

Design, Fabrication and Experimental Analysis of Vapour Compression Refrigeration System with Ellipse shaped Evaporator coil

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ABSTRACT: A refrigerator is machine which cool and maintain a body at a temperature below that of surrounding. Majority of refrigerator system works on vapour compression refrigeration system. This system consists of compressor, condenser, expansion valve and evaporator. The performance of the system depends upon these system components. The main objective of the project is to increase the performance of the system by increasing the heat transfer rate through the evaporator. Heat transfer from the evaporator increased by the changing the shape of the evaporator and by extended surfaces. In view of the above it is proposed to fabricate the ellipse shaped evaporator coil and to carry out the experimental investigation on it evaluate it performance and to compare it with the existing evaporator in the vapour compression refrigeration system. In this experiment involves 165 Litres capacity of domestic refrigerator which in turn results the better performance than the previous one, and same results can be seen in the coefficient of performance.

KEYWORDS: Vapour compression refrigeration system, Ellipse shaped evaporator coil, Pressure and temperature indicators.

I. INTRODUCTION

The vapour compression system is the most widely used refrigeration system in practice. This refrigeration system adopts the vapour compression cycle. This cycle requires the addition of external work for its 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 (c) to (d) in Fig. 1.1 represents the expansion process using an expansion device. 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. Fig 1.2(a) and 1.2(b) shows simple vapour compression refrigeration cycle on T-s and p-h co ordinates.

The ellipse shape coil is used in almost all small refrigeration systems. Vapour refrigerant enters the ellipse shaped evaporator coil and as it flows through the suction pressure, the pressure drops because of friction and acceleration of the refrigerant. Some of the liquid flashes into the vapour as the refrigerant flows through the coil. Once the ellipse shape coil has been selected and installed, it cannot adjust to the variations in discharge pressure, suction pressure or load. Compressor and expansion device must arrive at suction and discharge conditions such that the compressor pumps the same flow rate of the refrigerant from the evaporator that the expansion device feeds. The designer of a new

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refrigeration unit employing a ellipse shaped coil must select the bore and length of the coil so that the compressor and its components operate under balanced operating condition at the desired evaporator temperature.

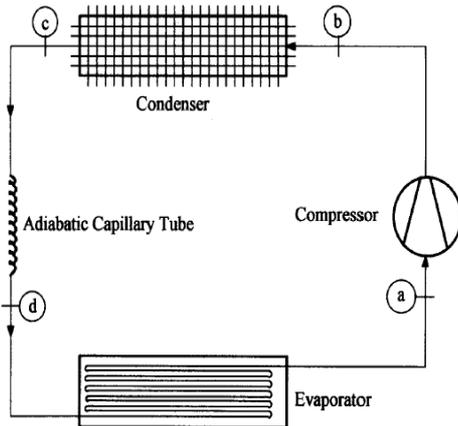


Fig. 1.1 Schematic diagram of vcr

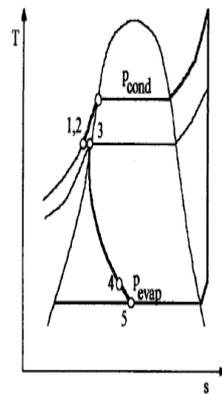


Fig. 1.2(a) T-s coordinates

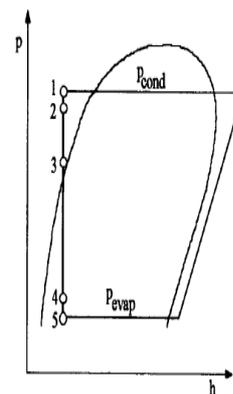


Fig1.2(b) p-h coordinates.

II. RELEVANT WORK

Vapour compression refrigeration system has been in use for many decades in many engineering applications. Even though there are many types of evaporator coil, the most commonly used device for low capacity systems. Physical models aid mathematical models in representing the physical phenomena taking place in the flow and transfer processes and in improving the accuracy of prediction. Empirical correlations are also necessary to predict the mass flow rate for a given ellipse shaped coil and the operating conditions.

