Comparison Performance of the Elliptical Flow Condenser for a Domestic Refrigerator with Wire-on-Tube Condenser

Dheya Ghanim Mutasher
University of Technology / Mechanical Engineering Department
Email: dheya_ghanim@yahoo.com

Abstract

This paper presents an experimental investigation into the performance of a novel design of condenser consisted of number of loops as elliptical shape for domestic refrigeration system and comparison with wire-on-tube condenser. The purpose of this study is designing and manufacturing a new type of condensers (Elliptical condenser) that depends on the experimental data by heat exchanger performance under various operating conditions. The experiment was conducted with a refrigerator designed to work with HFC134a, under no load and with loads (1.5,3 and 12 litters of water). The results showed that the work done by the compressor decreases with elliptical condenser, and then the power consumption also decreases about (0.3Amp to 0.5Amp). Also, the effects of shape change of the condenser were very important in enhancement heat transfer rate and reduction the frictional loss as result of reducing the pressure drop in the condenser. Therefore, the elliptical condenser can be used instead of the wire-on-tube air cooled condenser in a domestic refrigeration system.

Keywords- Heat Transfer, Household Refrigerator, Elliptical Condenser, Wire-on-Tube Condenser,

A refrigerator condenser is one of the main operating components that make up the cooling system on a standard refrigerator. The refrigerant vapour condenses in the condenser by rejecting heat to an external fluid. Wire on tube heat exchanger has been used in refrigerating systems for many decades. In the present paper, heat exchanger as elliptical shape without fins with natural air movement will be considered.

The thermal performances of various kinds of wire on tube heat exchanger have been reported by many works. The report of Witzell and Fontaine [1] in (1957) studied condenser, got correction for condenser, and concluded that any additional of wire on the external surface of condenser did not increase the rate of heat transfer from condenser. Kirshbaum and Chato [2] (1996) modified program developed previously to optimize condenser size with respect to surface area. Also developed method of modeling pipe bends incorporating pressure drop correlation. Wilson et al. [3] (2003) investigated experimentally effect of tube profile change from round to flat shape on condensation heat transfer coefficient. Choi et al. [4] (2004) introduced the new design wire woven heat exchanger using small tube diameter. Nuntaphan et al. [5](2010) presented a new design by taking an oscillating heat pipe as extended surface of a wire-on- tube, investigated the thermal performance of a newly designed wire-on-tube heat exchanger and developed a semi-empirical model for predicting heat transfer characteristics. They concluded that the heat transfer rate of wire-on-tube heat exchanger can be enhanced by using an oscillating heat pipe. Gupta et al. [6](2013) used a method such as tilting of the condenser tube with respect to horizontal and calculating the heat transfer rate and the amount of heat transfer increased by providing some angle of inclination from the horizontal. They observed with use of convergent divergent construction of condenser can enhance the heat transfer rate. However, all of the previous works used wire -on- tube heat exchanger, solid metal wire as an extended surface.

Improving heat transfer effectiveness or/and controlling pressure losses requires novel techniques to develop systems of progressively higher heat transfer performance.

In this study, the wire-on-tube condenser is replaced by design and manufacturing a new type of refrigerator condenser as the elliptical shape. The thermal performance of a newly-designed and the wire-on-tube condenser have been investigated.

2 Analysis

Conventional condenser consists of a steel tube bended into a single-passage serpentine shape, with wires spot welded perpendicularly on both sides, as shown in figure (1a). Condensers may be assembled with tubes in a vertical or horizontal position and the air movement can be forced or natural. From the heat transfer point of view, the exchanger is assumed to be made up of a multiplicity of horizontal tubes, with the wires acting as extended surfaces to increase the heat transfer from the wall to the external environment. The pipe bend pressure drop occurs in wire-on tube condenser causing the frictional pressure drop.

In this study, the new design taking the elliptical condenser instead of a wire-on-tube has been presented. When the compressor provides the vapor of refrigerant with high pressure and temperature to the condenser, the vapor of refrigerant starts up and down with first loop from the outer to the inner and continues rotating moving in the rest of loops and finally delivers the flow to the capillary tube. However, for a better understanding of the work on the new model of condenser, see the figure (1b).

