Mass Flow Rate and Pressure Analysis of Refrigerant with Variation of Diameter

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Abstract: In many applications, refrigeration systems are used in appropriate conditions for goods. But very large amounts of energy are used by these refrigeration systems, which can contribute to increased global warming. There are various types of refrigerants that are used by the vapour compression cooling system at the commercial level for heat transfer from high to low temperature reservoirs. When researching the environmental effects of R134a, relative to the mixture of R134a and HC, it can generate more global warming. In this work, VCRS with straight capillary tube is analysed for R134a and mixture. The ratio of the two components is perceived to be 28:72 by weight. In this job, a 1.12 mm, 1.4 mm, 1.52 mm diameter spiral coiled capillary tube is used. The experiment is conducted on two R134a refrigerants, and the combination of R134a and HC is another. The outcome analysis reveals that the maximum mass flow rate for 1.12 mm diameter tubes was 3.63 g/s. The pressure ratio was 1.12 mm for R134a, while the mixture was 1.52 mm.

Keywords: Refrigeration system; mass flow rate; pressure; compressor.

1. INTRODUCTION

In many stationary and mobile applications, refrigeration systems are used to provide an acceptable atmosphere for food and other creatures/products sensitive to temperature/humidity [1][2]. A large amount of energy is absorbed by these processes, contributing to global warming. There are a large number of coolants that are commonly used to transfer heat into a vapour compression cooling device from a low-temperature reservoir to a high-temperature reservoir. R134a has a high global warming potential relative to the R134a and HC combination when it comes to environmental issues. Capillary tubes, including domestic refrigerators and window style room air conditioners, are used as an expansion device in the refrigerating system [3]. This is the simple, low cost, zero maintenance, capillary tubes have been used in a number of vapour compression systems and require a low starting torque motor to operate the compressor. Over the past six decades, a number of researchers have been studying the different flow elements of the capillary tube. The coolant flows in a simple way in a straight capillary configuration [4]-[8].

Kulmitra [1] explains that the capillary tube is used in the devices most commonly used in refrigerant flow control. Therefore, the performance of the capillary tube is best for good refrigerant flow. The numerous researchers had completed the work experimentally, theoretically and on the basis of analysis. In this thesis, the analysis of the refrigerant flow in a capillary tube is analyzed for the adiabatic flow conditions. The proposed model allows to predict the flow properties in adiabatic capillary tubes for a given mass flow. In the present work, R-22 was replaced with an ammonia refrigerant, which was used as the working fluid in the capillary tube, and the capillary tube design was directly changed to a coiled capillary, taken from good literature. The analysis takes place in the ANSYS CFX 16.2 software. From the results, it is observed that the dry fraction using the helical capillary tube (ammonia refrigerant flow) is better than the existing straight helical capillary tube (R22 refrigerant flow). The most suitable spiral design is suggested.

Saravanakumar et al. [2] aimed to carry out an exergy analysis of the hydrocarbon-refrigerant mixture of R290 / R600a as an alternative to R134a for the performance of a household refrigerator, which was originally designed to work with R134a. The performance of both refrigerants was evaluated using an exergy analysis. The effects of the evaporator temperature on the coefficient of performance (COP), the exergy loss, the exergic efficiency and the efficiency error in the four main components of the system for the mixture R134a and R290 / R600a were investigated experimentally.

Payne et al. [3] examined the mass flows of R12, R134a, R502, R22, R407C and R410A through short tubes. The length of the short tube was between 9.5 mm and 25.4 mm and the sharp edge diameter between 1.09 mm and 1.94 mm. The correlation includes both single-phase and two-phase input conditions with approximately limited flow. The correlation consists of non-dimensional parameters that are a function of upstream conditions, downstream conditions, the geometry of the short pipe and the pressure / temperature of the critical point. Related data are drawn from previous work and from work carried out during this study. The general form of correlation is a function for a single-phase flow multiplied by a function that contains parameters for a two-phase flow.

Rasti and Jeong [4] established empirical correlations using a spiral-wound adiabatic capillary tube to predict refrigerant mass flows. A generalized continuous correlation to predict refrigerant mass flow through a helically wound adiabatic capillary tube was developed to compensate for the shortcomings of previous correlations in all previous correlations of the present research.

