with regulations of the Institute.

Date :   Supervisor

Prof. S. K. ACHARYA

ACKNOWLEDGEMENT

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Abstract

The rapid development in the field of nano-particles over the past 20 years has driven tremendous advances in the field of nanotechnolgy. While there remains significant interest in the use of nano particles as fillers in polymer materials to enhance mechanical and physical properties, many research efforts are being carried out that focus on precise structures of nano-particles in polymers, including their assembly in arrays and along interfacial boundaries. The objective of this study is two fold

1. Preparation and characterization of alumina nano particles and

2. Tribological behavior of silicon carbide alumina nanocomposite.

INTRODUCTION

1.1 TRIBOLOGY

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication and wear. It was coined by the British physicist David Tarbor and also by Peter Jost in 1964, a lubrication expert who noticed the problems with increasing friction on machines, and started the new discipline of tribology. It includes the study and application of the principles of friction, wear and lubrication. Tribology is a branch of mechanical engineering. The tribological interactions of a solid surface's exposed face with interfacing materials and environment may result in loss of material from the surface. The process leading to loss of material is known as "wear". Major types of wear include abrasion, friction (adhesion and cohesion), erosion, and corrosion. Wear can be minimized by modifying the surface properties of solids by one or more of "surface engineering" processes (surface finishing) or by use of lubricants (for frictional or adhesive wear) [1].

1.2 DEFINITION OF COMPOSITE:

The most widely used meaning is the following one, which has been stated by Jartiz [2] "Composites are multifunctional material systems that provide characteristics not obtainable from any discrete material. They are cohesive structures made by physically combining two or more compatible materials, different in composition and characteristics and sometimes in form". Accordingly one may classify among the composite materials nearly all substances such as bones, wood, shell etc., and also some man-made materials such as certain powder metallurgy products, electrical insulators, resin bonded magnetic materials, powder charged plastics, paper laminates etc..

The weakness of this definition resided in the fact that it allows one to classify among the composites any mixture of materials without indicating either its specificity or the laws which should give it which distinguishes it from other very banal, meaningless mixtures.

Kelly [3] very clearly stresses that the composites should not be regarded simple as a combination of two materials. In the broader significance; the combination has its own distinctive properties. In terms of strength to resistance to heat or some other desirable quality, it is better than either of the components alone or radically different from either of them.

Berghezan [4] defines as "The composites are compound materials which differ from alloys by the fact that the individual components retain their characteristics but are so incorporated into the composite as to take advantage only of their attributes and not of their short comings", in order to obtain improved materials.

1.3 Classification

Composite materials can be classified in different ways [5].

1.3.1 Classification based on reinforcing material

Particulate Composites

The reinforcement is of particle nature (platelets are also included in this class). In this type of composites, 1μm to 200μm size particles are dispersed in the matrix. It may be spherical, cubic, tetragonal, a platelet, or of other regular or irregular shape, but they are equiaxed. Generally particles are not very effective in improving fracture resistance but they enhance the stiffness of the composite to a limited extent. Particle fillers are extensively used to improve the properties of matrix materials such as to modify the thermal and electrical conductivities, improve performance at elevated temperatures, increase wear, reduce friction and abrasion resistance, improve machinability, increase surface hardness and reduce shrinkage.

Fibrous composites

A fiber is characterized by its length being much greater than its dimension of crossection. The dimensions of the reinforcement determine its capability of its properties to the composite. Fibers play very effective role in improving the fracture resistance of the matrix since a reinforcement having a long dimension discourages the growth of incipient cracks normal to the reinforcement that might otherwise lead to ultimate failure, particularly with brittle matrix composites.

1.3.2 Classification based on matrix material

(1)   Metal matrix composites

Metal matrix composites possess better properties, when compared with organic matrices. These include (i) can retain their strength even at higher temperatures, (ii) higher transverse strength, (iii) better electrical and thermal conductivities,(iv) better erosion resistance etc. Major disadvantage of metal matrix composites is higher densities and low specific mechanical properties when compared to polymer matrix composites. Another notable difficulty is requirement of very high energy for fabrication.

(2)   Polymer matrix composites

A very large proportion of polymeric materials consisting of both thermosetting and thermoplastic, are used as matrix materials in the preparation composites. The resinous binders (polymer matrices) are selected taking fatigue resistance, adhesive strength, heat resistance, chemical and moisture resistance etc into account. The resin must have mechanical strength with that of the reinforcement. It should be easy to be employed in the fabrication process selected and also satisfy the service conditions. On the other hand, the resin matrix must have the capability of wetting and penetrating into the bundles of fibers which provide the reinforcement, replacing the dead air spaces with in and offering those physical characteristics capable of enhancing the performance of fibers.

(3) Ceramic matrix composites

Ceramic fibers, such as alumina and SiC (Silicon Carbide) have better results in very high temperature applications, and also where the environment attack is a major problem. Since ceramics show poor properties in tension and shear, most of its applications as reinforcement are in the particulate form (e.g. zinc and calcium phosphate). Ceramic Matrix Composites (CMCs) used in very high temperature environments, these materials use a ceramic material as the matrix and reinforce it.

Composites as engineering materials normally characterized by

1. These are artificially made (thus, excluding natural material such as wood).

2. These consist of at least two different species with a well-defined interface.

3. Their properties are influenced by the volume percentage of ingredients.

4. These have at least one property not possessed by the individual constituents.

LITERATURE SURVEY

2.1 WHY POLYMER MATRIX SELECTION?

Polymers are structurally more complex than metals or ceramics. They are cheap and can be easily processed. On the other hand, polymers have low strength and modulus of rigidity and used in lower temperature applications. Prolonged exposure to ultraviolet light and some solvents can cause the deterioration of polymer properties. Because of predominant covalent bonds, polymers are poor conductors of heat and electricity. Polymers, however, are generally show more resistance to chemicals than metals. Structurally, polymers are giant chainlike molecular structures (hence the name macromolecules) with covalent bonded carbon atoms forming backbone of the chain. The process of formation large molecules from smaller ones is called polymerization; that is, polymerization is the process of joining many monomers, the building blocks put together to form polymer. Polymers that are used to manufacture advanced PMCs which are of two basic types thermoset and thermoplastics resins.

a)   Thermosetting resins:

Thermoset resins play prominent role in the advanced composites industry today, while thermoplastics have only a minor role. It requires addition of a hardener or curing agent and impregnation onto a reinforcing material, then followed by a curing step to produce a finished part. Some of the more common thermoset resins are described briefly here.

