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Performance analysis of vapour compression refrigeration system by inserting twisted strip in condenser along with liquid suction heat exchanger

[1]A.Pratyush, [2]Dr.K.Dilip kumar, [3]Dr.K.Appa rao

[1,2,3]Department of Mechanical Engineering, [1,2,3]LBRCE, Mylavaram, India.

Abstract - This paper experimentally studies the behavior of VCR cycle by inserting twisted strip in the condenser tube and liquid suction heat exchanger (lshe).Taking R134a as refrigerant in the VCR setup. The experiment was performed on plain condenser tube with three different twisted angle strips inserted in condenser tubes along with liquid suction heat exchanger for subcooling to extract more COP from existing VCR system .The three twisted strip angles are α=10^0,14^0 &18^0 along with plain tube by applying and not applying subcooling using lshe. The performance coefficient is investigated with and without subcooling for all Three condensers. It was found that the drop in pressure is 16% for the twisted strip tube condenser when compared to plain tube .The coefficient of performance, refrigeration effect, refrigeration effect rate, refrigeration efficiency are investigated in this present work. It was concluded that twisted strip inserted tube condenser results fast reduction in the evaporator temperature compared to plain tube. By subcooling with lshe the twisted strip inserted tube condenser gains more refrigeration effect than plain tube condenser. Under no subcooling condition α=18^0 twisted strip inserted tube condenser is best in refrigeration effect, COP, refrigeration effect rate, refrigeration efficiency. While with subcooling α=10^0 twisted strip attain best results in improving performance of VCR unit.

Key Words: COP, VCR, Liquid suction heat exhanger.

I. INTRODUCTION

Wide studies are conducting on VCR system due to number of applications. Lshe is employed in the VCR cycle which helps in the reduction of quality of vapour refrigerant by subcooling .That helps in the improvement of COP of the cycle. There are many methods introduced to improve the performance of refrigeration cycle like subcooling, superheating, nano particles etc. lshe is one of the method which improves performance of the device by subcooling the refrigerant from condenser and superheating the refrigerant flowing to compressor .Both can be done by lshe at a time. This heatexchanger may or may not influence the performance of system it depends on operating conditions and refrigerant properties.

Domanski et.all (1994) theoretically evaluated the performance of lshe. Studied the thermodynamic operating conditions and fluid properties. Refrigerant required for the improvement in the performance of the system. Working pressure is unchanged and cooling capacity is varied. They derived mathematical formulation between COP, evaporator capacity, compressor work, volumetric capacity for both liquid suction heat exchanger and standard VCR cycle. This study was continued for 29 different refrigerants. They concluded that increase in COP and volumetric capacity of modified cycle compared to standard cycle. Refrigerants with poor performance in ordinary cycle benefit from liquid suction heat exchanger.

S.A.Klein et.all (2000) did work on exchange energy between refrigerant coming to expansion valve and refrigerant going to compressor. On refrigerants R507A, R134a, R12, R404A, R290, R407c, R600& R410A are used in this study. They analyzed the impact of pressure drop in liquid suction heat exchanger on the system performance. Concluded that liquid suction heat exchangers are useful at high temperature lifts and for refrigerants having relatively small valve of Δh_{vap}/ (C_pLT_c).

Christian J.L.Hermes (2013) conducted the study on liquid suction heat exchanger on the refrigerants R134a, R22, R290, R410A& R717 used in VCR system. The refrigerants having poor performance on basic VCR system derives advantage from modified VCR system i.e. VCR system with liquid suction heat exchanger COP of the used refrigerant may or may not influenced. Depend on working pressure, specific heat ratio, heat exchanger effectiveness and latent heat. Concluded that COP improved for R134a, R290, and R410A & R600a refrigerants.

Md.Reza Salimpour et.all (2014) investigated the performance of the VCR system with condencer inside coiled wire inserts runned by refrigerant R404A.the experiment was conducted on plain tube and 5 coiled wire inserted tubes .the coiled wire helps in heat transfer

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increase and pressure drop. That leads to improvement in the system performance. It was found that increased the pressure drop by 1200% compared to plain tube and also concluded that as pitch of coiled wire reduces, the pressure drop is more.

A wide research is done on effect of liquid suction heat exchanger and twisted strips individually, it is noticed that only few studies conducted on twisted strip inserts. In the present experimental investigation includes both liquid suction heat exchanger and twisted strip inserted conducted tubes in VCR system.

II. EXPERIMENTAL SETUP

The schematic view of the experimental setup is illustrated in fig-1 .The system consists of two flow lines one with liquid suction heat exchanger and other line is without liquid suction heat exchanger. Four shell and tube condensers are constructed with no strip inserted and strip inserted. The copper tube of ID-10mm OD-12mm are used to construct the condenser of length 3m,this long tube is formed like cage with seven passes. The strips are twisted with an angle of 10^0,14^0 &18^0 mild steel sheet of thickness 0.4mm is used to made strips. These strips are inserted in each condenser tubes. This arrangement is closed in a shell made of tin sheet and length=52cm. A fan is provided to blow air on to the tubes. There are control valves at each condenser inlet and outlet to operate the respective condenser.

