EXPERIMENTAL ANALYSIS OF CAPILLARY TUBE AND THERMOSTATIC EXPANSION VALVE IN DOMESTIC REFRIGERATOR USING ECO FRIENDLY REFRIGERANT

NIRUPAM KUMAR[1], Rohit Pathak[2], Vinay Yadav[3]

1. **Research Scholar, Department of Mechanical Engineering, Rabindranath Tagore University, Raisen, M.P.**
2. **Professor, Department of Mechanical Engineering, Rabindranath Tagore University, Raisen, M.P.**
3. **Professor, Department of Mechanical Engineering, Rabindranath Tagore University, Raisen, M.P.**

ABSTRACT

The objective of this experimental work is to evaluate the performance of capillary tube and Thermostatic expansion valve suitable for expansion device in domestic refrigerator as well as compare the performance of different refrigerants (R134a, R290 and R600a). In this research work we have analysis various refrigerants used in the refrigeration cycle which affect the environment, and our effort is to reduce the effect of global warming by using suitable refrigerants. R134a is used in vapor compression refrigeration system having zero ozone depletion potential (ODP) and almost good thermodynamic properties, but it has a high Global Warming Potential (GWP) of 1300. Therefore it is going to be banned very shortly for environmental safety. Hydrocarbon refrigerants mainly propane, butane and isobutene are proposed as an environment friendly refrigerants. So we have used the blend refrigerant of R134a and R-290 (90/10 %) which are environmental friendly, having low GWP, zero ODP and also having better efficiency as compare to conventional refrigerants In this research work 40% (200g) of R-600a is more efficient on capillary tube while the efficiency is decrease by 20% on thermostatic expansion valve. the blend refrigerant of R-134a and R-290 (90/10 %) give better performance on both devices, the Coefficient of performance is increase by 25.8% on Thermostatic expansion valve and 22.5% on capillary tube. Thermostatic expansion valve is found to produce controlled degree of superheat of refrigerant and higher efficiency than capillary tubes across the entire range of operating conditions.

Keywords: *Capillary tube, Thermostatic expansion valve, Eco friendly refrigerant, Compressor work, COP*

---

1. INTRODUCTION

Stratospheric ozone absorbs the sun’s high energy ultraviolet rays and protects both humans and other living things from exposure to ultraviolet radiation. Results from many researches show that this ozone layer is being depleted. The general consensus for the cause of this event is that free chlorine radicals remove ozone from the atmosphere, and later, chlorine atoms continue to convert more ozone to oxygen. The presence of chlorine in the stratosphere is the result of the migration of chlorine containing chemicals. The chlorofluorocarbons (CFCs) and hydro chlorofluorocarbons (HCFCs) are a large class of chemicals that behave in this manner. These chemicals have many unusual properties, for example, non flammability, low toxicity and material compatibility that have led to their common widespread use by both consumers and industries around the world, especially as refrigerants in air conditioning and refrigerating systems.

Since discovery of the depletion of the earth’s ozone layer and as a result of the 1992 United Nations Environment Program meeting, the phase out of CFC-11 and CFC-12, used mainly in conventional refrigeration and air conditioning equipment, is expected by 1996 and that of HCFCs is expected after 2030 [1]. Many corporations have been forced to find alternative chemicals to CFCs and HCFCs. Because the thermophysical properties of HFC-134a are very similar to those of CFC-12 and are also non-toxic environmentally safe refrigerant, the American Household Appliances Manufacturers have recommended HFC-134a as a potential replacement for CFC-12 in domestic refrigerators [2]. However, while the ozone depletion potentials (ODPs) of HFC-134a relative to CFC-11 are very low.

2. LITERATURE

Rao et al. [1] his paper illustrate that the energy consumption of the thermostatic expansion valve system was found to be lower than that of the capillary tube system at higher cooling loads and at lower cooling capacities. They observed that the value of Carnot COP > theoretical COP > actual COP which is accordance to the theory.

