Study of Nanopartical as lubricant used for reciprocating engine: A Review

Omkar C. Nikam
M.Tech. (Heat Power Engg.), Department of Mechanical Engineering,
Government Collage of Engineering, Karad,
Maharashtra, India.

Sagar S. Thosre
M.Tech. (Heat Power Engg.), Department of Mechanical Engineering,
Government Collage of Engineering, Karad,
Maharashtra, India.

Dr. Anil R. Acharya
Professor, Department of Mechanical Engineering,
Government Collage of Engineering, Karad,
Maharashtra, India.

Abstract
A high cost of fissile fuels and limited resources we required minimise the losses . The methods of improving performance by adding nanoparticles in lubricating oil.
A remarkable part of power loss in Reciprocating air compressor is due to the undesirable friction between rubbing surfaces of mechanical components.
The development of low friction compressor is necessary for reduce the power input requirement. Since there are many sliding and rolling parts operating under various conditions in an compressor.
A substantial part of the friction losses, however, can be considered as those of hydro dynamically lubricated contacts under normal running conditions. It is evident here that the friction losses increase with compressor speed, This may be attributed to the increasing part played by boundary lubrication higher feed oil temperature plus increased temperature rise at the contacts reduces the viscosity of the oil such that sufficient hydrodynamic film thickness can no longer be maintained. Lubricating oils play several key roles in compressors, such as lubrication of the parts exposed to friction prevention of gas leakage at the compression chamber, and cooling of the pieces heated by friction.

Keywords:nanopartical, compressor, lubrication, friction.

Introduction

Nano lubrications are very effective method of reducing the frictional power and increasing the life of compressor. Hence, they have attracted considerable research attention. Many researchers have done friction study experimentally with tribotesters and tribological models. Researcher has also attempted to carry out experimentation on actual engine with different nano-particles as oil additives and study its effect on performance of engine.
Lubricating oil play a critical role in reducing the frictional losses. Using high viscosity oil in compressor will reduce the components wear and friction but may increase fuel consumption, otherwise the thin lubricant film will decrease fuel consumption but there is a danger of higher component wear rate. Engineers and scholars are working constantly to develop and test new lubricants to meet these challenges. Nanofluids are an innovative new class of fluids which can be engineered by suspended nanosized particles (1–100 nm) in conventional base fluids. A large number of papers have reported that surface modified nanoparticles stably dispersed in lubricants are effective in enhancing load-carrying capacity, antiwear, and friction reduction properties.
The component contributions to friction losses listed in Fig1. of reciprocating compressor. It is seen that losses in the piston systems account for the largest part, the proportion contribution increasing with engine speed. Losses in the crankshaft and connecting rod systems combined, almost compare with those in the piston systems. Valve system losses seem to become important at lower speeds.

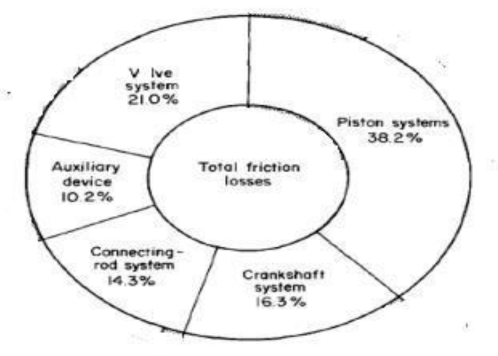

Fig 1 Frictional contributions of the components to the total friction losses

Methods

Nano-Lubricants

Mixture of nanoparticles in base oil (engine oil) is known as nano-lubricating oil. Researcher find out that addition of

nanoparticles in lubricating oil enhances its viscosity, anti-frictional , anti-wear as well as thermo physical properties. So attains ion has to be made in this tribological study so that it can be effectively utilized for Engine lubricating system.
From Tribological study it is found that addition of nanoparticles results in reduction in coefficient of friction which may be one or more of the following reasons.
The spherical shape of nano-particles converts sliding contact into effective rolling contact mechanism;
Physical mechanisms of nanoparticles filling out the liner voids and valleys, thus providing a hydrodynamic effect .
Increase in viscosity at elevated temperature.
Third body material transfer.
Tribochemical film produced at higher temperature.

