SYNTHESIS, CHARACTERISTICS AND TRIBOLOGICAL PROPERTIES OF NANOMATERIAL IN NANO LUBRICANT

Ajithkumar K[1], Dr Muthukumar K[2]

[1]PG Student, Industrial Safety Engineering, Bannari Amman Institute of technology, Tamil Nadu, India
[2]Professor, Industrial safety Engineering, Bannari Amman Institute of Technology, Tamil Nadu, India

---***---

Abstract -

To minimize the frictional power losses in automotive engines, it is imperative to improve the tribological characteristics of the engine lubricant. This study examined the tribological characteristics of Nano lubricant using nanoparticles as Nano-lubricant additives. The average size of Fe_2O_3 nanoparticles were 8–12 nm respectively. The nanoparticles were suspended two different concentrations in the 15W-40 CI 4 engine oil (0.3 and 0.5wt%) by using magnetic stirrer and ultra sonicator. The tribological behavior of Nano-lubricants was evaluated using pin on disc under different operating conditions. The results showed a decrease in Wear and increase in viscosity, thermal conductivity, Flash & Fire point. The study provides insights into how Nano-lubricant additives could contribute towards energy saving and improve wear resistance.

***Key Words*: Base oil, Nano material, Wear, Tribological properties.**

1. INTRODUCTION

The most important key challenge in modern automotive developments is the reduction of friction power losses. Engine is the heart of an automobile which produce power required for operating a vehicle etc. Engine converts chemical energy or fuel in vaporization to mechanical work piston will be the major component used for transmitting power from burning of fuel to crank shaft. Piston will slide on the inside surface of the cylinder in the sliding friction will happen between the surfaces. Friction with high temperature will lead to wear on both piston outside surface and cylinder inside surface. Piston rings are provided to reduce wear on piston surface. During the timing on power stroke heat produced in the engine will more than 1000ºC. Lubrications will provide on the engine will reduce the heat production on the engine but in the high temperature and heavy work load cases base oil will not sufficient to meet the required lubrication rate.

So, researchers will try to develop Nano lubricant additives to meet the sufficient lubrication rate. Nowadays, smart lubricants consist of base oil blend with special additive packages to protect and control the piston against friction and wear under conditions like extreme pressure and temperature. The use of nanomaterial's as a lubricant additive in tribology management is widely explored in recent years due to their small size and large surface area. An improvement in the tribological performance of the lubricating oils leads to an improved efficiency and fuel economy of engines because the friction between the piston ring and the liner accounts for almost 40–50% of the power losses. Furthermore, controlling friction via the use of Nano-lubricants leads to a decline in the level of wear and an increase in the service intervals for which an oil change is required. This ultimately translates into minimized maintenance costs.

Furthermore, the lower elastic modulus and the comparatively higher magnitude of hardness possessed by Nanomaterial's can be considered as the main reasons for the excellent lubricating properties. TATA 15W-40 CI 4 is the base oil used in this research.it is a heavy-duty engine oil is recommended to use for a truck, heavy vehicles and agricultural vehicles.

2. MATERIAL USED

It is one of the three main oxides of iron, the other two being iron (II) oxide (Fe_2O_3), which is rare; and iron (II,III) oxide (Fe_3O_4), which also occurs naturally as the mineral magnetite. As the mineral known as hematite, Fe_2O_3 is the main source of iron for the steel industry. Fe_2O_3 is readily attacked by acids. Iron (III) oxide is often called rust, and to some extent this label is useful, because rust shares several properties and has a similar composition. To a chemist, rust is considered an ill-defined material, described as hydrated ferric oxide. Fe2O3 can be obtained in various polymorphs. In the main ones, α and γ, iron adopts octahedral coordination geometry.

PURE COPPER

Table-1 properties of Fe_2O_3

Chemical formula	Fe_2O_3
Appearance	Red-brown solid
Odor	Odorless
Density	5.242 g/cm3[1]
Meltingpoint	Decomposes 50 °C (122 °F; 323 K) α-dihydrate
Solubility in water	Insoluble
Solubility	Soluble in diluted acids, sugar solution Trihydrate slightly soluble in aq. tartaric acid, citric acid, CH3COOH
Magnetic susceptibility (χ)	+3586.0·10−6 cm3/mol

Table 2 Properties of copper

Boiling Point	2567˚ C
Density @ 20˚ C	8.96 g/cm3
Melting Point	1083˚ C
Hardness-Vickers	49
Izod Toughness	58
Tensile Strength	224
Thermal Conductivity, @ 0 - 100˚ C	401 W/m-K

