International Journal of Research in Engineering, Science and Management
Volume-1, Issue-11, November-2018
www.ijresm.com | ISSN (Online): 2581-5792

The Effect of Capillary Tube Design and Refrigerant on the Performance of the Vapor Compression Refrigeration Cycle – A Review

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***Abstract*: A comprehensive review of the literature on the flow of different refrigerants through the capillary tubes of different geometries and different diameter viz. spiral, straight and helical coiled capillary tube, and 1.12mm, 1.4mm, 1.52mm diameter of capillary tube and R134a and mixture of R134a+hydrocarbon with 28:72 by mass refrigerant has been discussed in this paper. In this paper presents in chronological order the numerical and experimental investigations systematically under different condition. Flow aspects like mass flow rate C.O.P, pressure ratio through the capillary tube have been discussed. Furthermore, comparison of R134a and mixture of R134a + hydrocarbon have also been discussed. In this paper, we have found the best diameter for R134a and for the mixture, and we have also discussed the different geometry of the capillary tube. The paper provides key information about the range of input parameters viz. tube diameter, coil pitch and coil diameter, inlet pressure, and condensing pressure or temperature. Other information includes the type of refrigerants used, in this analysis methodology adopted. Flow through the capillary tubes of different geometries operating with different refrigerant under diabatic flow conditions. It has been found from the review of the literature that there's a lot additional to research for the flow of varied refrigerants through completely different tube geometries and different diameter of the capillary.**

***Keywords*: Spiral capillary tube, helical capillary tube, straight capillary tube, R134a, Mixture of R134a/H.C**

1. Introduction

Refrigeration is the branch of science which is producing and maintaining temperatures below that of the surrounding environment, in this literature we are focus on capillary tube and refrigerant. A capillary tube is a generally used as a expansion device in the domestic refrigerators. A capillary tube is a narrow tube of constant diameter. The word "capillary" is a name since surface tension isn't necessary for refrigeration application of capillary tubes. Typical tube diameters of refrigerant capillary tubes vary from 0.5 millimeters to 3 millimeters and also the length ranges from 1.0 m to 6 m. The pressure reduction in an exceedingly capillary tube occurs due to the following two factors

1. The refrigerant has got to overcome the frictional resistance offered by tube walls. This results in some pressure drop
2. The liquid refrigerant flashes (evaporates) into a mixture of liquid and vapor as its pressure reduces.

The density of vapor is a smaller amount than that of the liquid. Hence, the typical density of refrigerant decreases because it flows within the tube. The mass flow rate and tube diameter (hence area) being constant, the velocity of refrigerant will increase since m= $_{\varrho}$va. The rise in velocity or acceleration of the refrigerant additionally requires a pressure drop.

Several combinations of bore area unit accessible for constant mass flow rate and pressure drop. However, once a capillary tube of some diameter has been installed in an exceeding refrigeration system, the mass flow through it'll vary in such a way that the entire pressure drop through it matches with the pressure distinction between the condenser and also the evaporator. Its mass flow rate is completely dependent upon the pressure difference across it; it cannot modify itself to the variation of load effectively.

We are using 3 types of capillaries of same length of 4.4m with different diameter 1) d1=1.12mm2) d2=1.4mm 3) d3=1.5mm. Block diagram and P-h diagram of Vapor compression refrigeration system show in Fig. 1 and Fig. 2.

