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EXPERIMENTAL ANALYSIS OF STEPPED SHORT TUBE ORIFICE AS EXTENSION TO THE CAPILLARY TUBE IN DOMESTIC REFRIGERATOR BY USING R-290 REFRIGERANT WITH SiO_2 NANO LUBRICANT

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Abstract : Steppped short tube orifice has been proposed as an extension to the expansion device in the domestic refrigerator working on R-290. In this present work mainly focused on stepped short tube orifice and its efffects on system parameters like net refrigeration effect, compressor work, pull down time and coeffcient of performance. A stepped short tube orifice is consisting of two serial connected short tube orifices with different diameters. It is employed to the refrigeration system as extension to the capillary tube. In this experiment stepped short tube orifice is manufactured and fabricated to the domestic refrigerator. Experiments has to be conducted on the domestic refrigerator with stepped short tube orifice, refrigerant R-290, and .5%wt SiO_2 nanoparticle. After all the experiments the effects of the stepped short tube orifice on the domestic refrigerator has investigated with help of comparison charts. The results may show that the performance of the domestic refrigerator with incorporation of stepped short tube orifice and inclusion of SiO_2 nano particle improved than the domestic refrigerator without stepped short tube orifice.

IndexTerms - Stepped short tube orifice, R290 Refrigerant, Nanolubricant, Net refrigeration effect.

I. INTRODUCTION

Compression refrigeration cycles take an advantage of the fact that highly compressed fluids at certain temperature tend to get colder when they are allowed to expand. If the pressure change is high enough, then the compressed gas will be hotter than our source of cooling (outside air, for instance) and the expanded gas will be cooler than our desired cold temperature. In this case, fluid is used to cool a low temperature environment and reject the heat to a high temperature environment.

Vapour compression refrigeration cycles have two advantages. First, a large amount of thermal energy is required to change a liquid to a vapour, and therefore a lot of heat can be removed from the substance to be cooled. Second, the isothermal nature of the vaporization allows extraction of heat without raising the temperature of the working fluid to the temperature of whatever is being cooled. This means that the heat transfer rate remains high, because the closer the working fluid temperature approaches that of the surroundings, the lower the rate of heat transfer. Suction line heat exchanger arranged between the condenser outlet and compressor inlet to increase net refrigeration effect by getting sub-cooling of liquid refrigerant at condenser outlet and superheated vapour refrigerant before entering compressor.

Nanofluids or nano-refrigerants are prepared by suspending nano sized particles (1-100nm) in conventional fluids or base oils used in compressor. The heat transfer capacity increased by using nanofluids because of thermal conductivity of nanolubricants was better than the base oils.

II. LITERATURE REVIEW

Numerous scientists have achieved examines vapour compression refrigeration system (VCRS) and survey the impact of performance parameters on the system with some modifications or by adding some components within the cycle and adding nanoparticles into the compressor lubricant oil.

[1] M.S.Bandgar, R.N.Kare: In this evaluated the performance of vapour compression refrigeration system using nanoparticles mixed with Polyolester (POE) oil / Mineral oil (MO) as Nanolubricant and R600a as refrigerant. POE Oil / Mineral Oil are mixed with Silica (SiO_2) Nano particles by ultrasonic sonication and stirring process to prepare the Nano lubricants. The investigation done on compatibility of POE-Mineral oil mixed with Silica (SiO_2) nanopowder (concentration of 0.5% by mass fraction) as Nanolubricant. It gives better results at mass fraction of 0.5% for all combination of Nano-oils. It was found that the time required to reducing the temperature of water though 10C is less and the power consumption reduces 12.02% when POE oil is replaced with a mixture of (MO+ 0.5% Silica). It has been observed that coefficient of performance is increased 11.66% when POE oil is replaced by a Nano lubricant (mineral oil (MO) + 0.5% of SiO_2).

[2] Nilesh S.Desai and P.R.Patil: SiO_2 Nano-oil is proposed as a promising lubricant to enhancing the performance of compressor in VCRS system. Application of Nano-oil with the specific concentrations 1%, 2% and 2.5% (by mass fraction) are added in the compressor oil. VCRS performance with addition of Nanolubricant investigated and results shown that COP (Coefficient of Performance) of the system increased by 7.61%, 14.05%, 11.9% respectively with the varying mass concentrations 1%, 2% and 2.5%. Energy saving can be achieved from minimum value of 7.03% to maximum value 12.3% using Nano-lubricant instead of normal refrigerants.

