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The Effect Of Capillary Tube-Suction Line Heat Exchanger Design And Refrigerant Flow On The Performance Of The Vapor Compression Refrigeration System- A Review

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***Abstract**:*
In this article, a theoretical and mathematical analysis of different geometrical combinations of different kinds of capillary tubes (CT) with suction line heat exchanger designs about refrigerant flow on the performance of vapour compression refrigeration (VCR) method was performed. The effect of a liquid suction heat exchanger on vapour compression cooling performance, a liquid suction heat exchanger (LSHX) has been installed in an existing refrigerator, and theoretical studies have been conducted to explain the impact of the LSHX on the overall performance of the refrigerator. The purpose of this paper is to make refrigerants and processes with flow conditions available. Heat exchange between high pressure and high-temperature refrigerant liquid from the condenser and low pressure and low-temperature refrigerant vapour from the evaporator is found to have a significant effect on its coefficient of performance (COP), with an observed range of 15-35% higher.

Keywords: *Diabatic Capillary Tube, Adiabatic Capillary Tube, Capillary Tube Suction Line Heat Exchanger, Group of Refrigerant.*

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I. Introduction

The vapour-compression refrigeration (VCR) system is a science field that generates and maintains temperature and pressure that are lower than the ambient temperature [1]. This research will concentrate on capillary tubes and refrigerant flow though the capillaries. Capillary tubes are a common type of throttling device found in air conditioning and refrigeration systems [2]. To improve the system's coefficient of performance (COP), a capillary tube is made of various materials; usually, copper the most desirable material utilized in the refrigeration system [3]. The capillary tube's inner diameter varies from 0.5 to 2.28 mm, and also its length varies from 2 to 6 m [4]. The Capillary tubes (CT) are used as throttling devices in household refrigerators, deep freezers, water coolers, and air conditioners [5]. The pressure in the capillary tube reduces as a result of two variables: Because the refrigerant must overcome the friction coefficient offered by the walls, there is a pressure loss in the capillary tube [6]. The liquid refrigerant flashes (evaporates) into a mixture of liquid and vapour as the pressure in the capillary tube decreases [7]. Vapour refrigerant has a lower density than liquid refrigerant [8]. The characteristic thicknesses of the refrigerant decrease while a consequence of the constant diameter tube [9]. The refrigerant velocity increases when the capillary tube diameter and mass flow rate remain constant because m= $_{\rho}$av [10]. A pressure drop occurs when the velocity of the refrigerant increases. A pressure drop is due to an increase in the velocity or acceleration of the refrigerant. Capillary tubes are simple to design, low in cost and simple to maintain because there are no moving parts [11]. Furthermore, it regulates the rate of flow of refrigeration system flowing into it to maintain the required level, allowing the capillary tube to perform as a fully automated refrigerant flow control system when the load varies. Capillary tubes are most commonly used in simple vapour transport. Compression refrigeration systems are divided into two categories [12].

This research paper presents the state of the art as well as a review of various literature related to experimental with numerical results on the different geometrical configurations of various types of capillary tubes with suction line heat exchanger design and refrigerant flow on the performance of the VCR system. The proposed correlation and methodology for analysing refrigerant flow through a capillary tube under diabatic flow conditions According to the literature review, there is a lot more to research for the flow of various refrigerants through non-adiabatic capillary tubes with a variety of geometrical and operating parameters of the capillary tube.