Bolstad and Jordan [1948] performed the first major study on evaporator flow and tried to explain that an undetermined error of flow rate prediction of refrigerant in an adiabatic evaporator coil might be due to the assumption of the thermal equilibrium in two-phase flow. Authors also presented an analytical solution for adiabatic evaporator coil based on the homogeneous flow and constant friction factor. The flow equations were solved using simplified methods based on the conservation of mass, energy and momentum. Later, authors did a similar study by using vapour viscosity for the calculation in place of two-phase Reynolds number.

Mikol and Dudley [1963] reported experimental study of adiabatic single-phase and two-phase flow in capillary tubes. Their work involved visual studies of refrigerant flow in glass capillary tubes and data collection while using copper capillary tubes. Authors first obtained typical distributions of pressure and temperature along the adiabatic capillary tube, which included the region of metastable flow. Mikol and Dudley [1964] used photographic means to improve upon the observations of Cooper *et al.* [1957]. In their experiments, the maximum length of the metastable flow was 0.7 m.

III. OBJECTIVE AND SCOPE

Objective and scope of the present work are

- To perform studies on the ellipse shaped evaporator coil of vapour compression refrigeration system with alternative refrigerant.
- To numerically simulate the helical ellipse shape coil to understand the vapour flow and heat transfer involved in the system.
- To study experimentally the effect of the coil diameter and the tube diameter on the performance of the vapour compression refrigeration system.
- To compare experimentally evaluated results with that obtained by numerical simulation.

IV. ELLIPSE SHAPED EVAPORATOR COIL

The ellipse shape coil used as an expansion device in small capacity hermetic sealed refrigeration units such as in domestic refrigerators water coolers room air conditioners, especially in small capacity installations. It is a copper tube of small internal diameter and of varying length depending upon the application. The inside diameter of the tube used in refrigeration work is generally defreeze box aluminium. But here ellipse shaped coil .at the inlet of the coil in order to protect it from contaminants.

In its operation, the liquid refrigerant from the condenser enters the capillary tube. Due to the frictional resistance offered by a small diameter tube, the pressure drops, since the frictional resistance offered by a small diameter tube, the pressure inversely proportional to the diameter, therefore longer the ellipse shape coil and smaller its inside diameter, greater is the pressure drop created in the refrigerant flow, in other words, greater pressure difference between the condenser and evaporator is needed for a given flow rate of the refrigerant. The diameter and length of the ellipse shape coil once selected for a given set of conditions and load cannot operate efficiently at other conditions.

The refrigeration system, using ellipse shaped coil, has the following advantages:

1. The cost of ellipse shaped coil is less than all other forms of evaporator.
2. When the compressor stops, the refrigerant continues to flow into the evaporator and equalizes the pressure between the high side and low side of the system. This considerably decreases the starting load on the compressor. Thus a low starting torque motor (low cost motor) can be used to drive the compressor, which is a great advantage.
3. Since the refrigerant charge in a evaporator system is critical, therefore no receiver is necessary.
4. Ellipse shaped coil does not have threaded or moving parts there by the cost of maintenance and repair is almost negligible. The major disadvantage of using expansion valve is the refrigerant must be free from contaminants otherwise they will block the passage and may lead to damage of the system.

Fig (2) shows the plots of mass flow rate of compressor and the mass flow rate of capillary with varying suction pressure. At high condensing pressures, the feeding rate of capillary increases due to high pressure difference across the tube. The plots of compressor are also shown for different condensing temperature.

For example, for 30 c condensing temperature, the capillary and compressor match at a particular suction pressure which allows them to handle the same flow rate of refrigerant. Such a point is shown as B. similar matching points at 40 c and 50 c are A and C resp.,

Fig (3) shows the fabrication of evaporator coil it is in the shape of ellipse which is made by cooper tube and it is welded to the bottom of the evaporator. This evaporator is made by the iron sheet in a shape of rectangular. The refrigerant flow through the evaporator coil from the outlet of the capillary tube.

