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Study on the influence of ZNO - R152a in the performance enhancement of Air-conditioning system

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Abstract: *Generally in Air conditioning systems R22 is used as working fluid. In recent years, Global Warming Potential (GWP) has turn out to be as important as Ozone Depletion Potential (ODP) when evaluating a probable refrigerant. In domestic air conditioning system the most widely used refrigerant is R22, which has a high GWP of 1700 and an ODP of 0.05. Hence a new solution for this refrigerant is to be identified. R152a is identified as an alternative to R22 refrigerants due to low GWP of 132 and zero ODP. In this work, experimental investigation was made to find the alternate of R22 as R152a by lowering the refrigerant charge and improving system refrigerant containment. The use of Nano-fluids as a fluid in air conditioning system was studied experimentally and the results are discussed. Here, ZnO is mixed in the volume fractions of 0.1%, 0.3% and 0.5% with R152a refrigerant, to study the performance of these Nano-fluids in the air conditioning system. Experimental result shows an improvement in performance while using ZnO with 0.5% volume fraction with base refrigerant as R152a.*

Keywords: *Nano-refrigerant, COP, GWP, Air conditioning*

I. INTRODUCTION

Technological advancement, development and unprecedented growth have been achieved because of the rapid industrialization. Due to the rapid growth, ozone layer depletion, global warming has been experienced. On the other side, due to the rising oil prices have made the industrialization procedure more challenging. Fossil fuels are depleting and the harmful radiation effects of nuclear energy should also be considered in this era. In this state of energy crisis, researchers were developing energy efficient thermal systems. Enormous amount of electricity is consumed by thermal energy systems such as air conditioners and refrigerators, which are used in both industrial and domestic purpose. Demand is building up to develop eco-friendly refrigerants that can be used in air conditioning and refrigeration systems with reduced electric power with high efficiency and reducing the ill effects towards the environment. New generation heat transfer fluids, obtained from the rapid advances in nanotechnology leads to Nanofluids. Nanofluids are a new class of fluids engineered by dispersing nanometer-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, nanosheet, or droplets) in base fluids. In other words, nanofluids are nanoscale colloidal suspensions containing condensed nanomaterials. Nanofluids have been found to possess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. For a two-phase system, there are some important issues we have to face.

One of the most important issues is the stability of nanofluids, and it remains a big challenge to achieve the desired stability of nanofluids. In recent years, nanofluids have attracted more and more attention. The main driving force for nanofluids research lies in a wide range of applications. The depletion of the ozone layer due to the release of chlorine from CFC and HCFC refrigerants has raised serious concerns about using them in vapor compression systems. Therefore, according to the amended version of the Montreal protocol, CFCs were phased out by January 1996, except for essential users, and HCFCs are to be phased out by 2020. Hence refrigerants or refrigerant blends with properties similar to CFCs and HCFCs and with zero ozone depletion potential (ODP) must be discovered to be used as replacements in existing systems.

II. PROBLEM IDENTIFICATION

The Refrigerant R22 is a single hydrochloroflurocarbon or HCFC compound, widely used in refrigeration and air conditioning systems. Due to high Ozone Layer Depleting Potential (ODP) and Global Warming Potential (GWP), R22 cannot be used in air conditioning system for long run. The concept of alternative refrigerant comes into picture. R152a is identified as an alternative to R22 refrigerants because of low

GWP of 132 and zero ODP. The use of nanofluids as a heat transfer medium in air conditioning system was studied using the nanoparticles of ZnO in the percentile of 0.1, 0.3 and 0.5 and the results have been discussed.

