EXPERIMENTAL EVALUATION OF Al_2O_3 WATER-EG NANOFLUID AS A NANOCOOLANT IN A REFRIGERATION SYSTEM

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ABSTRACT

Performance enhancement of refrigeration and heat pump systems is an emerging research topic recent technological developments in the fields of electronics, transportation, medical and HVAC systems have resulted in a pressing need for a performance enhanced cooling system. Now a days, refrigeration and heat pump systems have become one of the most important systems for people's daily lives. Based from some research, the use of refrigeration & air conditioning systems consumes 30 to 40% of total electricity consumed. The traditional method for increasing heat dissipation is to increase the area available for exchanging heat but it requires more space. The innovative concept of 'nanofluids' heat transfer fluids consisting of suspended of nanoparticles has been proposed as a prospect for these challenges. In this work experimental investigation is carried out using Al_2O_3-water-ethylene glycol nanofluids with 0.1% ,0.2% volume concentration as a cooling medium in condenser of refrigeration system. From experimental the results it is found that amount heat transfer in condenser found more as Compared to Base fluid (Water and mixture of Water+EG) due to enhanced thermal conductivity. Overall, the performance of the system working with nanofluid as a coolant was superior to that where just the base fluid (i.e., pure water, water-ethylene glycol mixture) is used.
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Keyword : - *Nano-coolant ,Nano-fluid, VCR system ,Alumina-water-Ethylene glycol.*

1. INTRODUCTION

Recent Technological development in the fields of electronics, Transportation Medical, HVAC&R systems and mechanical system have resulted pressing a need for performance enhanced cooling system. Heat transfer through a fluid medium finds many applications such as heat Exchangers, Automobiles, Heating and cooling system and Power Plants. Heat transfer through in fluids is essentially through convection. However the heats transfer coefficient depends upon the thermal conductivity of the fluid. To improve the thermal conductivity of the fluids Suspensions of solid particles is an effective strategy as the thermal conductivity of solids is greater than that of fluids. Nano fluids are a new class of heat transfer fluids which are engineered by dispersing nanometer-sized metallic or non-metallic solid particles or tubes in conventional heat transfer fluids such as water, ethylene glycol, and engine oil. This is a rapidly emerging interdisciplinary field where Nano science, nanotechnology, and thermal engineering meet. In the field of heat transfer, all liquid coolants currently used at low and moderate Temperatures exhibit very poor thermal conductivity and heat storage capacity resulting in their poor convective heat transfer performance. Although thermal conductivity of a fluid plays a vital role in the development of energy-efficient heat transfer equipment's and other cooling technologies, the traditional heat transfer fluids possess orders-of-magnitude smaller thermal conductivity than metallic or nonmetallic particles. Therefore, the thermal conductivities of fluids that contain suspended metallic or nonmetallic particles or tubes are expected to be significantly higher than those of traditional heat transfer fluids. With this classical idea and applying nanotechnology to thermal fluids, Steve Choi from Argonne National Laboratory of USA coined the term "Nano fluids" to designate a new class of heat transfer fluids (Choi, 1995). From the investigations performed thereafter, Nano fluids were found to show considerably higher conductive, boiling, and convective heat transfer performances compared to their base fluids (Murshed et al., 2005, 2006, 2008a, 2008b & 2011; Das et al., 2006, Murshed, 2007; Yu et al., 2008). These Nano particles suspensions are stable and Newtonian and they are considered as next generation heat transfer fluids which can respond more efficiently to the challenges of great heat loads, higher power engines, brighter optical devices, and micro-electromechanical systems. (Das et al., 2006; Murshed et al., 2008).

Remarkable improvement in thermo physical and heat transfer capabilities to enhance the performance of refrigeration systems. In a VCRs the nanoparticles can be added to the lubricant (compressor oil) & the lubricant nanoparticles mixture is known as nanolubricant. Therefore, researches about convective heat transfer in nanofluids have been increasing for various applications such as electronics, air conditioning & refrigeration system.

