International Information and Engineering Technology Association
Advancing the World of Information and Engineering

International Journal of Heat and Technology
Vol. 42, No. 5, October, 2024, pp. 1769-1776
Journal homepage: http://iieta.org/journals/ijht

Impact of the Capillary Tube Length on the Refrigeration Cycle Exergy

Ghassan F. Al-Doori[1*], Samer M. Khalaf[2], Ibrahim T. Nazzal[2]

[1] Air-conditioning and Refrigeration Department, Al-Imam University College, Tikrit 34001, Iraq
[2] Mechanical Engineering Department, Tikrit University, Tikrit 34001, Iraq

Corresponding Author Email: ghassan@alimamunc.edu.iq

https://doi.org/10.18280/ijht.420531

Received: 19 July 2024
Revised: 11 September 2024
Accepted: 26 September 2024
Available online: 31 October 2024

Keywords:
capillary tube length, COP, exergy, exergy of capillary tube

ABSTRACT

This study presents an exergetic examination of a vapour compression refrigeration system. The exergetic balance conditions have been defined. Experimental work depending on the change of the capillary tube length (800, 1000, and 1200) mm with refrigerant mass flow rate changes from (10.3 to 21.3) kg/hr has been done to represent the different exergy flow occurring in the system components. The results were compared for each condenser temperature, evaporator temperature, coefficient of performance, exergy losses, exergy efficiency, efficiency defects, and rational efficiency. Results have been presented graphically. The finding indicated that the coefficient of performance decreased by 7% as the capillary length increased from 800 to 1200 mm. Also, the total exergy increases by 2.3% with increasing mass flow rates.

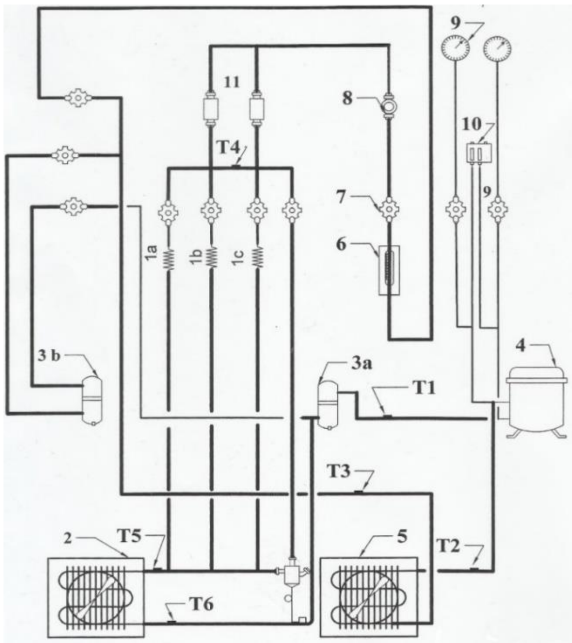
1. INTRODUCTION

A throttling device is one of the most commonly used in refrigeration cycles and is named an expansion device. This device is important because it divides the refrigerating system into low-pressure and high-pressure sides. One of most important the throttling devices is a capillary tube used in air conditioning and refrigeration systems. The capillary tube is usually used as the throttling valve in the refrigeration system and is made of copper tubes [1, 2]. The capillary tube extends to work for all small air conditioning and refrigeration systems for refrigerating capacities (10 kW). The function of a capillary tube is to reduce the pressure of refrigerant from a high level to a low level. The pressure drop through the refrigeration system is one of the important parameters that controls the mass flow rate of refrigerant. Consequently, the rate of the mass flow rate of refrigerant through the capillary tube dominant increases as the condenser regulates through the evaporator (reduce or rise). The length of the capillary tube is considered one of the main factors that affects the pressure drop across a given device [3]. However, the thermal processes through the refrigeration system leads to the dislodging of great quantities of heat into the atmosphere. Then, heat transfer between the refrigerant system and the ambient occurs with a limited temperature differential. This temperature difference is a reason for the main source of irreversibility for the cycles. The irreversibility causes a decrease in the performance of the system. To achieve better refrigeration performance, the estimation of the losses in the refrigerant system should be taken into account by individual thermodynamic processes for each part of the cycle to reach better performance. The first law of thermodynamics didn't show facts on how the refrigeration system performance is decreased. Exergy calculation can deliver increased and deeper insight into the process [4].