2. METHODOLOGY

We use a wrought iron stand as a frame for the installation of compressors and condensers in this experiment. Wrought iron is readily available and very cheap on the market. The frame is a square shape created between 30 and 30 cm2. I installed the compressor between 1 and 2 after creating the frame. At the base of the stand is the compressor installed. Build a hole for the suitable nozzle with the boiling unit. The compressor was now mounted with the aid of a nozzle but for movement prevention use the gas welding and the compressor is reinforced. The wood plate is used to support the capillary evaporator and hold. The arrangement is also balanced. The rear of the compressor is fitted with a screw in the condenser. The condenser is positioned between 2 and 3. Caste iron and quarter size diameter are made of the condenser. The dryer cum filter or liquid receiver that is located between 3 and x now works after mounting the condenser. After the liquid receiver at x point was situated, a hand operated valve was also provided. The hand valve regulates the flow of coolant in the capillary tube by bypassing the coolant.

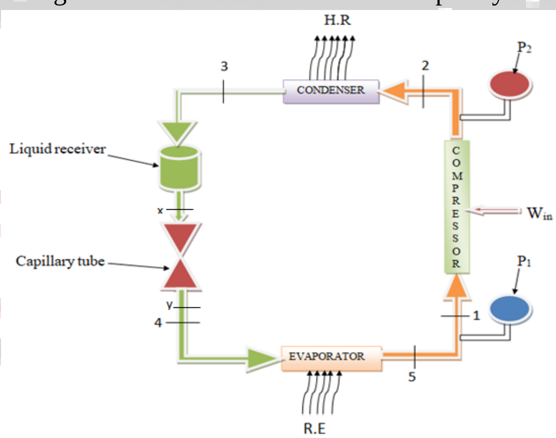

Fig. 1. Block diagram of Experimental set-up

In this experiment, the capillary must be adjusted several times so that the valve must be operated by the hand. Among the major components of the experimental setup, a variety of hand shut-off valves were installed in the event of a leak or repair; the damaged part could be easily repaired. The temperature is determined at various locations by means of k-type thermocouples linked to the six-channel temperature indicator. The pressure of the coolant was measured using pressure gauges. The pressure gauge is located at the 1 & 2 point set-up.

Now users go to the capillary fitting, which is the big part of our experiment. We create the spiral shape of the capillary before the capillary is mounted. The test section of the spiral tube was shaped by creating a spiral first. The form of the appropriate pitch is 310mm to 310mm on the face of the wooden plate. And it's 10mm thick. Two points' c1 'and' c2 'offset by a distance of' x 'mm were required for the making of a spiral. A semicircle of 'x' mm radius was drawn using a compass to take 'c1' as the centre and the second inverted semicircle is twice the offset distance (i.e. 2x) to take 'c2' as the centre.
The relationship between the offset distance and the spiral pitch is: p = 2x. The capillary tube in the marked spiral diagram overlaps after being marked on the wooden plate. And by using the screw, do the patch. The spiral's pitch is 2cm and the spiral's diameter is 30 cm. Similarly, with the same technique, two other spiral capillaries were made. Three different diameters of the spiral capillary tube are obtained in this process.

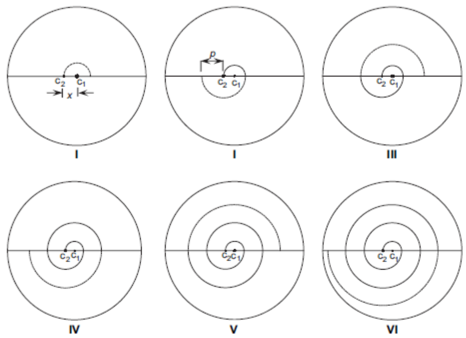

Fig.2. Creation of Spiral Shape

We need to change the tube very often in our project in order for the capillary tube to be easily attached and removed. Here one end of the capillary tube is swept into a copper tube, a flange is grooved at the other end of the tube and flare nut for easy access. Another end is the evaporator's suction after having a spiral capillary connoted on an end-hand operated valve. This is centred at the point between x and y.