2. LITERATURE REVIEW

In literature several applications of nanofluids in HVAC&R have been studied, both as primary or secondary fluids. For refrigeration applications, scientists usually investigated the use of NPs as additives with conventional refrigerants & oils in order to make refrigeration systems more efficient. Recently, some investigators have conducted studies on vapour compression refrigeration systems, to study the effect of nanoparticles in the refrigerant/lubricant on its performance. Wang et al. (2003)[3], they studied a refrigeration system working with R134a & mineral oil added with TiO_2 nanoparticles; better performances than using Polyolester (POE) oil. Shengshan et.al (2007) [4], Bi et al. (2008) [5], conducted studies on a domestic refrigerator using mixture of mineral oil TiO_2 was used as the lubricant with R134a They found that the refrigeration system with the nanorefrigerant worked normally & efficiently & the energy consumption reduced & refrigerator performance improved when compared with R134a/POE oil system. Similar results were found by Subramani & Prakash (2011)[9], they employed Alumina nanoparticles at 0.06% by weight in mineral oil instead of POE in the cycle compressor & they found about 25% reduction of power consumption. Jwo et.al (2009) [6], conducted studies on a refrigeration system replacing R-134a refrigerant and polyester lubricant with a hydrocarbon refrigerant & Alumina mineral lubricant. Their studies show that the 60% R-134a & 0.1wt% a Alumina nanoparticles were optimal. & the power consumption was reduced by about 2.4%, & the COP was increased by 4.4%. Kristen Henderson et.al (2010) [7], conducted an experimental analysis on the flow boiling heat transfer of R134a based nanofluids in a horizontal tube. They found excellent dispersion of CuO nanoparticles with R134a & POE oil & the heat transfer coefficient increases more than 100% over baseline R134a/POE oil results. K.P. Kumar et.al [2013] [1], studied the heat transfer Properties of Nano fluids (volume fraction 0.1 % to 0.5%), sisal & silicon Nano particles in Shell & coil Heat Exchanger & concluded that Heat Transfer Rate Enhanced by Using Nano fluids as Compared to base Fluid. Dr. Nimai Mukhopadhyay et.al (2013)[8], they summarized the nanofluid preparation methods reported by different investigators in an attempt to find a suitable method for preparing stable nanofluids. Moreover, challenges and future directions of applications of nanofluids have been reviewed. R. Reji Kumar et.al (2013) [11], Investigated heat transfer enhancement numerically using Alumina Nanolubricant & R600a/mineral oil/nano- Alumina as working fluid in domestic refrigerator they found that Freezing capacity higher & the power consumption reduces by 11.5 % & the COP increases by 19.6 %. Subramani et al. (2013)[17], investigated performance of a VCRs using nano-lubricant with mineral oil and mineral oil with different nanoparticles added to it. They concluded nanolubricant works normally and safely. It is found that power consumption reduces by 15.4% & the COP increases by 20% when TiO_2 nanolubricant is used instead of SUNISO 3GS. T. Coumaressin and K. Palaniradja (2014) [12], carried out Performance Analysis Using CuO-R134a Nanofluids in the VCRs with concentrations ranged from 0.05 to 1% with using FLUENT Heat transfer coefficients were evaluated for heat flux ranged from 10 to 40 KW/m^2. & found evaporator heat transfer coefficient increases with the usage of nano CuO. Laura et.al (2014) [13] Several Nanolubricants, formed by Polyolester (POE) or mineral oil as base fluid, & TiO_2 or SWCNH as nanoparticles, were studied in a dedicated test rig. In contrast with the published literature, no improvement was detected using nanofluids instead of commercial oil. Fatou Toutie Ndoye et.al (2014) [15], studied numerically energy performance secondary loops of refrigeration Systems using nanofluids for various types of nanoparticles (Alumina, CuO, Fe,

SiO_2 and TiO_2) and a wide range of volume fraction they found that heat transfer coefficients significantly & pumping power also increased with the increase of nanoparticles concentration whatever the flow regime.R S Mishra (2014)[16], described thermal modeling of VCRs using R134a in primary circuit & Alumina-Water based nanofluids in secondary circuit. The model uses information of the secondary fluids input conditions geometric characteristics of the system, size of nanoparticles and the compressor speed to predict the secondary fluids output temperatures, the operating pressures, the compressor power consumption and the system overall energy performance. Simulation results have shown that for the same geometric characteristics of the system performance increased from 17% to 20% by application of nanofluid as a secondary fluid in VCS.

3. METHODOLOGY

3.1 Experimental test rig

A vapor compression test rig is a table mounted unit which uses water as a heat sources & sink for both cooling and heating purposes. The apparatus consists of, the compressor is mounted centrally and both evaporator and condenser are mounted on either sides of compressor.