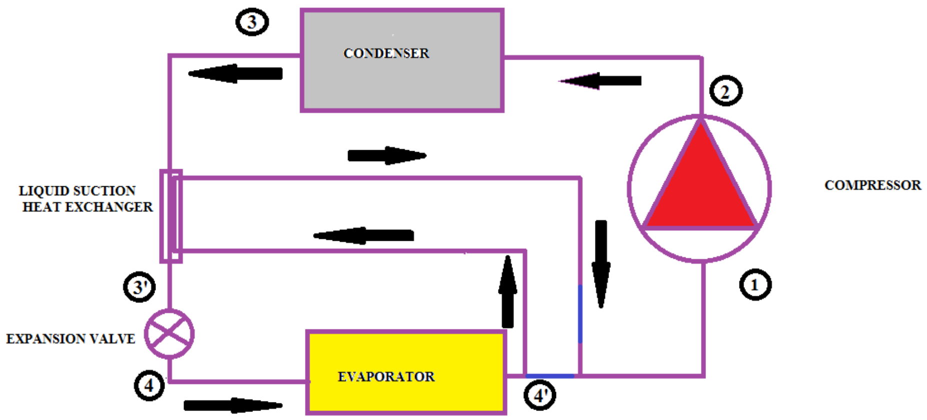

Fig -1. Schematic representation of the VCR system with Liquid suction heat exchanger

Fig -2. Experimental set up of the VCR system test rig.

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Fig-3. Condensers tubes are placed in the shell

The liquid suction heat exchanger is made of copper tubes of OD=12mm, ID=10mm and OD=6mm, ID=4mm copper tubes. It is a tube in tube heat exchanger with parallel flow and length 200mm.In OD=6mm tube refrigerant from condenser will flows and in 12mm tube refrigerant coming from evaporator flows. There are valves to operate liquid suction heat exchanger.

Refrigerant absolute pressure is measured by pressure gauges placed at three locations at inlet and outlet of condenser, inlet of compressor with accuracy of 0.1psi.Temperature of refrigerant is measure at inlet and outlet of condenser. Leaving refrigerant from condenser is cooled down to sub-cooled liquid using liquid suction heat exchanger. The water initial and final temperatures are measured by using k-type thermocouples with an accuracy ± 1^0C.The water is placed in evaporator can as heat load. In the single tube evaporator, refrigerant flows through tube and water is outside the tubes. To reduce the heat loss, the tube is well insulated. The energy consumed by system is calculates by voltage and current.

Initially experiment was conducted without liquid suction heat exchanger on four condensers (no strip, α=10^0,14^0&18^0).Each condenser is opened or closed by valves provided at inlet and outlet of condenser. During experiment only one condenser is opened, remaining are closed. Later experiments are conducted by applying liquid suction heat exchanger,on liquid line of the VCR system. To find out its effect on the COP of the system.

III. INDENTATIONS AND EQUATIONS

The experimental results on VCR without liquid suction heat exchanger and strips were used as a reference for this study. In the present experimentation, refrigeration effect, refrigeration efficiency and drop in pressure across condenser was calculated and these parameters are required to calculate COP of the system. Equations i & ii are employed for the calculation of COP of vapour compression system and heat absorbed from water. The refrigerating effect and COP of the system are been calculated as follows.

$$COP=\frac{RE}{Compressor\ power} \quad \text{---------} \ (i)$$

$$Q=m\,C_p\frac{dT}{dt} \quad \text{------------------------} \ (ii)$$

Where,

Q - Refrigeration effect
m - Mass of the water
dT - Change in water temperature
C_p - Specific heat of water
dt - Time logged corresponding to dT

IV. RESULTS AND DISCUSSION

Effect of twisted strip inserted condenser with and without applying liquid suction heat exchanger:

Due to drop in pressure across condenser with increasing the twist angle of the strip results in improving refrigeration effect. Fig -4 represents drop in water temperature with increase in twist angle for the four condensers. At 18^0 twist strip condenser increased in cooling effect was observed without applying lshe. Application of lshe shows improvement in cooling performance. Study has shown that application of lshe reduces the temperature of refrigerant and enhances the cooling capacity in the evaporator. Cooling capacity increases by increasing drop in temperature of water was identified.