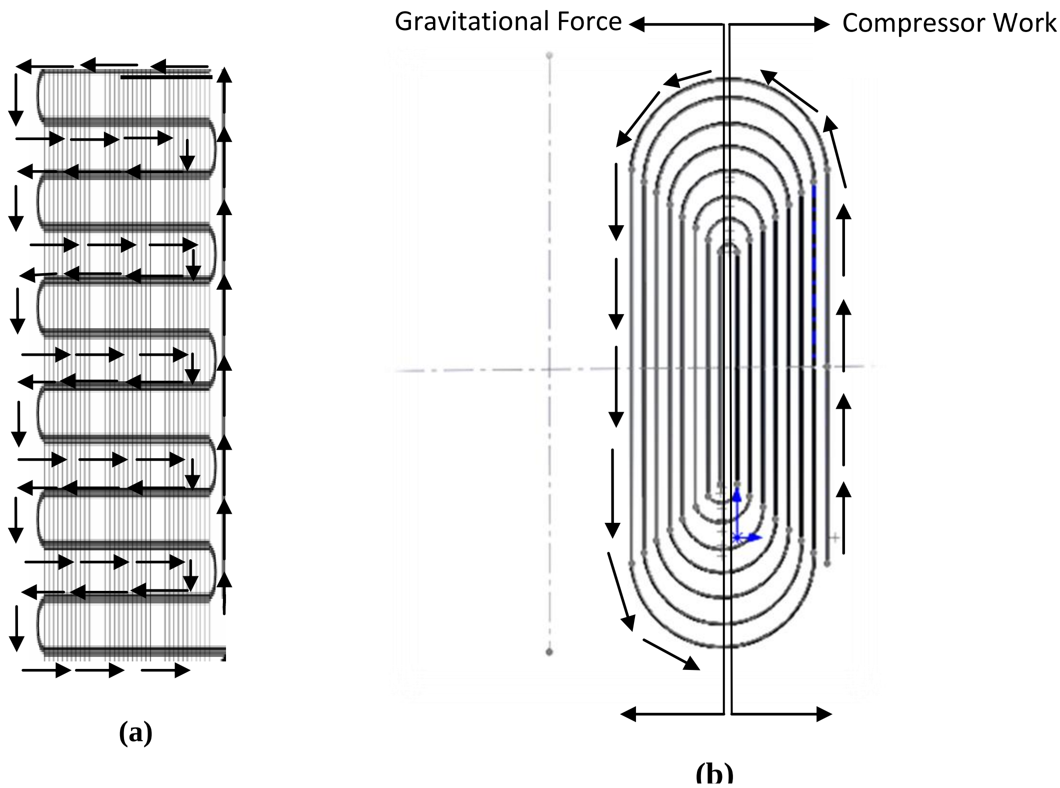


Figure 1: (a) Schematic of a wire-on-tube condenser and (b) The Elliptical condenser

3 Experimental Setup

3.1 Experimental System

This section provides a description of the facilities developed for conducting experimental work on a domestic refrigerator. The system was manufactured as elliptical shape condenser instead of the conventional condenser. The experimental setup of the test unit and apparatus is shown in Fig.2. The refrigerator specifications are given in table 1.