Fig. 3. Photographic View of Spiral Capillary Tube

An evaporator is linked to a compressor inlet located between 4 and 5 stages. With the support of the insulation board, the evaporator and aluminum pipe are insulated to avoid heat loss to the atmosphere. Before starting the setup, we now have to vacuum the entire system to prevent compressor damage. The set-up is completely manufactured. The explanation is that it results in compressor damage if any moisture content is present in the compressor unit. In order to vacuum the entire experimental setup, we first open the stopper valve mounted between the capillary tube and the evaporator, we also remove the capillary tube at x position, which with the aid of flare nut assembly was connected to that stopper valve. After this we start a compressor and a finger is connected to the capillary's mouth, so our valve is open and the compressor starts to suck all the air in the machine supply and throw it through the condenser. And supply 10 g of coolant to create the atmosphere of the refrigerant. Now our system gets rid of any moisture absolutely, so we attach the capillary tube with Teflon tape coating to the condenser, to make the whole system leak proof. Now the machine is completely vacuumed, so we start filling in refrigerant gas. Tests were initially performed using R134a to evaluate the performance of the R134a/H.C and R134a systems. First, according to the manufacturing requirements, the device was charged with 120 g of R134a and energy output tests were carried out to determine the COP, pressure ratio, mass flow rate, energy efficiency and total energy destruction in the 4.4 m capillary tube refrigeration system.

We are operating the set-up for the first time using R134a as a coolant. Fill the coolant with a mass of 120 g. Charged mass as determined by the optical weighing machine. One end of the compressor remains closed and we welded a gas charging valve to charge refrigerant when needed for charging refrigerant. A compressor charging line is attached to one end of the charging valve, and another end is connected to the refrigerant cans. The hand-regulated valve in the charge valve is fitted. Valve is open and the refrigerant is beginning the charging after 120 g stop the valve and remove the charging pipe. And ready to be tested. Turn on and supply power through the energy metre now. We use a soap bubble test here to run a test for leak detection. In this test, we use a sponge that is submerged in soapy water, if any leak has come into contact with this foam, it begins to form soap bubbles that clearly indicate the leak present in the system we have to fix. Leak detection test is very commonly used and popular test.

The solution is produced by detergent powder with water in the soap bubble test and using sponge and cover in the joint component, such as pressure gauge, capillary joint, evaporator joint, etc. If any leakage happens, fix it. We are given the load 1 kg of water at normal temperature. At a 15-minute interval reading start and every 15 minutes take the reading after the test device is ready to operate with R134a refrigerant in the beginning. Set the 1.12 mm diameter capillary first and take the reading to completion. And change the capillary 1.4mm diameter after reading and similarly change the reading 1.52mm diameter reading again and take all reading after reading.

Adjust the system's refrigerant, which is another critical aspect of this experiment, now. The new refrigerant is a hydrocarbon and R134a mixture with a mass ratio of 72:28. The mass of the mixture for this experiment is 100 g. The hydrocarbon mass of the mixture is 72 g and R134a is 28 g. In the previous technique, this charge is filled. We are increasing the load in this phase. The new load will be 4 kg.

The assumptions required for the simulation of vapor compression refrigerator are following*:*

- All operation is steady state.
- There are no loss and gain of heat.
- There is no pressure loss in the pipes, that is pressure change occurs only in the capillary tube and compressor.
- The compressor ideal isentropic efficiency and ideal volumetric efficiency of 65 %
- Evaporator is completely insulated.

3. RESULT ANALYSIS

Pressure ratio and Carnot COP for 1.12 mm diameter capillary tube

Spiral capillary, d =1.12 mm, L = 4.4M, T_0 =25 °C

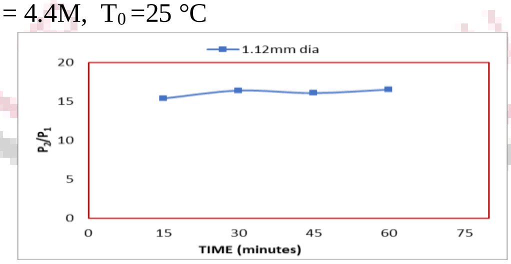

Fig. 4. Variation of pressure ratio with time using 1.12 mm diameter capillary tube

The pressure ratio difference is shown in Fig.4. The minimum stress ratio of 1.12mm is 14.41 and the overall pressure ratio is 16.49. Fig. Fig. It indicates an increase in pressure ratio of up to 15 minutes over time. The pressure ratio decreases by up to 30 minutes after 15 minutes and the pressure ratio increases by up to 60 minutes after 30 minutes and reaches 16 minutes.