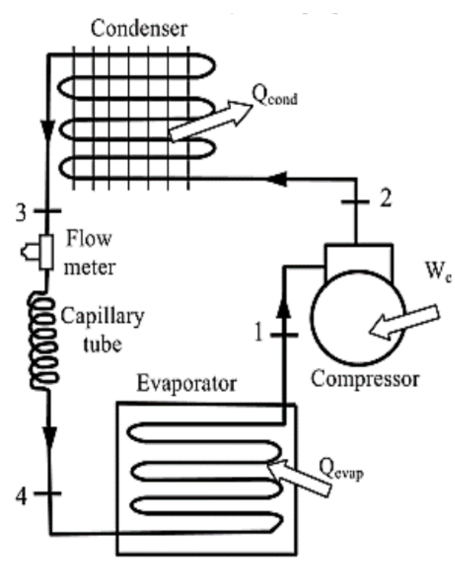

Fig. 1. Block diagram of VCRS cycle

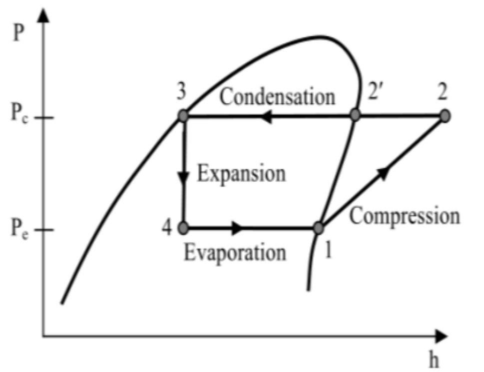

Fig. 2. P-h diagram of VCRS cycle

2. Spiral capillary tube, with different diameter and different refrigerant

Spiral capillary tube is the very useful in refrigeration system, in spiral capillary tube refrigerant feel vortex flow. In vortex flow rate of pressure is decrease with increasing the radius. So we are enter the refrigerant center of the spiral, refrigerant flow outward direction and rate of pressure decrease. So spiral capillary tube give additional pressure drop in capillary. spiral structure with diameter of spiral is 30cm and pitch is p=2 cm and helical structure with 2cmm dia and pitch length 1.5cm, and straight structure with 30 cm length and 2cm pitch.

Table 1
Spiral capillary tube parameters

S. No.	Diameter (d)	Outer dia (D)	length	Pitch(p)
1	1.12 mm	300mm	4.4 m	20 mm
2	1.4 mm	300mm	4.4 m	20 mm
3	1.52 mm	300mm	4.4 m	20 mm

The schematic diagram of spiral capillary tube shown in Fig. 3.

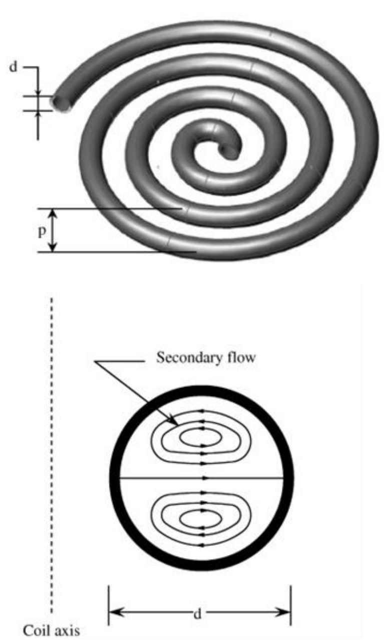

Fig. 3. Spiral capillary tube

In this literature another focus point is refrigerant. R134a is also known as Tetra Fluoro Ethane (CF3CH2F) it is of family of H.F.C refrigerant. With the discovery of the damaging effect of C.F.CS and H.C.F.CS refrigerants to the ozone layer, the H.F.C family of refrigerant has been widely used as their replacement. It is now a day used as a replacement for R-12 C.F.C refrigerant in the area of centrifugal, rotary screw, scroll and reciprocating compressors. It is safe for traditional handling because it is non-toxic, non-flammable and non-corrosive.

Another refrigerant use mixture of hydrocarbon and R134a which give the better result than R134a.in in the ratio 72:28 by mass, hydrocarbon we are mixed propane and isobutene

3. Helical capillary tube, with different diameter and different refrigerant

In a helical coiled tube, the centrifugal force of a flowing fluid produces a pressure gradient in a cross section. This pressure gradient yields secondary flows. The secondary flows cause a larger quantity of pressure drop or heat transfer rate than that for a straight tube.

Table 2
Helical capillary tube parameters

S. No.	Diameter (d)	Core dia.(D)	Length	Pitch(p)
1	1.12 mm	40 mm	4.4 m	20 mm
2	1.4 mm	40 mm	4.4 m	20 mm
3	1.52 mm	40 mm	4.4 m	20 mm

The schematic diagram of the helical capillary tube show in Fig. 4.