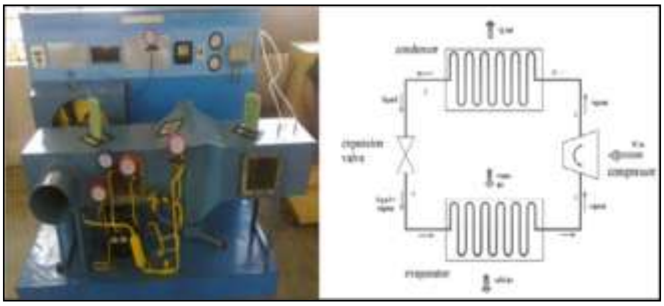
III. REFRIGERANT AND NANOFLUIDS

Difluoroethane (R 152A) is used as propellant for aerosol and for extruded polystyrene foams, it is used as a blowing agent.R152a combines a comparatively low global warming along with zero ozone depletion potential. It has refrigerant desirable properties such as chemical stability, low toxicity and compatibility with other lubricant oils, but flammability being the disadvantage of this refrigerant.Oxides of nanoparticles were the first materials prepared for nanofluids because they can be easily produced and are chemically stable in solutions. Thermal conductivities of nanofluids are substantially higher than those of same liquids without nanoparticles. With volume fraction of nanoparticles, the thermal conductivity of nanofluids increases almost linearly. The particle size of nanoparticle and thermal conductivity of nanoparticle and base fluids have an impact on thermal conductivity of nanofluids. With decreasing particle size, thermal conductivity of nanofluids increases. The preparation of nano-fluid includes the production of nano-sized particles and then dispersed into the base fluid. The two techniques used to produce Nanofluids are single-step method and two-step method. For the preparation of aluminum oxide, Copper Oxide and Zinc Oxide particles, two-step method is more suitable. In the current study, aluminium oxide, copper oxide and zinc oxide of 0.1%, 0.3% and 0.5% mass concentration is used and the reason for choosing ZnO is due to its widely known thermal properties and easy dispersionThe required volume fraction of 0.1%, 0.3% and 0.5% are prepared by dispersing the specified quantity in de-ionized water using an ultrasonic bath and sonication was done for 6 hours. This ultrasonic vibrator generates ultrasonic pulses in the power 180 W at 40 KHz. The stability of dispersion is determined by measuring its pH value.

IV. EXPERIMENTAL SETUP

The experimental used for the analysis is shown in Figure 1, consisting of compressor, fan cooled condenser, expansion device and an evaporator section. Capillary tube is used as an expansion device. The evaporator is of coil type which is loaded with water. Service ports are provided at the inlet of expansion device and compressor for charging the air conditioner. The mass flow rate is measured with the help of flow meter fitted in the line between expansion device and dryer unit.

The experimental setup was placed on a platform in a constant room temperature. The ambient temperature was 30°C. The air flow velocity was found to be less than 0.35m/s. The temperatures at different parts of the experimental setup are measured using resistance thermocouples. For experimentation, 12 resistance thermocouples were used. The pressure at compressor suction, discharge, condenser outlet and at evaporator outlet is measured with the help of pressure gauges. The power consumption of the system was measures by a digital Watt-hr meter. A digital wattmeter is also connected with the experimental setup.



V. RESULTS AND DISCUSSIONS

ZnO nanofluids added in the proportion of 0.1%, 0.3% and 0.5%v concentration with particle size of 40-50 nm and 150 gm of R152a was charged and tests were conducted. The addition of nanoparticles in the refrigerant is limited to 0.5%v. From literature, oxide nanoparticles of concentrations less than 0.5%v have shown proven enhanced thermal conductivity than the base fluids. Higher concentration of oxide nanoparticles turns to be more of insulator. Agglomeration of nanoparticles takes place when the percentage exceeds 0.5 leading to reduction in heat transfer rate and hence the concentration of nanoparticles in this study is limited to the maximum of 0.5%. The concentration of nano additives namely ZnO in this work was taken in the order of 0.1%v, 0.3%v and 0.5%v.

Tests were conducted with three concentrations of the three nano-additives in the system. The suction temperature, discharge temperature, suctions and discharge pressures were noted and coefficient of performance is determined from the temperatures measured at different points on the air-conditioning system.

Pressure drop developed during the flow of coolant is one of the important parameters determine the efficiency of nanofluids application. Pressure drop and coolant pumping power are closely associated with each other. There are few properties which could influence the coolant pressure drop: density and viscosity. It is expected that coolants with higher density and viscosity experience higher pressure drop. This has contributed to the disadvantages of nanofluids application as coolant liquids. Pressure drop and pumping power of a refrigeration system with nano-refrigerants were obtained and is found that nano-refrigerants have a much higher and strongly temperature-dependent thermal conductivity at very low particle concentrations than conventional refrigerant. This can be considered as one of the key parameters for enhanced performance for refrigeration and air conditioning systems.

