PERFORMANCE OF AN IMPROVED EJECTOR AIR-CONDITIONING SYSTEM

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ABSTRACT

Living in the Asia Pacific and other tropical countries presently with high temperatures and humidity, people tend to look forward to better lifestyle with technology which is more environmental friendly and energy efficient. Two-phase ejector as expansion valve in air-conditioning system has been studied since 1900s for a better performance of the system. This study aims to investigate the performance of an improved ejector air-conditioning system as compared to that of the conventional air conditioning system. The conventional air-conditioning system and an improved ejector air-conditioning system are studied experimentally using R22 as the working fluid. The coefficient of performance (COP) of both air-conditioning system were conducted and analysed based on the results collected from the experiments. It was found that the improved ejector air-conditioning system has COP of 12% - 14% higher than that of conventional air-conditioning system.

Keywords : *Split-type air conditioner, ejector, R22, COP improvement.*

1.0   INTRODUCTION

Global warming and the changes of our climate need to have an effective and sustainable solution. Contemporary livings in the world, especially in Asia Pacific countries which have higher temperature and humidity, most people are contented to have comfort environment regardless of economic and environmental issues. With the increasing comfort factors that affect human life, technology solution has been advancing and improved practically for the contemporary problems. One example of daily appliances is the split-type air conditioner (AC) which is important to reduce the electrical energy consumption and its operation costs. The HVAC and refrigeration industry play the important role in addressing the rising of these problem when it comes to environment and energy conservation.

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Nowadays, split-type air conditioner has been applied widely as one of the appliances to maintain the thermal comfort for resident and commercial buildings and it is an emerging research topic to study the performance enhancement of refrigeration and heat pump cycle in order to reduce the electricity consumption as well as the rises of environmental pollution issues [1]. Recently, the use of two phase ejector in refrigeration system has became promising and modified cycle because of its simple structure and low maintenance requirements as well as its advantage on the recovery of the expansion work which is normally wasted at expansion valve [2].

This study presents the development of air-conditioning system and its applicable technology to further enhance the refrigeration system by improving its COP through modification of ejector air-conditioning cycle. An ejector is a device that drives secondary flow with low pressure together with primary flow with high pressure as driving force. By doing this, secondary flow pressure can be improved before the vapor enters the compressor.

The ejector had been used widely across the industrial processes and it is recognised with the application of ejector in refrigeration cycle for performance improvement. Until now, there are several studies conducted to with different configuration of ejector vapour refrigeration cycle (EVRC). The main different between the proposed cycle and the current ejector air-conditioning system is in the design of the separator as a heat exchanger device. This idea is accomplished by introducing ejector into the refrigeration system and modifying the cycle with the combination of separator and heat exchanger [3].

Based on the previous researches, internal heat exchanger has been introduced in refrigeration system and it has shown a significant result on the improvement of COP for the system. Hence, this investigation probes into the potential usage of an internal heat exchanger in the new system by combining both separator and heat exchanger together.

2.0   LITERATURE REVIEW

The performance enhancement by ejector for vapor compression system was only proposed in the 1990s by Kornhauser [2] using refrigerants of R12 in thermodynamic performance of the ejector expansion refrigeration cycle analysis. Yapici and Ersoy [4] studied the ejector refrigeration system based on the constant-area ejector flow model through theoretical analysis. The optimized result had been obtained for R-123 and it had been concluded in the report that the variations in the temperature of condenser and evaporator have greater effect which had resulted on the optimum coefficient of performance (COP) as compared to the variation in generator temperature.

Bilir and Ersoy [5] investigated the performance of a vapour compression system that uses an ejector as an expansion device. A two-phase constant area ejector flow model with R134a as the refrigerant was used. As the difference between condenser and evaporator temperatures increases, the improvement ratio in COP rises whereas ejector area ratio drops. The minimum COP improvement ratio in the investigated field was 10.1%, while its maximum was 22.34%.