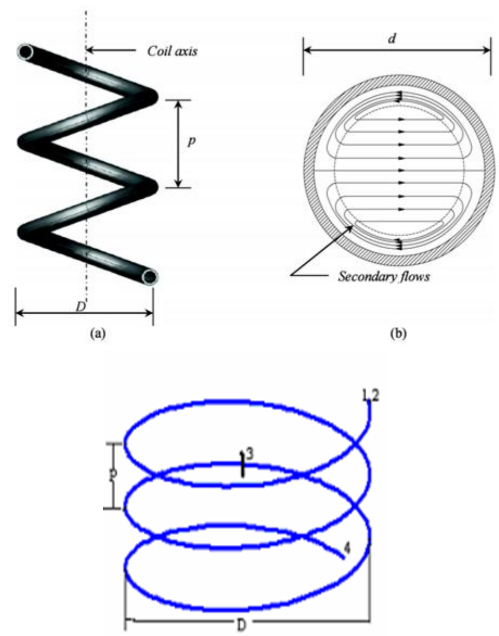

Fig. 4. Helical capillary tube

The flow through a helical capillary is divided into two distinct regions: a liquid single-phase and a two-phase region. In this Fig. 4, point 1and point 2 denotes condenser exit and the capillary inlet respectively. There is little pressure drop from point 1 to 2 due to sharp contraction to capillary diameter. The refrigerant is sub-cooled between points 2 and 3, saturated liquid at point 3 and is a two-phase mixture has existed between points 3 and 4. Point 4 denotes capillary exit.

4. Straight capillary tube, with different diameter and different refrigerant

In straight capillary configuration capillary, stricter is straight and refrigerant flows in a straightforward manner. In straight capillary tube refrigerant not feel any centrifugal force. A various researcher has done the work on a straight capillary tube which given below in the table. The height of the capillary tube is 300mm and pitch of the capillary is 20mm.remaning parameter given in Table 3.

Table 3
Table title comes here

S. No.	Diameter (d)	Height (h)	Length	Pitch(p)
1	1.12 mm	300mm	4.4 m	20 mm
2	1.4 mm	300mm	4.4 m	20 mm
3	1.52 mm	300mm	4.4 m	20 mm

The schematic diagram of the straight capillary tube show in Fig. 5.

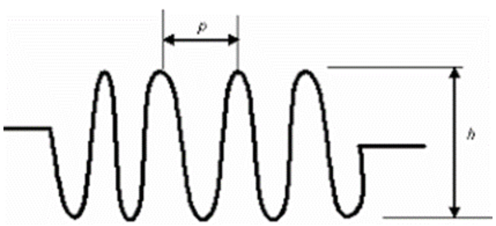

Fig. 5. Straight capillary tube

5. Experimental investigations on capillary tube

Capillary tubes are used as an expansion device in the refrigerating system like domestic refrigerators and window type room air conditioners. These are narrow drawn C.O.P per tubes of 0.5–2.0mm diameter and 2–6m length. This is the simplicity, low cost, zero maintenance and requirement of a low starting torque motor to run the compressor, capillary tubes have been used in a various type of vapor compression systems. Various researcher investigates about capillary characteristic and flow characteristic, which has given.

Bolstad and Jordan (1948) [1] pioneered the investigations on capillary tubes. They conclude the effect of oil entrainment on the mass flow rate through the capillary tube. It was found that when oil separator is used then 8% mass flow rate decrease from without using oil separator. Mikol (1963) [2] study about extensive experimental investigation metastability and choking. They created a friction factor correlation by flowing water through the same condition of the capillary tube. Kuehl and Goldschmidt (1990) [3] carried out experiments on the flow of R-22 through adiabatic capillary tubes of straight and coiled geometries. They have found that due to the coiling of the capillary tube, the mass flow rate of the refrigerant was reduced by not more than 5%. Zhou and Zhang (2006) [4] confirmed the hysteresis in refrigerant mass flow rate with changing inlet sub cooling in an adiabatic helical capillary tube. And also found that in the coiled capillary tube the refrigerant flashed earlier with decreased coil diameter as a reduction in coil diameter caused the pressure drop to increase. Park et al. (2007) [5] study for the flow of R-22 and its alternatives, R-407C and R-410a, has revealed a slightly higher drop in mass flow rates of the coiled capillary tubes compared to those in straight capillary tubes as presented by Kim et al. (2002) [6]. It was found by Park et al. (2007) that the mass flow rate of the coiled capillary tubes was decreased by 5–16 percent in comparison to that for the straight capillary tubes. They also developed a generalized mass flow rate correlation for helically coiled capillary tubes based on Buckingham-p theorem. Valladares (2007) [7] also create a numerical simulation model for the coiled capillary tubes based on the finite volume formulation. Khan et al. (2007) [8] have proposed a numerical model for the calculation of the length of the adiabatic spiral capillary tube. It has been found that due to coiling the length of the capillary tube is decreased considerably for a given set of input conditions.