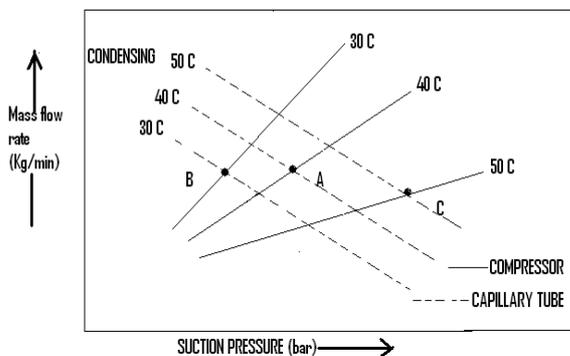


Fig: 2. Actual vapour compression refrigeration cycle



Fig.3. Ellipse Shaped Evaporator Coil

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v. EXPERIMENTAL SETUP

Experimental study on a system helps to evaluate its performance experimentally under varying operating conditions. Comparing this performance with that of the theoretical studies help in understanding the acceptability limits. In this line, the performance of the helical capillary tubes is studied experimentally. Effects of various parameters like mass flow rate, inner diameter, length, coil diameter, etc over a range of operating conditions are studied. The detailed description of the experimental system, various components of the system, controls and measurements systems and experimental procedure are presented

Fig (4) shows the pictorial back view of the experiment in this experiment four gauges are fixed those are at compressor, condenser, capillary tube and expansion valve. By using of this pressure gauges here we can measure the pressure. Temperature can be measured by the thermometer.



Fig. 4. Pictorial back view of the experiment

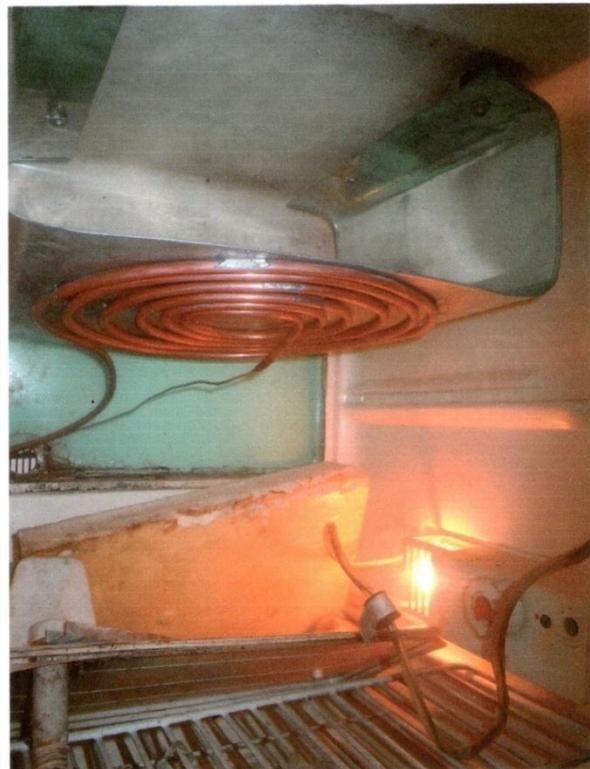


Fig. 4.1 Pictorial Front view of the experiment

Fig (4.1) Shows the Pictorial front view of the experiment here the final assembly of the evaporator is fixed at the top side of the refrigerator. The flow of refrigerants through helical evaporator coils. In practical situations, the capillary tube is not adiabatic. Diabetic nature of the evaporator coil is not considered in any of the models developed. Two phase flow in diameter coils may be also not entirely homogeneous due to the phase interaction. Separated flow model seems promising for predicting the performance of the evaporator coils and will be more appropriate for designing the evaporator coils.

