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Efficiency Improvement of Refrigeration using Nanoparticles

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***Abstract*: Nano refrigerant is nothing but the combination of nano-particle with the refrigerant for the sake of better refrigeration process. It has been observed that, as compared to alternative refrigerant, there is better improvement in heat transfer capacity of the refrigerant after addition of nanoparticles. The use of nano-particles along with the conventional refrigerant with vapour compression cycle is relatively a new idea, where nano-refrigerants, so obtained are found to have their improved thermo-physical properties over the conventional refrigerants. Nano-particles can be used along with refrigerant in order to improve the performance of vapour compression refrigeration system. In this paper, alumina (Al2O3) nanoparticles of 50 nm diameter are dispersed in refrigerant R134a to improve its heat transfer performance to have their improved thermal & physical properties over the conventional refrigerants.**

***Keywords*: Vapour compression refrigeration cycle, COP, Heatexchanger, Compressor and Refrigeration.**

1. Introduction

The energy requires to the refrigeration system is much high in Industrial and Domestic area, so the energy efficient refrigeration system must be introduce without affecting it's performance. The mixture of nanoparticles with the conventional refrigerant increases the thermodynamic properties of the systems which results the less energy consumption for the system. This review paper is mainly focused on the working of nano refrigerant in the refrigeration system. It indicates effect of the parameters like thermo physical properties and heat transfer characteristics of refrigerant and how it reducing cooling period and improved the COP of the system, while the nanoparticle was mixed with conventional refrigerant.

In past time only refrigerants were used in refrigeration process and they were having a global warming coefficient at high level. Nano- refrigerant has become more popular for large number of experimental vapor compression systems because of shortage in availability of energy and environmental considerations. The addition of nanoparticles to the refrigerant results in improvements in the thermo physical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system. The concept is based on the fact that solids have high heat capacity as compared to fluid. Hence, there is huge scope of its application in heat transfer area. Therefore, there is need to improve the performance of vapour compression refrigeration system with the help of suitable refrigerant. The advantage of this project is suspended Nano particles increase the surface area and the heat capacity of the fluid due to the very small particle size. The suspended Nano particles enhance the thermal conductivity which results improvement in efficiency of heat transfer systems. Heating within the fluid volume, transfers heat to a small area of fluid and allowing the peak temperature to be located away from surfaces losing heat to the environment. The dispersion of Nano particles flattens the transverse temperature gradient of the fluid.

A. Testing

They are finally testing in this project. The domestic refrigerator has used in 50litre capacity. Then added to refrigerant components in R134a and Al2O3 nano fluid. Next, function of this project to working compressor and hermitecially sealed type is used in this type of compressor. Condenser is natural convection air cooled to using the temperature decrease. Expansion valve is used in capillary tube to the function of work is to reduce the temperature and pressure. But, they are pressure gauges used to compressor suction line and the delivery at the refrigeration another fins part to measuring liquid-vapour and vapour-liquid phase change condition. They evaporate in condition to using shell and coil and expansion coil are to using to reduce vapour to cooling. The functions is to working in to change of liquid to vapour. The refrigerant compressor motor is used in shaded pole single phase ac motor has to running. Those, following methods to using run a refrigerant test part at good performance has given in after adding nano particles to improve heat exchanger surface area.

B. Objectives of the work

The addition of nanoparticles to the refrigerant results in improvements in the thermo physical properties and heat transfer characteristics of the refrigerant, thereby improving the performance of the refrigeration system. Nanoparticles directed the innovative world into a new direction by its ability to influence working properties of fluid. Nano fluids are advanced class of fluids with particles of Nano size (1-100 nm). The concept is based on the fact that solids have high heat capacity as compared to fluid.

