Performance Scrutiny of Domestic Refrigerator Using a Stepped Mini Orifice as A Capillary Tube Extension with Sio_2 Nano Lubricant And R-290 Refrigerant

BAIRI LEVI RAKSHITH[1], RAPAKA JAGADEESH[2], DR. M.P. RANGAIAH[3]
[1]PG Scholar, Mechanical Engineering, Chaithanya Bharathi Institute of Technology, Hyderabad
[2] PG Scholar, Mechanical Engineering, JNTUA College of Engineering (Autonomous), Anantapur
[3] Assistant Professor, Mechanical Engineering, JNTUA College of Engineering (Autonomous), Anantapur

Abstract- A stepped short tube orifice has been proposed as a replacement for the expansion mechanism in a residential refrigerator that runs on R-290. The present work is primarily concerned with the impacts of stepped short tube orifices on system characteristics such as net refrigeration effect, compressor effort, pull down time, and coefficient of performance. A stepped short tube orifice is made up of two short tube orifices linked serially and having varying sizes. It is used as an extension to the capillary tube in the refrigeration system. A stepped short tube orifice is built and fitted to a home refrigerator in this experiment. The experiments must be done on a home refrigerator equipped with a stepped short tube orifice, R-290 refrigerant, and a 0.5% weight SiO_2 nanoparticle. Following the completion of all trials, the effects of the stepwise short tube orifice on a residential refrigerator were studied using comparison charts. The results indicate that the performance of the home refrigerator with stepped short tube orifice and SiO_2 nano particle inclusion was much better than the domestic refrigerator without stepped short tube orifice

Indexed Terms- stepped short tube orifice, R290 Refrigerant, Nano lubricant, Net refrigeration effect.

I. INTRODUCTION

Compression refrigeration cycles take use of the fact that when strongly compressed fluids at a specific temperature are allowed to expand, they tend to get cooler. If the pressure difference is sufficient, the compressed gas will be hotter than our cooling source (for example, outside air), while the expanded gas will be colder than our targeted cold temperature. Fluid is utilised to cool a low temperature environment and to reject heat to a high temperature environment in this situation. There are two advantages to vapour compression refrigeration cycles. To begin, because it takes a significant quantity of thermal energy to convert a liquid to a vapour, a significant amount of heat may be eliminated from the item being cooled. Second, the isothermal characteristic of vaporisation enables heat to be extracted without raising the working fluid's temperature to that of the object being cooled. This indicates that the heat transfer rate stays high, because the rate of heat transfer decreases when the working fluid temperature approaches that of the surroundings. Suction line heat exchanger installed between the condenser outlet and compressor intake to maximise net refrigeration effect by subcooling liquid refrigerant at the condenser outlet and superheating vapour refrigerant prior to entering the compressor. Nanofluids or nano-refrigerants are made by suspending nanoparticles (1-100nm) in conventional fluids or compressor base oils. The capacity for heat transmission was improved by employing nanofluids, since the thermal conductivity of nano lubricants was superior to that of base oils.

II. REVIEW OF THE LITERATURE

Numerous scientists have examined the vapour compression refrigeration system (VCRS) and the effect of performance parameters on the system by modifying or adding components to the cycle, as well as by incorporating nanoparticles into the compressor lubricating oil. [1] Bandgar, M.S., and Kare, R.N. The performance of a vapour compression refrigeration system was tested utilising nanoparticles combined with polyol ester (POE) oil / mineral oil (MO) as a nano lubricant and R600a as the refrigerant. To create the Nano lubricants, POE Oil / Mineral Oil is combined with Silica (SiO_2) Nano particles using an ultrasonic sonication and stirring procedure. The compatibility of POE-Mineral oil with Silica (SiO_2) nano powder (concentration of 0.5 percent by mass fraction) as a nano lubricant was investigated. It produces superior outcomes at a mass fraction of 0.5 percent for all Nano-oil combinations. When POE oil is replaced with a combination of (MO+0.5 percent Silica), the time required to lower the temperature of water by 10 ^{o}C is reduced and the power consumption is reduced by 12.02 %. When POE oil is replaced with a Nano lubricant (mineral oil (MO) + 0.5 percent SiO_2), the coefficient of performance increases by 11.66 %.

[2] Nilesh S. Desai and P.R. Patil: SiO_2 Nano-oil is presented as a potential lubricant for improving the compressor performance in VCRS systems. Nano-oil is added to compressor oil at particular quantities of 1%, 2%, and 2.5 % (by mass fraction). The performance of the VCRS was studied with the addition of Nano lubricant, and the results indicated that the system's COP (Coefficient of Performance) rose by 7.61%, 14.05%, and 11.9%, respectively, with various mass concentrations of 1%, 2%, and 2.5 percent. Energy savings ranging from 7.03 % to 12.3 % are possible when utilising Nano-lubricant in place of conventional refrigerants.