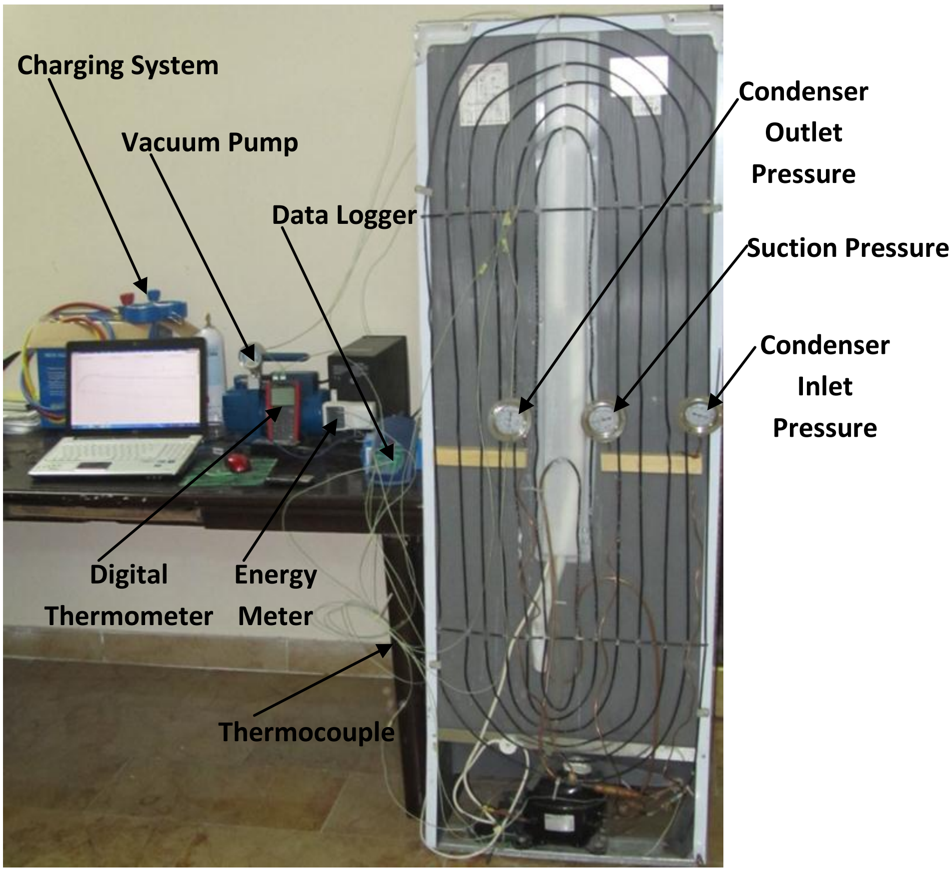


Figure 2: Experimental Setup of the Investigation Unit and Apparatus

Table 1: Specifications of the Refrigerator

TETN1600	Concord
Voltage, current and frequency	220V , 0.8A and 50Hz
Gross capacity	190 Litters
Compressor type	Hermetic
Refrigerant	HFC-134a
Charged mass	140 gram
Length of tube for both type	19.25 m
Diameter of the tube	4mm
Distance between the tube (pitch)	35mm

3.2 Experimental Procedure

The domestic refrigerator consists of an evaporator, elliptical air-cooled condenser, capillary tube and hermetically sealed reciprocating compressor.

The refrigerator was instrumented with pressure gauge was fitted at the inlet and outlet of the compressor and pressure gauge for measuring the suction pressure. To measure the pressure at desired position, the pressure gauge is fitted with T-joint and then brazed with the tube. Eight K-type thermocouple wires, 2m) were used for local surface temperatures after calibrating these thermocouples connected to data logger. The thermocouple sensors fitted at inlet and outlet of the compressor and condenser also, fitted at number of the location on the condenser to measure average temperature of the condenser as shown in figure 3. Thermocouples sensors were interfaced with a TC-08 thermocouple data logger (Pico) via a PC through USB cable.

As per the refrigerator manufacturer recommendation, quantity of the required charge for HFC-134a is 140g. In the experiment, refrigerant charge is 10% higher due to the presence of instruments and connecting lines. A Service port was installed at the inlet of compressor for charging and discharging the refrigerant. The system was evacuated by vacuum compressor before charging the system to remove

The air and moisture and charged with the aid of charging system. During the experimentation, the temperature inside test room was 29 ± 2°C. The experiment was conducted on the domestic refrigerator at four load conditions namely, (no load, 1.5, 3 and 12 Litter of water put in the freezer compartment). At each load conditions, the temperature and pressure at salient points were noted down at every one second interval, recorded by the data logger connected to the laptop. The experiment was done until steady state conditions were attained in most the temperature down. The energy consumption of the system was measured by using a digital energy meter. The typical accuracy for voltage is in the range of 190V-250V; and for current is in the range of 0.2A-15A.The performance of the Elliptical condenser was first measured and after that replaced it by wire-on-tube condenser, then the test results of two condensers were compared.

