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Tribological behaviour of Pin under Vegetable oil based lubricants with the addition of Biodiesel and metal oxide nanoparticles

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ABSTRACT: In the present scenario, metals have very wide applications where generation of friction is the major problem. Due to continuous friction, wear rate increases which lead to deformation of the metals. Here, Sunflower oil and additives (biodiesel and ZnO) were experimented using Pin on disc apparatus. Tests under dry conditions and base oil with/without additive were used as reference in order to analyse the influence of vegetable oil lubricant, its biodiesel and nanoparticle added lubricant on the wear of metallic surface.

Along with the dry condition, seven more lubrication condition Raw sunflower oil, Raw oil (80%) + B20, Raw oil (60%) + B40, Raw oil (80%) + B20 + Nano1 (0.5%), Raw oil (60%) + B40 + Nano1(0.5%), Raw oil (80%) + B20 + Nano2 (0.2%), Raw oil (60%) + B40 + Nano2 (0.2%) are tested on pin on disc apparatus to assess the wear rate, frictional force and coefficient of friction. In this experiment stainless steel disc and brass pin were used. The wear rate, frictional force and coefficient of friction for all lubricants at three loads (1, 3 & 5 kgf) and three speeds (300, 500 & 700 rpm) is evaluated. The Nano scale particles added lubricants have shown great potential in improving the tribologicalproperties.

The wear rate, frictional force and coefficient of friction are higher for dry conditions. The base oil (sunflower oil) shows the least value than dry conditions because of less frictional force and coefficient of friction due to viscous nature. Nano lubricant shows least value than base oil and dry lubricant because addition of ZnO nanoparticles, the wear rate, frictional force and coefficient of friction significantly decreases compared with base oil and dryconditions.

Abbreviations

The below are the abbreviations used in report.

ZnO	Zincoxide
POD	Pin on disc
COF	Coefficient offriction
LVDT	Linear variable differentialtransducer
PC	Process controller
C2H4	Methanol
H2SO4	Sulphuricacid
NAOH	Sodium hydroxidepallets
CNC	Computerized numericalcontrol
D	m/v
D	Density
m	mass
V	Volume
V	At-B/t
V	Kinematic viscosity of bio lubricant in centistokes
T	Time of flow for 50ml of bio lubricant inseconds
A &B	Are instrument constant are obtained from the belowtable
l	Litre
hr.	Hours
MPa	MegaPascal
nm	Nanometer
Sec	Seconds
G	Gram
ml	Millilitre
mm	Millimeter
0c	Centigrade
0F	Fahrenheit
W/Mk	watt per meterKelvin
g/cm^3	Gram per cubiccenti-meter
Kw	Kilo watt
HP	Horsepower
A	Ampere
V	Volt
Kg	Kilogram

I. INTRODUCTION

Today's world leading by technology, every country was developing because of great inventions by converting information into applications in every field. Some of the applications are advanced internal combustion engines, automobiles, manufacturing industries and refrigeration and air conditioning. For making different applications different metals are using and different metals are in contacting with other metals. So, where contact is there, Friction is also occurring over there, where friction is there, wear is also occurs over there. Because of friction and wear the lifetime of the product or service was decreasing and also not working effectively.

Friction:

Friction is a force that resists the sliding or rolling of one solid object over another. Friction is the resistance to sliding of a solid when a contacting body produces the resistance. It is therefore a vital factor in the operation of most mechanisms. Frictional forces, such as the traction needed to walk without slipping, may be beneficial; but they also present a great measure of opposition to the motion. The major cause of friction between metals appears to be the forces of attraction, known as adhesion, between the contact regions of the surfaces, which are always microscopically irregular. Under magnification, these surface irregularities appear as hills, peaks and valleys. Due to this friction wear occurs between themetals.

Wear:

Wear is the removal of material from a solid surface as a result of the mechanical action exerted by another solid. Wear chiefly occurs as a progressive loss of material resulting from the mechanical interaction of two sliding surfaces under load. It is such a universal phenomenon that rarely two solid bodies slide over each other or even touch each other without measurable material transfer or material loss. Wear can be minimized by modifying the surface properties of solids by one or more of "surface finishing" processes or by use of lubricants.

In order to decrease the Friction and wear, lubricant plays a crucial role for reducing wear and friction [3].

Lubrication:

A lubricant is a substance which helps to reduce the friction between the mating parts or two moving surfaces so that it leads to increasing efficiency and reduce the wear so that it leads to improving reliability and durability of parts or surfaces. In order to minimize the friction and wear by providing lubricant between the mating surfaces is called lubrication.

Classification of lubrication:

The following are the classification of lubrication.

- Fluid-filmlubrication
- Boundarylubrication
- Solidlubrication

Fluid-filmlubrication:

Fluid film lubrication occurs when two contacting surfaces are completely set apart by a lubricant and asperities are not in contact as shown in **Figs.1.1 (b) & (c)**. The load which is applied carried by pressure developed with in the lubricant and frictional resistance to motion arises entirely from the shearing of the viscous lubricant (fluid). This type of lubrication depends upon the viscous properties of lubricant.

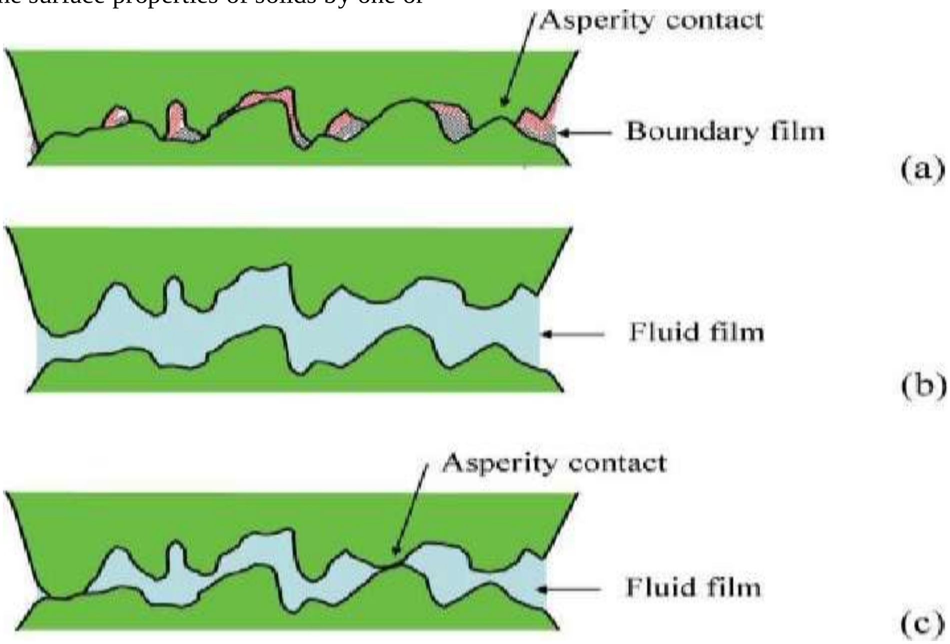

Fig 1.1 (a) Boundary and (b) &(c) Fluid film lubrication

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Boundarylubrication:

A condition that lies between non-lubricated sliding and fluid-film sliding lubrication is referred to called as boundary lubrication as shown in **Fig.1.1 (a)**. Boundary lubrication plays a significant portion of lubrication phenomena and normally occurs during the starting and stopping ofmachines.

Solidlubrication:

This is the lubrication in which lubricants are solid materials which used to reduce the friction between the contacting surfaces and no need of liquid film in this lubrication. Solids or dry lubricants such as graphite, molybdenum disulphide and PTFE (Teflon) are widely used when normal lubricants do not possess sufficient resistance to load or temperature extremes. But lubricants need not to take only in that familiar forms as fats, powders, and gases, even some metals normally serve as sliding surfaces in some sophisticated machines.

Classification of lubricants:

In the following session discussed about classification of lubricant

1. **MineralOil**

Some of the mineral oil lubricants classified as chemical structure they are Paraffinic, Naphthenic and Aromatic etc.,

2. **SyntheticOil**

Some of the synthetic oil lubricants are Hydrocarbon, Silicon Oil and Organohalogens etc.,

3. **Bio-Lubricants**

Some of the bio-lubricants are Animal Fat and Vegetable Oil etc.,

1 Mineral oil

These oils were obtained from the distillation of crude oil. The maximum elements contained in the mineral oils are hydrocarbons. Hydrocarbons used in lubricants have three basic chemical structures they are paraffinic, naphthenic and aromatic. Mineral oils are economical and easily available but source was non-renewable and is non-ecofriendly in nature, these oils were oxidized at high temperature, the chance of explosion and loss of viscos nature in lubricant are good which increase itsuse.

2. Syntheticoil

Synthetic oil, the name itself telling that synthesized from the other raw material these oils are the substitutes for the petroleum-based oils and made from the chemical modification of petroleum-based instead of using completely mineral oil or crude oil. They are artificially made with uniform hydrocarbon elements which help them to work under extremely high temperature to lowtemperature.

3. Bio-lubricant oil

Animal fats and vegetable oils are included in bio-lubricant. These are readily available in nature, eco-friendly and having good anti-frictional and anti-wear properties and these lubricants are bio-degradable and eco-friendly. Bio-lubricants are best alternative for mineral oil lubricant or petroleum basedlubricants.

Bio-lubricants are having very good lubricating properties because high viscous nature and bio-lubricant, the name itself telling that these are bio-degradable. And in order to increase the anti-frictional properties of the bio-lubricant for that Iron oxides or Nano particles uses as an additive to enhance the properties of the lubricant.

For bio-lubricant some of the vegetable oils are sunflower oil, soya bean oil, coconut oil, palm oil, olive oil and cotton seed oil etc., and some of the Nano particles are Zno, Cuo, Mos_2, Tio_2 and Al_2o_3 etc., are uses as an additive to the bio-lubricants to improve its properties of the bio-lubricant.

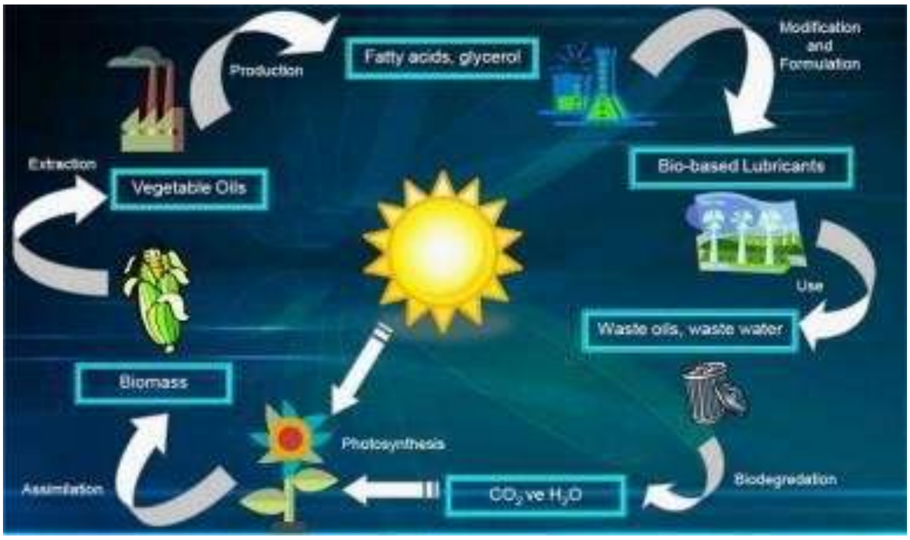

Fig1.2. Bio lubrication process

Nano technology was also developed and it also contributing key role to make better applications in each field and it was influenced even lubricants also. So there is an option to adopt Nano technology in to the lubricants for making best lubricant for improving anti-frictional and anti-wearproperties.