TYPES OF NANOPARTICLE AND BASE FLUID

Nanofluids are new class of fluids engineered by dispersing nanometre sized materials i.e nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nenosheet, or droplets in base fluids. Materials commonly used as nanoparticles include chemically stable metals e.g gold, copper etc, metal oxides e.g. Al2O3, CuO, metal carbides e.g.SiC, carbon in various form e.g diamond, graphite and carbon nanotubes. Common base fluids are water, organic liquids e.g ethylene, tri-ethylene-glycols, refrigerants, oils and lubricant, bio-fluids, polymeric solutions and other common liquids.
From the literatures of tribology is found that addition of nanoparticles in lubricating oil improves the tribological properties of lubricating oil as they acts like antifriction and antiwear materials. So from the literature comparative study is made as shown in Table 1.1
Also one of researcher carried out experiment on hermetically sealed compressor by using TiO2 (0.2 % by wt) as additives in base oil. His results reduction of 9.33% of average compressor power consumption was observed.
Table 4.1 Effect of nano-materials in lubricating oil on COF and wear

Sr. No	Nano- lubricant	% Reduction in friction coefficient	% Reduction in worm & scar
1	API SF +CuO (0.1 %)	18.4	16.7
2	API Base Oil + CuO (0.1 %)	5.8	78.8
3	SF Oil + Diamond (< 0.1 %)	Not Considerable	43.3
4	Base Oil + Diamond (< 0.1 %)	Not Considerable	62.1
5	Base oil + TiO_2 (1%)	13	Nil
6	PAO 10 + MoS_2 (3% wt)	38	Not mentioned
7	PAO 10 + BN (3%wt)	No improvement	No improvement

Table 1.1 Effect of nano-materials in lubricating oil on COF and wear

So from the above it is clear that the CuO and TiO_2 gives best results towards the reduction of coefficient of friction and wear as well.
Table 4.2 and 4.3 show the specification of the TiO_2 and CuO Nanoparticles used for this dissertation work which purchased from the USA based Nanoshell Chemicals Private Ltd. Company.

Chemical Formula	$Ti0_2$
Colour	White
Morphological	Spherical
Density, g/cc	3.9
Average particle size, nm	10-25

Table 1.2 Specifications of $Ti0_2$ Nanoparticles

Chemical Formula	CuO
Colour	Black
Morphological	Spherical
Density, g/cc	6.315
Average particle size, nm	25-55

Table 1.3 Specifications of CuO Nanoparticles

The purpose of this study is to investigate the settling and agglomeration of the nanofluid over the time period for its application in engine as a lubricating oil . After preparation of nanofluids, agglomeration might occur over the time which results in fast sedimentation of nanoparticles due to enhancement of downward body force. To provide better cooling effect using nanofluids in industry, they are expected to possess long term stability. During application of, nano-oil in engine, stability might be one key issue. Therefore, this issue of fast sedimentation of nanoparticles in base oil is to be resolved. During preparation of nano-oil these issues should be taken into account to make a stable nano-oil, which also has better lubrication properties. There are many techniques forpreparing the stable nanofluid. Few of them are used for this dissertation work which is discussed below.

Magnetic Stirring
Magnetic Stirring process is carried out on the each concentration of TiO_2 and CuONanofluid for preparing the stable nanofluid which is shown in. This is done with the help of stirrer which is kept in the beaker containing TiO_2 and CuOnanofluid. The stirring is carried out for 3 hour for each beaker containing 1.2 litre of nanofluid.

Fig2 :Photographic Image of Magnetic Stirring

Ultra sonication

In the ultra-sonication process the ultrasonic sound waves of 20 kHz are produced from the bottom of the container for about 6 hour for 1.2 litre of nano-oil. This will help to prepare a homogeneous mixture of TiO_2 and CuOnanofluid.

0.3 %TiO_2 0.2% TiO_2 0.1%TiO_2 BASE OIL

Fig3 Photographic Image of TiO_2 Nano-Oil after Preparation

0.3% CuO 0.2% CuO 0.1%CuOBASE OIL

Fig4 Photographic Image of CuO Nano-Oil afterPreparation

MEASUREMENT OF VISCOSITY OF LUBRICATING OIL

Viscosity represents resistance to the flow of liquid. It is one of the important tribologicalproperty of lubricating oil. It can be measured by various methods.

Capillary or tube viscometer

Couette viscometer

Cone and plate viscometers

1 Capillary or tube viscometers

When a fluid flows through a round bore capillary or tube, there is a viscous drag restraining the flow. The fluid in immediate contact with the wall is motionless while that at the center is at maximum velocity. Between these two limits is then a velocity gradient. The form of capillary most frequently used is the glass system typified by the Ostwald viscometer. The difference in height between the upper and lower meniscuses of the fluid corresponds to pressure Experimental Method and Preparation of Aqueous Surfactant Solution difference.

There is a change in head resulting from the flow of the liquid from the bulb as measured by the movement between two markings of the upper meniscus. Simultaneously, the lower meniscus rises as the flow enters the lower reservoir. Therefore, measurements are at a varying shear stress and shear rate. This is not a problem when relative viscosity measurements are made by comparing a standard reference and unknown. In each case the volume flowing is the same but the time for flow is different. In general, use of Ostwald's Viscometers is restricted to one shear range measurement only and the instrument must be selected for the individual sample under investigation. The alternative is a general instrument containing replaceable capillary tubes and variable driving force. Such an instrument provides maximum flexibility of use.