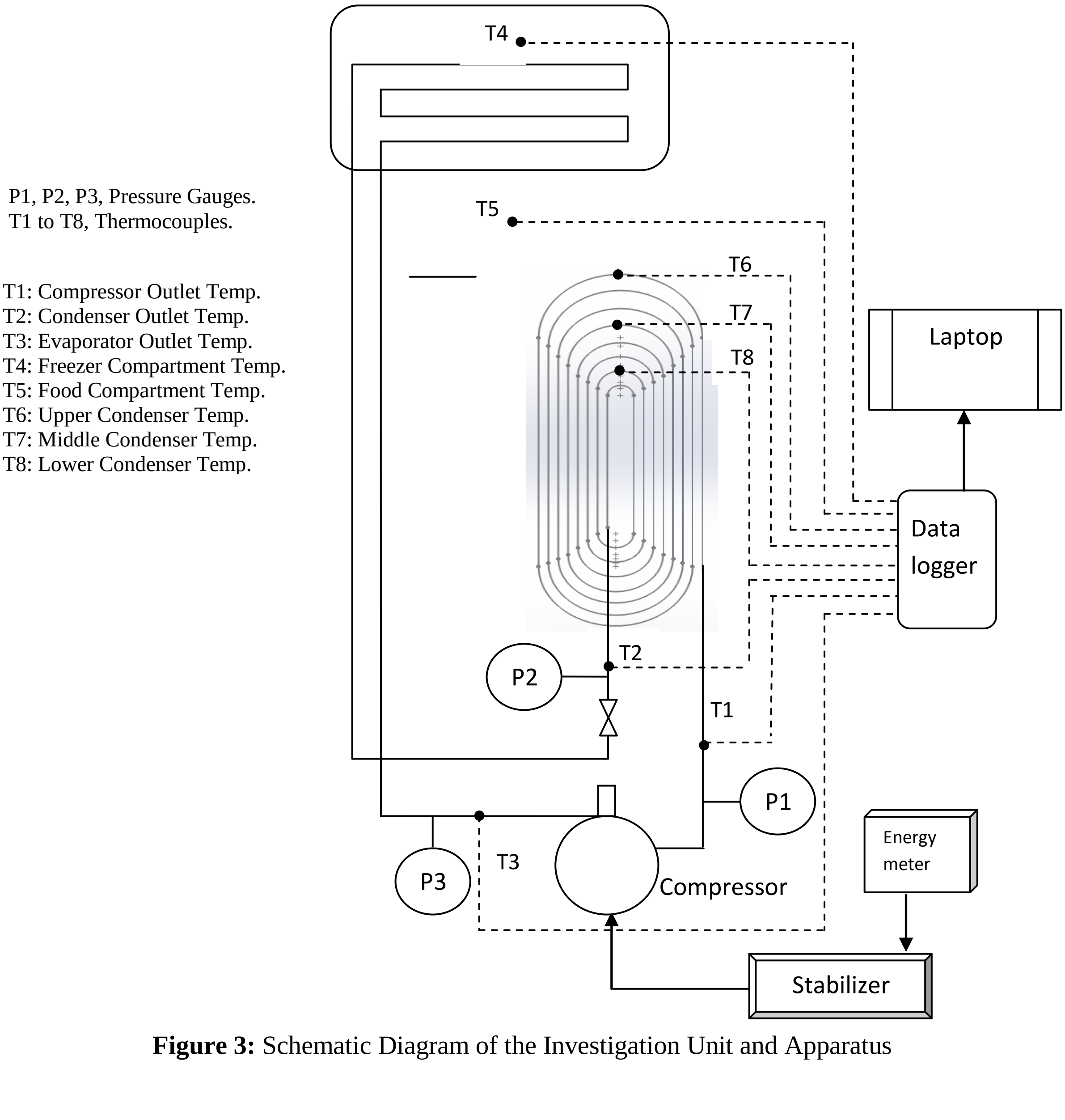
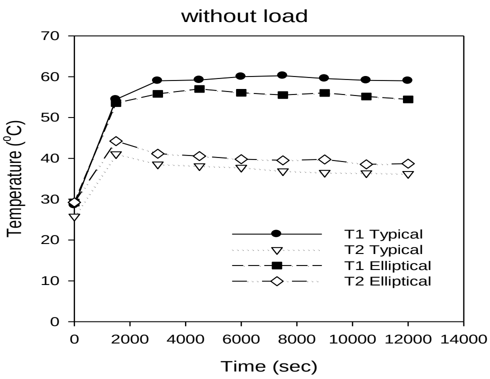