II. Previous Study about Literature review

The capillary tubes of various sizes use to control the pressure and temperature in the refrigeration unit were investigated. According to their findings, a single CT with a smaller inside diameter is appropriate for freezing applications, where as CT with a larger inner diameter are appropriate for cold storage [13]. The mass flow rate through straight and helical coil adiabatic capillary tubes in a vapour compression refrigeration system was investigated experimentally using an R134a and LPG refrigerant mixture. Under steady-state conditions, various experiments were performed, modifying the capillary tube size, coil diameter, inner diameter, and degree of sub-cooling, and the rate of mass flow though the helical coil capillary tubes was noticed to be 8-20% smaller than straight capillary tubes [14]. To evaluate the performance of the refrigerator, an experimental study was conducted using capillary tubes with diameters of 0.9, 1.2, and 1.4 mm at different evaporator loads and R-12 as the refrigerant. In the case of 0.9 mm diameter CT incorporated with VCR, the compressor work required is less. The compressor work consumed with 0.9 mm diameter CT is 25 kw at 17 kg evaporator load, whereas it is 30 kW and 31 kW with 1.2 mm and 1.4 mm diameter CT, respectively. When particularly in comparison to other CT incorporated VCR systems, the loss of heat in the condenser for the 0.9 mm diameter CT fully integrated VCR system is marginally lower [15]. In his work, R-22 is modified as a fluid within the CT by ammonia, and the CT design is changed from straight to coiled. The analysis is carried out using the ANSYS CFX 16.2 software. The dryness fraction procured by utilizing the helical CT was determined to be superior to the straight and current helical CT (R22 refrigerant flow) [16]. Make a continuous observed relationship for the rate of refrigerant flow rate though the non-adiabatic CT and suction line heat exchangers (CT-SLHX) in to enhance refrigeration ability and make sure superheated refrigerant vapour needs to enter the compressor, small storage refrigeration and air-conditioning systems are used. [17]. The flow behaviour of a non-adiabatic capillary tube was investigated using experimental and theoretical work for CO2 refrigerant. The effect of tube geometry and operating conditions on heat and mass transfer was investigated experimentally. The observations revealed that the length of the capillary tube had the greatest effect on the heat flux. In contrast, the suction line tube diameter and heat exchanger location had a much smaller effect [18]. Under various cooling loads, the performance of a control valve (NEV) used as an expansion device in a small VCR was investigated. The performance and parameters of the NEV were compared to those achieved with CT and thermostatic expansion valves (TEV). According to the results discussed in this work, using NEV as the development device in a VCR-based chiller generates a similar isenthalpic procedure (same throttling loss) as TEV and CT [19]. The tests were conducted on a CT with a basic structure that included a helical, straight, suction line heat exchanger (SLHX) section. The pressure loss in the CT straight section's single-phase region was larger than that of the pressure loss in the two-phase zone. The helical section had the greatest pressure drop, followed by the SLHX section [20]. The effect of the suction line on evaporator efficiency was experimentally investigated using R-134a refrigerant. With differing refrigerant (R134a) volume flow rate and air velocities, three types of suction lines (concentric, lateral and coil) have been used. When compared to the other types, the concentric suction line produced the highest coefficients of heat transfer [21]. The performance of an air conditioning system with condenser sub-cooling and refrigerants R134a and R1234yf was investigated. The maximum COP improvement from condenser sub cooling was 18%, compared to 9% for the system with IHX. It was discovered that systems using R1234yf performed better at condenser sub-cooling than systems using R134a [22]. A homogeneous two-phase model was used to investigate the helical capillary tube numerically. The refrigerants used in the study were R407C, R410A, R125, R134a, and R32. Size and correlation tables were created for the refrigerants R407C, R410A, R125, R134a, and R32 [23]. studied the performance of a minichannel parallel flow (MCPF) condenser used in home and commercial refrigeration systems using a calorimeter chamber and a wind tunnel The heat rejection and pressure drop properties of the heat exchanger were compared to those of the refrigerants R22, R410A, and R407C. The heat rejection of the R410A condenser was found to be greater than that of R22 and R407C [24]. The performance of an existing residential refrigerator was investigated using a zeotropic propane/isobutane (50:50 by mass) mix as an alternative refrigerant to R134a. The performance of various refrigerant mass charge values at constant load was investigated. The optimal refrigerant mass charge was determined to be 60 g, with a matching lowest temperature of -3.5°C. The cooling capacity increases with charge amount, reaching 83.5 W at a 100 g charge with hydrocarbon blend. Furthermore, when compared to R134a, the charge amount for the same amount of cooling capacity is significantly lower with the R290/R600a blend [25]. In a VCR system, the rate of mass flow though the straight and helical coil adiabatic capillary tubes was investigated experimentally using an R134a and LPG refrigerant mixture. Under steady-state conditions, various experiments were carried out by varying the capillary tube inner diameter, length, coil diameter, and degree of sub-cooling. The rate of mass flow through with a helical coil CT was found to be 5-16% lower compared to a straight CT [26]. Created an empirical correlation to predict mass flow rate, the adiabatic straight and helical capillary tubes for R-22, R-134a, R-407C, R-410A, and LPG were studied. This relationship can be applied to refrigeration simulation software to reduce run - time and improve the accuracy of refrigerant mass flow rate assumptions for a variety of refrigerants. The developed correlations demonstrated good agreement in terms of their application range [27]. The performance of capillary tubes with varying lengths and inner diameters for R22, R410A, and R407C was investigated. It is clear that the combination of capillary tube length and inner diameter is the same in both the analytical approach and the cooling capacity test for all refrigerants used. The capillary length for R22 and R407c for the same 75 thou diameter is exactly the same, i.e., 0.62m. R410A, on the other hand, is 0.85m longer than R22 [28].