Pure copper and some selected copper alloys are widely used in experimental plasma confinement devices and have also been proposed for various fusion power plant applications where a high thermal or electrical conductivity material is required. Copper based alloys have been considered as possible candidate materials for first wall, limiter and divertor components and as field coils and stabilizers for coils in magnetic confinement fusion devices. Their use as a first wall material has been proposed in designs where high thermal loads are expected on the first wall or where a shell of high electrical-conductivity material is required. Copper alloys have also been considered for the electrically-conducting central column of the tight aspect ratio tokamaks. The main advantage of copper alloys lies in their high thermal conductivities, which allows for higher heat fluxes.

3. METHODALOGY

SYNTHESIS OF FERROUS OXIDE

The γ-Fe_2O_3 nanoparticles were synthesized under the oxidizing environment as follows $FeCl_36H_2O$ and $FeSO_47H_2O$ (2:1 w/w) were dissolved in 40 mL H_2O and sonicated for 1 minute. Then the solution was stirred in a water bath at 80 C for 5 min at 500 rpm. After that, 5 mL of NH_4OH (25–29%) was added into the solution at once and stirred further for 1 h. After 1 h, the formed nanoparticles were washed with acetone: methanol dried at 50 C for 10 h, obtaining the γ-Fe_2O_3 nanoparticles. The Nano particles are shown in figure.

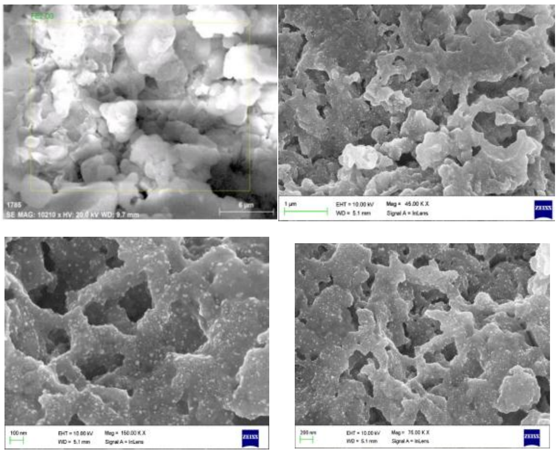
Fe_2O_3 Nano particles

After that, 5 mL of NH_4OH (25–29%) was added into the solution at once and stirred further for 1 h. After 1 h, the formed nanoparticles were washed with acetone: methanol (1:1) solution 5 times. The sample was then vacuum dried at 50 C for 10 h, obtaining the γ-Fe_2O_3 nanoparticles.

4. RESULT AND DISCUSSION

4.1 SEM

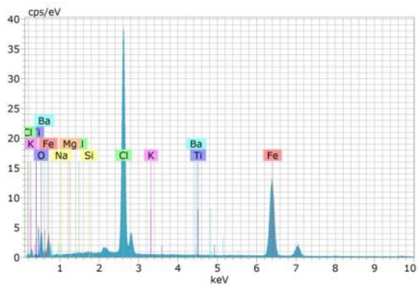
The surface morphology of iron oxide nanoparticles was investigated by SEM. It is clear from the FE-SEM images that the synthesized products are NPs, which grown in a very high-density and possessed non-uniform shape presented in Figure.



The micrograph obtained for the concentrated solution show that the particles were not of same sizes the diameter of iron NPs is calculated in the range of 50-90 nm where the average diameter of iron oxide NPs is close to 60 ± 10 nm.

4.2 EDX

The surface morphology of iron oxide nanoparticles was investigated by and EDX analyses. EDX analysis reported in Figure showed that the respective percent weight of oxygen and iron on the surface of iron oxide nanoparticles was found to be 22.07 and 77.93 %. The EDX data displayed only the peaks for Fe and O atoms which thus confirmed the absence of any impurities during the preparation of desired material.



