Review on Performance analysis of Vapour Compression Refrigeration System by using Microchannel heat exchanger

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***Abstract*— Most of the household refrigerators work on the Vapour compression refrigeration system which has high coefficient of performance. The system consists of components like compressor, condenser, expansion valve and evaporator. The system performance depends on the influence of all the components of the system. This paper presents the study of performance of different condenser by changing the pressure and change in COP of vapour compression refrigeration system, by changing the conventional condenser by micro channel heat Exchanger. Due to change of pressure there are changes in heat transfer rate for different condenser. Hence it is very essential to study and check the heat transfer mechanism occurring at condenser section. The heat transfer will help to study and control the various heat losses occurring at condenser section. In this paper coefficient of performance of different condenser is compared at different pressure and it is found that microchannel condenser gives higher performance than other condenser and also vapour compression refrigeration cycle gives different COP at different pressure.**

***Index Terms*— Vapour compression refrigeration, COP, micro channel heat exchanger**

I. INTRODUCTION:

The vapour compression system is widely used refrigeration system in practice. This refrigeration system works on the vapour compression cycle. This cycle requires the addition of external work for its smooth operation. Basically it consists of four processes namely: 1). Isentropic compression 2). Constant pressure heat rejection 3). Isenthalpic expansion 4). Constant pressure heat addition Change of state from 3 to 4 in Fig. 1.1 represents the expansion process using an expansion valve. The purpose of the expansion device is twofold it must drop the pressure of the liquid refrigerant, and also regulate the flow of refrigerant to the evaporator. Some common types of expansion devices, super heat controlled expansion valve, float valve and constant pressure expansion valve.

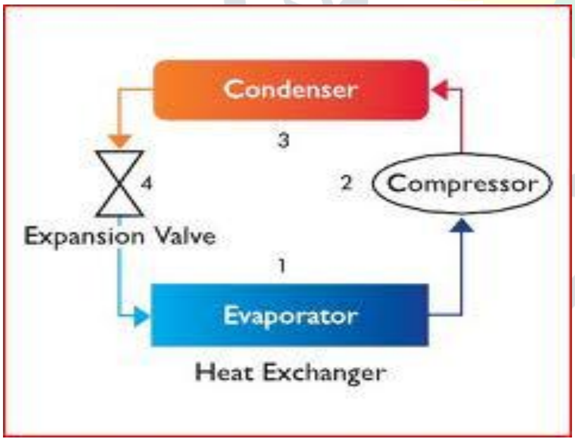

Figure.1.1: Vapour Compression Cycle layout

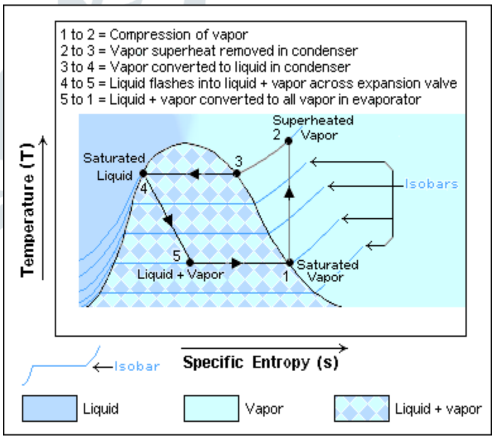

Figure.1.2: T-s diagram of Vapour Compression Cycle

In recent years, an important contribution on increasing the performance of these systems, sometimes to levels once inconceivable, was obtained by using Nano-technologies which have allowed the production of a new generation of compact heat exchangers with microchannel. Microchannel Heat Exchangers (MCHEX) have, according to the classification proposed by Kandlikar and Grande, a hydraulic diameter *h D* =0.2….0.01mm involving the advantage of a large heat exchange surface in a very small volume. Also, at very small sizes, the processes of heat and mass transfer occurring in the dynamic and thermal boundary layers are very effective. These new types of heat exchangers provide high heat transfer coefficients and thus they are up to 45% more compact than the classic ones, at the same thermal performances. Due to high thermal performance, MCHEX are used increasingly in both single-phase (liquid or gas) and two-phase heat exchange (condensation - evaporation); while the disadvantage of higher pumping power is compensated by the lower scale and cost obtained in the case of improved series production based on Nano-technologies series production improvement. Using the MCHEX in vapor compression refrigeration systems, micro channel tubes having a lower internal volume will reduce the amount of refrigerant charged in the plant.

