ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

*An ISO 3297: 2007 Certified Organization,* *Volume 2, Special Issue 1, December 2013*

**Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)**

**On 12th to 14th December Organized by**

**Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India**

# PERFORMANCE ANALYSIS OF NANOFLUID BASED LUBRICANT

**Sajumon.K.T, Jubin V Jose, Sreejith S, Aghil V Menon, Sreeraj Kurup P N, Sarath Sasi**

Assoc.prof, Dept. of Mechanical Engineering Rajiv Gandhi Institute of Technology, Kottayam, Kerala- 686501, India
Government Engineering College, Thrissur, Kerala- 680009, India
Rajiv Gandhi Institute of Technology, Kottayam, Kerala- 686501, India
Government Engineering College, Thrissur, Kerala-680009, India
Rajiv Gandhi Institute of Technology, Kottayam, Kerala- 686501, India
Rajiv Gandhi Institute of Technology, Kottayam, Kerala- 686501, India

## ABSTRACT

Nanoparticles have attracted great attention in different fields as they show unique properties which can't be attained by conventional macroscopic materials. Low cost additives like nanoparticles play a vital role in modern lubricants. It improves the performance and life of machines by reducing frictional work, wear and prevents failure of its components. In the situations of high thermal loading and high heat flux nano fluids with stabilized nano particles emerge as a key for efficient heat transfer. Here a performance analysis was conducted on a hermetically sealed compressor, in a refrigeration system working with both conventional mineral oil lubricant and nanofluid containing Titanium dioxide nanoparticles as additive. Power consumption in both cases are studied. Compressor working with nanofluid as lubricant shows lower power consumption. Heat transfer rate was also found to be higher by the use of nanofluids. The viscosity of mineral oil and nanofluid were measured and are compared. From this study it was found that use of nanoparticles as additives is economical and aids in better performance compared to mineral oil lubricant.

## NOMENCLATURE

COP Coefficient of performance
z Kinematic viscosity
$TiO_2$ Titanium dioxide

## 1.INTRODUCTION

Almost all moving mechanical systems rely on effective lubrication system for smooth and long-lasting operations. The potential applications of nanoparticles as additives are thus very broad in several industries. Hence synthesis and use of nanoparticles had become a subject for intense research due to their unique properties. In the modern era of miniaturisation of machines, it is essential to have effective lubricants that reduce power consumption and carry's away heat generated effectively. One of the major limitations of conventional heat transfer fluids is the poor thermal characteristics. This inherent inadequacy of these fluids makes the heat removal mechanism less effective even with the best utilization of their flow properties.

Therefore, the thermal conductivities of fluids containing suspended solid metallic particles like nanofluids are significantly higher than those of conventional heat transfer fluids.

Choi et al. [1] proposed the creation of nanofluids by dispersing nano scale materials in base fluid. As these materials possess high thermal conductivity, nano fluids hence formed possess high heat transfer capability. In 2001, Qiu *et al.*[2] performed an experiment on the friction mechanism, in which they added 10 nm spherical nanoparticles to oil. Their results obtained show that the friction property of the lubricant is improved by the distribution of nickel nanoparticles. The diameter of wear and tear reduced from 0.71 to 0.49 nm and the relative coefficient of friction by 26%.

Lee et al.[3] in 2007 showed that the presence of fullerene nanoparticles in lubrication oil improved lubrication performance by reducing metal surface to surface contacts based on the results of friction tests under refrigerant condition. They also found that the volume fraction of fullerene nanoparticles in nano-oil was a key factor in controlling the friction coefficient and the magnitude of wear on the frictional surfaces. Y.Y. Wu et al.[4] proposed a mechanism in the process of lubrication with nanofluids. Spherically shaped nanoparticles opens possibility for effective rolling friction mechanism. Presence of nano particles serve as a third body, which decreases the contact between the two mating surface. The tribosinterization of nanoparticles on wear surface forms a protective film avoiding direct contact and reduce the effect of friction. Z.S. Hu et al. [5] in 2001 found that nanoparticles adsorbed on wear scar surface at first, which then forms an amorphous anti – wear film due to the shearing effect.

An experimental study presented here is an evaluation of performance on a hermetically sealed compressor of a vapour compression refrigeration system working with both mineral oil and nanofluid as lubricant. A study is also conducted on the performance of modified lubricant in compressor on power consumption and on enhancement in heat transfer ability. Variations in viscosity of nanofluid compared to the basefluid at different temperatures are studied.

