Effect of Nano Lubricant on the Performance of Vapour Compression Refrigeration System: A Review

[1] M. S. Bandgar, [2] S.S. Ragit, [3] K.P. Kolhe, [4] N. S. Biradar

[1]ME Student, [2]Associate Professor, [3]Professor, [4]Assistant Professor
Department of Mechanical Engineering
JSPM's Imperial College of Engineering & Research, Wagholi, Pune-14, India

***Abstract*— Lubricant oil is necessary in all the vapour compression refrigeration systems, particularly for the efficient operation of the compressor. However, some portion of the oil always circulates with the refrigerant through the cycle. Now a day, a lot of research is going on the nanoparticles like metals, oxides, carbon nanotubes or carbides. Nano-lubricants are a special type of nano-fluids which are mixtures of nano-particles and lubricants and have a broad range in the fields of refrigeration systems. In this paper, researches have done on the application of nano-particles suspended in lubricating oils of refrigerating systems are reviewed. The aim of this work is to study and find which type of lubricant oil works better with nanoparticles in the field of refrigeration. From literature survey, it has been observed that nano-particles mixed with mineral oil gives better results than polyol-easter oil.**

***Index terms*—Nano lubricants, COP, Nano-particles, POE, mineral oil, Vapour compression refrigeration system**

I. INTRODUCTION

The coefficient of performance (COP) of a refrigeration system is defined as the ratio of heat removal rate on the evaporator side to the mechanical work input on the compressor side. The COP can be upgraded in two ways: firstly, by increasing the heat removal rate at the evaporator side, and secondly, by decreasing the compressor work. Many researchers have investigated the possibility of introducing nanoparticles in refrigerants to develop a new class of nanofluids called "nanorefrigerants", Use of nano-refrigerants will increase the heat transfer in refrigeration systems and thus enhance the system performance. [6]

In the refrigeration and air-conditioning vapour compression systems, oil is necessary for a correct working of the compressor. Its main role is to ensure the existence of a thin oil film allowing the lubrication of the mechanical moving elements, in order to protect them against wear. The lubricant also plays several secondary roles as a tightness element, reducing the noise, or helping the evacuation of chemical deposits or impurities that may be present in the system. Nano-particles as additives are also considered to improve the lubrication properties of lubricant oil for the compressor of vapor compression refrigeration systems. Recently, different types of nano-oils have attracted special attention because it has ability to reduce the friction and wear in compressor, which, in turn, improve the efficiency of the compressors and also reduce energy consumption. Thus, the use of nano-oils is more beneficial to compressor performance. [7]

This review paper focuses on the energy consumption reduction by using nano-lubricant. However, there is very less literature on the nano-particles as additives with oils used in refrigeration system. It is revealed that this review will be useful to overcome the challenges of nano-lubricant.

II. STUDIES RELATED TO NANOPARTICLES MIXED WITH POE AND MINERAL OIL

In this paper, it is intended to include many articles on refrigeration systems that use nanolubricants, published up to 2016. Although this is an extensive review, it cannot include all the papers, and only some major research works related to nano-particles mixed with POE and mineral oil are selected.

Table 1 Nanoparticles mixed with POE and mineral oil in VCRS

Researcher (Year)	Nanoparticles, size(nm), Concentration (%)	Evaluation
N. S. Desai et al. [1] (2015)	SiO_2, (50), 1, 2 , 2.5 by mass	COP of system was improved by 14.05 % with nano-oil of mass concentrations of 2%
Bi et al [2] (2008)	TiO_2-Al_2O_3 (50), 0.06–0.1 by mass	26.1 % less energy consumption achieved with 0.1% of TiO_2
Subramani et al [3] (2011)	Al_2O_3 , (<50) , 0.06% by mass	25% less energy consumption and COP is increased by 33%
R. kumar et al. [4] (2013)	Al_2O_3 , (<50) , 0.06% by mass	The reduction in power consumption of the compressor is 11.5 %

Subramani et al. [5] (2013)	TiO_2 , (50) , 0.06% by mass	Power consumption reduces by 15.4% and the COP is increases by 20%

Nilesh Desai et al. [1] has carried out an experimental investigation of a vapor compression refrigeration system using R134a/SiO_2/polyester nanorefrigerant as working fluid. In the experiment the nano-oil with specific concentrations of 1%, 2% and 2.5 % (by mass fraction) were added in the compressor oil. The VCRS performance with the nanoparticles was then investigated using energy consumption tests. They found that as the nanoparticles concentration in POE oil increases, there is decrease in compressor work and it is optimum at 2%. It has been observed that energy saving can be achieved from a minimum value of 7.03% to a maximum value of 12.30% using nanolubricant compared to traditional refrigerants.