Fig -1: Experimental set up

Specifications:
01. Compressor-Hermetically sealed Reciprocating Type; 02. Condenser. Water Cooled, Shell & Helical Coil type; 03. Evaporator-Water cooled Shell and Helical Coil type; 04. Expansion Device-Capillary tube;05. Pressure Gauges. i)Discharge pressure gauge: gauge pressure from -1kg/cm^2 to 28 kg/cm^2,micro pre temperature mfg. ii)Suction pressure gauge: -1kg/cm^2 to 14 kg/cm^2. Refrigerant R-134a (Non – CFC); 07. Rotameter : Range 0 to 100 LPH; 08. Voltmeter and Ameter for compressor input power measurement; 09.Temperature indicator Multichannel, Digital. Range up to 1000^{0}C with PT 100(-120 to 850 ^{0}C) type thermocouples.

3.2 Preparation of nanofluid

The preparation of nanofluids is that the first key step in experimental studies with nanofluids. There are commonly two methods for the preparation of nanofluid that is single step and two step method. In these study two step methods is employed for preparation of nanofluids. The Nanoparticles of Aluminum Oxide purchased directly from Autus nanolab Pvt Ltd. the Aluminum Oxide nanopowder with 0.1, 0.2 vol% was added in to the pure distilled water(80%) and ethylene glycol(20%) act as base fluids then, composition dispersed by magnetic stirring followed by sonication & total solution Agitated using Agitator. No surfactant was used in aluminum oxide water suspensions.

Properties of nanoparticles:- Chemical Formula- Al_2O_3; Color- White; Morphology- Spherical; Density-3.950 g/cm^3; Phase- Alpha phase; Average particle Size- Less than 100 nm; Surface area-15-20 m^2/gm.Properties are calculated by using propert formulas which are given below.

Different fluids	Thermal conductivity (W/m-K)	Viscosity (N s/m^2)	Specific heat (kJ/kg-K)
Pure water	0.6077	0.0007493	4.187
Water(80%)+Eg(20%)	0.53	0.0012	3.743
0.11%Al_2O_3water+EG	0.718	0.001606	3.625
0.22%Al_2O_3+water+EG	0.9564	0.002233	3.518

Table-1. Properties of base fluids and nanofluids

3.3 Experimental procedure and calculations

In this experimental work, Experimentation is carried out with fluids like pure water, water(80%)+Ethylene-glycol(20%),0.1%Al_2O_3+water(80%)+Ethylene-glycol(20%),0.2%Al_2O_3+water(80%) +Ethylene-glycol(20%) as a coolant in condenser.At that time evaporator secondary fluid(pure water available in city) is allowed in continuous flow at mass flow rate of 60 LPH . Experiments are carried out till steady state is achieved. At the end of each experiment, refrigerant effect is measured. Power consumed by compressor is measured by using voltmeter and ammeter. Then, coefficient of performance of refrigerator for each nanofluid's experiment is found using below equations. Then, graphs are generated.

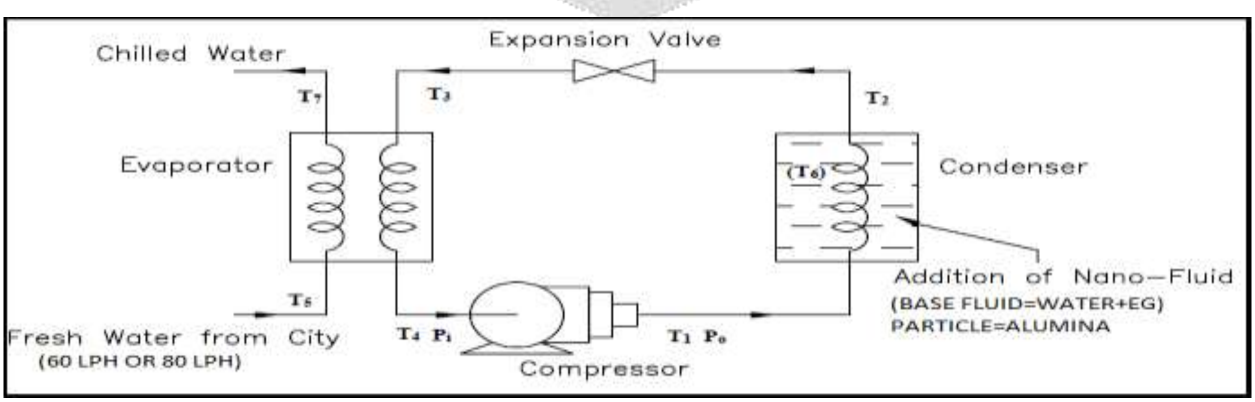


Fig -2: Refrigerator line diagram.