III. Methodology

Adiabatic capillary tube:

In an adiabatic capillary tube, the refrigerant flows from condenser pressure to evaporator pressure under adiabatic flow conditions. The refrigerant needs to enter the capillary in a subcooled liquid state, and as it flows through the capillary tube, friction causes the pressure to reduce linearly while the the refrigerant's temperature remains constant. When the refrigerant pressure falls below the saturation pressure, a portion of the liquid refrigerant flashes into vapour at the flash point. The density of the refrigerant decreases due to vaporisation, causing the velocity of the refrigerant to increase; by increasing the velocity of the refrigerant, both temperature and pressure begin to fall rapidly until choked flow conditions are attained.

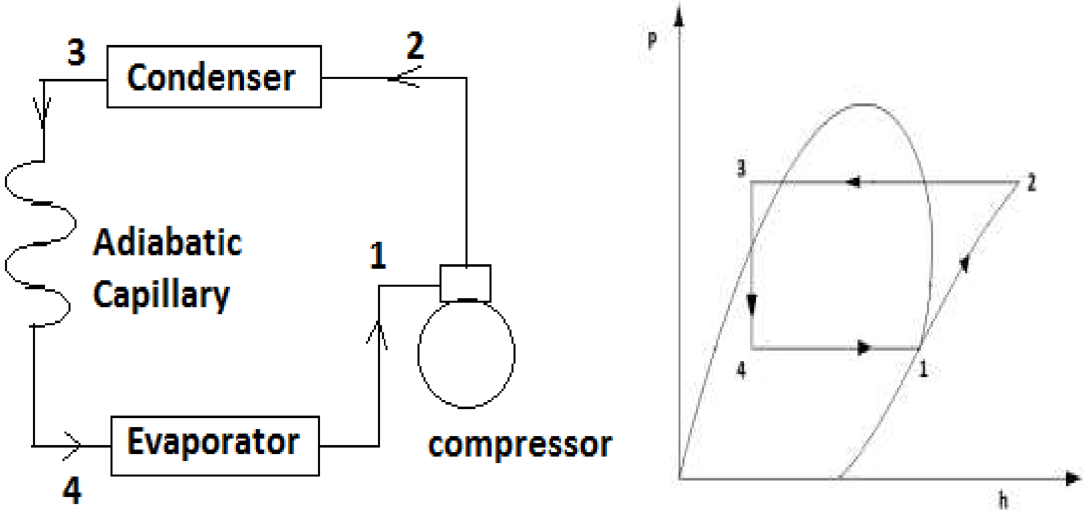

Figure1: Simple VCR with adiabatic capillary tube and p-h diagram.

Diabatic Capillary Tube

The diabatic CT serves as a heat exchanger in a simple VCR system. As shown in fig2, the CT is diabatically soldered or brazed to the compressor suction line. As a result, that configuration functions as a heat exchanger with counterflow. The refrigerant expands from high temperatures and pressures to low temperature and pressure through diabatic capillary tube, transferring refrigerant heat to low temperature refrigerant passing through the compressor's suction line. This counter flow configuration has two advantages: first, it delays vaporisation; second, superheated vapour is routed to the compressor, preventing compressor damage. Diabatic capillary tubes are primarily used in two configurations in VCR systems: lateral and concentric.

