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Performance Analysis of VCR System with Twisted Tape Condenser by Using R134a Refrigerant

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ABSTRACT

This research work reports on the performance analysis of a vapour compression refrigeration system with twisted taped condenser by using R134 as refrigerant. Majority of the refrigerators today works on the VCR system. This system consists of the following important components, compressor, condenser, expansion valve and evaporator. The accomplishment of the system depends upon the all the parts of the system. The main purpose of this research work is to intensify the heat transfer rate through the condenser coil by inserting the twisted tapes into the condenser coil .The twisted tapes with twisting ratio (y/d=2.134) is used. In this research work two twisted tapes one with Al and another one with Cu are separately inserted into the condenser coils and the performances of both the coils compared with the existing system. Twisted tape is a type of vertex generator which can give the swirl flow to the fluid, due to this the temperature difference of the fluid with the surroundings increases, which can finally results to a high heat transfer coefficient. Finally it is observed that the COP of the twisted taped condenser coil refrigerator is more while comparing with the existing system. The performance parameters such as refrigerating effect, mass flow rate, compressor work and coefficient of performance are calculated. Finally the performances for both Cu and Al twisted tapes are compared.

INTRODUCTION

Refrigeration:

Refrigeration is defined as the process of getting and keeping the temperature underneath that of the temperature of surroundings and to cool the products or area is nothing but the space to the required temperature. The first and foremost application of the refrigeration is, it is used for the preservation of the perishable goods or food products by storing them at the underneath temperatures. The spell 'Refrigeration' is not a synonym of cooling even both the words are associated with the lowest temperature maintenance. This can be understood by the following explanation. In general the spell "Cooling" is a heat transfer process to decrease the temperature gradient, it is natural, unplanned process means it is going on the spot or an artificial process by manually. However the spell "Refrigeration" is not a spontaneous process, because it requires the expenditure of energy. The example for the cooling process is the cooling of a hot cup of tea while the example for refrigeration process is transforming a glass of water from room temperature to the required temperature [1].

Refrigerators are nothing but the devices which produce refrigeration. A refrigerator is nothing but a reversed heat engine which is used for either cooling or maintaining the temperature of a skull (T_1) underneath than the temperature of atmospheric (Ta). This is done by removing the heat (Q_1) from the body which is cold and transferring it to the hot body (Q_2).In this process work WR is needed and this work is done on the system. In accordance with the First Law of Thermodynamics [2-5], [7]

$$W_R=Q_2 - Q_1$$

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The Coefficient of Performance of a refrigerator is expressed as the ratio of amount of heat removed from the body which cold (Q_1) to the amount of work needed to be done on the system (W_R).

$$C.O.P = Q_1/W_R = Q_1/(Q_2 - Q_1)$$

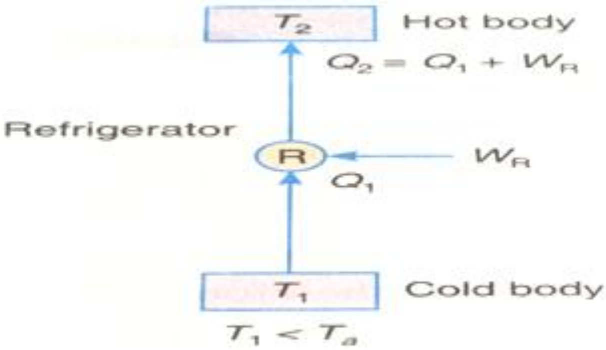

Figure 1.1Refrigerator

Vapor Compression Refrigeration System:

Before the introduction of Vapor compression Refrigeration system, the mechanical refrigeration system is widely used for refrigerating purpose. But due to the wide applications of vapour compression refrigeration system while compare with the mechanical refrigeration it is used now in a wide range. Improved type of the mechanical refrigeration is nothing but the vapour compression refrigeration System. Some liquids have the capability to sponge the large quantities of heat as they vaporize is the basic process of the system.