2 Couette Viscometers

Couette, or rotational, viscometers comprise two members, a central bob or cylinder and a coaxial or concentric cup. One or both are free to rotate in relation to each other. Between these is the test substance, in the annulus. Three basic configurations have been utilized. These are a rotating cup with strain measurement on the central bob, a rotating central bob with strain measurement on the cup, and a fixed cup with both rotation and strain measured on the bob. The first of these configurations originally provided the cup rotation by the force of weights hanging on a pan that was suspended from a cord wound around the cup. The central bob displacement was restrained by an appropriate spring of known modulus so that angular displacement could be equated to angular torque on the bob. The second type of Couette viscometer is merely a mechanical inversion of the first. The third classification represents the majority of modern mass produced instruments. The rotation, usually of the inner member, is provided by a synchronous electric motor, usually with variable ratio drives that provides a series of discrete speeds, with other member rigid. The classic instrument of this category is Brookfield viscometers, whose use in a wide range of pharmaceutical and cosmetic literature testifies to its general versatility.

Result

EFFECT ON VISCOSITY OF OIL.

The dynamic viscosity is not only dependent on mass fraction of nanoparticle but also highly dependent on other parameters such as particle shape, size, mixture combinations and slip mechanisms, surfactant, etc. The results are presented in Fig. 6.1 and 6.2. Figure shows the viscosity variation with the temperature ranged from 30 ºC to 80ºC. Both nano-oil and base oil, the viscosity has the same trend, decrease with the increase in temperature, and increase with the increase in concentration of nanoparticles. Compared with the base oil, maximum increase in viscosity value of TiO_2 nano-oil lubricant is 16.12% with 0.3 % concentration. Similarly maximum 17.8% increase in viscosity of CuO nano-oil lubricant with 0.3 % concentration is observed at 30 ºC.

Table 1.4: Viscosity Variation With Temperature For TiO_2 Nano-Oil

Temperature (°C)	Viscocity (mPa.S)			
	BASE OIL	0.1TiO2	0.2TIO2	0.3TiO2
30	176.43	189.14	195.67	204.88
40	110.721	112.76	124.48	128.33
50	80.171	85.66	90.41	93.89
60	57.664	61.49	64.73	65.92
70	40.576	42.22	43.82	43.92
80	19.35	20.03	20.12	21.03

Fig. Viscosity –Temperature Curve of TiO_2 Lubricants

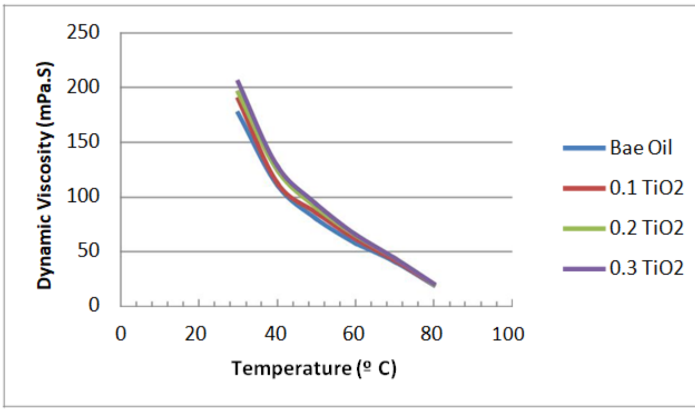

Fig.5 Viscosity –Temperature Curve of TiO_2 Lubricants

Table 1.5: Viscosity Variation With Temperature For CuO Nano-Oil

Temperature (°C)	Viscocity (mPa.S)			
	BASE OIL	0.1CuO	0.2CuO	0.3CuO
30	176.43	195.35	198.87	207.92
40	110.721	117.17	124.48	138.51
50	80.171	89.12	92.41	93.71
60	57.664	64.59	66.73	66.12
70	40.576	42.99	42.82	42.92
80	19.35	21.58	21.12	21.01

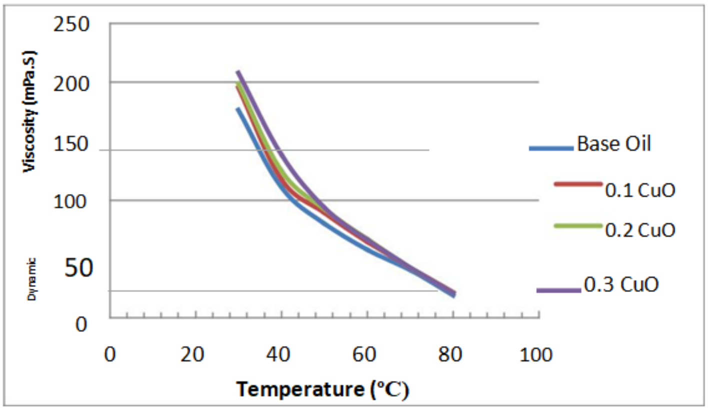

Fig6.. Viscosity –Temperature Curve of CuO Lubricants

Conclusion

1. Friction loss in compressor is the one of the major cause of lower efficiency and higher power consumption.

2. Addition of nanoparticles in lubricating oil enhances the tribological properties of lubricating oil hence it reduces the frictional power.