Spectrum: FE2 O3

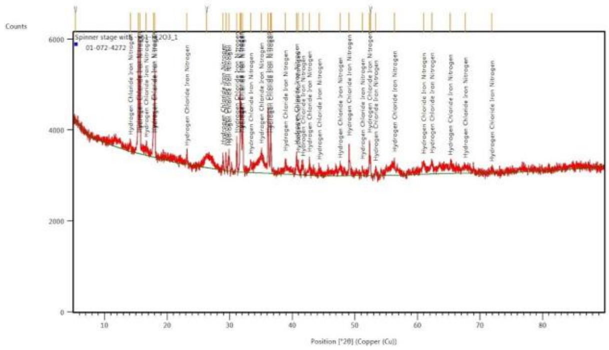
Element	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Compound	norm. Comp. C [wt.%]	Error (3 Sigma) [wt.%]
Oxygen	10.70	14.66	32.70		0.00	4.98
Iron	36.85	50.48	32.26	FeO	64.94	3.06
Silicon	0.04	0.05	0.07	SiO2	0.12	0.09
Aluminium	0.08	0.11	0.15	Al2O3	0.21	0.10
Titanium	0.02	0.03	0.02	TiO2	0.05	0.09
Barium	0.08	0.11	0.03	BaO	0.13	0.10
Potassium	0.03	0.04	0.03	K2O	0.05	0.09
Sodium	0.00	0.00	0.00	Na2O	0.00	0.00
Magnesium	0.00	0.00	0.00	MgO	0.00	0.00
Chlorine	25.19	34.51	34.74		34.51	2.62
Total:	72.99	100.00	100.00			

Present Element in Nano Particle

Figure 2 shows the Nano particles contain 64% of Fe O and the next major content chlorine are present 34.5% total weight.

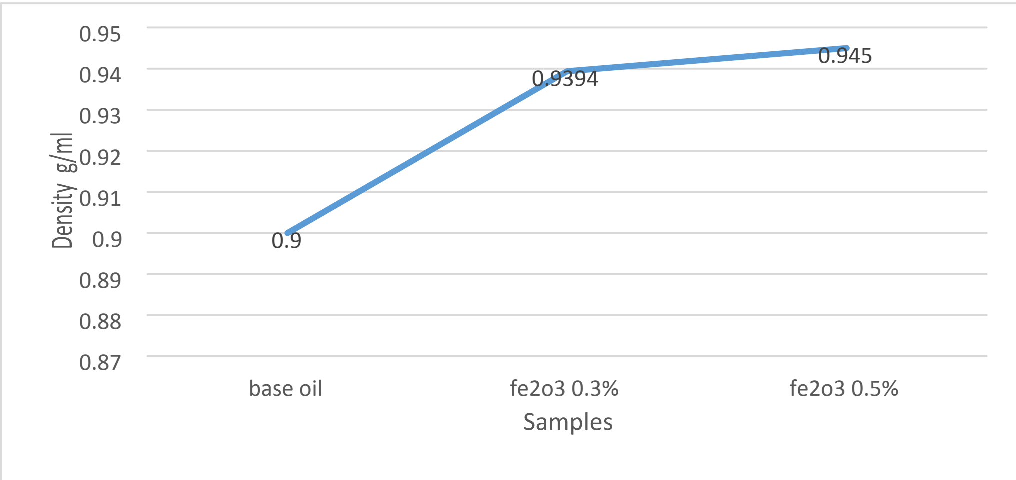
4.3 XRD

X-ray diffraction yields the atomic structure of materials and is based on the elastic scattering of X-rays from the electron clouds of the individual atoms in the system. The most comprehensive description of scattering from crystals is given by the dynamical theory of diffraction X-ray diffraction can be used to determine which iron oxide compounds are present in NPs by calculating or comparing with the standard value of lattice parameters, crystal structures and crystallinity. The test were conducted in position of 20 degree. The XRD patterns of α-Fe_2O_3 powders synthesized using different surfactant concentration values are displayed in Figure.



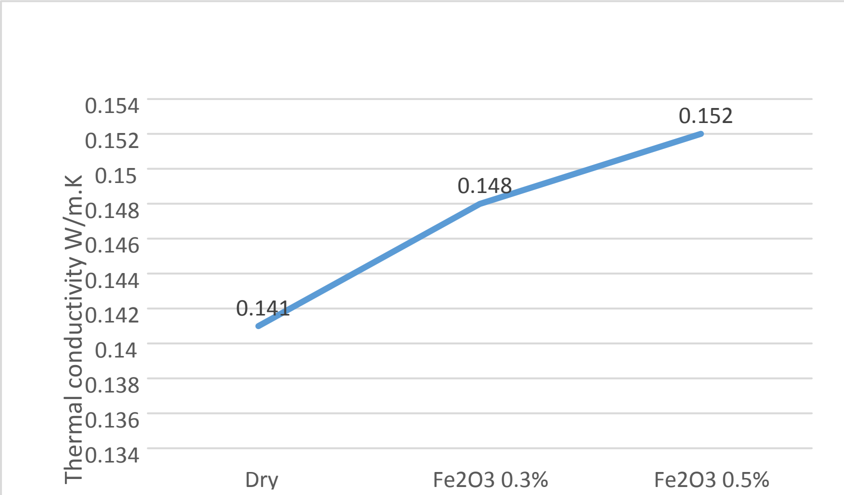
4.4 DENSITY

Density for Fe_2O_3 0.3% are improved to 4.377% and for Fe_2O_3 0.5% are improved to 5% when compare with base oil.