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VI. DESCRIPTION OF THE EXPERIMENTAL SETUP

- **Test rig is a single stage vapour compression refrigeration system of 165 LTRS capacity. Figure 4. Shows the experimental setup. This test rig mainly consists of compressor, condenser, expansion device, and evaporator.**

The high-pressure gas from compressor flows through an oil separator where the compressor lubricant oil and refrigerant are separated and oil is fed back to the compressor. Compressed high-pressure gas is condensed in an air cooled condenser. A sight glass is provided to see the condition of refrigerant entering to the expansion valve. The liquefied and sub cooled refrigerant from the receiver enters into the expansion valve. A manually controlled needle valve in parallel is used to maintain constant pressure in the evaporator. A refrigerant flow meter is provided at the inlet of the expansion valve to measure volume flow rate of the refrigerant. A water tank with the facility for controlling temperature of the content with temperature sensors was used to reduce the temperature of coolant water at high temperature. Evaporator pressure is controlled by varying the electrical load. Temperatures at various locations were measured using digital thermo meter.

Gauges at 6 locations in the system as given below.

- 1). Discharge pressure of compressor
- 2). Suction pressure of compressor
- 3). Pressure at the outlet of condenser
- 4). Pressure at the ellipse shape coil inlet
- 5). Pressure at the ellipse shape coil outlet
- 6). Pressure at the inlet of evaporator

VII. EXPERIMENTAL PROCEDURE

Experimental procedure, which is carried out during the experiment, is given below:

- a) The vapour compression refrigeration is switched on
- b) The required evaporator temperature is attained, by adjusting the expansion valve and maintained constant
- c) The required degree of super heat is maintained by regulating the water flow rate and its temperature through the evaporator.
- d) The required condensing temperature and pressure are attained by varying the inlet flow rate of air.
- e) The data acquisition system at frequent intervals
 - Temperature at inlet and outlet for all the components.
 - Pressure at the inlet and exit for all the components.

Parameters which affect the performance of the system are flow rate of refrigerant, flow rate of air, capillary inner diameter, tube length, capillary coil diameter, condensing pressure, sub cooling and evaporating pressure.

VIII. EXPERIMENTAL RESULTS

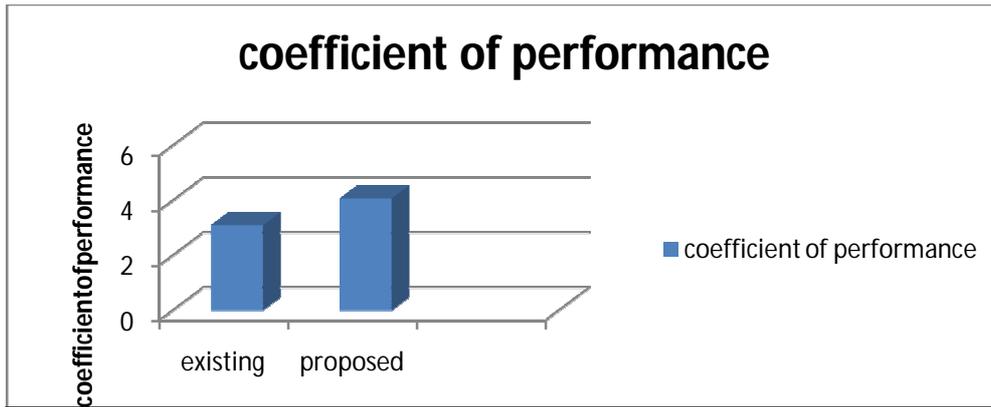
The performance of vapour compression refrigeration cycle varies considerably with the ellipse shapes coil has greater effect. To illustrate these effects the calculated values at the different pressure existing and proposed systems have been plotted on the graphs. The relationships between existing and proposed systems ratio of ellipse shaped coil and performance parameter have been compared and shown in the following graphs.