Figure 3: Schematic Diagram of the Investigation Unit and Apparatus

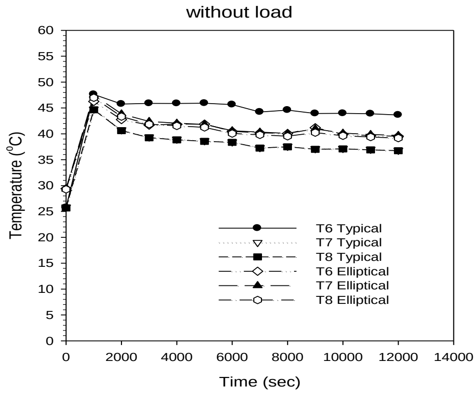
4 Results and Discussions

Figure 4 (a-d) reveals the comparison of the temperature at the inlet and outlet of the condenser for two types of typical and elliptical with time. For all load conditions, the temperature difference through the elliptical condenser was less than the typical condenser. This is contributed to developed turbulences inside the rotating flows in the tube and increasing the velocity of the flow as a result of changing the shape of the condenser to elliptical that resulted in the increase of the dissipation of heat. Also, half of the total length of the tube for the elliptical condenser was worked with aid the gravitational force as shown in the figure (1a).

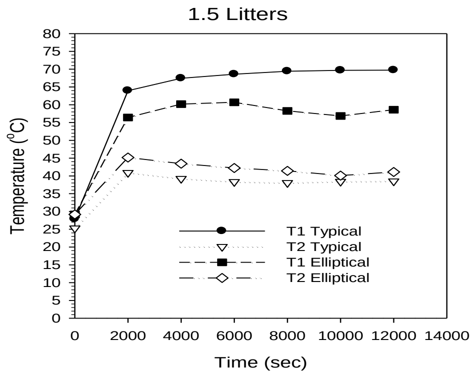
Figure 4 (e-h) manifests the temperature at the surface of the condenser for two types of typical and elliptical with time. For all load conditions, the surface temperature of the condenser at the upper, middle and lower (T6,T7 and T8) was nonuniform for the typical condenser while in elliptical condenser, the temperature at these locations converge with all loads where flow characteristics are the same for each region of the condenser . This is ascribed to that the pressure drop through the condenser was low and that means the heat dissipation from the elliptical condenser was uniform.



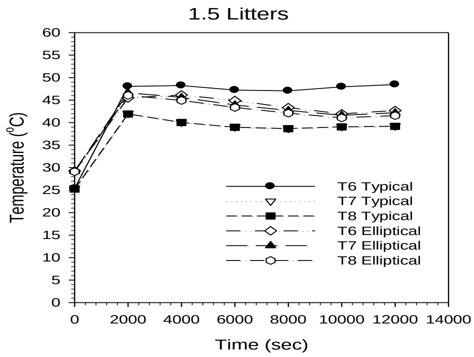
(a)



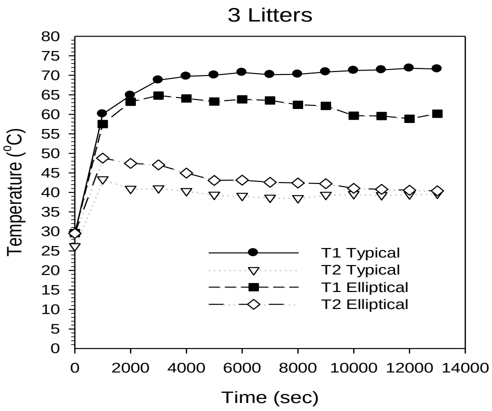
(e)