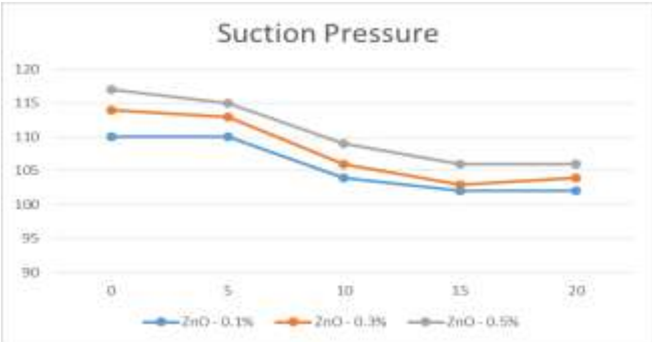


Fig. 2 Variation of Suction pressure with volume fraction of Nano-particles in Refrigerant

With addition of more amount of nanofluids with refrigerant increases the suction pressure in all conditions. But as the system operates, suction pressure gets reduces for ZnO. With inclusion of nano-particles in refrigerant, pressure at the suction head drops due to the increase in density of the nano-refrigerant as shown in Fig. 2. Maximum suction pressure for ZnO nanoparticle is 117 for 0.5% and minimum is 102 for 0.1%.

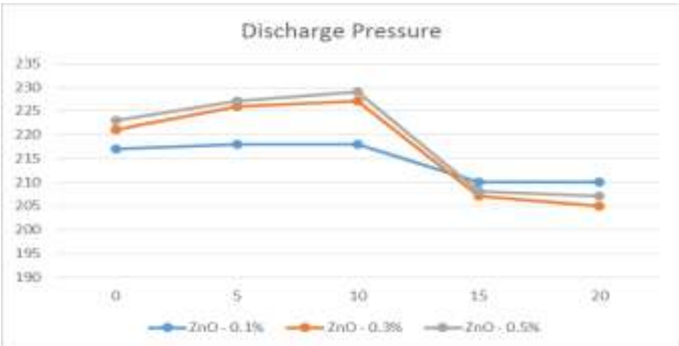


Fig. 3 Variation of Discharge pressure with volume fraction of Nano-particles in Refrigerant

Discharge pressure reduces as the volume fraction ZnO as in Fig. 3. Lowest discharge pressure is observed with 0.5% of CuO addition. Maximum and minimum discharge pressure for Al_2O_3 nanoparticle addition is 232 and 210 for 0.5% and 0.1% addition, whereas for ZnO, maximum discharge pressure is sensed as 229 for 0.5% and minimum as 205 for 0.3%.

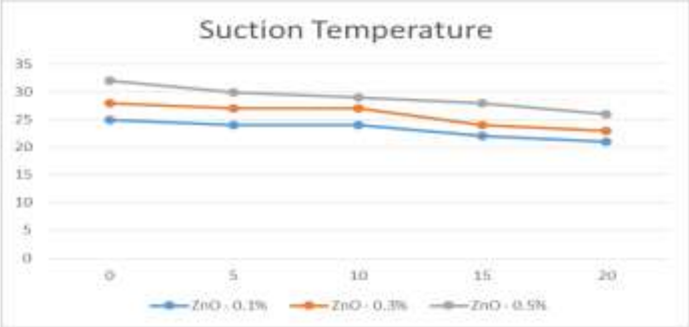


Fig. 4 Variation of Suction temperature with volume fraction of Nano-particles in Refrigerant

Figure 4 shows drop in the refrigerant temperature in the condenser of the refrigeration system. Temperature drop of the refrigerant is high with nano-refrigerant when compared with the other cases. The enhanced heat transfer rate in the condenser is due to the presence of nanoparticles in the refrigerant. Suction temperature increases with increase in addition of more percentage of nanofluids. Higher suction temperature is observed in ZnO. For maximum addition of nanofluids, a downward trend in suction temperature is observed as the system progresses. Maximum suction temperature is sensed for 0.5% addition of nanoparticles and minimum is observed at 0.1% addition.