[3] Domanski, P. A., and Didion: By installing a suction line/liquid line heat exchanger in a simple vapour compression refrigeration system, the influence of performance parameters is investigated. It evaluates the cycle parameters and thermodynamic characteristics of the refrigerant to determine if the installation improves the COP and volumetric capacity. Suction line/liquid line heat exchangers are used to sub cool high-pressure refrigerant at the price of superheating vapour entering a compressor.

[4] Domola S. Adelekan: They experimented with varying the mass charge of LPG gas in a home refrigerator's R-134a compressor. At steady state, performance tests were conducted. The results indicate that all tested nano lubricant mixtures operate safely and effectively in home refrigerators without modifying the capillary tube length, but require appropriate optimization.

[5] Senthilkumar D: The effect of silicon carbide nanoparticles on the R134a refrigerant used in VCRS is studied in this study. The refrigeration system's coefficient of performance has increased significantly as a result of the nano-improved refrigerant's thermophysical characteristics and heat transfer capabilities. The increase in thermal conductivity of SiC nanoparticles results in a decrease in power usage. As a result, the system's operating costs decrease. The freezing capacity of the system rises when the rate of cooling is increased. The use of Nano refrigerants reduces the risk for global warming by reducing the refrigerant's overall mass fraction. Suction and delivery pressures increase when nanoparticles are added to the refrigeration process.

[6] Redhwan: The viscosity and thermal conductivity of SiO_2 nanoparticles dispersed in polyalkylimide glycol (PAG) lubricants were examined and compared to those of Al_2O_3 nanoparticle lubricant at 0.2-1.5 percent volume concentrations and 303-353 K operating temperatures. This paper proposed correlations for the viscosity and thermal conductivity of SiO_2 nano lubricants at various concentrations and temperatures. Volume concentrations of SiO_2 and Al_2O_3 nano lubricants are permitted in car air conditioning compressors of up to 1% and 0.3%, respectively. Thermal conductivity of SiO_2 nano lubricants at a concentration of 1% is greater than that of Al_2O_3 nano lubricants at a concentration of 0.3 %.

[7] R.RejiKumar: The performance improvement of a home refrigerator using R600a and mineral oil/Al_2O_3 nanoparticles was tested in this study. It was discovered that when POE oil is replaced with a combination of mineral oil and aluminium oxide (Al_2O_3) nanoparticles, freezing capacity increases and power consumption decreases by 11.5 %. It is conceivable to use aluminium oxide nanoparticles in refrigeration systems, and the refrigeration system's coefficient of performance (COP) rises by 19.6 % when standard POE oil is substituted with nano-refrigerant.

III. EXPERIMENTAL SETUP

In a vapour compression refrigeration cycle, refrigerant expands in a capillary tube from the condenser to the evaporator. It is proposed in this experiment to add a stepped short tube orifice as an expansion extension to the capillary tube. A stepped short tube orifice is a passive device that transfers pressure energy to kinetic energy without the addition of external labour. The current study proposes to expand the refrigerant from the condenser pressure to the evaporator pressure using both a stepped short tube orifice and a capillary tube in order to determine the effect of the stepped short tube orifice. The following steps were taken during the course of the current experimental activity.

- Nano lubricant preparation:

In refrigeration systems, SiO_2 nanoparticles are added to the compressor lubricant. POE (Polyol ester) oil is the most often used lubricant in refrigeration systems. This nano lubricant will be prepared in two steps. To begin. By direct mixing, 5% weight SiO_2 nanoparticles are introduced to the Poe oil. After direct mixing, the mixture is agitated for 10 hours using a magnetic stirrer. The mix is then vibrated for 15 hours in an ultrasonic homogenizer. This is to avoid clustering of nanoparticles within the mix. To get a homogeneous and stable combination, adequate stirring using an ultrasonic vibrator is required. The produced nano lubricant is then injected into a home refrigerator's compressor.

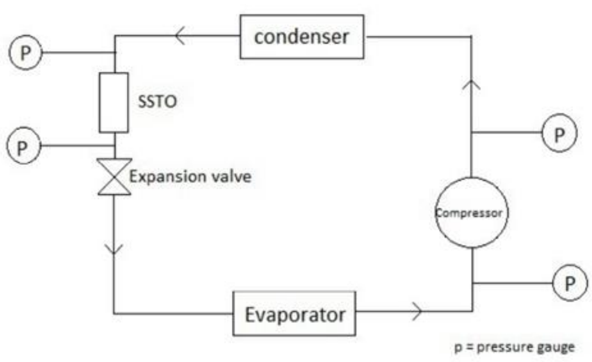

Figure 1: Schematic representation of Line diagrm

- Incorporating the nozzle in the vapour compression system:

The compressor, condenser, expansion device, stepped short tube orifice, and evaporator are all combined into a modified VCRS. Pressure and temperature gauges are fitted to monitor the functioning of the vapour compression system. At the condenser's output, a stepped short tube orifice is included.