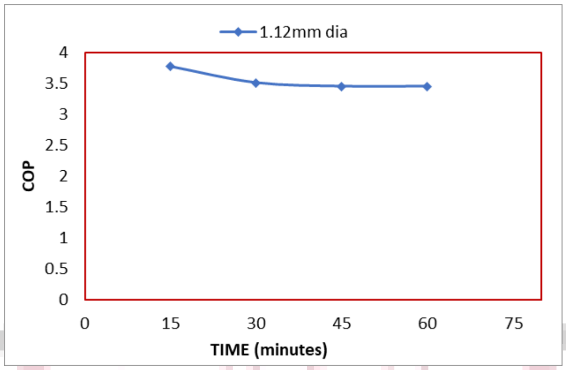

Fig. 5 Variation of Carnot COP with time using 1.12 mm diameter capillary tube

Fig. 5 Variation of Carnot COP with time using a capillary tube diameter of 1.12 mm Fig. The variance of Carnot COP with time is demonstrated in 5. At the start of COP, COP decreases continuously after a while. The maximum COP detected for 15 minutes is 3.8 and the minimum COP detected for 60 minutes is 3.5.

Mass flow rate, cooling power and COP for a capillary tube diameter of 1.12 mm

The variance of the mass flow rate in Figure 6 shows that the starting mass flow rate increases with time up to 30 minutes but continuously decreases after 30 minutes of mass flow rate with increasing time the maximum mass flow rate occurs at a 30-minute reading of 2.9 g/sec. At 1.12 mm in diameter, the average mass flow rate is 2.8 gm/sec

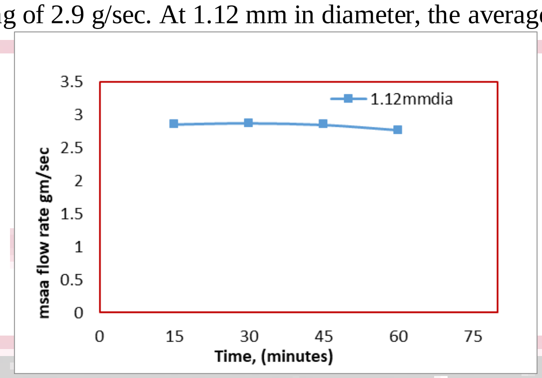

Fig. 6 Variation of mass flow rate with time using 1.12 mm diameter capillary tube

Show your Fig. 7 C.O.P variance with regard to time. When C.O.P begins, the maximum C.O.P decreases continuously for some time. The median C.O.P is 2 in 15 minutes and the minimum C.O.P is 1.9 in 60 minutes.

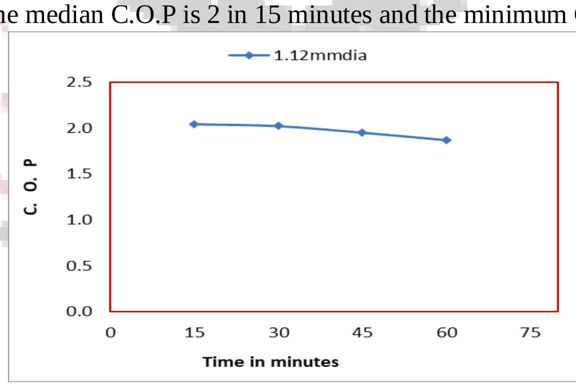

Fig. 7 Variation of actual COP with time using 1.12 mm diameter capillary tube

Variation of the pressure ratio to 1.12 mm dia with respect to time.

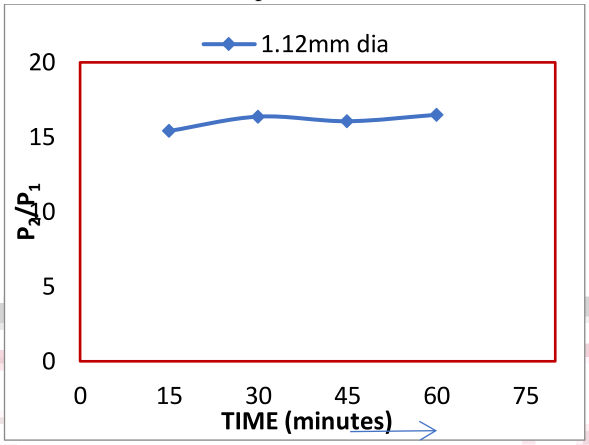

Fig. 8 Variation of pressure ratio with respect to time 1.12mm dia.

