International Journal of Research in Engineering, Science and Management
Volume-1, Issue-12, December-2018
www.ijresm.com | ISSN (Online): 2581-5792

A Review on Performance of Vapour Compression Refrigeration System with Different Refrigerants

Sharad Dharpure[1], Rajiv Varshney[2], Pradyumna Vishwakarma[3]
[1]*M. Tech. Student, Dept. of Mechanical Engineering, Radharaman Inst. of Research and Tech., Bhopal, India*
[2]*Director, Dept. of Mechanical Engineering, Radharaman Inst. of Research and Tech., Bhopal, India*
[2]*Professor and HoD, Dept. of Mechanical Engineering, REC, Bhopal, India*

***Abstract*: Refrigeration systems find applications in many stationary and mobile applications to provide an appropriate environment for food preservation and other temperature/ humidity sensitive items. These systems consume a large amount of energy leading to global warming. A variety of refrigerants are there, which are used in vapour compression refrigeration system. R134a has a higher global warming potential as compare to R134a and HC mixture. The various flow aspects of the capillary tube were investigated by a number of researchers in the past. In the present article, a review of various refrigerants presently used in the vapour compression refrigeration system and their performance have been analyzed and compared.**

***Keywords*: COP, HC (hydrocarbon), Vapour compression refrigeration system (VCRS), GWP, ODP, refrigerant, R134a**

1. Introduction

Refrigeration systems are used in many stationary and mobile applications to provide an appropriate condition for food and other temperature/humidity sensitive creatures/ products. These systems consume a huge amount of energy leading to global warming. A large number of refrigerants are there, which are used frequently to transfer heat from low temperature reservoir to high temperature reservoir using vapour compression refrigeration system. When it comes to environmental concern R134a have high global warming potential as compare to R134a and HC mixture. Capillary tubes are used as an expansion device in the refrigerating system like domestic refrigerators and window type room air conditioners. This is the simple, low cost, zero maintenance and require a low starting torque motor to run the compressor, capillary tubes have been used in a various type of vapor compression systems. The various flow aspects of the capillary tube were investigated by a number of researchers since past six decades. In straight capillary configuration refrigerant flows in a straightforward manner. In straight capillary tube refrigerant not feel any centrifugal force. Different refrigerants and their range of parameters are shown in Table 1.

Table 1
Different refrigerants and their range of parameters

S. No	Author (s)	Refrigerant (s)	Range of Parameters
1	Park et al., [5]	R-22, R-407C and R-410A	d = 1.5, 1.2 mm L = 1 m
2	Khan et al. [16]	R-134a	d = 1.12, 1.4, 1.63 mm L = 2.4-6.4 m
3	Mittal et al. [6]	R-407C	d = 1.02, 1.27, 1.52 mm L = 1.0, 1.5, 2 m
4	Chingulpitak and Wongwises [19]	R-134a, R-22, R-407C and R-410a	d = 0.84, 1.02, 1.52 mm L = 1.5, 3.05m

2. Effect of various parameters on the performance of VCRS

A. Effect of capillary tube structure on the performance of VCRS

Kumar et al. [1] carried out flow of different refrigerants through adiabatic and diadibatic capillary tubes of different geometries viz. straight and coiled and conclude that in case of coiled capillary tube, the mass flow rate hysteresis was more prominent due to secondary flow caused by centrifugal force and the mass flow rate of refrigerant through the coiled capillary tubes is 5-16% less than that of straight one. Jadhav et al. [2] studied helically coiled capillary tubes where flow is characterized for transcritical CO_2 refrigerant numerically, developing theoretical model established on fundamental equations of mass, energy and momentum considering homogeneous two phase flow. Mittal et al. [3] developed a homogenous model including the metastable liquid region for the adiabatic flow of refrigerant through the spiral capillary tube. The model developed has been validated with the available experimental results and presents reasonably well in the range of 0 to 10 percent. They concluded that the mass flow rate increases with increase of pitch. However, for a capillary tube of 1.5 mm diameter and 2 m length, the rise in mass flow rate is quite slow beyond a pitch of 120 mm. Dubba et al. [4] studied a helically coiled capillary tube with an adiabatic flow of R-600a they studied the effect of geometry and inlet operating conditions on the mass flow rate of R-600a flowing