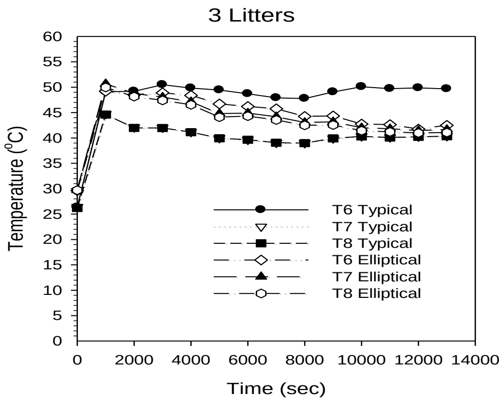
(b)



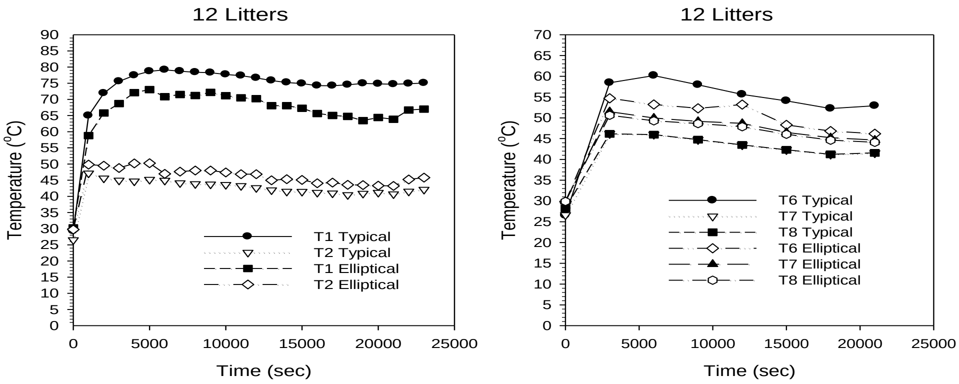
(f)



(c)



(g)



(d) (h)

Figure 4: (a) to (h) the variation of temperature with time for all loads

Figure 5 presents the comparison of the temperature at the inlet and outlet of the condenser for two types of conventional and elliptical condenser with steady state condition. For all load conditions, the outlet temperature from the compressor or inlet temperature to the condenser (T1) was greater for the typical condenser than elliptical condenser. That is because the condenser inlet pressure was high for typical condenser than the elliptical condenser then the work done by the compressor increased with typical condenser, and then the power consumption also increases. While the outlet temperature from the condenser (T2) was little greater for the elliptical condenser that because the elliptical condenser was without fins. This figure shows that the temperature difference between the inlet and outlet of the condenser is smaller for elliptical condenser than the typical condenser.

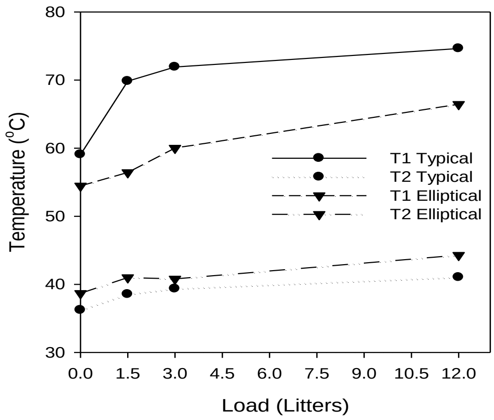


Figure 5: Variation the Inlet and Outlet Temperature of the Condenser with All Loads

Figure 6 shows the comparison of the average temperature at the surface of the condenser for two types of conventional and elliptical condenser at a steady state condition. For all load conditions, the average temperature of the condenser was greater for the typical condenser than elliptical condenser, especially, at high loads. This is due to that the pressure drop for typical condenser was higher than that for the elliptical condenser, then increasing the frictional losses as a result of elbow of the typical condenser. Also, the work done by the compressor decreases with elliptical condenser, and then the power consumption also decreases. These results confirmed that the performance of household refrigerator with elliptical condenser was better than that of the typical condenser.