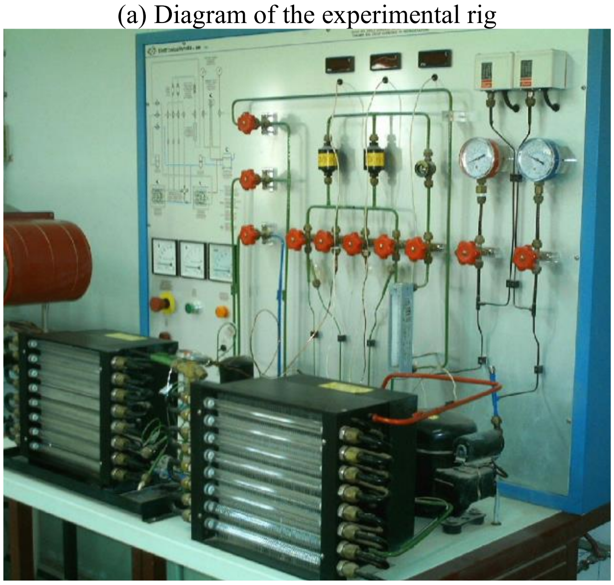
Exergy analysis is the best tool for optimizing, designing, and performance calculation of energy systems. The principles of exergy analysis are introduced [2, 5-9]. For more explanation, Saidur et al. [3] identified the losses in the devices used in Malaysia's residential sector using exergy analysis. They indicated the main consumptions in the vapour compressor system like refrigerators and air conditioners. The highest exergy losses were in the air conditioner by 21% while the lowest losses were in the fan, washing machines, and rice cooker. An experimental study was presented by Padilla et al. [4] to use the exergy analysis for replacing R134a refrigerants instead of (retrofit) in a domestic refrigeration system. They found that refrigerant R134a gave the highest overall performance of the system compared with refrigerant R12. The effect of three types of refrigerants (R134a, R407c, and R404a) on the coefficient of performance (COP) of compression refrigeration was investigated by Farhan et al. [10]. The finding showed that at various compression ratio ranges, the refrigerants R134a and R407c achieve the best performance. In addition, a decrease in the exergy destruction ratio (EDR) is a result of an increased exergy efficiency; for R134a, the maximum increases in exergy efficiency and decrease in EDR are 117.8% and 75% respectively. Ali and Mahdi [11] utilized the exergy analysis to reduce the power consumption using R-134a and R-600a refrigerant. They identified the losses in components of the air condition and refrigeration system. For R-600a and R134a, the capillary tube losses were 99.5% and 87% respectively. Anand and Tyagi [12] carried out an experimental analysis of window-type air-conditioners using refrigerant R22 as a working fluid for a different amount of R22 charge utilizing exergy analysis. The results revealed that the major losses and the minor losses are achieved for the compressor and the other components (condenser, evaporator, and expansion device) respectively. Moreover, the maximum and minimum total exergy destruction obtained at the weight percentage of refrigerant was 100% and 25% respectively. On the other hand, the absorption-compression Cascade Refrigeration system was examined experimentally and theoretically by Dixit et al. [13]. The experimental device consists of a vapour absorption refrigerant system at the high-temperature step and a vapour compression refrigerant system in the low-temperature step The H_2O-LiBr has been used as a refrigerant in the absorption part, while the CO_2, NH_3, and R134a refrigerants in the compression portion. A mathematical model has been utilized to analyze the refrigeration system. The work presents the maximum exergy destruction that happened in the cascade condenser, refrigerant throttle valve, and compressor. The foremost target of the present work introduces the experimental comparison of the refrigeration cycle with different lengths of the capillary tube. In addition, all experimental tests are carried out to discover the best capillary tube length that gave the highest value of COP and exergy efficiency. Enhancement of the length of the capillary tube using two DC-powered compressors was studied by Sidney et al. [14]. They found that the performance increased with the increase till reached 4.57 m. Salem et al. [15] study looked at how the heat exchanger–based performance of a refrigeration system concerning the lengths of the capillary tubes. They tested several lengths of the capillary tubes, which were 190 cm, 175, and 160. Their finding indicated that the system's performance increased by 17.96% when the nondiabetic capillary tube length from 190 to 160 cm. Moreover, the highest enhancement of the exergy efficiency and the refrigeration system performance was observed at 35% and 6.7% respectively, which was obtained at air speeds of 1 and 3 m/s. The influence of the suction line on the evaporator performance using R-134a was investigated experimentally by Ferhan et al. [16]. They employed three kinds of sections which were coil concentric, and lateral. According to their finding, the concentric suction line had the highest values of the coefficient of heat transfer when compared to other varieties. In addition, the air velocity and mass flow rate of refrigerant are 3.8 m/s and 14.87 kg/h, capillary tube underwent the greatest rise in both of the overall and the internal heat transfer coefficient, measuring 50% and 16% respectively. When compared to the other kinds of suction lines, they found that the concentric line is the most effective. Afterwards, using refrigerant R152a, Baskaran et al. [17] examined the impact the capillar length of tube on the domestic refrigerator. They used three kinds of lengths of the capillary. They obtained the maximum performance at the length of 3.65 m and temperature of the evaporator (−12℃) compared with other lengths of the capillary, which were 3.96 and 3.35m. Mohammed Ali et al. [18] compared the effect of several diameters and lengths of the capillary tube on the air conditioner system using R-134a and R-12 refrigerants. They concluded that the system using R-134a works with a capillary tube length less than R-12 refrigerant.

According to previous studies that related to the influence of the length of capillary tubes on the refrigeration systems performance. There is still a lack of the length's effect of the capillary tube which should be studied extensively under exergy analysis where the losses should be considered. Therefore, the exergy and energy analysis of the length of the capillary tube for the refrigeration system. Thus, the exergy analysis will be utilized to study the impact of capillary tube length on the performance of the refrigeration system.