Microchannel have received considerable attention especially in microelectronics, that has limited space and where fins, fans and baffles cannot be used because for the reason of size. Microchannel heat exchanger provides powerful means for dissipating high heat flux with small allowable temperature difference. The important characteristic of microchannel heat exchanger is smaller hydraulic diameter of channel result in large heat transfer coefficient in microchannel, as shown in figure 1.3. The channel cross-section is one of the prime factors for optimizing the performance of micro channel evaporator. Therefore, the main objective is to compare the various channel designs on the basis of second law of thermodynamics and to find the effect of different refrigerants on the performance of various designs of micro channel evaporator.

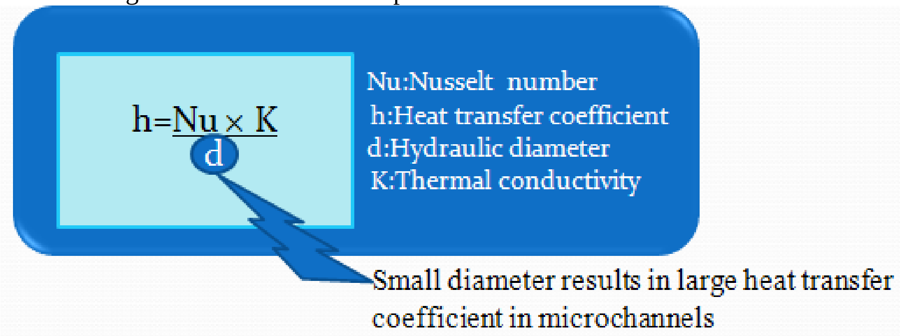

Figure 1.3 Relationship coefficient of conductivity and hydraulic diameter

II. LITERATURE REVIEW

Micro channel heat sink concept was first introduced by Tuckerman and Pease. The heat sink they manufactured was able to dissipate 790W/cm^2. Phillips, presented a detailed analysis of the forced convection, liquid cooled micro channel heat sinks [1]. Bergles et al. discussed the design considerations for small diameter internal flow channels. A design problem with given heat rate and chip dimensions was studied in detail, the main focus being on pumping power and material thickness required. They concluded that cooling systems having smaller diameter channels result in a compact system and generally does not impose a larger pumping power requirement. Fin effects were found to be significant in designs where thin solid sections were utilized [2].

Qu and Mudawar tested microchannel heat sink 1cm wide and 4.8cm long. The microchannel machined in the heat sink were 231μm wide and 712μm deep. Apart from this they also presented numerical analysis for a unit cell containing a single microchannel and surrounding solid. The measured pressure drop across the channels and temperature distribution showed good agreement with the numerical results. They concluded that the conventional Navier-Stokes and energy equations remain valid for predicting fluid flow and heat transfer characteristics in microchannel. [3]

Knight et al. presented the governing equations for fluid dynamics and heat transfer in the heat sink in a dimensionless form and then presented a scheme for solving these equations. Solution procedure for both laminar flow and turbulent flow through the channels was presented. [4]

B. Santosh Kumar has investigated that system consists of components like compressor, condenser, expansion valve and evaporator. The system performance depends on the performance of all the components of the system. Further an attempt is made in modifying the conventional shaped condenser to spiral shaped condenser and with varying pitch the performance of system is evaluated. Finally, it is noticed that spiral shaped condenser has given the maximum COP among all observations. They concluded that the conventional shape of condenser is again compared with spiral shape condenser by varying pitch from 1.5 inch to 2.25 inch. The optimum COP is obtained at 2-inch pitch of the coil of the value 4.25 for the spiral shape condenser which shows an increase of 18.8% when compared to the conventional copper condenser COP of value 3.577. [5]