Epoxy resins have relatively low molecular weight monomers with low shrinkage during cure. These can be partially cured and stored in that transition state. The cured epoxy resins have high resistance to chemical and corrosion, good mechanical thermal properties, but they are more expensive compared to polyester resin. The second of the essential ingredients of an advanced composite system is hardener or curing agent. These compounds are very important because they have control over rate of reaction and determine the performance characteristics of the finished part. Since these material serve as catalysts for the reaction, they must have active

sites on their molecules. Some of the most commonly used curing agent in the advanced composite industry is the aromatic amines like 4.4 methylene-dianiline (MDA) and 4.4-sulfonylianiline (DDS)

Unsaturated polyester resins are most widely used because of their good corrosion resistance, mechanical properties, low weight and low cost. They consists of linear polymer chains in styrene monomer. These polymer chains contain reactive sites resulting from the incorporation of the anhydrous forms of unsaturated dicarboxylic acids (e.g. maleic anhydride). The reactive unsaturation sites on the polymer chains react and crosslinking with the styrene monomer via a free radical reaction. This reaction is initiated by the addition of a peroxide catalyst, such a methyl ethyl ketone peroxide (MEKP). The addition of an accelerator in the resin, such as cobalt octate, speed the rate of reaction at a given temperature. The addition of heat considerably speeds up the rate of cross-linking reaction.

Polyurethanes are another group of resin used in advanced composite process. These compounds are formed by reaction the polyol component with an isocynate compound, typically toluene diisocynate (TDI). Methylene diisocynate (MDI) and hexamethylenediisocynate (HDI) are also widely used. These are used to preparation of fiber reinforced foams. Amino and Phenolic resins are used extensively in aircraft interiors because of the exceptional low smoke and heat release properties in the event of a fire.

b) Thermoplastic resins:

Thermoplastic resins require only heat and pressure to form the finished part. Unlike the thermoset resins, thermoplastics resins can usually be reheated and reformed into different shapes. Common examples of thermoplastics resins are known to be polyethylene, polyphenylenesulfine, polystyrene, nylon, polysulfone, polycarbonate etc. Polyamides, Polyimide, PEEK are relatively newcomers to the composite industry and are used for high temperature applications. These resins have better characteristics of thermal stability and flame resistance than the epoxy resins. Polyamide based composites have excellent retention of strength in how-wet environment but they are brittle and have a very low elongation at break.

2.2   Reinforcement:

Reinforcement increases the stiffness, strength and the temperature resistance capacity and lowers the density of polymer matrix composites. In order to achieve these properties the selection depends on the type of reinforcement and its method of production and chemical compatibility with the matrix and the following aspects must be considered while selecting the reinforcement material.

- Size – diameter and aspect ratio
- Shape – Chopped fiber, whisker, spherical or irregular particulate, flake, etc:
- Surface morphology – smooth or corrugated and rough:
- Poly – or single crystal
- Structural defects – voids, occluded material, second phase
- Surface chemistry
- Impurities
- Inherent properties – strength, modulus and density.

2.2.1   Reinforcement materials:

Fibers used as reinforcing material offer two advantages. Primarily the bulk material is always stronger when produced as smaller diameter fibers due to the natural omission of large scale defects. Secondly, fiber configuration allows the tailoring of properties in specific directions. Fibers are added to the resin system to provide strength to the finished part. The selection for reinforcing material is based on properties desired to be in the finished product. Fibers used in advanced composite manufacture come in various forms, such as roving, chopped strands, yarns and mats. Each of these has its own special application. In processes such as pultrusion or filament winding, yarns and roving are used. When performs are used in parts manufacture, woven fabric or mats are required.

[6] Jihong She, *et al*

In this paper Fibrous Al2O3 ceramics with a mixture of SiC and Al2O3 as the cell boundaries were fabricated by extrusion-molding and hot-pressing techniques. The effects of the cell boundary composition on the mechanical properties and fracture behavior are investigated. It is shown that a 65:35 mixture of SiC:Al2O3 can act as a suitable cell boundary for Al2O3 cells. In bending tests, such a ceramic displays a non-catastrophic fracture behavior with reasonable load-carrying capability, and its fracture energy and appar- ent toughness are up to 1349 J/m2 and 6.0 MPa m1/2 , respectively

[7] M. Belmonte, *et al*

In this paperDry ceramic block-on-steel ring wear tests were performed at high loads in several Al2O3/20 vol.%SiC composites as a function of the SiC grain size, which ranged from0.2 to 4.5μm in d_{50}. The wear resistance of themonolithic alumina was radically improved by the addition of the silicon carbide particles, reducing down to one order of magnitude of wear rate. Two different behaviours were identified according to the microstructural observations on the worm surfaces: intergranular fracture and grain pull-out in the monolithic Al2O3, surface plishing and plastic deformation in the composites. The wear resistance of the Al2O3/SiC composites increased with the SiC grain size due to their fracture toughness enhancement.

[8] Guo-Dong Zhan, et al

In the present study, piezoelectric $Nd_2Ti_2O_7$ second phase toughening nanocrystalline alumina composites with higher toughness were successfully developed at relatively low temperatures Spark plasma sintering technique.

[9]. David L. Burris, W. Gregory Sawyer

Past studies with PTFE nanocomposites showed up to 600× improvements in wear resistance over unfilled PTFE with the addition of Al2O3 nanoparticles. Irregularly shaped nanoparticles are used in this study to increase the mechanical entanglement of PTFE fibrils with the filler. The tribological properties of 10wt.% filled samples are evaluated under a normal

pressure and sliding speed of 6.3MPa and 50.8mm/s, respectively. The wear resistance was found to improve 3000× over unfilled PTFE with the addition of 1wt. % nanoparticles. The 5wt.% sample had the lowest steady state wear rate of K= 1.3×10^{-7} mm3 /Nm and the lowest steady friction coefficient with μ= 0.21.

3.1 Experimental work

Aim

Fabrication of best alumina nano powder from aluminum nitrate using auto combustion process.

Process followed to fabricate nano alumina is Auto combustion

Auto combustion is a chemo mechanical process to produce nano alumina with chemical ingredients having variable compositions to obtain the best nano alumina.

Chemical ingredients used

- Aluminium nitrate (Al (NO3)3.9H2O)
- Glycine

Equipment used

Magnetic hot plate

Fig 3.1 magnetic hot plate

Auto combustion [10]process involves heating and stirring up of the solution until the solution changes to gel form and once the solution changed to gel then stop stirring and heating is continued till it forms foamy mass and still heated up to remove all the water molecules present in the solution

Procedure

In the preparation of Nano alumina one mole of Aluminium nitrate $(Al(NO_3)_39H_2O)$.was taken as constant and varying the mole fractions (0.5, 1 and 1.5) of Glycine to get the optimum nano size.