[3] P. A Domanski and Didion: In this effect of performance parameters are evaluated by placing suction line/liquid line heat exchanger in the basic vapour compression refrigeration system. It examines cycle parameters and refrigerant thermodynamic properties that determine whether the installation results in improvement of COP and volumetric capacity. As a result of employing suction line/liquid line heat exchanger high pressure refrigerant is sub cooled at the expense of superheating of vapour enter into a compressor.

[4] Domola S. Adelekan, Olayinka S. Ohunakin, Taiwo O. Babarinde, Richard O. Leramo, Sunday O. Oyedepo, Damilola C. Badejo: experimentally invested varied mass charge of LPG gas in R-134a compressor of a domestic refrigerator. Performance tests were investigated at steady state. Results obtained almost equal evaporator temperatures and reduction in power consumption for all tested nano lubricant mixture works safely and effectively in domestic refrigerator without modification of capillary tube length but requires adequate optimization.

[5] D.Senthilkumar 2017: In this study, the influence of silicon carbide nanoparticle in R134a refrigerant used in VCRS is investigated. The COP of the refrigeration system shows a significant development due to improvement of thermo-physical properties and heat transfer capabilities of Nano-refrigerant. Due to increase in thermal conductivity of SiC nanoparticles, the power consumption decreases. Hence the running cost of the system reduces. The freezing capacity of the system increases with the enhancement in the rate of cooling. The usage of Nano refrigerants decreases the global warming potential due to reduction in total mass fraction of refrigerant. Both suction and delivery pressure rises with addition of nanoparticles in refrigeration process.

[6] A.A.M. Redhwan, W.H. Azmi and M.Z. Sharif: In this work viscosity and thermal conductivity of SiO_2 nanoparticles dispersed in polyalkylene glycol (PAG) lubricants for 0.2-1.5% volume concentrations 303-353 K working temperatures was investigated and compared with Al_2O_3 Nanolubricant. The correlations for viscosity and thermal conductivity of SiO_2 nanolubricants at various concentrations temperatures were proposed in this work. Allowable volume concentrations of SiO_2 and Al_2O_3 nanolubricants for automobile air conditioning compressors are up to 1% and 0.3% respectively. Thermal conductivity of SiO_2 nanolubricants at 1% concentration is higher than Al_2O_3 nanolubricants at 0.3% concentration.

[7] R.Reji Kumar et al: In this evaluated Performance enhancement of domestic refrigerator with R600a and mineral oil/ Al_2O_3 nanoparticles was working fluid. It was founded that freezing capacity higher and power consumption reduces 11.5 % when POE oil replaced with the mixture of mineral oil and Aluminium oxide (Al_2O_3) nanoparticles. Using Aluminium oxide nanoparticles in refrigeration system feasible and the coefficient of performance (COP) of the refrigeration system also increases 19.6% when conventional POE oil is replaced with Nano-refrigerant.

III. EXPERIMENTAL SETUP

In vapour compression refrigeration cycle expansion of refrigerant from condenser to evaporator will takes place in capillary tube. In this present experiment, it is proposed to incorporate a stepped short tube orifice as extension to capillary tube for expansion. Stepped short tube orifice is a passive device which converts the pressure energy into kinetic energy without using any external work input. In the current work we are proposed to use both stepped short tube orifice and capillary tube to expand the refrigerant from condenser pressure to the evaporator pressure, with a view to find the effect of stepped short tube orifice. The following Steps involved in the present experimental work.

Preparation of nano lubricant:

SiO_2 nanoparticle is added to the compressor lubricant in refrigeration system. In general the most commonly used lubricant in refrigeration system is POE (Polyolester) oil. This preparation of nano lubricant will be done by two step process. First .5% wt SiO_2 nano particle is added to the Poe oil by direct mixing. After direct mixing the mixture is stirred with a magnetic stirrer for 10 hours. Then thw blend is vibrated in a ultrasonic homogenizer for 15 hours. This is to be done to avoid bunching of nano particles in the blend. To get uniform and stable mixture proper stirring has to be done ba a ultrasonic vibrator. Then the prepared nano lubricant is infused into the compressor of a domestic refrigerator.

Incorporating the nozzle in the vapour compression system

The vapour compression system has the components compressor, condenser, expansion device, stepped short tube orifice and evaporator in modified VCRS. To analyze the performance of vapour compression system, pressure gauges, temperature gauges are installed. Stepped short tube orifice is incorporated at the outlet of the condenser.

