Experimental Analysis Of Vapour Compression Refrigeration System With Superheating By Using R-134a, R-12, R-717 Refrigerant

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Abstract: *It is necessary to modify the simple vapour compression refrigeration cycle in order to improve the performance. The COP of system can be improved by increase the refrigeration effect or by decreasing the work required to run the compressor. The refrigeration effect can be increasing by maintaining the superheated refrigerant at exit of evaporator. On the basis Experimental analysis on vapour compression refrigeration system (VCRS) with R-134a,R-12,R-717 as a refrigerant are used and their result was recorded. The effect of increasing evaporating temperature (superheating) on various performance parameter such as COP, power required to run the compressor ,volumetric efficiency , percentage increase in Cop, percentage reduction in power to run compressor are find out. The main objective of this paper is evaluate the performance of VCRS cycle with the help of liquid line heat exchanger by using R-134a,R-12,R-717 as a refrigerant.*

Key words: **Vapour compression refrigeration cycle, COP , heat exchanger ,compressor , refrigeration**

1. INTRODUCTION

A simple VCRS system consist of a compressor ,condenser, expansion valve , evaporator .in VCRS system low pressure and low temperature vapour refrigerant enter into the compressor. During compression pressure, temperature both is increases. This high pressure and temperature refrigerant passes through the condenser where it loses its sensible and latent heat. Then this low pressure and low temperature refrigerant passes through the expansion valve where both pressure and temperature are reduced suddenly. This low temperature refrigerant passes through the evaporator where it absorbs the latent heat of vaporization. Thus this cycle is also known as sensible heat cycle.

PROCESSES

Process 1-2: reversible adiabatic and isentropic compression in compressor.

Process 2-3: constant pressure heat rejection in condenser.

Process 3-4: isenthalpic expansion in expansion device.

Process 4-1: constant pressure heat absorption in evaporators.

2. LITERATURE REVIEW

G. maruthiprasad yadav et al: in this paper author uses liquid line heat exchanger to improve the performance of the VCRS system. authored said if uses liquid line heat exchanger increase refrigeration effect 3.81% by using r-134a as a refrigerant and 5.35 increases in refrigeration effect by using r-404a as a refrigerant.

K.s. rawat et al: authored in this paper uses low grade energy in Rankin cycle and with the help Rankin cycle it drive the VCRS system to produce refrigeration effect. Generally the low grade energy used in this system are solar, geothermal, and weast heat of industries. Due to this system the environmental pollution will be reduced.

J.u.ahamed et al: in this paper it uses exargey analysis of VCRS system. the exergey analysis are used to calculate the inefficiency and loss of energy . it has been found that major exergy losses have been caused in refrigerator, washing machine, AC, fan, iron, and about 21%of total losses are caused by refrigerator freezer and 12% of total losses are caused by ac .it also uses hydrocarbons are considered as a refrigerant due to low GWP it uses r-407a, r-600a, r-134a are considered and analysis with respect to exergy efficiency. it concluded that refrigerant r-134a give better performance with respect to other refrigerant.

3. SYSTEM OVERVIEW

In simple vapour refrigeration system basically four device are used. Compressor, condenser, expansion valve, evaporator. in this system basically two heat exchanger are used . One is absorb heat and one is rejected heat .

Compressor – a compressor is a device used to increase the pressure of refrigerant. it also increase the saturation (boiling point) temperature of refrigerant.

Condenser- condenser is basically a heat exchanger is used to remove the heat of refrigerant. It removes both sensible and latent heat of refrigerant.

Exp ansion valve – the basic functions of an expansion valve to reduce pressure of refrigerant from condenser pressure to evaporator pressure.

Evaporator – a evaporator is a important parts of a VCRS system. it absorb heat from air and cooled it. in VCRS system it basically absorb latent heat of.

Capillary –a capillary tube is a long narrow tube of constant diameter. Typically the capillary tube diameter varies from 0.5to 3mm and length varies from 1.0to6m .capillary tube is made of copper.