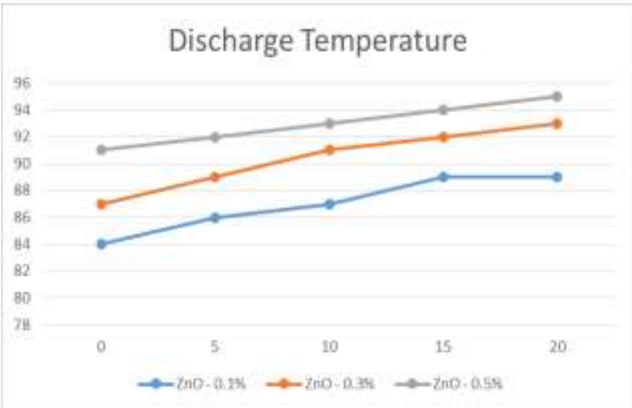


Fig. 5 Variation of Discharge temperature with volume fraction of Nano-particles in Refrigerant

Increase in discharge temperature is observed as in Fig. 5 with increase in volume fraction of nanoparticles in the refrigerant. This is due to the addition of nanoparticles in the refrigerant, which improves the heat transfer rate in the condenser. Due to this the efficiency of the air conditioning system is improved. Discharge temperature increases with increase in nanopartilce addition. 0.5% addition of nanoparticles produces maximum discharge temperature and minimum discharge temperature is produced by least addition i.e., 0.1% addition of nanoparticles.. ZnO addition increases the discharge temperature up to 95° and lower side as 84^{o}.

The advantages of adding nanoparticle to the lubricant is manifold. 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. COP is related to power consumed by the system, higher the COP of the system lesser the power consumption of the system. It was found from Fig. 6 that, as the concentration of the nano-fluid in refrigerant increases the COP will also increase. Highest COP value was obtained at 0.5 wt%, which was highest nanoparticle composition of this study. 0.5% addition of ZnO develops the maximum COP as 4.12 respectively and 0.1% addition of ZnO develops minimum COP as 2.31 .

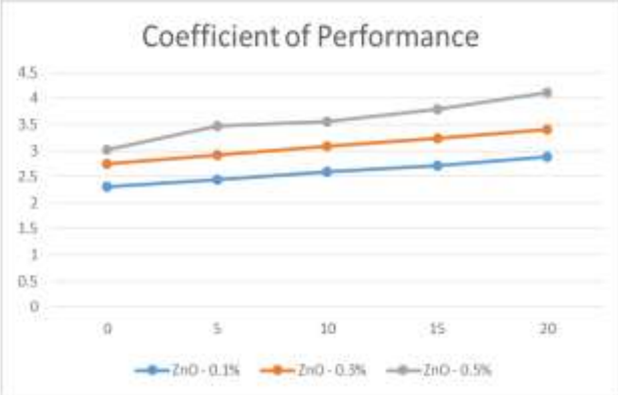


Fig. 6 Variation of COP with volume fraction of Nano-particles in Refrigerant

VI. CONCLUSIONS

This experimental analysis aims to determine the most efficient refrigerant towards minimizing electrical power with increase in coefficient of performance using different refrigerant separately and in mixed condition with nanoparticles. The observations made are:

- Performance of Air-conditioning system is studied with conventional refrigerants R22 and R152a.
- In order to improve the performance of air-conditioning system, nano additives are added to the refrigerants. The system works safely with the nano fluids suspended in it and no system modification was done for the retrofitting process which is a major advantage of the work.
- Furthermore nano-additives i.e ZnO is added with R152a to enhance the performance of the air-conditioning system in volume fractions of 0.1, 0.3 and 0.5%.
- Experimental results shows that, nano- ZnOlubricant has good miscibility and thus the lubricity of oil increases than the other two nano-additives and COP increases with the usage of nano ZnO refrigerant and maximum COP was obtained with 0.5%v of ZnOnano-refrigerant.
- Addition of nanoparticle reduces compressor power consumption of the compressor and sub-cooling of the nano-refrigerant in the condenser increases the COP. Highest COP value was obtained at 0.5 wt%, which was highest nanoparticle composition of this study.

It is concluded that the performance of air-conditioning system can be improved significantly by using R152a as refrigerant with addition of 0.5% of ZnO nanoparticles producing low GWP and zero ODP.

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