2. MATERIALS AND METHODS



(a) Diagram of the experimental rig



(b) Photograph of the experimental rig

Figure 1. Experimental rig

The schematic and photographic of the mechanism of the experiment is depicted in Figures 1(a) and (b). Figure 2 displays the P-h diagram illustrating the compression cycle. The test part (capillary tubes) (1) was made from copper. It is connected by a parts condenser and evaporator; three capillary tubes are used for different lengths (800, 1000, and 1200) mm with a 2 mm inner diameter. Once the working fluid leaves the capillary enters the air evaporator (2). The evaporator was installed inside the duct with an electrical heater to provide hot air with a capacity ranging from 0.7 to 1.2 kW. To protect the compressor from any saturated refrigerant the receiver of liquid (3a) is mounted before the compressor. Then (0.25 hp) reciprocating compressor type (4) is used in this study. The present investigation utilizes a fin and tube air condenser of type (5). The fluid flow rate and temperature of the cooling air regulate the thermal load of the condenser. To maintain a continuous flow of liquid refrigerant to the capillary tubes, the receiver (3b) was linked to the high-pressure, saturated liquid from the condenser. The mass flow rate of liquid refrigerant was measured using a Roto-meter (type 6) instrument. The flow rate of the working fluid is controlled by a valve (7) to prevent any vapour of refrigerant. After the valve (7) a sight glass (8) is mounted to observe the working fluid before inter the filter drier. Both high and low pressures are read by pressure gauges (9). The compression cycle was connected to different pressure switches to protect the cycle from extremely high or low pressures that may happen during the test.

Instrumentations tools:

Temperature monitor: Digital Thermostat Controller type (Lae Electronic MT11 L3D with Pt100 sensors typically have an accuracy of ± 0.15°C the range of temperatures of -50°C to 150°C was used to measure the temperatures of working fluid in the cycle.

Flow meter: Flow meter type (Cryotek) model 10C was used to measure flow rate of range from zero 0.03 to 0.35 L/min.

Pressure gauge. Analogue pressure gauges with Pressure differential switch types (Danfoss) were used to monitor and control the pressures of the cycle.

Analogue panel ammeter type (Elettronica Veneta) range 0-5 Amper.

Analogue panel voltmeter type (Elettronica Veneta) range 0-300 volt.

Analogue panel wattmeter type (Elettronica Veneta) range 0-1 kW.

PT100 calibration method.

An ice bath with a heater and mercury thermometer was used to calibrate the PT100s with errors of less than 0.5°C for all the PT100 sensors. Figure 3 shows the calibration results of the mercury thermometer with the PT100 sensor.

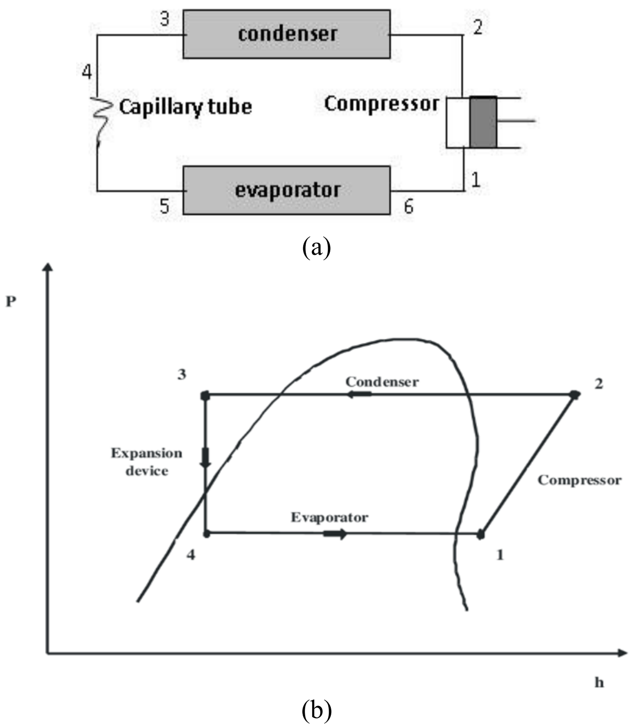


Figure 2. (a) A schematic representing the cycle, (b) P-h diagram of the cycle

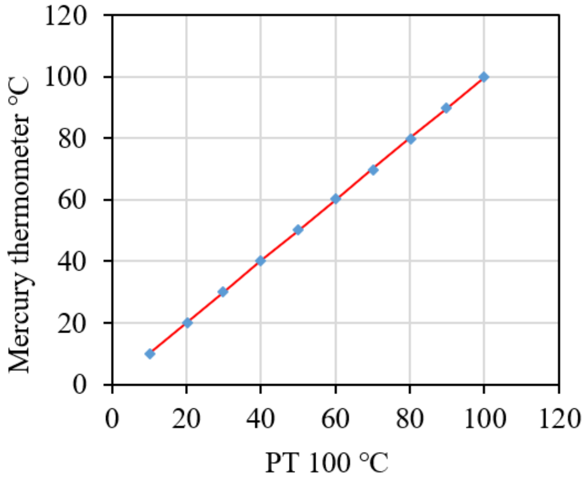


Figure 3. Calibration of the PT100 sensors

3. EXERGY TECHNIQUE

Application of the 2nd law of thermodynamics to determine the coefficient of performance by considering the continuous decrease in exergy caused by irreversibility. The exergy method is the mixture between both laws (first and second laws) of thermodynamics [19]. Kotas [20] defined the exergy as a kind of energy concerning the surrounding atmosphere. Consequently, in an exergy examination, the losses indicate the true losses of work. The primary factors contributing to the irreversible losses in the system are friction, heat transfer under temperature fluctuations, and uncontrolled expansion [21].

The theoretical expression for the exergy content of a pure material is given by Kotas [20] as the following equation:

$$X = (h - h_o) - T_o\,(S - S_0) \tag{1}$$

3.1 Governing equations

The theoretical formulation for exergy investigation for four parts of the vapour compression system can be calculated in the following procedure [22, 23].

