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ANALYSIS THE SIMULATION OF VAPOUR COMPRESSION REFRIGERATION SYSTEM CIRCUIT FLOW THROUGH CFD- A BRIEF REVIEW

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Abstract - The performance of heat transfer is one of the most important research areas in the field of thermal engineering. There are a large number of refrigerants, which are used to transfer heat from low temperature reservoir to high temperature reservoir by using vapour compression refrigeration system. Various affecting parameters like compressor discharge temperature, pressure ratio, volumetric cooling capacity (VCC), volumetric efficiency and mass flow rate are analyzed to calculate the performance of the vapour compression refrigeration system.

In this paper presents different types of refrigerant using in vapour compression refrigeration system and reviewing the performance of system with different refrigerants. In this paper, we mainly focus on the mass flow rate on evaporator, compressor, throttle value and capillary tube.

Index Terms— Vapour compression refrigeration cycle, CFD analysis, Refrigerant, Volumetric efficiency

I. Introduction

Refrigeration technology is commonly used in domestic and industrial applications. The basic principle of refrigeration is simple. You simply pass a colder liquid continuously around the object that is to be cooled. This will take heat from the object. In the example shown, a cold liquid is passed over an apple, which is to be cooled. Due to the temperature difference, the apple loses heat to the refrigerant liquid. The refrigerant in turn is heated due to heat absorption from the apple. It is clear that, if we can produce cold liquid refrigerant continuously, we can achieve continuous refrigeration. This simple fact forms the core of the refrigeration technology. We will next see how this is achieved. It has 4 main components: compressor, condenser, evaporator, and throttling device. Of these components, the throttling device is the one that is responsible for the production of the cold liquid. So we will first analyze the throttling device in a detailed way and move on to the other components. The throttling device obstructs the flow of liquid; cold liquid is produced with the help of this device. In this case, the throttling device is a capillary tube. The capillary tube has an approximate length of 2 m and an inside diameter of around 0.6 mm, so it offers considerable resistance to the flow. For effective throttling at the inlet, the refrigerant should be a high-pressure liquid. The throttling device restricts the flow, which causes a tremendous pressure drop. Due to the drop in pressure, the boiling point of the refrigerant is lowered, and it starts to evaporate. The heat required for evaporation comes from the refrigerant itself, so it loses heat, and its temperature drops. If you check the temperature across the throttling device, you will notice this drop.It is wrong to say that the throttling is a process. We know only the end points of throttling, that is, the states before and after throttling. We don't know the states in between, since this is a highly irreversible change. So it would be correct to call throttling a phenomenon rather than a process. The next phase is simple: this cold liquid is passed over the body that has to be cooled. As a result, the refrigerant absorbs the heat. During the heat absorption process, the refrigerant further evaporates and transforms into pure vapor. A proper heat exchanger is required to carry the cold refrigerant over the body. This heat exchanger is known as an evaporator. So we have produced the required refrigeration effect. If we can return this low-pressure vapor refrigerant to the state before the throttling process (that is the high-pressure liquid state), we will be able to repeat this process. So first step, let's raise the pressure. A compressor is introduced for this purpose. The compressor will raise the pressure back to its initial level. But since it is compressing gas, along with pressure, temperature will also be increased. This is unavoidable. This heat exchanger is fitted outside the refrigerator, and the refrigerant temperature is higher than atmospheric temperature. So heat will dissipate to the surroundings. The vapor will be condensed to liquid, and the temperature will return to a normal level. So the refrigerant is back to its initial state again: a high-pressure liquid. We can repeat this cycle over and over for continuous refrigeration. This cycle is known as the vapor compression cycle. Refrigeration technology based on the vapor compression cycle is the most commonly used one in domestic and industrial applications.

A. Refrigeration Accessories

You can find more details on refrigerator components here. Evaporators and condensers have fins attached to them. The fins increase the surface area available for convective heat transfer and thus will significantly enhance heat transfer. Since the evaporator is cooling the surrounding air, it is common that water will condense on it, forming frost. The frost will act as an insulator between the evaporator heat exchanger and the surrounding air. Thus it will reduce the effectiveness of the heat removal process. Frequent removal of frost is required to enhance the heat transfer. An automatic defrosting mechanism is employed in all modern refrigerators.