Figure 2 : Stepped short tube orifice

Figure 3 : Experimental setup

- Experimental design:

This stepped short tube orifice will be machined in two stages. In the first stage, a 15mm copper rod will be machined to a length of 13mm by the facing operation. Following the facing operation, the component will be turned to decrease the diameter from 10mm to 7.5mm. This copper rod must be faced and turned on a lathe machine. Orifices of 4mm and 2mm diameter will be drilled into copper rods of 6mm and 3mm lengths using a drilling machine. Attach this produced stepped short tube orifice to the system at the condenser's output. Pressure gauges and thermocouples will be installed at the schematic diagram's designated places. After that, put 40g of R-290 refrigerant into the compressor of an experimental home refrigerator. Following refrigerant charge, a leak test must be done to identify any leaks. If no leaks are discovered, operate the system from ambient to -10^{o}C evaporator temperature. Simultaneously record temperature and pressure readings. Continue running the system until the evaporator reaches -10^{o}C and record the pull-down time. Now, replace the lubricating oil (POE oil) with a nano lubricant POE-SiO_2 at a concentration of.5% by weight, or.2g/L SiO_2. Again, make a note of the relevant pressure temperature and pill down time measurements in the system. Collect all pressure and temperature readings, then create a P-h chart and extract enthalpy values for calculating purposes.

IV. RESULTS AND DISCUSSIONS

- Net Refrigeration Effect Comparison (NRE):

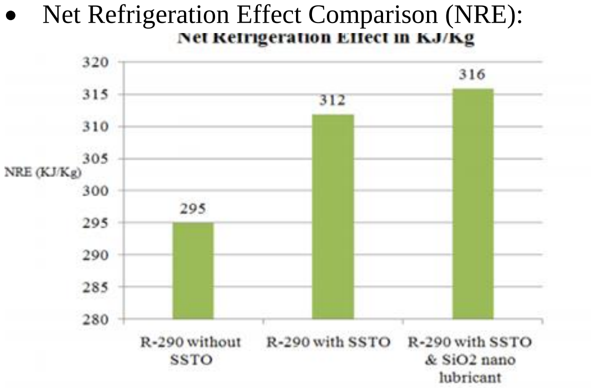

Figure 4: Comparison chart for Net Refrigeration effect

The net cooling effect of a vapour compression refrigeration system operating on R-290 with a stepped short tube orifice has been enhanced by 5.76%, which is more than the cycle R290 without the stepped short tube orifice. Additionally, when SiO_2 nanoparticles are used as a lubricant, the net refrigeration effect is enhanced to 7.11%, compared to the vapour refrigeration system without stepped short tube aperture. This increase in net refrigeration effect is accomplished by converting the refrigerant's available pressure energy to kinetic energy.

- Comparison of Compression work:

Compression work in a vapour compression refrigeration system operating on R-290 has been reduced by 6.32 % with the addition of a stepped short tube orifice. That compressor effort is less than that required in the R290 cycle without the Stepped short tube orifice. Additionally, when SiO_2 nanoparticles are used as a lubricant, the compression effort is reduced by 10.1 % compared

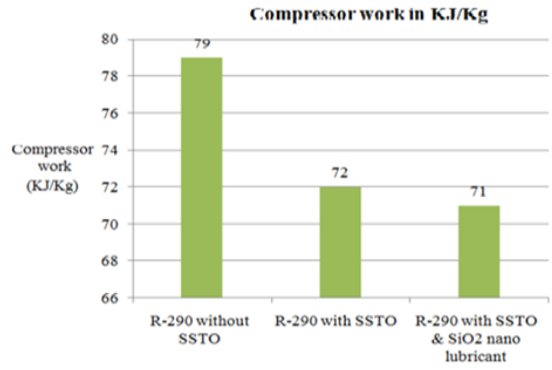

Figure 5: Comparison chart for Compressor work

to the vapour refrigeration system without stepped short tube orifice. Compression work will be reduced as a result of reduced friction in the compressor components owing to the introduction of nanoparticles.