A. Compressor exergy:

$$X_{comp} = \dot{m}_r(h_1 - T_o(S_1)) + W_c - \dot{m}_r(h_2 - T_o(S_2)) \tag{2}$$

B. Condenser exergy:

$$X_{cond} = \dot{m}_r(h_2 - T_o(S_2)) - \dot{m}_r(h_3 - T_o(S_3)) \tag{3}$$

C. Analysis of capillary tube exergy:

$$X_{cap} = \dot{m}_r(h_3 - T_o(S_3)) - \dot{m}_r(h_4 - T_o(S_4)) \tag{4}$$

D. During the expansion process through the capillary tube (isentropic process) *($h_3 = h_4$)* therefore, Eq. (4) can be written as:

$$X_{cap} = \dot{m}_r T_0(S_4 - S_3) \tag{5}$$

E. Exergy of evaporator:

$$X_{evap} = \dot{m}_r(h_4 - T_o(S_4)) + Q_e\left(1 - \frac{T_o}{T_r}\right) - \dot{m}_r(h_1 - T_o(S_1)) \quad (6)$$

F. Total exergy of the system:

$$X_{total} = X_{comp} + X_{cond} + X_{cap} + X_{evap} \quad (7)$$

G. Exergy efficiency:

Defined the exergy efficiency as a proportion of exergy output (X_{out}) divided by exergy input (X_{in}) by [24]:

$$\eta_X = \left(1 - \frac{X_{total}}{W_c}\right) * 100\% \quad (8)$$

The (COP) of the cycle is determined by:

$$COP = \frac{Q_e}{W_c} \quad (9)$$

Efficiency defects and rational efficiency were calculated by [25]:

$$\psi = (1 - \delta_{total}) * 100\% \quad (10)$$

4. RESULTS AND DISCUSSION

Experimental results show that the effect of capillary tube length on compression refrigeration exergy which changes from L = (0.8 to 1.2 m) with refrigerant flow rates variation:

Figure 4 illustrates the relationship between condenser temperature and fluid mass flow rate. The graph illustrates a positive correlation between the temperature of the condenser and the coolant mass flow rate. Conversely, condenser temperature drops as capillary tube length increases. The condenser temperatures were measured to be 307.7 K, 314 K, and 319.9 K for lengths of 1.2 m, 1 m, and 0.8 m respectively, given an overall flow rate of 10.3 kg/hr.

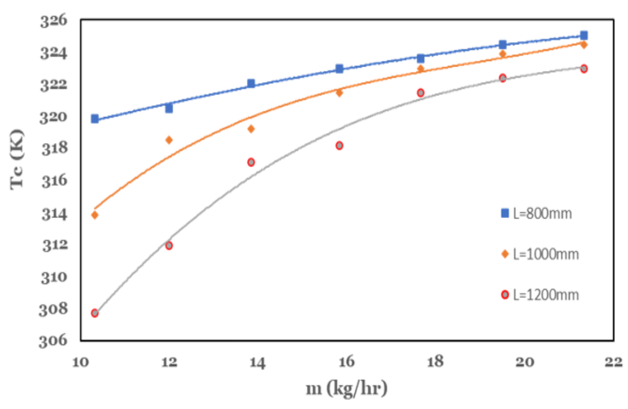


Figure 4. Relationship between condenser temperature and refrigerant flowrate

Figure 5 depicts relationship between evaporator temperature and refrigerant mass flowrate. As the flowrate increases, the temperature of the evaporator also increases. This behaviour is the same for different lengths (L = 1.2, 1, and 0.8) m. The lowest temperature was 253 K for a 1.2 m capillary tube length and 255 K for a 0.8 m capillary tube length at same flowrate. Figure 3 and Figure 4 display a feasible relationship between condenser temperature and evaporator temperature.

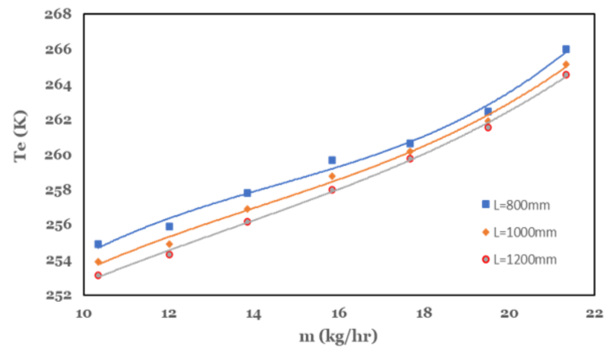


Figure 5. Effect of evaporator temperature with refrigerant mass flowrate

Figure 6 illustrates the effect of coolant mass flow rate on the coefficient of performance for three types of capillary tubes. The results achieved presented that the COP reached 4.6 at L = 1.2 m, 5 at L = 1 m, and 5.2 at L = 0.8 m at 10 kg/hr working fluid. The performance decreases when increasing the mass flowrate until reach 3.2 at 21.3 kg/hr.

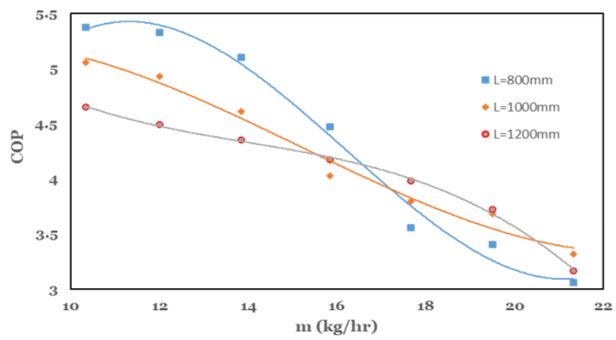


Figure 6. Change in coefficient of performance with refrigerant mass flowrate

Figure 7 shows a general increase of compressor exergy with the refrigerant mass flow rate, showing peak values at certain points before slightly decreasing. As well as The exergy of the compressor rose proportionally with increases in the length of the capillary tube.