Compared with the melting of the ice to get the refrigeration effect vaporization of the liquid have the huge no of advantages. It can be seen in the following one. In the refrigeration process the rate of cooling can be preset and it can be started when and while required. Whereas it is not possible in melting of ice. In this vapour compression refrigeration system the vapor refrigerant can be willingly posed and condensed again into the state of liquid. Hence, the same liquid can be re-circulated again and again. So the vapor compression refrigeration system enrolls a liquid refrigerant which is evaporated and condensed willingly. And also the vapour compression refrigeration system is a closed system, hence once charged never leaves the system [9].

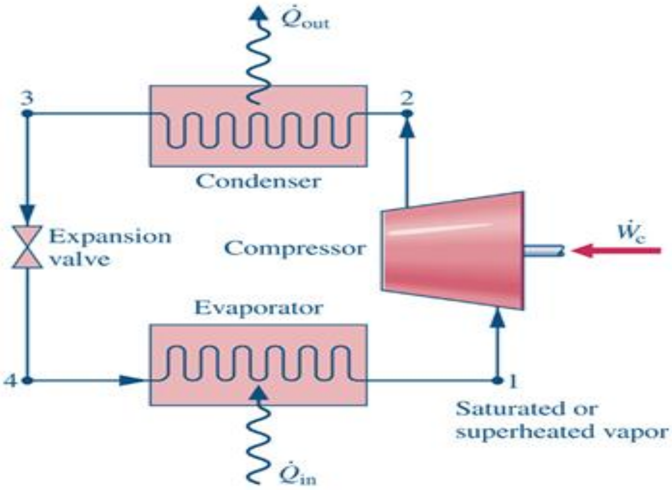

Fig. 1.2Schematic diagram of a vapor compression refrigeration system

In the reversed Carnot cycle if we made two modifications it can completely remove the impossibility. This can be done by vaporizing the refrigerant wholly before its compression and by using expansion devices. Now the cycle which is obtained is called “the ideal vapor-compression refrigeration cycle”, and the schematic T-s diagram is also shown. The vapor compression refrigeration cycle is the cycle which is widely used cycle for refrigerators, air-conditioning systems, and heat pumps [11].

It consists of four processes:

1. 1-2 Isentropic compression by using the compressor
2. 2-3 Constant-pressure heat rejection in a condenser
3. 3-4 Throttling in an expansion device
4. 4-1 Constant-pressure heat absorption in an evaporator

PRESSURE (P)- ENTHALPY(H) Diagram

For studying the characteristics of a refrigerant p-h chart is most useful and convenient. In this p-h chart the pressure is represented by the vertical ordinates and the enthalpy is represented by horizontal ordinates.A typical diagram of p-h chart as shown in the figure in which some important lines of the whole chart are drawn. A saturated liquid line is nothing but the one which has a temperature equals to the saturated temperature corresponding to its pressure. Hence the sub cooled

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region is present to the left side of the saturated liquid line. The lines of saturated liquid and saturated vapour are merging into one another at the critical point. The area between the vapour lines and the liquid is called as Wet vapour region [13].

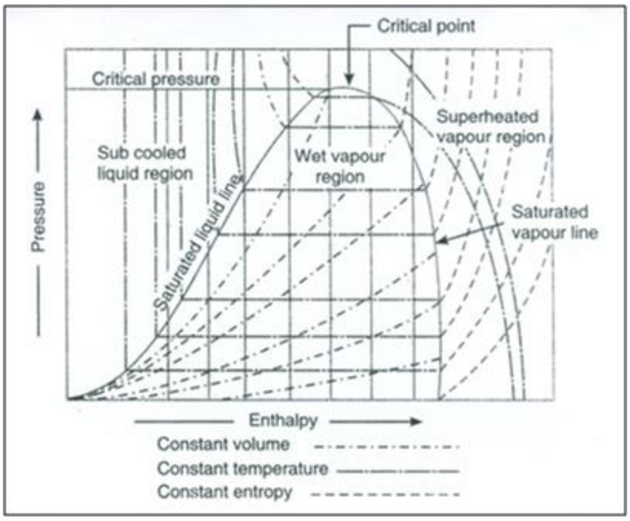

Fig. 1.4 Pressure – Enthalpy (P-h) chart

STUDY OF CALSSIC VCRS WITH P-h DIAGRAM

The Pressure-Enthalpy (p-h) impression of Vapour Compression Refrigeration System is entitled in the figure. The detailed examination of Vapour Compression Refrigeration System [2] is carried out by using steady flow energy equation.

