© January 2021| IJIRT | Volume 7 Issue 8 | ISSN: 2349-6002

Experimental Study and Analysis of Vapour Compression Refrigeration System Using (R134A-Cu nano particles) Mixture as a Nano-Refrigerant

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***Abstract* - The performance of the Refrigeration system mostly depends upon the heat transfer capacity of the refrigerant. The most common used refrigerants are R22, R134A, R22, R600 etc. for these refrigerants the heat transfer capacity is not quite good and hence to overcome these limitations and to increase the heat capacity of the refrigerant we have tried to use nano particles as an additive in base refrigerant. In this experimental analysis we have used mixture of copper nanoparticles and R-134A as a nano-refrigerant. The addition of nano particles results in improvement of heat capacity of refrigerant and thus various performance parameters such as Refrigeration effect and coefficient of performance of the system also improves by some factor. The experimental studies indicate that the refrigeration system with nano-refrigerant works normally.**

1.INTRODUCTION

The term refrigeration may be defined as the process of removing heat under a controlled condition. it also refers to the term of reducing or maintaining an object temperature below ambient or surrounding temperature. Nowadays refrigeration plays a very vital role in human's day to day life from domestic to industrial purpose.

Vapour compression refrigeration system (VCRS):
is an improved type of air refrigeration system in which a suitable working substance is used, generally referred as Refrigerant. It uses mechanical energy by repeating compression and expansion of coolant fluid to achieve cooling by Joule–Thomson effect. The VCRS system is nowadays used for all purpose refrigeration from domestic refrigerator to an industrial air conditioning plant. Due to the need of compression, it is called as a vapour compression refrigeration system.

The VCRS system consists of mostly four major components:

- Compressor: It compresses low temp. and pressure vapour from evaporator to high temp. and pressure vapour and supplies this vapour to condenser.
- Condenser: it condenses the vapour from compressor and supplies high pressure low temp liquid refrigerant to expansion valve.
- Expansion valve: it reduces the pressure of liquid refrigerant and sends low pressure low temp liquid to evaporator.
- Evaporator: here the liquid refrigerant absorbs its latent heat of vaporization from the medium which is to be cooled and low pressure and temp refrigerant flows toward the compressor.

Nano-refrigerant:
Nano-refrigerant is a sol in which solid nano particles are suspended in liquid refrigerant medium. These nano refrigerants are quite stable in nature. Nano particles mostly consist of metal or metal oxide with size of mostly (1-100) nm. Due to the presence of these solid nano particles conduction or convection coefficient of heat transfer increases thus increases the heat carrying capacity of nano refrigerant.
This nano refrigerant has various advantages over traditional refrigerant such as,

- Increased amount of heat transfer capacity.
- Better dispersion stability with predominant Brownian motion.
- Reduced pumping power to obtain equivalent heat transfer.
- Reduced particle clogging.
- The morphology of nanoparticles was ex examined by Transmission Electron Microscopy (TEM)

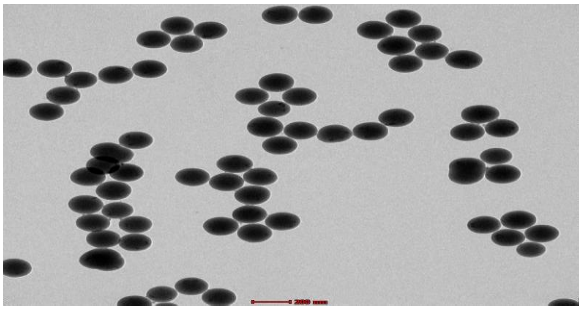

Figure 1.1 TEM image of cu nanoparticles at 200nm

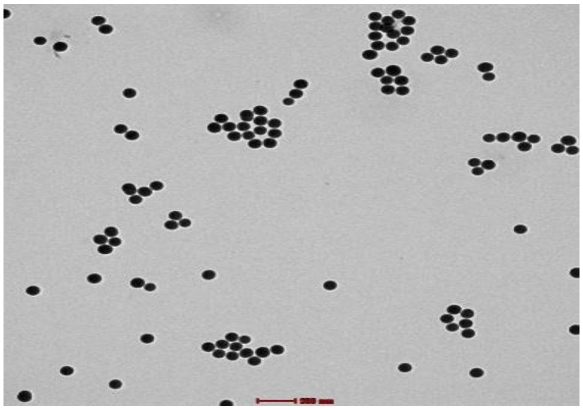

Figure 1.2 TEM image of cu nanoparticles at 500nm

2. EXPERIMENTAL SETUP AND METHODOLOGY

Here we discuss the detailed explanation on the facilities provided for conducting the experimental work on vapour compression refrigeration system. The experimental test rig consists of the following components.