Kairouani et al. [6] had researched on the usage of ejector to recover throttled pressure with high evaporator's temperature and to reduce compression energy consumption. Besides, the analysis and results of compression/ejector hybrid cycle studied by Elakhdar et. al. [7] for domestic refrigeration showed that entrainment ratio and the coefficient of performance depend mainly on the fluid nature and the operating condition. Nakagawa et. al. [8] studied the effect of mixing length on ejector system performance for both ejector and conventional expansion systems with and without internal heat exchanger at different operating conditions. Based on the experimental results, mixing length had significant effect on entrainment ratio and on magnitude and profile of pressure recovery. A COP improvement of up to 26% over conventional system was obtained but improper sizing of mixing length lowered the COP by as much as 10%.

Jahar [9] mentioned that the use of ejector will be given the benefits of work recovery or COP improvement and evaporation size reduction. Ejector can act as an expansion device to substitute the throttling valve in vapor compression refrigeration cycle. This could be another effective method to decrease the losses due to throttling effect or expansion irreversibility in air conditioning system. Compressor work can be reduced by leveling up the suction pressure to a higher level with an ejector which results in the improvement of COP of the air conditioning system.

As mentioned by Lin et. al. [10] there is two applications of ejectors in refrigeration processes. One of the applications is using primary flow with high pressure to draw secondary flow with low pressure while the other application is using the high pressure primary flow to improve secondary flow pressure before the vapor enters the compressor.

These studies had presented the favorable improvement of the performance of ejector in vapour refrigeration cycle (VRC) system. It is more attractive for the ejector vapor refrigeration system (EVRC) for the application of domestic refrigeration as compared to that of basic VRC systems. Ejector can be used as an expansion valve to replace the throttling valve in the vapour compression refrigeration cycle which can be one of the most effective ways to reduce the throttling losses or the expansion irreversibility in the refrigeration/heat pump cycle.

For air conditioning applications, entrainment ratio and pressure lift ratio are the most important parameters of an ejector which are related to the cooling capacity and compressor work of the applications. These parameters are directly depends on the ejector geometry and its working fluid. The ejector with the operating condition that has high entrainment ratio and pressure lift ratio tend to be the most desire ejector.

The conventional cycle (SC), standard ejector cycle (SEC) and modified ejector cycle (MEC) have been studied and the results have shown that MEC has better performance as compared to SC and SEC, both experimentally and

theoretically by Sumeru et.al [11]. Figure 1 show the three different configuration of the vapour compression refrigeration cycles ie. conventional cycle, standard ejector cycle and modified ejector cycle. Figure 2 show the P-h diagrams of ie. conventional cycle, standard ejector cycle and modified ejector cycle, which was used to analyse the performance of the systems.
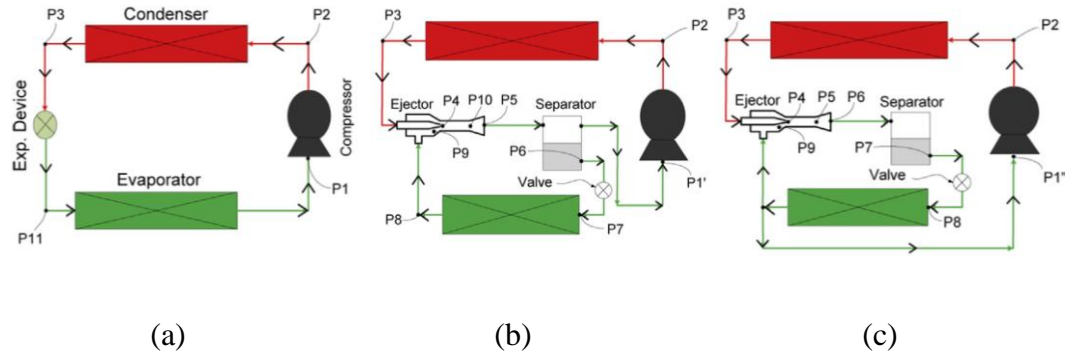

(a)   (b)   (c)

Figure 1: Schematic diagram of the vapor compression refrigeration cycle (VCRC): (a) conventional cycle, (b) standard ejector cycle and (c) modified ejector cycle [11].