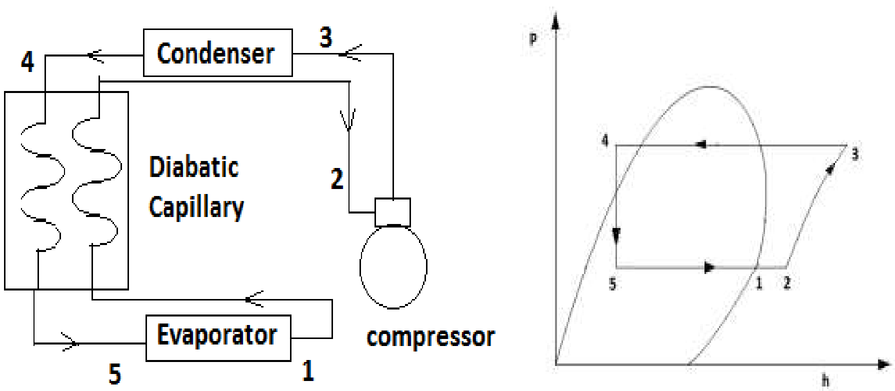

Figure 2: Simple VCR with non adiabatic capillary tube and ph diagram.

Non-adiabatic CT is utilized in two configurations in VCR systems: concentric and lateral. The CT is straight soldered by the suction line leading to compressor in lateral non-adiabatic capillary tube configurations, as shown in Figure 3(b), constructing a counter flow heat exchanger for which transfers heat from of the CT to the compressor's suction line. A number of the CT initial length and some of the CT final length, which is bonded with suction line, are kept adiabatic. Heat is transfer from the tube to suction line by keeping capillary tube inside the suctionline in the concentric configuration shown in Figure 3(a). Hot refrigerant flows throughout into the CT, while cold refrigerant flows through to annulus created by outer surface of the capillary tube and the inner surface of the suction line.

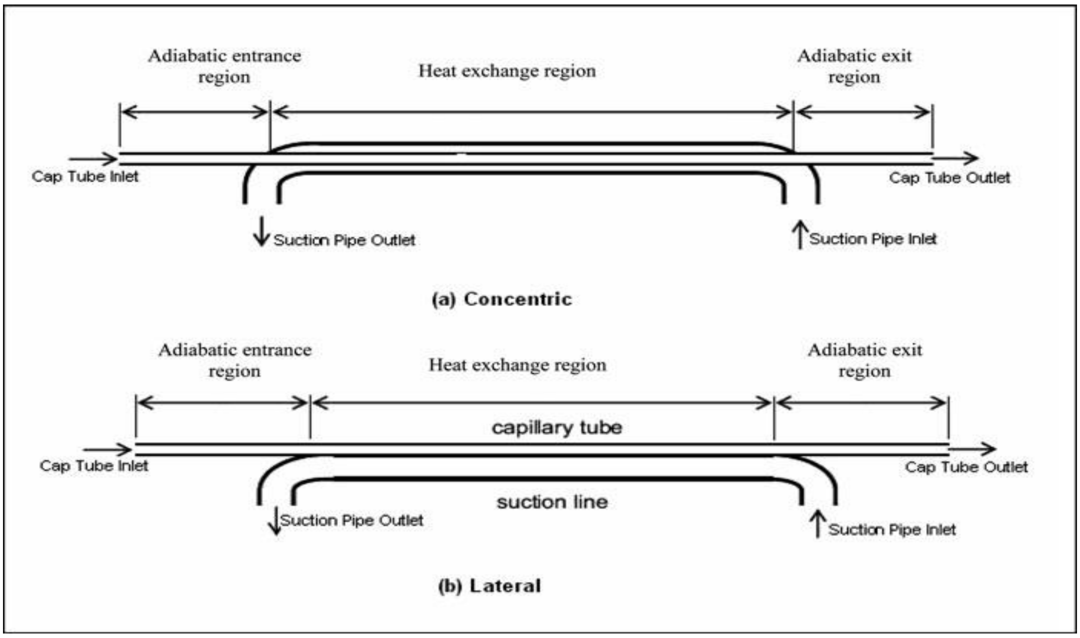

Figure 3: Concentric type and lateral type arrangement [25].