It consists of a compressor unit, condenser, evaporator, cooling chamber, controlling devices and measuring instruments those are fitted on a stand and a control panel. Electric power input to the compressor is given through thermostatic switch.

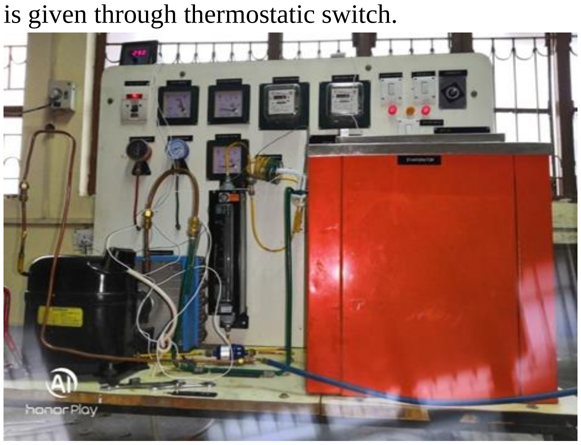

Figure 2.1 Experimental Rig

Figure 2.2 Charging kit

Table 2.1 Experimental rig. Specifications

Compressor Capacity	1/3 Ton at rated at test condition
Refrigerant	R-134a
Compressor	Hermitically sealed
Condenser	Forced convective air cooled
Condenser	fan motor Inductive type
Dryer/filter	Dry all make
Expansion device	Capillary tube
Magnetic stirrer	200-2000 RPM
Ultrasonic vibrator (Sonicator)	20KHz
Charging kit	For charging refrigerant
Vacuum Pump	Rotary vane type

3. EXPERIMENTAL PROCEDURE

- First take nanoparticles in refrigerant container and fill desired amount of refrigerant in it now put that container in ultrasonic vibrator for uniform mixing of refrigerant and nanoparticles for at least 3 hrs.
- Fill the compressor with fresh PAG oil.
- Charge test rig with air.
- Check for leakage.
- Evacuate the air with the help of vacuum pump.
- Now fill the test rig with the nano refrigerant.

4. OBSERVATION AND CALCULATION

The system was charged with refrigerant (R 134) and PAG oil with different concentration of nanoparticles using a charging line attached to the system. The temperature data were noted continuously, and the readings were taken at an interval of 5min.It was ensured that a constant temperature and humidity prevails in the surrounding space, when the experimental readings were taken. The experiment involved the measurement of the temperature T1-T5 of compressor, condenser, expansion valve, evaporator, and inlet - outlet of water temperature. The power consumption rate of the compressor was determined by noting the time taken by the digital energy meter for 5 pulses. Using these data, the heat transfer rate at the evaporator cabin and the power consumption rate in the compressor were calculated.

Calculation of experimental data

1.Refrigeration effect = Heat removal by the refrigerant- (1)

Calculated as RE = m*Cp *($T_{5(initial)}$ - $T_{5(final)}$) in KJ.

Where m = mass of the water

C_p = Specific heat of water in KJ/KgK

T_5 =Water temperature

2.Compressor work is measure by the energy meter,

Electrical input power, Ip = (5/ Te) *(1/EMC)

Where, Energy Meter constant (EMC)=1200 rev/kw/hr

Te = Time of revolution for Indications to Complete 5 revolutions

Taking motor efficiency as 75% we have input shaft power

Work input (SP) = Elect. I.P x 0.75

3.Coefficient of Performance= Refrigerating effect /Work Input

5. RESULTS

5.1 Refrigeration Effect of VCRS System

Nano Particles Concentration	Refrigeration Effect
0.0%	491.385
0.1%	510.622
0.2%	538.738
0.3%	593.993
0.5%	524.924
1.0%	635.432

Table 5.1 Refrigeration effect at various cu nano-particles concentration

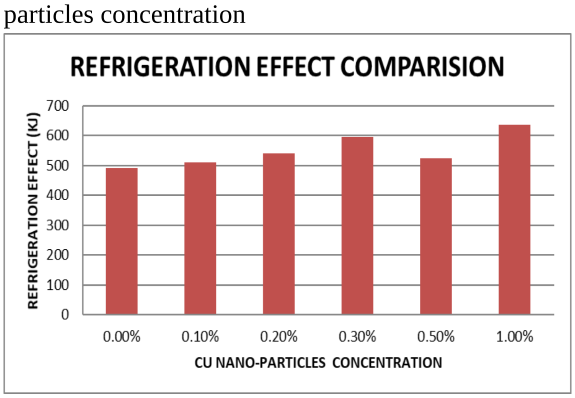

Figure 5.1 Refrigeration effect at various cu nano-particles concentration

From the above figure it has been observed that the refrigeration effect goes on increasing as we increase the cu nano-particles concentration, whereas at 0.5% concentration a decrement in refrigeration effect has been found out.