In the nano fabrication different steps are involved

Step 1: 0.4 mole of Aluminium nitrate (Al (NO3)3.9H2O) was mixed with 100 ml of water and stirred to get the solution and add slowly the other gradient (Glycine) of selected mole to produce 20 gms of alumina.

Step 2: Keep the solution on the magnetic hot plate and keep the temperature 50^0C to 60^0C and put one magnetic stirrer in the solution as after some time the solution start becoming galley remove the stirrer and keep the solution on the magnetic up to complete removal of water from the material.

Step 3: The material obtained after heating on magnetic hot plate is fired in furnace up to 800^0C to 1000^0C..

The furnace takes 3to 4 hours to reach the temperature and 2 hours soaking time and 6 to7 hours time to reach the room temperature thus nano alumina powder is obtained which in white colour.

For particle size optimization of alumina different mole of Glycine is mixed with Aluminium nitrate $(Al(NO_3)_39H_2O)$.

Calculations

$$2(Al(NO_3)_3.9H_2O) \quad \text{-----------}> \quad Al_2O_3 + 6NO + 4O_2 + 18\ H_2O$$
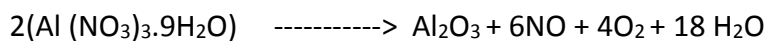
Two moles of aluminium nitrate gives one mole of Al_2O_3

Molecular weight of aluminum nitrate is 375.13

Molecular weight of Al_2O_3 is 102

2*375.13 gm of aluminium nitrate gives 102gm of alumina

20 gm of alumina require =2*375.13*20/102

=147.1 gm

i.e. 147.1/375.13 = 0.4 moles of aluminium nitrate is required

Molecular weight of glycine = 75.067

Molecular formula of glycine $C_2H_5NO_2$

Aluminium nitrate vs glycine

case 1   0.4 mole $(Al(NO_3)_3.9H_2O)$ ------- 0.2 mole glycine

case 2   0.4 mole $(Al(NO_3)_3.9H_2O)$ ------- 0.4 mole glycine

case 3   0.4 mole $(Al(NO_3)_3.9H_2O)$ ------- 0.6 mole glycine

moles of glycine

0.2 mole ----------- 15.0134 gm of glycine

0.4 mole ----------- 30.026 gm of glycine

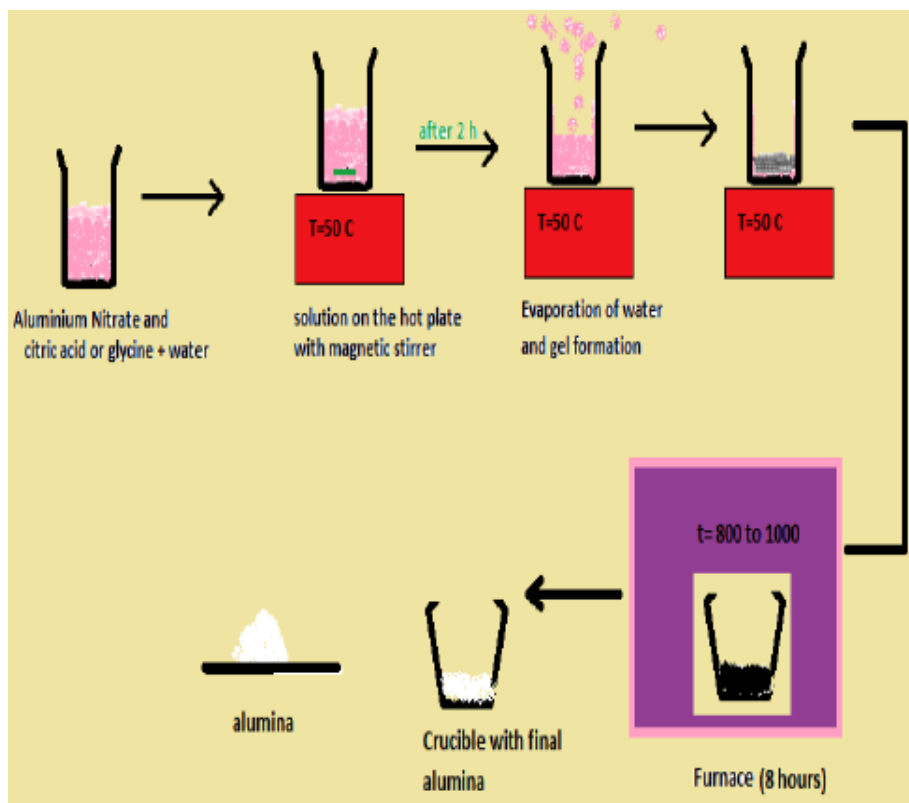0.6 mole ----------- 45.0402 gm of glycine

Fig 3.2 schematic diagram of auto combustion process

Alumina powder obtained is analysed for density, surface area, particle size using BET analysis and XRD techniques.

3.1.1 Testing of nanoparticles surface area

BET analysis

BET analysis is used to calculate the surface area of nano particles. BET analysis provides precise specific surface area evaluation of materials by nitrogen multilayer adsorption measured as a function of relative pressure using a fully automated analyser. The technique considers external area and pore area evaluations to determine the total specific surface area in m^2/g yielding important information in studying the effects of surface porosity and particle size in many applications.