4.5 THERMAL CONDUCTIVITY

In this experiment thermal conductivity of base oil and Nano lubricant are measured by KD2 Pro KS-1 at temperature range of 24-27°C in atmospheric pressure respectively. Thermal conductivity of Fe_2O_3 0.3% are increased 4.96% when compared to base oil, Fe_2O_3 0.5% are increased to 7.80% to base oil and 2.72% to 0.3% of Fe_2O_3.



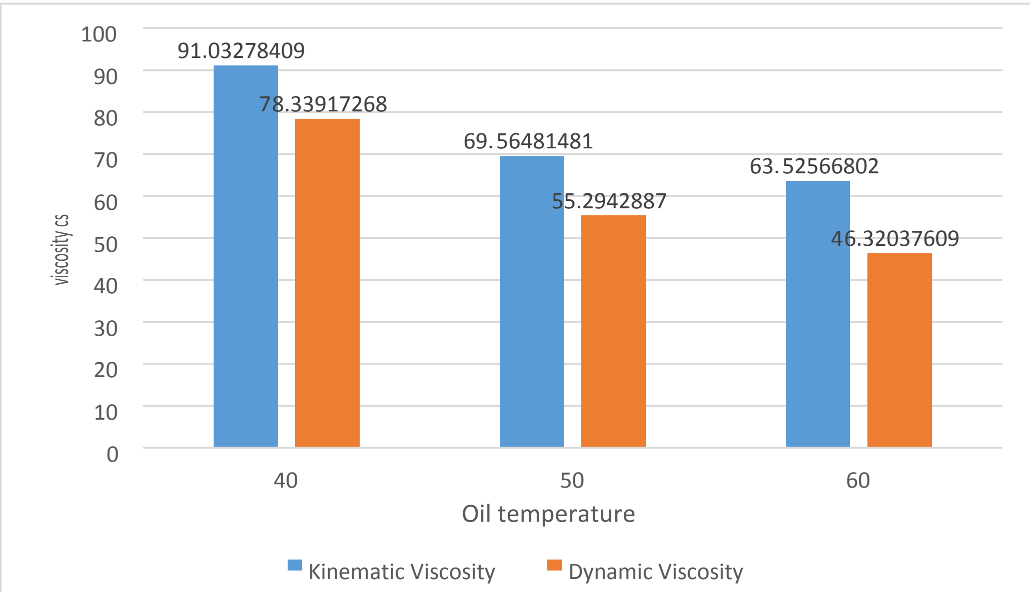
Thermal conductivity of Fe_2O_3 0.3% are increased 4.96% when compared to base oil, Fe_2O_3 0.5% are increased to 7.80% to base oil and 2.72% to 0.3% of Fe_2O_3.

Thermal Conductivity of Nano lubricant with temperature

Sample	Temperature °C	Thermal conductivity W/m K
Base oil	25.64	0.141
Base oil+Fe_2O_3 0.3%	25.78	0.148
Base oil+Fe_2O_3 0.5%	25.79	0.152

4.6 VISCOSITY

In the viscosity test observed that the kinematic and dynamic viscosity of 15 w40 CI4 oil with Fe_2O_3 Nano particles in various concentration increased with the addition of Fe_2O_3 as compared to base oil. viscosity test has been conducted at various temperature 40,50,60 °c in redwood viscometer. Time to fill 50 ml of oil in container was noted for the future.