Joshi et al. [2] In This Study the Coefficient of performance of vapour compression refrigeration system is calculated for Thermostatic expansion valve, constant expansion valve and capillary. Carnot, theoretical and actual COP of thermostatic expansion valve is more than constant expansion & capillary tube Thermostatic expansion valve provides maximum efficiency over a wide temperature and load range., it gives improved refrigerant return to the compressor hence assures better cooling at high temperatures and reduces the possibility of liquid slugging which can be destroy the compressor.

Chavan et al. [3] they have used domestic refrigerator working on vapour compression refrigeration for optimization capillary tube with various diameter and performance analysis with refrigerant R 134a and R 600a. R 600a exhibited higher compressor work than R 134a, but R600a exhibited significantly high refrigerating effect. R 600a has the higher COP all most 23% compare to R 134a.They found that the capillary tube with 0.031 inch inner tube diameter offer best desirable requirements; it has low compressor work with high refrigerating effect. It results in higher COP compare to other studied diameter capillary tube. They analyze that in morning, refrigerating effect were more and compressor work were less as compared to whole day time. As per their result Compressor work and power consumption was more for same refrigerating effect in after noon.

Amol et al. [5] has investigated and performed the experiment on vapour compression refrigeration system of 0.33 TR and refrigerant used was R-12. and used both expansion valve thermostatic expansion valve and Capillary tube for analysis with R12. The analysis focuses on Coefficient of Performance (COP) for both expansion devices (Capillary tube and Thermostatic expansion valve). The Carnot, Theoretical and Actual Coefficient of Performance of system is increase while using Thermostatic expansion valve compare to capillary tube. To provide energy saving a thermostatic expansion valve equipped VCR system is provided. Thermostatic expansion valve adjusts the minor pressure difference in the charged R-12 refrigerant. Capillary tube provides constant expansion so it doesn’t have the compensating 15 ability for changes in load. With Thermostatic Expansion, the returning of refrigerant into compressor is improved so possibility of liquid slugging is avoided with better cooling at high temperature. Also, the work required by thermostatic expansion valve is less than that of the capillary tube.

3. OBJECTIVE OF WORK

The objective of the present study is to analyze the flow characteristics.

1. To calculate the refrigerating effect, work done and COP of system by using capillary tube and Thermostatic expansion valve respectively.
2. To conduct analysis of different type of Refrigerant (R-134a, R-290 & R-600a) and blended mixture of R-134a and R-290.
3. Compare the results of different configurations of expansion devices and also compressor work.
4. The aim of the present work is to compare the flow performance of conventional and non conventional refrigerants.
5. To simulate the performance of capillary tube, & Thermostatic expansion valve for adiabatic flow arrangement.

4. EXPERIMENTAL

The test facility used in the experimental investigation is shown in figure 3.2 Water is used as the working fluid and it is stored in evaporator. Firstly the refrigeration cycle is charged by refrigerant R-134a with charging system and evacuated with vacuum pump to remove the moisture and to create vacuum in system. After charging refrigerants, shut off the hand operated valve of TXV and open the valve of capillary tube and data were collected after collecting data close the valve of capillary and open the valve of thermostatic expansion valve at interest point with same operating condition. The system attains steady state condition after a run of half an hour, after which experimental observations were made. The following parameters were obtained to compare refrigerant like refrigerating effect, compressor work, mass flow rate and coefficient of performance.

At second stage refrigeration system is charged by refrigerant R-134a and R-290 (mixture of 90%and 10 %) and evacuated with vacuum pump to remove the moisture and to create vacuum in system. After charging refrigerants, all above process are repeat again and obtain all data.

At final stage refrigeration system is charged by refrigerant R-600a and evacuated with vacuum pump to remove the moisture and to create vacuum in system. After charging refrigerants, all above process are repeat again and obtain all data.

Fig 3.1 Photographic View of Experimental Set

5. RESULTS & DISCUSSIONS

The result of coefficient of performance, refrigeration effect and compressor work of the system using two expansion devices namely capillary tube and thermostatic expansion valve. Furthermore we have used three refrigerants R134a, R-600a (40 % 200g) and blend of R-134a & R-290 (90/10%). The main motive of this research is to find out the replacement of R-134a which leads to the Global Warming Potential (GWP). So with R-134a we have used R-600a as well as a blend of R-134a and R-290 and measure the coefficient of performance, refrigeration effect and compressor work. Further we have used two expansion devices with the above mention refrigerants and find out the best suitable combination in terms of coefficient of performance, refrigeration effect and compressor work. The main objective is to identify new refrigerant and their blend which are environment friendly and give good performance in domestic refrigerator.