Previous researchers have also proposed a number of correlations to predict the refrigerant mass flow rate for a given capillary tube. For instance, correlations for the mass flow rate of different refrigerants proposed by Wolf et al. (1995) [9] are available in ASHRAE handbook (2006). Another important study about the flow of newer refrigerants inside capillary tubes has been carried out by Melo et al. (1999) [10]. The proposed separate correlations for R-12, R-134Aa, and R-600a, and a combined mass flow rate correlation for all three refrigerants for the flow inside an adiabatic capillary tube. Since in above discussion experimental data for the flow of R-134Aa refrigerants through the spiral capillary tube are not available, so an experimental investigation has been undertaken to study the flow of R-134Aa through a spiral capillary tube. The vapor compression refrigeration (V.C.R) cycle is the most extensive system for a cold generation. It is mostly used in domestic, commercial, and industrial refrigeration.

These systems typically present high energy consumption, and running cost is high, see Buzelin et al. 2005; Harby (2017) [11], and this use may increase in case of system failure. Thus major concern in vapor compression refrigeration systems is reduction of energy consumption is a Harby et al., (2016) [12]. For the reduction of energy consumption, it is necessary to have efficient systems. Inside developing nation, most of the refrigeration system running on halogenated refrigerants because of these are excellent thermophysical properties as well as thermodynamics. In addition to the low price. However, the international protocols (Montreal and Kyoto) hardly restrict the use of the halogenated refrigerants in the refrigeration systems. As per Montreal protocol 1987, the use of chlorofluorocarbons was strictly banned in most of the nations. However, hydrochlorofluorocarbons refrigerants can be used in developed nations, is up to 2030 and until 2040 in developing nations, and. Thus to meet the large demand in the refrigeration and air-conditioning sector, it is necessary to look for long-term alternatives to satisfy the objectives of international protocols (Sarbu, 2014) [13]. As per the Kyoto protocol to the United Nations framework convention on climate change, the particular emission of hydro fluoro carbon (H.F.C) refrigerants required to lessen possibly. Many developing countries still use R134a (H.F.C) in refrigeration devices due to low cost and excellent thermo physical properties as well as thermodynamics. Moreover protecting against the specific loss of R134a by refrigeration devices seriously is not very easily attainable and leakage of H.F.C refrigerants make a substantial contribution to the global warming (Sanchez et al., 2017) [14].consequently, to obtain environmentally safe practices, R134a is going to be prohibited quickly. Also, there are a few additional difficulties connected with R134a for example, high global warming potential (GWP) of 1430 (IPCC, 2007; Rasti et al., 2013) [15] and its immiscible nature along with conventional mineral oils (Sekhar and Lal, 2005) [16].

For this reason, polyester oil use in R134a systems. The high hygroscopic character of polyester oil requires strict maintenance practices to prevent the moisture absorption, therefore; the need for long-term alternative refrigerants which meet the objectives of international protocols is obvious (Mohanraj et al., 2011) [17]. Many researchers have reported that liquefied petroleum gas (H.C) refrigerants are found to be energy efficient and environment eco-friendly alternative option in vapor compression refrigeration systems. In the related work, Akash and said (2003) [18] study that liquefied petroleum gas (composed of R290, R600, and R600a, in the ratio of 30:55:15, by mass) showed the best performance compared to that of R12. Furthermore study, Fatouh and el Kafafy (2006), Ahamed et al. (2012), Srinivas et al. (2014), Taiwo Babarinde et al. (2015) and Adelekan et al. (2017) also study and reported that H.C showed a better performance compared to that of R134a in domestic refrigerators. Due to hydrocarbons (H.C) including H.C have flammability issues, they used not more than 150 g in the refrigeration system. Because of being not expensive, zero ozone depletion potential, available in bulk and low global warming potential (Mohamed, 2015) [19].

