FABRICATION & COP CALCULATION OF REFRIGERATION USING MICRO-CHANNEL HEAT EXCHANGER SET-UP

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ABSTRACT
In this era, the utilization of heat exchangers is increasing rapidly. So, it is the task for the industries like Power Plants, HVAC, Automobiles and waste heat engines to use this equipment in a proper way according to the purpose of their application. There are many types of heat exchangers like shell and tube, plate types and radiator type heat exchangers. All these heat exchangers having copper tubes for refrigerant for the purpose of heat transfer. In this research we introduced new type of heat exchanger (Micro-Channel Heat Exchanger) that is efficient then all economically and environmentally. Micro-channel heat exchanger is a new type in which the main channel in which refrigerant flows is further categorized into small channels, results in more surface area and hence more heat transfer according to the direct relation between heat transfer rate and surface area. Basically our experiment is based on the vapor compression cycle, in which we made retrofitting and replace the conventional heat exchanger having copper tubes with silver made micro-channel heat exchanger. And also we use R-22 refrigerant which works efficiently in the compact design of heat exchanger. In order to calculate the COP of the system we installed several temperature gauges and pressure gauges at the inlet and outlet of the compressor and evaporator to calculate the work done by the compressor and the latent heat absorption in the evaporator. And at the end calculate the COP values for different readings and then draw the graph to predict the relation between COP and work done and COP and latent heat absorption. And at last we compare our results with conventional heat exchanger results. We get a COP of 3.37 in case of micro-channel heat exchanger and 3.03 for conventional heat exchanger.

Keywords: Heat Exchanger, Micro-Channel, COP & Refrigeration.

Introduction
Thermodynamic systems either they are having motors, cooling systems and heat pumps have achieved better performances over the last twenty years. This can be explained on one hand by the better knowledge of the processes that occur in these systems, thus
allowing their design and functional optimization. A lot of improvements have come that have been using new methods and materials in especially heat exchanger category by doing so, our per unit volume for heat transfer increases which automatically increase the transfer rate for that specific heat exchanger. In recent years, a very important contribution on increasing the performance of these systems, sometimes to levels once inconceivable, was obtained by using new technologies which have allowed the production of a new generation of compact heat exchangers with micro-channels. In this research the coefficient of performance of micro-channel heat exchanger is calculated experimentally by installing a micro-channel heat exchanger as condenser in an air conditioning system. Micro-channel heat exchanger is the most efficient design that is totally made of silver having a main channel for the refrigerant flow and this channel is further categorized into small channels named as micro-channel and thus we referred this heat exchanger as micro-channel heat exchanger. Micro-channel heat exchanger has small channels that offered more in-contact surface area for the refrigerant which is R-22. According to the heat transfer laws, more surface area will leads to increase the heat transfer rate. Now here we made a retrofitting in the vapor compression cycle and replaces the conventional heat exchangers with micro-channel heat exchanger. We installed a high pressure gauge and a low pressure gauge at the outlet and the inlet of the compressor along with digital temperature meters. Similarly across the evaporator we installed two digital temperature meters and calculated the coefficient of performance of the unit.

Background

Micro-channel heat exchangers due to their high effectiveness and lower cost are very in demand these days so firstly the concept of their heat sink was introduced by Pease and Tukerman and they manufactured it as well. They study its effects under different conditions. They worked on the micro-channel heat sink manufactured by them and they dissipated heat through it which was almost 790W/cm². Later on Phillips also worked on it he observed liquid cooled micro channel heat sinks and he analyzed liquid cooled micro-channel heat sinks and the forced convection [1]. The designs of small flow channels are of great importance they are usually small in diameter and similar designs were discussed by Bergles et al. The main requirement was of the material thickness and the pumping power for which they worked on it. They presumed that cooling frameworks having smaller distant channels does not require a bigger pumping power and so result in a minimized system. In their study
fin impacts were observed to be critical where thin strong segments were used [2]. They studied the designed problem in details which include heat rate and measurements of the chip. Micro-channel heat sink was studied and analyzed by many people and one of them was Qu and Medawar. They tried micro-channel heat sink with 1cm in width and 4.8cm in length. And the micro-channel in the heat sink was 231μm in width and 712μm in depth. The measurement of temperature & pressure drop across the channel was in great concurrence with the numerical outcomes. They also worked on numerical examination of single micro-channel unit cell. Navier-Stokes also come to conclusion that in micro-channel, energy equations conditions stay legitimate for anticipating fluid flow and heat transfer. [3] The dimensionless form & the solution of the heat transfer and fluid dynamics in laminar and turbulent flow in channels for the heat sink was given by Knight et al. Many attempts were made to modify condensers to get more effective results in the system and many people worked on it. The performance of the system depends on all of its components which adds to it. A system contains many components like condensers, compressors etc a similar system was studied by B. Santosh Kumar that includes expansion valves, evaporator, condenser and the compressor. It is observed that the COP of spiral shaped condenser is maximum. There is an increase of COP to 18.8% in comparison with conventional copper condenser having COP value of 3.577. So this attempt was made to modify conventional condensers to spiral ones by varying their pitch from 1.5 to 2.25 inch. Vapor compression refrigerating system is a lot common now a days and its performance in various systems can be increased in many ways. The concept of two heat exchangers for the absorption of heat and for the removal of heat was firstly introduced by V Mahanadi Reddy. He explains that heat is absorbed by the evaporator and the removal of heat is done by the refrigerant which flows in the system and finally condenser condenses it in to liquid. They used two different refrigerants to compare condensers of domestically used refrigerators so they can achieve more COP. So they concluded that COP can be increased by helical shaped condenser coil in vapor compression refrigeration system because performance of the condensers helps to achieve more COP. The thermal performance of micro-channel heat sinks are also studied in detail for many reasons. One of the reasons was studied by Ryu et al that is to minimize thermal resistance through numerical optimization. For this purpose they had done a lot of things including variation in channel depths and width to get better solution for their numerical optimization solution. They concluded that in depicting the performance of a micro-channel heat sink, the width of the channel is one of the most important factors to be considered.
EXPERIMENTAL SET UP