Nano particles as oiladditives

Because of the excellent properties of nanoparticles due to their high surface to volume ratio, the role of the nanoparticles as additives in lubricating oil has gained much focus. Different Nano-additives have different characteristics of extreme pressure, anti-wear, friction modifier, antioxidant, an anti-corrosion additive which can be used in various tribological applications.

The addition of nanoparticles to bio lubricant can improve tribological properties. With this, a smoother and more compact tribo-film has formed on the worn surface, which is responsible for the further reduced friction and wear between the surfaces [5, 6 & 9].

The main advantages of the Nano lubricant are having spherical shape, so good high surface to volume ratio so that good in dispersion stability and it was used for antioxidant and anti-corrosion. And, it was good in anti-frictional properties [6].

The dis-advantage of the Nano lubricant is high in cost and difficult to synthesis [4].

II. LITERATURE REVIEW

In the following are discussed about literature survey from the journals

Hoel.M, Kverndokk.S (**1996**) **[1]** Conducted experiments and concluded that depleting resources and damages caused to the ecosystem and living organisms by the lubricants come out from mineral oil are the greatest challenges faced by the world in this century. The mineral oils are come out from the crude oil which were extinguishing and levels are decreasing due to heavy usage. By using these lubricants, the pollution levels in the environment were drastically increasing.

Mikael Hook, Xu Tang (**2012**) **[2]** Made investigations and found that global warming was gradually increasing by year to year due to emissions of the lubricants which are derived from the mineral oil by the purified from the crude oil. Due to global warming the seasonal times was also changed. And also identified that due to over usage, fossil fuels aredepleting.

N.J. Fox, G.W. Stachowiak (**2006**) **[3]** Reported that day by day the demand of lubricant was increasing in the field of industrial and automobile areas so it promoted to research for alternative lubricant which compensate the lubricant derived from the mineral oil and also identified that Good lubricity, higher thermal stabilities, renewability, biodegradability and non-toxic nature are few advantages of the vegetable oil-based lubricants. But, they possess poor tribological, low temperature properties and low oxidativestability.

Wani Khalid Shafi, M.S. Charoo (**2018**) **[4]** Conducted experiments and concluded that Nano lubricants, its classifications and synthesis of Nano particles, its shape and size and also observed that by adding Nano particles to the vegetable oil, the tribological properties of the lubricant was increased and also it was bio-lubricant so no pollution to the environment and bio-degradable. So the Nano bio-lubricant has no pollution to the environment and easily available in nature and also having good properties than mineral based lubricant it can be compensate in the place of mineral basedlubricant.

S.M.Alves & at all [5] (**2013**) Made investigations and found that the anti-wear behaviour of the oxide Nano-particles depends on the lubricant base oil. They do not show good anti-wear ability when combined with epoxizided vegetable oil like sunflower and soybean oils, because of the influence of chemical nature of vegetable oil on film formation due to polar groups that adhere to surface. In this case, the Nano particles have a third body behaviour increasing the friction. ZnO shows excellent performance in friction and wear reduction when combined with mineral oil. A good film formation was found.

The anti-wear mechanism is attributed to the deposition of Nano-particles in surface and physical film formation, which may reduce the friction and wear.

P.D. Srivyas, M.S. Charoo (**2018**) **[6]** reported that classification of lubricants, vegetable oil and Nano-lubricants and also discussed about the influence of Nano size and shape on its dispersion on lubricant for influencing tribo parameters. And also this paper gave detailed comparison of different Nano- lubricating oils with other different Nano-lubricant oils. And also Observed that ZnO having excellent in performing the reduction of friction and having some anti-wear properties. And also it having spherical shape so good high surface to volume ratio so that good in dispersion stability and also it was used for anti-oxidant and anti-corrosion. The optimum amount of ZnO is 0.5 wt.%.

Chiranjeeva Rao seela ,**B. Ravi Sankar & D. Sai Kiran** (**2016**) **[7]** Made investigations on jatropha bio-diesel and experimented on CI engine by taking various blends of bio-diesel and concluded that high brake thermal efficiency and low emissions. Identified that sunflower oil have good viscosity and high flash point which are performing good in reduction of anti-wear properties comparatively other readily available vegetable oils. And also studied that, preparation of biodiesel from raw oil by transesterificationprocess.

Marinalva Ferreira Trajano (**2014**) **[8]** reported that detailed information about classification of Nano-lubricants and also discussed about the influence of Nano size and shape on its dispersion on lubricant for influencing tribo parameters. And concluded that epoxidized sunflower and soybean oils have properties suitable for the formulation of lubricants, especially for applications operating over a wide temperature range, because of its excellent viscosity index. These bio-lubricants showed good performance in boundary conditions, decreasing friction coefficient and improving film formation on metal surface. However, better performance was observed for epoxidized sunflower oil. ZnO has spherical shape. The ZnO particles are dispersed in lubricant by using ultrasonic probe for 30 minutes in concentration of 0.5wt% was giving better results in sunflower oil and also observed that the combination of sunflower oil lubricant and ZnO giving good results in reducing friction and good anti-wearproperties.

Wani Khalid Shafi, Ankush Raina & Mir Irfan Ul Haq (**2018**) **[9]** Made investigations on that detailed information about classification of Nano-lubricants and also discussed about the influence of Nano size and shape on its dispersion on lubricant for influencing tribo parameters and also observed that the global demand of lubricating oil was increasing and the level of crude oilorfossilfuelsaredecreasingtheresourcesaredecreasingso,leadtoresearchonanother source so focus shift to non-resources to renewable sources. Vegetable oils having good anti wear properties and Nano lubricants having good reduction of coefficient offriction.

N.Nuraliza, S.Syahrellail (**2015**) **[10]** Conducted experiments and concluded that POD under various loads, speeds and time by changing initial parameters and concluded that the experimental results, the rate of COF (coefficient of friction) rose when sliding speed and

Load was high. Meanwhile, the wear rate for a load of 100N for all lubricants was almost always higher compared to lubricant with a load of 50N. The results of this experiment reveal that the palm oil lubricant or vegetable oil can be used as lubricating oil, which would help to reduce the global demand of petroleum-based lubricants substantially. And Studied that in tribology pin on disc is an apparatus to find out the friction and wear under the dry and lubricating conditions at various parameters. And also, it gives accurate results on tribology and also studies preparation of specimen pin and disc for theexperiment.

Observations made from the literaturesurvey:

- Increasing global demand for lubricants and limited crude oil resources has led to the

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research from non-renewable to renewable oilsources.

- Vegetable oil-based lubricating oil exhibiting better performance in terms of wear where as the mineral oil based lubricating oil exhibiting better performance in terms offriction.
- The addition of nanoparticles to bio lubricant can improve tribological properties. With this, a smoother and more compact tribo-film has formed on the worn surface, which is responsible for the further reduced friction and wear between thesurfaces.
- ZnO having excellent in performing the reduction of friction and having some anti-wear properties. And also, it having spherical shape so good high surface to volume ratio so that good in dispersion stability and also it was used for anti-oxidant andanti-corrosion.
- The ZnO particles are dispersed in lubricant by using ultrasonic probe for 30 minutes in concentration of 0.5wt% was giving better results in sunflower oil and also observedthat the combination of sunflower oil lubricant and ZnO giving good results in reducing friction and good anti-wearproperties.
- Sunflower oil has good viscosity and high flash point which are performing well in reduction of anti-wear properties comparatively other readily available vegetableoils.
- ZnO nanoparticles in the base lubricants significantly increased the lubricationefficiency of the sunflower oil (base lubricant) and notably reduced both the friction coefficient and surfaceroughness.
- The rate of COF (coefficient of friction) increased when the sliding speed and load were high.

Definition ofproblem:

Increasing global demand for lubricants and limited crude oil resources has increased the scope for the research in renewable oil sources. The work is focused on prepare the biodiesel and its Nano (ZnO) added lubricant emulsion. The work is intended to assess the influence of Novel lubricants on the wear rate, frictional force and coefficient of friction of POD TRIBOMETER

ResearchAim

1. Investigate the impact of dry and vegetable oil on the tribological properties on POD TRIBOMETER.
2. Investigate the impact of Nano (ZnO) added vegetable oil on the tribological properties on PODTRIBOMETER.

Researchobjectives

1. To prepare thebio-diesel.
2. To prepare the Nano (ZnO) addedlubricant.
3. To assess the influence of Novel lubricants on the wear Rate of PODTRIBOMETER.
4. To assess the influence of Novel lubricants on the frictional force of PODTRIBOMETER.
5. To assess the influence of Novel lubricants on the coefficient of friction of POD TRIBOMETER.

ExperimentalMethodology

In the current experiment brass material used as pin and tested on stainless steel disc. The sunflower oil is selected as bio-lubricant , its bio-diesel and metal oxide, ZnO is blended as an additive to improve the performance of lubricating properties, in turn, will be used in the enhancement of Tribological properties. To avoid the agglomeration of particles, sonication was done on ultrasonic machine for 1 hour. The Nano-bio-diesel lubricant is prepared.

The combinations of process variables are framed by taking speed and load at three different levels under constant time. The experimentation is done with these 8 combinations to assess the Tribological properties like wear, frictional force and coefficient of friction.

The present work aims at the study of wear characteristics of stainless Steel under the influence of Nano lubricants. The variable input parameters include speed and load. In the current study friction and wear characteristics are studied on stainless Steel using pin-on-disk tribo-tester under varying loads of 10N to 90N, with rotating speeds from 100-900 rpm in a given operation time. The experiments are conducted using brass pin and stainless steel disc is lubricated with Nano-bio-diesel lubricants and the variation of wear and frictional force under variable input factors like load and speed isstudied.