Recently, workability of HC (hydrocarbons) including LPG (Liquefied petroleum gas) in existing refrigeration system, with or without modification and their high energy efficiency has the primary justification for their application in the VCRS (Adelekan et al., 2017) [20]. Moreover, a decrease inflammability of H.C may be accomplished just by blending along with R134a (H.F.C) (Yang et al., 2004) [21]. H.C and H.F.C refrigerant mixtures with small environmental impacts are considered as potential alternatives to phase out the existing halogenated refrigerants (Sarbu, 2014). In addition to this, H.C/H.F.C blends have good miscibility with conventional mineral oil (Avinash et al., 2005) [22]. The global warming potential (GWP) associated with H.C/H.F.C blends is also less than one-third of H.F.C if it used alone (Tshtoush et al., 2002) [23]. The literature in this paper refers that R134a (H.F.C) refrigerant has high GWP, immiscibility with conventional mineral oils issues and H.C has flammability issue, and these problems can be overcome by mixing the R134a and H.C with an appropriate mass fraction. Therefore, the mixture composed of R134a and H.C in the ratio of 28% of R134a and 72% of H.C considered as an alternative to R134a (Gill and Singh, 2017) [24]. H.C used in this is a mixture of three hydrocarbons.

(Taiwo Babarinde et al., 2015) [25]. have studied with H.C as an alternative to R12 and R134a in a vapor compression refrigeration system. However, the possibility of replacing R134a in the vapor compression refrigeration system with R134a/H.C (composed of 28% of R134a and 78% of H.C by mass) by energy analysis needs investigation. Moreover, a study on energy analysis of the vapor compression refrigeration system using R134a/H.C (28:72) as a refrigerant is not available in the literature. In this literature study with three sizes of the capillary and compare to one another. Structure of capillary is spiral. Most of the refrigerator with R134a refrigerant due to the excellent cooling characteristic. And another major region is a solution of ozone depilation. Many researchers propose the use of hydrocarbon as a refrigerant.

Jagdev Singh and Jatinder Gill (2017) [26] Study that energy analysis of vapor compression refrigeration system using mixture of R134a and H.C as a refrigerant in this analysis the results show that R134a and H.C mixture has a higher coefficient of performance and lower compressor discharge temperature and pull downtime as compared to R134a by about 15.1-17.82 %, 2.1-13.86% and 1.01 to 5.91% respectively. In this analysis, the result is given a reduction in charge about 64.21% and 49.45% respectively to achieve a maximum coefficient of performance. Compressor power consumption R134a/ H.C (118 gram and 5.1m of capillary tube length) system found lower than R134a (240g, 3.1m of capillary length) system by about 3.83 to 8.08 % over the entire range of evaporator and condenser temperature in this study 22 leisure work of compare compression refrigeration capacity of mixture its higher than our 1348 up 2 7.04 to 11.41 percentage the C.O.P of mixture is higher than R134a about 15.12- 17.82 %. Pull-down temperature of the mixture is lower than lower than R134a. Compressor discharge temperature of the mixture is lower than R134a. Mohd. Kaleem Khan et al (2009) [27] study that investigation on the diabatic flow of R-134Aa through the spiral capillary tube. It has been concluded that the flow behavior of the diabatic capillary tubes is entirely different from those of adiabatic capillary tubes. In the case of the diabatic 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. And an empirical correlation for the refrigerant mass flow rate through diabetic spiral capillary tube geometry has been developed. It has been found the proposed correlation predicts the refrigerant mass flow rate in the error band of ±7%