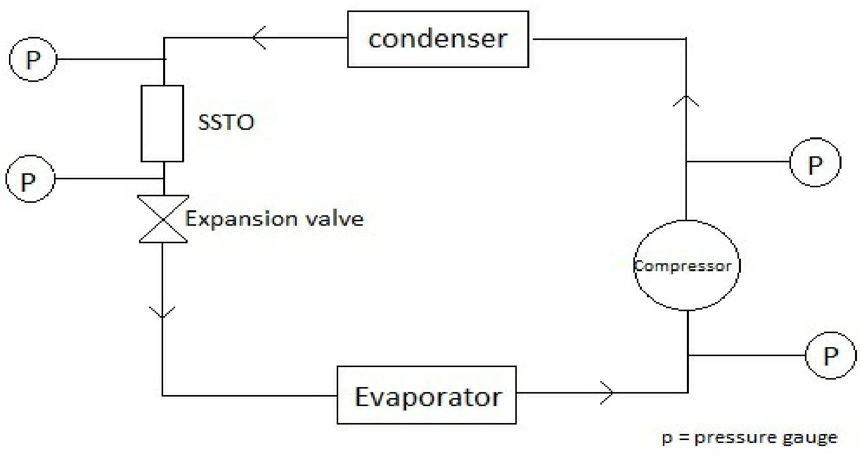

Figure 1: Schematic representation of Line diagrm

Experimental procedure:

Manufacturing of this stepped short tube orifice will be done by 2 stage machining operations. In the first satage copper rod of lenth 15mm will be machined for reduction in lenght to a lenth of 13mm by the facing operation. Once the facing operation is done, turning operation will performed on the component to reduce the diameter of 10mm to 7.5 mm. Both the facing and turning operatins of this copper rod has to be carried out on a lathe machine. By using drilling machine orifices of 4mm and 2mm diameters will be made on to the copper rod of lenths 6mm and 3mm.fix this manufactured stepped short tube orifice to system at the outlet of the condenser. Prssure gauges and thermocouples will be fixed at the desired locations as mentioned in the schematic diagram. Then inject a mass charge of 40g of R-290 refrigerant into compressor of exerimental domestic refrigerator. After refrigerant charging leak test has to be conducted to detect leakages. If no leakages are confirmed run the system from ambient conditions to -10ºC of evaporator temperature.simultaneously note down the readings of temperatures, pressures. Run the system till eveporator reaches to achieve -10ºC and note down the pull down time. Now replace the lubricating oil (POE oil) by nano lubricant POE-SiO_2 .5%wt i.e .2g/L of SiO_2. Again note down the corresponding readings of pressure temperature and pill down time in the system. Collect all the data pressure and temperature readings then draw P-h chart, extract enthalpy values for calculations.

Figure 2 : Stepped short tube orifice

Figure 3 : Experimental setup

IV. RESULTS AND DISCUSSIONS

1. Comparison of Net Refrigeration Effect (NRE)

In a vapour compression refrigeration system working on R-290 with incorporation of stepped short tube orifice, the net refrigeration effect has got increased by 5.76% that is more than the cycle R290 without Stepped short tube orifice. In addition with the inclusion of SiO_2 nano particle to lubricant the net refrigeration effect is further increased to 7.11% than the vapour refrigeration system with out stepped short tube orifice. This improvemrnt in net refrigeration effect is achieved by transforming available pressure energy of refrigerant into kinetic energy.