C. Scope of the work

The nanoparticle materials are usually of metal, non-metal and their oxides, which enhance the heat transfer performance of base fluids. Hence, there is huge scope of its application in heat transfer area. Recently, some investigations revealed the application of nanoparticles in refrigeration systems and significant improvement in performance has been observed. In refrigeration systems the nanoparticles can be either added to compressor lubricating oil or to refrigerant. Dispersion of nanoparticles into lubricating oil (Nano lubricant) improves the lubrication of compressor or decrease friction of moving parts. Additionally, the in case hermetically sealed compressor fractional amount of lubrication oil is carried away by refrigerant in compressor dome. So, by this means the heat transfer characteristics can be improved and hence performance of the refrigeration system. On other hand when nanoparticles are dispersed in refrigerant (termed as Nano-refrigerant), then it directly enhance the refrigerant thermal properties and thereby performance of refrigeration system is found to be improved. The conventional refrigerants have major role in global warming and depletion of the ozone layer. Therefore, there is need to improve the performance of vapor compression refrigeration system with the help of suitable refrigerant.

2. Methodology

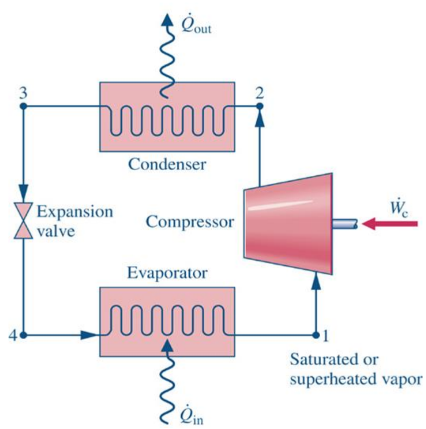

Fig. 1. Compressor

A. Compressor

The low pressure and temperature vapour refrigerant from evaporator is drawn into the compressor through the inlet or suction valve and it is compressed is entropically to a high pressure and temperature and discharged into the condenser through the delivery or discharge valve.

B. Condenser

The condenser consists of coils of thin copper pipe in which the high pressure and temperature vapour refrigerant is cooled and condensed by the process of forced convection. The refrigerant, while passing through the condenser, gives up its latent heat to the surrounding condensing medium which is normally air or water.

C. Receiver

The function of the receiver vessel is to store the condensed vapour-liquid mixture at high temperature and pressure and supply pure liquid refrigerant to the expansion valve so as to get better throttling and controlling effect.

D. Expansion Valve

It is also called throttle valve and the function of this valve is to allow the liquid refrigerant under high pressure and temperature to pass at a controlled rate after reducing its pressure and temperature. Some of the liquid refrigerant evaporates as it passes through the expansion valve, but the greater portion is vaporized in the evaporator at the low pressure and temperature.

E. Evaporator

An evaporator usually consists of coils of copper pipe in which the liquid-vapour refrigerant at low pressure and temperature is evaporated and changed into vapour refrigerant at low pressure and temperature. In evaporating, the liquid vapour refrigerant absorbs its latent heat of vaporization from the medium (air, water or brine) which is to be cooled.

3. Fabrication

The fabrication of the model is done such that it should not deviate with the designed model. First process of fabrication involves the selection of appropriate materials which will be available readily and should have optimum cost. The selection of materials is done such that the component should have good strength and serve the required and optimum performance. The material is also selected based on the availability and cost. The second process of fabrication involves the procurement of the required models. The necessary components and raw materials were purchased. First the raw materials using frame at the required length was purchased which is the selected model. The single-step method is a process of combining the preparation of nanoparticles with the synthesis of nanofluids, for which the nanoparticles are directly prepared by physical vapour deposition (PVD) technique or liquid chemical method. In this method the processes of drying, storage, transportation, and dispersion of nanoparticles are avoided, so the agglomeration of nanoparticles is minimized and the stability of fluids is increased. But a disadvantage of this method is that only low vapour pressure fluids are compatible with the process. A suitable power source is required to produce an electric arc between 6000-120000C which melts and vaporizes a metal rod in the region where arc is created. Two-step preparation process is extensively used in the synthesis of nanofluids by mixing base fluids with commercially available nanopowders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapor phase methods. Stability is a big issue that inherently related to this operation as the powders easily aggregate due to strong van der Walls force among nanoparticles. In spite of such disadvantages this process is still popular as the most economic process for nanofluids production.