5.1 When System Works on Capillary Tube Operating Mode

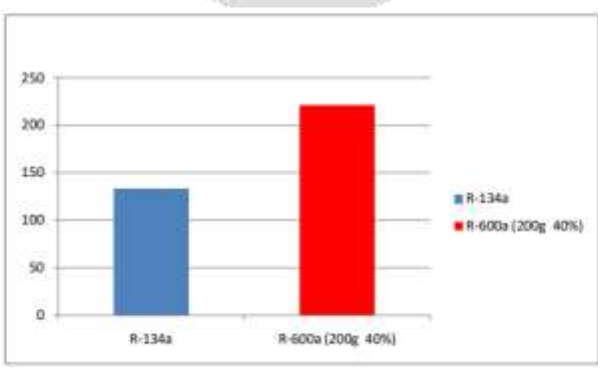
The system is run on all refrigerants and gives the experimental result and as well as theoretical result is calculated with the help of Ph chart of the refrigerants.

5.1.1 Refrigerating effect

The refrigerating effect of the system is shown the heat absorbing capacity of the refrigerant into the evaporator. The heat is absorbed by the refrigerant and makes it evaporator cool.

a. Theoretical refrigerating effect

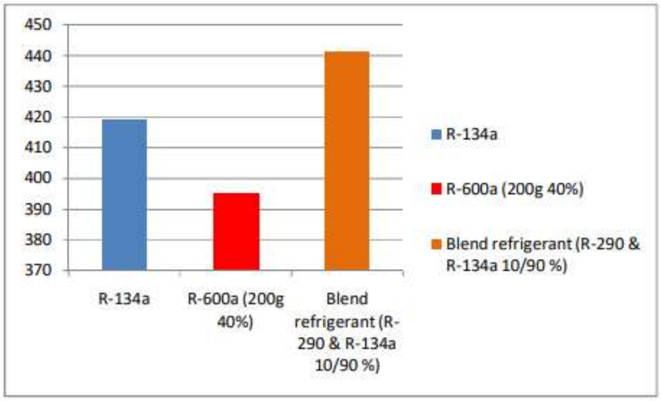
The theoretical refrigerating effect is calculated with the help of Ph chart of R-134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the refrigerating effect is increase by 39%. Its mean the theoretical refrigerating effect of R-600a is better than the R-134a. It’s occurring due to chemical composition of hydrocarbon.



Graph: 5.1 Theoretical Refrigerating effect on Capillary tube

b. Actual refrigerating effect on capillary tube

The actual refrigerating effect is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the actual refrigerating effect is decrease by 5.7%. And while we are using blend of R-134a and R-290 the refrigerating effect is increase by 5%. Its mean the actual refrigerating effect of R600a (40%) is less comparatively R-134a due to fewer amounts of R-600a. but in blend refrigerant of R-134a and R-290 give the better effect due to their mix-up ratio 9:1 and chemical composition of HFC and HC.



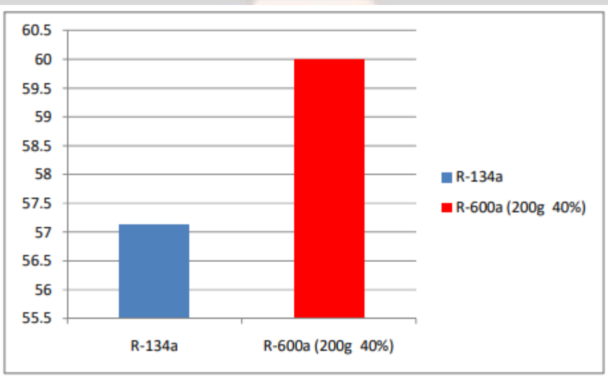
Graph: 5.2 Actual Refrigerating effect on Capillary tube

5.1.2 Compressor work

The compressor work of the system is shown the power consuming capacity of the system. The compressor compresses the refrigerant and increases the pressure and temperature the refrigerant.