of the measured experimental M.Rasti et al. (2017) [28] conclude the energy efficiency index using an H.C (hydrocarbon) mixture as a refrigerant. It concludes that the on-time ratio and energy consumption per day were reduced by 13% and 5.3% respectively. And for R134a mass of charge is 105g, and optimum charge of R436a to 55g .that exhibits 48% reduction in mass of charge for same refrigeration capacity. M.fatouh and M.EI Kafafy [29] is carried out evaluation of a domestic refrigerator working with H.C. It find out for R134a with 4m capillary tube length and charge of 100 g or H.C with 4-6m capillary tube length and charge of 50 g or more satisfy the required freezer air temperature of-12°C.it also conclude that H.C consume lower electric power than R134a. And actual C.O.P of H.C is greater than R134a. Ravi Kumar et al. (2008) [30] study that investigation for the flow of R-134Aa inside an adiabatic spirally coiled capillary tube. It has been carried out that the effect of coiling of capillary tube reduces the mass flow rate by 5–15% as compared to those of the straight capillary tube operating under similar conditions. And data obtained from the experiments are analyzed and a semi-empirical correlation has been developed. The developed the correlation predicts more than 91% of the mass flow rate which is in agreement with measured data in an error band of ±10%. M.K Mittal et al. (2009) [31] 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 an 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. On increasing the coil pitch, capillary tube length increases and the rising trend becomes monotonous beyond a pitch of 120 mm for a capillary tube of 1.5 mm diameter and 2 m length. The flow characteristics of R22 and R407c are quite similar at the same condenser pressure and the same degree of subcooling. Jatinder Gill And Jagdev Singh (2017) [32] deals with predicting the mass flow rate of R-134a/H.C as refrigerant inside a straight and helical coiled adiabatic capillary tube of VCRS cycle by combining dimensionless analysis and adaptive neuro-fuzzy inference system techniques. For this purpose, the experimental system was fabricated and analyze under steady-state conditions, by changing the length of the capillary tube, the inner diameter of the capillary tube, the mean diameter of the coil and the degree of subcooling of the refrigerant at the capillary tube inlet. Dimensional analysis was utilized to provide generalized dimensionless parameters and to reduce the number of input parameters, while the adaptive neuro-fuzzy inference system was applied as a generalized approximate of the nonlinear multi-input and single-output function. The comparison of the absolute fraction of variance (r2) (0.998 and 0.961), the root mean square error (RMSE) (0.105kg/h and 0.489kg/h) and the mean absolute percentage error (MAPE) (0.954% and 4.75%) found the result for combination of dimensional analysis and adaptive neuro-fuzzy inference system and dimensionless correlation model predictions respectively. The results show that the combination of dimensional analysis and adaptive neuro-fuzzy inference system gave the best statistical prediction efficiency. Santosh Kumar et al. (2016) [33] carried outflow of different refrigerants through adiabatic and diabatic capillary tubes of different geometries viz. Straight and coiled and conclude that in case of the 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 the straight one. In case of the 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 the straight one. This is ultimately due to the frictional effect included by the secondary flow and thereby, larger pressure drops are possible with the coiled capillary tube. Hence a good compactness of an overall system could be achieved. M.K Mittal et al. (2010)[34] drawn a conclusion for a given capillary diameter, the mass flow rate variation with subcooling is independent of capillary length, inlet pressure and coil diameter. The parametric study has been conducted 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.non-dimensional correlations to predict the refrigerant mass flow rate through straight as well as helical capillary tube have been proposed. The developed correlations for mass flow rate yield good agreement with the measured data of present study with deviations of about 10 percent. Also, the proposed correlations predict very well the results reported in the literature by previous investigators. Mehdi Rasti and Ji Hwan Jeong (2018) [35] over the past few decades, certain empirical correlations have been developed 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. The developed correlation has a power function form of the dimensionless parameters based on a database yielded by a mechanistic model. The reference data generated by the mechanistic model includes the three refrigerants of R-22, R-134a, and R-600a with a wide range of influencing parameters.

Hossein Shokouhmand and Masoud Zareh (2014) [36] introduced a numerical simulation with proper accuracy and no refrigerant-oriented advantages. These experimental results indicate that when evaporator pressure decreases from unchoked region to the choked region by about 8.2%, mass flux increases by only 0.4%, indicating there is no major difference