For sample 1

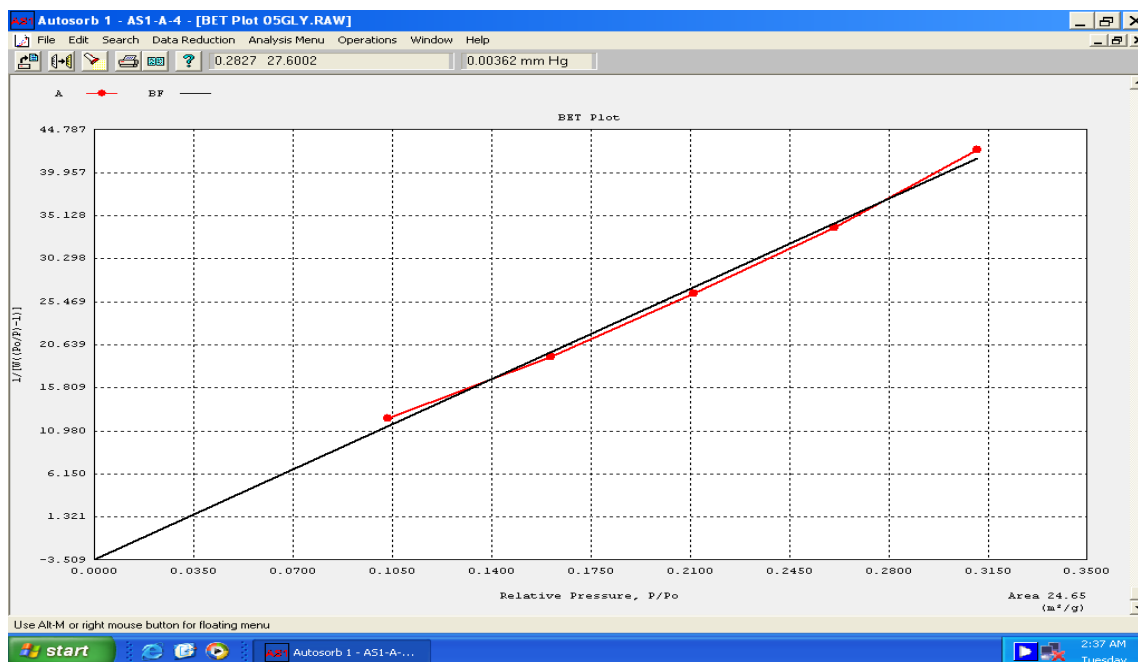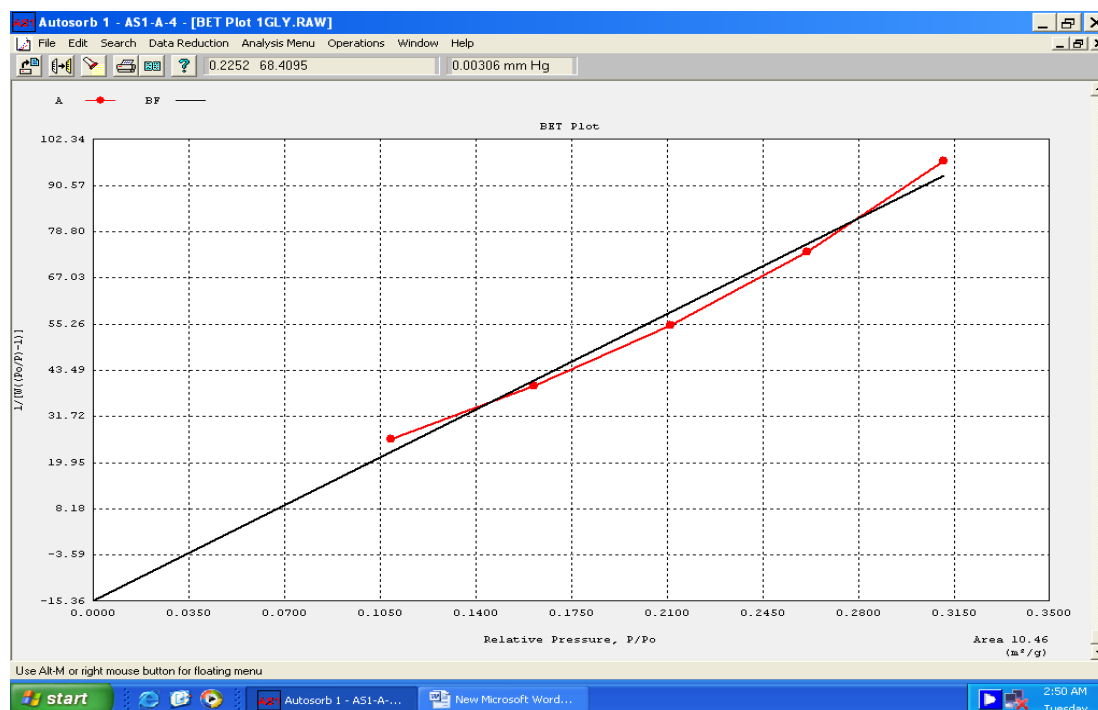(Aluminium nitrate : glycine = 1:0.5)

Fig 3.3 BET result of sample Aluminium nitrate : glycine = 1:0.5

For sample 2

(Aluminium nitrate : glycine = 1:1)

. Fig 3.4 BET result of sample Aluminium nitrate : glycine = 1:1

21

Sample 3

<p align="center">Aluminium nitrate : glycine = 1:1.5</p>
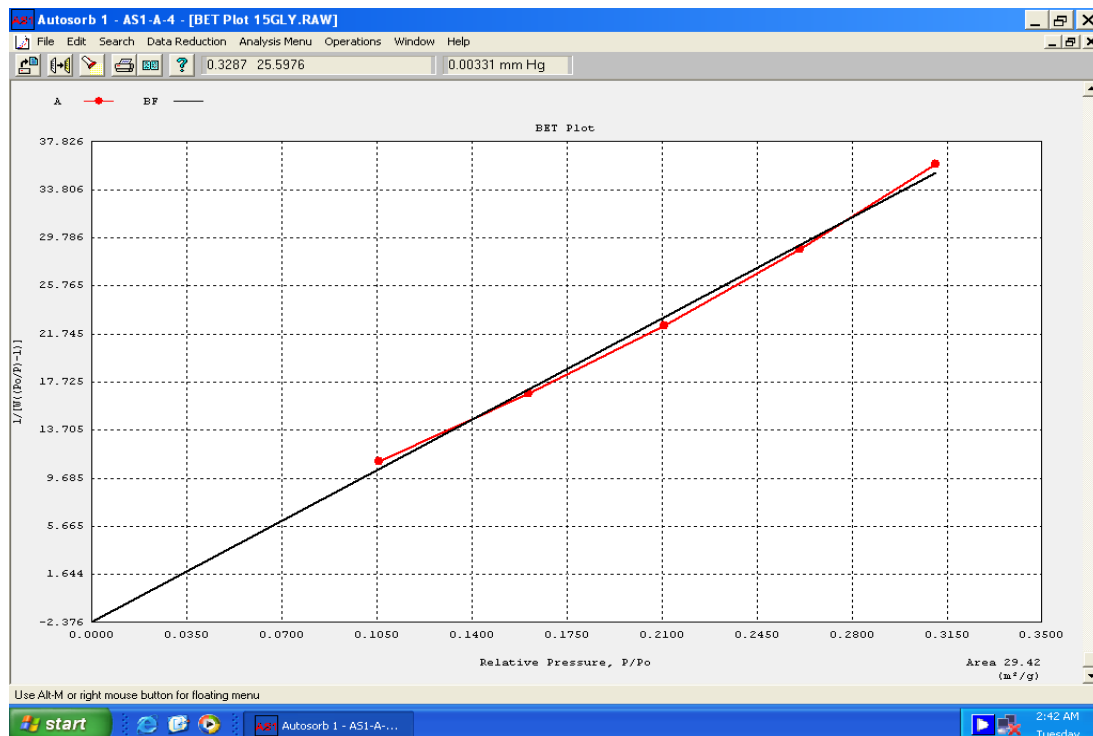

<p align="center">Fig 3.5 BET result of sample Aluminium nitrate : glycine = 1:1.5</p>

3.1.2 Density calculation

Specific gravity of each sample is measured using a picnometer

$$S = \frac{(w1 - w2)}{(w1 - w2) - (w3 - w4)}$$

W1 = weight of empty Pycnometer

W2 = weight of the Pycnometer with nano powder

W3 = weight of the Pycnometer, nano powder and kerosene

W4 = weight of Pycnometer filled with kerosene only

S   = specific gravity of sample

True density of sample = specific gravity × 0.8(density of kerosene)

Density of sample 1(Aluminium nitrate: glycine = 1:0.5) is found to be 0.9015 gm/cm^3.

