Experimental Testing of Oil Flooded Hermetic Scroll Compressor Effect on the Vapour Compression Cycle Performance

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ABSTRACT

An experimental studies of the performance of a heat pump are conducted to cover the effect of oil flooding, oil cooling and type of expansion devices. These studies show that there is an improvement in the performance factor with oil addition up to 9.2% for capillary tube and 8.6% for thermal expansion valve. The performance improvement is combined with decreasing power consumption of the system by 2% and 2.5% for capillary tube and thermal expansion valve respectively, in comparison to the standard case. The cooling of oil also improved the performance factor for the thermal expansion valve by 4.3% and 3.2% for natural and forced cooling respectively. There is also decrease in power consumption of the system by 2.6% and 4.9% for the above cases. However, using capillary tube with two way of oil cooling cause a decrease of the performance by 6.6% and increase in the power consumption by 9.5% and 3.4% respectively for natural and forced oil cooling. It can be concluded that the use of capillary tube with oil addition, led to better performance factor than the thermal expansion valve with no cooling of oil. Conversely with oil cooling by natural and forced the thermal expansion valve has better performance factor.

Keywords: Oil flooding, Scroll compressor, Heat pumps.

إختبار تجريبي لتأثير غمر الضاغط المحكم الدوار في الزيت على أداء الدورة الأنضغاطية

الخلاصة

أجريت الدراسات التجريبية لبيان تأثير غمر الضاغط بالزيت , تبريد الزيت ونوع جهاز التمدد على أداء المضخة الحرارية. من هذه الدراسات وصل التحسن بمعامل الأداء عند أضافة الزيت 9.2 ٪ مع الأنبوب الشعري و8.6٪ مع صمام التمدد الحراري. حيث أقُترن تحسين الأداء مع تقليل استهلاك الطاقة بنسبة 2٪ و2.5 ٪ للأنبوب الشعري وصمام التمدد الحراري على التوالي مقارنتا" مع المنظومة الأعتيادية. أن تبريد الزيت

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كذلك يُحسن معامل الأداء بأستخدام صمام التمدد بـ 4.3٪ و3.2٪ بالتبريد الطبيعي والقسري على التوالي. يوجد كذلك انخفاض لأستهلاك طاقة للمنظومة بـ2.6 ٪ ، 4.9 ٪ للحالات أعلاه. أن إستخدام الأنبوب الشعري لطريقتي تبريد الزيت سبب أنخفاضا" في الأداء بـ 6.6 ٪ وزيادة بأستهلاك الطاقة بـ 9.5٪ و3.4 ٪ على التوالي لتبريد الزيت الطبيعي والقسري. ويمكن الأستنتاج بأن أستخدام الأنابيب الشعرية وإضافة الزيت يسبب أفضل أداء" من صمام التمدد الحراري بعدم تبريد الزيت وعلى العكس فأن تبريد الزيت بوسائل التبريد الطبيعي والقسري بأستخدام صمام التمدد الحراري أعطت معامل أداء أفضل من الأنابيب الشعرية.

INTRODUCTION

The vapor compression system efficiency is measured by the coefficient of performance (COP) or performance factor of a system (PF), which is analogous to the thermal power cycle efficiency. For heat pumps systems, COP is the ratio between heat rejected from refrigerant in condenser to the work done by compressor, or to electrical energy consumed called actual COP [1].

Improving the performance of the vapor compression system results in economical working systems, and this is an active research topic. In case of heat pumps systems, the improving of performance factor depends upon the ability of increasing the heat rejected from condenser, for a given compressor work or by decreasing the compressor work needed to reject a certain amount of heat .

One possible means of increasing vapour compression cycle efficiency (coefficient of performance) is to flood the compressor with an excess oil quantity and cooling to achieve a semi-isothermal compression process [2]. Oil cooling reduce refrigerant temperature at compressor exit, the goal is to reduce the work of compression process as well as to enhance condenser function, consideration is given to reduce energy consumption through optimal choice of compressor type with an appropriate working conditions.

In refrigeration system, oil acts a coolant to remove heat from the bearings and to transfer heat from the crankcase to the compressor exterior [3]. Oil also reduces noise generated by moving parts inside the compressor. Good lubricating oil is that which has high miscibility and low solubility in the refrigerants. The main primary function of lubricant is to reduce the friction and wear in the mechanical parts [4] [5].

In this study an experimental work was carried out using 5 T.R. split air conditioner working with R-22. The apparatus was modified for additional parameters such as different expansion devices (capillary tube and thermal expansion valve) and oil cooling methods (natural and forced). A controlled environment room was prepared for the heat pump system testing.

Experimental work

The refrigeration unit is selected of 5TR split type air conditioning of scroll type compressor. The unit is equipped with additional measuring and laboratory devices. An environmental controlled test zone was adopted to run all system tests in which the temperature of supplied air is fixed.

Refrigeration system based on vapor compression cycle, consisting of the four major parts: compressor, condenser, expansion device, evaporator, modified to add the oil lubrication and equipped with the accurate measuring equipment of pressures, temperatures, mass flow rate.

The parameters under study are :

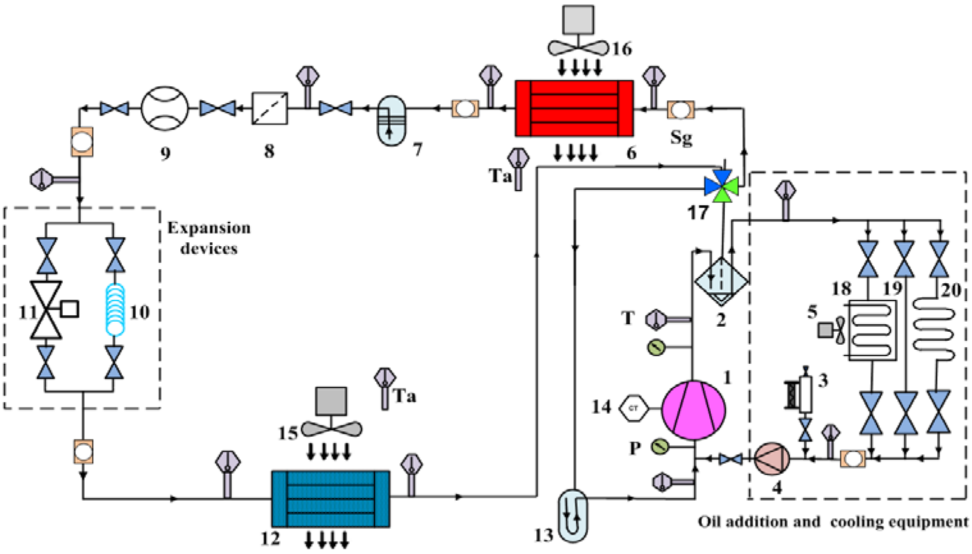
1. Condensing pressure and temperature.

