

Reduction in power consumption of refrigerator by using parallel expansion

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Abstract. This study aims to determine the reduction in power consumption of refrigerators by using parallel expansion. A refrigerator with a capacity of 120 liters has been used as a test instrument and R134a acts as a working fluid. Recording of refrigerator energy consumption is based on changes in cooling load temperature from range 3C to -3 C. The parameters observed during the test include suction pressure, discharge pressure, electric current, and weight of refrigerant circulated. The results indicate that installation of parallel expansion device on the refrigerator generates a decreased 1.5% - 4% of the electrical power consumption (ECP) so that it implicates for the save on power consumption required a refrigerator.

1. Introduction

Energy consumption has become an important issue for policy makers on a global scale. In Indonesia, the household sector contributes to the nationwide final energy consumption by approximately 16.62% in 2016 [1] and household electricity consumption has risen continuously over the years [2].

Refrigerator is a household appliance that requires electrical energy as a source of energy. Although the electrical power of one refrigerator is very low right now, but these household appliances still have great potential for energy savings because of their large numbers. They have an almost complete market penetration and operate continuously throughout the year [3]. If one refrigerator is assumed to be used by every six people in the world, the electricity consumed is approximately equal to 6% of the world's total electricity production [4]. Therefore, it is necessary to find ways to save the use of electrical energy in the refrigerator.

In recent years, a common way to reduce energy consumption and improved the coefficient of performance a vapor compression systems have implemented by the researchers. First, improvement of a compressor efficiency [5],[6],[7]. This method controlling operation of a compressor, reduction of frictionless, and reduction of losses associated with the pressure equalization during compressor off times. Second, improvement in refrigeration systems [8],[9]. In this case, an additional energy saving was obtained by the optimization of the operating sequence and refrigerant recovery operation. Third, the method to reduce the power consumption an improve the performance of a vapor compression systems can be done by using hydrocarbons as refrigerants [10],[11],[12]. The experimental results show that the hydrocarbons could reduce the energy consumption and improve the actual COP. Finally, the other relevant studies on the system performance of a vapor compression systems have also demonstrated that modifying cooling system using a heat exchanger could improve energy efficient and



performance [13],[14]. This study is focused on the reduction power consumption of refrigerator by using parallel expansion.

In general, a conventional vapor compression system uses a single expansion device. The parallel expansion device is an engineering method on refrigeration system to reduce throttling loss of the refrigerant liquid as it flows through the liquid line to the evaporator. The state of the refrigerant entering the expansion device is usually assumed to be saturated liquid [15]. When the liquid flows through the expansion device, a part of the liquid vaporizes. The pressure of the liquid is reduced to the evaporator pressure so that the saturation temperature of the refrigerant entering the evaporator will be below the temperature of the refrigerated space. The refrigerant is discharged from the expansion device into the evaporator as a liquid-vapor mixture. Obviously, only the liquid portion of the liquid-vapor mixture will vaporize in the evaporator and produce useful cooling [16]. Therefore, expansion parallel a liquid refrigerant can reduce throttling losses resulting from an isenthalpic expansion. So, it can increase the refrigerating effect, reducing the power consumption and potentially improve the coefficient of performance (COP).

The purpose of this study was to determine the reduction in power consumption of refrigerator by using parallel expansion. The experiment was conducted by replacing the single expansion device with a parallel expansion device on a refrigerator. Therefore, the application of this engineering method to a refrigerator is expected to decrease of energy/power required as the driving force of compressor.

2. Materials and experimental method

Figure 1 shows the schematic installation of parallel expansion device used for the experiment. The main components of the refrigerator consisted of an evaporator, compressor, and condenser (Sanyo). Component of the parallel expansion device made from copper capillary tubing diameter of 0,97 mm. In this study, the working fluids was used R134a. Two pressure gauges (Robin Air) and two temperature sensors (Lutron) were placed on the inlet and outlet of the compressor to measure the suction and discharge pressures-temperature. On the inside of the refrigerator, a container of the brine (salt water) concentration of 12% was kept, serving as a cooling load. A thermometer (Beuer) was placed in the brine container to determine changing in temperature every 1°C.

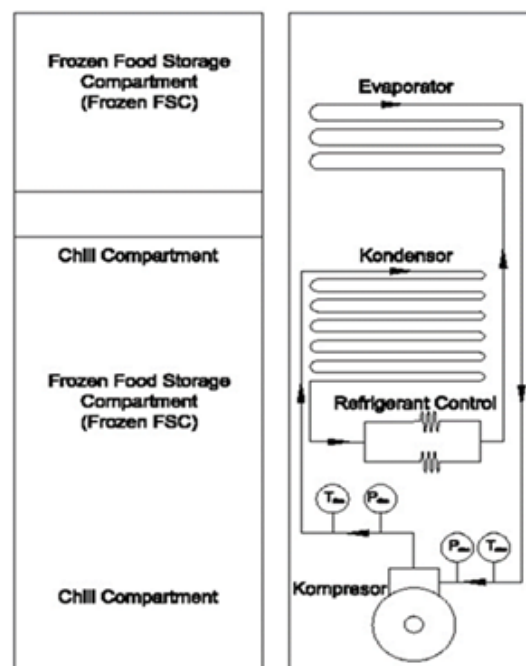


Figure 1. The schematic installation of parallel expansion device used for the experiment.