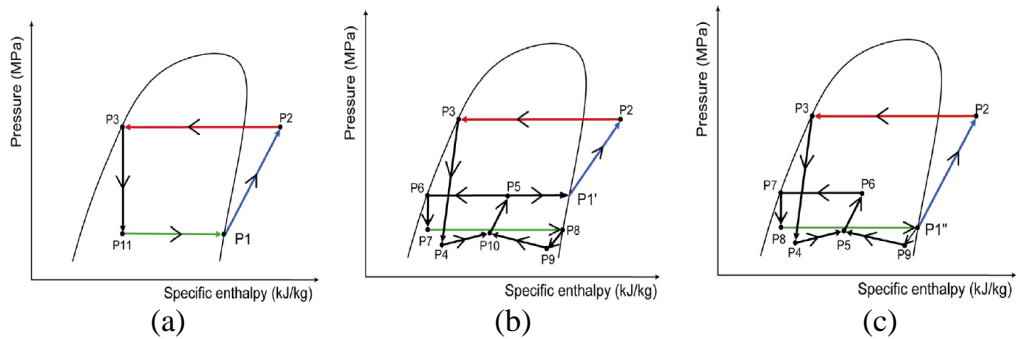(a)   (b)   (c)

Figure 2: P-h diagram of the vapor compression refrigeration cycle (VCRC): (a) conventional cycle, (b) standard ejector cycle and (c) modified ejector cycle [11].

Ani and Kooi [12] carried out experiments on standard and modified ejector cycle using R22 and R290 on split-type air conditioning system. Their results show that the modified ejector cycle has higher COP than the standard cycle. Based from the previous studies, the improved design has been proposed on the air-condtioning with new configuration by introducing the heat exchanger into the system and combining it with the liquid vapour separator. The reason is to investigate the potential of using this combined separator and heat exchanger component in the performance of the refrigeration system and air conditioning system in the new configuration cycle. The new configuration of the improved ejector cycle is shown in Figure 3.
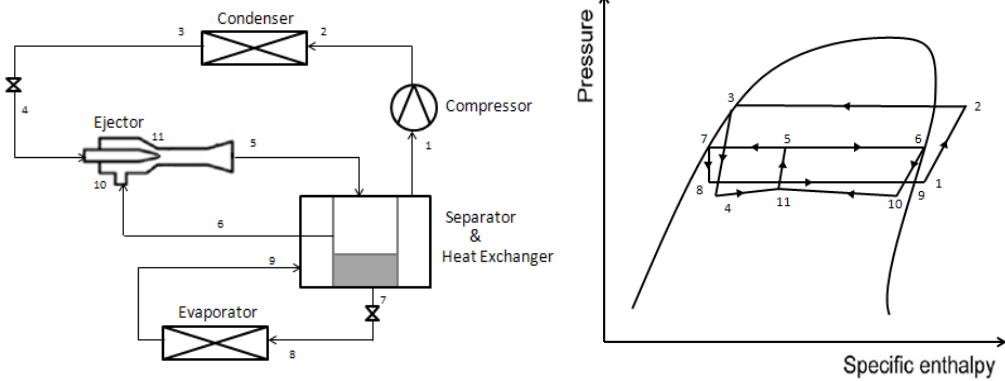
Figure 3: Schematic diagram and P-h diagram of improved ejector cycle (IEC) configuration.

3.0   METHODOLOGY

The experimental work was carried out on conventional cycle (SC) and improved ejector cycle (IEC) in order to compare the performance of each air-conditioning system. The conventional cycle (SC) was conducted by using capillary tube as an expansion device while the other cycle (IEC) was conducted by using ejector as an expansion device with a combined heat exchanger and separator of 100 cm^3 (0.1 L). The experimental rig of both cycles is shown in Figure 4.