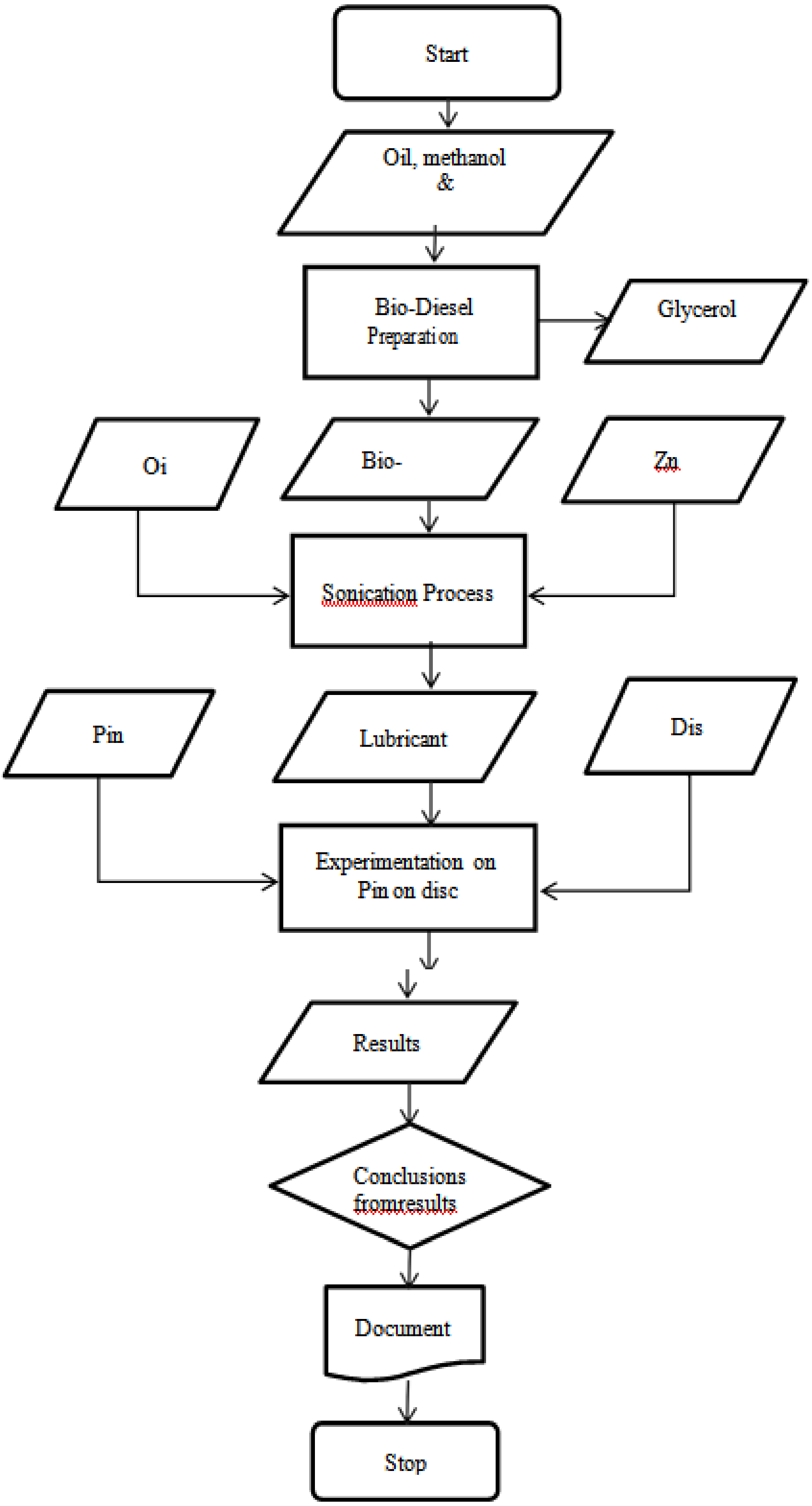

Fig 2.1 Flowchart for Experimental methodology:

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III. PREPARATION OF LUBRICANT AND ITS PROPERTIES

In the following are discussed about material selection for lubricant and its preparation.

Material selection:
In the following session discussed about selection of lubricating oil and metal oxide for lubricant from based on literature survey [5, 6&7]

1. Sunfloweroil:
Sunflower oil has good viscosity and high flash point which are performing well in reduction of anti-wear properties comparatively other readily available vegetable oils.
It is easily available and it has high viscosity than other readily available oils which are coconut oil, soybean oil (7) and so it helps to reduce wear, frictional force.

Sunflower oil properties:
Density: 0.915 g/ cm^3at 15 to 25^{o}C
Viscosity: 623MPa at 20^{o}C **Smoke point:** 209^{o}C
Flash point: 320 ^{o}C
Fire point: 341 ^{o}C

2. **ZnO**:
ZnO having excellent in performing the reduction of friction and having some anti-wear properties. And also, it having spherical shape so good high surface to volume ratio so that good in dispersion stability and also it was used for anti-oxidant and anti- corrosion (5, 6).
ZnO nanoparticles in the base lubricants significantly increased the lubrication efficiency of the sunflower oil (base lubricant) and notably reduced both the friction coefficient and surface roughness.

ZnO properties:
Molecular Formula: ZnO
Purity: 99.9%
Average Particles Size: 30-50nm **Colour:** milky white **Morphology:** Nearly Spherical
Bulk Density: 0.28-0.48 g/ cm^3
True density: 6 g/ cm^3

Preparation ofbiodiesel:
In the following session discussed about preparation of biodiesel, for preparation of biodiesel discussed about required materials, equipment and its procedure.

Requiredmaterials:
Raw oil (sunflower oil), Methanol (C2H4), Sulphuric acid (H2SO4), Sodium hydroxide pallets (NAOH) and Distilled water

Requiredequipment:
Electric magnetic stirrer with heater, conical flask,Thermometer, Decanter and Airbubbler

Procedure for Preparation of biodiesel (From sunflower oil)
In the following session discussed about preparation of biodiesel. Transesterification makes blends suitable for engine applications. Figure 3.4 shows the steps involved. A total of 100 ml of methanol and 2-3 ml of sulphuric acid is added to 1 L of raw oil at 60^{o}C. Settling is carried out in a decanter for 3 h and the pulp is separated. Sodium methoxide is added to the acid treated oil at 60^{o}C. It is allowed to settle for 6 h and the glycerine is removed. The base treated oil is water washed and afterwards dehydrated at 110^{o}C to get pure biodiesel.

Fig 3.1: Sunflower oil(Raw oil)

Fig3.2:Glycerol

Fig 3.3Biodiesel

Sequence of steps in biodieselpreparation

The following figure describes about bio-diesel preparation by transesterfication method

Fig 3.4 Biodiesel production by the transesterification process

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BIODIESELPROPERTIES

The properties of the biodiesel are follows:

- **Density:** 0.868 g/cm^3
- **Viscosity:** 6.51MPa at28^{o}C
- **Flash point:**188 ^{o}C
- **Fire point:**193 ^{o}C

DENSITY:

- "Density" is defines the amount of mass per unit of volume. Density often has units of grams per cubic centimeter (g/cm^3). Remember, grams are a mass and cubic centimeter is a volume. The symbol most often used for density is D (Latinword).

D = m/V

Where, D = density

m = mass V =volume

- Density = mass(m)/volume(V)

- D= ((mass of flask with 50 ml of bio-lubricant)-(mass of empty flask)) / (volume of bio-lubricant)

D = ((82.086) -(38.637)) / (50)

= (43.449) /(50)

= 0.86898g/cm^3

Viscosity:

- "Viscosity" is a measure of a fluids resistance to flow. It describes the internal friction of a moving fluid. The internal drag arising between two successive layers of the liquid is known asviscosity.
- Viscosity is measured by using device "Redwood viscometer". If the viscosity of the bio-lubricant is to be determined at room temperature28^{0}C.
- In the equipment the "oil cup" is filled with bio-lubricant to be tested carefully up to the level ofindicated.
- One 50 ml flask is kept in position below the jet. "Brass ball" is used to stop the flow of thebio-lubricant.
- When the temperature of the bio-lubricant has quite steady and reaches the required temperature, the brass ball is lifted and simultaneously the "stopwatch" isstarted.
- The bio-lubricant is allowed to flow through the "orifice" and collected in theflask.
- Stopwatch is stopped when 50 ml of bio-lubricant is collected in the flask up to the mark and immediately the orifice is covered with the brass ball to stop the overflow of thebio-lubricant.
- The time required to flow the 50 ml of the oil isnoted.
- The oil cup is refilled again with bio-lubricant and same procedure is repeated for threetimes.
- The same temperature is also adopted to determine the viscosity of bio-lubricant at anytemperature.
- The **"**kinematic viscosity**"** of bio-lubricant is calculated at roomtemperature.
- The kinematic viscosity of the bio-lubricant at room temperature is given by the formula V= At –B/t

V = kinematic viscosity of bio-lubricant in centistokes. T = Time of flow for 50 ml of bio-lubricant inseconds.

A and B are instrument constants are obtained from the below table

Table 3.1 Redwood viscometer constant values:

S.NO	TYPE OF EQUIPMENT	TIME OF FLOW	A VALUE	B VALUE
1	Redwood 1	40 to 85 sec	0.264	190
2	Redwood 2	85 to 2000 sec	0.247	65
3	Redwood 3	……	0.247	65

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Table 3.2 Experiment readings:

S.NO	QUANTITY OF BIO-LUBRICANT IN ML	TIME TAKEN
1	50 ML	41.96
2	50 ML	42.26
3	50 ML	41.44
	AVG	41.88

- The average time 41.88 sec is required to flow the 50 ml of bio-lubricant at room temperature. So, the equipment is redwood1.
- The average time 41.88 sec is lies between the redwood 1 time offlow.
- So consider the A and B constant values as 0.264 and 190.
- By using the formula, kinematic viscosity V =At –B/t

V = (0.264*41.88) – (190/41.88)
V = 6.5195 centistokes V = 0.065195 stokes

FLASH POINT:

- The temperature at which the oil produces enough vapour to catch a fire andproduce a blue flash when a tiny flame is brought near the surface of the liquid under specific conditions momentarily is known as “flashpoint”.
- The principle of the flash point is temperature increases the vapour pressure of the any liquid increases. So that flash point can be determined by heating the oil slowly at the rate of 1^0C per minute and by bringing the tiny flame near the surface of theliquid.
- Flash point is determined by taking 100 milliliter of bio-lubricant in 100 ml beaker. Then put the 100ml beaker filled with 100ml of the bio-lubricant upon the heater and heat the bio-lubricant slowly at the rate of 1^0C per minute, At some time the tiny flames are form near the surface of thebio-lubricant.
- Actually “Diesel**”** fuel flash point varies between 52^0C and 92^0C. The preparation of the “bio-lubricant” flash point is188^0C.

Fig 3.5 Flash point sample

Fig 3.6 Fire on bio-diesel sample

FIRE POINT:

- The temperature at which the bio-lubricant produces enough vapor at catch a fire and burn with flame at least for five seconds when a tiny flame is brought near the surface of the bio-lubricant under specific conditions is known as "firepoint".
- Another term for fire point is "flamepoint".
- Fire point occurs when the temperature is high enough to cause not just ignition but a continues or sustainable combustion.
- The principle of the fire point is determined by heating the bio-lubricant at the rate of 1^0C per minute. At certain temperature the bio-lubricant produces enough vapour to catch a fire and burn with flame at least for fiveseconds.
- Actually "Diesel**"** fuel fire point would be about 93.33^0C (200^0F). The preparation of the "bio-lubricant" fire point is193^0C.

Fig 3.7 Flash point and Fire point apparatus

Preparation of Nanolubricant:

The Nano lubricant was prepared by using ultrasonic sonicator and before sonication of ZnO and lubricant; we need to prepare the lubricant. Lubricant contains raw oil and bio-diesel at predefined proportions for respective conditions. It

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was prepared by stirring for 30minutes without heating.

Then we need to mix or sonicate ZnO in to that already prepared lubricant by sonicating machine as shown in **Fig 3.9**.

Sonicator:

The following section discussed about sonicator, sonication and its procedure.

COMPONENTS OFSONICATOR:

A sonicator has three main components

a. Generator
b. Transducer
c. Probe

SONICATION:

Sonication is the process in which sound waves are used to agitate particles in solution. Such disruptions can be used to mix solution, speed the dissolution of a solid into a liquid (like sugar into water) and remove dissolved gas from liquids.

TYPES OF SONICATION METHODS:

There are two types of sonication methods

1. **Direct sonication method:**
Inserting a probe directly into a sample vessel.
2. **Indirect sonicationmethod:**
Eliminate the need for a probe to come in contact with your sample.