a. Theoretical compressor work

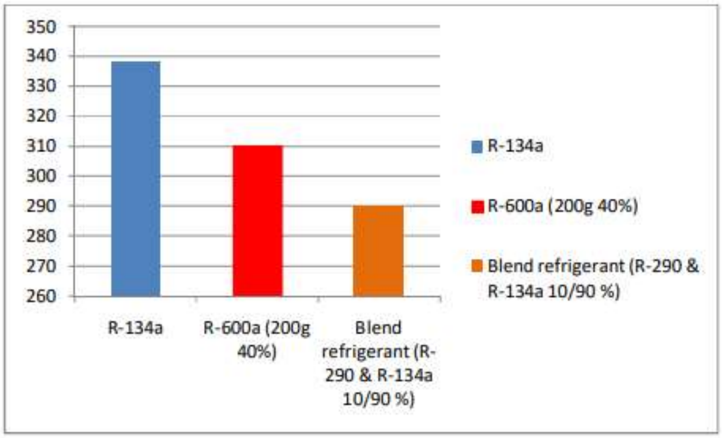
The theoretical compressor work is calculated with the help of Ph chart of R-134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the compressor work is increase by 5%. Its mean the compressor done more work to compress the refrigerant due to variation in suction and discharge pressure as well as temperature and the smaller amount of R-600a is also responsible to increase in compressor work.



Graph: 5.3 Theoretical Compressor work on Capillary tube

b. Actual compressor work

The actual compressor work is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the compressor work is decrease by 8.3%. And while we are using blend of R-134a and R-290 the compressor work is decrease by 14.2%. Its mean the compressor done less work to compress the refrigerant while using HC and the mixture of HCFC and HC in the ratio of 9:1. Comparatively HFC due to chemical composition of these refrigerants.



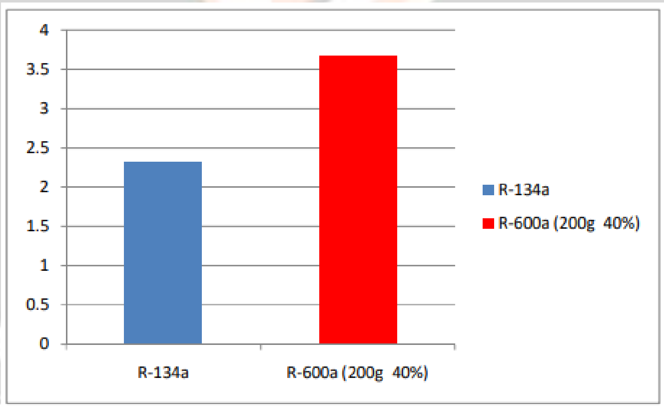
Graph: 5.4 Actual Compressor work on Capillary tube

5.1.3 Coefficient of performance of system

The coefficient of performance of system is shown the overall efficiency of the system. The cop of the system is calculated with the help of experimental data and theoretical data.

a. Theoretical coefficient of performance

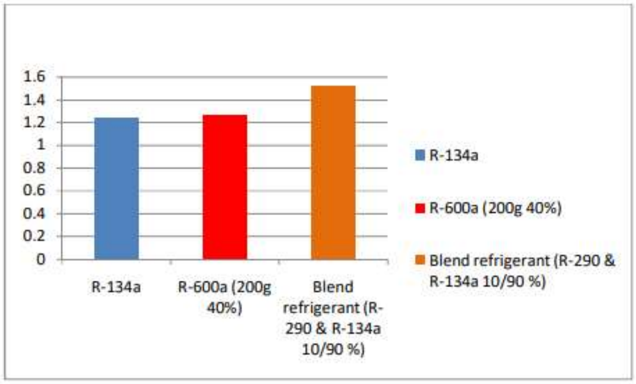
The theoretical coefficient of Performance is calculated with the help of Ph chart of R134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the coefficient of Performance is increase by 2.5%. Its mean the cop of HC is better Comparatively HFC due to chemical composition of refrigerants.