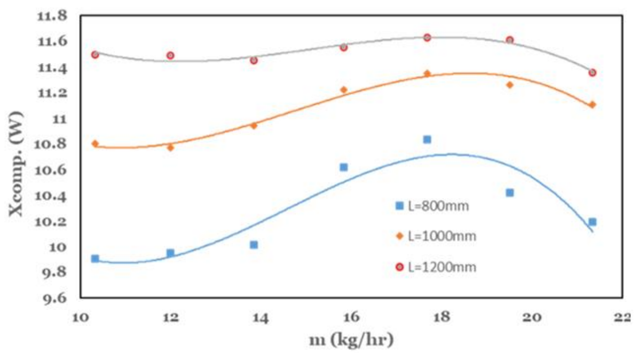


Figure 7. Disparity of compressor exergy with working fluid flowrate

Figure 8 illustrates the relationship between condenser exergy and refrigerant flowrate. The behaviors of the exergy curves of the condenser exhibited a positive correlation with the mass flow rate across all capillary types.

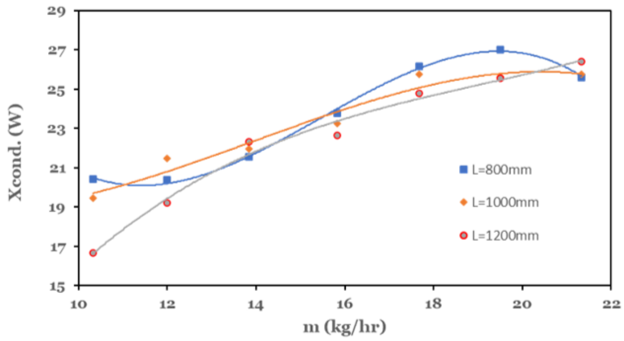


Figure 8. Variation of condenser exergy with flowrate of refrigerant

Figure 9 illustrates the relationship between capillary tube exergy and mass flow rate of refrigerant. The behaviour of the curves of the exergy of the capillaries was decreased to a minimum value at 16 kg/hr and, after that increased to a maximum value high flowrate.

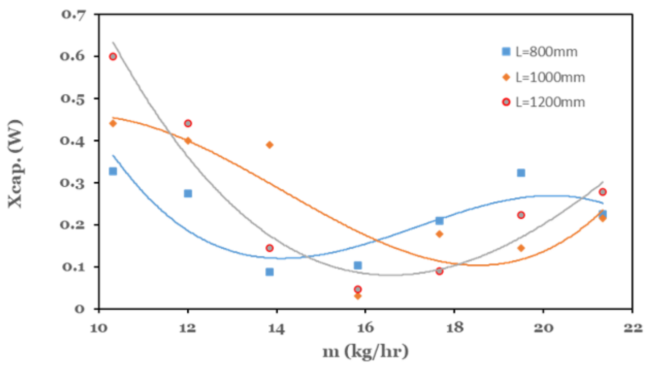


Figure 9. Difference of capillary tube exergy with a working fluid mass flowrate

Figure 10 illustrates the variation in evaporator exergy at different working fluid mass flow rates. The evaporate exergies increase with an increased mass flow rate.

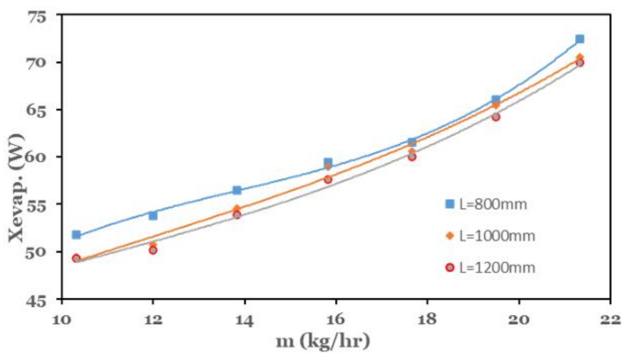


Figure 10. Measurement of the relationship between evaporator exergy and mass flow of the refrigerant

Figure 11 displays the change between total exergy through the working fluid flowrate. The total exergy correlates positively with a higher mass flowrate.

Figure 12 illustrates that the exergy efficiency in capillary tubes rises with higher refrigerant mass flow rate for all lengths of the tubes. An increasing mass flow rate possibly improves the exergy efficiency up to a certain point, after which it might decrease.