1. Compression Process:

The vapour refrigerant at low pressure P1 and temperature T1 is compressed is entropically. For reversible adiabatic or isentropic compression of 1kg of vapour the shaft work per kg input is given by

$$Wc= \ (h_2-h_1)$$

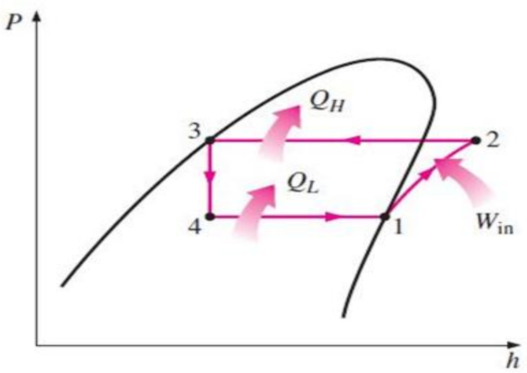

Figure 1.5: P-h Diagram

Where Wc=shaft work
h_1=enthalpy of vapour refrigerant at the inlet of the compressor.
h_2 = enthalpy of vapour refrigerant at the exit of the compressor.

2. Condensing Process:

The high pressure and high temperature vapour refrigerant from the compressor is passing through the condenser and now it is completely condensed at constant pressure P2 and temperature T2. The vapour refrigerant is transformed into liquid surrounding condensing medium [4].

$$q = h_2- h_3$$

Where
h_3= enthalpy of saturated vapour refrigerant at compressor outlet.
h_2= enthalpy0f saturated liquid refrigerant at condenser outlet.
q= heat rejected in condenser.

3. Expansion Process:

The refrigerant which is in liquid form at pressure P3=P2and temperature T3=T2is enlarged by throttling process through the expansion value to a low pressure P4=P1and temperature T4=T1. Some portion of the liquid refrigerant evaporates as it passes through the expansion value but the larger portion is vaporized in the evaporator [6].

During the throttling process no heat is absorbed or removed by the liquid refrigerants.

$$h3=h4$$

Where h3= enthalpy of saturated vapor refrigerant at compressor outlet.
h4 = enthalpy of refrigerant at inlet to the evaporator.

4. Vaporizing Process:

In this process the mixture of liquid vapour refrigerant at the pressure P4=P1 and temperature T4=T1is evaporated and transformed into vapour refrigerant at constant pressure and temperature. During evaporation process the liquid vapour refrigerant sponges up its latent heat of vaporization from the mediator such as air, water or brine solution which is to be cooled. This heat which is sponged up by the refrigerant is called "the refrigerating effect" and it is denoted by RE [8]. The process of vaporization is continue still the p0int 1 which is the starting point and thus the cycle is completed.

The refrigerating effect of the heat sponged up or removed by vapor refrigerant during evaporation per kg of refrigerant is given by

$$R_E = h_1 - h_4$$

h1=enthalpy of vapour refrigerant at the inlet of the compressor.
h4 = enthalpy of refrigerant at inlet to evaporator.

It may be observed that from the cycle that liquid vapor refrigerant has evicted heat during the evaporation and the work will be done by the compressor for isentropic compression of the high pressure and temperature vapour refrigerant.

Refrigeration Methods

Refrigeration used in several methods to provide temperature gradient between the two bodies. Following are the different types of refrigeration methods.

1. Ice refrigeration
2. Dry ice refrigeration
3. Air expansion refrigeration
4. Evaporative refrigeration
5. Gas-throttling refrigeration
6. Steam jet refrigeration
7. Liquid gas refrigeration
8. Vapor compressi0n refrigeration
9. Vapor absorption refrigeration
10. Thermo electric refrigeration

Applications of Refrigeration

The important applications of refrigeration are grouped into following four major equally important phenomenons.