In the automotive industry, millions of cars use micro channel technology for radiators, air conditioning condensers and oil cooler coils. The utilization of micro channel heat exchangers was initiated in the automotive industry in the late 1980s [7]. In the past, attempts to increase capacity have focused on increasing the surface area to accommodate higher heat transfer rates. In an industry in which cost, size and weight are significant concerns, it was important to find an alternative to increasing the surface area. Since the automotive industry could not accommodate larger coil sizes, they required more efficient thermal performance to allow for a smaller heat exchanger that would be more compact and not add weight or size to the vehicle. The industry turned to micro channel heat exchanger technology. This technology takes advantage of established heat transfer principles through the utilization of multiple small-channels in parallel to maximize heat transfer surface contact. More efficient heat transfer results in the ability to maintain or potentially reduce the amount of heat transfer surface required.

![Experimental Set-up](image)

Figure 1 Experimental Set-up

One of the most important parts of the any refrigeration cycle is the compression of the refrigerant since all the further operations depend on it. In vapor compression refrigeration system the compression of the refrigerant is done by compressor which can be reciprocating, rotating or centrifugal type. In vapor compression refrigeration system after compression of refrigerant, refrigerant goes to condenser for heat rejection. Conventional condenser will be replaced by micro channel heat exchanger to check the performance of System.
Data reduction

Rate of heat transfer for evaporator:

The heat transfer coefficients for evaporation are different than the conventional convection relations. The process by which the refrigerant changes from liquid to vapor is a combination of boiling and evaporation, although a clear distinction between the two is usually not made. For both mechanisms, the surface temperature is higher than the saturation temperature. In boiling, vapor is produced at the solid surface and bubbles up through the liquid to the surrounding vapor, while in evaporation the liquid changes phase at the interface between the liquid and the vapor. The process of evaporation on the outside of tubes is often described as nucleate pool boiling [8]. The term pool boiling refers to boiling from the hot tubes submerged in a pool of liquid, and nucleate refers to the boiling regime in which steady streams of small vapor bubbles are produced along the tubes. The bubbles rise to the surface of the refrigerant agitating the fluid and allowing cold liquid to flow to the tube surface and evaporate. The phase change occurs where the liquid is in contact with the surface, yielding high transfer rates. The refrigerating effect is calculated by the given formula

\[ Q = c_p \cdot (h_{\text{out}} - h_{\text{in}}) \]

- Here Q is the heat transfer,
- \( c_p \) is the specific heat at constant pressure for the R-22 refrigerant
- \( h_{\text{out}} \) and \( h_{\text{in}} \) are the outlet and inlet enthalpies respectively.

Rate of heat transfer for compressor

In compressor, the compressor takes the refrigerant at low temperature and pressure from the evaporator and compresses it at high temperature and pressure and then delivers it to the condenser which is also holds the high pressure refrigerant. In this all process the heat transferred by the compressor is sensible heat means that the compressor only risen the temperature and pressure of the refrigerant and the heat transferred by the compressor is given by the following formula:

\[ Q = m \cdot c_p \cdot (T_{\text{out}} - T_{\text{in}}) \]

- Here Q is the heat transfer,
- \( m \) is the mass of the refrigerant that is going to be compressed in the compressor.
- \( c_p \) is the specific heat at constant pressure for the R-22 refrigerant.
- \( T_{\text{out}} \) and \( T_{\text{in}} \) are the outlet and inlet enthalpies respectively.
COP Calculation

COP is abbreviated as the coefficient of performance and it is calculate by the relation of refrigerating effect and the work done by the compressor. The formula of cop is given below:

$$\text{COP} = \frac{\text{Refrigerating Effect}}{\text{Work Done}}$$

Or,

$$\text{COP} = \frac{c_p \times \text{input - heat}}{c_p \times (T_{\text{in}} - T_{\text{out}})}$$

Geometric properties

Peripheral area is given by the formula:

$$A = 2 \times l \times (w + h)$$

Where ‘L’ is the length, ‘w’ is the width and ‘h’ is the height of flattened tube of micro-channel heat exchanger. Hydraulic diameter of tubes can be calculated by the formula:

$$d = \frac{4A'}{P}$$

In the above equation ‘A’ represents the tube surface area and ‘P’ is the perimeter of the tubes.