Fig 3.9 Sonicator

SONICATION OPERATINGPROCEDURE:

1. Take the Lubricant into one plastic flask then add Nano powder into thatflask.
2. Then keep probe in to that flask and close the door of sonicatingmachine.
3. Switch ON the Power supply of sonicating machine and then adjust the frequencyand time intransducer.
4. Then click the start button to start thesonication.
5. Generator produces a sound waves to agitate the particles in to thelubricant.
6. When time completes, generator stops producing the sound wavesautomatically.
7. Finally, take the flask from sonicator by taking probe out of flask and switch OFF the powersupply.

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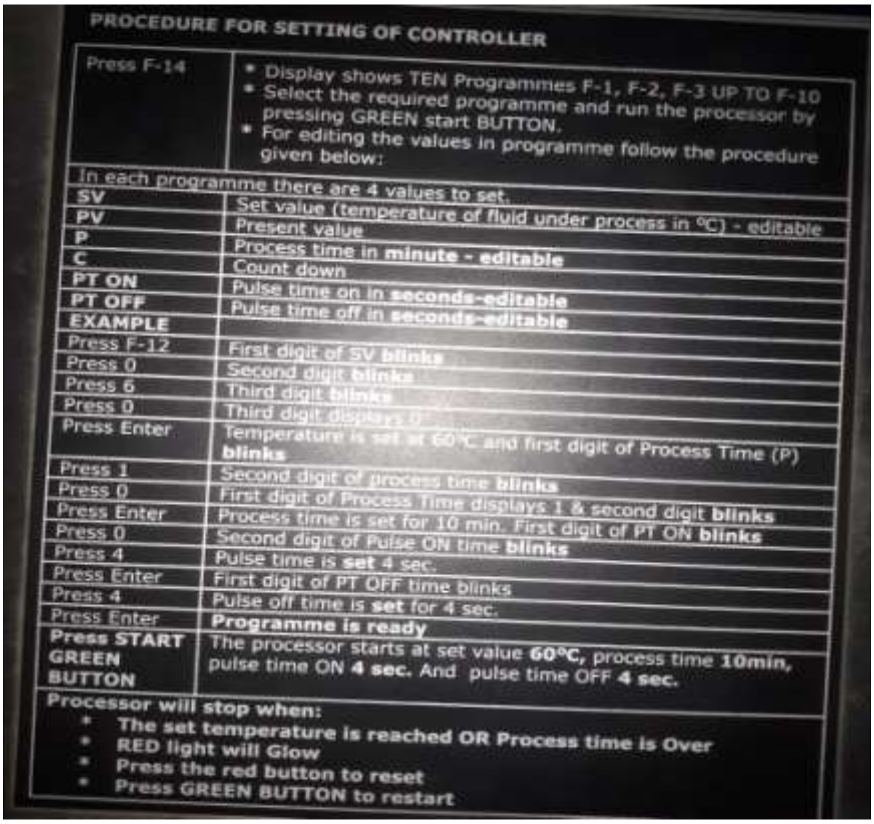

PROCEDURE FOR SETTING OF CONTROLLER

Press F-14	• Display shows TEN Programmes F-1, F-2, F-3 UP TO F-10 • Select the required programme and run the processor by pressing GREEN start BUTTON. • For editing the values in programme follow the procedure given below:
In each programme there are 4 values to set.	
SV	Set value (temperature of fluid under process in °C) - editable
PV	Present value
P	Process time in minute - editable
C	Count down
PT ON	Pulse time on in seconds-editable
PT OFF	Pulse time off in seconds-editable
EXAMPLE	
Press F-12	First digit of SV blinks
Press 0	Second digit blinks
Press 6	Third digit blinks
Press 0	Third digit displays 0
Press Enter	Temperature is set at 60°C and first digit of Process Time (P) blinks
Press 1	Second digit of process time blinks
Press 0	First digit of Process Time displays 1 & second digit blinks
Press Enter	Process time is set for 10 min. First digit of PT ON blinks
Press 0	Second digit of Pulse ON time blinks
Press 4	Pulse time is set 4 sec.
Press Enter	First digit of PT OFF time blinks
Press 4	Pulse off time is set for 4 sec.
Press Enter	Programme is ready
Press START GREEN BUTTON	The processor starts at set value 60°C, process time 10min, pulse time ON 4 sec. And pulse time OFF 4 sec.

Processor will stop when:
* The set temperature is reached OR Process time is Over
* RED light will Glow
* Press the red button to reset
* Press GREEN BUTTON to restart

Fig 3.10 Procedure for setting of controller (Operating)

LUBRICANT CONDITIONS FOREXPERIMENT:

The following are the lubricant conditions for experiment

3. Dryconditions
4. Raw oil

3. Raw oil (80%)+B20
4. Raw oil (60%)+B40
5. Raw oil (80%) +B20+Nano1(0.5%)
6. Raw oil (60%) +B40+Nano1(0.5%)
7. Raw oil (80%) +B20+Nano2(0.2%)
8. Raw oil (60%) + B40+Nano 2(0.2%)

1. Dryconditions:

Operating or doing experiment without lubricant.

2. Rawoil:

Operating the experiment under the lubricant conditions where the raw oil is sunflower

3. Raw oil (80%) + B20:

Lubricant contains 80% of raw oil and 20% of Biodiesel. It was prepared by stirring for 30minutes without heating.

4. Raw oil (60%) + B40:

Lubricant contains 60% of raw oil and 40% of Biodiesel. It was prepared by stirring for 30minutes without heating.

5. Raw oil (80%) + B20 + Nano 1(0.5%):

Lubricant contains 80% of raw oil and 20% of Biodiesel. It was prepared by stirring for 30minutes without heating. After that 0.5% of ZnO (in terms of weight percentage) was added to the lubricant. Here, the dispersion of Nano by using sonication process for 1 hour under the frequency of 20-25Hz by using ultrasonic probe machine.

6. Raw oil (60%) + B40 + Nano 1(0.5%):

Lubricant contains 60% of raw oil and 40% of Biodiesel. It was prepared by stirring for 30minutes without heating. After that 0.5% of ZnO (in terms of weight percentage) was added to the lubricant. Here, the dispersion of Nano by using sonication process for 1 hour under the frequency of 20-25Hz using ultrasonic probe machine.

7. Raw oil (80%) + B20+Nano 2(0.2%):

Lubricant contains 80% of raw oil and 40% of Biodiesel. It was prepared by stirring for 30minutes without heating. After that 0.2% of ZnO (in terms of weight percentage) was added to the lubricant. Here, the dispersion of Nano by using sonication process for 1 hour under the frequency

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of 20-25Hz using ultrasonic probe machine.

8. Raw oil (60%) + B40+Nano 2(0.2%):

Lubricant contains 60% of raw oil and 20% of Biodiesel. It was prepared by stirring for 30minutes without heating. After that 0.2% of ZnO (in terms of weight percentage) was added to the lubricant. Here, The dispersion of Nano by using sonication process for 1 hour under the frequency of 20-25Hz using ultrasonic probe machine.

IV. EXPERIMENTAL SETUP AND EXPERIMENTATION

In the following session discussed about equipment used and experimentation.

Equipmentused

In the following session discussed about pin on disc machine and its parts.

Tribometer:

A tribometer is an instrument that measures Tribological quantities, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact. A tribotester is the general name given to a machine or device used to perform tests and simulations of wear, friction, and lubrication which are the subject of the study of tribology. In most test applications using tribometer, wear is measured by comparing the mass or surfaces of test specimens before and after testing. Tribometers are often referred to by the specific contact arrangement they simulate or by the original equipmentdeveloper.

Pin onDisc:

Pin on disc wear testing machine is simple and convenient to operate. This is used for both wear testing and measurement of coefficient of friction. This apparatus facilitates the study of friction and wear characteristics in sliding conditions at different conditions. The sliding occurs between the stationary pin and rotating disc. The normal load, rotational speed, track diameter can be varied to suit our experiments. The following are the different parts of a wear testing machine and the experimental setup is shown in**Fig4.1**.

- Machine
- Controller
- Data acquisitionsystem
- Sensors
- Cables

Machine:

The assembly of the spindle, loading lever, sliding plate etc., all known as a machine. The structure of the machine is made of tubes welded in the form of a homogeneous unit. In order to minimize the vibrations attained during experiment 4 anti-vibration pads at the bottom are fitted. These also level the machine parallel to the ground. It uses AC motors, drive & all electrical items which fit inside the structure and sides of it are covered with the panels. An emergency switch is fixed on the front panel to switch off power when necessary. The disc is mounted on spindle top, which is driven by AC motor by screws. The belt arrangement provides positive drive with low vibration. The spindle is supported on taper roller bearings inside a housing, which is fixed firmly to base plate bottom, such that spindle top projects over baseplate.

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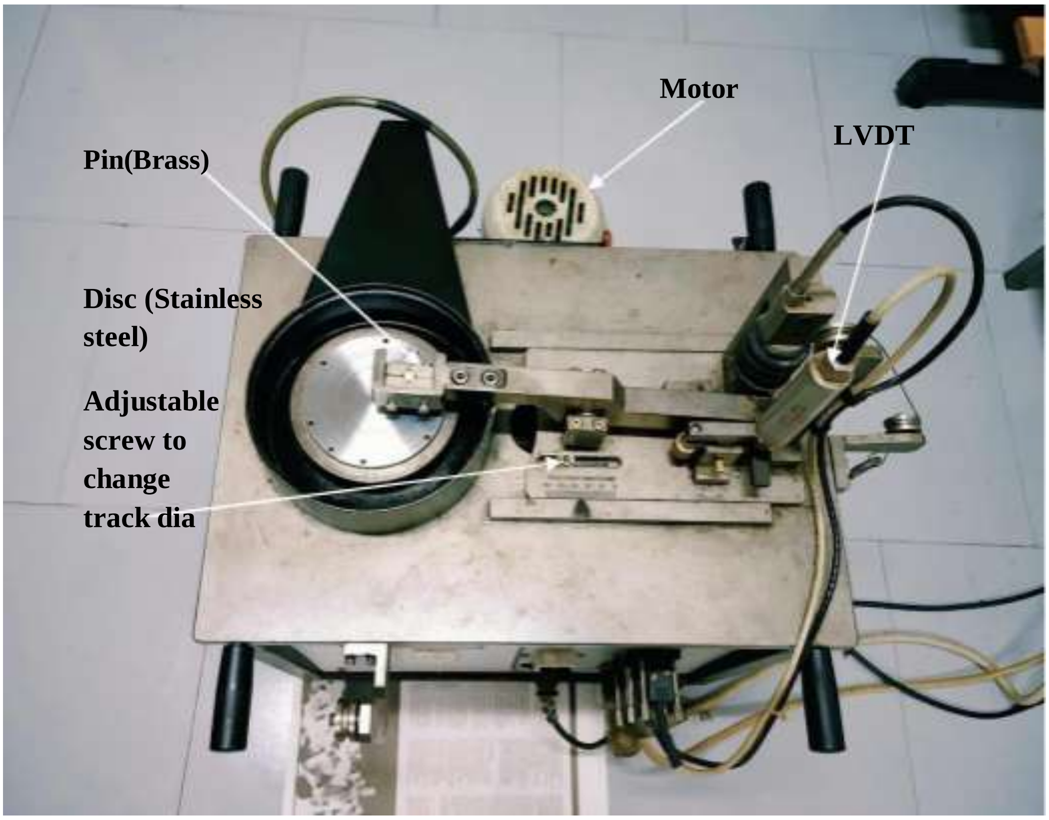

Fig. 4.1. Pin on disc Setup

The wear disc used for test is clamped on holder by screws. The driven pulley is fitted with a proximity sensor disc at spindle bottom. When spindle rotates the sensor, disc rotates along with it; a proximity sensor mounted perpendicular to this disc measures this rotation. The loading lever is made of a single bar with specimen holder fixed at one end and at the other end it carries a wire rope for suspending dead weights to apply normal load on the specimen, a counterweight balances the loading lever. The pivot point of the lever is fixed at one end of lever equals load on specimen disc at specimen end is directly measured by load cell at another end. The loadinglever assembly, pulley for loading pan, wear and friction force sensors are mounted on sliding plate assembly, this assembly moves over base plate to set wear track diameter, the wear track diameter is set by using the graduatedscale.