2. Evaporating pressure and temperature
3. The amount of oil added.
4. Oil cooling methods.
5. Expansion device types.

Table(1) Shows the Components of refrigeration system for figure (1)

Part No.	**Description**	**Part No.**	**Description**
1	Compressor	13	Accumulator
2	Oil separator	14	Power meter
3	Oil container	15	Fan evaporator
4	Oil pump	16	Fan condenser
5	Fan oil coil	17	Reversing valve
6	Condenser	18	Forced oil cooling
7	Receiver	19	No oil cooling (direct)
8	Filter drier	20	Natural oil cooling
9	Flow meter	T	Refrigerant temperature measurement
10	Capillary tube	Ta	Ambient air temperature measurement
11	Thermal expansion valve	P	Refrigerant pressure gage
12	Evaporator	Sg	Sight glass

The test rig is located in the refrigeration and air conditioning work-shop in the Technical of Refrigeration and Air Conditioning Engineering Department of Technical Engineering College / Baghdad. The test room is divided into two parts, the conditioned zone at room area (7.4 x 4.8 x 2.4) m provided with additional window air conditioner of 2 T.R. and air cooler capacity with volume flow rate of 2000 m3/h to simulate the internal heat load. The conditioned zone can be controlled to be 15 – 25 °C . The outside zone represents a workshop space with dimension of (7.4 x 15 x3) m. The air conditioner manufactured by Gibson Company, Korea. A schematic diagram which shows the experimental arrangement of the cycle of the present work is shown in Figure (1), and experimental work is shown in Figure (2). Expansion devices modification is divide to thermal expansion valve and capillary tube as shown in Figure (3).



Figure(1) Experimental arrangement of refrigeration system.

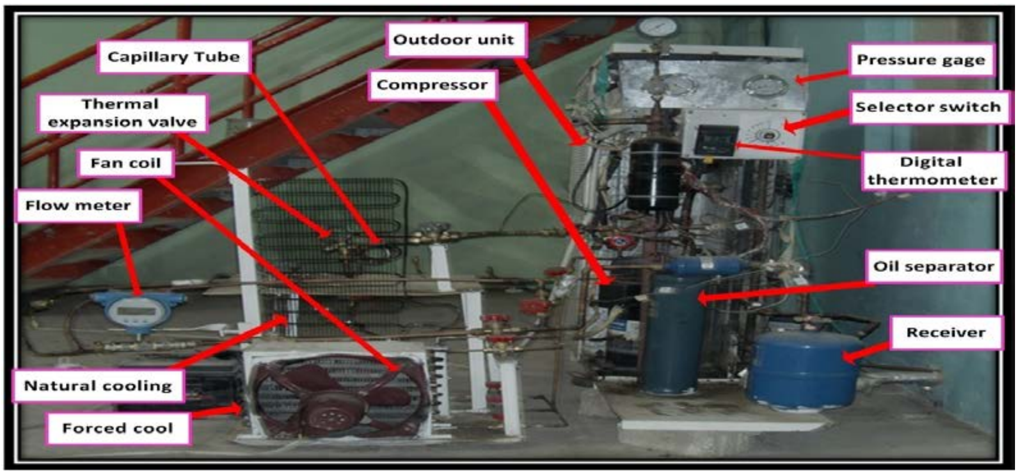


Figure (2) Experimental Test Rig.

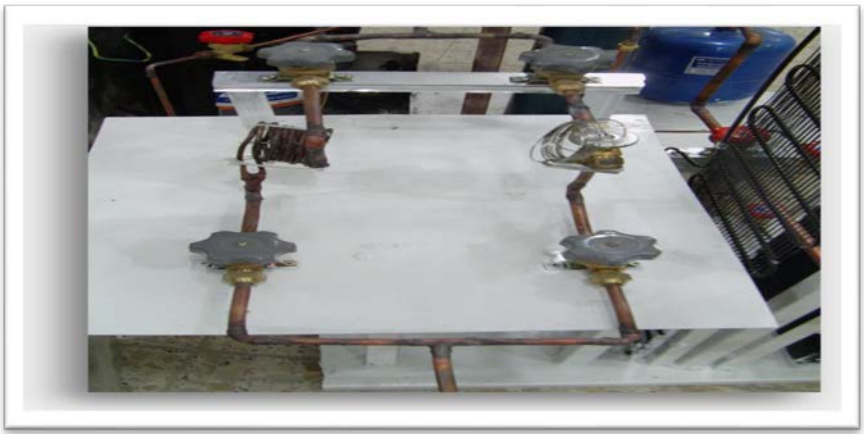


Figure (3) Branched Expansion Devices.

The addition and cooling of oil system is constructed as an extension and linked with outdoor unit. It starts from oil separator and ends in the compressor suction line, Oil cooling is done by three methods, a natural from the pipe, natural by using radiator and forced when using a fan with coil. The oil cooling in the previous three ways is done separately to compare the results. The oil addition is done through oil pump linked with oil bottle (container) filled with the quantity of oil to be added. This bottle exists above electronic mass balancer to adjust the quantity of oil, as shown in Figure (4). Only one passage is opened at a time of operation. The oil pump is 1/4 HP, 2000 rpm, 6.2 A, General Electric, USA.