## 2.PREPARATION OF NANOFLUIDS

Nanofluids are colloidal suspensions of nanoparticles in a base fluid. In general the size of these nanoparticles varies from 1-100nm. The type of nanoparticle used is a key factor on the enhancement of the required properties of the base fluid. The additive used in the mineral oil based lubricant was $TiO_2$ nanoparticles. The nanofluid is not just a liquid-solid mixture of the mineral oil and $TiO_2$. It must be stable and durable suspension with negligible agglomeration. This makes it possible to use in the compressor for a long run. The average size of the nanoparticles has a range of ~21 nm and was supplied by Sigma Aldrich Limited USA. The reason for the use of $TiO_2$ nanoparticles as lubricant additives is due to following reasons such as lower inter facial friction coefficients, high dispersion properties, enhancement in extreme pressure properties of lubricant, enhancement of thermal conductivity etc. The nanoparticles used possess 99.5% trace metal basis purity.

Following are the steps involved in the preparation of nanofluid used here:

First step involves the weighing of the nanoparticles, nano particles are precisely weighed by a high precision electronic balance (supplied by M/s Shimatzu).

Figure 1. Titanium dioxide nanoparticles

The next step is to disperse the nanoparticles in the base fluid. Stirring is done in a mechanical stirrer for a period of 20min at 650rpm. Even after stirring, most of the particles remain agglomerated. To overcome this and to form a stable suspension, ultrasonic agitation is done by a probe type sonicator (supplied by Sonics Germany) for duration of 70min, which is the third and final process in the preparation of the nanofluid.

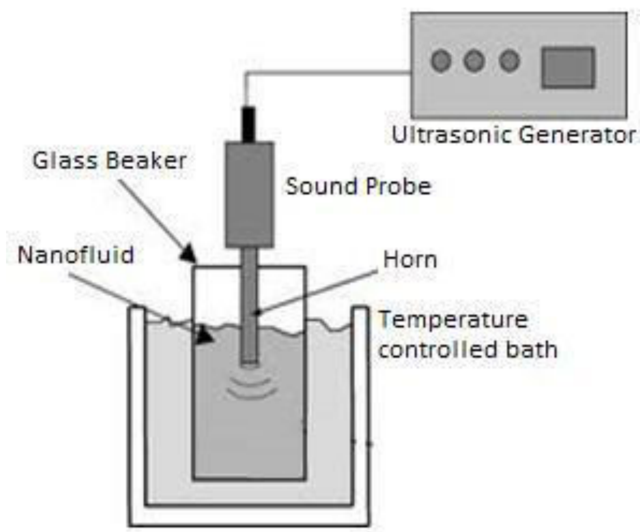


Figure 2. Line diagram of a sonicator system

Sonicator settings Pulse-10sec, Break-2sec, Amplitude-20% power (of 1500W) and external cooling is provided using ice during sonication to avoid overheating. Stabilizers are not added as their presence may affect the performance of lubricating oil due to the formation of froath. As studies conducted in this experiment are dealing with low volume fractions of nanoparticles, agglomeration does not occur and nano fluid was found to be stable and no sign of settlement was observed.

## 3.EXPERIMENTAL STUDY

### 1. MEASUREMENT OF VISCOSITY

Load carrying capacity and power consumption of machines like compressor depends directly on the viscosity of lubricant oil used. In the case of boundary lubrication system, increasing the viscosity upto an optimum level brings notable reduction in power consumption. Nanoparticle addition must be low so as to be effective in reducing power consumption, else may lead to agglomeration and sedimentation.

A Redwood viscometer is used to determine the kinematic viscosity of the oil. The viscosities of mineral oil and nanoparticle-mineral oil mixture were found out at different temperatures using the relation;

Kinematic viscosity (in cSt)

$$z = \mathrm{A}t - B/t \qquad (1)$$

Where, A= (0.247 above 80s or 0.264 below 80s), B=65, t = redwood seconds.

