Performance of Vapor Compression Refrigeration System using Nanoparticles – Based Mineral Oil Lubricant

Devendra, RaviPrakash M, N. Kapilan, Shiv Pratap Singh Yadav

Abstract: In general, mineral oil and polyester oil are used as lubricants in a refrigeration system compressor. The present work focuses mainly on the mineral oil based lubricant based on MWCNT nanoparticles. The different characterization of the multi-wall carbon nanotube (MWCNT) was performed using different methods such as Scanning Electron Microscopy (SEM), X-Ray Diffraction (XRD), and Transmission Electron Microscopy (TEM), which will result in size, structure and morphology of the CNT nanoparticle. First prepare the Nano-lubricants by adding nanoparticles in mineral oil with different concentrations of 0.05, 0.075 and 0.1wt% with the help of an ultrasonicator which will give the homogeneous mixture of Nanolubricant. Nanoparticles mixed with mineral oil used in a refrigeration system work safely and normally. The experiment were conducted on refrigeration system for different concentration, namely 0.05, 0.075 and 0.1wt% which will mixed with mineral oil and without nanoparticles in mineral oil. The result shows that 0.1wt% Nanolubricant which will give higher improvement in heat transfer efficiency and increase in the Coefficient of Performance (COP) by 37%. And energy savings is 9.6%.

Keywords: Nanoparticle, Nanolubricant, Refrigeration system.

I. INTRODUCTION

Lubricants increase the performance of a system in different ways when Nanoparticles are added in base fluid. The improved critical parameters are anti-friction, anti-wear, anti-corrosion, extreme pressure, detergent and antioxidant. With the increase in difficulties in operating conditions and the growth of technology, together with the increase in lubrication requirements. Nanoparticles are considered the most possible prospect to meet these needs. The performance of composite materials, oils, fluids, etc. Nanolubricants are a relatively new type of fluids which contain a Nanoparticle of size 1 – 100 nm and base fluid [1]. The capacity of the nanoparticles dispersed in the POE oil reduces the compressor's energy consumption, increases the heat transfer capacity and provides better system performance. The performance coefficient of the system with only polyol-etster oil is used in the compressor and therefore the different weight of the nanoparticles is mixed in POE oil and transfer into the compressor of refrigerator to perform the experiment. In their study, the selected refrigerant is R134a and the nanoparticles are Al2O3 and TiO2 [2].

Lee et al. (2009) state that there is an enhancement in lubrication features when refrigeration contains mineral oil containing 0.1 vol. % of fullerene nanoparticles. Bi et al. (2008) have studied that the 0.1% mass fraction of the TiO2 nanoparticles in R134a and the ester polyol oil (POE) systems are used to reduce power consumption by about 26%. It is challenging because the fluid undertakes a phase change in each cycle.

Manuscript published on 30 September 2019
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II. LITERATURE SURVEY

Pawl et al. [1] achieved some studies on nanofluids and found that there was using of nanofluid increase in thermal conductivity compared to base fluid. It has also been discovered that the addition of nanoparticle results reduces energy consumption and increases critical heat flow. **Bi et al. [2]** in this work, the performance and reliability of a domestic refrigerator have been experimentally studied using nanoparticles as a working fluid. The TiO2 nanoparticles were used with a mixture of mineral oil as a lubricant instead of the polyol ester oil (POE) in the HFC134a refrigerator. He also showed that using nanoparticles in household refrigerators to reduce energy consumption. **Saidur et al. [3]** in this work, he examined that the physical-thermal properties of the nanoparticles were suspended in the lubricating oil and refrigerant of the refrigeration system. Along with these, the performance of boiling heat transfer of the carbon nanotube refrigerant pool (CNT) was reported. Nano refrigerants have been found to have a higher thermal conductivity and are very temperature-dependent at very low particle concentrations compared to conventional refrigerants. **Abbas m et al. [5]** in this work, it focuses mainly on the nano-based CNT lubricant in the refrigeration system because the CNT nanoparticle has a large thermal conductivity. Thus it improves the heat transfer coefficient and reduces energy consumption. The results show that 0.1% by weight of CNT nanoparticles has the maximum improvement in heat Transfer and increases the Coefficient of Performance (COP) by 4.2%.