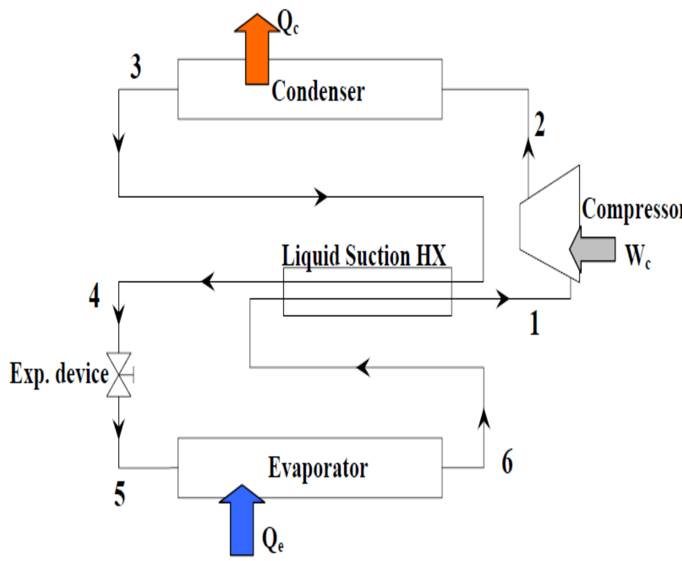
the capillary is a throttling device used for reducing the pressure of refrigerant when it is passes through the expansion valve .when a high pressure and low temperature refrigerant passes through the capillary tube its pressure is reduced due to very small diameter of capillary tube .the decreases in refrigerant pressure is a function of capillary diameter and length of capillary. small the diameter and greater the length the capillary greater the pressure drop.

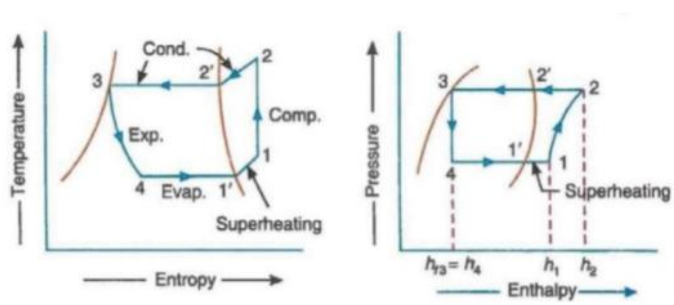
Thermometer –a thermocouple is a device used to measure temperature.

A thermocouple is comprised of at least two metals joined together to form two junctions. One end of this junction is connected with the body of higher temperature (a body whose temperature is measured) and other end of a junction is connected to the body lower temperature (whose temperature is known) .therefore the function of thermocouple is to measure the unknown temperature with reference to known temperature.

3.1 SUPERHEATING

super heating is the super heating the refrigerant at outlet to the evaporator if the super heating of refrigerant takes place due to heat transfer with the refrigerant space then it is call useful super heating





Processes

1′-1= degree of super heating

1-2= isentropic compression

2-2′= degree of sub cooling

2′-3= constant pressure heat rejection

3-4= isenthalpic expansion

4-1′= constant pressure heat absobstion

3.2 EFFECT OF SUPERHEATING

s.no	Parameter	effect of superheating
1.	Refrigeration effect	Increase
2.	suction temperature	Increase
3.	mass flow rate	Decreases
4.	specific volume at inlet of compressor	Increase
5.	Cop	may or may not increase depending the nature refrigerant
6.	pressure ratio	Constant
7.	volumetric efficiency	Constant
8.	work done	depends on inlet temperature
9.	Capacity	Decreases

3.3 LIQUID-SUCTION HEAT EXCHANGER

A a LSHX is a counter flow heat exchanger installed between outlet of compressor and inlet of compressor. In LSHX the hot refrigerant at outlet of the condenser exchanges heat with the cooled refrigerant at outlet of evaporator. Figure shows the schematic of a single stage VCRS with a liquid-suction heat exchanger. note if the exit temperature of refrigerant at evaporator is not sufficient super heated then this refrigerant super heated by exchanging heat with the atmosphere (surrounding) it flow through connecting pipe line (unuseful superheating) which is detrimental to system performance. Science the temperature of vapour refrigerant at outlet of evaporator is less than the temperature of the refrigerant liquid at the exit of condenser. Then heat is transfer from higher temperature to a lower temperature. then sub cooled the liquid refrigerant at outlet of the condenser and super heat the refrigerant at exit of evaporator.