through an adiabatic capillary tube and concluded that the coiling reduces the mass flow by 1.5–16 percent as compared to straight capillary tube. Park et al. [5] studied the performance of straight and coiled capillary tubes with R22 as the operating conditions, tube geometries, and coiled shape were varied. The mass flow rates of the coiled capillary tubes decreased by 5 to 16% more than those of the straight capillary tubes under the same operating conditions due to increased flow friction resulting from strong coiled effects. These results were confirmed by numerical simulation of the performance of the coiled capillary tubes.

B. Effect of capillary tube diameter on the performance of VCRS

Mittal et al. [6] conducted parametric study for the mass flow rate of R-407C through the capillary tubes of straight and coiled geometry. As compared to the mass flow rate of R-407C in straight capillary tube, the mass flow rate in coiled capillary with coil diameter of 60mm, 100mm and 140 mm is reduced by an average of 10 %, 7% and 5%respectively. Lee and Su [7] studied the performance of VCRS with isobutene and compare the results with R12 and R22. They used R600a 150 g and set the refrigeration temperature about 5 °C and -11 °C to maintain the situation of cold storage and freezing applications. They used 0.7 mm internal dia. and 4 to 4.5 m length of capillary tube for cold storage applications and 0.6 mm internal dia. and 4.5 to 5 m length of capillary for cold applications. They observed that the COP lies somewhere between 1.2 and 4.5 in cold storage applications and about 0.8 to 3.5 in freezing applications. They also observed that the system with two capillary tubes in parallel performs better in the cold storage and AC applications, whereas that with a single tube is suitable in the freezing applications.

C. Effect of using different refrigerants on the performance of VCRS

Calm [8] studied the emission and environmental severe impacts of R123, R134a leakage from centrifugal chiller system. He also investigated the overall impact and change in system efficiency or performance due to charge loss. He studied the methods to reduce the refrigerant losses by the system like design modifications, improvement in preventive maintenance techniques, use of purge system for refrigerant vapour recovery, servicing and lubricant changing in experimental system. Dib and Benzaoui [9] concluded that the uses of halogenated refrigerants are not suitable for environment and the use of "natural" refrigerants become a good solution. Here natural refrigerants work as an alternative solution to replace halogenated refrigerants. The solution to the environmental impacts of refrigerant depends on a gas which contains no chlorine no fluorine and does not reject any carbon dioxide emissions in the atmosphere. The researchers showed that emissions have severe effects on our environment. Granryd [10] enlisted the different HC as working medium in refrigeration system. He studied the different safety standards regarding to these refrigerants. He showed the properties of HC (i.e. no ODP and negligible GWP) that make them better refrigerating alternatives for energy efficient and ecofriendly. But safety precautions due to flammability have to be seriously taken into account. Cabello et al. [11] analyzed the performance of a vapour compression refrigeration system using different working fluids (R134a, R407c and R22). The operating parameters are the evaporating pressure, condensing pressure and degree of superheating. They analyzed that the power consumption decreases when compression ratio increases using R22 than using the other working fluids. He et al. [12] conducted experimental research on the main refrigeration performances of domestic refrigerators under the different proportions and refrigerant charge amounts, when R152a/R125 is used to substitute R12 as a refrigerant. The experimental results indicated that R152a/R125 can be used to replace R12 as a modern refrigerant of domestic refrigerators because of its well environmental acceptable properties and its favorable refrigeration performances.