Density of sample 2(Aluminium nitrate: glycine = 1:1) is 1.37 gm/ cm^3.

Density of sample 3 (Aluminium nitrate: glycine = 1:1.5) is 0.79 gm/ cm^3.

3.1.3 Particle size (average particle diameter)

The average particle size can be estimated by assuming all the particles to have the same spherical shape and size. The average particle diameter, D, is given by:

$$D = 6 / (S_{sp} \times \rho_a)$$

Ssp = specific surface area

ρa = true density

Sample	Average particle size
0.5 mole glycine	270 nm
1 mole glycine	417 nm
1.5 mole glycine	258 nm

Table 3.1 average particle size of sample

3.2 Observation

Observing the three samples considering surface area and particle size in each case the sample aluminium nitrate : glycine = 1:1.5 has smallest particle size and better surface area. This sample is further used in the preparation of nano composite.

4.1 Preparation of Nanocomposite

Materials used

- Silicon carbide
- Epoxy
- Hardener
- Nanopowder

Procedure

A mould is prepared with the dimensions 14cm × cm × 0.8cm = 89.6 cm^3.

Four moulds are made of same dimensions given above.

30% volume fraction of silicon carbide i in epoxy gives better wear resistance compared to other volume fractions[11].

Density of silicon carbide is found to be 2.21 gm/cm^3 using picnometer.

Volume of silicon carbide required = 0.3 × 89,6 = 26.88 cm^3.

Mass of silicon carbide required = 26,88 × 2.21 = 59.4 gms

59.4 gms of silicon carbide is added to epoxy of 63 ml of epoxy and this ingredients are well mixed and poured into the mould.

Mould 1

    Silicon carbide fillers are added to epoxy in 30 % volume fraction to epoxy and hardener is added then this mixture is thoroughly mixed and poured into the mould.

Mould 2

    Nanofillers of 2% volume fraction and silicon carbide of 30% volume fraction are added to epoxy along with hardener and this mixture is poured into the mould.

2% volume fraction = 0.02 $\times$ 89.6 = 1.792 cm^3

Mass of nanofillers = density of nano(0.79 gm/ cm^3) $\times$ 1.792 cm^3 = 1.5 gms approx..

Mould 3

    Nanofillers of 4% volume fraction and silicon carbide of 30% volume fraction are added to epoxy along with hardener and this mixture is poured into the mould.

4% volume fraction = 0.04 $\times$ 89.6 = 3.584 cm^3

Mass of nanofillers = density of nano(0.79 gm/ cm^3) $\times$ 3.584 cm^3 = 3 gms approx..

Mould 4

    Nanofillers of 6% volume fraction and silicon carbide of 30% volume fraction are added to epoxy along with hardener and this mixture is poured into the mould.

6% volume fraction = 0.06 $\times$ 89.6 = 5.376 cm^3

Mass of nanofillers = density of nano(0.79 gm/ cm^3) $\times$ 5.376 cm^3 = 4.5 gms approx..

4.2 Wear

Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear is also defined as the progressive loss of material from contacting surfaces in relative motion. Many scientists have developed various wear theories in which the Physico-Mechanical characteristics of the materials and the physical conditions (e.g. the resistance of the rubbing body and the stress state at the contact area) are taken in to consideration. In 1940 Holm [12] starting from the atomic mechanism of wear, calculated the volume of substance worn over unit sliding path.

Table 4.1 type of wear in industry[13]

Type of wear in Industry	Approximate percentage involved
Abrasive	50
Adhesive	15
Erosion	8
Fretting	8
Chemical	5

ABRASIVE WEAR:

Abrasive wear can be defined as wear that occurs when a hard surface slides against and cuts groove from a softer surface. It can be responcible for most failures in practice. Hard particles or asperities that cut or groove one of the rubbing surfaces produce abrasive wear. This hard material which may be originated from one of the two rubbing surfaces in contact. In sliding mechanisms, abrasion can arise from the existing asperities on one surface (if it is harder than the other), starting from the generation of wear fragments which are repeatedly deformed and hence get work hardened for oxidized until they became harder than either or both of the sliding surfaces, or from the entry of hard particles, such as dirt particles from outside the system. Two body abrasive wear occurs when one surface (usually harder than the second) cuts material away from the second, although this mechanism changes very often to three body abrasion as the wear

debris then acts as an abrasive between the two surfaces. Abrasives can also act as in grinding where the abrasive is fixed relative to one surface or as in lapping where the abrasive tumbles producing a series of indentations as opposed to a scratch. According to the recent tribological survey, abrasive wear is mainly responsible for the large amount of material loss in industrial practice
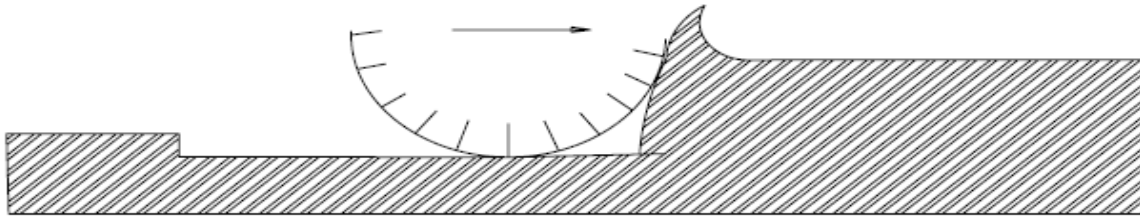
Schematic representations of the abrasion wear mechanism

4.2.1Calculation of wear

Wear rate was estimated by measuring the weight loss of the specimen after each test. The weight loss is calculated taking the weight difference of the sample before and after the test. The weight loss is given by

$$(\Delta w) = (w_a - w_b)\text{gm}$$

Abrasion wear of samples is tested using DRY SAND ABRASION TEST RIG. The samples obtained are tested for abrasion wear for different load and number of revolutions