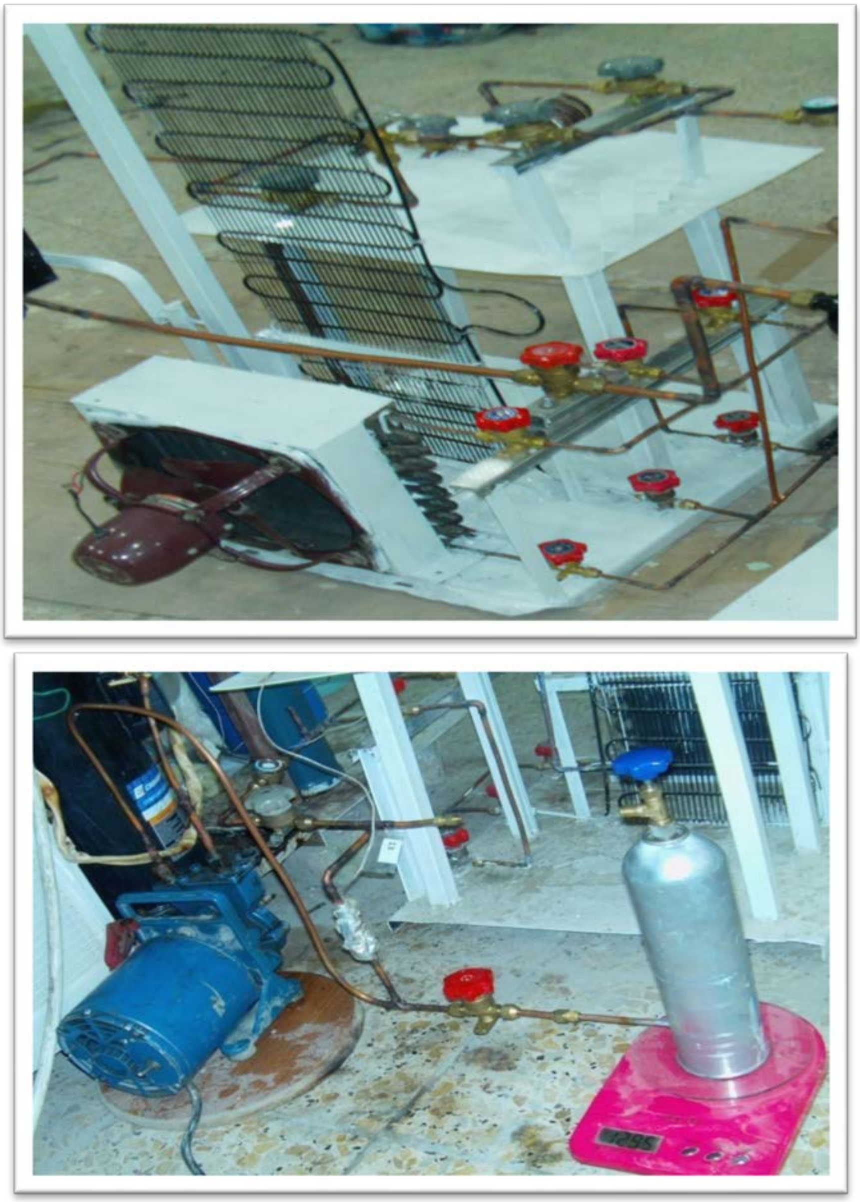


Figure (4) Oil Addition and Cooling System.

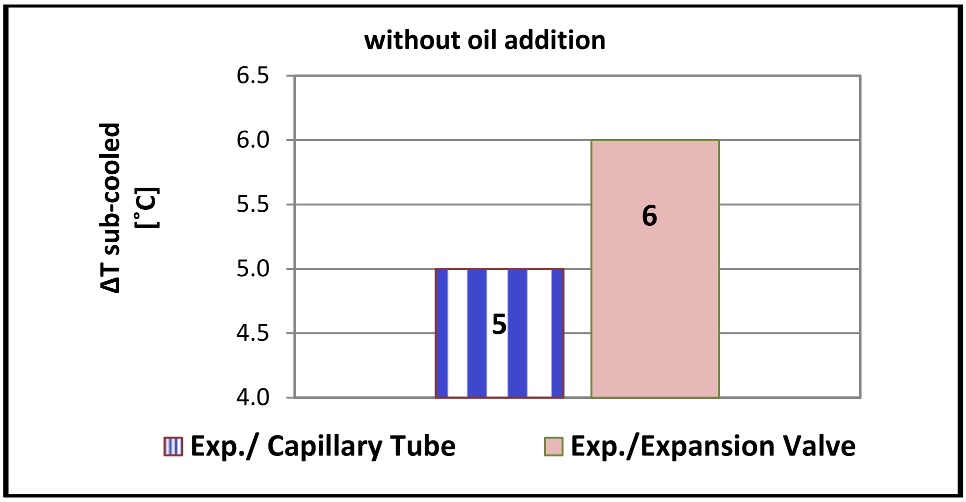
Oil is added to the system in certain quantities gradually in step of 2.5% to 22.5% of the normal quantity of oil. Measuring instruments are include pressure gauges, digital clamp meter and electronic weight balance had been calibrated in the Central Organization of Standardization and Quality Control -Baghdad. After connecting all instruments and measuring devices to the A/C unit, the unit was charged with full charge 5.1 kg of refrigerant-22.

Onset the adoption of the original system without any modification nor any oil addition. For thermal expansion valve, natural convection oil cooling path is open and close other paths and operate A/C unit until the steady condition reaches to recorded parameters readings, then repeat the steps for other oil path, same steps for capillary tube. Adopt the same how for system with oil addition.

Results and Discussion

The results of the original cycle without oil addition is compared to the same cycle with oil addition and its impact on the performance factor (PF). Also, the effect of oil cooling method and different expansion devices, thermal expansion valve and capillary tube on the cycle PF, are discussed.