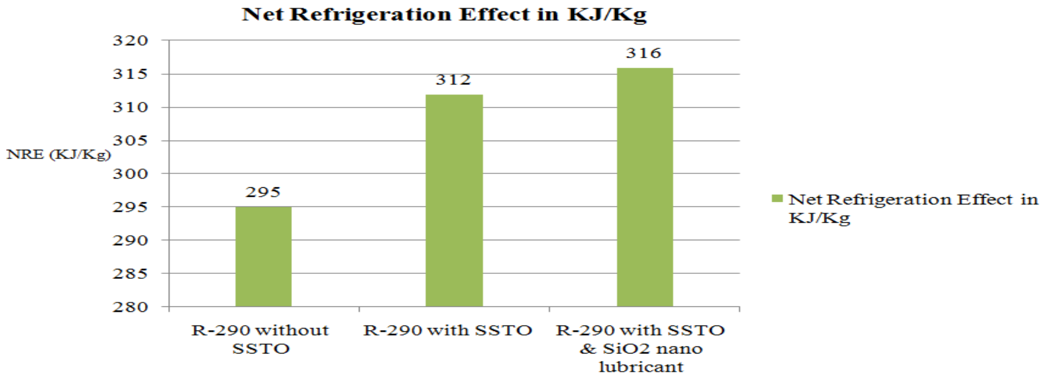

Figure 4: Comparison chart for Net Refrigeration effect

2. Comparison of Compression work

In a vapour compression refrigeration system working on R-290 with incorporation of stepped short tube orifice, the compression work has got decreased by 6.32%. That compressor work is less than the compressor work which required in the cycle R290 without Stepped short tube orifice. In addition with the inclusion of SiO_2 nano particle to lubricant the compression work is further decreased to 10.1% than the vapour refrigeration system with out stepped short tube orifice. Cpmpression work will be decreased due to friction will decreased in the compressor parts with nano particle inclusion.

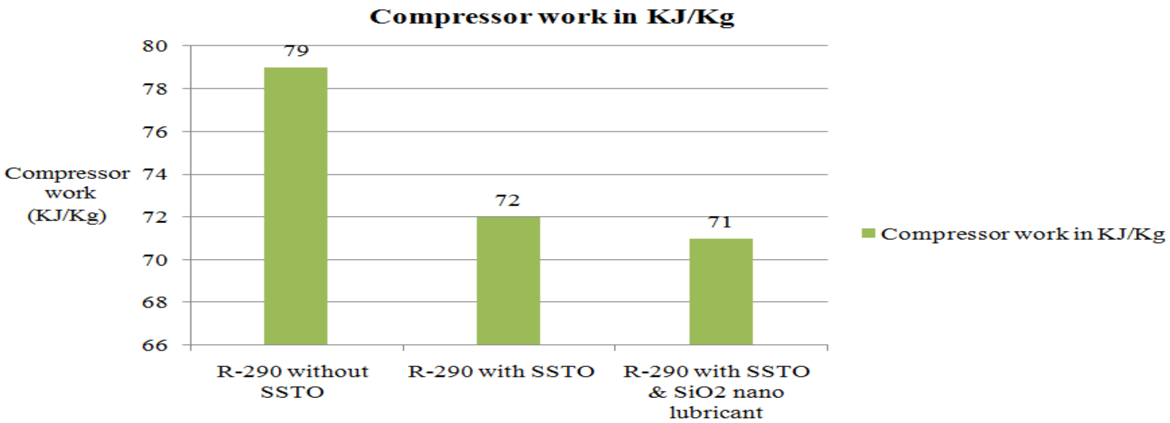

Figure 5: Comparison chart for Compressor work

3. Comparison of Pull down time

In a vapour compression refrigeration system working on R-290 with incorporation of stepped short tube orifice, the pull down time to achieve -10ºC is has got decreased by 3.77%. That pull down time is less than the pull down time of cycle R290 without Stepped short tube orifice. In addition with the inclusion of SiO_2 nano particle to lubricant the pull down time is further increased to 9.43% than the vapour refrigeration system with out stepped short tube orifice. This improvemrnt in pull down time is achieved by transforming available pressure energy of refrigerant into kinetic energy, with that the refrigerant flow velocity will increase and leads to decrease the pull down time.