Different types of dimensionless numbers have been used in our given study shown by the formula:

Reynolds number is given by the famous correlation:

$$Re = \frac{\rho V d}{\mu}$$

In the above equation ‘Re’ represents the Reynolds number, ‘velocity of the flow is denoted by V’, hydraulic diameter of the tubes is denoted by‘d’, ‘μ’ is the viscosity of the fluid.

The relation to calculate Nusselt number is given below

$$Nu = \frac{h d}{k}$$

In the above equation the convective heat transfer is denoted by ‘h’, the hydraulic diameter of the tubes by‘d’, and ‘k’ is the thermal conductivity of the fluid.
RESULTS AND DISCUSSION

The performance of vapor compression refrigeration cycle various considerably with the micro-channel condenser is calculated. These results are then comparing with traditional condenser which shows that micro-channel heat exchanger gives high COP than any other condenser. The formula of COP is given below:

\[
\text{COP} = \frac{\text{Refrigerating Effect}}{\text{Work Done}}
\]

To illustrate these effects, the calculated values at the different pressure existing and proposed systems have been plotted on the graphs. The relationships between existing and proposed systems i.e. using micro-channel condenser and performance parameter have been compared and shown in the following graphs.

**Chart 1: COP V/S Refrigerating Effect for Micro-Channel**

The above mentioned graph is for micro-channel heat exchanger and this graph is drawn between the value of COP and Refrigerating effect by taking the value of COP on y-axis because it is dependent on refrigerating effect across the evaporator.

**Chart 2: COP v/s Refrigerating Effect for Conventional**
The above mentioned graph is for conventional heat exchanger [9] and this graph is drawn similarly between the value of COP and Refrigerating effect by taking the value of COP on y-axis because it is dependent on refrigerating effect across the evaporator.

**Comparison**

Both the graphs are drawn between the same parameters but the only one part that can make a difference is condenser heat exchanger in our experiment we used micro-channel heat exchanger as a condenser and compare it with conventional condenser heat exchanger. Our heat exchanger is made up of totally silver and conventional heat exchanger tube is made up of copper, due to the high heat transfer value of copper we get better exchanged heat in micro-channel heat exchanger due to fine diameter tubes in the main channels and thus named as micro-channel heat exchanger. In our experiment used 1.5 TON capacity unit and we will get the maximum COP of 3.37 in a very large hall due to the unavailability of space but we get a handsome value of COP that is 3.37 as we can shown from the graph above. On the other hand on case of conventional heat exchanger we get a maximum COP of 3.09 with copper tube and we all know that it has high heat transfer rate operating under the same conditions as shown in the graph above. In both these graph both exchangers COP values increases with the increases in refrigerating effect and due to more surface area in micro-channel heat exchanger we get the maximum COP than conventional heat exchanger under the same operating conditions.

![Chart 3: COP V/S Temperature difference across compressor for Micro-Channel](chart3.png)

The above mentioned graph is drawn between COP and temperature difference across compressor for the micro-channel heat exchanger. In this graph it is clearly shown that COP and temperature difference across the compressor in inversely proportional with each other.
Greater the value of COP smaller will be the temperature difference or work done of compressor.

**Comparison**

From the above graph it is clearly shown that the value of COP is gradually increasing with the decrease in denominator value that is the work done by the compressor. In case of micro-channel heat exchanger compressor did less work when its couple of refrigeration cycles completed because the refrigerant evaporates efficiently in the evaporator due to the better condensing in the condenser that’s why for the upcoming cycle that is going to be enter in the compressor need to do less work in case of micro-channel heat exchanger. On the other hand, in case of conventional heat exchanger the condenser condenses the gas less efficiently due to less surface area and hence in this case compressor needs to do more work to compress the refrigerant at a desired temperature and pressure.

![Chart 4 COP vs Compressor Power for Micro-channel](chart.png)

The above mentioned graph is for micro-channel heat exchanger and this graph is drawn between COP value and the compressor power. It can be predicted that the value of COP increases when the compressor did less work and vice versa. In case of micro-channel heat exchanger, this is the same as work done by the compressor.

**CONCLUSION**

In the present experiment, review is carried for different experiments conducted for the micro-channel condenser of a vapor compression refrigeration system used for a domestic refrigerator. The data obtained from the fabricated experimental set-up is used to analyze the
performance of - condenser of a vapor compression refrigeration system with existing condenser of vapor compression refrigeration system. By incorporating the micro-channel condenser of the refrigeration system the C.O.P enhance of by 1.5%, as a result of 1.5% increase in refrigeration effect and 1% reduction in compressor work and same in heat absorption. When system pressure is slightly increased, the micro-channel heat exchanger increases the C.O.P compared to existing condenser, which is perhaps due to reduction in compressor work and increase in refrigeration effect. According to this micro-channel condenser of domestic refrigeration system performance is better as compared with privies general domestic refrigeration system.

REFERENCES