Capillary tubes could be straight, spiral, or helical, and can be arranged laterally or concentrically. The most typical of CT utilized in domestic refrigerators is the helically coiled non-adiabatic CT. The CT requires more space when it is used straight than that when utilised helical or spiral, but when used vertical location, the gap condition is reduced for the reason that there is enough gap on the backside of the refrigerator.

IV. Conclusion

The present paper about literature summary on effect of different diameter and size of CT on VCR system i.e., non-adiabatic CT with different refrigerants, variety of process parameter considered and type CT approach. The maximum literature available on effect of different geometric tubes and mass rate flow has considered. The research was conducted on different refrigerants and capacity of system. Based on an extensive review of the literature, the following conclusions have been reached:

- In the preceding literature, it is concluded that the diameter of the capillary range from 0.5-3 mm and the length of the capillary is commonly used.
- The helical coil capillary tube performs better than the straight tube, but the optimum length and diameter size will vary depending on system capacity.
- The CFD analysis is extremely useful in determining the optimal diameter and length.
- According to the literature, the length of a non-adiabatic capillary tube is greater than that of an adiabatic capillary tube. Because the literature on non-adiabatic capillary tubes is limited, more research is needed.

References

[1]. Thamerkhalif Salem, Saad Sami Farhan, Israa Sami Farhan, “Energy And Exergy Analysis Study Of Heat Exchanger In A Refrigeration System With Different Lengths Of Capillary Tube”, International Journal Of Thermodynamics, Vol. 23, No. 4, Pp. 260-266,

[2]. Masoudzareh, Mortezakhayat And Hamedfouladi, “Numerical Simulation Of Two Phase Refrigerant Flow Through Non-Adiabatic Capillary Tubes Using Drift Flux Model”, Journal Of Mechanical Science And Technology, Vol. 32, No.1, Pp.381-389, 2018.

[3]. Praveen Alok And Debjyotisahu, “Flow Analysis Of Isobutene (R-600a) Inside An Adiabatic Capillary Tube”, IOP Conf. Series: Materials Science And Engineering, Vol.310, Pp. 012148, 2018.

[4]. Abhinav Kulmitra And Narendra Yadav, “Comparative Study Of Capillary Tube By Changing Refrigerant And Diameter Of Tube By Experimental And CFD Analysis”, International Journal For Scientific Research & Development|, Vol.5, No.10, 2018.