B. Compressor

Apart from raising the pressure, the compressor also helps maintain the flow in the refrigerant circuit. Usually, a hermetically sealed reciprocating type compressor is used for this purpose. You might have noticed that, your household refrigerator consumes a lots of electricity compared to the other devices. In a vapor compression cycle, we have to compress the gas; compressing the gas and raising pressure is a highly energy intensive affair. This is the reason why the refrigerator based on the vapor compression refrigeration technology consumes a lot of electricity.

C.Coefficient of Performance

The heat and power transfer happening in a vapor compression refrigeration circuit. A simple energy balance of the system yields the following relationship.

$$P_{in} + Q_{ABSORBED} = Q_{REJECTED}$$

It is often required to evaluate performance of a refrigerator or compare between different refrigeration technologies. A term called Coefficient of Performance (C.O.P) helps in doing this. To understand this term completely, we need to know what is the input and output of a refrigeration system. What we need from a refrigerator is the cooling effect. Or QABSORBED is the output of a refrigeration cycle. Input to the refrigerator is the power given to the compressor. So the term C.O.P can easily be defined as output by input and is expressed as follows.

$$C.O.P = \frac{Q_{ABSORBED}}{P_{in}}$$

II. LITERATURE REVIEW

K.Rajasuthan, M.PalPandi [1] is studied All the conventional automobiles, thermal power plant, refineries use VCR system for air conditioning purposes. VCRS system utilizes the engine shaft power as input to drive the compressor. We develop a VAR system using Electrolux which is coupled to an IC Engine. IC Engine has an efficiency of about 35-40% which means that only 1/3rd of the energy is converted into useful work and about 60-65% is wasted.In Vapour Absorption Refrigeration system , a physicochemical process replaces the mechanical process of VCRS by using the energy in the form of heat rather than mechanical work.The heat required to run the VARS can be obtained from the Exhaust of the IC Engine. As VARS uses ammonia refrigerant. It cannot be used for domestic purposes. As the future scope, NH3 is replaced by LiBr as refrigerant.

Mohan M. Tayde, Lalit B. Bhuyar, Shashank B. Thakre [2] is studied a mini-scale scale vapour compression refrigeration system of 300 Watt cooling capacity using R134a as a refrigerant was designed, built and tested. This system includes a commercial miniature compressor, capillary tubes, a custom-made condenser and cold plate i.e. micro channel evaporator. The experimental results show that the system was able to dissipate CPU heat fluxes of approximately 48 W/cm2 and keeps the junction temperature (Predicted chip) below 82 ˚C for a chip size of 25X25 mm2. After extensive experimental investigation, the main energy losses occurring in the condenser, evaporator and compressor were highlighted. The experimental results also indicate that the compression ratio of the compressor was 3 and the coefficient of performance of the developed system was 1.6 with second law efficiency of 19%. The refrigerant charge quantity was 200 gm and the optimal capillary tube length was 850 mm.

MD. Mansoor Ahamed, J.Kannakumar, P.Mallikarjuna reddy [3] is concluded that use of PCM in the walls of a cold store can limit the rise in air temperature inside the cold storage during loss of electricity. As the PCM melts, it absorbs the thermal load that enters the cold storage space, thus limiting the rise in the cold store temperature. The experimental results shows that PCM could be utilised to limit temperature rises during loss of electrical power, which may occur due to an accidental power loss or done purposely to achieve electrical load shifting. The modelling was extended to predict the temperature changes in a large cold store and the results also indicate that PCM can limit the rise in air temperature. This modelling work can be extended to investigate the effects of increasing the surface area, and positioning of PCM panels in different way. It is also observed that when power supply is off this technique is cheapest when compared to other alternate power sources.

Shubham R. Yennawar, Prajyot P. Borkar, Akshay S. Harkare,Vishnu L. kale,Abhilash K. Kamble,Vineet A. Bhandari [4] is concluded a performance analysis of vapour compression refrigeration system with using refrigerants like R-134a & R-600a (Isobutane). Various performance measures like compressor discharge temperature, pressure ratio, volumetric cooling capacity (VCC), volumetric efficiency and mass flow rate are analyzed. The performance in term of coefficient of performance (COP), refrigerating capacity (RC), and compressor work (We) were evaluated for the investigated refrigerants at various evaporating and condensing temperatures. The system performance increases as the evaporating temperature increases, but reduces as the condensing temperature increases. The COP of R134a obtained was lower than R-600a (isobutane).