Graph: 5.5 Theoretical COP Capillary tube

b. Actual coefficient of performance

The actual coefficient of Performance is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the coefficient of Performance is increase by 2.5%. And while we are using blend of R134a and R-290 the coefficient of Performance is increase by 22.5 %. Its mean the actual coefficient of Performance of 40 % of HC is better comparatively R-134a and blend refrigerant of R-134a and R-290 give the better COP due to their mix-up ratio 9:1 and chemical composition of HFC and HC.



Graph: 5.6 Actual COP Capillary tube

5.2 When System Works on Thermostatic Expansion Valve Operating Mode

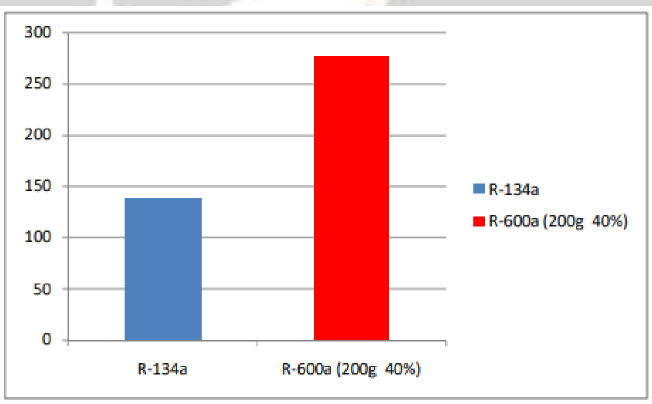
The system is run on all refrigerants and gives the experimental result and as well as theoretical result is calculated with the help of Ph chart of the refrigerants.

5.2.1 Refrigerating effect

The refrigerating effect of the system is shown the heat absorbing capacity of the refrigerant into the evaporator. The heat is absorbed by the refrigerant and makes it evaporator cool.

a. Theoretical refrigerating effect

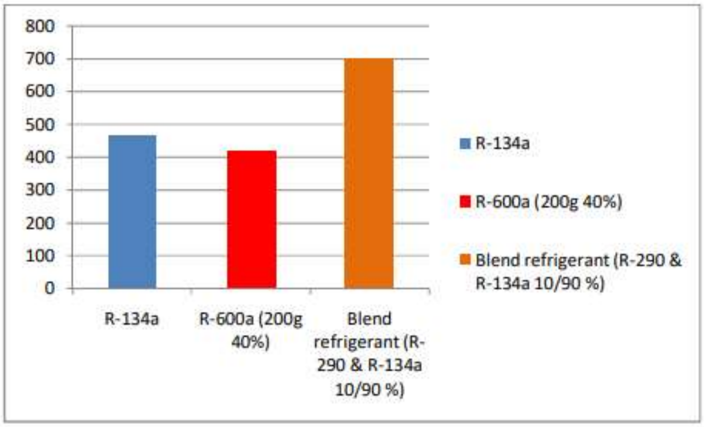
The theoretical refrigerating effect is calculated with the help of Ph chart of R-134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the refrigerating effect is increase by 100 %. Its mean the theoretical refrigerating effect of R-600a is better than the R-134a. It's occurring due to chemical composition of hydrocarbon.



Graph: 5.7 Theoretical Refrigerating effect on TXV

b. Actual refrigerating effect

The actual refrigerating effect is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the actual refrigerating effect is decrease by 9.6%. And while we are using blend of R-134a and R-290 the refrigerating effect is increase by 50%. Its mean the actual refrigerating effect of R600a (40%) is less comparatively R-134a due to fewer amounts of R-600a. but in blend refrigerant of R-134a and R-290 give the better effect due to their mix-up ratio 9:1 and chemical composition of HFC and HC.