Park et al. [13] analyzed performance of two pure hydrocarbons and 7 mixtures composed of propylene, propane, R152a, and dimethyl ether were measured to substitute for R22 in domestic air-conditioners and heat pumps at the evaporation and condensation temperatures of 7 °C and 45 °C, respectively. Test results show that coefficient of performance of these mixtures is up to 5.7% higher than that of R22. However, propane showed 11.5% reduction in capacity, most fluids had a similar capacity to that of R22. For these fluids, Compressor-discharge temperatures were reduced by 13–17 °C. For all fluids tested, the amount of charge was reduced by up to 54% as compared to R22. Overall, these fluids provide good performances with reasonable energy savings instead of any environmental problem and thus can be used as long-term alternatives for residential air-conditioning and heat-pumping applications. Park and Jung [14] studied thermodynamic performance of two pure HC and seven mixtures composed of propylene (R1270), propane, R152a, and dimethyl ether (R170) in an attempt to replace R22 in residential air-conditioners. The pure and mixed refrigerants tested have GWP of 3–58 as compared to that of CO2 at the evaporation and condensation temperature of 7 and 45 °C, respectively. Test results refers that COP of these mixtures is about 5.7% higher than that of R22.Propane showed 11.15% less in capacity, most of the fluids had the similar capacity to that of R22. Compressor discharge temperatures were reduced to 10–17 °C with these fluids. There was no such problem found with mineral oil since the mixtures were mainly composed of HC. The amount of charge was reduced up to 56% as compared to R22.K. Mani and Selladurai [15] analyzed a vapour compression refrigeration system with the new R290/R600a refrigerant mixture as drop-in replacement was done and compared with R12 and R134a. The VCRS was designed to operate with R12.The results showed that the refrigerant R134a showed slightly lower COP than R12. The discharge temp and discharge pressure of the R290/R600a

mixture was close to R12. The R290/R600a mixture can be considered as a drop-in replacement refrigerant for R12 and R134a.

D. Effect of mass flow rate of refrigerants on the performance of VCRS

Kumar et al. [16] compared the refrigerant mass flow rate characteristic curves of the diadiabatic capillary tubes with those of the adiabatic capillary tubes. They found that the flow behavior of the diadiabatic capillary tubes is entirely different from those of adiabatic capillary tubes. In case of diadiabatic capillary tube, the refrigerant mass flow has been found to be the function of suction-line inlet superheat and heat exchange length in addition to capillary tube diameter, capillary tube length, coil pitch and capillary inlet subcooling. Rasti and Jeong [17] developed certain empirical correlations to predict refrigerant mass flow rates through an adiabatic helically coiled capillary tube. All previous correlations in the present study, a generalized continuous correlation for the prediction of the refrigerant mass flow rate through an adiabatic helically coiled capillary tube was developed to offset the defects of previous correlations. Gill and Singh [18] Found that compared to the mass flow rate of R134a/LPG as refrigerant in straight capillary tube, mass flow rate in the helically coiled capillary tube with a coil diameter of 60, 90 and 120 mm reduced by an average of 16, 12 and 5%.Using experimental data obtained in steady state test conditions, the dimensionless correlation and ANFIS models of the straight and helical coiled adiabatic capillary tubes in the vapor compression refrigeration system were developed to predict the refrigerant mass flow rate. The statistical prediction performances of both models are measured in terms of the absolute fraction of variance; root means square error and mean absolute percentage error. Although the predictions of both models yielded a good statistical performance, the accuracies of ANFIS predictions were usually slightly better than those of Dimensionless correlation. Chingulpitak and Wongwises [19] validated model by comparing with the experimental data of Zhou and Zhang for R-22 and was found to give an average discrepancy at around 3%. The mass flow rates of refrigerant flowing through the helical capillary tubes are lower compared with those for the straight capillary tubes, especially for lower coil diameters. The mass flow rates of the helical capillary tubes with coil diameters of 40 mm, 80 mm, and 120 mm are decreased by5–9% more than those of the straight capillary tubes under given conditions due to increased flow friction resulting from strong coil.

3. Conclusion

R134a is most widely used refrigerant in the domestic refrigerator as well as in commercial refrigeration plants where very low temperature has to be maintained as per the requirement. In the present work a review has been carried out on VCRS with straight capillary tube using R134a and a mixture of R134a and Hydrocarbon at 28:72 ratio (by mass) as working refrigerant. The detailed results of the experiments by different researchers at different capillary tube diameters using different refrigerants are discussed. Further, the effect of the structure of capillary, length of capillary, diameter of capillary tube has been discussed.