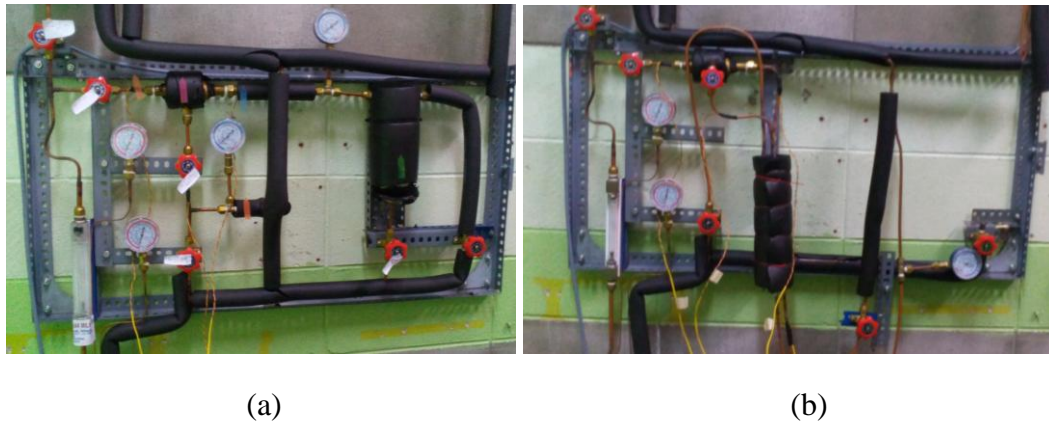(a)   (b)

Figure 4: Pictorial diagram of (a) conventional cycle and
(b) improved ejector cycle.

Before charging refrigerant into the air-conditioning system, vacuum or system evacuation had been used to remove air and other non-condensable gaseous from the system as well as to ensure the dehydration of the system. Sufficient amount

of refrigerant, R22 was charged into the system by using the flow meter and sight glass as flow indicator together with the refrigerant charging hose kit.

The ejector air-conditioning system experiments were conducted by operating the system and recording the readings of pressure and temperature which were obtained from the pressure gauge and Picolog multi-channel data recorder respectively at different ambient air temperature to the condenser. Pressure – enthalpy diagrams have been plotted with the data collected so that the coefficient of performance (COP) could be calculated. The air condition of the indoor temperature was set at 16°C by thermostat for these air-conditioning cycles.

Coefficient of performance, COP is used to analyse the efficiency of the air conditioning system through the ratio of evaporator's cooling capacity and the power input to the compressor.

$$COP = \frac{\dot{Q}_e}{\dot{W}_{comp}} \tag{1}$$

where $\dot{Q}_e$ is the cooling effect at the evaporator and $\dot{W}_{comp}$ is the work consumed by the compressor.

Meanwhile, there must be a comparison between the coefficient improvement of both standard vapour compression refrigeration cycle and improved ejector refrigeration cycle as stated in equation (2).

$$COP_i = \frac{COP_{ej} - COP_{SC}}{COP_{SC}} \tag{2}$$

where COP_{ej} = COP of improved ejector refrigeration cycle and COP_{SC} = COP of standard cycle.

