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Experimental Analysis and Comparative Study on Performance of Domestic Refrigerator Using R134aby Varying Capillary Size and Length

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ABSTRACT

The study of the expansion device in simple vapor compression refrigeration system is necessary to understand the parameters which can augment the overall performance of system. It is essential to study the effect of capillary tube on the performance of refrigeration systems.A domestic refrigerator test rig charged with R134ais used to find out the effect of capillary tubes in Co-efficient of Performance(COP) of the refrigerator. Capillary tubes of sizes 3.1mm and 3.6mm of length 1500mm and 1800mm and 2130mm(6feet) and 2743(9 feet) are used. The findings of the experimental study show that the COP for the refrigerator is maximum for 3.6mm dia capillary tube when compared to 3.1mm dia in both the lengths.The values of COP are compiled in C complier to check for the accuracywith the calculations and also optimization technique is used in C compiler to find out the optimal COP amongst the obtained COP's. The inlet and outlet temperatures of the test rig parts, suction and discharge pressures of compressorare measured and used to calculate the COP. The experimental work shows that, capillary of bigger size gives out the higher COP for the refrigerator.

KEYWORDS: Co-efficient of Performance, Capillary tube, suction and discharge pressures, R134a, Optimisation

1. INTRODUCTION

Vapour Compression Refrigeration Cycle is the most widely used refrigeration system. In this system, the working fluid is a vapor. It readily evaporates and condenses or changes alternatively between the vapor and liquid phase without leaving the refrigerating plant.

During evaporation, it absorbs heat from the cold body and this heat is used as its latent heat for converting it from liquid to vapour whereas in Condensing or cooling, it rejects heat to external bodies, thus creating a cooling effect in the working fluid.

Components of Vapour Compression Refrigeration Cycle(VCR):

1. Compressor
2. Condenser
3. Expansion device
4. Evaporator

Thiscyclerequiresthe addition of external work for its operation. Basically, itconsistsoffour processesnamely:

- Isentropiccompression.
- Constantpressureheatrejection.

- Isenthalpicexpansion.
- Constantpressureheataddition.

ExpansionDevices

The expansion device (also known as metering device orthrottling device) is an important device that divides the high-pressuresideandlow-pressuresideofrefrigeration system,it is incorporated between receiver and the evaporator (ifreceiver not used in the system, the expansion device isintroduced between condenser and evaporator). It is usualpracticeprovedafilteranddrierbeforetheexpansion deviceinordertopreventcontaminantscloggingtherefrigerant flow passage. The expansion device performs thefollowing functions:

- It reduces the high-pressure liquid refrigerant to lowpressurerefrigerantbeforebeingfedtotheevaporator.
- It maintains the desired pressure difference between thehigh- and low-pressure sides of the system, so that theliquid refrigerant vaporizes at the designed pressure intheevaporator.
- It controls the flow of refrigerant according to the loadonthe evaporator.

Typesof ExpansionDevices

- Capillarytube,
- Handoperatedexpansionvalve,
- Automaticorconstantpressureexpansionvalve,
- Thermostaticexpansionvalve,
- Lowsidefloatvalveand
- Highsidefloatvalve.[1]

2. RELATED WORK

Expansion device in refrigeration and air conditioning is the most predominant device, as it is the main source for the cooling of the refrigerant. Capillary tubes are mechanically operated expansion devices. There exsists many kinds of capillary devices of different geometries and sizes and lengths. A capillary maybe staright, coiled, helical geometries varying in size and length.

In existing system, two coiled capillary tubes of length 1500mm and diameter 3,1mm and 3.6mmare used for conducting experiment. And for another approach two other capillary tubes are used of same diameter but with different lengths. Experiment can also be conducted by using different capillary geometries as mentioned above.