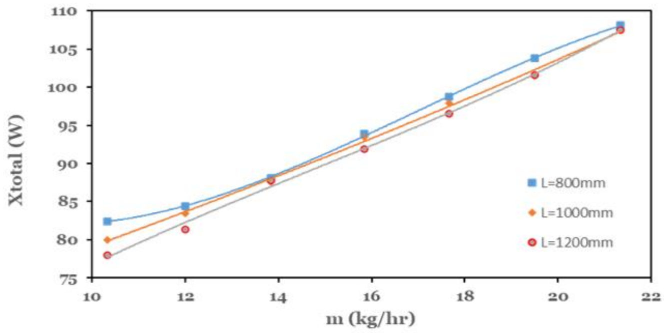


Figure 11. Variation of total exergy with refrigerant mass flowrate

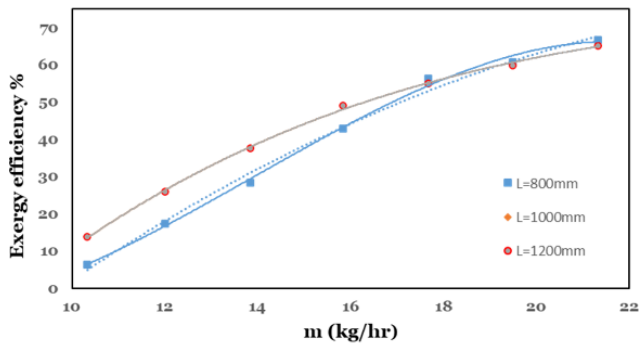


Figure 12. Variation of exergy efficiency with working fluid mass flow rate

Figure 13 illustrates efficiency defects in a compressor vary with changes in refrigerant mass flow the results show the efficiency defects of the compressor decreased when decreasing the length of the capillary tube. This variation is vital for improving compressor performance. If defects decrease with increasing flow, higher mass flow rates might be desirable. Equally, if defects increase, it suggests a limit to the effective mass flowrate.

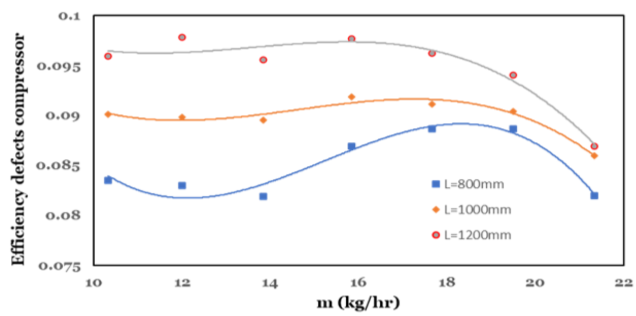


Figure 13. Analysis of the relationship between efficiency faults and refrigerant mass flow in a compressor

Figure 14 illustrates the efficiency defects in the condenser change with refrigerant mass flow. This figure specifies how sensitive the condenser's performance is to variations in refrigerant mass flow. Lower defects at certain flow rates can help in determining the best operating conditions.

Figure 15 illustrates the efficiency deficiencies of the capillary tube as the mass flowrate of the refrigerant varies.

The capillary tube's performance might show a specific tendency, for example increasing defects at higher mass flowrates, indicating the essential flowrate control to minimize losses.

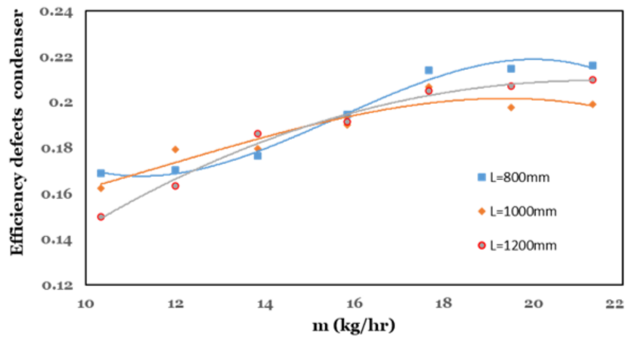


Figure 14. Correlation between refrigerant mass flow and efficiency problems of the condenser

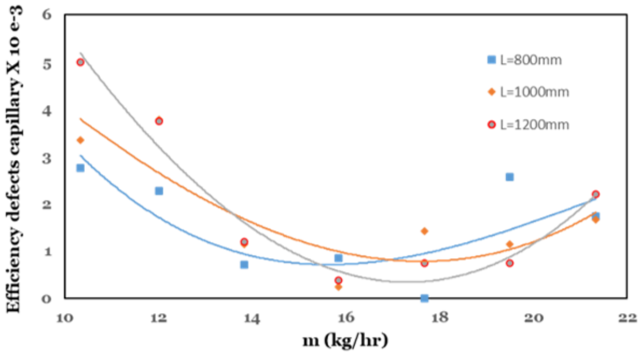


Figure 15. Variation of efficiency defects of capillary with a refrigerant mass flowrate

Figure 16 displays that Efficiency defects in the evaporator vary with the refrigerant mass flow. Recognizing the best flow rate where efficiency defects are minimized will be essential for enhancing the evaporator's performance.

Figure 17 shows the total efficiency defects vary with the refrigerant flowrate. This complete figure helps to understand the overall system performance. A best working fluid flowrate can be deduced where the total defects are minimized, improving overall system efficiency.

Figure 18 presents the rational efficiency is reduced as the refrigerant flowrate increases for all lengths. The higher mass flowrates negatively impact the system's efficiency.