The experiment conducted under two conditions. The first, the system was operated in a normal mode (with a single expansion device) to obtain baseline data of the refrigerator performance. The second, the system operated with a parallel expansion mode. Data retrieval conducted four times under each condition. The beginning of the study carried out calibration of all measurement equipment. Then the process of vacuum removed water content and other substances in the cooling system. After that, checking was done to any leaks from all the parts and installation of the pipe. Then, the system was filled with R134a weighing 30 g in accordance to the recommendation of the manufacturer. The next stage operated the refrigerator for about one hour to reach a steady state condition and then entered a container of brine into the freezer. Data capture started when the temperature of the brine was 3°C, with the assumption that the system was on steady state condition. Next, the changing were observed until the temperature of the brine reached -30C. During the study, the temperature of the environment was kept at $28^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

3. Results and discussions

The results were obtained from the test refrigerator in two operating conditions: normal mode and parallel expansion mode. Tests were carried out at an ambient temperature of 28°C in the refrigeration cycle operating mode under load conditions of 3°C to -3°C .

3.1. Theoretical horsepower of compressor

Figure 2 shows the results of the theoretical horsepower (hp) of the refrigerator under two testing conditions. In general, the hp generated by the system using parallel expansion mode has a lower value than that of the normal system.

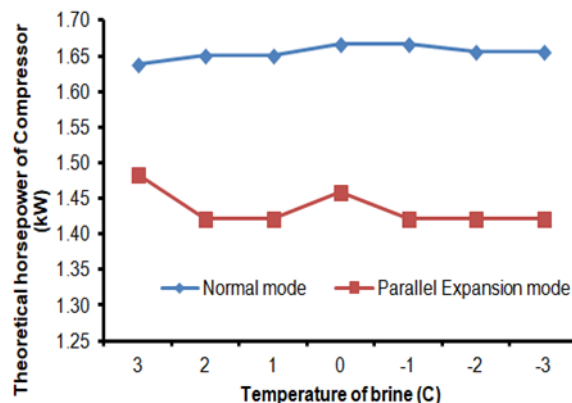


Figure 2. Theoretical horsepower of compressor based on temperature changes of brine in two mode operation; normal mode and parallel expansion mode.

In the normal mode, the hp generated when the brine was 3C was 1.64. Then, this increased gradually to 1.67 when the temperature of the brine was -1C. After that, it fell back to 1.66 when the temperature of the brine was -3C. On the other hand, in the system which used parallel expansion, the hp generated when the brine was 3C was 1.48. Further, this gradually decreased to 1.42 when the temperature of the brine was -3C. Based on the results, there had been 9% - 14% decrease of the hp in the system using parallel expansion.

The effects of the use parallel expansion device on the refrigerator resulting evaporation process in the expansion device become shorter followed by more liquid refrigerant flowing into the evaporator to absorb heat from cooling load (brine). Furthermore, the ratio between the discharge pressure and suction pressure generated by the system becomes lower so that the work of compression needed to compress the refrigerant from evaporating pressure to condensing pressure becomes shorter. The achievement of this value will contribute to smaller energy consumption needed to operate the compressor.

3.2. Electrical power consumption

Figure 3 presents the electrical power consumption (EPC) of two mode conditions of the refrigerator testing. Overall, the electrical power consumption generated by the system using parallel expansion mode has a lower value than that of the normal system.

At first, the obtained EPC was 149.6 W when the temperature brine was 3C on normal mode. Then, this decreased to 138.6 W when the temperature of the brine was 0C. After that, it feel back to 149.6 W when the brine temperature was -3C. Further, when the system employed parallel expansion, EPC decreased significantly. When the temperature of the brine was 3C, the obtained EPC was 147.4 W. Then, the value fluctuated decreased to 143 W when the brine temperature was -3C. These results indicate that the use of parallel expansion on the refrigeration system decreased 1.5% - 4% of EPC.

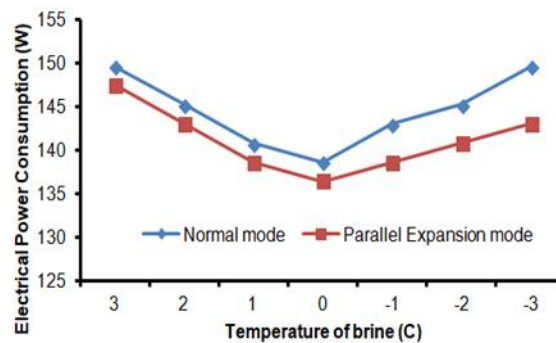


Figure 3. Electrical power consumption based on temperature changes of brine in two mode operation; normal mode and parallel expansion mode.

4. Conclusions

Research on the use of parallel expansion to reduce electrical power consumption of refrigerator has been conducted. The results indicate that installation of parallel expansion device on the refrigerator generates a decreased 1.5% - 4% of the electrical power consumption (ECP) so that it implicates for the save on power consumption required a refrigerator.

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