Table 2 Compressor work [1]

Nanoparticles concentration (%)	Compressor work done (kW)
0	0.484
1	0.45
2	0.4245
2.5	0.4327

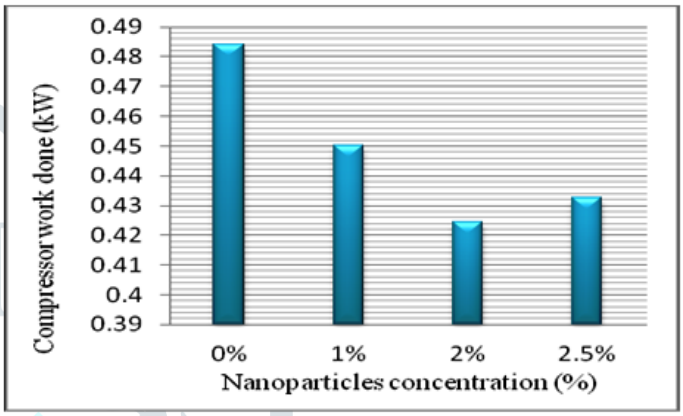

Fig. 1 compressor work done Vs Nanoparticle concentration [1]

The result shows the COP of system were improved by 7.61%, 14.05% & 11.90%, respectively, when the nano-oil was used instead of pure oil.

Table 3 Increase in COP [1]

Nanoparticles concentration (%)	Increase in COP (%)
1%	7.61
2%	14.05
2.5%	11.90

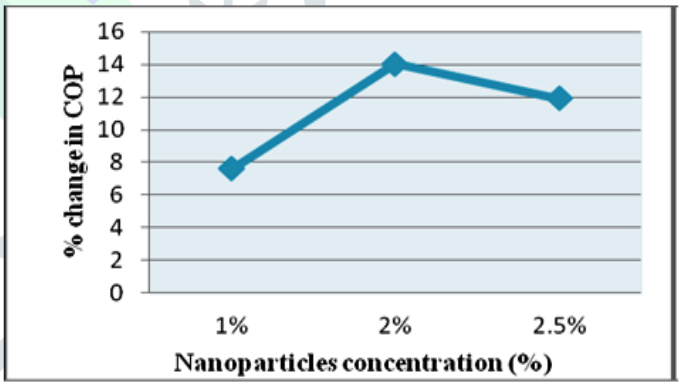

Fig. 2 COP Vs Nanoparticle concentration [1]

Bi et al [2] found that there is remarkable reduction in the power consumption and significant improvement in freezing capacity. They pointed out the improvement in the system performance is due to better thermo physical properties of mineral oil and the presence of nanoparticles in the refrigerant.

Table 4 Energy consumption of R-134a/POE oil and R-134a/mineral oil/ TiO2 Nanoparticles systems [2]

Mass Fraction %	POE	0.06 TiO_2	0.1 TiO_2
Energy consumption KWh/day	1.077	0.849	0.796
Energy saving %	-	21.2	26.1

From the above table it has been observed that the energy consumption of the system with Nanoparticles was lower than that of the system with POE oil.

Table 5 Energy consumption of R-134a/ mineral oil systems [2]

Mass Fraction %	POE	MO	0.06 TiO_2
Energy consumption KWh/day	1.077	0.897	0.849
Energy saving %	-	16.67	21.2
Oil return ratio	-	84.0	92.0

From the above table it was conclude that compressor with mineral oil consumes 16.67% less energy than POE oil. It has been observed that energy saving can be achieved to a maximum value of 21.2 % using nanolubricant compared to traditional refrigerants. The oil return ratio of mineral oil was only 84% compared to 92% for the nanolubricant.

Subramani et al. [3] has carried out an experimental investigation of a vapor compression refrigeration system. In experimental study, three cases have been considered. The hermetic compressor filled with i) pure POE oil ii) SUNISO 3GS oil (mineral oil) and iii) SUNISO 3GS+ Al_2O_3 nano-particles as lubricant. The mass fraction of the nano-particles in the nano-lubricant is 0.06%.

Figure 3 shows the comparison of power consumption of the compressor. The reduction in power consumption is 18% if the SUSISO 3GS is used instead of POE Oil and a reduction of 25% is observed when SUNISO 3GS is mixed nano-particles.

Figure 4 shows that the SUNISO 3GS + Al_2O_3 nano-particle mixture has the highest COP when compared with the other cases. The advantages of adding nano-particle to the lubricant is that it reduces the power consumption of the compressor and there is sub cooling of the nano-refrigerant in the condenser which in turn increases the COP.

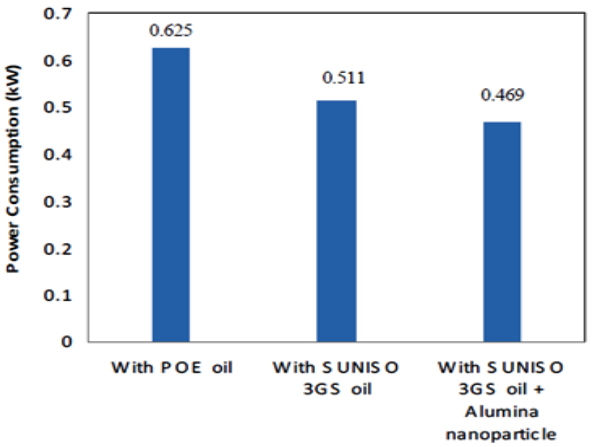

Fig. 3 Comparison of Power Consumption [3]