Abrasion wear test

Experimental conditions for the abrasion test

Test Parameters

Abrasive	Silica sand
Silica sand particle size size (μm)	200±50
Hardness of silica particle(HV)	1420±50
Diameter of rubber wheel (mm)	228
RPM	200±5
Sand flow rate rate (gm/min)	312
Test temperature	27°C
Load(N)	12,24 and 36
Thickness of the rubber wheel	12.7 mm
Loading lever ratio	2.4:1
Specimen size	75*25*12 mm
Rubber wheel material	steel disc with chlorobutyl rubber mound
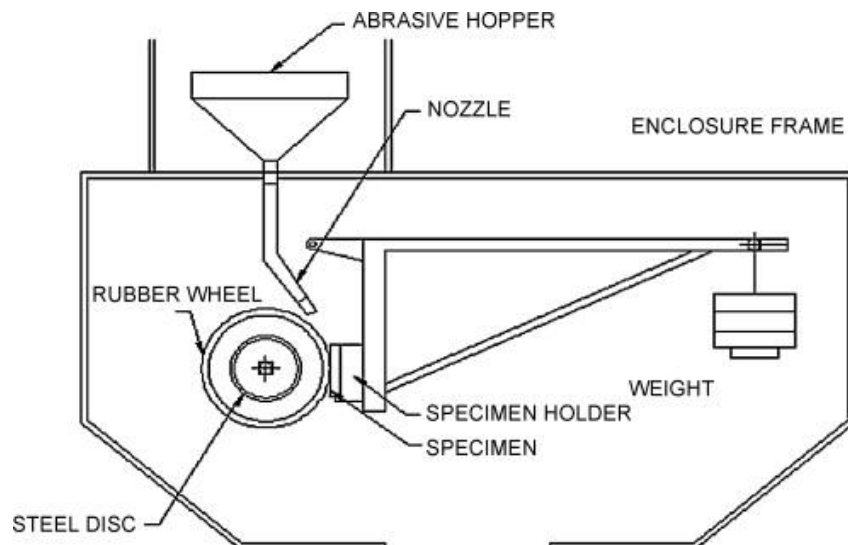
[14] Fig 4.1 Schematic diagram of dry sand/rubber wheel abrasive wear test rig.

Fig 4.2 dry sand abrasion test rig

Procedure

The composite obtained by the casting process described above is cut into pieces of dimensions (75*25*12 mm) for testing the abrasive wear of particular sample under different loads and revolution of the wheel.

Sliding distance for 300 revolutions = radius of wheel (0.114) m × 300 = 34.2 m

Sliding distance for 600 revolutions = radius of wheel (0.114) m × 600 = 68.4 m

Sliding distance for 900 revolutions = radius of wheel (0.114) m × 900 = 102.6 m

Sample 1

Table 4.2 0% nano fillers 30% silicon carbide

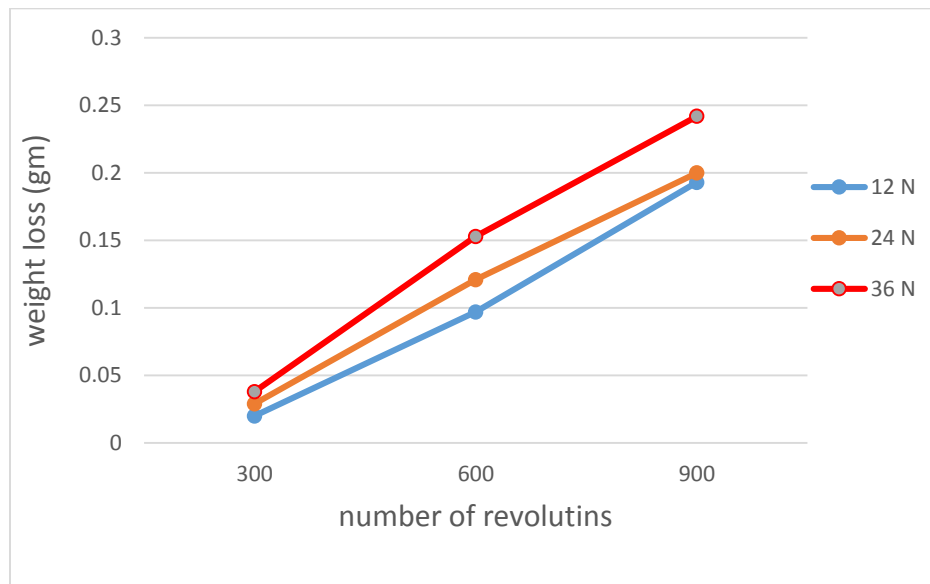| Applied load(l)	Load acting L=l×2.4(N)	revolutions	Initial weight w_1	Final weight w_2	Weight loss
5	12	300	22.299	22.279	0.02
5	12	600	22.279	22.182	0.097
5	12	900	20.288	20.095	0.193
10	24	300	20.095	20.066	0.029
10	24	600	24.786	24.665	0.121
10	24	900	27.652	27.452	0.2
15	36	300	22.456	22.418	0.038
15	36	600	20.681	20.528	0.153
15	36	900	22.182	21.94	0.242

Fig4.3 weight loss due to abrasion wear for sample having 30% volume fraction silcon carbide and zero percentage of nano fillers for varying applied loads of 5N,10N,15N and number of revolutions 300,600,900