All results were calculated at inlet air temperature to the evaporator 19˚C. To understand the effect of oil addition it is necessary to present the behavior of the basic heat pump system without oil addition and cooling. The effects of expansion methods on sub-cooling temperature difference are shown in Figure (5). Higher sub-cooling temperature difference is produced using expansion valve which in turn leads to an increase in gross PF because of the increasing heat rejected from condenser.



Figure(5) Comparison of Sub-cooling Temperature Difference Between Thermal Expansion Valve and Capillary Tube .

Figure (6) shows the effects of different expansion devices on the performance factor of the cycle. Performance factor calculated depending on difference enthalpy refrigerant in compressor, gross performance factor calculated depending on work oil and refrigerant in compressor. It can be seen from the figure that thermal expansion valve value gives higher PF than the that of capillary tube. The gross PF obtained from system using capillary tube and expansion valve as shown in Figure (7), so the thermal expansion valve gives gross PF higher than that of the capillary tube. In general, the values of gross PF are lower than that of PF values because oil work took part from refrigerant work to minimize net work of system.

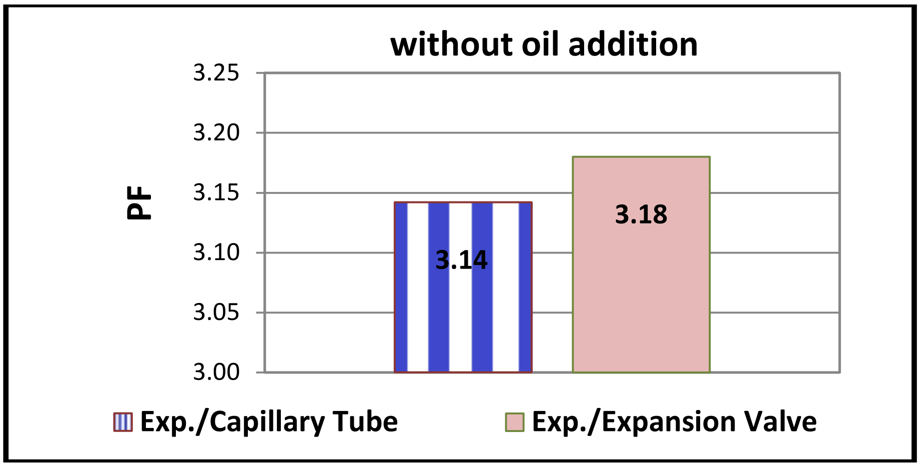


Figure. (6) Comparison of Performance Factor Between Thermal Expansion Valve and Capillary Tube.

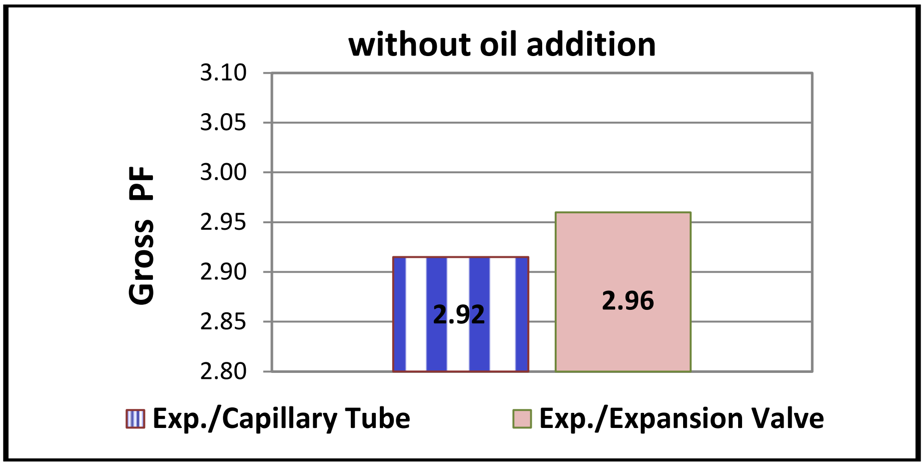


Figure. (7) Comparison of Gross Performance Factor Between Thermal Expansion Valve and Capillary Tube.

After presenting the system without oil cooling, Figure (8) shows that the best gross performance factor of the system without oil addition with oil cooling methods is to use forced oil convection cooling with capillary tube. By using capillary tube when oil cooling without oil adding, oil temperature drops, this leads to increased oil viscosity, which causes the compressor overload, thus performance increases value slightly. Natural cooling by pipe method may be considered no oil cooling in standard design.

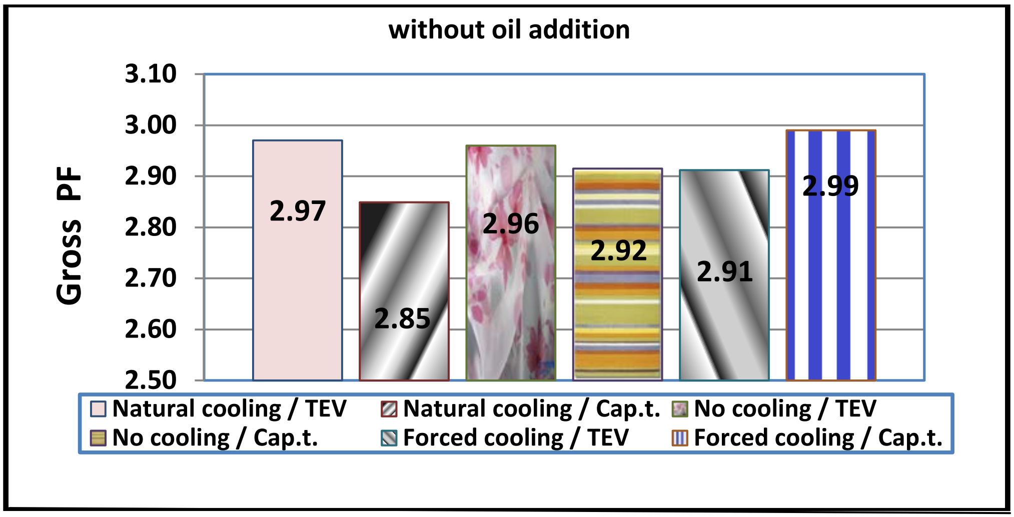


Figure. (8) Experimental Results of Gross Performance Factor for Different Expansion Devices and Oil Cooling Methods without Excess Oil.