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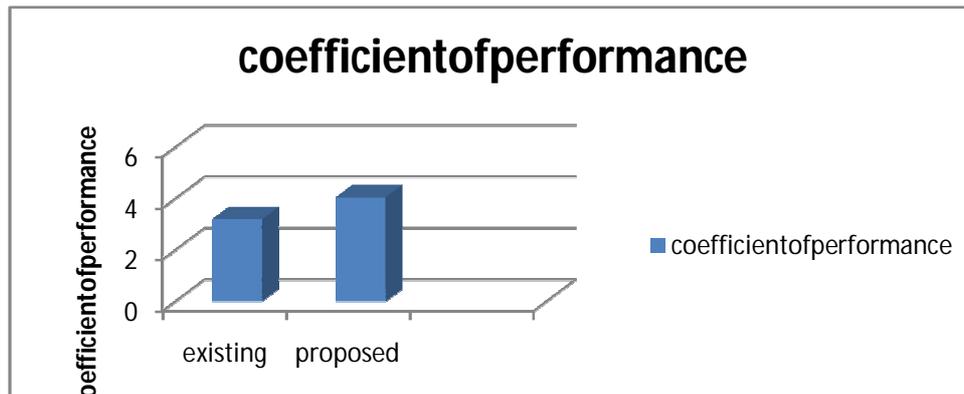
1. Effect of at the pressure 15psi of ellipse shaped coil on coefficient of performance



Graph1: Effect of at the pressure 15psi of ellipse shaped coil 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 ellipse shapes coil 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 17psi of ellipse shaped coil on coefficient of performance



Graph2: Effect of at the pressure 17psi of ellipse shaped coil on coefficient of performance

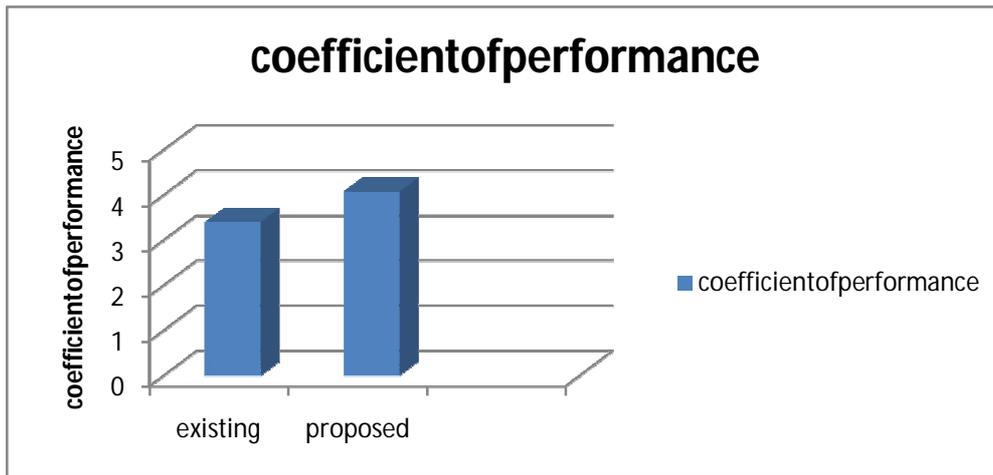
Referring to the graph-2, it is seen that mass flow rate of refrigeration system decreases as the existing and proposed system ratio of ellipse shaped coil increases

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3. Effect if at the pressure 20psi of ellipse shaped coil on coefficient of performance:

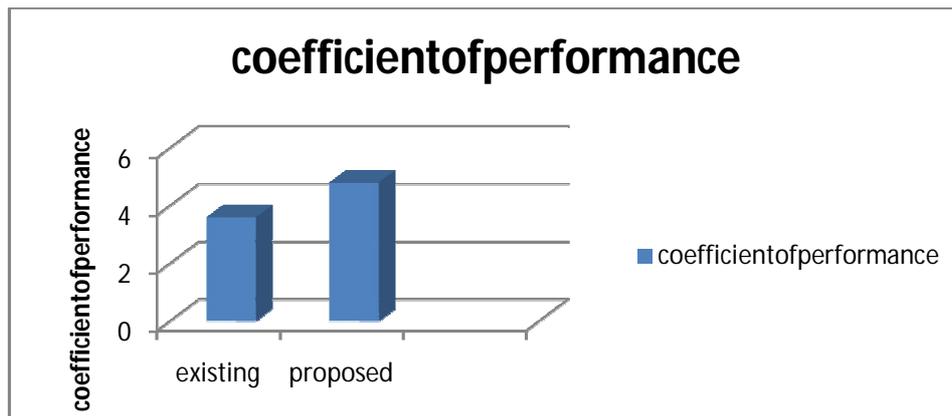


Graph3: Effect of at the pressure 20psi of ellipse shaped coil on coefficient of performance

Referring to the graph-3,the proposed system is greater than existing system in ellipse shaped evaporator coil

4.Effect of at the pressure 24psi of ellipse shaped coil on coefficient of performance:

Referring to the graph-4, it is seen that compressor power decreases as the length of the ellipse shaped coil. Here compare proposed system is more than existing system of coefficient of performance.



Graph4: Effect of at the pressure 24psi of ellipse shaped coil on coefficient of performance

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VIII. CONCLUSION

In the present work, experiments are conducted for the ellipse shaped design evaporator of a vapour compression refrigeration system used for a domestic refrigerator of 165 liter's capacity.

The data obtained from the fabricated experimental set-up is used to analyse the performance of ellipse shaped evaporator of a vapour compression refrigeration system with existing evaporator of vapour compression refrigeration system.

By incorporating the ellipse shaped evaporator 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.

Further, system pressure is slightly increased, the ellipse shaped evaporator increases the C.O.P compared to existing evaporator, which is perhaps due to reduction in compressor work and increase in refrigeration effect According to this ellipse shaped evaporator of domestic refrigeration system performance is better compared with privies general domestic refrigeration system

REFERENCES

1. **Ali, M. E.** (1998) Laminar natural convection from constant heat flux helicoidal tubes, *International Journal of Heat and Mass Transfer*, **41**, 2175-2182.
2. **Ali, S.** (2001) Pressure drop correlations for flow through regular helical coil tubes, *Fluid Dynamics Research*, **28**, 295-310.
3. **ASHRAE Handbook Fundamentals**, (1997)
4. **Awwad, A., R.C. Xin, Z.F. Dong and H.M. Soliman** (1995) Measurement and correlation of the pressure drop in air water two phase flows in horizontal helicoidal pipes, *International Journal of Multiphase Flow*, **21**, 607-619.
5. **Bansal, P.K.** and **A.S. Rupasinghe** (1996) An empirical model for sizing capillary tubes, *International Journal of Refrigeration*, **19**, 497-505.
6. **Bansal, P.K.** and **A.S. Rupasinghe** (1998) A homogeneous model for adiabatic capillary tubes, *Applied Thermal Engineering*, **18**, 207-219.
7. **Bansal, P.K.** and **B. Xu** (2003) A parametric study of refrigerant flow in non adiabatic capillary tubes, *Applied Thermal Engineering*, **23**, 397-408.
8. **Bansal, P.K.** and **G. Wang** (2004) Numerical analysis of choked refrigerant flow in adiabatic capillary tubes, *Applied Thermal Engineering* **24**, 851-863.
9. **Rowland, F.s.,M.J.Molina**(1989) Am Sci 77,36(1989).
10. **Churchill, S.W.** (1977) Friction factor equation spans all **Wong, T.N.** and **K. T. Ooi** (1996) Evaluation of capillary tube performance for CFC-12 and HFC 134a, *International Communications in Heat and Mass Transfer*, **23**, 993-1001.
11. **Xu, B.** and **P.K. Bansal** (2003) Non-adiabatic capillary tube flow: a homogeneous model and process description, *Applied Thermal Engineering*, **22**, 1801-1819.
12. fluid flow regimes, *Chemical Engineering*, **84**.

BIOGRAPHY

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