ijcrr
Vol 03 issue 10
Category: Research
Received on:05/07/11
Revised on:22/07/11
Accepted on:05/08/11

EXPERIMENTAL ANALYSIS OF PERFORMANCE OF THE REFRIGERATOR CONDENSER BY VARYING THE FINS SPACING OF THE CONDENSER

S.Sharmas Vali[1], M.L.S.Deva Kumar[1]

Department of Mechanical Engineering, JNTUA College of Engineering, Anantapur, Andhra Pradesh

E-mail of Corresponding Author: sharmasvali@gmail.com

ABSTRACT

This paper describes the Experimental Analysis of performance of the refrigerator condenser by varying the fins spacing of the condenser. Vapor compression machine is a refrigerator in which the heat removed from the cold by evaporation of the refrigerant is given a thermal potential so that it can gravitate to a natural sink by compressing the vapor produced. Majority of the refrigerators works on the Vapor compression refrigeration system. The system consists of components like compressor, condenser, expansion valve and evaporator. The performance of the system depends on the performance of all the components of the system. The main objective of the present work is to increase the performance of the condenser by increasing the heat transfer rate through the condenser. Heat transfer rate can be increased by the extended surfaces called fins. Heat transfer rate is also depends on the spacing between the fins of the condenser. In the present experimental work several condensers having different fins spacing are taken. By using this parameter experiments are conducted on a domestic refrigerator of capacity 165liters. The effect of varying the condenser fins spacing on the performance of refrigerator condenser is calculated experimentally.

I INTRODUCTION

A condenser is a heat exchanger is which desuperheating of high temperature vapor changes the phase from vapor to liquid and sub cooling of condensate occurs. The condenser is an important device used in the high pressure side of a refrigeration system. Its function is to remove heat of hot vapor refrigerant discharged from the compressor. The hot vapor refrigerant consists of the heat absorbed by the evaporator and the heat of compression added by the mechanical energy of the compressor motor. The heat from the hot vapor refrigerant in a condenser is removed first by transferring it to the walls of the condenser tubes and then from the tubes to the condensing or cooling medium. The cooling medium may be air or water or a combination of the two. An air cooled condenser is one in which the removal of heat is done by air. It consists of steel or copper tubing through which the refrigerant flows. The size of tube usually ranges from 6mm to 18mm outside diameter, depending upon the size of the condenser. Generally copper tubes are used because of its excellent heat transfer ability. The condensers with steel tubes are used in ammonia refrigerating systems. Majority of the domestic refrigerators uses the natural convection air cooled condenser. In the present work refrigerator uses the natural convection air cooled condenser. In natural convection air cooled condenser, the heat transfer from the condenser coils to the air is by natural convection. As the air comes in contact with the warm condenser tubes, it absorbs heat from the refrigerant and thus the temperature of air increases. The warm air being lighter, rises up and cold air from below rises to take away the heat from the condenser. This cycle continues in natural convection air cooled condensers. This paper is an experimental approach to increase the heat to be rejected in the condenser as well as increase the performance of the system. If the condenser is having more fins spacing then the number of fins available at the condenser are less. Due to this surface area decreases. Therefore less heat transfer occurs. On the other hand if the condenser is having less fins spacing then the number of fins available at the condenser are more. Because of more number of fins surface area increases. There fore more heat transfer takes place through the condenser.

II.PRESENT WORK:

The procedure for the present work is as follows. In vapor compression refrigeration system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to reject the heat absorbed at the evaporator and heat of compression added by the compressor which is done by the condenser.

The work focuses on heat transfer rate through the condenser. This is only possible either by providing a fan or extending the surfaces. The extended surfaces are called fins. The rate of heat transfer in the condenser depends upon the number of fins attached to the condenser.

The present work investigates the performance of the condenser using different fins spacing of the condenser. In the present domestic refrigerator the condenser fins spacing is 6mm.

The performance of the condenser will also help to increase the cop of the system as the sub cooling region occurs at the exit of the condenser. In general domestic refrigerators have no fan at the condenser and hence extended surfaces like fins play a very vital role in the rejection of heat.