An adjusting block fixed on sliding plate is used to set specimen height with loading lever horizontal. A wire rope from the end of loading lever passes over pulley and at its bottom a loading pan is hung. Normal load is applied by placing dead weights on loading pan, for this set weights are provided along with machine, maximum load applied is 100 N. The specimen pin or ball is placed inside hardened jaws made of EN-31 material and clamped to specimen holder, to clamp different sizes of specimens' individual sizes of jaws are provided; separate jaws are provided for pin & ball. The specimen holder is mounted to loading lever by two screws. To prevent oil spillage, a lubrication chamber made of EN-31 material is fixed around the wear disc; it is also an environmental chamber when gas medium is used. IT is made of two parts for easy clamping / removing of specimen pin, the top part is leak proof chamber with toughened glass at top to view test progress with ports for inlet & outlet for gases port for lubrication pipe, port to pass steel wire for frictional force calibrations and entry port for loading lever. The bottom part is a cylindrical leak proof chamber with large outlet for draining oil during test, the gap at the entry port of loading lever is covered by a bellow to prevent oil leakage. The oil for test is supplied by a lubrication unit fixed at the base of machine. It consists of a lube tank with motor and pump, inlet pipe supplies oil to near specimen through polyurethane tube and outlet carries used oil to tank for recirculation. Wire gauge provided at entry port to tank collects

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debris and allows oil to flow through. A flow control valve adjusts oil flow and it can regulate up to 20 drops/min. An overflow valve allows oil to flow back to sump when discharge rate required is low.

Controller:
The machine shall be equipped with a revolution counter or its equivalent that will record the number of disk revolutions, and preferably can shut off the machine after a pre-selected number of revolutions

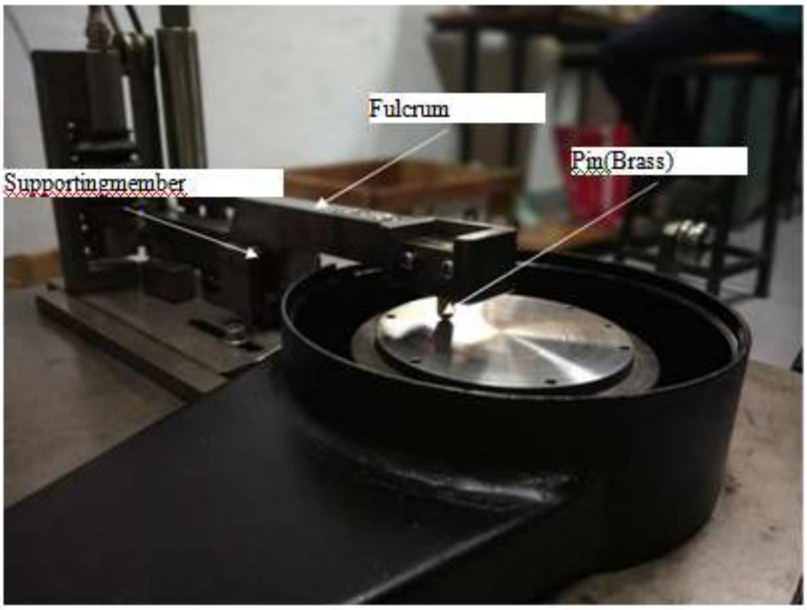

Fig.4.2. Arrangement of Pin on disc for experimentation

Data acquisitionsystem:
The signals from sensor after processing in controller are transmitted to pc and are displayed on software screen. The software used for acquiring these data are lab view based and installed in pc as Windcum 2008. The software has two screens one for acquiring and displaying data and other for post processed graph. The acquire graph display individual test parameters like wear and frictional force. The post processed screen displays a single parameter comparison.

LVDT (linear variable differentialtransducer):
A LVDT measures wear between specimen pin and disc, for this the sensor is mounted at exactly same distance of specimen from pivot point to get equal (1:1) lever ratio. The plunger of sensor rests on hardened pin projection from lever, during wear occurs at the loading lever lifts in upward direction pushing the plunger, this plunger movement as an indication of wear rate is sensed by LVDT as the plunger lifts up, and this movement is displayed as wear oncontroller.

The least count of LVDT is 0.1 micrometre, the initial position of plunger measurement is kept at mid-point to have both + ve & - ve wear readings. The LVDT is mounted on bracket mounted on sliding plate and moves along with it while setting wear track diameter, the maximum wear measures is between +2mm to-2mm.

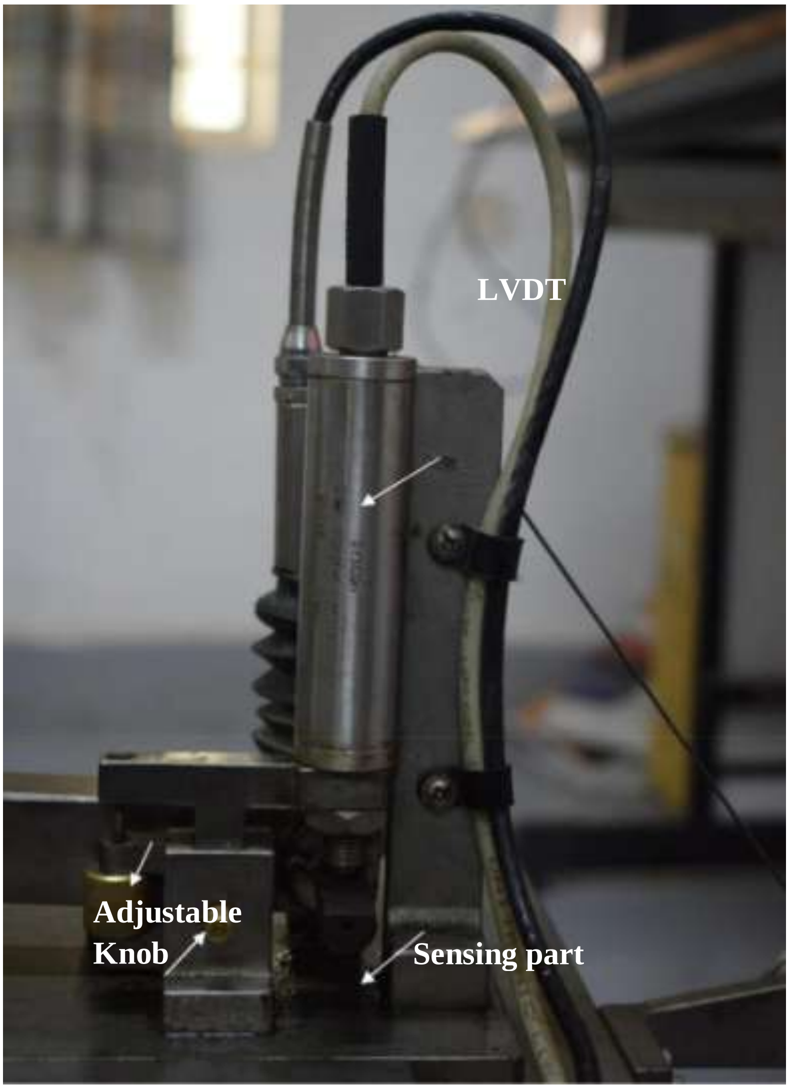

Fig.4.3. LVDT and frictional force load cell

Materials:
In the following session discussed about selected material for experiment and its specifications.

Materials ofpin:
The following table shows the properties of pin material

Table 4.1 Properties of pin material.

Material	Grade	Density g/cm3	Hardness	Ultimate Tensile
Brass	Pure	8.73	63.2(Rockwell hardness)	345

Dimensions: Pins of required dimensions are made using CNCmachine. The dimensions of pins are asfollows.

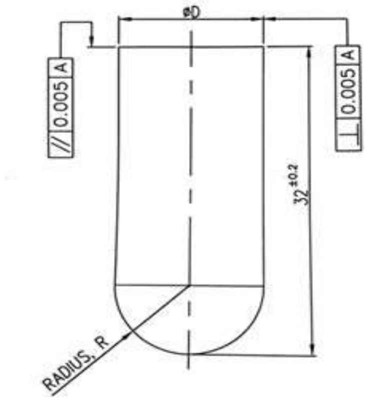

Fig.4.4 Dimensions of the Pins

Fig.4.5 Specimen Pins

Brass properties:-
Density : - 8.4 g\cm3 Thermal Conductivity: - 109 W\mk
Application: - Used for applications where low friction is required, such as lock Gears, bearings and other electrical applications.

Material of Disc:
The following table tell about properties of material (stainless steel)

Table 4.2. Properties of disc material

Material	**Grade**	**Hardness**	**Strength(MPa)**
Stainless steel	TYPE304	70(Rockwell)	505

Dimensions: Disc of required dimensions are made using manuallathe. The dimensions of disc are asfollows.

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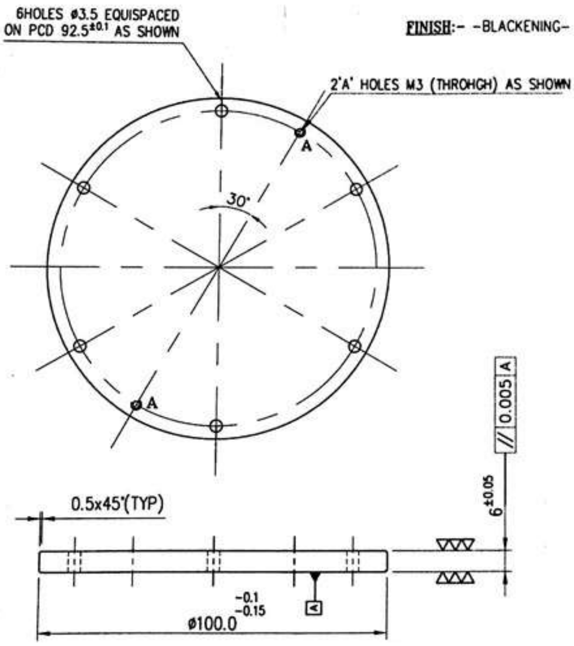

Fig.4.6 Dimensions of the Disc

Fig.4.7 Specimen Disc

Stainlesssteel:
Stainless Steel is an alloyed medium carbon steel grade with reasonable tensile strength and better strength than mild steel.

Experimentation

The following discussed about experimentation.

Technical data &specification

In the following are showed about specifications of machine.