V Mahanadi Reddy introduced that in vapor compression refrigerating system basically there are two heat exchangers. One is to absorb the heat which is done by evaporator and another is to remove heat absorbed by refrigerant in the evaporator and the heat of compression added in the compressor and condenses it back to liquid which is done by condenser. The performance of the condenser will also help to increase COP of the system. They concluded that the performance of vapor compression refrigeration system of domestic refrigerator can be increased by using helical shaped condenser coil and compared by using of two different refrigerants. [6]

Ryu et al. performed numerical optimization of thermal performance of micro channel heat sinks. The objective of the optimization was to minimize thermal resistance. They varied the channel width, channel depth and the fin thickness to come up with an optimized solution. Their observation was that the channel width is the most important parameter dictating the performance of a micro channel heat sink. [7]

Fundamental issues related to flow boiling in mini channels and microchannel. Flow boiling in small hydraulic diameter channels is becoming increasingly important in many diverse applications. The effects of the channel size on the flow patterns, and heat transfer and pressure drop performance are reviewed in the present paper. The fundamental questions related to the presence of nucleate boiling and characteristics of flow boiling in microchannel and mini channels in comparison to that in the conventional channel sizes (3 mm and above) are addressed. [8]

III. OBJECTIVES OF WORK

The objectives of paper are as listed below.

1. To study the heat transfer mechanism occurring at condenser section.

2. To study the performance of Micro channel heat exchanger and effect on Coefficient of Performance (COP) of the Vapour Compression System.
3. To study the change in coefficient of performance by changing the pressure.

IV. SCOPE OF MICRO CHANNEL

Micro channels have hydraulic diameter below 1 mm. Hydraulic diameter(d) is expressed as

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

Where A is the cross sectional area, and P is the perimeter. The small diameter tremendously enhances the properties of the micro channels. In heat transfer, components are made so that there is maximum possible heat transfer while they consume minimum energy. Considering small diameter of condenser coil, lesser volume of refrigerant charge is required thereby allowing the use of smaller capacity compressor which in turn reduces the energy consumption of the system. Micro heat exchangers, Micro-scale heat exchangers, or micro structured heat exchangers are heat exchangers in which fluid flows in lateral confinements with typical dimensions below 1 mm. The most typical such confinement are microchannel, which are channels with a hydraulic diameter below 1 mm. Micro channel heat transfer devices rely on process intensification afforded by the use of smaller fluid channels than are traditionally used, for example under 1 mm in characteristic diameter. For counter- and cross-flow heat exchangers, scaling rules can dictate a variety of performance features and pressure drop considerations. For example, if the cross-section area of a counter-flow heat exchanger is to remain constant, using smaller fluid channels results in a shorter device that uses less material (hence is lighter) and is more compact without a penalty in pressure drop. Other scaling rules do affect the pressure drop, and each case must be carefully considered for the approach to be used.

V. MATERIAL SELECTION OF MICRO CHANNEL

Copper material have many desirable properties for thermally efficient and durable heat exchangers. copper is an excellent conductor of heat. This means that copper has high thermal conductivity allows heat to pass through it quickly. copper in heat exchangers include its corrosion resistance, maximum allowable stress and internal pressure, creep rupture strength, fatigue strength, hardness, thermal expansion, specific heat, antimicrobial properties, tensile strength, yield strength, high melting point, alloy ability, ease of fabrication, and ease of joining. The combination of these properties enable copper to be specified for heat exchangers in industrial facilities, HVAC systems, vehicular coolers and radiators, and as heat sinks to cool computers, disk drives, televisions, computer monitors, and other electronic equipment. Copper is also incorporated into the bottoms of high-quality cookware because the metal conducts heat quickly and distributes it evenly. Non-copper based heat exchangers are also available. Some alternative materials include aluminium, carbon steel, stainless steel, nickel alloys, and titanium are also used. Copper known for its high thermal conductivity is undoubtedly the preferred choice in any heat conduction process. The metal having high ductility enables it to possess very good machinability, which is a vital consideration in the manufacturing of micro channels. Apart from good machinability Copper has high tensile strength, low thermal expansion, corrosion resistance. With these properties of Copper, it was easier to use it for making the condenser coil and bend it accordingly.