The accurate size of the capillary tube and its configuration can be predicted with the help of the calculations for the refrigeration effect, coefficient of performance (cop) of the system and mass flow rate of the system. The effects of different geometries of capillary tubes have been studied by many researchers. Since the capillary tube can be straight, helical coiled and also serpentine coiled and all three configurations have their own distinct effect on the system performance, thus the literature review here is focused to give a brief introduction of the effects of the various configurations of the capillary tube on the system performance and thus pave the path for further studies.[2]

3. PROPOSED WORK

In this paper, we propose a capillary size that gives out the best Co-efficient of Performance(COP) for a domestic refrigerator which automatically reduces the power consumption and gives the best cooling effect for the given capacity of the refrigerator.Various capillary sizes and capillary geometries are available which finds sutibale to the application, but finding an optimal size of amongst them is necessary to maximize the utilization of the refrigerator.

A domestic refrigerator attached with necessary test rig equipment shown in fig 5, is used to carry out the required experimentation process. Test rig equipment consists of the following:

1. Suction and Discharge pressure gauges
2. Eliminator
3. High pressure and Low-pressure cutoff
4. Sub Zero Indicator (Digital temperature indicator)
5. Ball valves
6. Capillary tubes with nut arrangement on either side.

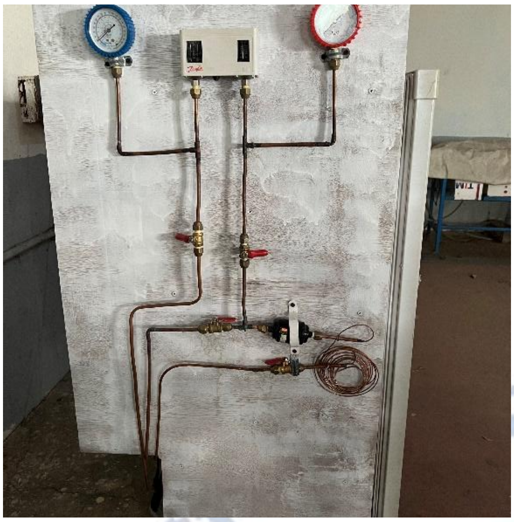

Figure1: Experimental Test Rig

The suction gauge(Shown in left side) and Discharge guage(Shown at the right side) are connected to the pipes coming from the suction and discharge side of the compressor respectively, On one side and to the HP-LP cut-off device on the other side. The flow of refrigerant into the gauges is controlled by the ball valves connected to respective pipes.

The pipe from the discharge side of the compressor is progressed towards the eliminator which is used to trap the unwanted gas particles or substitutes in the incoming high pressure-high temperature liquid refrigerant. This advances towards the capillary tube and therefore turning into low pressure-low temperature liquid refrigerant, Which headways into the evaporator. The outgoing pipe from the evaporator is connected to the suction side of the compressor therefore to repeat the cycle.

A sub-zero which is electrically powered digital temperature reading device is placed on the top, whose temperaturereading blub is left free in order to place it at the required spot to find out the temperature.

The entire system was pressure tested using R134a pressurizing to 15 bar. The system was left at that pressure for anhour. System was evacuated using a vacuum pump. Vacuum was held for 24 hours and finally estimated quantity of R134a in liquid form was charged into the system and ensured that the pressure is measured while system is at steady state operating condition.

A. *Experimental Procedure*

Experimental procedure, which is carried out during the experiment, is given below:

- The unit is switched on and left still for a half and hour to achieve stable state.
- After reaching the required stable condition, the ball valves on the suction side and the discharge side are opened to take the readingsfrom the respective gauges.
- The sub-zero bulb is then placed at the inlet and the outlet stages of refrigerator components to read out the respective temperatures.

B. *Experimental Observations*

Table 1: Observations for the capillary size of 3.1mm and length 1500mmare found to be as follows:

Device	Inlet	Outlet
Compressor pressure	21psi~1.4bar	250psi~17.23bar
Compressor	35° C	55°C
Condensor	49°C	44°C
Capillary	43°C	19°C
Evaporator	0°C	32°C

Table 2: Observations for the capillary size of 3.6mm and length 1800mmare found to be as follows:

Device	Inlet	Outlet
Compressor pressure	28psi~1.9bar	270psi~18.61bar
Compressor	28° C	46°C
Condensor	45°C	46°C
Capillary	43°C	15°C
Evaporator	-1°C	20°C