[5]. M. Krishna Prasanna And Kishore, "Enhancement Of COP In Vapour Compression Refrigeration System", International Journal Of Engineering Research & Technology, 2013.
[6]. Joybari, MM, Hatamipour, MS, Rahimi, A And Modarres, FG 2013, "Exergy Analysis And Optimization Of R600a As A Replacement Of R134a In A Domestic Refrigerator System", International Journal Of Refrigeration, Vol. 36, No. 4, Pp. 1233-1242.
[7]. Tao Ren, "Investigation Of Application Of Suction Line Heat Exchanger In R290 Air Conditioner With Small Diameter Copper Tube", International Refrigeration And Air Conditioning Conference, 2013.
[8]. Fiorelli F, Silva C, Huerta A, "Metastable Flow Of R-410A In Capillary Tubes." Applied Thermal Engineering, Vol.51, No.2, Pp. 1181–1190 , 2012.
[9]. Alberto, Fiorelli F, Silvares O, "Experimental Evaluation On The Oil Influence In Capillary Tubes", Applied Thermal Engineering, Vol.29, No.15, Pp.3066–3072, 2009.
[10]. Christian J.L. Hermes Cláudiomelo,Fernando T. Knabben , "Algebraic Solution Of Capillary Tube Flows Part2: Capillary Tube Suction Line Heat Exchanger", Applied Thermal Engineering, Vol. 30, Pp. 770-775, 2010.
[11]. Neeraj Agrawal And Souvik Bhattacharyya, "Study Of Helically Coiled Adiabatic Capillarytubes For Transcritical CO_2 Expansion", International Journal Of Low-Carbon Technologies , Vol.8, Pp. 245–252, 2012.
[12]. Sukkarin Chingulpitak And Somchaiwongwises, "A Comparison Of Flow Characteristics Of Refrigerants Flowing Through Adiabatic Straight And Helical Capillary Tubes", International Communications In Heat And Mass Transfer, Vol.38, Pp.398–404 , 2011.
[13]. Avinashkhanderao, Rohini Zade1 , Prashant Walke, "Experimental Investigation On The Performance Of V.C.R. System Using Refrigerant", International Research Journal Of Engineering And Technology, Vol.6, No.7, 2019.
[14]. Jatinder Gill, Jagdev Singh2 ''Depicting Mass Flow Rate Of R134a /LPG Refrigerant Through Straight And Helical Coiled Adiabatic Capillary Tubes Of Vapour Compression Refrigeration System Using Artificial Neural Network Approach'', Heat And Mass Transfer (2018) 54:1975–1987, 2018.
[15]. T.M.Chandrashekharaiah And Basavaraj Ganiger, "Effect Of Capillarity Tube Geometry On Vapour Compression Refrigerator Performance", AIP Conference Proceedings, 2018.
[16]. Santhosh Kumar Dubba , Ravi Kumar, "Adiabatic Flow Characteristics Of R-600a Inside A Helically Coiled Capillary Tube", Applied Thermal Engineering, Vol.132, Pp. 500–507, 2017.
[17]. Mehdi Rasti, Jeongho Ban, Ji Hwan Jeong, "Development Of A Continuous Empirical Correlation For Refrigerant Mass Flow Rate Through Non-Adiabatic Capillary Tubes", Applied Thermal Engineering , Vol.127, Pp.547–558, 2017.
[18]. Diogo L. Da Silva A, Adriano F. Ronzonia, "A Study Of Transcritical Carbon Dioxide Flow Through Diabatic Capillary Tubes, International Journal Of Refrigeration, Pp.8 34 -843, 2011.
[19]. Kittiwootsutthivirode And Tongchanathongtip; Feasibility Study And In-Depth Performance Assessment Of Needle Valve Using As Expansion Device In Refrigeration System. Case Studies In Thermal Engineering.
[20]. Kamel Sigar Hmood And Horatiu Pop, "Steady-State Performance Of Capillary Tubes For Small-Scale Vapour Compression Systems Using Different Refrigerants", International Journal Of Refrigeration, Vol.130, Pp. 87–98, 2021.
[21]. Saad Sami Farhan , Thamerkhalif Salem , Mahanazar Ismael , Thamir K And Ibrahim, "Impact Of Suction Line On Evaporator Effectiveness In Refrigeration Cycle, Case Studies In Thermal Engineering, Vol. 27, Pp.101270, 2021.
[22]. Pottker, G And Hrnjak, P 2015, "Experimental Investigation Of The Effect Of Condenser Subcooling In R134a And R1234yf Air-Conditioning Systems With And Without Internal Heat Exchanger", International Journal Of Refrigeration, Vol. 50, Pp. 104-113.2017.
[23]. Pirompugd W, Wongwises S, "Helical Capillary Tube Sizing Charts For All Mixtures Ratios Of R123, R134a, And R32", Int. Journal Of Air-Conditioning And Refrigeration, 2016.
[24]. Zhaogang Qi, "Experimental Investigation On Mini Channel Parallel Flow Condenser Performance With R22, R410A And R407", International Journal Of Refrigeration, Vol. 72, No. 800, Pp.74-80, 2017.
[25]. Agrawal, N, Patil, S And Nanda, P 2017, "Experimental Studies Of A Domestic Refrigerator Using R290/R600a Zeotropic Blends", Energy Procedia, Vol. 109, 2017.
[26]. Sukkarinchingulpitak, Omidmahian, "Sizing Charts Of Helical Capillary Tubes Used In
[27]. Refrigeration And Air Conditioning", 2017.
[28]. Mehdi Rasti, Ji Hwan Jeong, "A Generalized Continuous Empirical Correlation For Predicting Refrigerant Mass Flow Rates Through Adiabatic Capillary Tubes", Applied Thermal Engineering, Vol. 139, Pp.47–60, 2018.
[29]. K. Sainath, T.K. Kumar Reddy, S. Akella, "Optimization Of Capillary Tube Dimensions Using Different Refrigerants For 1.5 Ton Mobile Air Conditioner, Case Studies In Thermal Engineering", Pp.100528, 2019.