III. NANOPARTICLE SELECTION AND CHARACTERIZATION

The Thermo physical properties of nanoparticle (MWCNT powder)

Table3.1: Physical Properties of MWCNT nanoparticle

Individual MWCNT outer diameter	~10 – 30 nm
Individual MWCNT inner diameter	~5 – 10 nm
Individual MWCNT length	~10 –> 30 µm
Color	Black
Morphology	Dry powder of Nanotubes
Maximum density	~2.1 g/cm^3
COOH content	1.55 wt.%
Purity	More than 90%
Ash	Less than 1.5%
Specific surface area	55 m^2/g
Electrical conductivity	> 100 s/cm

3.1 Characterization of nanoparticles

a) X-ray Diffraction (XRD)

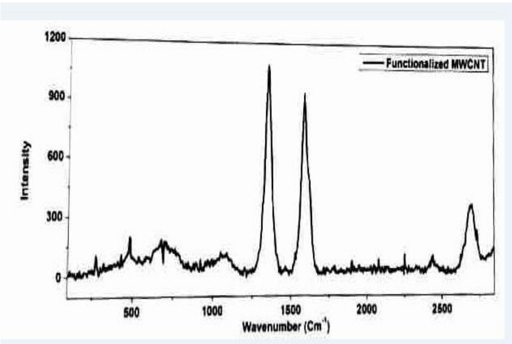

Figure: 3.1 Raman Spectrum of MWCNT

Multi-walled carbon nanotubes can be viewed as concentric layers of graphene rolled into cylinders. Its Raman spectra show three typical bands with maximum intensity, for a laser excitation at 2.41eV, about 1160 cm-1 (band D), 960cm-1 (band G) assigned to the vibration in the plane of the C-C bond. The curve adjustment shown in Figure 3.2 is somewhat similar to that showed in his research Bokobza et al. [11]. X-ray diffraction analysis (XRD) is based on the principle that crystalline materials diffractive X-rays in a unique characteristic pattern for each material. In this technique, an X-ray beam is diffracted in many specific directions in a regular atomic network, which allows determining the atomic and molecular structure of a crystal. The width of the reflections can also provide information on the size of the diffraction domains, which for Nanoparticles can often correspond to the particle size.

b) Transmission electron microscopy (TEM):

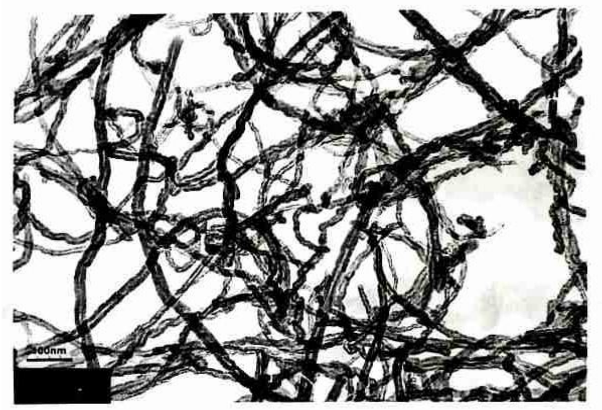

Figure3.2: Transmission Electron Microscopy

The transmission electron microscopy is one of the techniques available that allows this resolution. A TEM yield allows size dimensions and specific shape dimensions and characterization of surface topologies on a number basis (per particle). It allows characteristic between description of primary particles and aggregates was successfully applied to the MWCNT.