National Chemical Laboratory (CSIR-NCL), Pune, established in 1950, is a constituent laboratory of Council of Scientific and Industrial Research (CSIR). CSIR-NCL is a science and knowledge based research, development and consulting organization. It is internationally known for its excellence in scientific research in chemistry and chemical engineering as well as for its outstanding track record of industrial research involving partnerships with industry from concept to commercialization. Al2O3 Nanoparticles with concentration of 0.5wt%, and 0.1wt% were measured by digital weight balance. Each mass fraction of nanoparticles is mixed with R134a Resultant nano refrigerant was homogenized for 15 minutes followed by sonication for up to 4 hours using ultrasonicator.

A. Effect on suction & discharge Pressure of compressor with and without Nano Refrigerant

Table 1
Effect on suction & discharge Pressure of compressor with and without Nano Refrigerant

Composition	Suction pressure	Discharge pressure
R134a	3	17
R134a+0.5% Al2O3	2	17
R134a+1% Al2O3	3	18

For the above experiments the Pressures at suction and discharge have been recorded and are discussed in following section.

P1 and P2 refer the Pressure at compressor suction and compressor discharge. Suction pressure shows decrement for R134a + 0.5% Al2O3 by 28.94% and for R134a + 1% Al2O3 by 18.42%. The discharge pressure shows increment. The discharge pressure of R134a + 0.5% Al2O3 is increased by 0.005% and for R134a + 1% Al2O3 by 8%. Thus there is significant increment for both the mixtures. In actual practice, the discharge pressure (or condenser pressure) increases due to frictional resistance of flow of the refrigerant and the suction pressure.

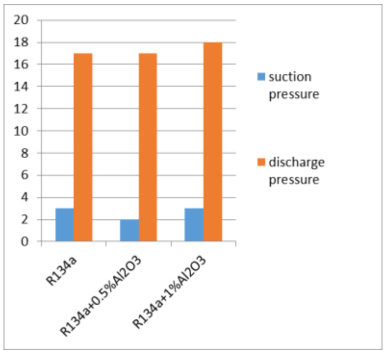

Fig. 2. Suction and discharge Pressure of compressor

B. Effect on Coefficient of Performance

Theoretical COP is evaluated as 4.17 for pure R134a. On the other hand, with R134a+0.5% Al2O3 and for R134a+1% Al2O3 theoretical COP is found to be 3.75 and 3.54 respectively.

R134a+0.5% Al2O3 shows the decline in theoretical COP by 10.07% and R134a+1% Al2O3 shows the decline in theoretical COP by around 15.10%.

Actual COP is evaluated as 2.69 for pure R134a. On the other hand, with R134a+0.5% Al2O3 and for R134a+1% Al2O3 actual COP is found to be 3.52 and 2.92 respectively. R134a+0.5% Al2O3 shows the improvement in actual COP by 30.85% and R134a+1% Al2O3 shows the decline in actual COP by around 8.55%.

Table 2
Effect on Coefficient of Performance

Composition	Actual value	Theoretical value
R134a	4.17	2.69
R134a+0.5% Al2O3	3.75	3.52
R134a+1% Al2O3	3.54	2.92

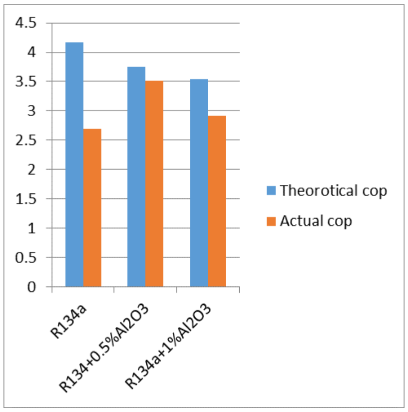

Fig. 3. Coefficient of performance

C. Model calculation

1) Coefficient of Performance (cop)

The coefficient of performance or COP, of a refrigeration system is the ratio of the heat removed from the cold reservoir to input work

$$COP_{cooling} = \frac{|\Delta Q_{cold}|}{\Delta W}$$

ΔQ_{cold} is the heat moved from the cold reservoir (to the hot reservoir).