4.0   RESULTS AND DISCUSSION

The most common used parameter to analyse the efficiency of the refrigeration system is the coefficient of performance (COP). The higher COP of the refrigeration system means a more efficient the refrigeration system. The coefficient of performance was calculated based on the thermodynamics analysis of the experimental results. The experimental readings were taken until it reaches stable states. The coefficient of performances of standard cycle and the improved ejector cycle was calculated and found to be stable after 10 minutes duration with input data of one minute interval. The coefficient of performances analysis depends on the enthalpies of the cooling effect at the evaporator and the work consumed by the compressor.
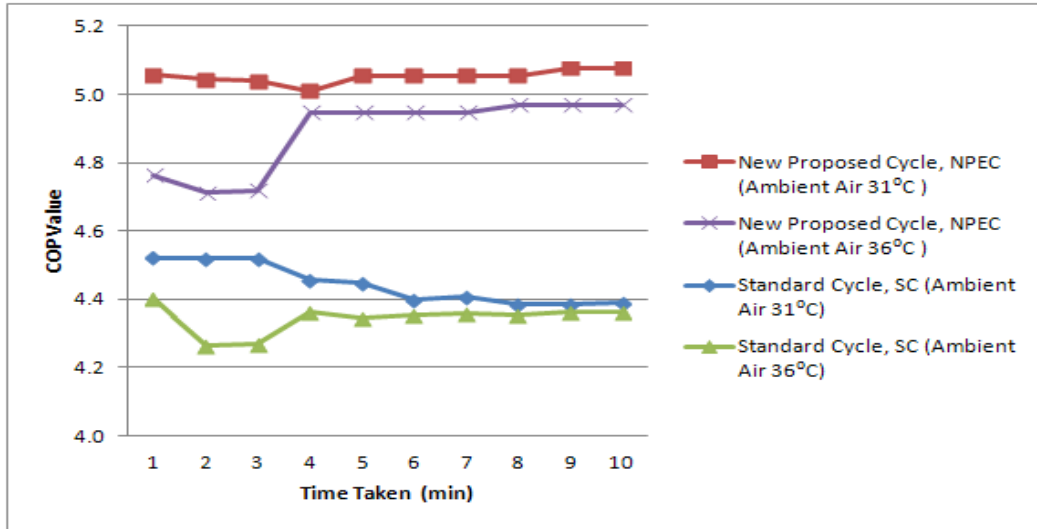
Figure 5: Coefficient of performance (COP) versus time taken

Figure 5 shows the coefficient of performance (COP) of the standard conventional cycle (SC) and the improved ejector cycle (IEC) versus time at two condenser ambient temperatures respectively. Initially the values of COP drops but after 3 minutes, then the COP for both systems rise to a constant value. It is clearly shown that the COP of improved ejector cycle is higher than that of conventional refrigeration cycle. It also shows that the COP at lower condenser ambient temperature is higher than that of higher condenser ambient temperature.
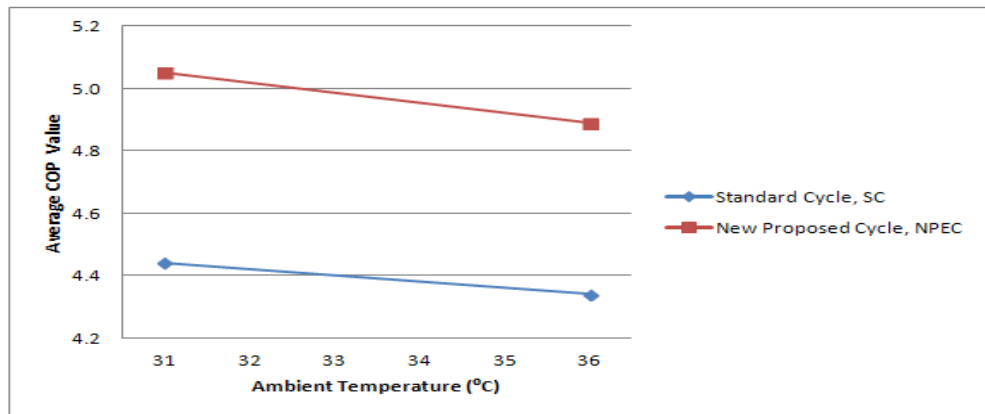

Figure 6: Coefficient of performance (COP) versus condenser ambient temperature.

Figure 6 shows the average coefficient of performance decreases as the condenser ambient temperature increases for both conventional cycle (SC) and improved ejector cycle (IEC). Based on the graph, the system has higher COP at the beginning of the experiment with ambient air of 31°C as compared to the systems