In order to know the performance characteristics of the vapor compression refrigeration system pressure and temperature gauges are installed at each entry and exit of the component. Experiments are conducted on several condensers having different fins spacing. All the values of pressures and temperatures are tabulated.

The domestic refrigerator selected for the present work has the following specifications.

Capacity of refrigerator	-	165liters
Refrigerant used	-	R134a
Compressor Capacity	-	1/7 HP Hermetically sealed.
Condenser		
Length	-	8.5m
Diameter	-	6.5mm
Evaporator		
Length	-	7.62m
Diameter	-	6.5mm
Capillary tube		
Length	-	2.128m
Diameter	-	0.8mm

Fig.1

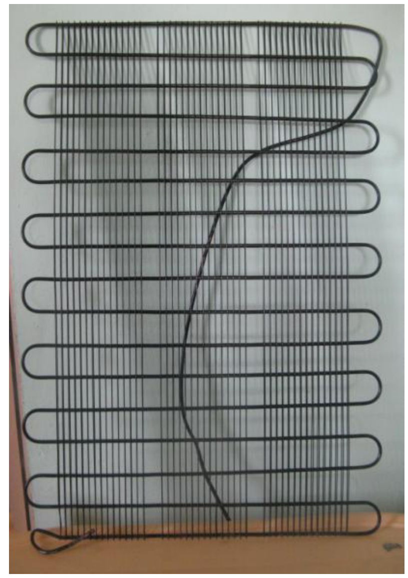


Fig.3

Fig.2

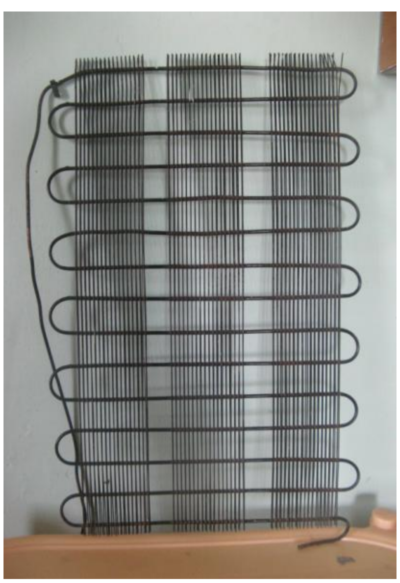


Fig.4

Fig.1 shows the pressure gauges which are used in the experimental work.
Fig.2 shows the temperature gauges which are used in the present work.
Fig.3 shows condensers with different fins spacing
Fig.4 shows the experimental set up of the present work.

Calculations and analysis:

Test no 1
Taken condenser fins spacing = 3mm

P_1 In bar	P_2 In bar	P_3 In bar	P_4 In bar
1.69	12.38	12.38	1.69
T_1 In ^{0}C	T_2 In ^{0}C	T_3 In ^{0}C	T_4 In ^{0}C
34.8	68.5	38.1	-17.6

Test no 2
Taken condenser fins spacing = 4mm

P_1 In bar	P_2 In bar	P_3 In bar	P_4 In bar
1.65	12.40	12.40	1.65
T_1 In ^{0}C	T_2 In ^{0}C	T_3 In ^{0}C	T_4 In ^{0}C
34.8	68.5	40.1	-17.1

Test no 3
Taken condenser fins spacing = 6mm

P_1 In bar	P_2 In bar	$P_{3.}$ In bar	P_4 In bar
1.65	12.41	12.41	1.65
T_1 In ^{0}C	T_2 In ^{0}C	**T_3** In ^{0}C	T_4 In ^{0}C
35.2	65.5	42.1	-17.0

Test no 4
Taken condenser fins spacing = 8mm

P_1 In bar	P_2 In bar	$P_{3.}$ In bar	P_4 In bar
1.65	12.41	12.41	1.65
T_1 In ^{0}C	T_2 In ^{0}C	**T_3** In ^{0}C	T_4 In ^{0}C
35.1	57.5	45.5	-16.9