5.2 Energy Consumption by Compressor

Nano Particles Concentration	Compressor Work
0.0%	349.137
0.1%	349.137
0.2%	355.263
0.3%	355.263
0.5%	355.263
1.0%	375

Table5.2 Compressor work at various cu nano-particles concentration

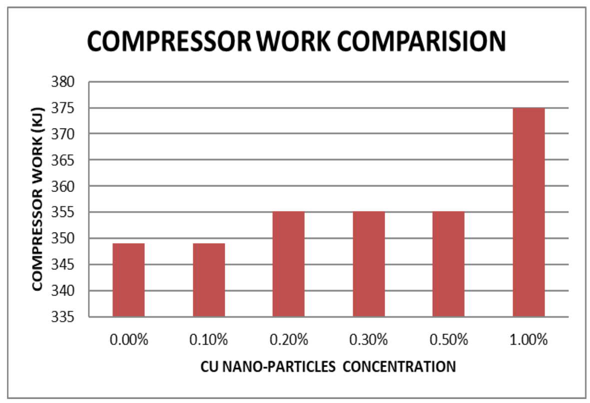

Figure 5.2 Compressor work at various cu nano-particles concentration

From the above figure it has been observed that the compression work goes on increasing as the quantity of nano particle increases. Whereas there is no gradual increase in the compressor work has found out. It increases then became constant and then increases. Maximum work found out to be 375KJ.

5.3 Coefficient of Performance of VCRS System

Nano Particles Concentration	Coefficient of Performance
0.0%	1.407
0.1%	1.462
0.2%	1.516
0.3%	1.671
0.5%	1.477
1.0%	1.656

Table 5.3 COP of VCRS system at various cu nano-particles concentration

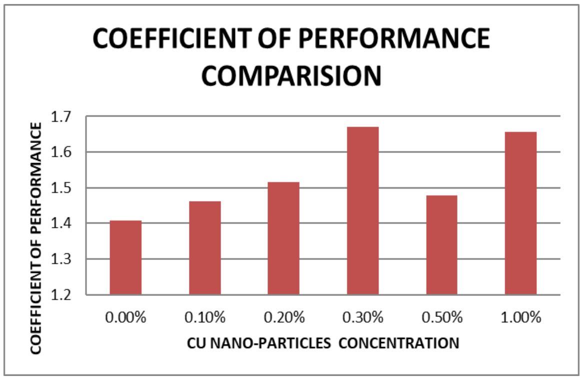

Figure 5.3 COP of VCRS system at various cu nano-particles concentration.

From the above results it is clearly observed that the cop of system increases gradually up to 0.3% copper concentration after which there is a decrement is being observed and then some increment at 1.0% copper concentration. The maximum COP value found out to be 1.671 at 0.3% copper concentration and lowest at 0.0% copper concentration.

6. CONCLUSIONS

The result of the experiment is evaluated by comparing the refrigeration effect, compressor work and coefficient of performance of R134a with copper nanoparticle by weight of refrigerant and PAG oil in the VCRS system. Apart from other literature studies the vapor compression cycle with constant energy input is fabricated and various mass concentrations of refrigerant and nano particles are fed into the compressor and various performance parameters are recorded and observed from the above.

- The thermal conductivity of Nano-refrigerant is higher than that of normal refrigerant. This led to higher refrigeration effect.
- The maximum increment in refrigeration effect is found out to be 29.31% at 1.0% copper concentration as compared to conventional R134A refrigerant.
- Compressor work increases with a maximum increment of 7.40% at 1.0% copper concentration.
- The cop variation is as follow 3.98% increase when we add 0.1% copper nano particle,
- 7.746% when the copper concentration is 0.2%, 18.76% growth at 0.3% copper, 4.975% at 0.5% copper and 17.69% growth at 1.0% copper nano particle concentration. Hence, the maximum cop is found out at 0.3% copper nano-particle concentration which is 1.671.
- At 1.0% copper concentration refrigeration effect is found out to be maximum whereas compressor work is also maximum at this point hence, the COP of the system does not attain its maxima at this concentration level.
- Hence, from the above we can conclude that at 0.3% cu concentration we get the maximum cop and hence further addition of nano particles is not advisable.
- Nano refrigerants stability and its production cost are major factors that hinder the commercialization. By solving these challenges, it can be expected that nano refrigerants can make substantial impact as coolant in refrigeration devices.

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