Graph: 5.8 Actual Refrigerating effect on TXV

5.2.2 Compressor work

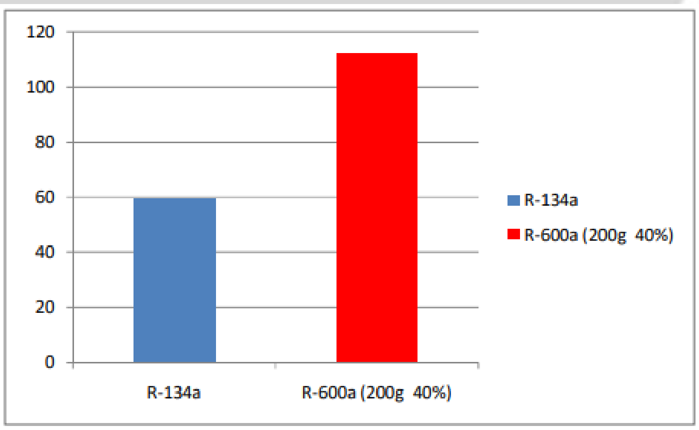
The compressor work of the system is shown the power consuming capacity of the system. The compressor compresses the refrigerant and increases the pressure and temperature the refrigerant.

a. Theoretical compressor work

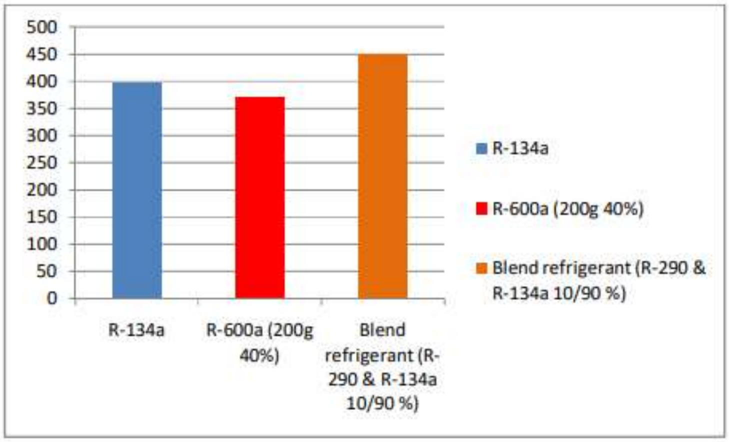
The theoretical compressor work as shown in Graph 5.9 is calculated with the help of Ph chart of R-134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the compressor work is increase by 88%. Its mean the compressor done more work to compress the refrigerant due to variation in suction and discharge pressure as well as temperature and the smaller amount of R-600a is also responsible to increase in compressor work.

b. Actual compressor work

The actual compressor work shown in Graph 5.10 is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the compressor work is decrease by 6.5%. And while we are using blend of R-134a and R-290 the compressor work is increase by 13.6%. Its mean the compressor done less work to compress the refrigerant while using HC and the mixture of HCFC and HC in the ratio of 9:1. Comparatively HFC due to chemical composition of these refrigerants.



Graph: 5.9 Theoretical Compressor work on TXV



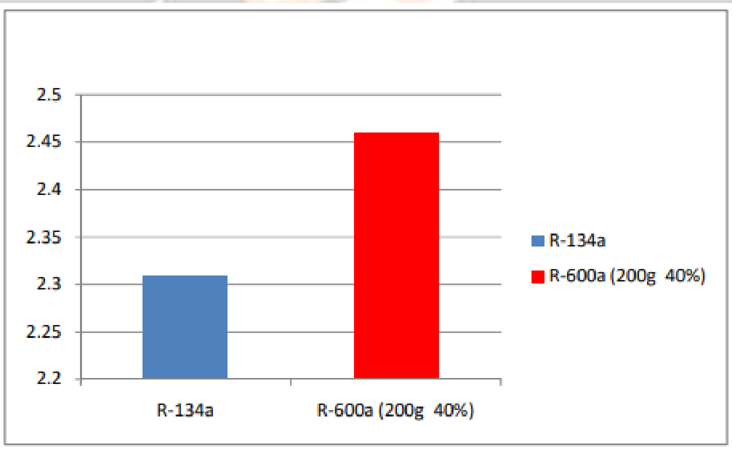
Graph: 5.10 Actual Compressor work on TXV

5.2.3 Coefficient of performance of system

The coefficient of performance of system is shown the overall efficiency of the system. The cop of the system is calculated with the help of experimental data and theoretical data.