Sample 2

Table 4.3 2% nanofillers 30% silicon carbide

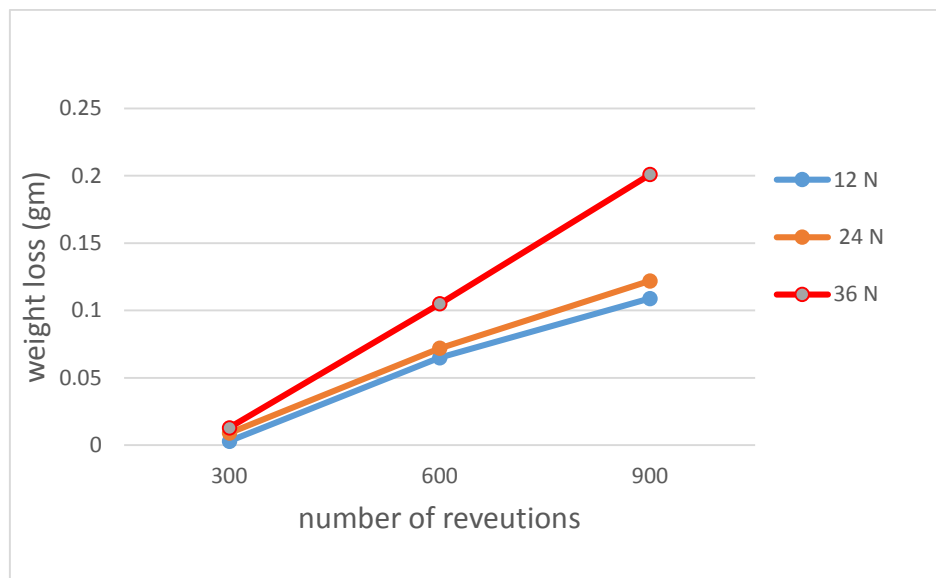| load	Load acting L=l×2.4(N)	revolutions	Initial weight w_1	Final weight w_2	Weight loss
5	12	300	21.790	21.287	0.003
5	12	600	21.287	21.222	0.065
5	12	900	21.222	21.113	0.109
10	24	300	23.408	23.399	0.009
10	24	600	23.339	23.327	0.072
10	24	900	23.048	22.928	0.122
15	36	300	20.807	20.794	0.013
15	36	600	20.794	20.689	0.105
15	36	900	19.107	18.906	0.201

Fig 4.4 weight loss due to abrasion wear for sample having 30% volume fraction silcon carbide and 2% of nano fillers for varying applied loads of 5N,10N,15N and number of revolutions 300,600,900.

Sample 3

Table 4.4 4% nano fillers 30% silicon carbide

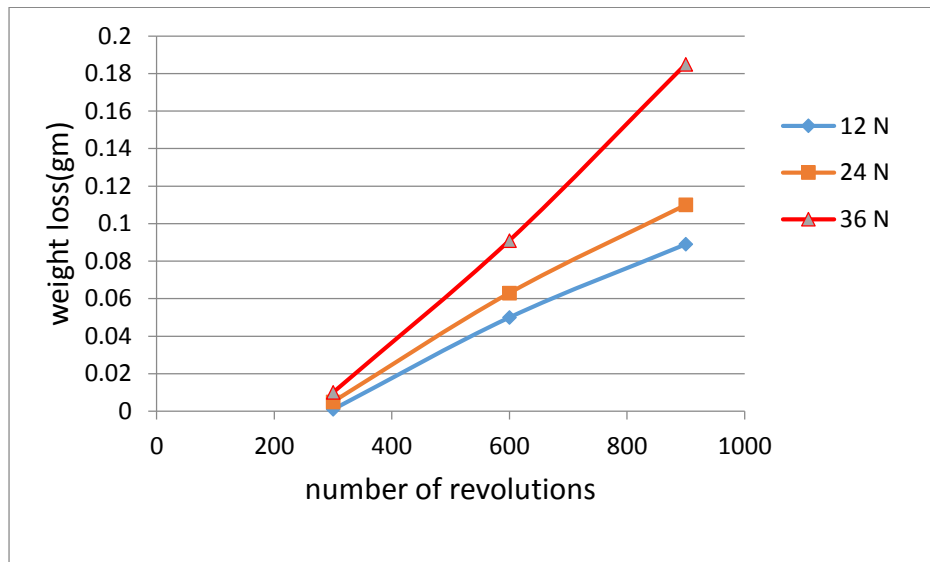| load	Load acting L=l×2.4(N)	revolutions	Initial weight w_1	Final weight w_2	Weight loss
5	12	300	21.732	21.731	0.001
5	12	600	21.731	21.681	0.05
5	12	900	21.681	21.592	0.089
10	24	300	23.315	23.310	0.005
10	24	600	23.310	23.247	0.063
10	24	900	25.876	25.766	0.11
15	36	300	21.214	21.204	0.01
15	36	600	27.972	27.881	0.091
15	36	900	26.782	26.597	0.185

Fig 4.5 shows weight loss due to abrasion wear for sample having 30% volume fraction silcon carbide and 4% of nano fillers for varying applied loads of 5N,10N,15N and number of revolutions 300,600,900.

Sample 4

Table 4.5 6% nano fillers 30% silicon carbide

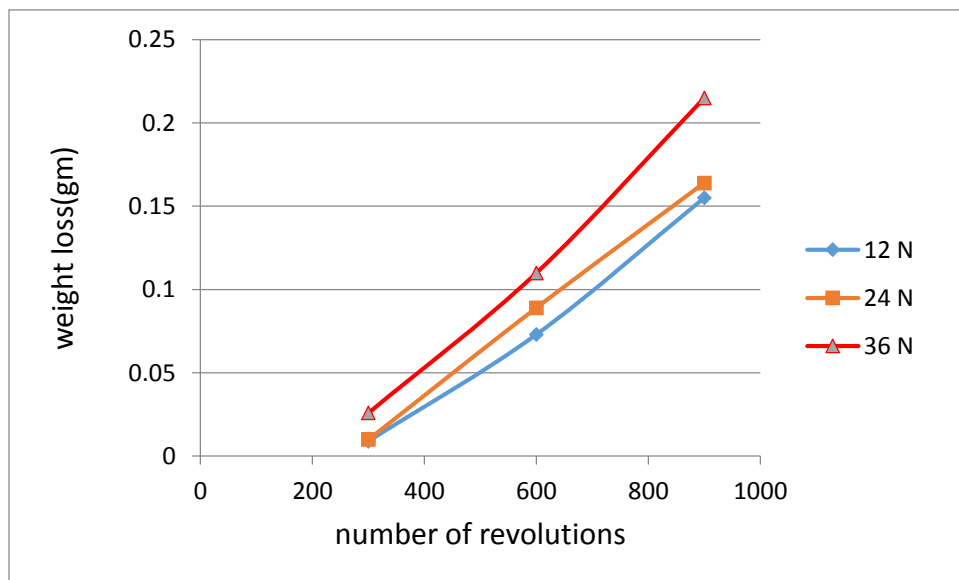| load	Load acting L=l×2.4(N)	revolutions	Initial weight w_1	Final weight w_2	Weight loss
5	12	300	25.283	25.274	0.009
5	12	600	25.274	25.201	0.073
5	12	900	25.201	25.046	0.155
10	24	300	27.276	27.266	0.01
10	24	600	27.266	27.177	0.089
10	24	900	25.403	25.239	0.164
15	36	300	27.097	27.071	0.026
15	36	600	25.743	25.633	0.11
15	36	900	24.922	24.807	0.215

Fig 4.6 weight loss due to abrasion wear for sample having 30% volume fraction silicon carbide and 2% of nanofillers for varying applied loads of 5N,10N,15N and number of revolutions 300,600,900.