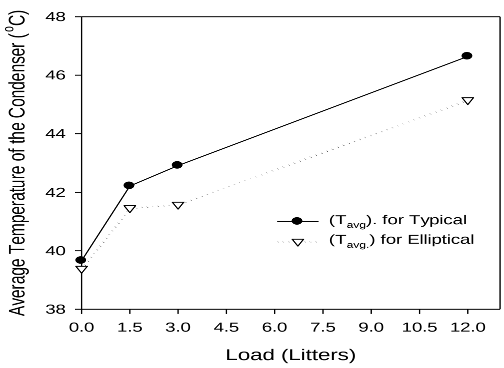
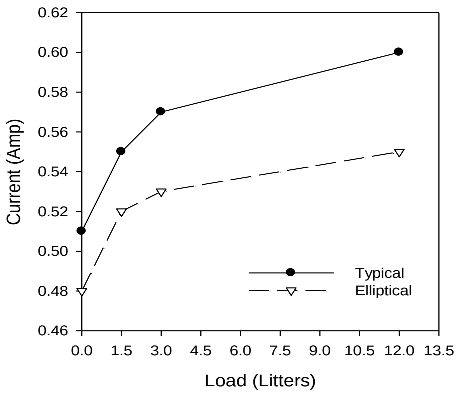
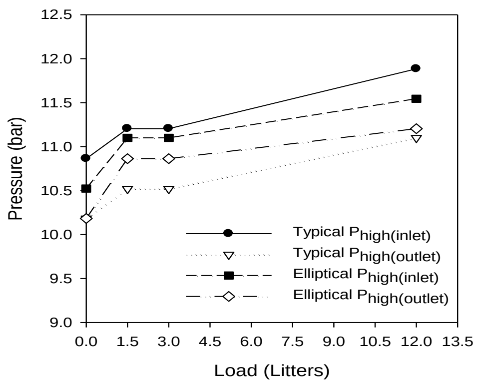


Figure 6: Variation of the Average Temperature at the Surface of the Condenser with All Loads

Figure 7 (a) and (b) illustrates the comparison of the current and pressure for two types of typical and elliptical condenser at a steady state condition. For all load conditions, the current was low for the elliptical condenser compared to the typical condenser. That is owing to the decrease of load on the compressor as a result of easily rotating flow in the elliptical condenser. Also, the pressure drop for elliptical was less than the typical condenser, due to the decrease of frictional losses as a result of improving the shape of condenser, where can rotate the flow without restriction to the flow in the elliptical condenser.



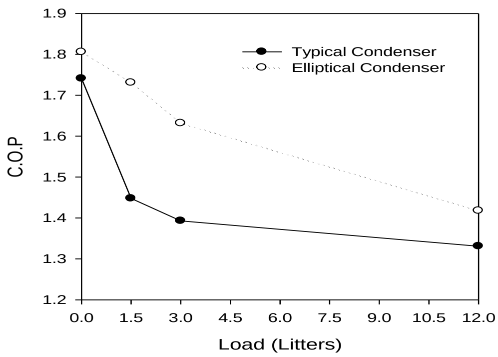
(a)



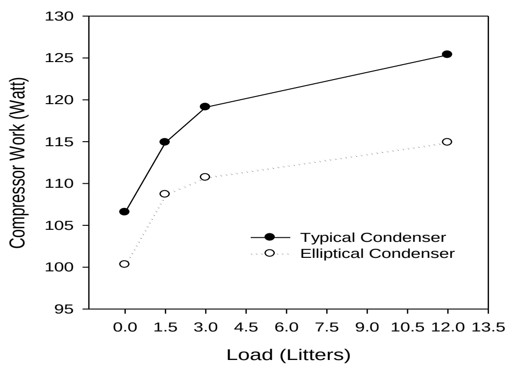
(b)

Figure 7: (a) and (b) Variation of the Current and the Pressure with All Loads

Figure 8. (a) and (b) shows that the coefficient of performance was higher for the elliptical condenser compared to the typical one by about (3.6% to 16.34%). Also, the compressor work with elliptical condenser was lower than that of typical condenser by about (5.4% to 8.34%). That is because of easily rotating flows in the elliptical condenser which can reduced the load on the compressor.