VI. MICRO CHANNEL HEAT EXCHANGER

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. 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.

In addition to benefits associated with thermal performance, the automotive industry was able to realize significant benefits related to the structural integrity of the coil design. Car condenser coils are located directly behind the front grill on a vehicle. Based on the exposure of the car condenser coil to many materials and elements, the rigid micro channel coil construction is better able to withstand oil, salt, material spills, sand, ash, and other chemical road treatments in all types of hot, humid coastal locations, or snowy environments. Furthermore, in contrast to traditional copper-aluminum coils, the aluminum microchannel coil design offers a significant reduction in galvanic attack between the materials of construction. From the use of microchannel heat exchangers in cars, the automotive industry has realized the following benefits:

- Reduced weight, which improves fuel economy
- Smaller components, which occupy less room under the hood
- More effective cooling
- Increased component life

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 vapour compression refrigeration system the compression of the refrigerant is done by compressor which can be reciprocating, rotating or centrifugal type. In vapour 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.

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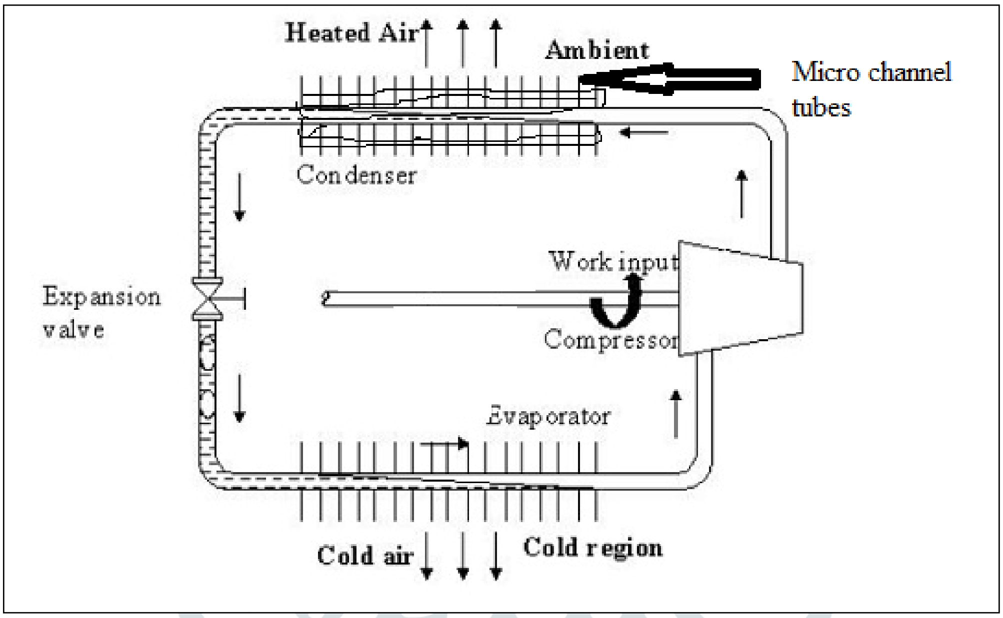
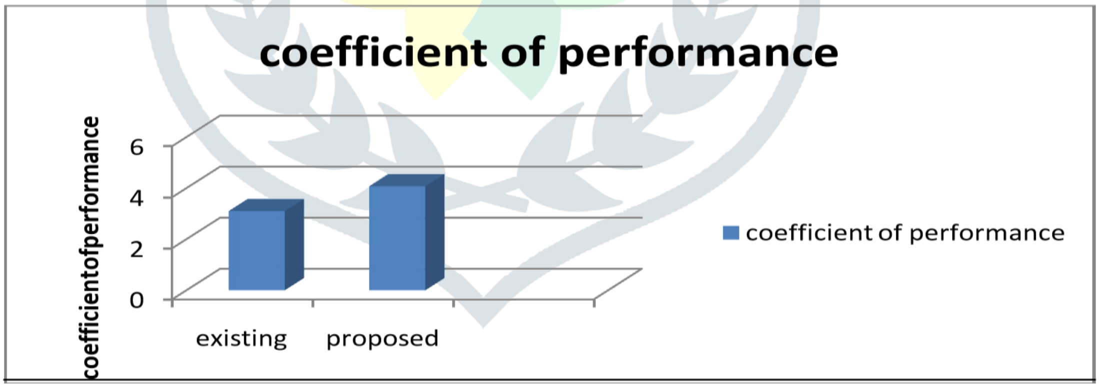