With Oil Addition

When the excess oil fraction is 12.5% the system gives a point of optimum power consumption with natural cooling by pipe, 10% with natural by using radiator and forced cooling methods to operate system with capillary tube as shown in Figure (9). While operating the system with expansion valve shows lower power consumption at excess oil fraction of 12.5% for forced oil cooling and 15% for oil natural cooling by radiator as shown in Figure (10).

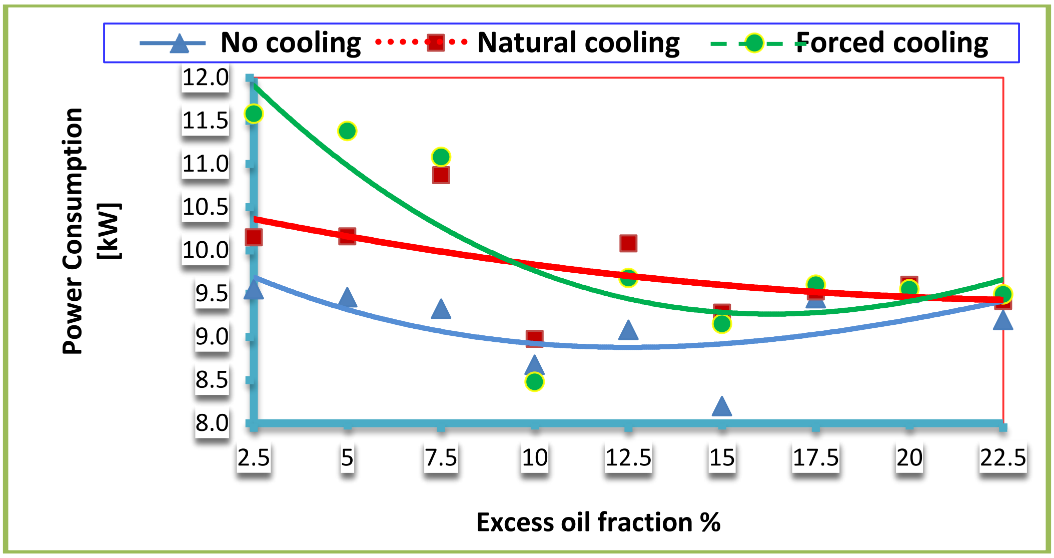


Figure. (9) Effect of Oil Addition and Oil Cooling Methods on Power Consumption with Capillary Tube.

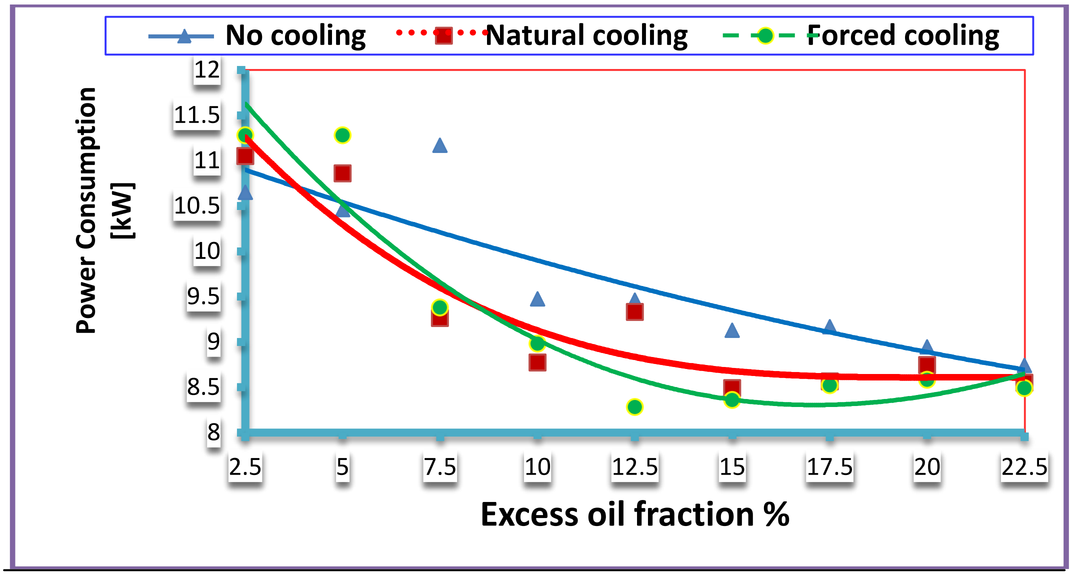


Figure. (10) Effect of Oil Addition and Oil Cooling Methods on Power Consumption with Expansion Valve.

Figure (11) shows the effect of oil addition on sub-cooling. This effect increases effective condenser and asset expansion device, this can be noticed for all oil cooling methods at excess oil fraction 12.5% by capillary tube and 10% by thermal expansion valve as shown in Figure (12).