(a)



(b)

Figure 8: (a) and (b) Variation the Coefficient of Performance and the Compressor Work with All Loads

5 Conclusions

From the experiments, it can be concluded that the heat transfer rate of wire-on-tube heat exchanger can be enhanced by using novel type as elliptical condenser.

1-The work done by the compressor decreases about (5.4% to 8.34%) with elliptical condenser and then the power consumption also decreases.

2- The temperature difference between the inlet and outlet of the condenser is smaller for elliptical condenser than the typical one.

3- The pressure drop through the elliptical condenser was about (0.340 bar) while in the typical one was about (0.748 bar).

4- The heat dissipation from the elliptical condenser was uniform.

5- Decreases of frictional losses caused as a results of improving shape of the condenser, where can rotate the flow without restriction to the flow in the elliptical condenser.

6- The coefficient of performance increases about (3.6% to 16.34%) with elliptical condenser respect to the typical condenser.

References

[1] O.W.Witzell,W.E.Fontaine,What are the heat transfer characteristics of wire and tube condensers .Refrigerating Engineering 65 (1957)33–37.

[2] D.J.Kirshbaum and J. C. Chato ,optimized design of refrigerant condensers .Air conditioning and refrigeration center, University of Illinois. 217 (1996) 333–3115.

[3] M. J. Wilson, T. A. Newell, J. C. Chato, C. A. Ferreira: Refrigerant charge, pressure drop, and condensation heat transfer in flatted tubes, in Int. J. Refrigeration, (2003), 26: 442–451.

[4] S.H. Choi, W.H. Cho, J.W. Kim, J.S. Kim, A study on the development of wire woven heat exchanger using small diameter tubes, Experimental Thermal and FluidScience 28 (2004) 153–158.

[5] A. Nuntaphan, S. Vithayasai, N. Vorayos, T.Kiatsiriroat, Use of oscillating heat pipe technique as extended surface in wire-on-tube heat exchanger for heat transfer enhancement, International Communications in Heat and Mass Transfer37 (2010) 287–292.

[6] R.M. Gupta, S. Singh, S. Srivastava , Performance Analysis and Calculation of Different Parameters of Condenser using Ansys Fluent Software, International Journal of Application or Innovation in Engineering and Management (IJAIEM)Volume 2, Issue 7, ISSN 2319-4847 (2013) 529–534.

مقارنة اداء مكثف بيضوي لثلاجة منزلية مع مكثف سلكي

ضياء غانم مطشر
الجامعة التكنولوجية / قسم الهندسة الميكانيكية
Email: dheya_ghanim@yahoo.com

الخلاصة

تمثل هذا الدراسة بحث تجريبي في اداء تصميم جديد للمكثف يتكون من عدد من الحلقات بشكل بيضوي لنظام الثلاجة المنزلية ومقارنته مع المكثف السلكي. الغرض من هذه الدراسة هو تصميم وتصنيع نوع جديد من المكثفات (المكثف البيضوي) والتي تعتمد على بيانات تجريبية من حيث اداء التبادل الحراري تحت ظروف عمل مختلفة. التجارب كانت تعمل على ثلاجة مصممة للعمل مع (HFC134a). وتحت احمال متغيرة (بدون حمل , 1.5, 3, 12 ليتر من الماء). توضح النتائج ان الشغل المنجز بواسطة الضاغط يقل مع المكثف البيضوي, وعليه القدرة المستهلكة كذلك تقل حوالي (0.3 أمبير الى 0.5 أمبير). كذلك , تاثير تغيير شكل المكثف مهم جدا في تحسين معدل انتقال الحرارة وتقليل خسائر الاحتكاك كمحصلة لتقليل الهبوط بالضغط في المكثف. لذلك يمكن استخدام المكثف البيضوي بدلا عن المكثفات التقليدية المبردة بالهواء في نظام الثلاجة المنزلية