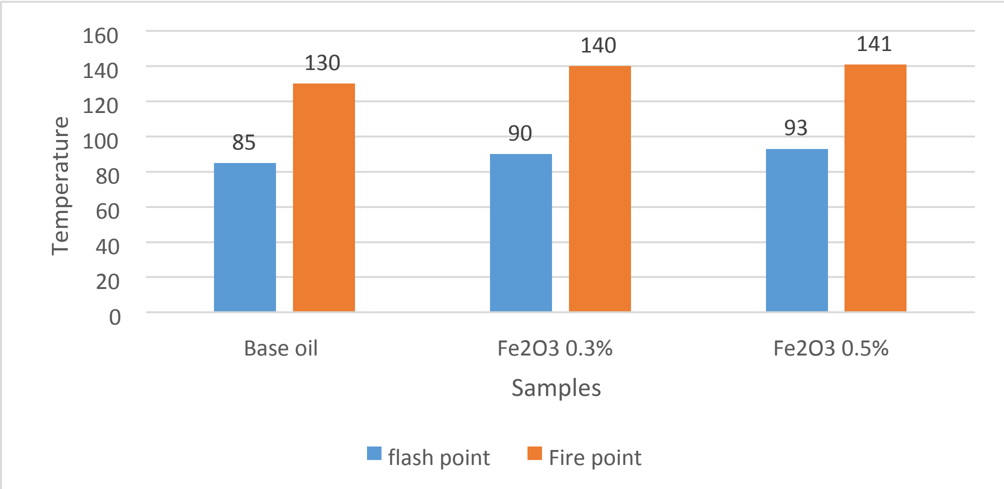


4.6.1 viscosity of Fe_2O_3 0.3% Nano Lubricat

From figure4.6.1 to fill 50 ml was reduced in high temperature because of temperature increased oil lost its viscosity. Figure shows the viscosity of base oil+Fe_2O_3 0.3wt% at various temperature. The viscosity of base oil+ Fe_2O_3 0.5wt% at various temperature.

4.7 FLASH AND FIRE POINT

Table shows the flash and fire point of the Nano lubricant and base oil. Flash & fire point test are conducted on Red wood viscometer in atmospheric pressure. Figure 4.7.1compares the results with various Nano lubricant.5.88& 7.69% of flash and fire point of Fe_2O_3 0.3% are improved when compare with 15w40 CI4 base oil.



4.7.1 Flash &Fire point of Nano lubricant

For 0.5% of Fe_2O_3 flash point and fire point are improved closely to 9.41&8.46%, 3.33&1% when compare with Base oil & Fe_2O_3 0.3%.

Flash and Fire point of Nano lubricant

Sample	Flash point°C	Fire point°C
Base oil	85	130
Base oil+Fe_2O_3 0.3%	90	140
Base oil+Fe_2O_3 0.5%	93	141

The result prove small quantity of Nano particles are enough to improve the properties of lubricating oil.

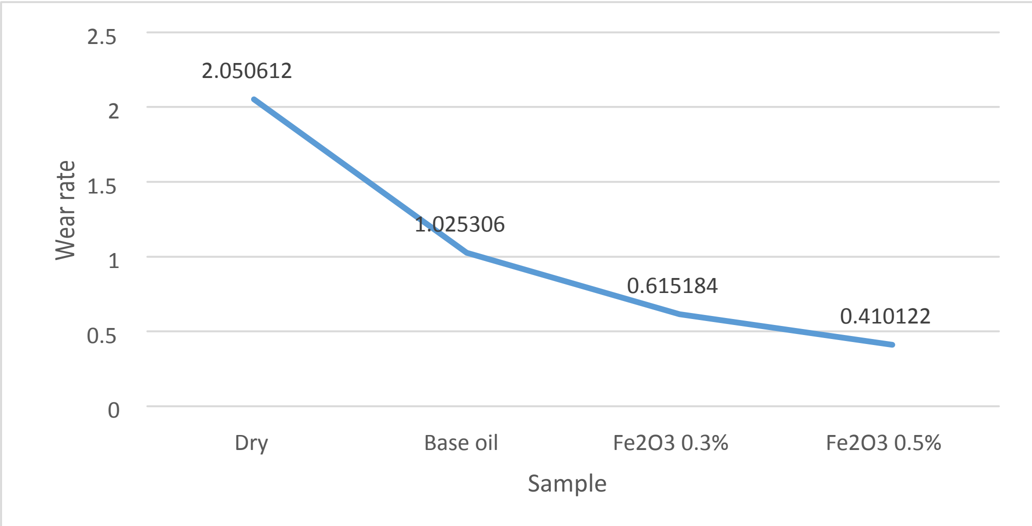
4.7 WEAR

Wear test are carried out on pin on disc apparatus with a load of 4.59 newton track diameter of 100 mm and rotating time of disc are 300 sec.

