Computational Fluid Dynamic Analysis of Mixed Refrigerants R290 and R-600a with Variable Compositions

Raja Sekhar Dondapati

School of Mechanical Engineering, Lovely Professional University, Phagwara 144 401, India.

Abstract

Refrigerants used for industrial cooling and domestic refrigeration occasionally results in decrease in Coefficient of Performance due to increase in cooling loads. As the mass of the refrigerant used, remains constant because of the fixed compressor capacity, therefore use of mixed refrigerants can prove to be a feasible solution to cater to the needs of cooling. Hence the present study aims at usage of mixed refrigerants R290 and R600a in industrial cooling systems. The objective of this project is to estimate heat transfer, pressure drop and temperature difference associated with the previously mentioned mixed refrigerants computationally. For this study, use of ANSYS FLUENT software is proposed. The operating pressure is set to be 3 MPa in a pipe of 0.064m diameter while simulation because higher pressures are maintained in the industrial cooling system. At fixed wall temperature of 350K, mixed refrigerants with varying composition is simulated in FLUENT. Initially, composition of 10% R290 and 90% R600a is selected and with varying mass flow rates i.e. from 0.05 kg/sec to 0.1 kg/sec, simulation is performed and pressure drop and heat transfer is estimated. After this step, simulations are performed for 20% R290 and R600a composition and composition is progressively increased to 90% R290 and 10% R600a. The analysis is then extended for corrugated pipes to obtain optimized results of pressure drop, heat transfer and temperature difference. Finally, Reynolds number and Nusselt number is calculated from Temperature difference and Heat transfer.

Keywords: CFD, heat transfer, pressure drop, refrigerants.

1. Introduction

The most regularly utilized strategy for cooling is with fume pressure cycles, since it is genuinely simple to build a cooling gadget utilizing this technique and the expense is low. Actually, traditional fridges utilize this technique for cooling to keep your scraps and beverages chilled! Climate control systems additionally utilize a fume pressure cycle to cool the encompassing air temperature in a room. Essentially, fume pressure refrigeration utilizes a warmth motor run in reverse, so heat vitality is taken from a chilly store and saved into a hot repository. Constantly Law of Thermodynamics, heat vitality doesn't immediately move from a cold to a hot supply. So as to have heat move toward that path (and not from hot to cold, as the framework is normally disposed to do), it is important to do deal with the framework. This refrigeration cycle is around a Rankine cycle run backward. A working liquid (regularly called the refrigerant) is pushed through the framework and experiences state changes (from fluid to gas and back). The inactive warmth of vaporization of the refrigerant is utilized to move a lot of warmth vitality, and changes in pressure are utilized to control when the refrigerant removes or assimilates heat vitality.

Bartosz Dawidowicz [1] et.al; the trial stand and system for stream bubbling examinations are depicted. Alberto Cavallini [3] et.al; The paper displays a thorough review of the latest research takes a shot at heat move. A.S. Dalkilic [4] et.al; test arrangement, the even test area was a 3.81 m long. Jianchang Huang [5] et.al; Plate heat exchangers (PHE's) are being utilized to an expanding degree as refrigerant. Xiangchao Huang [6] et.al; Flow buildup pressure drop attributes of R410A-oil blend inside little measurement (5.0 mm and 4.0 mm O.D.) flat small scale blade tubes were researched tentatively covering ostensible oil fixations from 0% to 5%. GiovannA.Longo [7] et.al; this paper shows the warmth move coefficients and weight drop estimated. Yang Zou [8] et.al; Refrigerant maldistribution among equal microchannel tubes deuteron. S. M. Sami [9] et.al; Heat move attributes of two-stage stream buildup and bubbling of quatemary (four segments) refrigerant blends. Rui Cao [10] et.al; The vaporous PVT properties of trans-1,3,3,3-tetrafluoropropene (R1234ze(E)) + 2-methylpropane (R600a) blends were estimated in temperatures from 280.15 to 330.15 K.

2. Research Methodology

The very first step in this research work is the selection of different refrigerants which are currently used in the Vapour compression refrigeration system. In this present research work mixed refrigerant Propane (R290) and ISO-butane (R600a) are selected that are used in the vapour compression refrigeration system. According to literature survey for selection of refrigerants, the minimum basic temperature difference has to be 30^0 C. So, for R290 and R600a the critical temperature difference is 50^0 C. Hence, these two refrigerants are selected for our CFD analysis. Thermo-physical properties like thermal conductivity, density, viscosity, and specific heat of propane and ISO-butane are studied. Different graph have been plotted with respect to temperature and graphs are shown in the succeeding chapter. These Thermo-physical properties vary from one composition of mixture to another composition of mixture and these values are obtained from NIST SUPERTRAPP software.