Test no 5
Taken condenser fins spacing =10mm

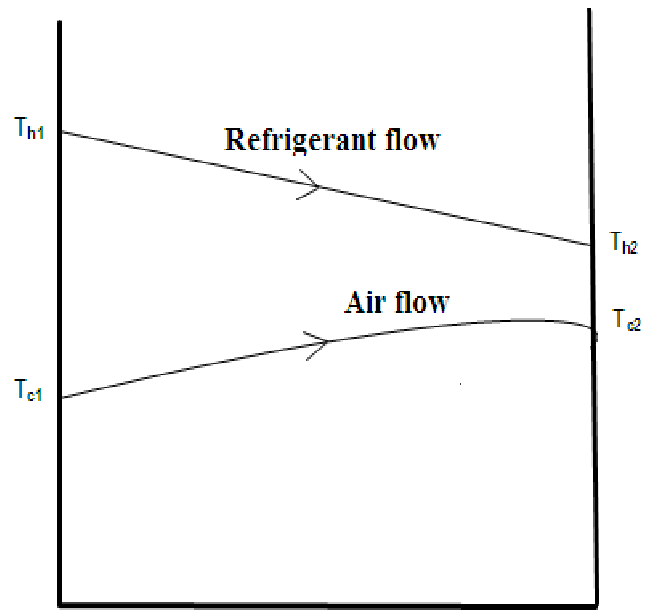
P_1 In bar	P_2 In bar	$P_{3.}$ In bar	P_4 In bar
1.64	12.42	12.42	1.64
T_1 In ^{0}C	T_2 In ^{0}C	T_3 In ^{0}C	T_4 In ^{0}C
36.1	52.5	47.8	-17.1

Where
P_1 = Compressor suction pressure
P_2 = Compressor discharge pressure
P_3 = Condensing pressure
P_4 = Evaporator pressure

T_1 = Compressor suction temperature
T_2 = Compressor discharge temperature
T_3 = Condensing temperature
T_4 = Evaporator temperature

Analysis of the condenser:
Thermal analysis in the heat exchangers can be done in two ways.
1. LMTD Method (Logarithmic Mean Temperature Difference)
2. NTU Method (Number of Transfer Units).
LMTD Method is useful when the inlet and outlet fluid temperatures of condenser and air are known. NTU Method is useful when the heat exchanger is designed for the particular mass flow rate. For the given conditions LMTD Method is suitable.

LMTD Method:
In a heat exchanger, the temperature of the heating and cooling fluids do not in general, remain constant, but vary from point to point along the length of the heat exchanger. Since the temperature difference between the two fluids keeps changing, the rate of heat transfer also changes along the length of the heat exchanger as shown.



Temperature Profile

Fig.5 shows the temperature profile along the length of the condenser.

The rate of heat transfer can be calculated from the relation

$$Q = U\,A\,\Delta T$$

Since ΔT changes from point to point in a heat exchanger, we propose to use ΔT_m, a suitable mean temperature difference between the two ends of a heat exchanger. The rate of heat transfer can be rewritten as

Where ΔT_m = Log Mean Temperature Difference (LMTD)
A = surface area of condenser in $m^2 = \Pi DL$

$\Delta T_m = (\Phi_1 - \Phi_2)/\ln(\Phi_1/\Phi_2)$

Where $\Phi_1 = T_{h1} - T_{C1}$

$\Phi_2 = T_{h2} - T_{C2}$

Th_1 = Condenser entering temperature

Th_2 = Condenser leaving temperature

Tc_1 = Air temperature at the condenser inlet

Tc_2 = Air temperature at the condenser outlet

$$U = \frac{1}{A_O/A_i \; 1/h_i + \frac{A_O \ln(r_o/r_i)}{2\Pi KL} + 1/h_o}$$

U = overall heat transfer coefficient in w/m^2k

A_O = outside tube Area in m^2

A_i = inside tube Area in m^2

h_i = convective heat transfer coefficient of R-134(a) in W/m^2k

h_o = convective heat transfer coefficient of Air in $W/m^2k = 10\ W/m^2k$

r_o = outside radius of pipe in m

r_i= inside radius of pipe in m

K = thermal conductivity of copper in w/m-k

If $A_O = A_i$ the above equation can be reduced to

$$U = 1/(1/h_i + 1/h_o)$$

Properties of R-134(a) are taken at bulk mean temperature of condenser with different fins spacing.