Just in Fig. 8 indicates the pressure ratio variation. Dia. For Dia. The minimum stress ratio of 1.12mm is 14.6 and the mean pressure ratio is 16.5. Fig. Fig. It indicates an increase in pressure ratio of up to 15 minutes over time. The pressure ratio decreases by up to 30 minutes after 15 minutes, and the pressure ratio increases by up to 60 minutes after 30 minutes and reaches 16.5.

Comparative pressure ratio with respect to diameter

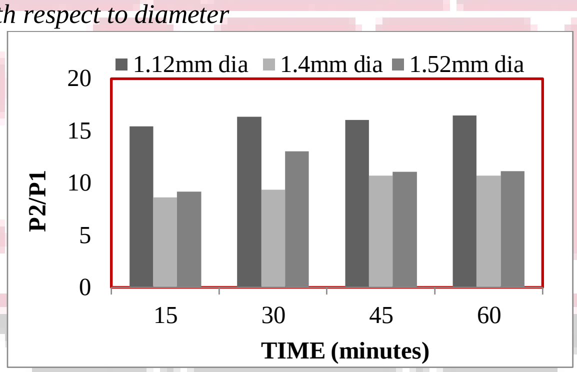

Fig. 9 Pressure Ratio With Different Diameter Of Capillary Tube For R134a

The Pressure Ratio difference with three different diameters is shown in fig 9. The pressure ratio obtained is 16.5 for diameter 1.12 mm and 14.5 as minimum ratio. Whereas the mean pressure ratio 10.8 is 8.7 .in 1.52 mm diameter, maximum pressure ratio 10.8 and minimum pressure ratio is 13. The minimum pressure ratio is 9 as well. We know that the system's COP is increased by decreasing the pressure ratio as the compressor function increases the pressure ratio and decreases the cooling effect. IN the entire pressure ratio analysis Fig., the minimum pressure ratio is 8.7 in the 1.4 mm diameter and the mean pressure ratio is 16.5 in the 1.12 mm diameter capillary.

Comparative Analysis

In fig 10, comparative analysis of mass flow rate is illustrated with variable time and diameter. The graph represents that refrigeration capability is directly proportional to mass flow rate whereas the COP is not related with such.

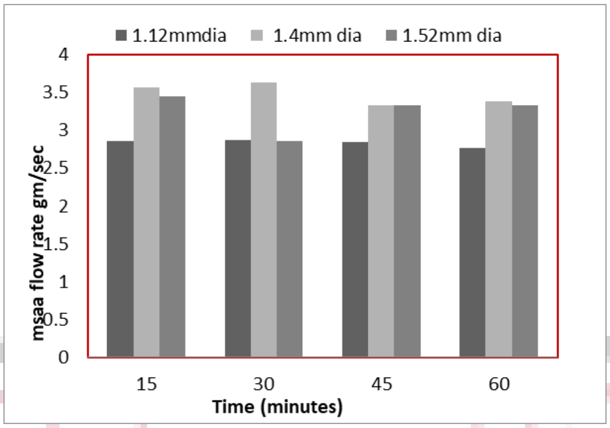

Fig. 10. Comparative mass flow rate

4. CONCLUSION

In this paper, we are examining three different diameters of 1.12mm, 1.4mm and 1.52mm in the spiral capillary tube and two forms of refrigerant, one is R134a and the second is a mixture of R134a and hydrocarbon. And the experiment's result is discussed below:

- For coolant (R134a), diameter 1.12m gives pressure ratio of about 16.5 and pressure ratio is approx. 30% greater than that of the mixture.
- For a 1.4mm diameter capillary tube, the minimum pressure ratio for R134a is 8.7. The R134a minimum pressure ratio is approx. 7% larger than the mixture.
- At a diameter of 1.4 mm, the maximum mass flow rate of the capillary tube is 3.6 g/sec.

In different fields, the use of refrigeration is continually growing. We conclude that the mixture refrigerant is stronger than the R134a refrigerant in this experiment. Another significant parameter in the refrigeration sector is power consumption. The power consumed less than R134a in the mixture. There is therefore the need for further research on the R134a/H.C. mixture in the field of refrigeration.

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