Table 3: Observations for the capillary size of 3.1mm and 2130mm(6 feet) are found to be as follows:

Device	Inlet	Outlet
Compressor pressure	43.6psi~3.01bar	224.80psi~15.5bar
Compressor	35° C	45°C
Condensor	48°C	36°C
Capillary	37°C	29°C
Evaporator	-1°C	31.7°C

Table 4: Observations for the capillary size of 3.6mm and 2743mm(9feet) are found to be as follows:

Device	Inlet	Outlet
Compressor pressure	41psi~2.86bar	207psi~14.3bar
Compressor	33°C	41°C
Condensor	46°C	37°C
Capillary	37°C	21°C
Evaporator	0°C	32°C

4. RESULTS

In this section, the output values obtained from the calculations based on the observational values are displayed in graphs.

Both the values of COP's are tabulated in a chart which was shown in the figure2 is seems to be as follows:

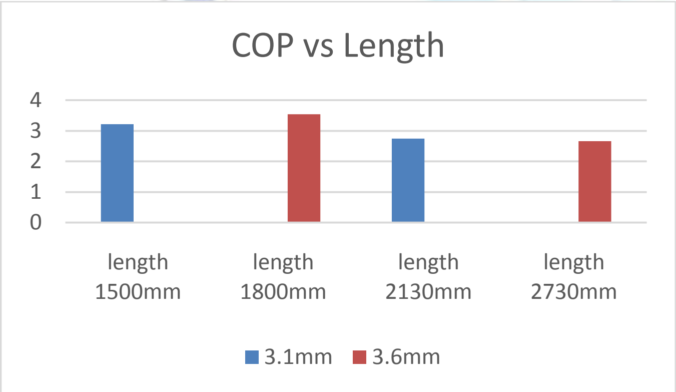

Figure2: Chart exhibiting the COP's of both the capillariesand different length's

Asper the above graph, the capillary size of 3.6mm is showing high COP at both the lengths when compared to the size of 3.1mm. And amongst both the lengths of 3.6mm size capillary, 1800mm length capillary is exhibiting the high COP followed by 2730mm length capillary.

The following shows the plotting of graphs against various factors of the refrigerator i.e, Suction and discharge pressure, refrigeration effect, COP, compressor work that effect the performance. The main considered factor in plotting the is l/d ratio of the capillary tubes.