IV. MATERIAL AND METHODS

a) The Nanofluid preparation:

The initial procedure is to prepare the Nanofluid by mixing of Mineral Oil and Multi Walled Carbon Nanotubes at the fraction of 0.05, 0.075 and 0.1 wt%. Per 200 ml. the nanoparticle (MWCNT) was bought from NOPO Nanotechnologies India Pvt. Ltd. Bangalore. The properties of MWCNT are shown in table 3.1. There are commonly two types of compressor oil is used in a compressor of refrigerator such as, Mineral oil and Polyol-ester oil. In this experiment R-134a is used as a refrigerant and the mineral oil is bought from ALPINE Refrigeration co, Bangalore. The nanoparticles were weighed by using electronic weighing machine for 0.05, 0.075 and 0.1 wt%. And that nanoparticle concentration is dispersed in 200 ml of mineral oil and makes mixture with help of magnetic stirrer for 20 minutes. Than the mixture is vibrated in ultrasonic machine for 2 hours at 30 ^{0}C for homogeneous mixing of nanoparticles in mineral oil. Thus, three types of nanolubricants were made ready. After that to check the stability test for each sample for checking the proper mixing of nanoparticles. After that the ready nanolubricant were charged into a compressor of a refrigeration system.

Fig 4.1: MWCNT Nanoparticle

Retrieval Number: C3986098319/19©BEIESP
DOI:10.35940/ijrte.C3986.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
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Figure 4.2: Ultrasonicator

Figure 4.3: Different concentration of Nanolubricant

V. EXPERIMENTAL SETUP AND TESTING

A. Experimental Set up:

The compressor is used as hermetically sealed Reciprocating compressor and in that compressor the refrigerant R-134a is used, a forced type cool condenser, an expansion valve and an evaporator is filled with water. Two pressure gauges are used one is measure the inlet pressure of compressor and another one is measure outlet pressure of compressor. And one energy meter are provided to calculate the power consumed by the compressor.

Figure 5.1: Experimental set up

B. Performance test on Vapor compression refrigeration system

The refrigeration system performance test takes in Energy consumption tests and freezing capacity tests. In this system the evaporator compartment is filled a water tank having a capacity of 6 liters. To measure the energy consumed during refrigeration system process, reading is noted from Energy meter for every 5 revolution. The test is carried out for 30minutes for each mixture of Nanolubricant and note down the readings for each 5 minutes.

C. Experimental Procedure

The refrigeration system experiment was carried out at various stages for different concentrations of Multi walled carbon nantube with R-134a refrigerant. The amount of R-134a refrigerant is charged in a compressor as 10 grams. The performance tests were carried out by using R-134a and mineral oil without Nanoparticle. Take all the readings of different temp, pressures, and energy meter reading for 5 revolutions take the time in seconds. After that the mineral oil with MWCNT Nanoparticle the system was run for 30 min, and for every 5 min take all the pressure, temperature and energy Meter readings are noted down. Now, after the completion of each test the Nanolubricant which is in the compressor was completely drained out and the refrigeration system were completely vacuum by passing the air with the help of vacuum pump for 10 min. After completing the one sample the compressor is filled with prepared Nanolubricant and performance test were carried for different samples.

VI. RESULT AND DISCUSSION

Initially the refrigeration system were run with refrigerant R134a and pure mineral oil and then the mineral oil is mixed with 0.05wt%, 0.075 wt.% and 0.1wt% Nanoparticle and each mixture is introduced in compressor of refrigeration system. Fig 6.1 shows that the variation of cooling loads temperature with time. From the figure it is shows that, the time necessary for decreasing the temperature of cooling load is less for the mineral oil containing the multi walled carbon nanotubes which will give better performance of the system instead of pure mineral oil is used.

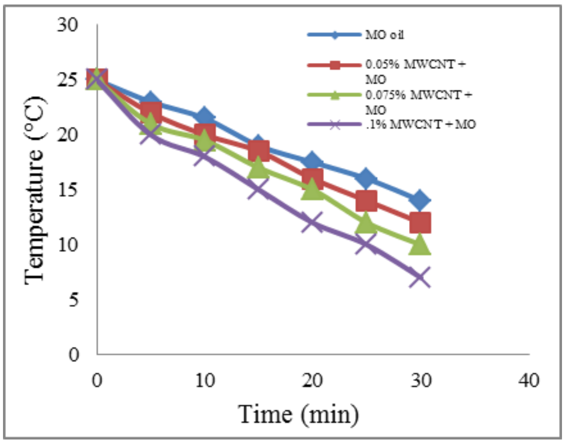

Figure 6.1: Temperature V/s. Time history

Also it will shows that the time required to decrease the cooling load temperature is minimum with mineral oil with 0.1 wt.% of MWCNT nanoparticles compare to other two concentration of nanoparticles.