with ambient air of 36⁰C. These results are in agreement with Sumeru et. al. [11] and Ani and Kooi [12].
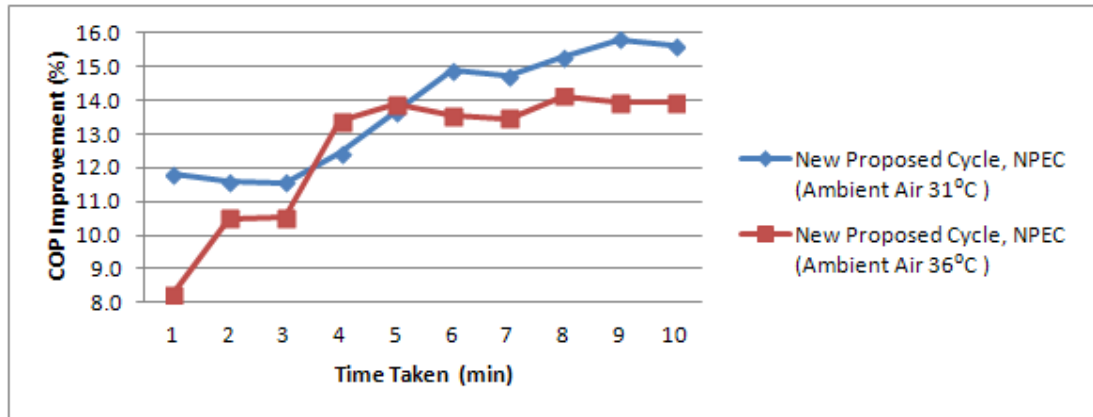

Figure 7: COP Improvement of improved ejector cycle versus time taken.

Figure 7 shows the COP improvement of the improved ejector cycle (IEC) versus time at condenser ambient temperatures of the 31⁰C and 36⁰C respectively. Based on the result, it shows that there is higher COP improvement at lower condenser ambient temperature. The COP improvement of the improved ejector cycle is influenced by the increase in cooling capacity compared with the input power but decreases with the condenser ambient temperature.
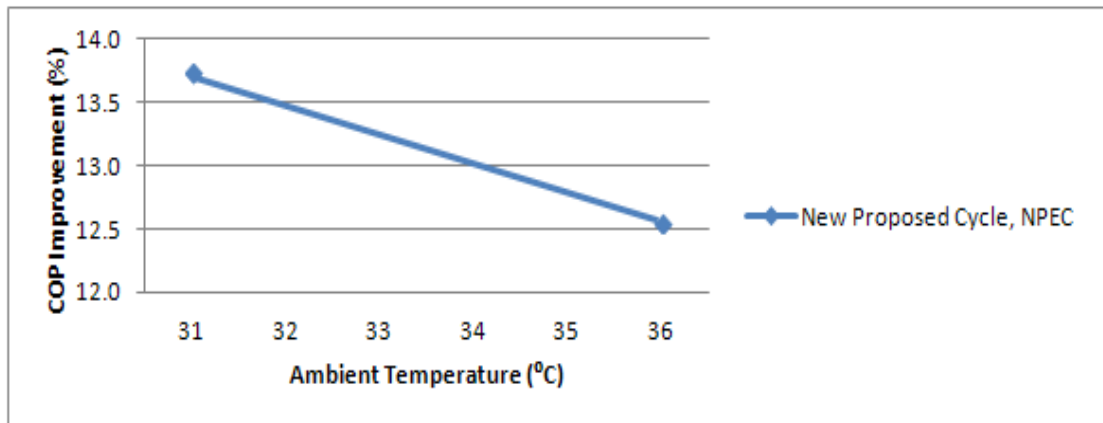

Figure 8: COP Improvement of improved ejector cycle for condenser ambient temperature 31⁰C and 36⁰C.

Figure 8 shows the COP improvement of the improved ejector cycle ranges from 12.6% to 13.7% depending on condenser ambient temperatures due to the high cooling effect of the evaporator of improved ejector cycle. The COP improvement of the improved ejector cycle is decreases with the condenser ambient temperature.

5.0   CONCLUSIONS

The current study on the performance of the improved modified configuration of ejector air-conditioning system using combined heat exchanger and separator was conducted. Based on the results of the study, it showed that this improved cycle is able to provide a higher COP for the air-conditioning system as compared to that of the conventional air-conditioning cycle. There is an improvement of COP with 12.6 % to 13.7 % for condenser ambient temperatures of 31°C and 36°C respectively through the improved ejector air-conditioning system. This increment of the COP improvement is due to the increase in cooling capacity of the system through the replacement of capillary tube with an ejector as expansion device in split-type residential air-conditioning system as well as with the additional component of combined heat exchanger and separator in this improved ejector cycle.

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