References

[1] Dubba, Santhosh Kumar, Ravi Kumar, Flow of refrigerants through capillary tubes: A state-of-the-art, Thermal Fluid Science, 81, (2017), 370–381.
[2] Pravin Jadhav, Neeraj Agrawal, Omprakash Patil, Flow characteristics of helical capillary tube for transcritical CO2 refrigerant flow, international journal of refrigeration, 109, (2017), 431-438.
[3] M.K. Mittal, Ravi Kumar, Akhilesh Gupta, Numerical analysis of adiabatic flow of refrigerant through a spiral capillary tube, International Journal of Thermal Sciences 48 (2009), 1348–1354.
[4] Santhosh Kumar Dubba, Ravi Kumar, Adiabatic flow characteristics of R-600a inside a helically coiled capillary Tube, Applied Thermal Engineering, 132, (2018), 500–507.
[5] Chasik Park, Sunil Lee, Hoon Kang, Yongchan Kim, Experimentation and modeling of refrigerant flow through coiled capillary tubes, International Journal of Refrigeration, 30, (2007), 1168-1175.
[6] M.K. Mittal, Ravi Kumar, Akhilesh Gupta, An experimental study of the flow of R-407C in an adiabatic helical capillary tube, Applied Thermal Engineering, 33, (2010), 840-847.
[7] Y.S. Lee, and C.C. Su, Experimental studies of isobutene (R600a) as the refrigerant in domestic refrigeration System, Applied Thermal Engineering, 22, (2002), 507–519.
[8] James M. Calm, Emissions and environmental impacts from air-conditioning and refrigeration systems, International Journal of Refrigeration 25, (2002), 293–305.
[9] Samira Benhadid-Dib, and Ahmed Benzaoui, Refrigerants and their environmental impact Substitution of hydro Chlorofluorocarbon HCFC and HFC hydro fluorocarbon. Search for an adequate refrigerant, Energy Procardia 18, (2012), 807 – 816.
[10] Eric Granryd, “Hydrocarbons as refrigerants, an overview, International Journal of Refrigeration, 24, (2001), 15-24.
[11] R. Cabello, E. Torrella, and J. Navarro-Esbri, Experimental evaluation of a vapour compression plant Performance using R134a, R407C and R22 as working fluids, Applied Thermal Engineering, 24, (2004), 1905–1917.
[12] Mao-Gang He, Tie-Chen Li,Zhi-Gang Liu, and Ying Zhang, Testing of the mixing refrigerants HFC152a/HFC125 in domestic refrigerator, Applied Thermal Engineering, 25, (2005), 1169–1181.
[13] Ki-Jung Park, TaebeomSeo, and Dongsoo Jung, Performance of alternative refrigerants for residential air-conditioning Applications, Applied Energy, 84, (2007), 985–991.
[14] Ki-Jung Park, and Dongsoo Jung, Thermodynamic performance of HCFC22 alternative refrigerants for residential Air-conditioning applications, Energy and Buildings, 39, (2007), 675–680.
[15] K. Mani, and V. Selladurai, Experimental analysis of a new refrigerant mixture as drop-in replacement for CFC12 and HFC134a, International Journal of Thermal Sciences, 47, (2008), 1490–1495.
[16] Mohd. Kaleem Khan, Ravi Kumar, Pradeep K. Sahoo, Experimental investigation on diadiabatic flow of R-134a through spiral capillary tube, international journal of refrigeration, 32, (2009), 261–271.
[17] Mehdi Rasti, Ji Hwan Jeong, A generalized continuous empirical correlation for the refrigerant mass flow rate through adiabatic straight and helically coiled capillary tubes, Applied Thermal Engineering, 143, (2018), 450-460.
[18] Jatinder Gill, Jagdev Singh, Use of Artificial Neural Network approach for depicting mass flow rate of R134a /LPG refrigerant through straight and helical coiled adiabatic capillary tubes of vapor compression refrigeration system, Applied Thermal Engineering, 86, (2018), 228-238.
[19] Sukkarin Chingulpitak, Somchai Wongwises, A comparison of flow characteristics of refrigerants flowing through adiabatic straight and helical capillary tubes, International Communications in Heat and Mass Transfer, 38, (2011), 398–404.