### 2. EVALUATION OF POWER CONSUMPTION

taken for analysis depends directly on the power loss occurring due to friction in the reciprocating parts of the compressor. The power consumption occurring in compressor is measured using a digital energy meter. Formula for the calculation of power consumption is

$$\text{Compressor input} = \frac{n * 3600}{k * tm}\ \text{kW} \qquad (2)$$

Where, n = Number of energy meter pulses = 10 k = energy meter constant = 3200 impulse/kWh $t_m$ = mean time taken for 10 energy meter pulses.

### 3. HEAT TRANSFER RATE

Heat transfer rate at the evaporator cabin is analysed to study the effect of nanofluids compared to mineral oil. The heat transfer in the evaporator can be found using the following relation

$$\text{Heat removal rate} = \frac{m * Cp * \Delta\theta}{T}\ \text{kW} \quad (3)$$

Where,
m = mass of water in the evaporator cabin
= volume used * density of water
= 12 L * 1 kg/L = 12 kg
$C_p$ = Specific heat of water = 4.187 kJ/kgK Δθ = Drop in temperature selected = $3^oC$ T = Time taken for $3^oC$ the drop in temperature.

### 4. EVALUATION OF COEFFICIENT OF PERFORMANCE (COP)

Performance of a refrigeration system can be effectively compared using the term COP. In this study COP of the system working with mineral oil and nanofluid as lubricant are compared. COP is found using the following relation

$$\text{Actual COP} = \frac{\text{Heat removal rate}}{\text{Compressor input}} \qquad (4)$$

## 5. RESULT AND DISCUSSIONS

The results obtained in the experiments are thoroughly studied and are discussed in this section.

### 1. Variation of viscosity

Kinematic viscosity of oils under the study is measured using a Redwood viscometer. From the experiment it was found that nanofluid shows higher value of viscosity. The increase in viscosity of the nanofluid is predominant under lower temperature range. The variation of viscosity at different temperatures measured is shown in the graph below.

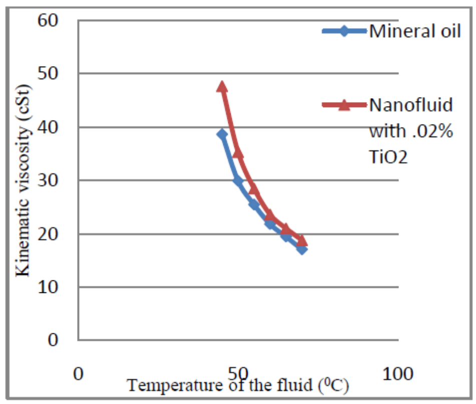


Figure 3. Viscosity variations graph

Increase in viscosity for lubricant enhances lubrication effect, because it is more difficult to squeeze higher viscosity lubricants out of the contact zone. Longer squeezing times lead to shorter times for the asperities to come into contact, and to smaller friction coefficients. The friction coefficient for all of nano-oil was less than that of the corresponding raw oil.

### 2. Evaluation of performance

**2.1. Power consumption:** The effectiveness of lubricant used can be easily observed from the changes in power consumption of the device. Graph shows the power consumption of the refrigerator over different temperature range from $30^0$C to $6^0$C.

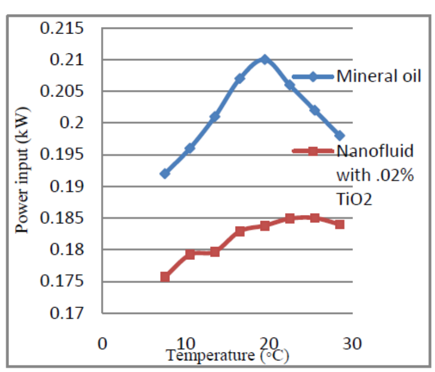


Figure 4. Power input variations graph

A notable reduction of 9.33% of average compressor power consumption was observed.

**2.2. Heat transfer rate:** Efficient heat transfer is an essential property of lubricant for dissipating away the heat generated in machine parts lubricated. Also in the case of refrigerator compressor used for the study here lubricant gets mixed with the refrigerant and is pumped to the lines. The oil with lower thermal conductivity remains as an insulating layer hindering the heat transfer. On using nanofluid with high thermal conductivity more effective heat transfer occurs. Variation of heat transfer in the evaporator with the use of both mineral oil and nanofluid is given in the graph shown below. Readings over temperature range from $30^0$C to $6^0$C.