1. Food processing, preservation and distribution
2. Chemical and process industries
3. Unique Applications

REFRIGERANTS

Any material which has an ability to suck up the heat fr0m the particular substance is known as a refrigerant. For example ice, water, air or brine. A mechanical refrigerant is a refrigerant which will suck up the heat from the source (lower temperature) and discharges the same heat to the sink (the temperature is higher than source) either in the form of sensible heat (in the case of refrigeration of air) or in the form of latent heat (in the case of vapor refrigeration).In dissipation of the latent heat refrigeration process the refrigerant transfer the heat in the form of latent heat. This type of latent heat refrigerants are well organized than the sensible heat refrigerants (sensible heat refrigerants transfer the heat in the form of sensible heat). The important physical property of the refrigerants of the initial group of refrigerants is it is willingly changes the states from liquid to gas and gas to liquid continuously. These changes of the state are done at the required temperatures for certain purp0se for which they are selected [10]. The handling pressures of the refrigerant must be suitable and agreeable for design, construction and economic working also.

When selecting the refrigerant for a specific work, the following characteristics are employed for efficient working. They are thermodynamic, chemical, physical and characteristics of safety. The selection of the refrigerant plays a key role in enhancement of the heat transfer rate. Hence for a best performance of the refrigeration the refrigerant is also necessary.

Classification of Refrigerants

In refrigeration process there are two types of refrigerants are present. They are,

1. Primary refrigerants
2. Secondary refrigerants

The refrigerants which are participated directly in the process of refrigeration are known as Primary refrigerants and the refrigerants which are participated in refrigeration with the help of primary refrigerants for cooling are called as Secondary refrigerants.

Condenser

In vapor compression refrigeration system condenser is placed after compressor to cool the saturated vapor refrigerant. So it acts as a heat exchanger which exchanges the heat with the surroundings by using medium as air or water. It rejects the heat sucked up by the refrigerant present in the evaporator and the compression heat is sum up in the compressor and condenses it changes into liquid [4]. The condenser extracts the latent heat from high pressure refrigerant at the same pressure and constant temperature. For this purpose the condenser employs a cooling medium as air or water.

For the efficacious working of the condenser two of the following considerations are compulsory in designing. They are,

a. Effective temperature differential

b. High heat transfer coefficient

By taking the capacity of the system, type of refrigerant used and available cooling medium there are numerous types of c0ndenser and selecti0n of condenser are ready for use.

Types of Condensers

- Air cooled condensers
- Water cooled condensers
- Evaporative condensers

Selection of condenser

In vapor compression refrigeration system condenser is placed after compressor to cool the saturated vapor refrigerant. So it acts as a heat exchanger which exchanges the heat with the surroundings by using medium as air or water. Its work is to reject the absorbed by the refrigerant during the evaporation (refrigeration effect) and compression (Heat of compression). Before sizing of a condenser, it should comprises of attentive evaluation, initial cost considerations, cost of operation, life time of service and type 0f l0ad. A condenser with a large size is expensive and brings 0perating pr0blems in l0wer ambient c0nditi0ns. Therefore it is important to consider the following circumstances [3].

- Gross heat rejection
- Ambient temperature
- Condensing temperature
- Temperature difference (TD)
- Flow of Air

EXPERIMENTAL SETUP

Basically there are two types of condenser coils are present in the vapor compression refrigeration system. One is evaporator and another one is condenser. In evaporator the heat forms the refrigerated space which is going to cooled is sucked up by the liquid refrigerant and then turns into saturated vapor state. This vapor refrigerated gets cooled in condenser by exchanging the heat with the surroundings. The main purpose of this research work is to intensify the heat transfer rate through the condenser coil by inserting the twisted tapes into the condenser coil .The twisted tape with twisting ratio (y/d=2.134) is used. In this research work two twisted tapes one with Al and another one with Cu are separately inserted into the condenser coils and the performances of both the coils compared with the existing system [6].

The first and foremost work in this experimental setup is making of the twisted tape. Before going to make the condenser coil it is necessary to select the material for the twisted tapes. By going through the list of the materials with the thermal conductivity it is observed that Cu and Al are having the best thermal conductivity, low cost and are available easily. Hence these two materials are used for making the twisted tapes.