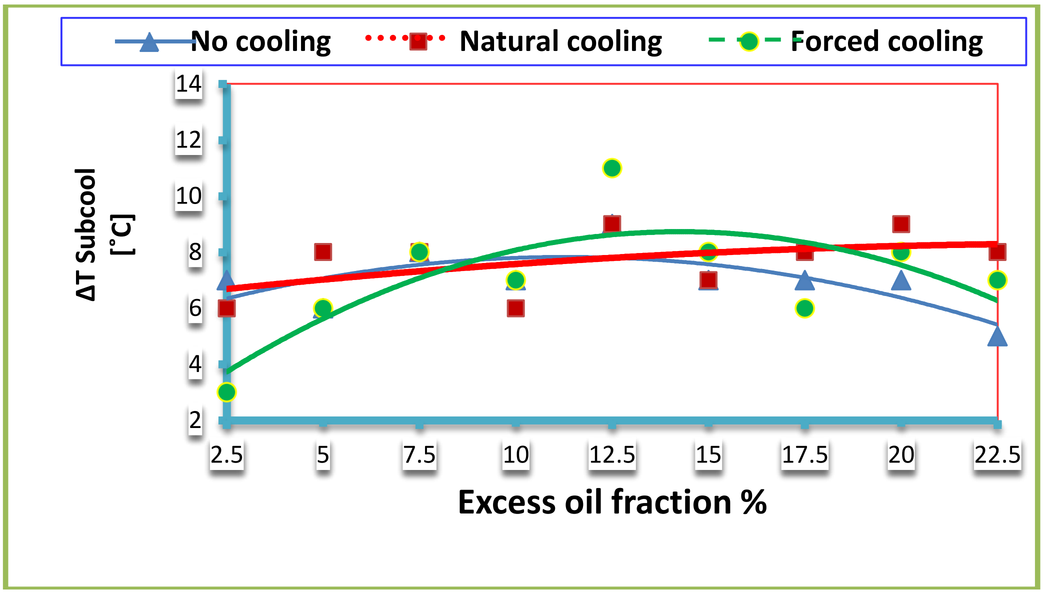


Figure. (11) Effect of Oil Addition and Oil Cooling Methods on Sub-cooling Temperature Difference with Capillary Tube.

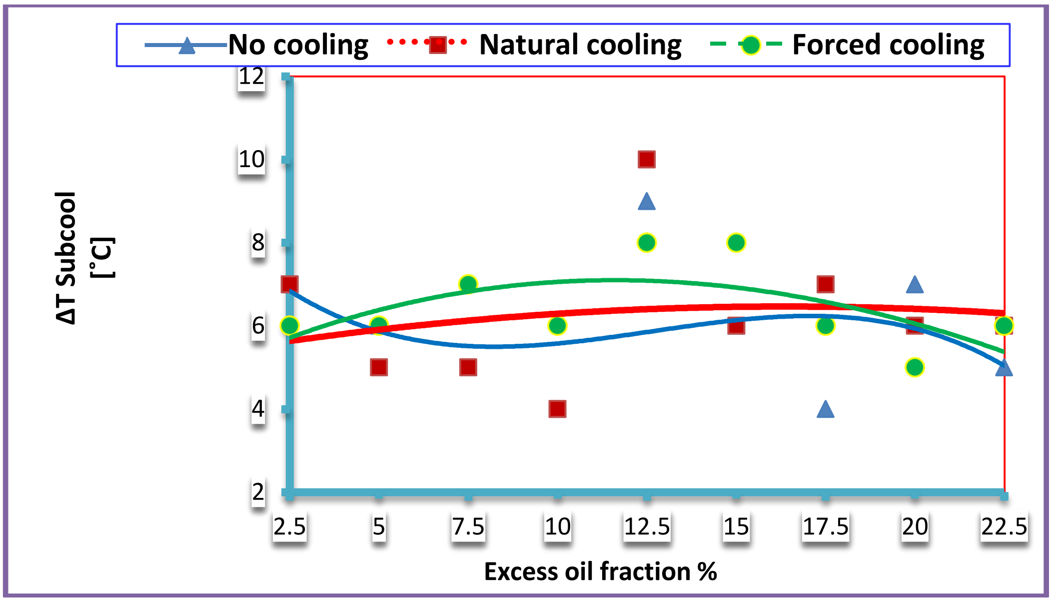


Figure. (12) Effect of Oil Addition and Oil Cooling Methods on Sub-cooling Temperature Difference with Expansion Valve.

Increasing the excess oil fraction with oil cooling methods to operate system with different expansion devices will decrease compressor discharge temperature, consequently compressor efficiency increases because decreasing work compressor as shown in Figures (13) and (14).

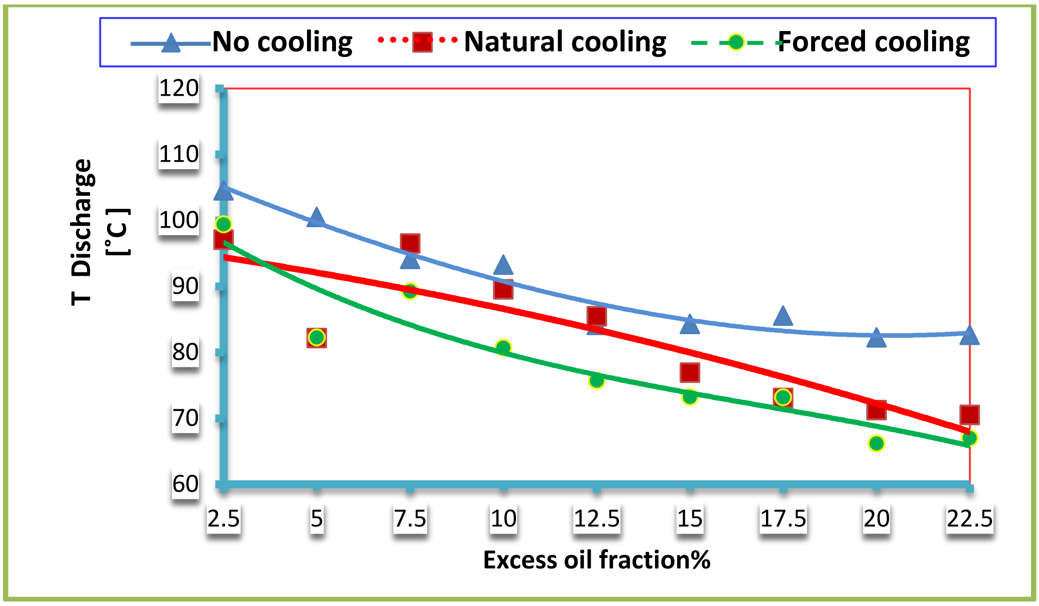


Figure. (13) Effect of Oil Addition and Oil Cooling Methods on Compressor Discharge Temperature with Capillary Tube.