Equations:

1) RE= Refrigerant effect produced $= m\ C_p\ (T_{wi} - T_{wf}) = m\ C_p\ (T_5 - T_7)$

Where, C_p=Specific heat of water ,

$T_5 = T_{wi}$=Inlet temperature of water entering in to evaporator

$T_7 = T_{wf}$=Outlet temperature of water going out evaporator.

2) W_c=Work consumption by compressor=$V\ I\ cos\emptyset$

Where, V= Average voltage, I=Average current , $cos\emptyset$=power factor=0.7

3) $(COP)_{ref} = \dfrac{Refrigerant\ effect\ produced}{Work\ consumption}$

4) Specific Heat of nanofluid (Cp_{nf})(kJ/Kg k):

$$Cp_{nf} = \frac{\emptyset\ D_S Cp_S + (1-\emptyset) D_b Cp_b}{D_{nf}}$$

Where, $\emptyset$=Volume fraction of nano particle

$$= \frac{\text{The Nanoparticles Volume in Nanofluid Suspension}(V_S)}{\text{Total Volume of Nanofluid }(V_t)}$$

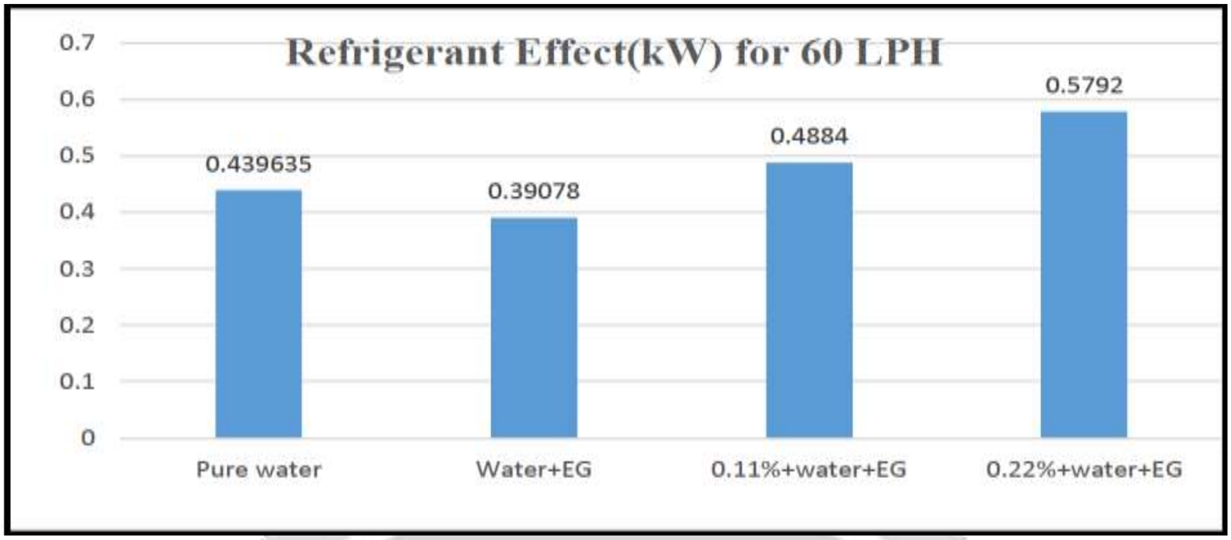
4. RESULTS AND DISCUSSION

Experiments are performed two times for different nanofluids , pure water and water ethylene glycol mixture as a condenser coolant. So total 4 number of experiments are performed. Readings are as follows. Graphs of refrigerant effect , work consumption, COP of refrigerator are as follows.