4.3 Results

For the above tabulated results graphs are drawn for different volume fraction of nanofillers by varying loads and number revolutions. Weight loss obtained for each sample is compared for a particular given load

For 5 N applied load actual load acting =2.4×5 = 12 N

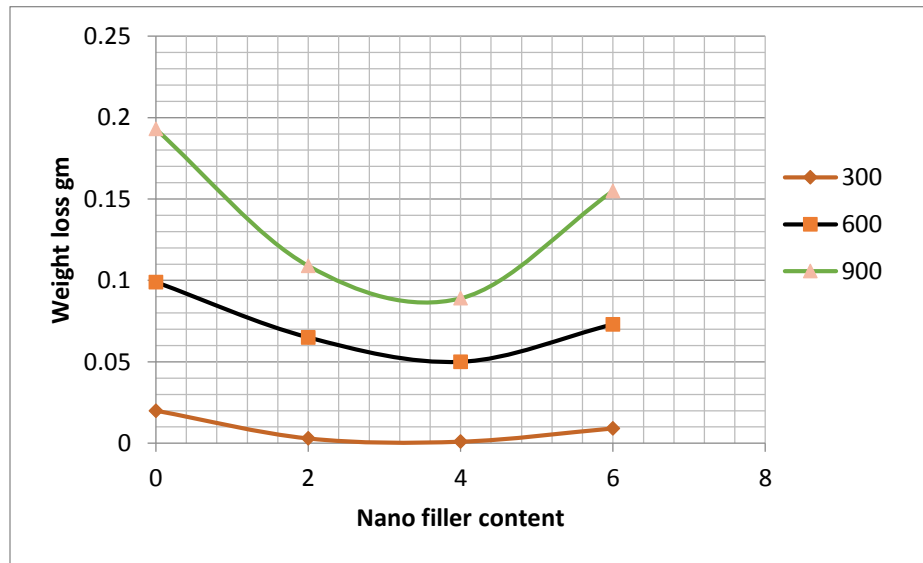Fig 4.7 amount of wear for 5kg applied load

For 10 N applied load actual load acting =2.4×10 =24 N
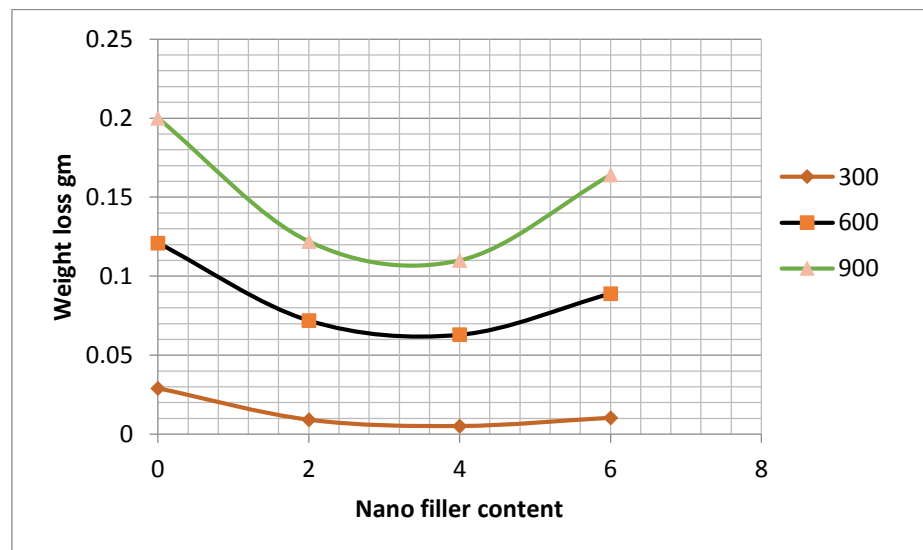

Fig 4.8 amount of wear for 10kg applied load
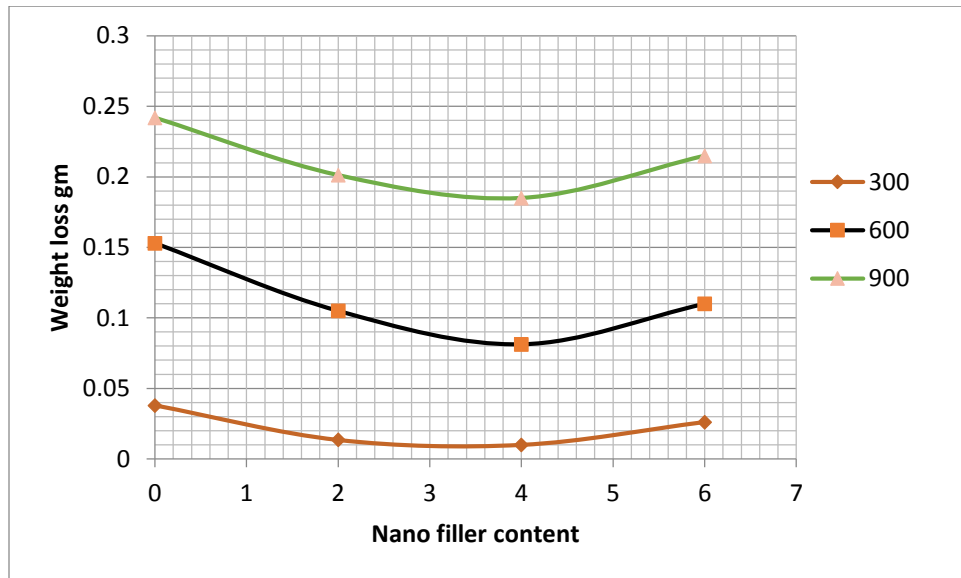
For 15 N applied load actual load acting =2.4×15 =36 N

Fig 4.9 amount of wear for 15 kg applied load

From the graphs plotted above its evident that the sample which is having 4% volume fraction of nanofillers in silicon carbide reinforced composite is having the lowest wear for different applied loads of 5N, 10N, 15N.

CHAPTER 5

Conclusions

From the above discussed results following conclusions are drawn

1. The nano alumina silicon carbide nanocomposites are successfully fabricated.
2. The sample having 4% volume fraction of nanofillers gave the best results showing less amount of wear.
3. Addition of nanofillers to composite in addition to the traditional fillers decrease the wear rate of composite by considerable extent.
4. Alumina nanocomposites show better wear resistance compared to the composites without nanofillers.
5. Amount of wear initially decreased from 2% volume fraction of nanofillers to 4% volume fraction nanofillers but for 6% volume fraction of nanofillers the amount of wear is higher than that of sample having 4% volume fraction of nanofillers.

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