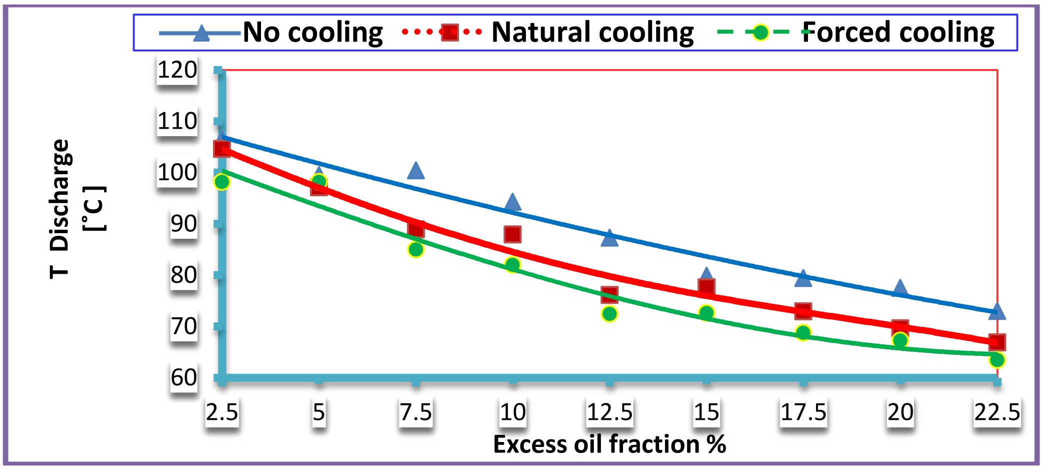


Figure. (14) Effect of Oil Addition and Oil Cooling Methods on Compressor Discharge Temperature with Expansion Valve.

Figures (15) to (18) present the effect of oil addition and oil cooling on performance factor and gross performance factor of the heat pump system. As noticed from the figures, the increase in oil addition yields some change in the behavior of system. The curve line indicates some points which improve the performance of the system and the other did not.

When the system is tested with capillary tube, the excess oil fraction is 12.5%, the system gives a point of maximum performance factor with any oil cooling method as shown in Figure (15). And higher maximum gross performance factor for natural cooling by pipe meets excess oil fraction 15%, for forced cooling at 12.5% and for natural cooling by radiator at 10% as shown in Figure (16).

This behavior could be attributed to the fact that the cooled oil causes a decrease in the compressor discharge temperature and subsequently more sub-cooling effect which leads to an increase in the rejected heat. Although the compressor work continues to increase with the quantity of excess oil, to a limited extent the increase in the rejected heat surpasses the increase in work. Further increase in excess oil beyond this limit is uneconomical because the increase in work is overwhelming.

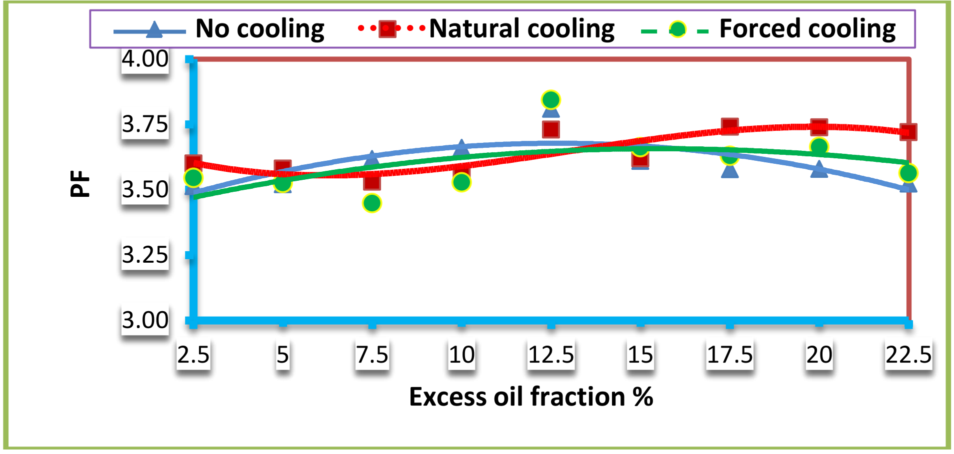


Figure. (15) Effect of Oil Addition and Oil Cooling Methods on Performance Factor with Capillary Tube.

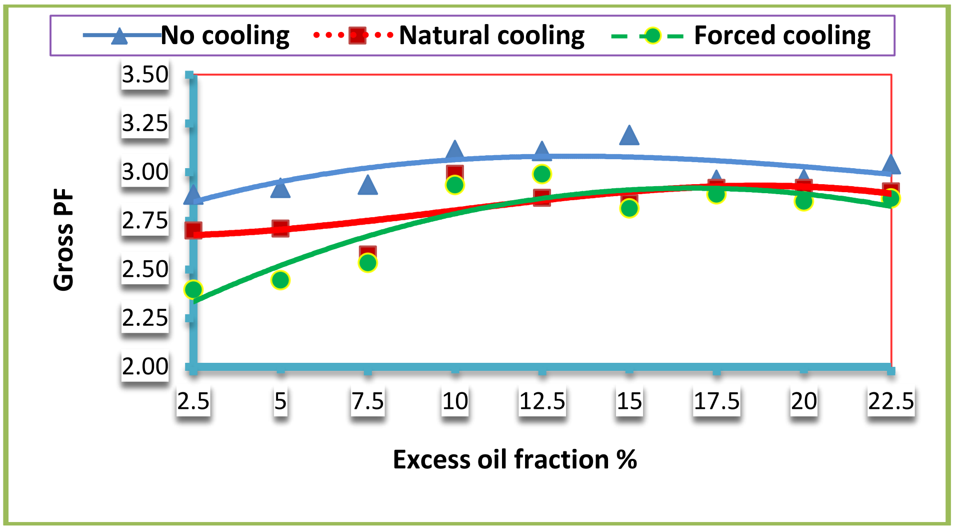


Figure. (16) Effect of Oil Addition and Oil Cooling Methods on Gross Performance Factor with Capillary Tube.