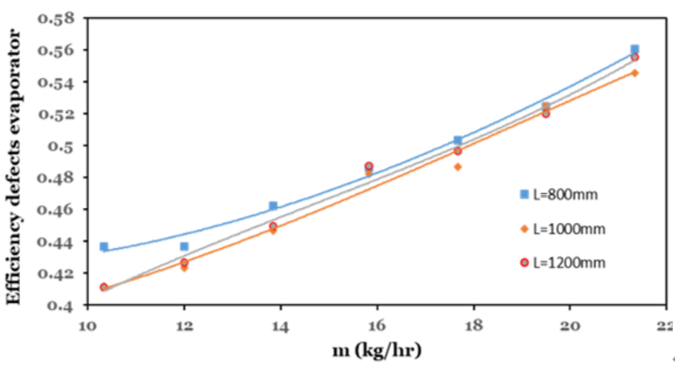


Figure 16. Variation of efficiency defects of the evaporator with refrigerant mass flow

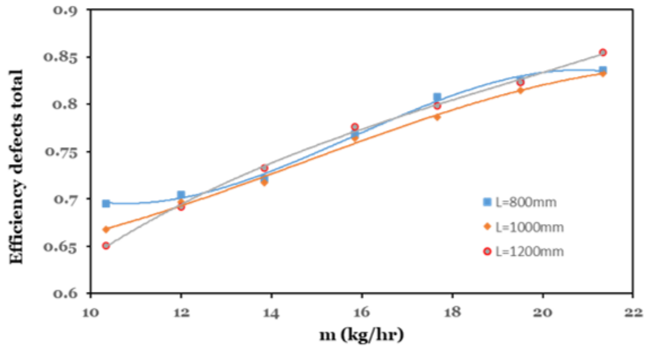


Figure 17. Relationship between the overall inefficiency faults and the mass flowrate of the refrigerant

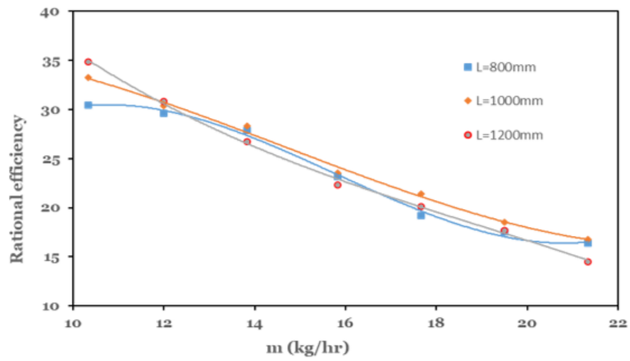


Figure 18. Variation of rational efficiency with refrigerant mass flow rate

5. CONCLUSIONS

An experimental comparison of refrigeration compression cycle exergy is presented using different capillary tube lengths. The compressor exergy, condenser exergy, capillary exergy, evaporator exergy, total exergy, and efficiency exergy are calculated. The results show shorter capillary tubes cause higher condenser temperatures and COP. In contrast, longer capillary tubes reduce condenser temperatures then may decrease COP slightly. Both condenser and evaporator temperatures increase with the mass flow rate. Increased mass flow rate tends to reduce COP. The Exergy of all components and the total system increases with mass flow rate, while rational efficiency decreases. The compressor efficiency and efficiency defects for condenser and capillary tubes are decreased with shorter capillary tubes. It can also be concluded that, as the mass flow rate increases, exergy efficiency enhances up to a certain point, after which it might decrease. The shorter capillary tube was better in terms of performance than other lengths. Moreover, exergy analysis showed that the shorter length of the capillary tube is better than other types in terms of exergy to all parts of the refrigeration system.

REFERENCES

[1] Sainath, K., Reddy, T.K.K., Akella, S. (2019). Optimization of capillary tube dimensions using different refrigerants for 1.5-ton mobile air conditioner. Case Studies in Thermal Engineering, 16: 100528. https://doi.org/10.1016/j.csite.2019.100528

[2] Agrawal, N., Bhattacharyya, S. (2009). Exergy assessment of an optimized capillary tube-based transcritical CO_2 heat pump system. International Journal of Energy Research, 33(14): 1278-1289. https://doi.org/10.1002/er.1536

[3] Saidur, R., Masjuki, H.H., Jamaluddin, M.Y. (2007). An application of energy and exergy analysis in residential sector of Malaysia. Energy Policy, 35(2): 1050-1063. https://doi.org/10.1016/j.enpol.2006.02.006

[4] Padilla, M., Revellin, R., Bonjour, J. (2010). Exergy analysis of R413A as replacement of R12 in a domestic refrigeration system. Energy Conversion and Management, 51(11): 2195-2201. https://doi.org/10.1016/j.enconman.2010.03.013

[5] Gaggioli, R. (1998). Available energy and exergy. International Journal of Thermodynamics, 1(1-4): 1-8. http://dergipark.org.tr/en/pub/ijot/issue/5730/76553.

[6] Moran, M.J., Sciubba, E. (1994). Exergy Analysis: Principles and practice. Journal of Engineering for Gas Turbine and Power, 116(2): 285-290. https://doi.org/10.1115/1.2906818

[7] Yumrutaş, R., Kunduz, M., Kanoğlu, M. (2002). Exergy analysis of vapour compression refrigeration systems. Exergy, An International Journal, 2(4): 266-272. https://doi.org/10.1016/S1164-0235(02)00079-1

[8] Ahamed, J.U., Saidur, R., Masjuki, H.H. (2011). A review on exergy analysis of vapor compression refrigeration system. Renewable and Sustainable Energy Reviews, 15(3): 1593-1600. https://doi.org/10.1016/j.rser.2010.11.039

[9] Aized, T., Rashid, M., Riaz, F., Hamza, A., Nabi, H.Z., Sultan, M., Krzywanski, J. (2022). Energy and exergy analysis of vapor compression refrigeration system with low-GWP refrigerants. Energies, 15(19): 7246. https://doi.org/10.3390/en15197246