In the present research work, pressure drop is evaluated for compressor pipe and corrugated pipe in addition with respect to different mass flow rates at different temperatures varies from 300-330K for a mixed refrigerant at different compositions. So from ANSYS software maximum and minimum pressures of the refrigerant mixture are calculated and the pressure drop is estimated. In the present research work, heat transfer rate is evaluated for compressor pipe and corrugated pipe in addition with respect to different mass flow rates at different temperatures varies from 300-330K for a mixed refrigerant at different compositions. The heat transfer rate is estimated computationally from the ANSYS software from options Fluxes – total heat transfer – wall.

3. Results and Discussion

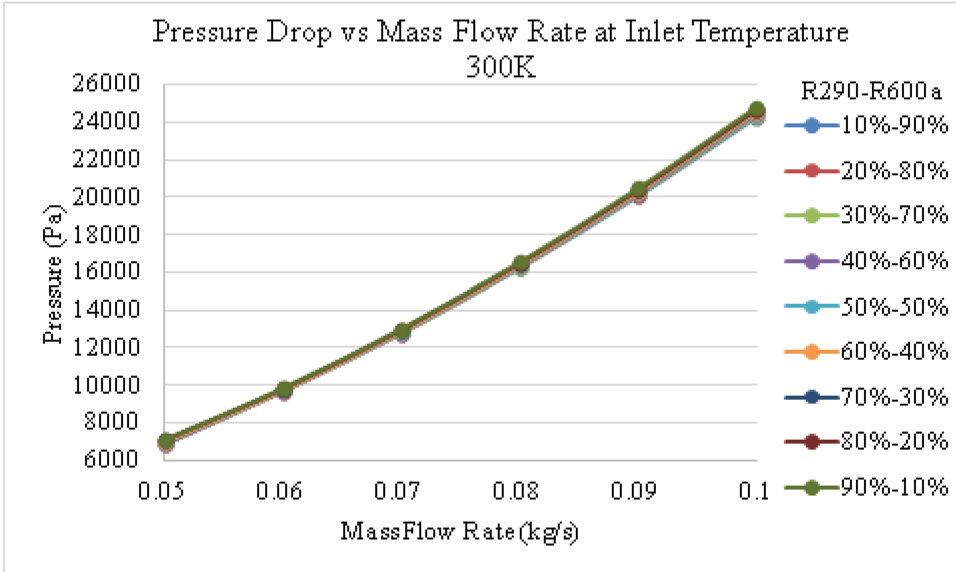

Figure 1 Pressure drop vs Mass flow rate at 300K

Figure 1 shows that variation of pressure drop with respect to different mass flow rate at 300K inlet temperature and different compositions of a mixed refrigerant. Moreover, it was observed that as the mass flow rate increases and pressure drop is increases exponentially.

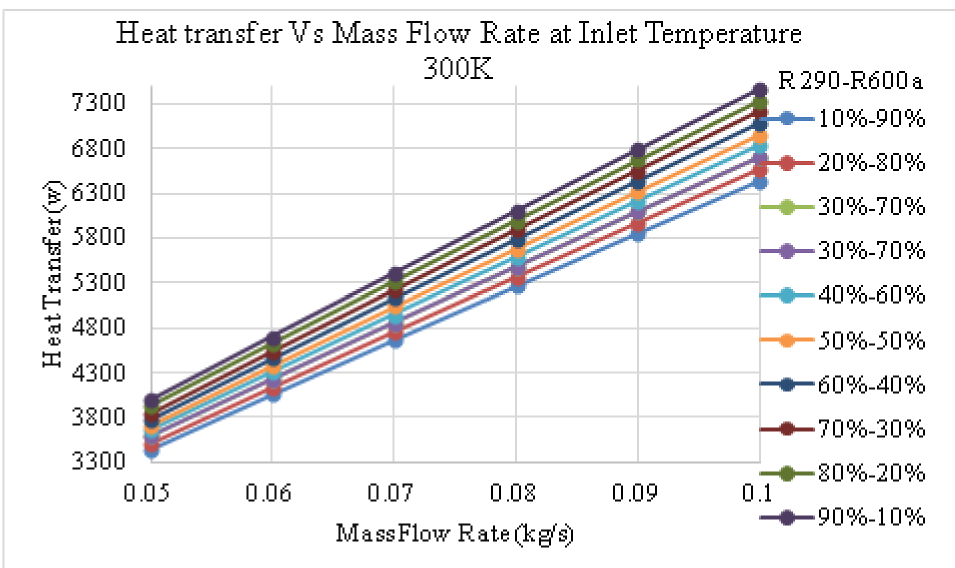

Figure 2 Heat transfer vs Mass flow rate at 300K

Figure shows that variation of heat transfer rate with respect to different mass flow rate at 300K inlet temperature and different compositions of a mixed refrigerant. Moreover, it was observed that as the mass flow rate increases and pressure drop is increases linearly.