The effects of the excess oil fraction on the performance factor with the expansion valve active are shown in Figures (17) and (18). The performance factor increases until the excess oil fraction reaches about 12.5% but decreases afterward. Difference method of oil cooling shows little effect on performance factor. Figure (18) shows a highly seated data and increase gross performance factor is evident at 12.5% excess oil fraction.

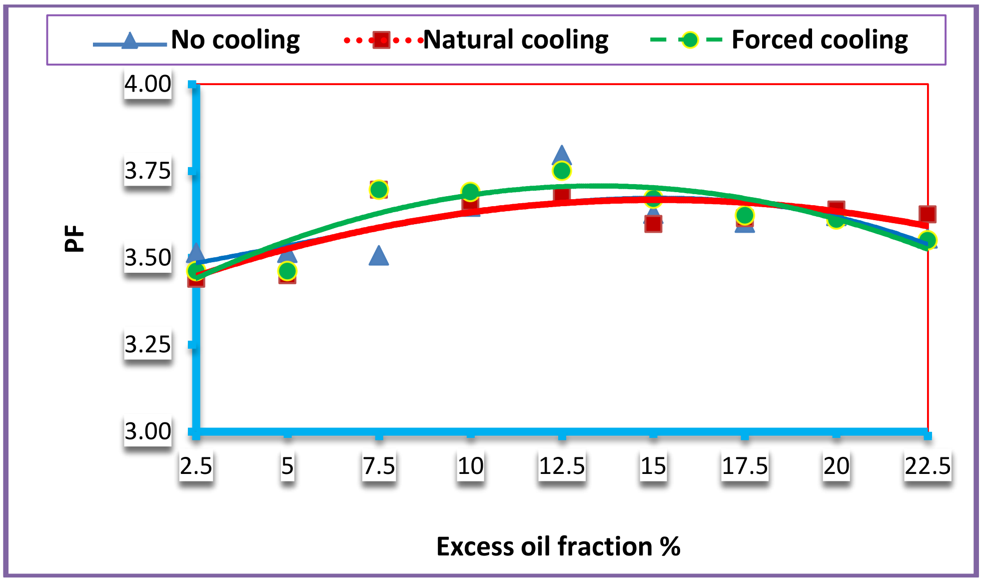


Figure. (17) Effect of Oil Addition and Oil Cooling Methods on Performance Factor with Expansion Valve.

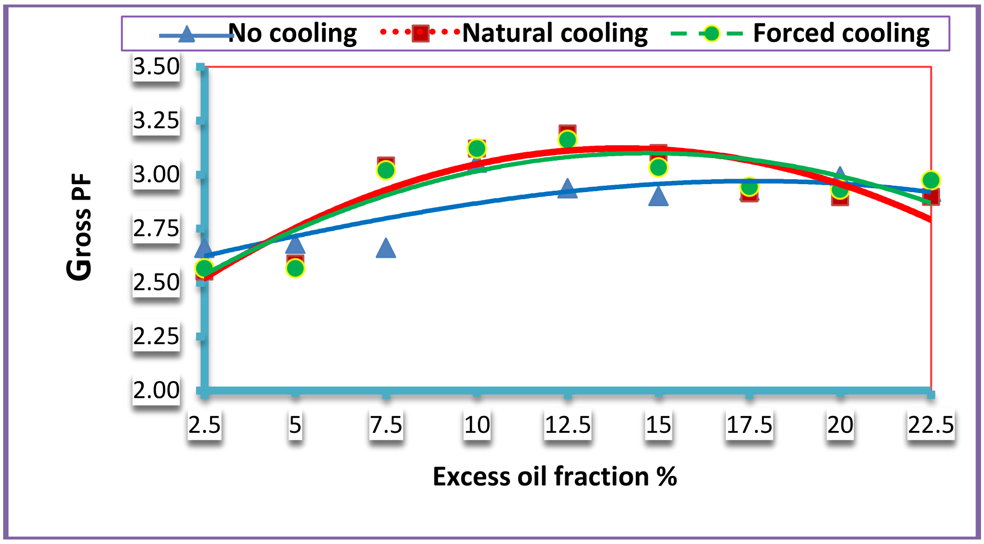


Figure. (18) Effect of Oil Addition and Oil Cooling Methods on Gross Performance Factor with Expansion Valve.

CONCLUSIONS

The main goal of this work is to examine the possibility of increasing performance factor (PF) of heat pump system working on a simple vapor compression cycle, by using excess amount of oil to the original oil and cooling it to reduce the compression work of the system. The following major conclusions are drawn from the work :

a. Increase in a performance factor of system with oil addition reaching 9.2% for capillary tube, 8.6% for expansion valve from the same system without any oil addition.

b. Higher performance factor using capillary tube met 12.5% excess oil fraction with forced convection oil cooling method, 10% for natural cooling method, 15% for no cooling. While higher performance factor using thermal expansion valve met 12.5% excess oil fraction with any oil cooling methods.

c. The performance factor of system increases with natural and forced oil cooling methods by 4.3%, 3.2% respectively over that with no cooling in the case of oil addition for expansion valve. On the other hand the performance factor of system decreases with natural and forced oil cooling methods by 6.6% which is lower than with no cooling for capillary tube.

d. Decreasing power consumption of system with oil addition is 2% for capillary tube, and 2.5% for expansion valve from the same system without any oil addition.

e. Power consumption is lower using capillary tube at 12.5% excess oil fraction with no cooling, 10% with natural and forced oil cooling methods. While lower power consumption is achieved when using thermal expansion valve at 12.5% excess oil fraction with forced oil cooling method and 15% for natural cooling method.

f. In the case of oil addition, power consumption of system decreases with natural and forced oil cooling methods by 2.6%, 4.9% respectively which is lower than with no cooling for expansion valve. On the other hand power consumption of system increases with natural and forced oil cooling methods by 9.5%, 3.4% respectively over that with no cooling for capillary tube.

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