Table 3
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Author(s) (Year)	Refrigerant(s)	Range of parameters	Characteristics/correlations	Remarks
Jatinder Gill, Jagdev Singh (2017) [26]	R134a/LPG	L ,m = 3.1,4.1,5.1,6.1 Ambient Temperature T_o (ºC) 33 ± 1 Capillary tube Diameter (d, mm) 1.12, 1.40,1.52 Inlet Subcooling (,0 ºC) 1-13 Coil diameter (D, mm) 60,90,120,	Mass flow rate through adiabatic capillary tubes is presented. Effect of dimensionless parameters on refrigerant mass flow rate is studied	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%
Mohd. Kaleem Khan et al (2009)[27]	R134a	d, mm =1.12, 1.40, 1.63 L, m 6.4–2.4 L_{hx}, m 5.6–1.6, p, mm 20, 40, 60 Tsub,ºC 0–25, Pin, kPa ,740	mass flow rate of R-134a with inlet subcooling	It has been found the proposed correlation predicts the refrigerant mass flow rate in the error band of 7% of the measured experimental mass flow rate.
Jatinder Gill and Jagdev Singh[32]	R134a/LPG (28:72) R134a	T_e (°C) −15 to −2 (L m) 3.1 T_o(°C) 33±1 (d, mm) 1.12 (T_c, °C) 35 to 40 (D, mm) 90 Refrigerant charged (g) R134a 240,mixture 108–128.	Compressor power consumption variation of R134a and R134a/LPG with evaporator temperature. Comparison of experimental COP and predicted COP from a mathematical model	R134a/LPG demanded to lengthen of capillary tube and reduction in refrigerant charge by about 64.21% and 49.45% respectively to achieve a maximum coefficient of performance.
Paliwal et al. (2003)[37]	R134a	d=0.87,1.05mm p=3d;Pk=11.2–15.1 bar	Flow characteristics	Homogeneous two-phase flow
Khan et al. (2007)[8]	R134a	d=1.07mm m=8.28kg/h,p=40,60,80mm,Tk 40°C	Comparison of the results of spiral capillary tube with straight capillary operating under similar conditions	Homogeneous two-phase flow, meta stability ignored
Bolstad and Jordon (1948)[1]	R-12	L = 1.83, 3.66, 5.49 m Pk = 827.4, 965.3, 1103.3 kPa d = 0.66–1.397 mm Po = 103.4 kPa	Temperature pressure profiles and flow characteristics	Little effect of varying evaporator pressure on the mass flow rate has been observed
Cooper et al. (1957)[38]	R-22	L = 0.305–0.914 m P_k = 1041.1, 1351.3 1654.7, 1965 kPa d = 0.914, 2.54 mm	Performance curves	Choking at capillary outlet, i.e., Po is constant. Flow visualization using glass capillary tube
Mikol (1963)[2]	R-12 R-22	L = 1.83 m Pk = 8.27, 9.65, 11.0 bar d = 1.41 mm Po = 1.034 bar	Pressure and temperature profiles Friction factor relationship for two- phase flow	Flow visualization using glass capillary tube, friction factor correlation obtained with water
Choi et al. (2003)[39]	R-22 R-290 R-407C	d = 0.96, 1.2, 1.36 mm, L = 0.7, 1.0, 1.3 m T_c = 38, 45, 52 ºC Tsub = 1.0–14.0 ºC	Development of generalized mass flow rate correlation	Nearly 97% of the experimental correlated within the relative deviation of ±10%
Mehdi Rasti, Ji Hwan Jeong (2018)[35]	R-22, R-134Aa, R-407C, R-410A, and LPG	Capillary tube inlet pressure kPa 600 –1400 Capillary tube straight length m 0.0 – 2.0 Capillary tube coiled length m 1.0 – 5.0 Coil diameter mm 10 – 60	A generalized continuous empirical correlation for the refrigerant mass flow rate through adiabatic straight and helically coiled capillary tubes	Correlation for mass flow rate through helically coiled adiabatic capillary Single correlation is continuous over whole range of inlet conditions New correlation can be used for straight and coiled capillary tube
Zhang and Zhao, (2007)[40]	R-600a and R-407C	d = 0.5-2 mm L = 0.5-5 m Tc = 20-60°C ΔTsub = 0-20°C x = 0-0.3	Homogeneous equilibrium flow model	The neural network predicts the experimental data within ±10%.
Jabaraj et al., (2006)[41]	R-407C / R-600a / R-290 mixture	d = 1.27, 1.397 mm L = 0.75, 1.25, 1.75 m	Flow characteristics of an adiabatic capillary tube. A correlation developed for mass flow rate	R-22: AD = 0.6%; MD = 5%; Ref. mixture: AD = -0.1%; MD = 5%; AD, avg. deviation; MD, mean deviation

in mass flux between steady and choked conditions. It is also observed that for the same test conditions and tube length, the critical mass flux through the helical tube with a coil diameter of 40 mm is about 16% less than that of the straight capillary tube.

Finally, the present model can be used as a suitable tool for the design and optimization of the vapor compression refrigeration systems (VCRS) with the helical capillary tube, thus avoiding a vast amount of repetitive experiments.

6. Conclusion

Based on the exhaustive literature survey in the previous sections, the following conclusions have been made:

1) In above literature conclude that the diameter of the capillary is the range of 0.5-3 mm and length of capillary 1-6 m frequently use.

2) A mixture of R134a and hydrocarbon refrigerant at 28:72 by mass give the better result over R134a.
3) After the study of the various literature it concludes that the 1.4mm Diameter of capillary gives the better C.O.P for R134a refrigerant compare to another diameter of the capillary tube.
4) In the spiral capillary tube, the outer diameter of the capillary is 300mm and pitch 20mm, for helical capillary tube mean diameter is 40mm and pitch 20mm and for the straight capillary tube length of one fold is 300mm and pitch is 20mm.

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