[10] Farhan, S., Al-Doori, G., Salem, K., Rashad, R., Al-Doury, R., Farhan, I. (2023). Energy and exergy assessment of a compression refrigeration system by utilizing different refrigerants. International Journal of Membrane Science and Technology, 10: 1692-1704. https://doi.org/10.15379/ijmst.v10i1.3088

[11] Ali, H.M., Mahdi, L.A. (2023). Exergy analysis of chest freezer working with R-134a and R-600a at steady state conditions. International Journal of Energy Production and Management, 8(2): 63-70. https://doi.org/10.18280/ijepm.080202

[12] Anand, S., Tyagi, S.K. (2012). Exergy analysis and experimental study of a vapor compression refrigeration cycle. Journal of Thermal Analysis and Calorimetry, 110(2): 961-971. https://doi.org/10.1007/s10973-011-1904-z

[13] Dixit, M., Kaushik, S.C., Arora, A. (2017). Energy and exergy analysis of absorption-compression cascade refrigeration system. Journal of Thermal Engineering, 3(5): 1466-1477. https://jten.yildiz.edu.tr/storage/upload/pdfs/1637057502-en.pdf.

[14] Sidney, S., Prabakaran, R., Dhasan, M.L. (2020). Thermal analysis on optimizing the capillary tube length of a milk chiller using DC compressor operated with HFC-134a and environment-friendly HC-600a refrigerants. Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 234(4): 297-307. https://doi.org/10.1177/0954408919871385

[15] Salem, T., Farhan, S., Farhan, I. (2020). Energy and exergy analysis study of heat exchanger in a refrigeration system with different lengths of capillary tube. International Journal of Thermodynamics, 23: 260-266. https://doi.org/10.5541/ijot.758705

[16] Farhan, S.S., Salem, T.K., Ismael, M.N., Ibrahim, T.K. (2021). Impact of suction line on evaporator effectiveness in refrigeration cycle. Case Studies in Thermal Engineering, 27: 101270. https://doi.org/10.1016/j.csite.2021.101270

[17] Baskaran, A., Manikandan, N., Jule, L., Nagaprasad, N., Saka, A., Badassa, B., Seenivasan, V. (2022). Influence of capillary tube length on the performance of domestic refrigerator with eco-friendly refrigerant R152a. Scientific Reports, 12(1): 14460. https://doi.org/10.1038/s41598-022-18606-w

[18] Mohammed Ali, M.F., Resen, I.S., Ibrahim, I.J. (2023). Capillary tube length and heat transfer dynamics in air conditioners: A comparative analysis of r-12 and its alternatives. International Journal of Heat and Technology, 41(6): 1573-1580. https://doi.org/10.18280/ijht.410619

[19] Talbi, M.M., Agnew, B. (2000). Exergy analysis: An absorption refrigerator using lithium bromide and water as the working fluids. Applied Thermal Engineering, 20(7): 619-630. https://doi.org/10.1016/S1359-4311(99)00052-6

[20] Kotas, T.J. (2012). The Exergy Method of Thermal Plant Analysis. Paragon Publishing.

[21] ASHRAE. (1997). American Society of Heating, Refrigeration and Air Conditioning Engineers Fundamentals Handbook (Si Edition).

[22] Bayrakçi, H.C., Özgür, A.E. (2009). Energy and exergy analysis of vapour compression refrigeration system using pure hydrocarbon refrigerants. International Journal of Energy Research, 33(12): 1070-1075. https://doi.org/10.1002/er.1538

[23] Bolaji, B.O. (2010). Exergetic performance of a domestic refrigerator using R12 and its alternative refrigerants. Journal of Engineering Science and Technology, 5(4): 435-446. https://core.ac.uk/download/pdf/25945193.pdf.

[24] Adegoke, C.O., Akintunde, M.A., Fapetu, O.P. (2007). Comparative exergetic analysis of vapor compression refrigeration systems in the superheated and subcooled regions. AU Journal of Technology, 10(4): 254-263.

[25] Kopac, M., Zemher, B. (2006). Effect of saturation-temperature on the performance of a vapour-compression refrigeration-cycle working on different refrigerants using exergy method. International Journal of Energy Research, 30(9): 729-740. https://doi.org/10.1002/er.1174

NOMENCLATURE

A	Cross section area, m^2
C	Velocity, m/s
COP	Coefficient of Performance
d	Capillary tube internal diameter, m
Ep	Electrical power input, watt
G	Mass flux, kg/s m^2
g	Local acceleration of gravity, m/s^2
h	Specific enthalpy, kJ/kg

I	Current, A
L	Capillary tube length, m
$\dot{m}_r$	Refrigerant mass flow rate, kg/h
n	Polytropic index
P	Pressure, bar
q	Heat transfer per unit mass, kJ/kg
Qv	Volumetric flow rate, l/min
Qe	Cooling capacity, watt
$\dot{m}_r$	Refrigerant mass flow rate, kg/h
Q	Heat transfer, Watt
qe	Refrigerant effect, kJ/kg
Qc	Heat reject from condenser, watt
s	Specific entropy, kJ/kg.K
2nd	Second
TCP	Theoretical Compression Power, watt
T	Temperature, °C
u	Internal energy, watt
v	Specific volume, m^3/kg
V	Voltage, volt
w	Work interaction per unit mass, kJ/kg
We	Mechanical power output, watt
Wc	Work of compression, kJ/kg
W	Work interaction, watt
X	Exergy, watt
X d	Dryness fraction
z	Height, Cartesian coordinate