Table 4.3 Machinespecifications

S. No	Parameter	Specification
1.	Wear disc diameter	Diameter 100 mm,6 to 8mm thick
2.	Pin diameter, length	4 to 8mm diameter in steps of 2mm, 20-30mm
3.	Ball diameter	10mm
4.	Wear track diameter	Min 50mm&max 80mm, infinitely variable
5.	Disc speed	Min 100rpm,max 1000rpm
6.	Normal load	Min 10N,Max 100N
7.	Frictional force	Max 100N
8.	Wear	0 to 2000 micron
9.	Test duration	99.59.59hrs

Table 4.4 Machine elementspecification

Overall size	560 x 460 x680mm	
Base plate height from floor	420mm	
Max height above base plate	200mm	
Base plate size	460 x 320 x 15mm thick	
Loading lever length	280mm	
Environmental chamber lower chamber fixed on base plate with slot on side for calibration unit &loading Lever. The upper half chamber has ports for gas inlet & Lubrication tube.	Diameter 150 x 70mm height	Two halves chamber, with passing frictional force
Lubrication motor	Make-Eltek, 0.1Hp, 1.0A ,230V	
Oil re-circulation unit 1lpm, pressure 6bar	Poly carbide motor	Size:3lit capacitywith gear pump,0.1Hp,discharge Rate
Total machine weight	89kg	Basic m/c=63kg, dead wts=13kg,controller=-13kg

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Table 4.5 Electrical specification & powerrequirement

Electricity required	230/1/50,5A
Power consumption	0.5KW
AC motor specification	0.5hp,1380rpm, 1.05A,flange mounting, make: Seimens
VF drive specification	230V, 0.5hp, make: OPTI DRIVE
MCB specification	C6, 2pole, make : indokupp

Procedure forExperimentation
The following are discussed about procedure for experimental setup of POD and Controller. Also discussed about, operation of software (WINDCUM 2010).

Pin on disc setup forExperimentation
The following are discussed about procedure for setup wear disc, specimen pin and wear track diameteretc.,

1. Clamping of weardisc:
The following are discussed about procedure of clamping of wear disc.

Procedure:
1. Clean wear disc thoroughly with solvent and allow it todry.
2. Clean the top face of wear disc holder thoroughly with solvent anddry.
3. Place wear disc over the disc holder and tighten 4 allen screws byhand.
4. using special allen key, for tighten all the screwsfirmly.

2. Clamping of specimen pin:
Specimen pin is clamped to loading lever tip by hardened jaws 4, 5, 6 &8 mm holders and clamp cylindrical specimen pins.

Procedure:
1. Clamp specimen pin inside hardened jaws and clamp by tightening by 2screws.
2. Tighten hardened jaws to specimen holder on loading lever by 2screws.
3. Slide the adjusting block below loading lever, loosen two screws on hardened jaws, allow specimen pin to touch the wear disctop.
4. The specimen pin projects by 5 mm from hardened jaws and in this condition the loading lever is parallel to base plate. Tighten 2 screws on hardened jaws to clamp specimenpin.

3. Set wear track radius: The path generated is circle, so the specimen pin can be positioned over wear disc between 50- & 80-mm dia. This can use the wear disc between each grind for many tests by positioning the specimen pins at different diameters (wear track diameter) on wear disc.

Procedure:
1. Unscrew to loosen the sliding plate, move it to position at 80 mm by looking at the graduatedscale.
2. Clamp screw at thisposition.

4. Applying normal load:
Place required weights on loading pan slowly without shaking.

Controller setup forExperimentation
The following are discussed about procedure for setup speed, set up time, wear rate and frictional force on controller.

Prepare controller for test:
1. Switch ON toggle switch to supply power tocontroller.
2. Allow 5 minutes to stabilize all electronic items insidecontroller.
3. Rotate the potentiometer knob (set rpm) in counter clockwisedirection.
4. Check for display of wear, frictional force, speed and time, some random values will be displayed for wear and frictional force, before start of test these values have to bezero.

Initializing sensor displays:
The following are discussed about procedure for setup of wear and frictional force etc.,

1. Procedure for wear display:
1. Loosen LVDT lock screw, rotate thumb screw to bring LVDT plunger visually to mid position the wear reading display on controller should be as near tozero>
2. Initialize wear display to “0” by pressing “ZERO” push button oncontroller.

2. Procedure for frictional force display:
1. Move loading arm away from frictional force load cell button and press frictional force “ZERO” button on controller.

3. Setting disc speed:

1. Set 3 min time oncontroller.
2. Press test start push button androtate.
3. Set rpm knob on controller in clockwise direction till required test speeddisplayed.
4. Continue to run for the remaining time to observe for anyfluctuation.
5. Press stop button on controller to switch offrotation.

4. Setting test duration oncontroller:

Test duration is set either in time mode (set in hr., min & sec) or counter mode (set in no of cycles max is 1,00,000 cycles). Mode selection is by the toggle switch below timer display, the switch position indicates selection as either time or counter.

5. For setting revolution (countermode):

Move toggle switch to counter position using set and enter push button, enter the no of cycles required.

6. For settingtime:

Enter the required data of duration of test in time mode using set and enter push buttons.

Data entry takes place from the last digits i.e., seconds, minutes and hours (two digits each separated by a decimal point) or counts to eight digits.

Enter push button is used to shift flashing display on time window on controller from last digit to 2^{nd}last digit,3^{rd}, 4^{th}digit and so on. Set button is used to increase display value by pressing once.

Procedure:

1. Initially last digit timer display will beflashing.
2. Press once ENTER button to shift flashing display to nextdigit.
3. Press once SET button to increase the displayedvalue.
4. Now display valueshows.
5. To setvalues.
6. Initially all display values are zero and last digit on display will beflashing.
7. Press SET button till displayshows.
8. Press ENTER button, flash from last digit display shifts to 2^{nd}lastdigit.
9. Press SET button till displayshows.
10. Similarly repeat till values areset.

Procedure for lubricationtest:

1. Pour Lubricant (minimum 1 litre) in the lubricantsump.
2. Connect the lubrication unit electric plug to 5A socket onmachine.
3. The discharge of oil is regulated by tuning the flow control valve, close the valve to decrease flow and viceversa.
4. The oil pressure is set by pressureregulator.
5. Place the lubricant pipe in the hole before starting the motor or switch on where both pin and disc isthere.

Setting of computer for dataacquisition:

1. Connect the data acquisition cable from controller topc.
2. Open the software Windcum 2010 on pc.
3. Click on mode run continuously icon on software screen to activatescreen.
4. Click on ACQUIRE tool bar at screen top to open acquiringscreen.
5. Enter a name on file namewindcum.
6. In the cell for sample ID, enter the material of the specimen and itsdimensions.
7. Fill the remaining empty cells for speed, load, wear track also data sampling rate required (the default value is 60, which is suitable only when switch is in timer in acquirecontrol)
8. In the remarks cell, enter dry test, duration of test, speedetc.
9. Click START button in pcwindow.

Test start:

1. Press START push button on the controller front panel to commence the test and send data topc.
2. On controller the acquired test parameters like wear, frictional force and speed are displayed, analog data is converted into digital and pre-processed in the instrumentation card. It is serially transmitted to through RS232 data acquisition cable. The data is received, displayed and stored on the pc using lab view based software Windcum2010.

Test stop: The test stops automatically after the elapse of pre-set time or count. The system can also be manually stopped, by actuating the STOP button.

Data acquisition and data processing:

Refer to Windcum 2010 operation manual for installation and operation of software.

Post-test evaluation:

- The online wear on specimen is always not taken as actual wear, when actual wear is required the mass loss method has to beadopted.
- To measure wear using mass loss the specimen is weighed before and after test on highly accurate weighing balance having least count of0.0001mg.

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- On software for post evaluation of result two screen views file and compare files are provided.
- On view file the test parameters of single test file aredisplayed.
- On compare file same test parameters of 4 test files can beviewed.

Graphsprocedure:
After set up Time completed
(a) Twographs:
1. Go tofile
a. Click printwindow
b. PDFcreator
c. Print
(b) Threegraphs:
1. View file (besides of labelACQUIRE)
a. Click on “open datafile”
b. Select your file ondirectory
c. click on“ok”
d. give your “filename”
2. Then
3. Go tofile
a. Click printwindow
b. PDFcreator
c. Print

V. RESULTS AND DISCUSSIONS

Sunflower oil and additives (biodiesel and ZnO) were experimented using Pin on disc apparatus. Tests under dry conditions and base oil with/without additive were used as reference in order to analyse the influence of vegetable oil lubricant, its biodiesel and nanoparticle added lubricant on the wear of metallic surface.
The wear rate, frictional force and coefficient of friction for all lubricants are displayed in Fig. 5.1-5.9, also for comparison effect, presents the wear rate, frictional force and coefficient of friction at three loads (1, 3 & 5kgf) and three speeds (300, 500 & 700 rpm). The performance of lubricant without and with additives wasevaluated.

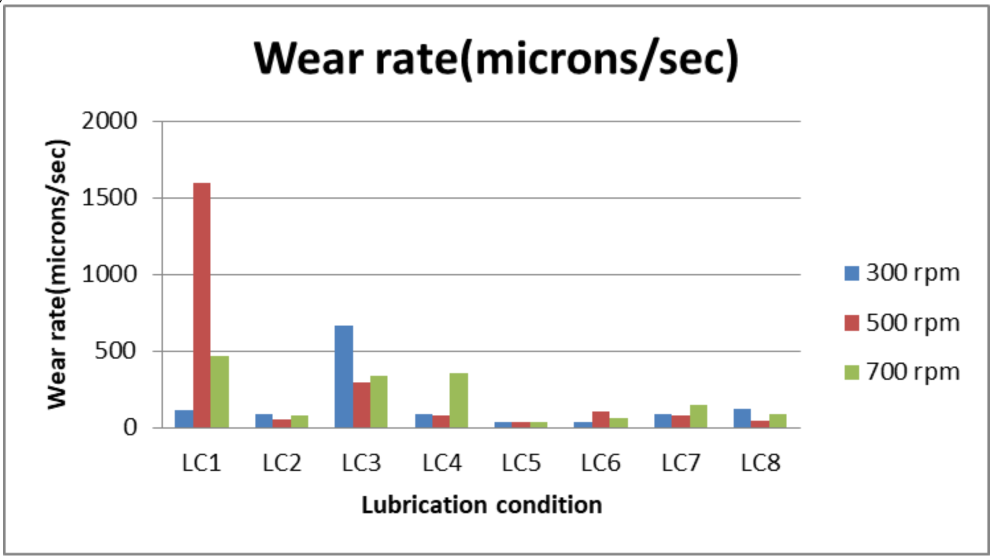

Fig 5.1 Wear rate (microns/sec) at1kgf

From the **Fig 5.1** it is observed that the wear rate was increased by increasing speed for conditions of lubrication. This is rapid contact of surfaces area. Out of eight conditions, dry lubricant condition (LC1) has given maximum wear rate. The raw oil (LC2) has given lesser wear rate than dry condition but giving higher than Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC5 (Raw oil (80%) +B20+Nano 1(0.5%)), has given lesser wear rate than all conditions and comparatively giving 43% less under low speed and 50% less under highspeed.

From the **Fig 5.2** As above (at 1kgf) similar trend of wear rate was observed with respect to speed. Out of eight conditions dry lubricant condition (LC1) has given maximum wear rate as usual, interestingly, the raw oil (LC2) has given lesser wear rate compared to other lubricant conditions. Under low speed and high-speed conditions a 29% and 26% lesser wear rate was observed with LC2 compared to dry lubricantconditions.
From the **Fig 5.3** it is observed that out of eight conditions, the dry lubricant condition (LC1) has given maximum wear rate, the raw oil (LC2) has

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given lesser wear rate than dry condition but it is higher than that of Nano lubricant condition. The LC8 (Raw oil (60%) +B40+Nano 2(0.2%)) has given lesser wear rate than all conditions. It is 60% lesser under low speed and LC7 (Raw oil (80%) +B20+Nano 2(0.2%) has given 56% lesser wear rate under high speed condition. This is because of the higher proportion of Nanoadditive.