Bulk mean temperature of condenser can be calculated by

= (Condenser inlet temp. + Condenser outlet temp.)/2

In order to calculate convective heat transfer coefficient of R-134(a) the following steps are to be followed and the convection is of forced convection pipe flow.

$$R_{eD} = (pvD)/\mu$$

$$P_r = (\mu\, C_p)/K$$

Where

R_{eD} = Reynolds number

p = Density of R-134(a) in kg/m^3

v = velocity in m/sec = 3 to 4 m/sec

D= Diameter of the pipe in m

μ = viscosity in pa.s

C_p= specific heat in j/kg k

K= thermal conductivity in w/m k

Forced convection correlations in turbulent pipe flow are given by

Dittus-Boelter

$N_{UD} = 0.023 R_{eD}^{4/5} Pr^n$

$N_{UD} = h_i D/K$

Where

D= Diameter of the pipe = $6.5\text{x}10^{-3}$m

Pr = Prandtl number

n = 0.4 for heating of the fluid and 0.3 for cooling of the fluid

The Dittus-Boelter equation is valid for

$0.7 < Pr < 160$ and $R_{eD} > 10000$

The Dittus-Boelter equation is good approximation where temperature differences between bulk fluid and heat transfer surface are minimal.

Nusselt number:

In heat transfer at boundary (surface) within a fluid, the nusselt number is the ratio of convective to conductive heat transfer across (normal to) boundary. Named after Wilhelm Nusselt, it is a dimensionless number.

A Nusselt number is close to one for slug or laminar flow. It varies for turbulent flow. For forced convection, the nusselt number is generally a function of the Reynolds number and prandtle number, or Nu = f (Re, Pr).

Calculation of overall heat transfer coefficient

Inside heat transfer coefficient for condenser coil

Sizes of tube:

Outer diameter of tube = 6.5mm

Inner diameter of tube = 6mm

For Test -1
Condenser entering temperature = 68.5 ^{0}C
Condenser leaving temperature = 38.1 ^{0}C
Air temperature at the condenser inlet = 31.2^{0}C
Air temperature at the condenser outlet = 32.2^{0}C

For Test -2
Condenser entering temperature = 68.5 ^{0}C
Condenser leaving temperature = 40.1 ^{0}C
Air temperature at the condenser inlet = 33.2^{0}C
Air temperature at the condenser outlet = 34.2^{0}C

For Test -3
Condenser entering temperature = 65.5 ^{0}C
Condenser leaving temperature = 42.5 ^{0}C
Air temperature at the condenser inlet = 34.2^{0}C
Air temperature at the condenser outlet = 35.5^{0}C

For Test -4
Condenser entering temperature = 57.5^{0}C
Condenser leaving temperature = 45.5 ^{0}C
Air temperature at the condenser inlet = 34.5^{0}C
Air temperature at the condenser outlet = 35.5^{0}C

Test -5
Condenser entering temperature = 52.5 ^{0}C
Condenser leaving temperature = 47.8 ^{0}C
Air temperature at the condenser inlet = 34.2^{0}C
Air temperature at the condenser outlet = 35.5^{0}C

Sample calculations for Test -1
Condenser entering temperature = 68.5 ^{0}C
Condenser leaving temperature = 38.1 ^{0}C
Air temperature at the condenser inlet = 31.2^{0}C
Air temperature at the condenser outlet = 32.2^{0}C

Mean temperature = (68.5 +38.1)/2 = 53.3 ^{0}C
Mean temperature = 42.5^{0}C at this temperature properties are

From R-134(a) refrigerant property tables
p = 1082.9 kg/m^3
D = 6.5 X 10^{-3} m
μ = 149.9 X 10^{-6} Pa.s
v = 3.5 m/s
K = 68.5 x 10^{-3} W/m k
C_p= 1.2562 x10^3 J/kg k