Figure 5.1: Simple VCC with Microchannel

VII. RESULTS AND DISCUSSIONS:

The performance of vapour compression refrigeration cycle various considerably with the microchannel condenser is calculated. These results is then compare with traditional condenser which shows that microchannel heat exchanger gives high COP than any other condenser. 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 microchannel condenser and performance parameter have been compared and shown in the following graphs.

1. **Effect of at the pressure 15 psi of microchannel condenser on coefficient of performance**

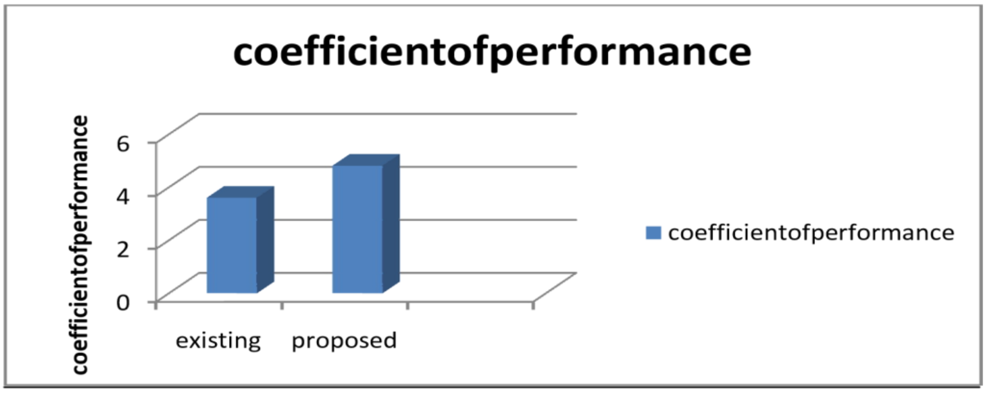


Graph1: Effect of at the pressure 15psi of microchannel condenser on coefficient of performance

Referring to graph-1, it is seen that the performance of the Refrigeration system increases as the coefficient of performance of the microchannel condenser increases. Because of further increase in pressure due to friction, the cooling performance, and velocity increase in the evaporator coil. It increases the mass flow rate of refrigerant and unbalanced conditions can be avoided

2.Effect of at the pressure 24 psi of microchannel condenser on coefficient of performance:

Referring to the graph-2, it is seen that compressor power decreases as the length of the microchannel condenser. Here compares proposed system is more than existing system of coefficient of performance.



Graph2: Effect of at the pressure 24psi of microchannel condenser on coefficient of performance

VIII. CONCLUSIONS:

In the present paper, review is carried for different experiments conducted for the microchannel condenser of a vapour compression refrigeration system used for a domestic refrigerator. The data obtained from the fabricated experimental set-up is used to analyze the performance of microchannel condenser of a vapour compression refrigeration system with existing condenser of vapour compression refrigeration system. By incorporating the microchannel 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 microchannel 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 microchannel condenser of domestic refrigeration system performance is better compared with privies general domestic refrigeration system.

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