4. Conclusions

The purpose this research work, was carried out in Fluent Analysis Work bench® for inspecting the pressure drop, heat transfer rate, Reynolds number, Nusselt number, of Propane (R290) and ISO-butane (R600a) at a temperature of 300-350K and pressure of 3MPa In addition, results are calculated.

Pressure drop of a mixed refrigerant at different inlet temperatures at operated pressure for different mass flow rates increased for compressor pipe and corrugated pipe. Heat Transfer Rate of a mixed refrigerant at different inlet temperatures at operated pressure for different mass flow rates increased for compressor pipe and corrugated pipe. Reynolds Number of a mixed refrigerant at different inlet temperatures at operated pressure for different mass flow rates increased for compressor pipe and corrugated pipe. Nusselt Number of a mixed refrigerant at different inlet temperatures at operated pressure for different mass flow rates increased for compressor pipe and corrugated pipe. Nusselt Number of a mixed refrigerant at different inlet temperatures at operated pressure with respect to Reynolds Number increased for compressor pipe and corrugated pipe. From the above results and discussions, we have concluded that pressure drop, heat transfer rate, Reynolds number, Nusselt number increased for both the compressor pipe and corrugated pipe. Moreover, it is also observed, that as the corrugated pipe liberates more pressure drop, heat transfer rate, Reynolds number and Nusselt number due to turbulence effect is caused for the corrugated pipe.

References

[1] Dawidowicz, B., & Cieśliński, J. T. (2012). Heat transfer and pressure drop during flow boiling of pure refrigerants and refrigerant/oil mixtures in tube with porous coating. *International Journal of Heat and Mass Transfer*, *55*(9–10), 2549–2558.

[2] Wen, M. Y., & Ho, C. Y. (2009). Condensation heat-transfer and pressure drop characteristics of refrigerant R-290/R-600a-oil mixtures in serpentine small-diameter U- tubes. *Applied Thermal Engineering*, *29*(11–12), 2460–2467.

[3] Wen, M. Y., & Ho, C. Y. (2009). Condensation heat-transfer and pressure drop characteristics of refrigerant R-290/R-600a-oil mixtures in serpentine small-diameter U- tubes. *Applied Thermal Engineering*, *29*(11–12), 2460–2467.

[4] Dalkilic, A. S. (2011). Condensation pressure drop characteristics of various refrigerants in a horizontal smooth tube. *International Communications in Heat and Mass Transfer*, *38*(4), 504–512. Huang, J., Sheer, T. J., & Bailey-Mcewan, M. (2012). Heat transfer and pressure drop in plate heat exchanger refrigerant evaporators. *International Journal of Refrigeration*, *35*(2), 325–335.

[5] Huang, X., Ding, G., Hu, H., Zhu, Y., Gao, Y., & Deng, B. (2010). Flow condensation pressure drop characteristics of R410A - Oil mixture inside small diameter horizontal microfin tubes. *International Journal of Refrigeration*, *33*(7), 1356–1369.

[6] Longo, G. A. (2010). Heat transfer and pressure drop during HFC refrigerant saturated vapour condensation inside a brazed plate heat exchanger. *International Journal of Heat and Mass Transfer*, *53*(5–6), 1079–1087. http://doi.org/10.1016/j.ijheatmasstransfer.2009.11.003

[7] Zou, Y., & Hrnjak, P. S. (2014). Single-phase and two-phase flow pressure drop in the vertical header of microchannel heat exchanger. *International Journal of Refrigeration*, *44*, 12–22.

[8] Sami, S. M., & Song, B. (1996). Heat transfer and pressure drop characteristics of HFC quaternary refrigerant mixtures inside horizontal enhanced surface tubing. *Applied Thermal Engineering*, *16*(6), 461–473.

[9] Cao, R., Qi, Y., & Chen, R. (2017). pVTx properties of binary R1234ze(E)/R600a system. *The Journal of Chemical Thermodynamics*, *111*, 191–198.

[10] Choudhari, C. S., & Sapali, S. N. (2017). Performance Investigation of Natural Refrigerant R290 as a Substitute to R22 in Refrigeration Systems. *Energy Procedia*, *109*(November 2016), 346–352.