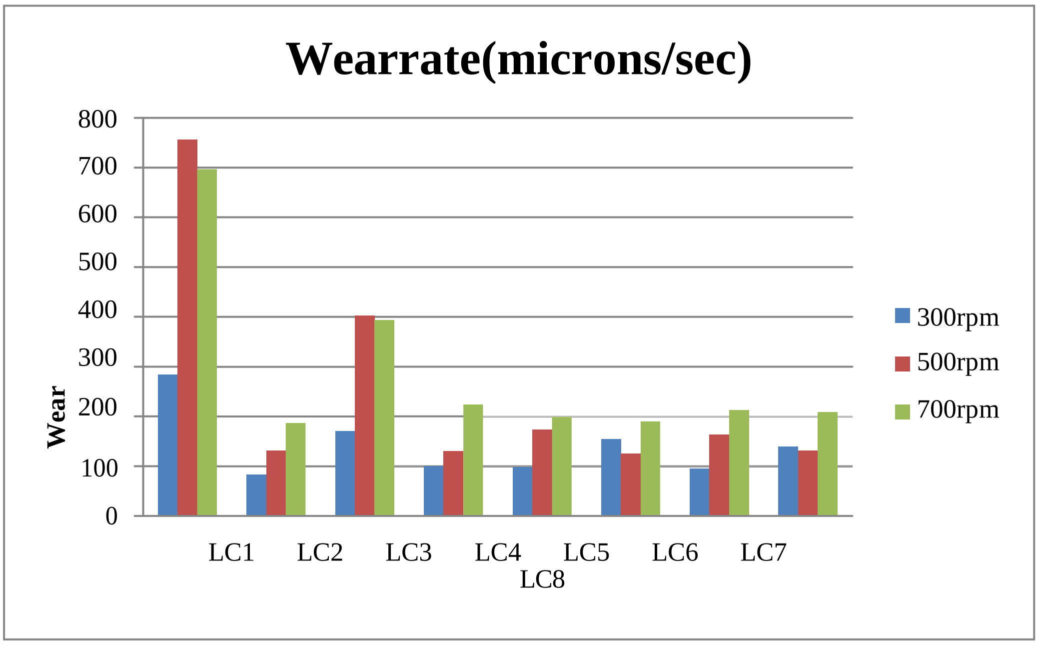

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Fig 5.2 Wear rate (microns/sec) at 3kgf

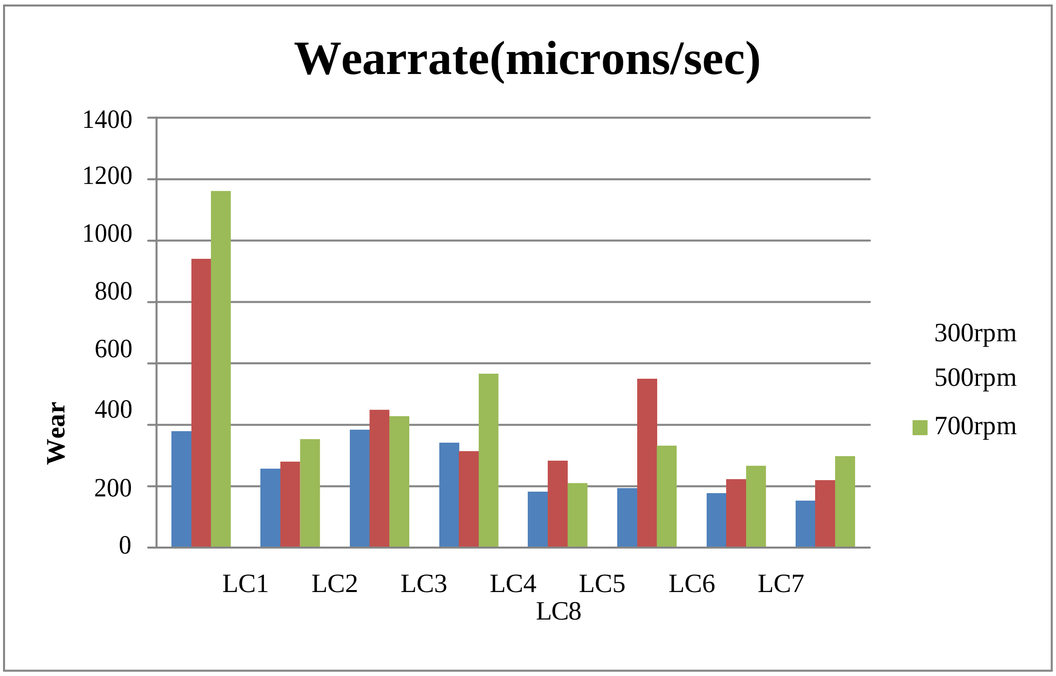

Fig 5.3 Wear rate (microns/sec) at 5kgf

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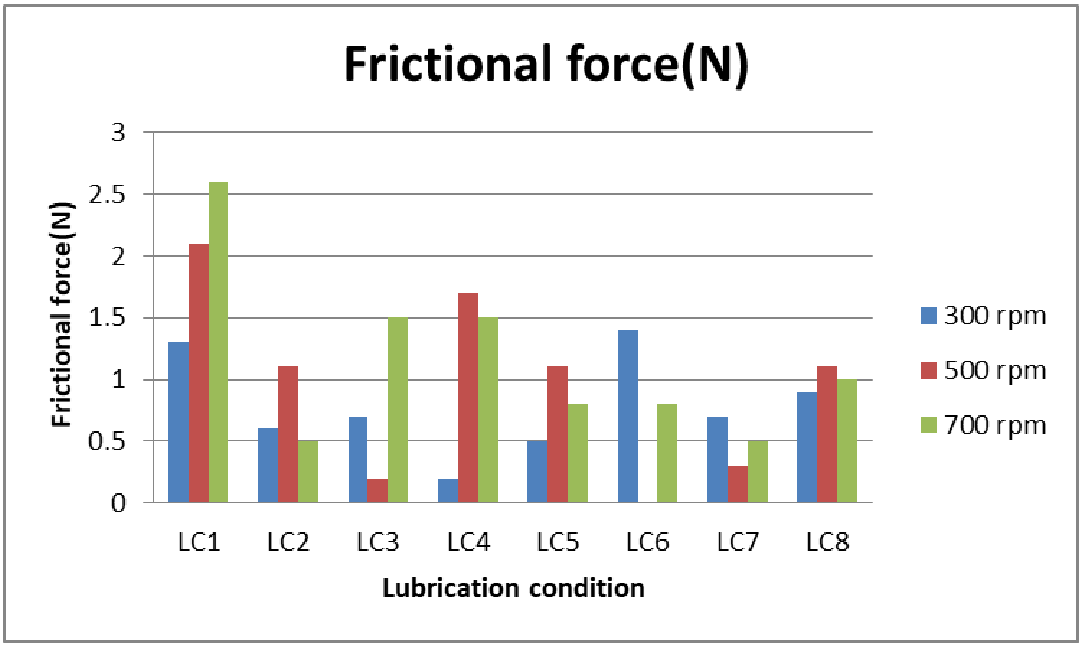

Fig 5.4 Frictional force (N) at 1kgf

From the **Fig 5.4** it is observed that the frictional force was increased by increasing speed for conditions of lubrication. This is rapid contact of surfaces area. Out of eight conditions, dry lubricant condition (LC1) has given maximum frictional force. The raw oil (LC2) has given lesser frictional force than dry condition but giving higher than Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC5 (Raw oil (80%) +B20+Nano 1(0.5%)), has given lesser frictional force than all conditions and comparatively giving 83% less under low speed and LC7 (Raw oil (80%) +B20+Nano 2(0.2%), raw oil are giving same frictional force under high speed.

From the **Fig 5.5** As above (at 1kgf) similar trend of frictional force was observed with respect to speed. Out of eight conditions dry lubricant condition (LC1) has given maximum frictional force as usual. The raw oil (LC2) has given lesser frictional force than dry condition but giving higher than Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC6 (Raw oil (60%) +B40+Nano 1(0.5%)), has given lesser frictional force than all conditions and comparatively giving 70% less under low speed and 76% less under highspeed.

From the **Fig 5.6** it is observed that out of eight conditions, the dry lubricant condition (LC1) has given maximum frictional force, the raw oil (LC2) has given lesser frictional force than dry condition but it is higher than that of Nano lubricant condition. The LC6 (Raw oil (60%) +B40+Nano 2(0.5%)) has given lesser frictional force than all conditions. It is 82% lesser under low speed and 50% less under high speed. This is because of the higher proportion of Nano additive**.**

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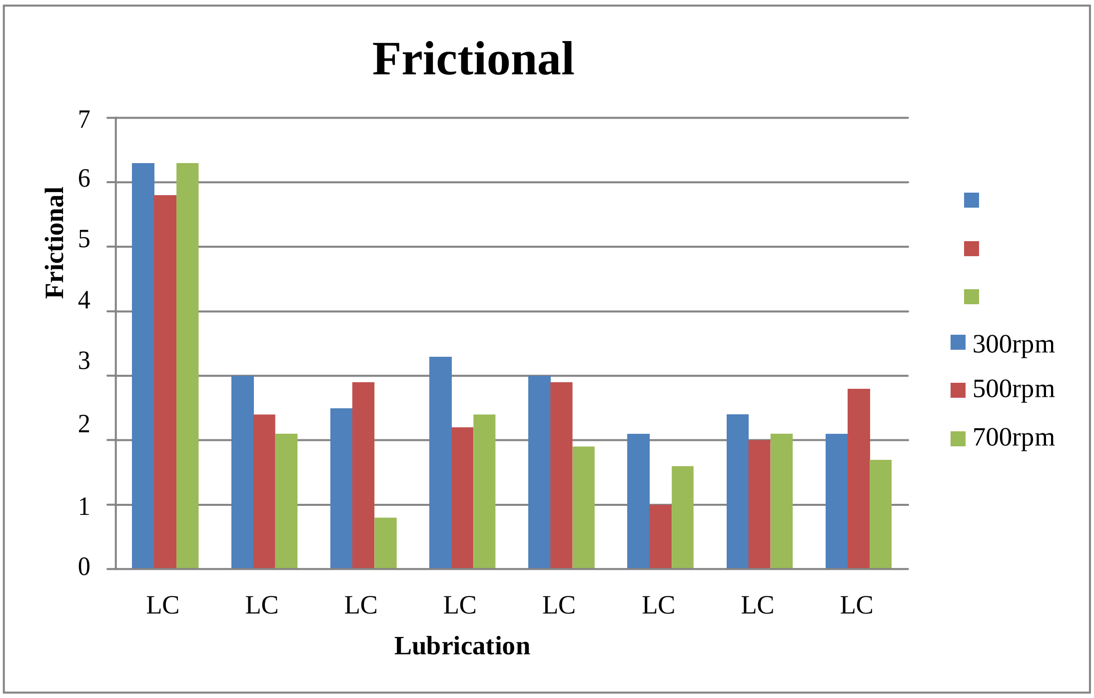