Analysis of LSHC

Energy in = Energy out

$m\ (h_3-h_4) = m\ (h_1-h_6)$

$(h_3-h_4) = (h_1-h_6)$

If we take average values of specific heats for the vapour and liquid, then we can write the above equation as;

$$c_{pl}\ (t_3-t_4) = c_{pv}\ (t_1-t_6) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Since $c_{pl} > c_{pv}$

Than from equation 1

Than

(t_1-t_6) will be greater than (t_3-t_4)

We known that

Amount of sub cooling = $c_{pl}\ (t_3-t_4)$

Amount of superheating = $c_{pv}\ (t_1-t_6)$

Since (t_1-t_6) will be greater than (t_3-t_4) that means the degree of super heating is always greater than degree of sub cooling

Effectiveness

Effectiveness is the performance parameter used in heat exchanger calculation.

If we define as the ratio of actual heat transfer rate in the LSHX to maximum possible heat transfer rate, then:

Effectiveness = $\varepsilon = Q_{actual} / Q_{actual}$
Effectiveness = $\varepsilon = t_3-t_4 \ / \ t_1-t_6$

the maximum possible heat transfer rate is equal to m $c_{pv}(t_3-t_6)$, because the vapour has a lower thermal capacity, hence only it can attain the maximum possible temperature difference, which is equal to (t_3-t_6) if the heat exchanger is 100%efficient i.e.(ε = 100%) then the exit temperature of refrigerant at heat exchanger is equal to condenser temperature $\varepsilon = 100\%$, $t_1=t_3$

4. EXPERIMENTALPROCEDURE

The following procedure is adopted for experimental setup of the vapor compression refrigeration system

(1) First off all selected a refrigerator, working on vapor compression refrigeration system.

(2) Then second is selected a working fluid we are selected r-134a as a working fluid.

(3) Pressure and temperature gauges are installed at each entry and exit of the components.

(4) r-134a refrigerant is charged in to the vapor compression refrigeration system it is necessary to remove the air from the refrigeration unit before charging the refrigerant.

(5) Leakage tests are done by using soap solution.

(6) Switch on the refrigerator and observation is required for 1.3 hour and take the pressure and temperature readings at each section.

(7) The performance of the existing system is investigated, with the help of temperature and pressure gauge readings.

(8) The refrigerant is discharged out and condenser is located at the inlet of the capillary tube.

(9) Temperature and pressure gauge readings are taken and the performance is investigated.

5. MATHEMATICAL ANALYSIS

With the help of experiment we find the temperature at different point of cycle and with the help of different temperature we find out the properties of three refrigerants R-123a,

1. For compressor – compressor work required.

$w_c = h_2 - h_1$ kj/kg

2. For condenser – amount of heat rejected by condenser.

HR= $q_2 = h_2 - h_3$ kj/kg

3. For expansion valve- work done is eual to zero. $h_3 = h_4$ kj/kg

4. for evaporator – amount of heat absorbed by evaporator.

HA= $q_1 = h_1 - h_4$ kj/kg note. ($h_3 = h_4$)

COP= it is defined as the ratio of refrigeration effect to the work supplied to the compressor.

$$COP = \frac{Refrigeration\ effect}{Work\ supplied\ to\ the\ compressore}$$

$$COP = \frac{Q_1}{WD} = \frac{h_1 - h_4}{h_2 - h_1}$$

R-134A calculation

S no.	Parameter	Numerical value
1.	Compressor Discharge Temperature T2(°C)	53.5
3.	Evaporator inlet Temperature T4(°C)	-2
4.	Degree of Superheated temperature T_1	6
5.	Enthalpy,$h1^1$ (kJ/kg)	397.51
6.	enthalpy h_1	404.956
7.	Enthalpy,h2 (kJ/kg)	436.68
8.	Enthalpy,h3 (kJ/kg)	254.35
9.	Enthalpy,h4 (kJ/kg)	254.35

Final result without super heating.

s.no.	Parameter	Numerical value (kj/kg)
1.	Compressor work	39.18
2.	Refrigeration effect	143.15
3.	Cop	3.6548

Final result with superheating.

s.no.	Parameter	Numerical value (kj/kg)
1.	Compressor work	31.724
2.	Refrigeration effect	150.606
3.	Cop	4.747