Naveen Prakash.G, Diwkar.B, Arul Anand.M, Panneer Selvam.N, Saravanakumar.R [5] is concluded Refrigerator is a device which keeps the system temperature below the atmosphere temperature. This uses refrigerant to remove heat from the system. The refrigerant is passed through the condenser to change the phase of the refrigerant from vapour to liquid, means latent heat transfer occurs in the condenser. The condenser used in the domestic refrigerator is of circular cross section. In this project an attempt has been made to change the cross section of condenser from circular to elliptical and corresponding heat transfer rate is calculated. From the literature review it is proposed that the heat transfer rate is increased in elliptical tube. In this heat transfer rate is increased by increasing the surface area of the condenser. The heat transfer rate is increased because of the increase in slenderness of the elliptical tube which offers resistance to flow of the refrigerant.

Shashank shekhar pathak, Prakhar shukla, Sanjeev chauhan [6] is concluded study the effect of capillary tube geometry on the performance of refrigeration systems. The literature review focuses on the effect that geometrical parameters like capillary tube length, bore diameter, coil pitch, number of twist and twisted angle have on the pressure drop, coefficient of performance (COP) and mass flow rate of the system. These parameters can be further studied using physical models and mathematical modeling concepts. The parameters stated above can be further optimized in order to enhance the performance of the refrigeration system.

Chethan kumar R, Dr. C. Badarinath, Mohan Kumar.C.P, H.V.Harish [7] is concluded vapour compression refrigerant plant was taken where the variables like suction pressure of compressor, delivery pressure of compressor, temperature of evaporator and condenser are noted and coefficient of performance is calculated. The results obtained will be validated through CFD simulation.
Further diffuser has been introduced in between compressor and condenser so that power input to the compressor has been reduced there by enhancing COP The enhancement will be done through CFD simulation; Modeling and meshing will be done in ICEMCFD, analysis in CFX and post results in CFD POST.

T. Coumaressin and K. Palaniradja [8] is concluded effect of using CuO-R134a in the vapour compression system on the evaporating heat transfer coefficient was investigated by CFD heat transfer analysis using the FLUENT software. An experimental apparatus was build according to the national standards of India. The experimental studies indicate that the refrigeration system with nano-refrigerant works normally. Heat transfer coefficients were evaluated using FLUENT for heat flux ranged from 10-40 kW/m2, using nano CuO concentrations ranged from 0.05-1% and particle size from 10-70 nm. The results indicate that evaporator heat transfer coefficient increases with the usage of nano CuO.

Andri Alexio Manzela, Jose Ricardo [9] is concluded prototype of the refrigerating unit was fabricated and the whole system was coupled with an IC engine. The system was made to run and it was observed that a cooling effect was obtained at the evaporator.
The COP of the system was found to be decreasing in the first 30 minutes then it shows an increase in COP with increase in time. Due to the improper cooling facility given to the air cooled 4 stroke petrol engines the experiment was conducted for 90 minutes, so we could not obtain the actual variation in COP, conducted the experiment for 5-10 hrs.

The temperature of the evaporator was found to be decreasing as expected. The refrigeration effect increased in the first 30 minutes then it shows a decrease in COP with increase in time for the next 30 minutes. After one hour the refrigeration effect shows a gradual increase.

III. Conclusion

Cooling of electronic equipments has become an important issue as the advances in technology enabled the fabrication of very small devices. The main challenge in cooling is the space limitation. The use of miniature refrigerators seems to be a solution alternative for the cooling problem. The objective of this study is to design and simulate a vapor compression refrigeration cycle . A CFD programming is developed for the simulations. The four components of the refrigerator, namely, the condenser, evaporator, compressor and the capillary tube are designed separately. The cycle is successfully completed nearly at the same point where it begins. The cold space temperature, ambient air temperature, condensation and evaporation temperatures, and the evaporator heat load are the predetermined parameters.

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