Fig 5.5 Frictional force (N) at 3kgf

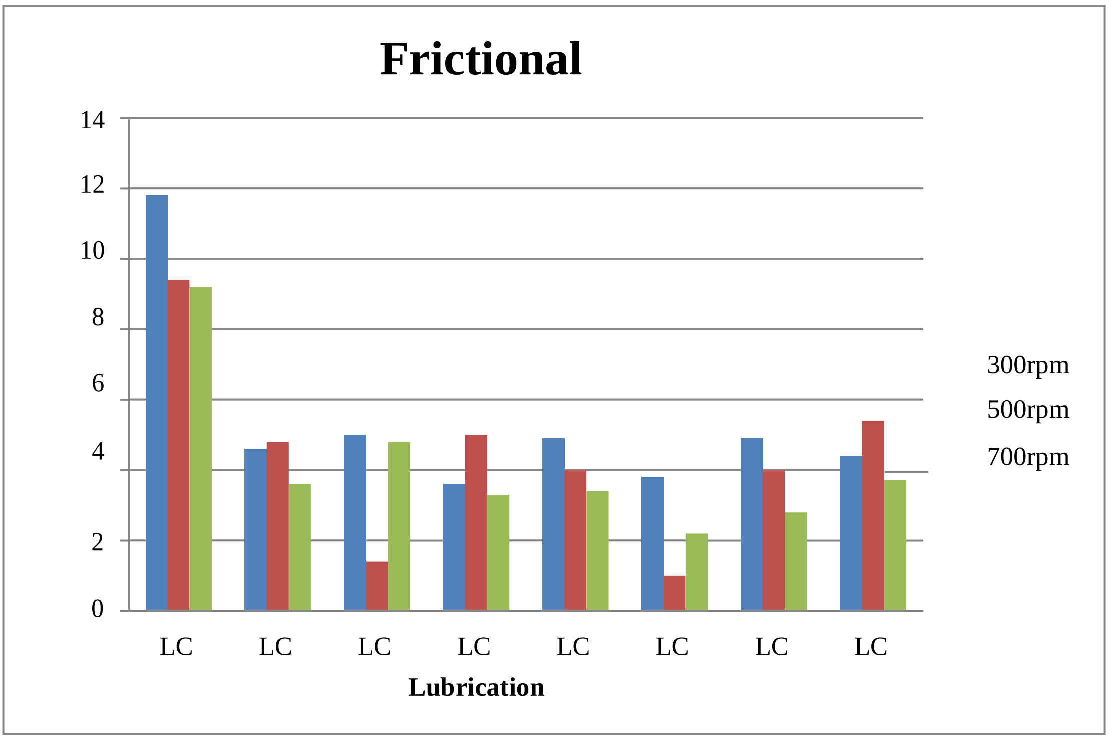

Fig 5.6 Frictional force (N) at 5kgf

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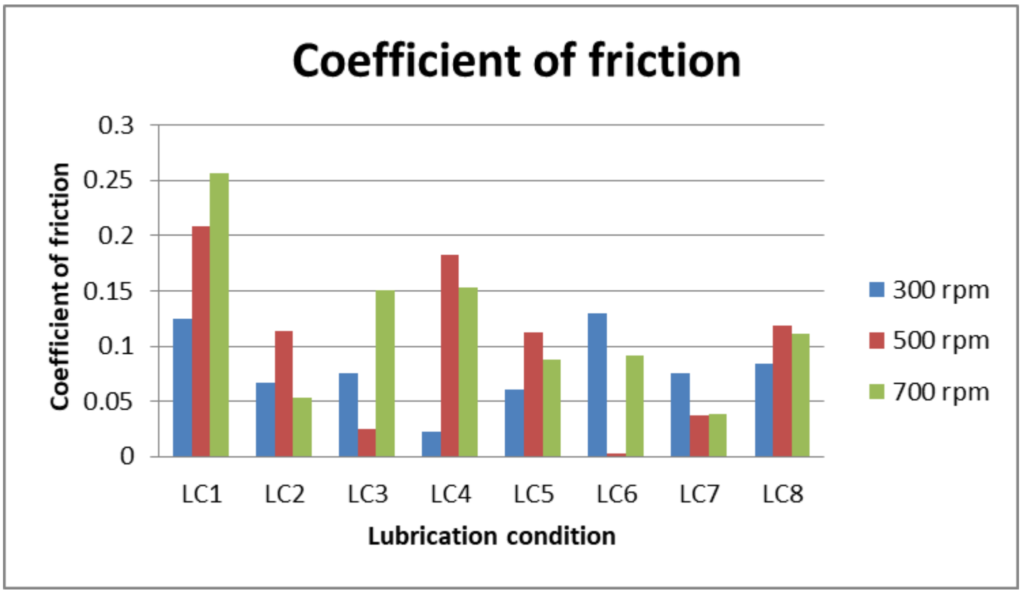

Fig 5.7 coefficient of friction at 1kgf

From the **Fig 5.7** it is observed that Out of eight conditions, dry lubricant condition (LC1) has given maximum coefficient of friction. The raw oil (LC2) has given lesser coefficient of friction than dry condition but giving higher than Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC5 (Raw oil (80%) +B20+Nano 1(0.5%)), has given lesser coefficient of friction than all conditions and comparatively giving 91% less under low speed and LC7 (Raw oil (80%) +B20+Nano 2(0.2%) has given 73% lesser coefficient of friction under high speed condition.

From the **Fig 5.8** it is observed that Out of eight; dry lubricant condition (LC1) has given maximum coefficient of friction as usual, raw oil (LC2) has given lesser than dry condition but giving higher than Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC8 (Raw oil (60%) +B40+Nano 2(0.2%)), has given lesser coefficient of friction than all conditions and comparatively giving 72% less under low speed and LC6 (Raw oil (60%) +B40+Nano 1(0.5%) has given 62% lesser coefficient of friction under high speedcondition.

From the **Fig 5.9** it is observed that Out of eight; dry lubricant condition (LC1) has given maximum coefficient of friction, raw oil (LC2) has given lesser than dry condition but it is higher than that of Nano lubricant condition. As compared to in raw oil lubricant condition, The Nano lubricant conditions LC7 (Raw oil (80%) +B20+Nano 2(0.2%)), has given lesser coefficient of friction than all conditions and comparatively giving 38% less under low speed and LC6 (Raw oil (60%) +B40+Nano 1(0.5%) has given 56% lesser coefficient of friction under high speed condition. This is because of the higher proportion of Nanoadditive.

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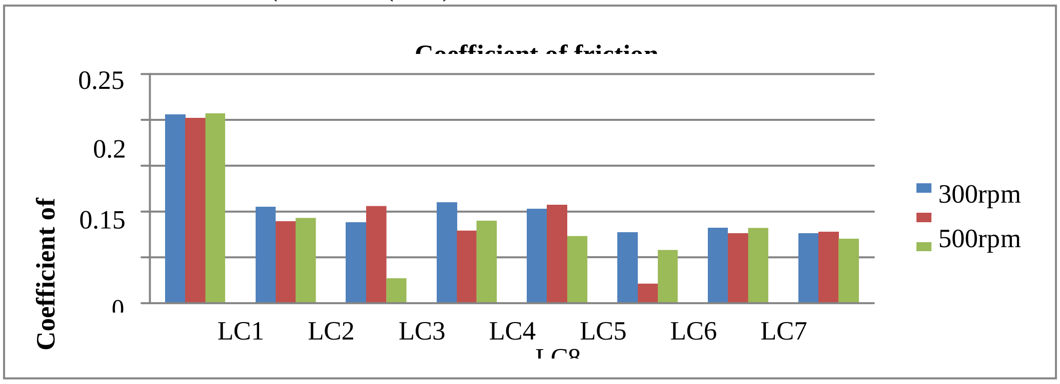

Fig 5.8 coefficient of friction at 3kgf

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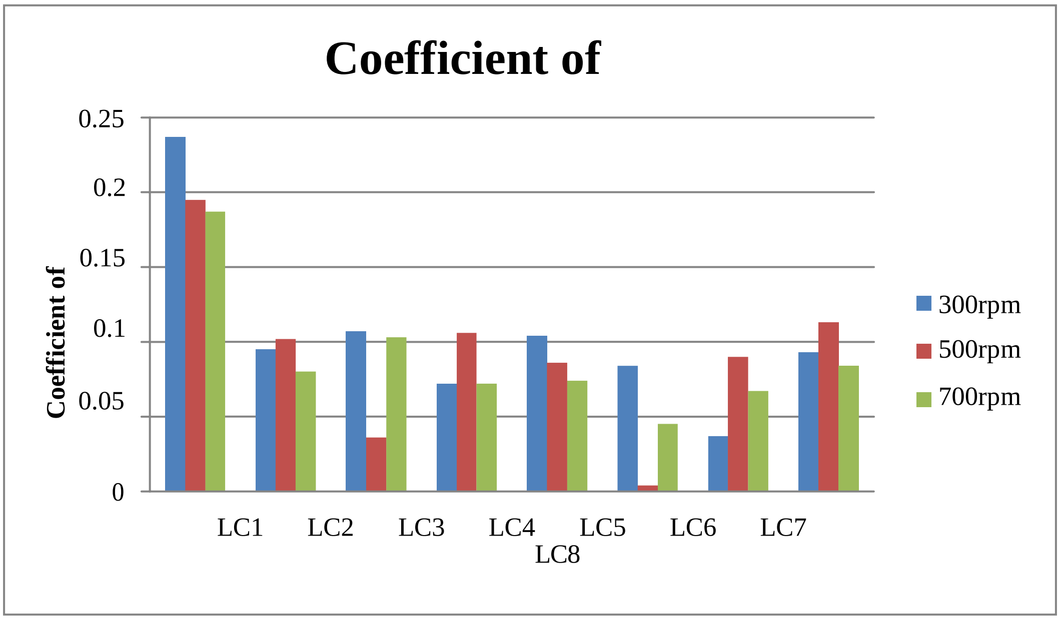

Fig 5.9 coefficient of friction at 5kgf

The wear rate, frictional force and coefficient of friction are shows the high value, mainly for dry conditions. While test under the lubricant conditions. Base oil (sunflower oil) shows the least value than dry conditions because of less frictional force and coefficient of friction due to viscous nature. Nano lubricant shows least value than base oil and dry lubricant because addition of ZnO nanoparticles, the wear rate, frictional force and coefficient of friction significantly decreases compared with base oil and dryconditions.

VI. CONCLUSIONS

The objective of present study is to investigate the effect of bio-Nano lubricant to reduce the wear and frictional properties. The experiments are carried out using POD Tribometer by considering Stainless Steel as disc material and Brass as pin material. Based on the results of these experimental investigations, the following conclusions are made.

[1]. Wear rate increases with increase in speed and load.

[2]. Base oil (sunflower oil) shows the less wear rate than dry conditions because of less frictional force and coefficient of friction due to viscous nature.

[3]. Nano lubricant gives lesser wear rate than base oil and dry lubricant because addition of ZnO Nanoparticles. From Nano LC5 is giving least wear rate under low load and both low and high-speed conditions. And LC8 is giving less wear rate under high load and low speed condition and LC7 is giving less wear rate under high load and high-speed condition.

[4]. Frictional force increases with increase in speed and load.

[5]. Base oil (sunflower oil) shows the less frictional force. Nano lubricant shows less value than base oil and dry lubricant because addition of ZnO Nanoparticles.

[6]. From Nano LC5 is giving less frictional force under low load and low speed condition and LC7 is giving less wear rate under low load and high-speed condition. And LC6 is giving least frictional force under high load and both low and high-speed conditions.

[7]. Coefficient of friction does not depend on speed or load but it depends on type of surface.

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