a. Theoretical coefficient of performance

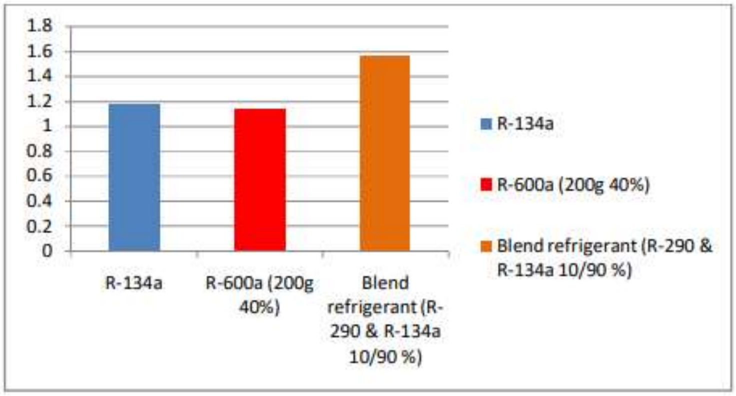
The theoretical coefficient of Performance is calculated with the help of Ph chart of R134a and R-600a. We could not find the theoretical value of Blend refrigerant due to unavailability of data. We find when we replace R-134a refrigerant with 40 % of R600a the coefficient of Performance is increase by 6.5%. Its mean the cop of HC is better Comparatively HFC due to chemical composition of refrigerants.



Graph: 5.11 Theoretical COP on TXV

b. Actual coefficient of performance

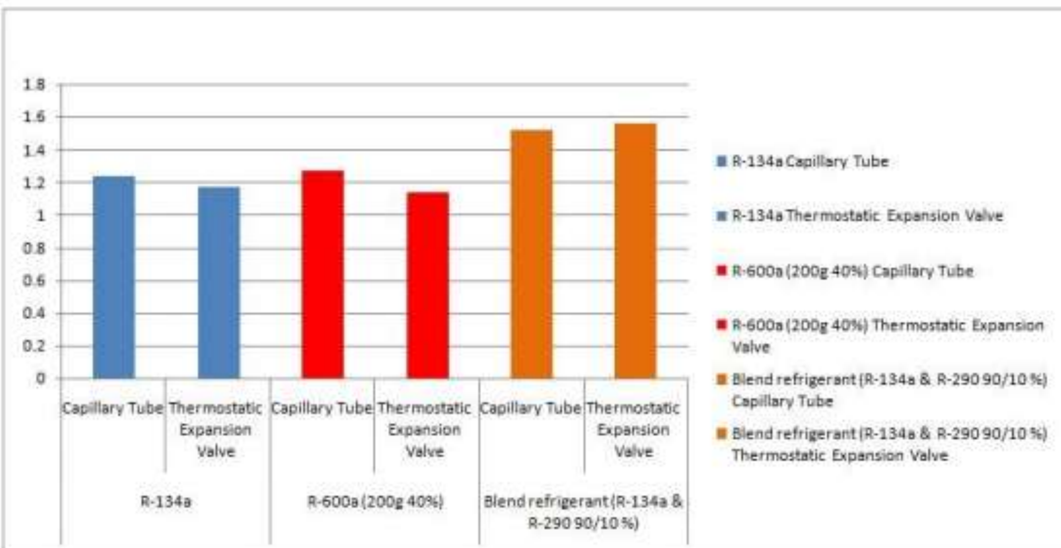
The actual coefficient of Performance is calculated with the help of experimental result. We find when we replace R-134a refrigerant with 40 % of R-600a the coefficient of Performance is decrease by 2.5%. And while we are using blend of R134a and R-290 the coefficient of Performance is increase by 33.3 %. Its mean the actual coefficient of Performance of R-134a is better comparatively 40 % of HC and blend refrigerant of R-134a and R-290 give the better COP due to their mix-up ratio 9:1 and chemical composition of HFC and HC.



Graph: 5.12 Actual COP on TXV

5.3 Compression of Actual COP on Both Expansion Devices

Coefficient of performance of the system shown the overall efficiency of the system. When the system is run on R-134a the coefficient of performance is comparatively more while using capillary tube as compare to Thermostatic expansion valve. Again the system is run on R-600a (200g 40%) and we find the coefficient of performance is 2.4% increase while using capillary tube. On Thermostatic expansion valve the cop is decrease up to 8%. But when we are using the mixture of R-134a and R-290 (90/10%) the coefficient of performance of the system is for Thermostatic expansion valve is high as compare to capillary tube. and overall the coefficient of performance of the system is 22.5% increase on capillary tube and 25.% increase on TXV on blend refrigerant comparing to R-134a.