Twisted tapes are the metallic strips twisted with some suitable techniques, desired shape, size and with suitable angle. In these making of the twisted tapes the twisting ration can play the key role in order to control the heat transfer rate. By varying the twisting ration the heat transfer rate also changes. The twisting ratio is defined as the ratio of the length of the twist to the diameter of the twist. The length of the twist is nothing but the pitch which means the distance between the two similar points lies on the same plane [10].

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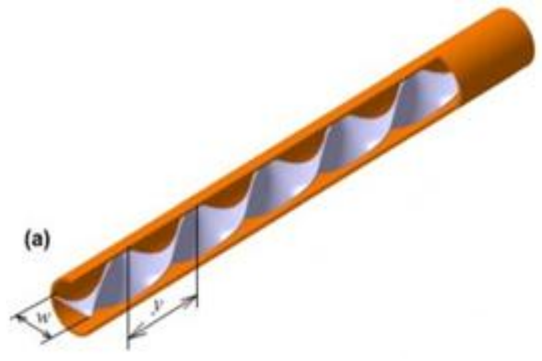

Fig: 5.1Representation of pitch and diameter of twisted tape

DESIGN OF TWISTED TAPE CONDENSER

Diameter(mm)	6.35mm
Length	10.973m
No of Turns	13
Twisting Ratio	2.134
Angle of twist	180^0

The twisting ratio = Length of the twist (y)/ Diameter of the twist

= 13.65mm / 6.35mm

= 2.134

By observing the above one it is easily understand that the twisting ratio is a dimensionless quantity. By the survey of literatures it is observed that the twisting ratio is lies in between 2 to 6 for better heat thermal coefficient. Hence in this research work the twisted tape with twisting ratio has chosen.

RESULTS AND DESCUSSIONS

Performance of a vapor compression refrigeration cycle:

The performance of vapor compression refrigeration cycle with the twisted tape condenser is compared with the existing condenser. The Existing condenser COP is 2.76 and twisted tape condenser COP is 3.19. To illustrate the effects graphs are drawn below by calculating the values of Coefficient of Performance, Net Refrigerating Effect, Mass flow rate and Power Consumption for both existing and proposed systems.

Comparison of Coefficient of Performance

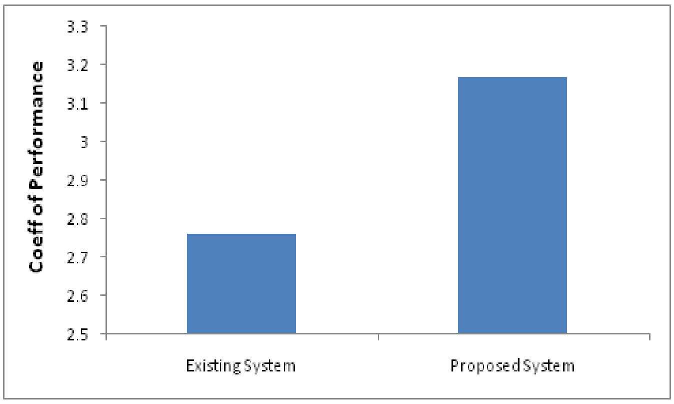

Fig: 7.1 Comparison of COP

The above figure shows the COP of both existing and proposed system. By using this graphs, it is clearly noticed that the proposed system has higher COP than existing one. The COP is increased by 15.57% from 2.76 to 3.19. By introducing these twisted tapes the thermal boundary layer thickness increases then heat transfer rate increase which intern leads to enhance the COP.