R_{eD} = (pvD)/μ = (1082.9x3.5x6.5 X 10^{-3})/ 149.9X 10^{-6} = 1.643x10^5
P_r = (μ C_p)/K = (174 x10^{-6} x1.513x10^{-3})/ (74.1x10^{-3}) = 2.748
$N_{UD} = 0.023 R_{eD}^{4/5} Pr^n$ = 0.023x (1.643 x10^5)$^{4/5}$ x (2.748)$^{0.3}$= 463.54

$N_{UD} = h_i D/K$
463.54 = (h_i 6.5 X 10^{-3})/ 68.5x10^{-3}
h_i = 4885.08 W/m^{2}k
U = 1/ (1/ h_i + 1/ h_o) = 1/(1/4885.04 + 1/10) = 9.998 W/m^2

$\Delta T_m = (\Phi_1 - \Phi_2)/\ln(\Phi_1/\Phi_2)$
Where
ΔT_m = log mean temperature difference.
Th1Condenser entering temperature = 68.5 ^{0}C = Th1
Condenser leaving temperature = 38.1 ^{0}C = Th2
Air temperature at the condenser inlet = 31.2 ^{0}C = Tc1
Air temperature at the condenser outlet = 32.2 ^{0}C = Tc2
$\Phi_1 = T_{h1}-T_{C1}$= 68.5-31.2 = 37.3
$\Phi_1 = T_{h2}-T_{C2}$ = 38.1-32.2 = 5.9
ΔT_m = (37.3-5.9)/ln(37.3/5.9) = 16.91^{o}C
Q=Heat transfer rate through the condenser = U A ΔT_m
Q= 9.998xπx6.5x10^{-3}x8.5x16.91 = 29.35 W

For Test -2
Q=Heat transfer rate through the condenser = U A ΔT_m
Q= 9.998xπx6.5x10^{-3}x8.5x16.43 = 28.51 W

For Test -3
Q=Heat transfer rate through the condenser = U A ΔT_m
Q= 9.998xπx6.5x10^{-3}x8.5x16.22 = 28.14 W

For Test -4

Q=Heat transfer rate through the condenser = U A ΔT_m

Q= $9.998 x \pi x 6.5 x 10^{-3} x 8.5 x 15.60 = 27.07$ W

For Test -5

Q=Heat transfer rate through the condenser = U A ΔT_m

Q= $9.998 x \pi x 6.5 x 10^{-3} x 8.5 x 15.10 = 26.20$ W

Advantages:

1. An advantage of present work is that it increases the performance of the Condenser.
2. The heat rejected by the condenser increases. Therefore sub cooling occurs at the exit of the condenser.
3. Because of more heat transfer condensing temperature of the refrigerant reduces considerably.

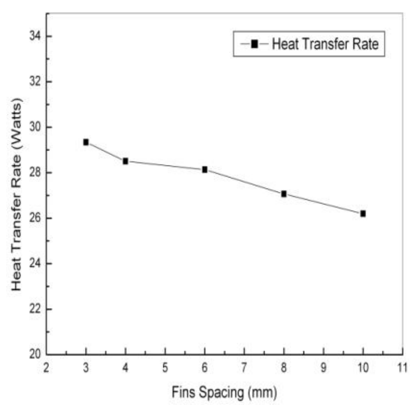


Fig.6

Fig.6 shows the graph between fins spacing Vs Heat Transfer Rate.

III RESULTS AND CONCLUSIONS

Referring to fig.6 it is seen that the performance of the Condenser decreases as the fins spacing increases and it is maximum at 3mm.

In the existing system condenser fins spacing is taken as 6mm. When compared with the existing system the present work produces the following results.

Heat transfer rate through the Condenser increased by 4.26% for the fins spacing 3mm.The condenser with less fin spacing has more number of fins because of more number of fins surface area increases. Therefore more heat transfer rate occurs through the condenser.

The present work found that the condenser with fins spacing 3mm has considerable effect on heat transfer rate through the Condenser.

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