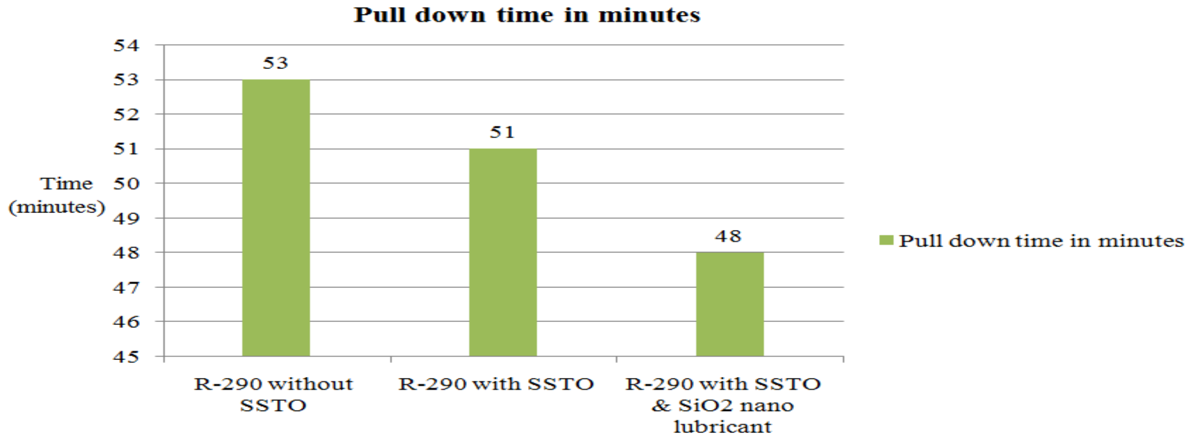

Figure 6: Comparison chart for Pull down time

4. Comparison of Coefficient of Performance (COP)

In a vapour compression refrigeration system working on R-290 with incorporation of stepped short tube orifice, the coeffcient of performance has got increased by 15.9%. This coeffcient of performance is more than the coeffcient of performance of cycle R290 without Stepped short tube orifice. In addition with the inclusion of SiO_2 nano particle to lubricant the coeffcient of performance is further increased to 19.19% than the vapour refrigeration system with out stepped short tube orifice.

In this experiment after all calculations it is observed that net refrigeration effect is increased where as compressor work is decreased by that the coeffcient of performance is increased.

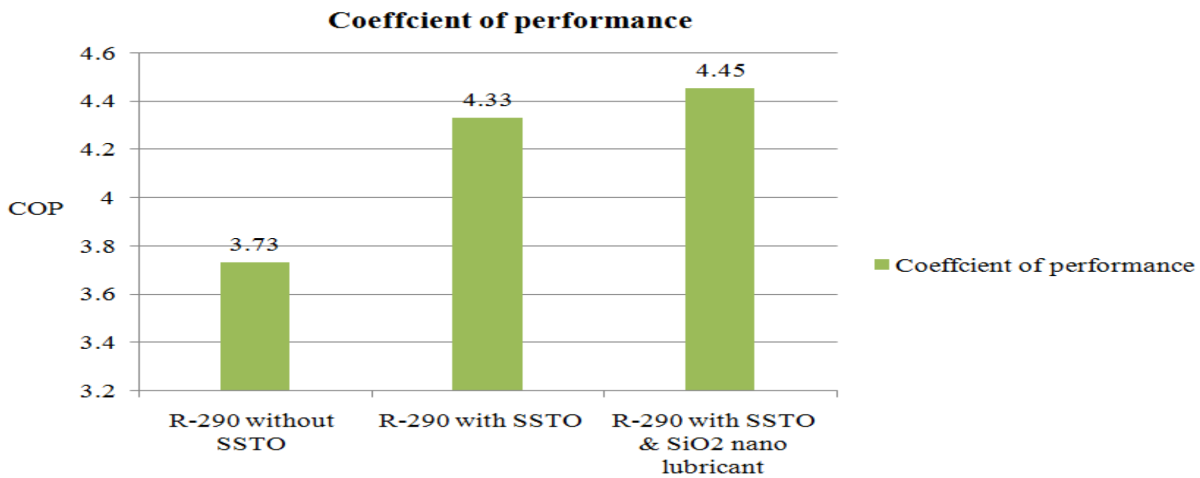

Figure 7: Comparison chart for Coeffcient of performance

IV. CONCLUSIONS

Experiments has been performed to investigate the effects of stepped short tube orifice which is incorporated as extension to the expansion device capillary tube to the domestic refrigerator running on the principle of vapour compression refrigeration system with refrigerant R-290. The results have been obtained for the experiments are followed as stated below.

1. The vapour compression refrigeration system, using refrigerant R-290, the Net refrigeration effect is increased to 5.76% with SSTO than the system without SSTO. The Net refrigeration effect is further increased to 7.1% with SSTO and inclusion of SiO_2 nano particle than the without SSTO.
2. The Compressor work is decreased by 6.3% with SSTO than the system without SSTO. The Compressor work is further decreased by 10.1% with SSTO and inclusion of SiO_2 nano particle than the without SSTO.
3. The Pull down time is decreased by 3.7% with SSTO than the system without SSTO. The Pull down time is further decreased by 10.1% with SSTO and inclusion of SiO_2 nano particle than the without SSTO.
4. The Coeffcient of performance is increased to 15.9% with SSTO than the system without SSTO. The Coeffcient of performance is further increased to 19.19% with SSTO and inclusion of SiO_2 nano particle than the without SSTO.

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