Percentage changes the performance parameter with and without superheating.

s.no.	Parameter	% change
1.	Compressor work	19.03 ↓
2.	Refrigeration effect	5.208 ↑
3.	Cop	29.88 ↑

For similar condenser inlet temperature, condenser outlet temperature, evaporator temperature, and degree of superheating the final result for refrigeration R-12,R-717 is

For R-12 final result is.

s.no	Parameter	Ans.without superheating	Ans.With super heating	% change
1	Refrigeration effect	h1'-h4 =113.098	h1-h4 =117.442	3.840 ↑
2	Compressor work	$h_2 - h_1'$= 30.5253	$h_2 - h_1$= 26.179	14.238 ↑
3	Cop	R.E./WD= 3.523	4.486	21.079 ↑

For R-717 final result is.

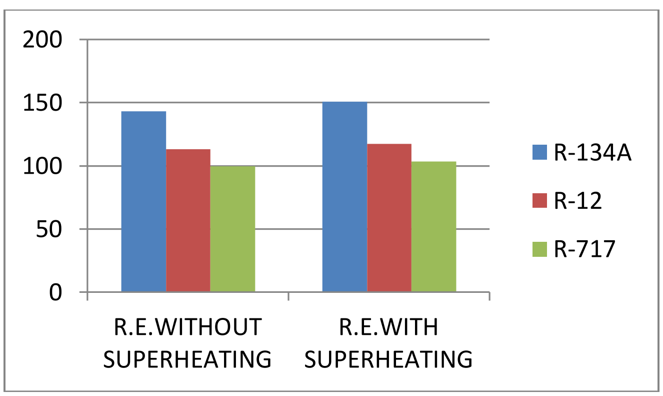
s. no	Parameter	Ans.without superheating	Ans.With super heating	% change
1	Refrigeration effect	h1'-h4 =99.791	h1-h4 =103.275	3.491 ↑
2	Compressor work	h_2-h_1'= 28.459	h_2-h_1= 24.115	18.013 ↑
3	Cop	R.E./WD= 3.5064	4.286	22.233 ↑

RESULT:

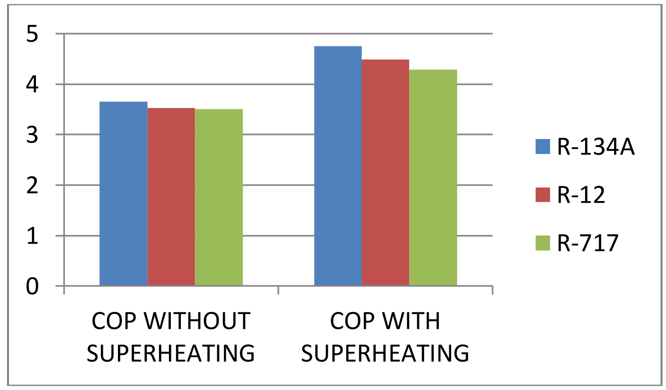
if we increases the evaporator temperature before entering to the compressor by 6^0 C from (-2^0C to 4^0C i.e. superheating the refrigerant) the cop of the cycle ,and refrigeration effect increases with the help of superheating.

(1) With the help of superheating the refrigeration effect increases 7.456 kj/kg if using R-134A refrigerant, 4.344 kj/kg using R-12 refrigerant and 3.484 kj/kg using R-717 refrigerant.

(2) With the help of superheating the cop increases 1.0922 if using R-134A refrigerant, .963 using R-12 refrigerant and 0.7796 using R-717 refrigerant.



Variation of refrigeration effect with and without Superheating



Variation of COP with and without Superheating

CONCLUSIONS:

In this paper we are doing experimental study of the simple VCRS cycle and VCRS cycle with superheating with the help of liquid line heat exchanger. If we increases the evaporator temperature before entering to the compressor by 6^0 C from (-2^0C to 4^0C i.e. superheating the refrigerant) the cop of the cycle ,and refrigeration effect increases with the help of superheating. Using the superheating significant effect on the increase of the cop by using the refrigerant R-134A compared to refrigerant R-12 and refrigerant R-717 . Broadly speaking that refrigerant R-134A is give the best result for same evaporator temperature, condenser temperature and degree of supcooling compared to refrigerant R-12 AND R-717.

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