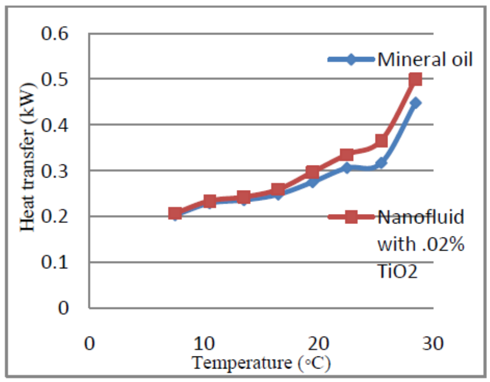


Figure 5. Variations of heat transfer with temperature

An increase of 5.17% in average heat transfer in the evaporator cabin was observed.

**Coefficient of performance:** Hence due to the enhancement in heat transfer and also reduction in compressor work, average COP found to increase from 1.429 to 1.66, i.e, 16.08% improvement in the performance of the system under study was observed.

The improvement in performance can be explained by the following, in 2007, Y.Y. Wu.et.al. [4] found the friction coefficients of lubricating oil containing nanoparticles found to be lower. Friction factor of lubricating oil is one of the main factors deciding the energy consumption. Viscosity of lubricating oil and friction factor are inversely related. As we have found that viscosity of oil found to increase with addition of nanoparticles. Therefore, we conclude about the phenomenon of decrease in friction factor.

Also increase in thermal conductivity found to be one of the vital factors causing the improvement in performance of lubricant. The dispersion of $TiO_2$ particles in lubricant causes increase in thermal conductivity of the fluid. Key mechanism for enhanced thermal conductivity is due to Brownian motion. This occurs through micro-convection, where high interaction in between the nanoparticles and base fluid molecules. And the smaller nanoparticles have higher surface area and number of interaction and it leads to more enhanced thermal conductivity of nanofluid.

Z.S. Hu et al. [5] proposed that nanoparticles adsorbed on wear scar surface at first, which then form an amorphous film due to the shearing effect. This effect helps to increase the load carrying capacity of the lubricating oil compared to pure mineral oil. The formation of the anti-wear film causes a reduction in the frictional power loss due to reduction in the friction between the contact surfaces.

## 3. CONCLUSIONS

The dispersion of nanoparticles in the lubricant resulted in overall performance enhancement of compressor. The working was found to be smoother and consuming lower power. The increase of rate of heat transfer in the evaporator and the lower power consumption facilitated an increase in COP of the system. The kinematic viscosity of the lubricant also showed an appreciable increase. The economic viability
of the process is very promising. The cost of nanoparticles is Rs. 18,000/100g but each charging requires only a very low volume fraction of nanoparticles which costs only about Rs.15/-. Hence the use of nanofluids is economically feasible and paves a new path as an effective lubricant.

## ACKNOWLEDGEMENT

The author wishes to thank Centre for Nanoscience and Nanotechnology, M.G. University for permitting us to utilize the lab facilities and Mr. Noble Chacko of Rajiv Gandhi Institute of Technology, Kottayam for his valuable contributions.

## REFERENCE

[1]. S.U.S. Choi, 1995 “Enhancing thermal Conductivity of fluids with nanoparticles”, ASME FED 231,(66), pp. 99–103.

[2]. Qiu S, Zhou Z, Dong J, Chen G, 2001 “Preparation of Ni nanoparticles and evaluation of their tribological performance as potential additives in oils”, Transactions of the ASME. J. Tribology,123(3) pp. 441–443

[3]. Lee, J. K., Cho, S. W., Hwang, Y. J., Lee, C. G. and Kim, S. H., 2007 “Enhancement of lubrication properties of nano-oil by controlling the amount of fullerene nano particle additives,” Tribol. Lett. Vol. 28, No. 2, pp. 203-208.

[4]. Y.Y. Wu, W.C. Tsui, T.C. Liu, 2007, “Experimental analysis of tribological properties of lubricating oils with nanoparticle additives”, Wear 262, pp. 819–825.

[5]. Z.S. Hu et al, 2002, “Preparation of tribological properties of nanometer magnesium borate as lubrcating oil additive”, Wear 252, pp. 370–374.

[6]. J.M, Wu, Jiyun Zhao, 2013, “A review of nanofluid heat transfer and critical heat flux enhancement- Research gap to engineering application”, Progress in nuclear energy, march, pp.13-24.