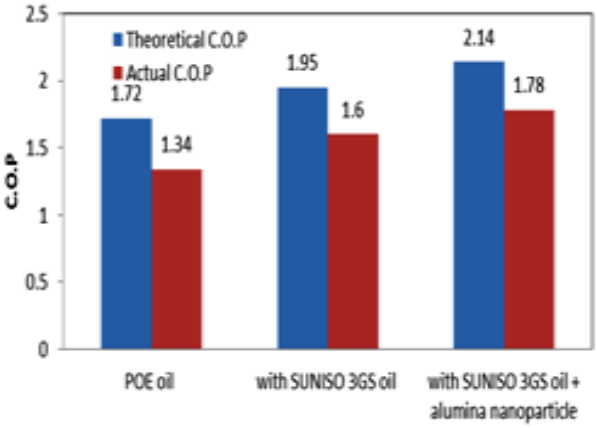

Fig. 4 Comparison of COP for the three cases [3]

R. kumar et al. [4] has conducted an experimental work to evaluate performance of a domestic refrigerator using R600a/mineral oil/nano- Al_2O_3 nanorefrigerant as working fluid. They found that the refrigeration system with nano-refrigerant works normally.

Table 6 Energy consumption results [4]

Parameter	**POE oil**	**Mineral oil**	**Mineral oil with Alumina nanoparticle**
Energy consumption kw hr	0.635	0.614	0.572
Energy saving %	-	6.0	11.5

It has been found that the freezing capacity is higher and the power consumption reduces by 11.5 % when POE oil is replaced by a mixture of mineral oil and Al_2O_3 nanoparticles.

Subramani et al. [5] has evaluated in his performance test on a vapor compression refrigeration system with mineral oil with different nanoparticles added to it. The mass concentrations of nanoparticles in the nanolubricant are same in the three cases and its value is 0.06%. The particles are spherical in shape and the average particle size is about 50 nm. Experiments have been conducted (i) with SUNISO 3GS oil (ii) alumina Nano lubricant (iii) with CuO Nano lubricant and (iv) TiO_2 nano-lubricant It is found that power consumption reduces by 15.4% and the coefficient of performance increases by 20% when TiO_2 nanolubricant is used instead of SUNISO 3GS

Figure 5 shows power consumption of the compressor. From the above histogram it is clear that there is considerable reduction in power consumption when nanolubricants are used. The reduction in power consumption is 15.4% when TiO_2 nanulubricant is used instead of SUNISO 3GS oil. The corresponding reductions in power consumption with CuO nanolubricant and Al_2O_3 nanolubricant are 11.9% and 8.4% respectively. The decrease in compressor work input may be attributed to better lubricity of the nanolubricants

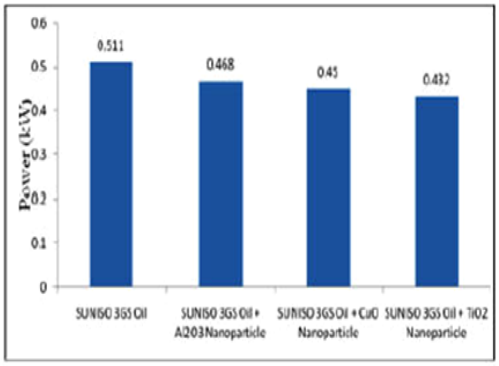

Fig.5 Comparison of Power Consumption [5**]**

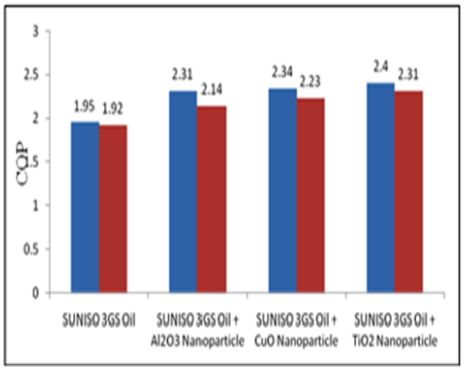

Fig.6 Comparison of COP for the four cases [5]

Figure 6 shows the improvements in coefficient of Performance (COP) of the refrigeration system when nanolubricants are used instead of pure SUNISO 3GS oil. The theoretical values of COP are also shown for comparison. It is very clear COP is more with nanolubricant when compared to pure lubricating oil. This may be due to the increase in heat transfer in the evaporator and condenser side of the refrigeration system and the decrease in work input to the compressor.The results indicated that the refrigeration system with nanolubricant worked normally and safely. It was found that power consumption reduced by 15.4% and the coefficient of performance increases by 20% when TiO_2 nano-lubricant is used instead of SUNISO 3GS

III CONCLUSION

The studies on the nanolubricants are summarized in this review. It was observed that nanoparticles mixed with mineral oil gives better results than POE oil. The size and material of nanoparticles also affects on the performance of Vapour compression refrigeration system. using the particles with a higher size leads to some problems like fouling, sedimentation, erosion and higher pressure drop. The compressor work can be reduced by increasing the concentration of nanoparticles up to a certain limit, further increase in concentration will cause increase in compressor work. Nanolubricant can be used in many domestic and industrial devices due to enhanced heat transfer characteristics and energy consumption reduction.

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