ΔW is the work consumed by the heat pump.

2) Unit of refrigeration

Domestic and commercial refrigerators may be rated in kJ/s, or Btu/h of cooling. Commercial refrigerators in the US are mostly rated in tons of refrigeration, but elsewhere in kW. One ton of refrigeration capacity can freeze one short ton of water at 0 °C (32 °F) in 24 hours. Based on that, Latent heat of ice (i.e., heat of fusion) = 333.55 kJ/kg ≈ 144 Btu/lb

One short ton = 2000 lb

Heat extracted = (2000) (144)/24 hr = 288000 Btu/24 hr = 12000 Btu/hr = 200 Btu/min

1 ton refrigeration = 200 Btu/min = 3.517 kJ/s = 3.517 kW.

3) Mild steel Composition

Mild steel contains –C45

Carbon 0.35 to 0.45 % (maximum 0.5% is allowable)
Manganese 0.60 to 0.90 %
Silicon maximum 0.40%
Sulfur maximum 0.04%
Phosphorous maximum 0.04%
Mildest grade of carbon steel or mild steel contains a very low amount of carbon - 0.05 to 0.26%
Tensile strength – 63-71 kgf/mm^2
Yield stress -36 kgf/mm^2
Izod impact valve min -4.1 kgf m
Brinell hardness (HB) – 229

4) Cop calculations

Evaporator Temperature (T1) = -30ºC
Condenser Temperature ($T2^1$) = 30ºC
From charts,
At -30ºC,
Enthalpy (h1) = 338.143 kJ/kg
Entropy (s1) = 1.57507 kJ/ (kg.K) At 30ºC,
Enthalpy ($h2^1$) = 363.566 kJ/kg
Entropy ($s2^1$) = 1.54334 kJ/ (kg.K)
Enthalpy (h3) = 228.540 kJ/kg
From the graph,
s1 = s2 and h3 = h4
We know that, $h2 = h2^1 + Cp\,(T2 – T2^1)$
Equation – A $s2 = s2^1 + Cp \ln (T2/T2^1)$ $1.57507 = 1.54334 + 0.7253 * \ln (T2/303)$ On simplification we get,
T2 = 316.5 K S
substituting in Equation – A we have,
h2 = 363.566 + 0.7253 * (316.5 – 303)
= 373.35 kJ/kg (1)
Refrigerating Effect = h1 – h4 = 109.603 kJ/kg (2)
Coefficient of Performance (C.O.P) = Refrigerating Effect / Work done by the Compressor = (h1 – h4)/ (h2 – h1) = 3.11.

4. Conclusion

From the above result and discussion it is concluded that, addition of 0.5% of Al2O3 Nanoparticles in the base refrigerant will leads to improvement in the overall performance of the VCRS than that of pure base Refrigerant. However, increase in the percentage of nanoparticles in the base refrigerant will result in decreased system performance. The mixture of refrigerant and nano lubricant are work normally in the refrigeration system. The addition of nanoparticles to the refrigerant results in improvements in the thermos physical properties and heat transfer characteristics of the refrigerant. Due to improved heat transfer characteristics the cooling period was reduced. It was observed that the power consumption is reducing while nano lubricant added in the traditional refrigerant. The COP of the system was improved while nano lubricant used with the tradition refrigerant. The cooling capacity was increased for the same system while the nano lubricant was mixed with traditional refrigeration.

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