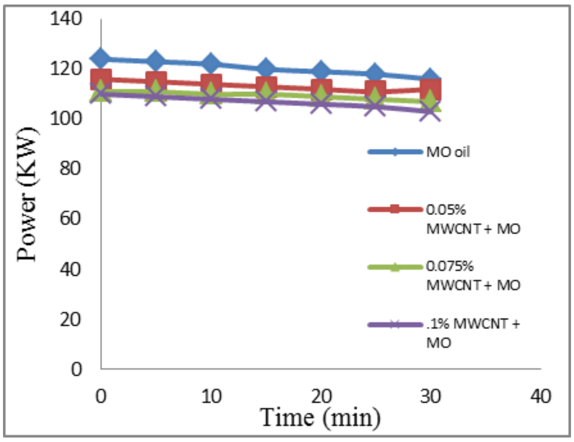

Figure 6.2: Power consumption V/s. Time

Figure 6.2 shows that the energy consumption V/s time. From the above figure it is clear that there is extensive decrease in energy consumption when Nanoparticles mixed with mineral oil are used in the compressor of refrigeration system. The decrease in power consumption is 9.6% when 0.1 wt% of MO + MWCNT nanolubricants is used instead of mineral oil and 6.14% and 2.6% for 0.075 wt% nanolubricant and 0.05 wt% nanolubricants respectively. The decrease in power input to the compressor which will give better lubricity of the nanolubricant.

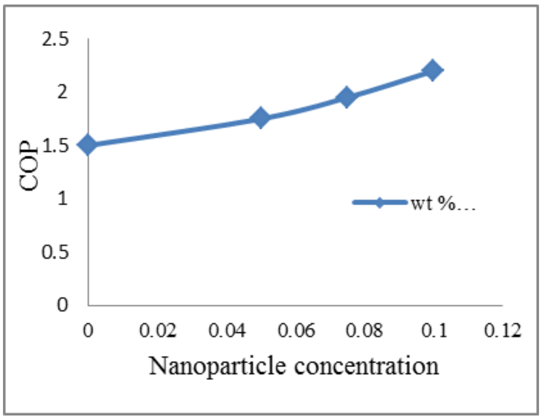

Figure 6.3: COP V/s. Nanoparticle concentration

Figure 6.3 shows CNT concentrations in lubricant vs. coefficient of performance COP. It illustrate that higher the concentration of CNT nanoparticles in a lubricant oil higher will be efficiency of the refrigeration system. The improvement of COP is 37% when 0.1 wt% of CNT nanolubricant used instead of pure mineral oil. 9.3% and 21% for 0.05 wt% nanolubricant and 0.075 wt% nanolubricants respectively. In this study the o.1 wt% nanolubricant which will shows the higher Coefficient of Performance of the system.

Table 6.1: performance of vapor compression refrigeration system by using nanolubricant

Type of fluid	Energy consumption of compressor (Kw)	Refrigeration effect (Kw)	Coefficient of performance (COP)
MO oil	114	181	1.6
0.05 wt% MWCNT + MO	111	195	1.75
0.075 wt% MWCNT + MO	107	209	1.95
0.1 wt% MWCNT + MO	103	251	2.2

VII. CONCLUSIONS

The experimentation was carried out to find the performance on vapor compression refrigeration system by using Nanolubricant (Mixture of mineral oil and MWCNT nanoparticle).

The conclusions drawn from the present study are

1. The Mineral oil with MWCNT Nanoparticles and refrigerant R-134a is used in Refrigeration system works normally, safely and efficiently.
2. The Freezing capacity is higher for 0.1wt% Nanolubricant compare to pure Mineral oil.
3. The Coefficient of Performance of the refrigeration system is increased by 37% when 0.1 wt% of Nanolubricant (MO + MWCNT) is used instead of using pure Mineral oil.
4. The power consumption is reduced by 9.6% when 0.1 wt% of nanolubricant (MO + MWCNT) is used instead of using pure Mineral oil.

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