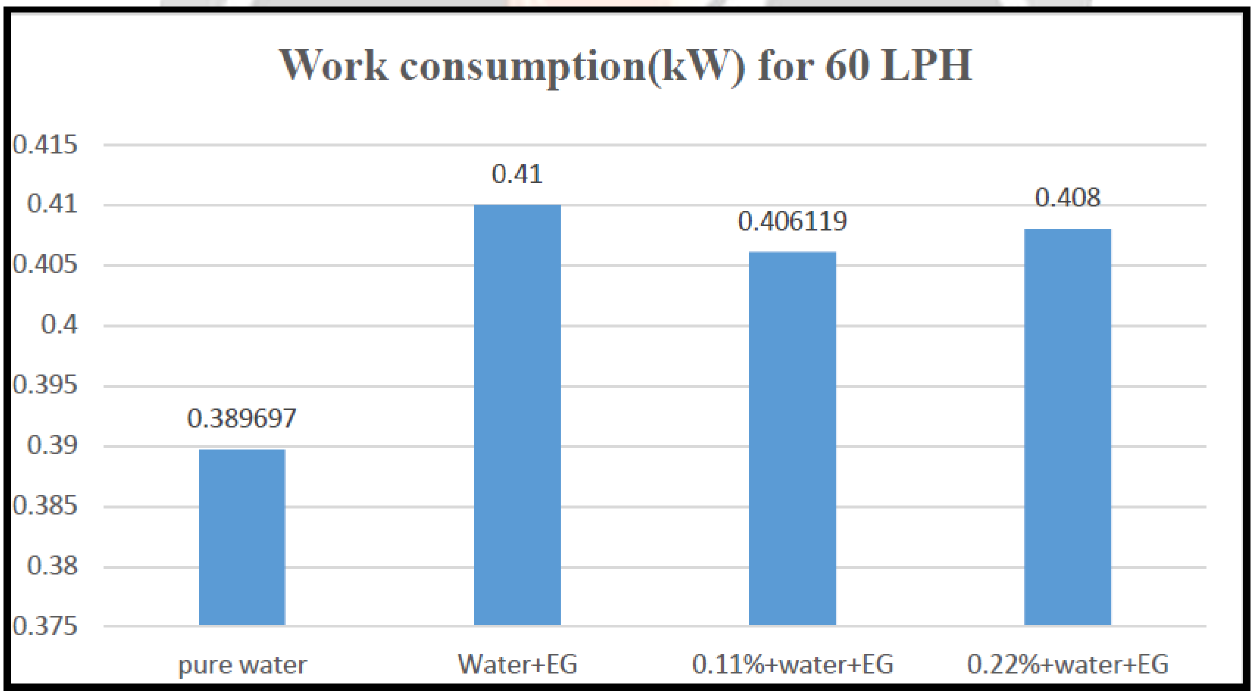
Refrigerator (evaporator water flow rate=60 LPH)

Pressure P(kg/cm^2),Temperature T(^{0}C),Time t(min)													
Sr no		**P_i**	**P_o**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**V**	**I**	**t**
1	**Pure water**	2.2	17	71	62.7	6.4	16	29	66	22.7	231	2.41	45
2	**Water+Eg**	2.2	17	74.8	65.9	7	18	29	68	23.4	235	2.65	45
3	**0.11%Al_2O_3 water+EG**	2.2	17	74	66	6.2	18.2	29	69	22.2	233	2.49	45
4	**0.22%Al_2O_3 +water+EG**	2.2	17	74.5	66.9	6.2	18.3	29	71	21.1	237	2.46	45