- Comparison of Pull-down time:

Pull-down time in a vapour compression refrigeration system operating on R-290 has been reduced by 3.77% with the addition of a stepped short tube orifice. This time is shorter than the time required for cycle R290 without the Stepped short tube orifice. Additionally, when SiO_2 nanoparticles are used as a lubricant, the pull-down time is enhanced by 9.43% compared to the vapour refrigeration system without stepped short tube

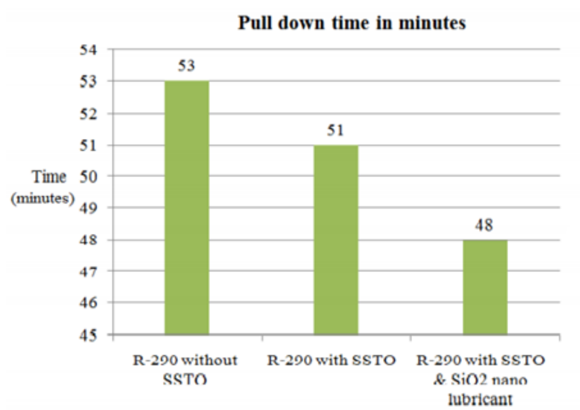

Figure 6: Comparison chart for Pull down time

aperture. This improvement in pull-down time is accomplished by converting the refrigerant's available pressure energy to kinetic energy, which increases the refrigerant flow velocity and therefore decreases the pull-down time.

- Comparison of Coefficient of Performance (COP)

The coefficient of performance of a vapour compression refrigeration system operating on R-

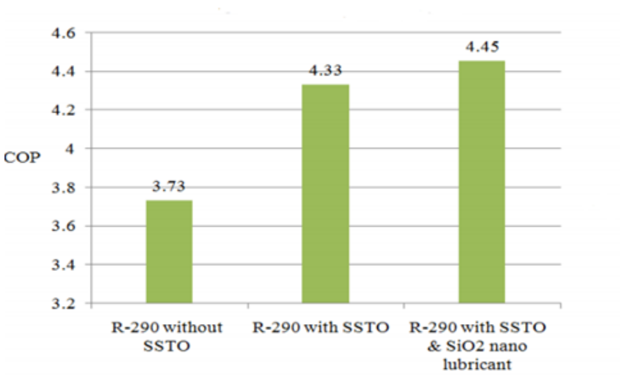

Figure 7: Comparison chart for Coeffcient of performance

290 has been improved by 15.9% by including a stepped short tube orifice. This performance coefficient is greater than the performance coefficient of cycle R290 without the Stepped short tube orifice. Additionally, the addition of SiO_2 nanoparticles to the lubricant increases the coefficient of performance to 19.19%, compared to the vapour refrigeration system without stepped short tube aperture. After all calculations are completed, it is noticed that the net refrigeration effect is enhanced while the compressor effort is lowered, therefore increasing the coefficient of performance.

CONCLUSION

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 Coefficient of performance is increased to 15.9% with SSTO than the system without SSTO. The coefficient of performance is further increased to 19.19% with SSTO and inclusion of SiO_2 nano particle than the without SSTO

REFERENCES

[1] B.C. Langley, Heat pump technology, Upper Saddle River, Prentice Hall, 2002.

[2] ASHRAE Handbook, HVAC Systems and Equipment, American Society of Heating, Refrigerating, and Air Conditioning Engineers, Atlanta, GA, 1996.

[3] D. Zhao, G. Ding, Y. Xu, et al., Development of a stepped capillary tube as a low-cost throttling device for a residential heat pump system, Int. J. Refrig. 42 (2014) 36–47.

[4] T. Liu, S. Wang, Y. Xu, et al., Experimental investigation of mass flow rate difference between forward flow and reverse flow of sub-cooled R-22 through stepped short tube orifices, Appl. Therm. Eng. 124 (2017) 1292– 1300.

[5] V.C. Mei, Short-tube Refrigerant-Flow Restrictors, Oak Ridge National Lab., TN (USA), 1982.

[6] D.A. Aaron, P.A. Domanski, Experimentation analysis and correlation of refrigerant-flow through short tube restrictors, ASHRAE Trans 96 (1) (1990) 729–742.

[7] Y. Kim, Two-phase Flow of HFC134a and HCFC22 Through Short Tube Orifices Ph.D. thesis, Texas A&M University, USA, 1993.

[8] Y. Kim, D.L. O'neal, Two-phase flow of R-22 through short-tube orifices, ASHRAE Trans. 100 (1) (1994) 323–334.

[9] Y. Kim, D.L. O'Neal, A comparison of critical flow models for estimating two-phase flow of HCFC22 and HFC134a through short tube orifices, Int. J. Re- frig. 18 (7) (1995) 447–455.

[10] S. Jin, T. Sung, T Seo, et al., Characteristics of R-123 two-phase flow through micro-scale short tube orifice for design of a small cooling system, Exp. Therm. Fluid Sci. 35 (7) (2011) 1484–1489.