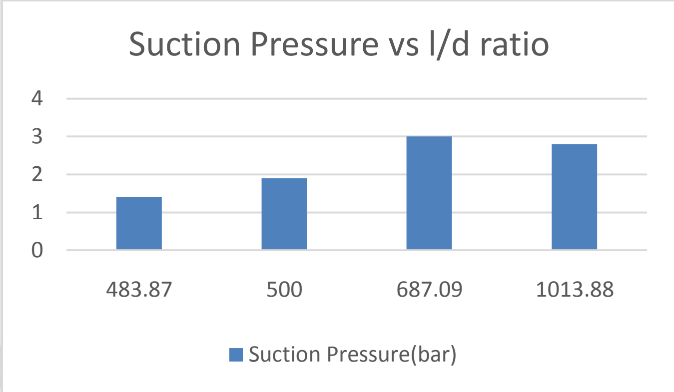

Figure3: Chart exhibiting the Suction pressure at various l/d ratios

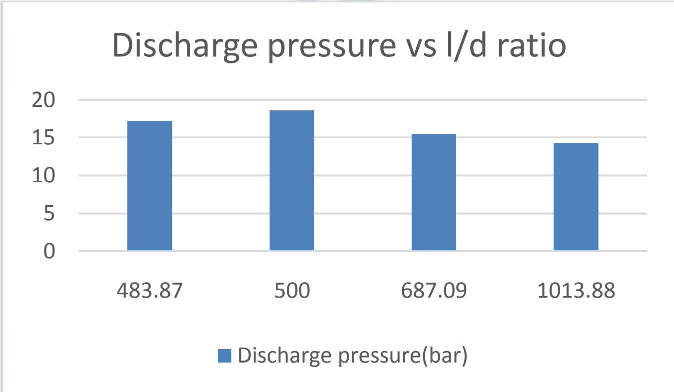

Figure4: Chart exhibiting the discharge pressures at various l/d ratios

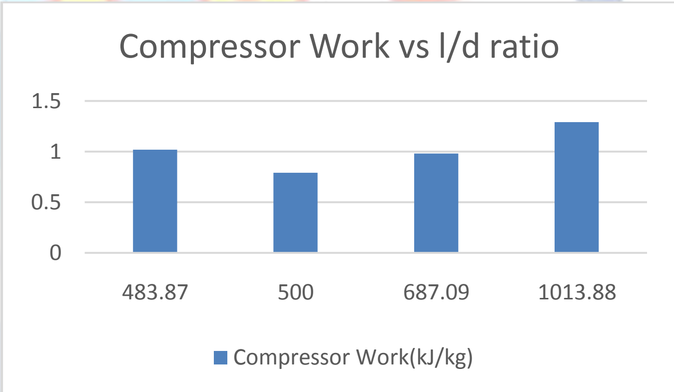

Figure5: Chart exhibiting the compressor work at various l/d ratios

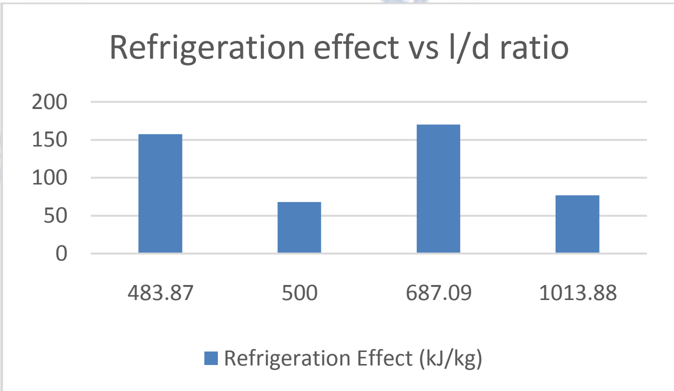

Figure6: Chart exhibiting the refrigeration effect at various l/d ratios

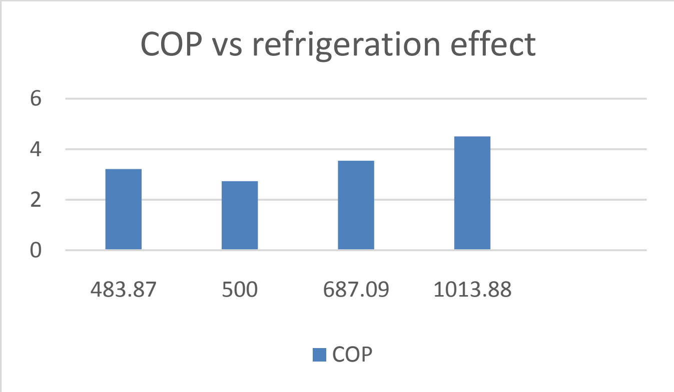

Figure7: Chart exhibiting COP's at various refrigeration effects

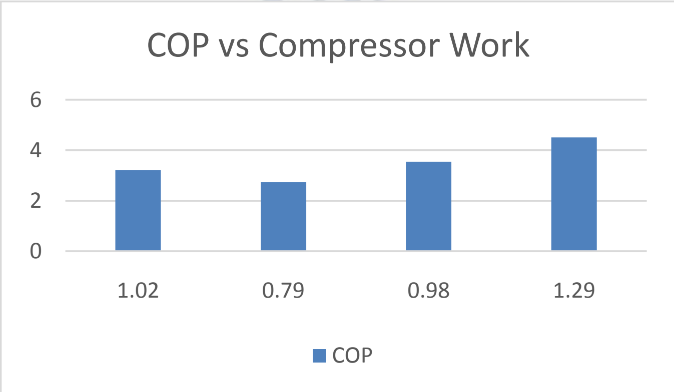

Figure8: Chart exhibiting COP's at various stages of compressor work

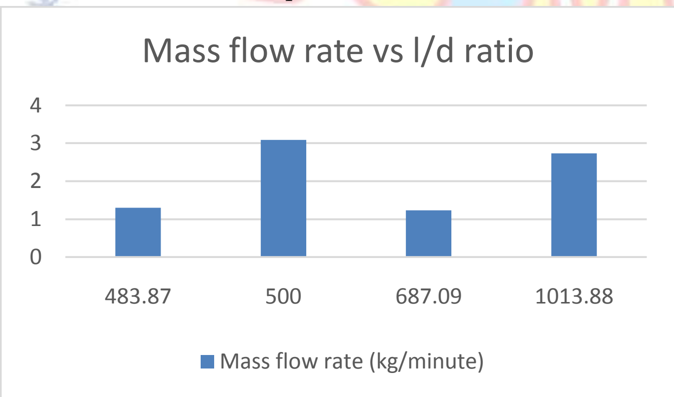

Figure 9: Chart exhibiting the mass flow rate at various l/d ratios

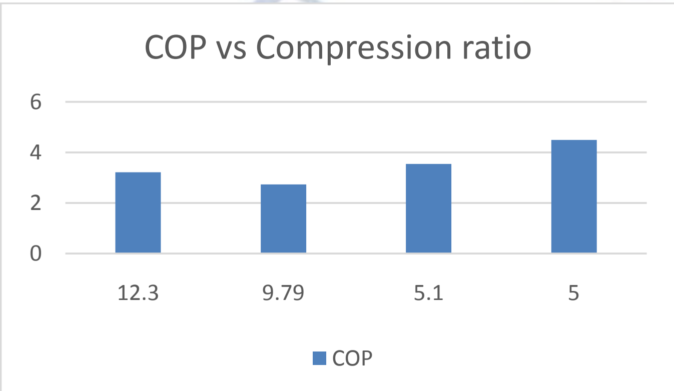

Figure 10: Chart exhibiting COP's at various Compression ratios

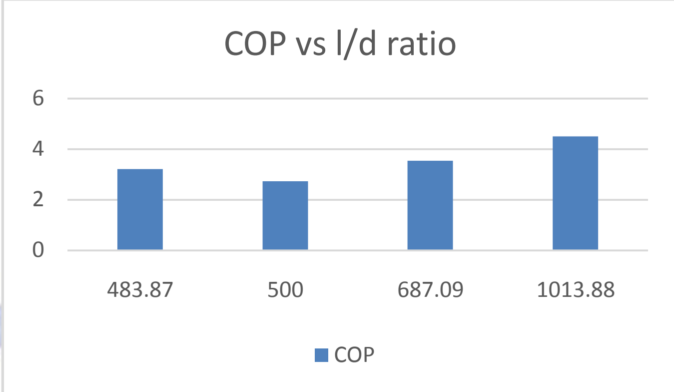

Figure 11: Chart exhibiting COP's at various l/d ratios

The following graphs indicate that the capillary size of 3.6mm is giving the highest COP for the considered test rid at the length if 1800mm. This was verified by the optimization technique which was performed in a C compiler based on the experimentation and observational values.

The obtained COP values of both the sizes and the lengths are optimized by using the C programming compiler to find out the optimal COP amongst the obtained values. And, as per the optimization technique used in C compiler, the optimal COP is obtained at the size of 3.6mm and length 1800mm.

5. CONCLUSION

In this paper, we suggested the capillary size for the considered refrigerator using R143a as refrigerant and it found to be the capillary of size 3.6mm diameter with 1800mm length which gives the highest COP of 3.54. The propsed capillary was scalable and outperformed other capillary sizes in terms of the obtained COP. By comparasion of the capillary to others there has been a significant increase in the COP and also the cooling effect produced in the evaporator of the refrigerator with increase in its diameter but only to certain extent. Due to this there will also be significant decrease in the power consumption by the refrigerator for the same given capacity and producing higher cooling effect. It is found that single capillary tube having smaller inner diameter is suitable for freezing applications, whereas capillary tubes having more inner diameter are suitable for cold storage or air conditioning applications.[3]

So, as we decrease the capillary tube diameter, the refrigeration effect produced tend to decrease [4].The optimal COP is found out through the optimization technique by using C programming.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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