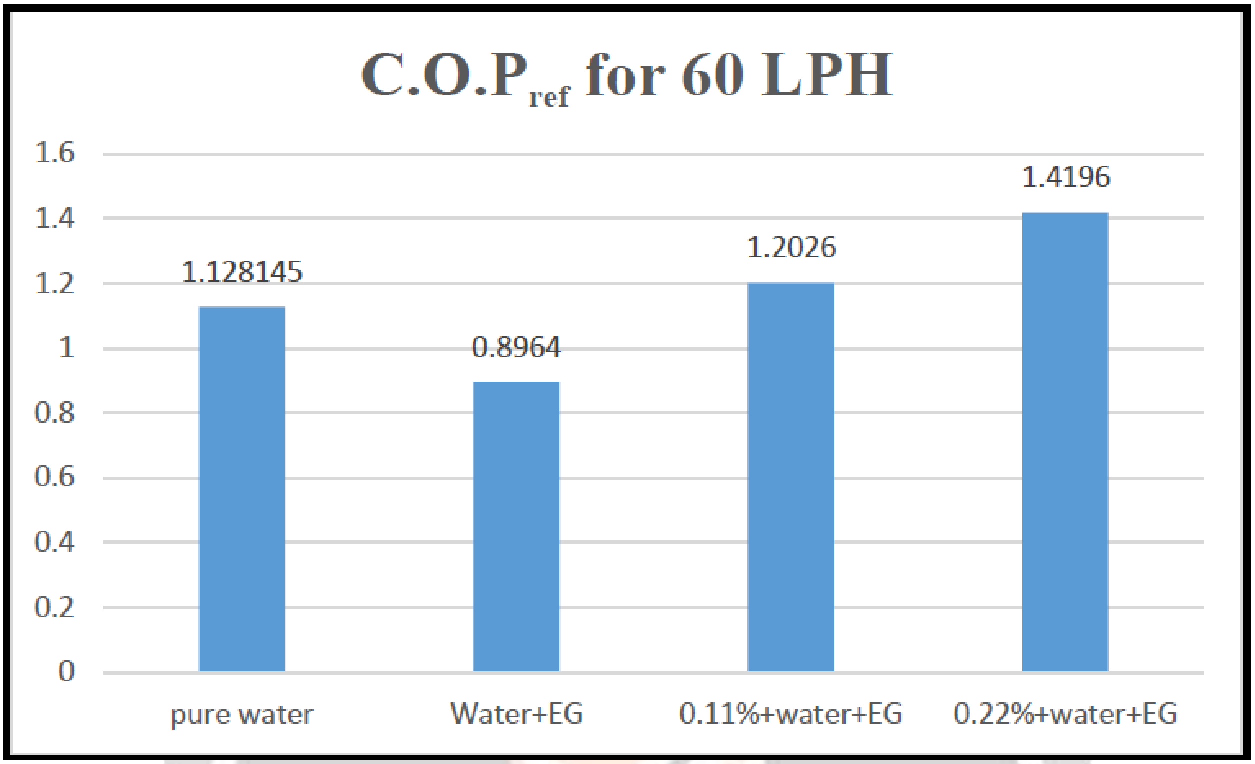
Table 2: Readings of experiments



Graph-1: Refrigerant effect vs different nanocoolant in condenser.



Graph-2: Work consumption vs different nanocoolant in condenser.



Graph-3: COP of refrigerator vs different nanocoolant in condenser.

Refrigerant effect graph1 shows that by utilizing nanofluid as a coolant , refrigerant effect increases because of enhanced thermal conductivity. Due to this enhanced thermal conductivity subcooling increases which is responsible for increment in refrigeration effect.As far as comparision of two base fluids(pure water and water eg mixture is concerned , mixture of water-ehylene gycol has lower thermal conductivity than the pure water's conductivity, subcooling might be lesser. So, water eg mixture gives a slightly reduced refrigerant effect.Then adding nano particles in water eg mixture causes increment in thermal conductivity and an increased heat transfer.So, subcooling phenomenon is assumed to be responsible for this enhancement.

As shown in graph 2 , Work consumption is not too much affected by utilizing nanofluid as a condenser coolant fluid. Work consumption nearly remains same. Similarly as shown in graph 3, COP of refrigerator increases using these nanofluis due to increment in refrigeration effect.

5. CONCLUSION

Al_2O_3-water-EG nanofluid presented a superior performance (refrigeration capacity and COP) when compared with the base fluid. For 0.1% nanofluid suspension gives 6.7% increment in COP as compared to pure water as a basefluid and also gives increment of 34% as compared to water-Eg base fluid. Similarly for 0.2% nanofluid suspension gives 25.83% increment as compared to pure water as a basefluid and also gives increment of 58.36% as compared to water-Eg base fluid. So, using nanoparticles , thermal conductivity increases but viscosity also increases.

Work consumption by compressor nearly remains same. So, Using nanofluid degree of subcooling increases ,this causes increment in refrigerant effect.So, For same refrigent effect condenser size can be reduced using nanofluid. Using this method there is no need to modify the current system or to add the extra components in the system.

6. FUTURE SCOPE

Preparation and maintaining the uniform/Homogenous suspension of nanoparticles water is the big challenge because it is found that nanoparticles settle down at the bottom of condenser after some time. Adding Surfactants in nanofluid which will results increase in stability of Nanofluids.

In this experiment nanofluid is made stationary in condenser this causes rapid increment in temperature and discharge pressure of fluid , which may increase load on compressor. To avoid this problem nanofluid can be made in circulation using external pump. That pump will also consume some power which is not included here. This is the limitation in above experiments because in this no pump is used .Increment in viscosity causes more power consumption by pump which is used to circulate nanofluid. But, here nanofluid is made stationary.

This things can be done in future.

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