Comparison of Net Refrigerating Effect:

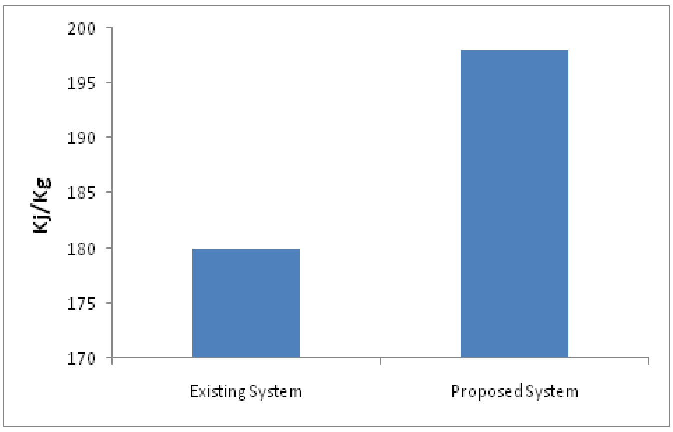

Fig: 7.2 Comparison of Net Refrigerating Effect

The above fig shows that the NRE of both existing and proposed system .By using this it is clearly noticed that the proposed system has the high NRE than existing one. The Net Refrigerating Effect is increased by 10% from 180 to 198 KJ/Kg. Due to swirl flow by the twisted tapes the heat rejection ratio increases which leads to intensify the Net Refrigerating Effect.

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Comparison of Mass flow rate:

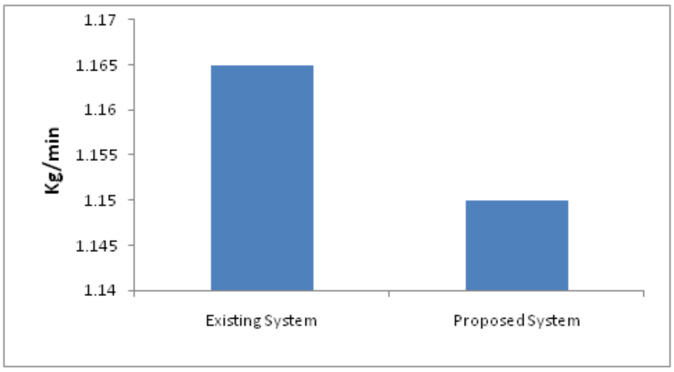

Fig : 7.3 Comparison of Mass flow rate

From the above fig it is clearly noticed that the proposed system has less mass flow rate while comparing with the existing one. The mass flow rate is decreased by 12% from 1.165 to 1.15Kg/min.

Comparison of power consumption:

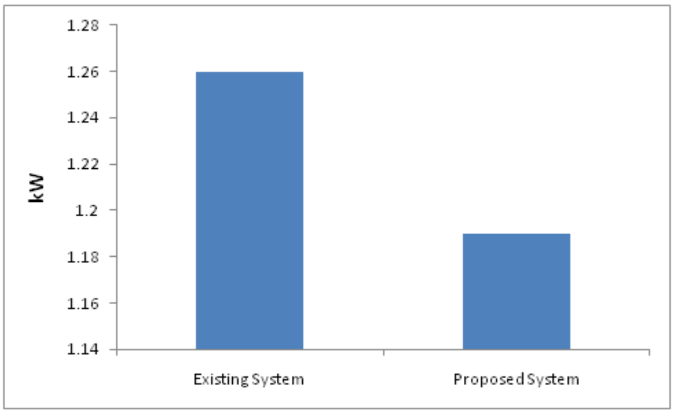

Fig :7.4 Comprison of Power Consumption

From the graph it is clearly noticed that the power required for proposed system is less than the existing system. The power consumption is decreased by 4.92% from 1.26 to 1.19 KW.As the compressor work decreases in the proposed system hence the power required is diminishing.

CONCLUSION

The performance of the refrigeration system is increased by introducing these twisted tapes into the condenser coil. High heat rejection through the condenser helped to increase the COP.As this is one of the passive technique to enhance the cop there is no need of additional power supply to achieve this high heat transfer rate. The cost of the twisted tape material and making of the condenser coil also are also less. Hence it is one of the efficient methods to enhance the coefficient of performance. Finally the advantages of this twisted tape condenser coil are understand by the following parameters,

For the proposed system,
Coefficient of Performance is increased by 15.57%,
Refrigerating Effect is increased by 10%,
Power Consumption is diminished by 4.92%,
Work done by the compressor is diminished by 12% and
Heat rejection is increased by 12.55%.

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