3. The reduction of coefficient of friction is might be attributed to physical mechanisms of nanoparticles filling out the liner voids and valleys, thus providing a hydrodynamic effect.

4. The deposition of nanoparticles on the worn surface can decrease the shearing stress, and hence reduce friction and wear.

5. Addition of nano particles in oil increases its viscosity, which increases its adhesive properties. It is beneficial in engine lubrication system as it working under elevated temperature.

6. As addition of nanoparticles reduces the wear rate of contacting surfaces. So nano particles in compressor oil lubrication system increase compressor life.

From the above it is found that very less experimental work has been done on actual reciprocating air compressorwith nano-oil as lubricant. Also it is clear that addition of nano particles in compressoroil reduces friction and wear of contacting surfaces. So it can be effectively utilized in compressor lubrication system which may reduce friction power lossand increases net brake power. To investigate how the performance will affect by addition of nanoparticles in lubricating oil of in compressor lubrication system which may reduce friction power loss.

References

[1]Navarro, E., J.M. orbera , J.M., Martı ez-Galvan, I.O., Gonzalvez, J., 2012. Oil sump temperature in hermetic compressors for heat pump applications. International Journal of Refrigeration 35, 397 -406.

[2]R. Dinesh , M. J. Prasad, R. Rishi Kumar, N. Jerome Santharaj,J. Santhip, A.S. Abhishek Raaj "Investigation of Tribological and Thermophysical Properties of Engine Oil Containing Nano additives" ScienceDirect Materials Today: proceeding 3 (2016) 45-53

[3]Y. Y. Wu ,W. C. Tsui, T. C. Liu "Experimental analysis of tribological properties of lubricating oils with nanoparticle additives " ScienceDirect ,Wear262 ,october (2006) 819-825.

[4] Victor W. Wong, Simon C. Tung "Overview of automotive engine friction and reduction trends–Effects of surface, material, and lubricant-additive technologies" Springer , Friction 4(1): 1–28 (2016)

[5] Prata, A., R.Barbosa Jr, J., 2011. Role of the thermodynamics, heat transfer, and fluid mechanics of lubricant oil in hermetic reciprocating compressors. Heat Transfer Engineering 30(7), 533–548.

[6] Hao Liu, Minli Bai, Jizu Lv, Liang Zhang, Peng Wang "Experimental Study and Analysis of Lubricants Dispersed With Nanodiamond Particles on Diesel Engine" ASME Journal of Nanotechnology in Engineering and Medicine, November 2014, Vol. 5

[7] Sajumon.K.T, Jubin V Jose, Sreejith S, Aghil V Menon, Sreeraj Kurup P N, Sarath sasi "performance analysis of nanofluid Based lubricant" IJIRSET , Vol. 2, December 2013

[8] Pullela K Sarma , Vadapalli Srinivas, Vedula Dharma Rao, Ayyagari Kiran Kumar "Experimental study and analysis of lubricants dispersed with nano Cu and TiO2 in a four-stroke two wheeler" Springer, Research Letters 2011, 6:233

[9]Nicholaos G. Demas, Elena V. Timofeeva, Jules L. Routbort, George R. Fenske "Tribological effectsof BN and MOS2 nanoparticles added to polyalphaolefin oil in piston skirt/cylinder liner tests" ASME /STLE International joint tribology conference October 2012

[10]Sudeep Ingole ,Archana Charanpahari , Amol Kakade , S.S.Umare , D.V.Bhatt , Jyoti Menghani "Tribological behaviour of nanoTiO2 as an additive in base oil" ScienceDirect ,Wear301 , january (2013) 776-785

[11]Yujin Hwang, Changgun Lee, Youngmin Choi, Seongir Cheong, Doohyun Kim, Kwangho Lee, Jaekeun Lee and Soo Hyung Kim "Effect of the size and morphology of particles dispersed in nano-oil on friction performance between rotating discs" Springer ,Journal of Mechanical Science and Technology 25 (11) (2011) 2853~2857

[12]Hamed Ghaednia, Robert L. Jackson "The Effect of Nanoparticles on the Real Area of Contact, Friction, and Wear" ASME , Journal of Tribology, Vol. 135 , , October 2013.