Wear & Volume loss of Pin

lubricator	Pin material	Wear loss G	Volume loss m^3
Dry	Copper	0.015	50.24
Base oil	Copper	0.007	25.12
Fe2O3 0.3%	Copper	0.004	15.072

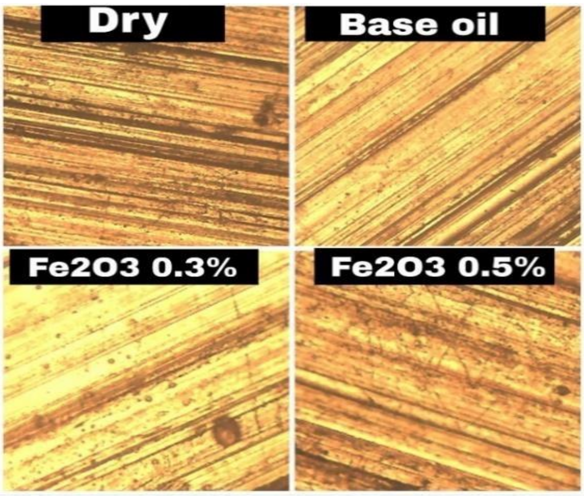
Fe2O3 0.5%	Copper	0.002	10.048
Dry	Brass	0.01	30.144
Base oil	Brass	0.009	25.12
Fe2O3 0.3%	Brass	0.005	20.096
Fe2O3 0.5%	Brass	0.002	10.048



Wear Rate of Copper Pin

4.8 WORM SURFACE

Due to the contact between the pin and disc on POD tester, there exists a mass transfer of the pin to the disc.



Worm Surface of Copper Pin

The mass transfer can be observed during each test. Due to this mass transfer the disc was predominantly clean at the end of each test, Pins are changed after one running.

5. CONCLUSION

The current study, the tribological and chemical performance of an Fe_2O_3 Nano lubricants has been investigated. On the basis of the results presented above, it can be concluded that the optimum concentration of Fe_2O_3 Nano particles blended with the engine oil was 0.3 & 0.5wt%. It reduces the friction wear rate of the pin by 40% & 60% respectively. The kinematic viscosity of Fe_2O_3 Nano lubricant increased due to the presence of Nano particles. On the other hand, dynamic viscosity increased with the use of Nano particles by 5.6% which could lead to reduction wear on friction surfaces. In Thermal conductivity of Nano-lubricant is improved to 4.96 & 7.8% for 0.3 & 0.5wt%. Density of lubricant are improved to 4- 5% because of presence of Nano particles.

6. REFERENCES

1. Arno Behrens et.al, (2018) "Wear investigation of selective α-Fe_2O_3 oxide layers generated on surfaces for dry sheet metal forming" Institute of Forming Technology and Machines, Toyohashi, Japan. Procedia Manufacturing 15 923–930.

2. Colla L et.al, "Water-Based Fe_2O_3 Nano fluid Characterization: Thermal Conductivity and Viscosity Measurements and Correlation" Hindawi Publising Corporation Article ID 674947.

3. Fouda M.F.R. et.al, (2002) "Synthesis and Characterization of Nano sized Fe_20_3 Pigments" International Journal of Inorganic Chemistry Article ID 9892281.

4. Hu Z.S. et.al, "Preparation and tribological properties of nanometer magnesium borate as lubricating oil additive" Elsevier Science B.V. Wear 252370-374.

5. Jiliang Ma et.al, "Synthesis and characterization of bio functional quaternized xylanFe_2O_3 core/ shell Nano composites and modification with polylysine and folic acid" CARP 13803.

6. Juozas Padgurskas et.al, (2013) "Tribological properties of lubricant additives of Fe, Cu and Co nanoparticles" Kaunas University of Technology, Kaunas, Lithuania. Tribology International 60224-232.

7. Mohamed Kamal Ahmed Ali et.al, "Enhancing the Thermo physical Properties and Tribological behaviour of Engine Oils using Nano-Lubricant Additives" Huazhong University of Science and Technology, Wuhan, China.

8. Mohamed Kamal Ahmed Ali et.al, (2016) "Improving the tribological characteristics of piston ring assembly in automotive engines using Al_2O_3 and TiO_2 Nanomaterial's as Nano lubricant additives" Wuhan, China Tribology international 103 page no: 540-554. 9. Mohammed M.R et.al, "Iron Oxide Nanoparticles" Kingdom of Saudi Arabia.

9. Naveenkumar Rajendhran et.al, (2018) "Enhancing the thermophysical and tribological performance of gear oil using Ni-promoted ultrathin MoS2 nanocomposites" Tribology International 124 page no 156-168.