Graph: 5.13 Coefficient of performance on different refrigerant and different expansion device

6. Conclusions

The main outcome of my research work is listed here.

- When we are using R-134a the COP is 5.6% decrease on TXV compare to capillary tube.
- 40% of the Refrigerant R-600a (200g) is efficient by 2.4 % on capillary tube and its COP is decrease by 20% on TXV.
- The blend refrigerant of R-134a and R-290 (90% & 10%) give better performance for both expansion devices as compare to R-134a and R-600a. The COP is increased by 25.8% on TXV and 22.5% on capillary tube.

- The actual COP is decrease on all refrigerants compare to theoretical value. The actual COP of R-134a on both expansion devices is decrease 46 to 49%. While we are using R-600a (40%) the actual COP is decreased in both cases.
- When we are using R-134a the compressor work is 17.1% is increase on TXV compare to capillary tube.
- The compressor work of R-600a (200g) is decrease 8.2% on capillary tube and increase by 6.4% on TXV.
- The compressor work of blend refrigerant of R-134a and R-290 is decrease 14.2% on capillary tube and increase by 33% on TXV.
- When we are using R-134a the Refrigerating effect is 11% is increase on TXV compare to capillary tube.
- The Refrigerating effect of R-600a (200g) is decrease 5.7% on capillary tube and approximately same on TXV.
- The Refrigerating effect of blend refrigerant of R-134a and R-290 is increase 5.23% on capillary tube and up to 67% on TXV.

Reference

[1] “Experimental verification of performance of capillary tube using vapour compression refrigeration system ” International Journal of Research In Science & Engineering e-ISSN: 2394-8299 Volume: 3 Issue: 2 March-April 2017 p-ISSN: 2394-8280 [Prof. S.V.Rao, Hitesh Sharma, Pankaj Kumar Gound, Tukaram Walgude, Shekhar Gavas]

[2] “Experimental analysis of Thermostatic expansion valve, Constant expansion device & Cap tube on vapour compression refrigeration system” (IJSEAS) – Volume-2, Issue-6, June 2016 ISSN: 2395-3470 [Prof. Vijay Patil, Rohit Joshi]

[3] "Experimental Optimization of Capillary Tube in Domestic Refrigerator” ISSN 2393- 8471 Vol. 2, Issue 1, pp: (59-65), Month: April 2015 – September 2015[S. P. Chavan,Suraj, Tushar]

[4] “Experiment analysis and performance testing of Capillary tube and thermostatic expansion valve”. International journal of science, engineering and technology. ISSN: 2348-4098 Volume 02 ISSUE 05 JUNE 2014[Amol A. Gawali, Madhav S. Joshi, Rupesh L. Raut, Rahul A. Bhogare]

[5] “A Review of an Alternative to R134aRefrigerant in Domestic Refrigerator”, International Journal of Emerging Technology and Advanced Engineering (ISSN 2250- 2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 9), (September2013) 550-556 [SandipP.Chavhan, Prof.S.D.Mahajan]

[6] “Exergy analysis and optimization of R600a as a replacement of R134a in a domestic refrigerator system”, international journal of refrigeration 36(2013) 1233-1242.[Mahmood Mastani Joybari, Mohammad Sadegh Hatamipour, Amir Rahimi, Fatemeh Ghadiri Modarres]

[7] “Energy efficiency enhancement of a Domestic refrigerator using R436A and R600a as alternative refrigerants to R134a”, International Journal of Thermal Sciences 74 (2013) 86- 94 [] Mehdi Rasti, Aghamiri, Mohammad-Sadegh]

[8] “Performance Analysis of Vapour Compression Refrigeration Systems Using Hydrofluorocarbon Refrigerants”International Journal of Scientific & Engineering Research, Volume 3, Issue 12, December-2012 ISSN 2229-5518[Dr. A.C. Tiwari and Shyam kumar Barode]