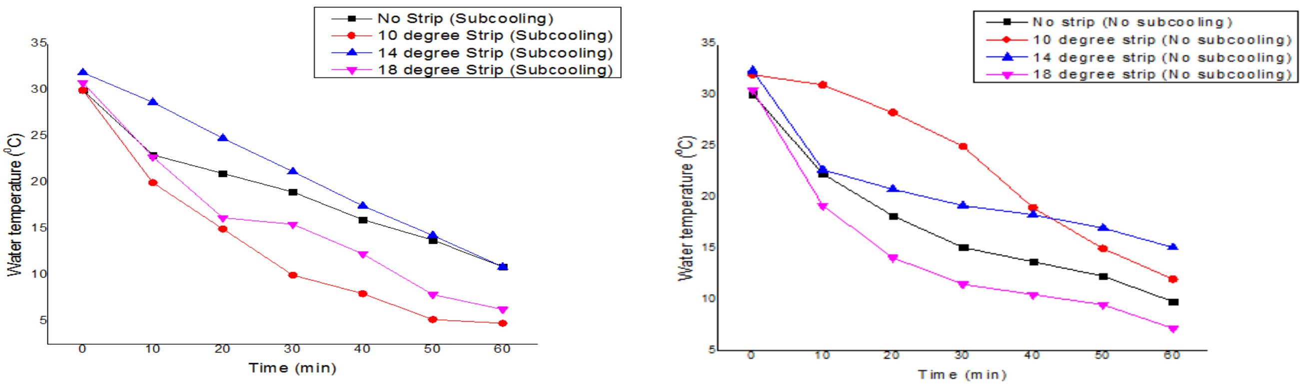

Fig-4. Effect of strip inserts on water temperature with and without Subcooling

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Effect of twisted strip inserted condenser on refrigerating effect and pressure drop:

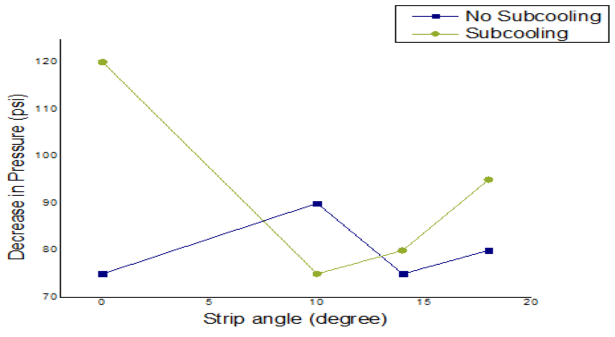

Fig-5. Effect of strip inserts on decrease in pressure across the condenser

Fig-5 represents effect of twisted strip inserted condenser on refrigerating effect and drop in pressure across condenser. It was found that for increased pressure drop there is no change in the mass flow rate of refrigerant. As the twisted strip angle increases, the pressure drop also increases. For no subcooling condition (without lshe) the refrigerating effect increases up to 18^0 twisted strip inserted condenser because drop in pressure on increasing twisted angle of the strip. Under sub cooling condition (with lshe) the refrigerating effect increases upto 10^0 strip angle. Due to more reduction in pressure the evaporation process effects. It is also observed that the temperature of refrigerant out of lshe coming from condenser and refrigerant flows into lshe from outlet of evaporator is narrow .So; refrigeration effect reduces on progress of time. And the temperature of the refrigerant after condenser is higher than refrigerant temperature after LSHE (before expansion valve) only 2 to 3^0C.Means on increasing strip angle the performance of LSHE reduces so the refrigerating effect reduces.

Effect of twisted strips on COP:

Application of twisted strips inserted condenser have positive effect on cooling capacity and power consumption remains unchanged.Fig-6 shows relationship between strip angles and improvement in COP for R134a refrigerant with and without lshe. When subcooling is applied in between the condenser and expansion device of VCR system, shows enhancement in COP.

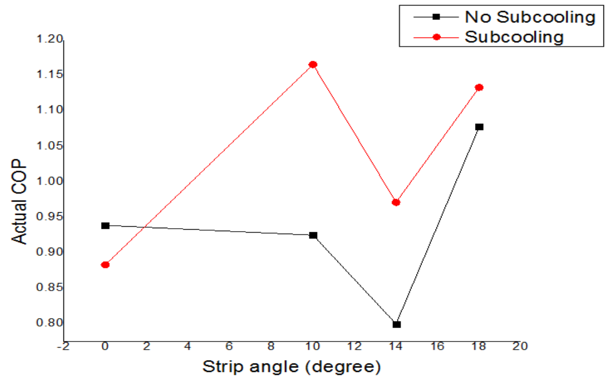

Fig -6. Effect of strip inserts on Actual COP

V. CONCLUSION

In this study of VCR system with twisted strips inserted condenser and lshe on liquid line improves the performance parameters of VCR system. The COP was measured for all four condensers with plain tube ,10^0, 14^0 & 18^0 inserted strips, without lshe and lshe applied to liquid line.COP increased by increasing twisted strip angle from no strip to 18^0 twisted strip condenser without applying lshe.For 18^0 strip angle increases in COP of the system upto 12.87 % . With lshe the COP is increased upto 10^0 strip angle and the increase in COP upto 24.206% .

NOMENCLATURE

COP	coefficient of performance,dimensionless
C_p	specific heat of water,kj kg^{-1} K^{-1}
dT	change in water temperature,^{0}C
dt	time logged corresponding to dT
h	specific enthalpy ,J kg^{-1}
ID	inner diameter,mm
lshe	liquid suction heat exchanger
m	mass of the water,kg
OD	outer diameter,mm
Q	refrigeration effect,kj
VCR	vapour compression refrigeration
α	twisted strip angle,degree

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