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Experimental study of refrigerator truck cold box for a constant temperature of 10°C based on variations in condenser dimensions

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Abstract

Transportation equipment equipped with a cooler box is needed for food delivery to keep the product fresh until it reaches its destination. Evaluation is carried out to determine the cooling temperature performance through testing using variations in condenser dimensions. The test was carried out to achieve a cold temperature in the cooler box of 10°C. The condenser used includes three variations, namely the 1st dimension is (P 23 x H 14) inch² x 19 mm, the 2nd dimension is (P 23 x H 14) inch² x 26 mm, and the 3rd dimension is (P 23 x H 14) inch² x 44 mm. The test gives the result that the condenser in dimension-3 gives time to cool down at a temperature of 10°C faster than the condenser in dimensions-2 and 1. The condenser in dimension-1 can produce a cold time of 660 seconds, while the condenser for dimensions-2 and 1 is 960 seconds and 1320 seconds respectively. In addition, the lowest compression work occurs in the condenser with the 3rd dimension of 33.408 kJ/kg when compared to the 1st and 2nd dimensions of 38.984 kJ/kg and 35.923 kJ/kg. The smaller the dimensions of the condenser have an impact on the higher the compressor outlet pressure. This condition has an influence on the coefficient of performance (COP) in the refrigeration system, namely the condenser with dimension-3 gives the highest COP of 4.622 compared to dimensions-1 and 2, respectively 3.531 and 4.081. It was found in this study that the condenser at the largest dimension produces the most optimum performance, that is, an efficient refrigeration system has low compression power and high COP.

Keywords: Condenser; Cooling Temperature; Refrigeration System; Coefficient of Performance

1. Introduction

The process of preserving food and fresh food ingredients in the tropics through cooling is needed to extend their shelf life. The cooling process application is carried out when storing in a fixed place or when moving. Specifically for cooling carried out on moving food ingredients, a transportation device that is equipped with a refrigeration system is needed. This transportation tool is very necessary for the process of sending food items such as drinks, ice cream, fresh meat, food, etc. Transportation equipment equipped with a cooling system functions to increase comfort and freshen the air. This is necessary so that the food that is sent from one place to another remains durable and maintains its quality. In this case, the need for a constant cooling room temperature is analyzed, namely 10°C with several variations of the condenser dimensions.

The condenser is a very important component in the cooling system so that the cooling process continues. The condenser is an important component of Air Conditioning (AC) and the amount of heat generated by the condenser can affect comfort, and function as a heat exchanger [1]. The cooling system in rooms, personal transportation equipment, and for the purposes of cooling food has the same function. The condenser is a heat exchanger that functions to condense the vapor phase into liquid [2]. The condenser removes hot air from the cooled room so that the room temperature can

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be maintained constant. In transportation, the condenser also has the same role as a part of the refrigeration system. Refrigeration follows the concept of heat transfer, but heat transfer occurs from a lower temperature to a higher temperature. Heat absorption occurs in a room that has a low temperature. Meanwhile, heat dissipation occurs in rooms that have high temperatures. In general, the refrigeration system in transportation equipment is an application of the vapor compression cycle as shown in Figure 1.

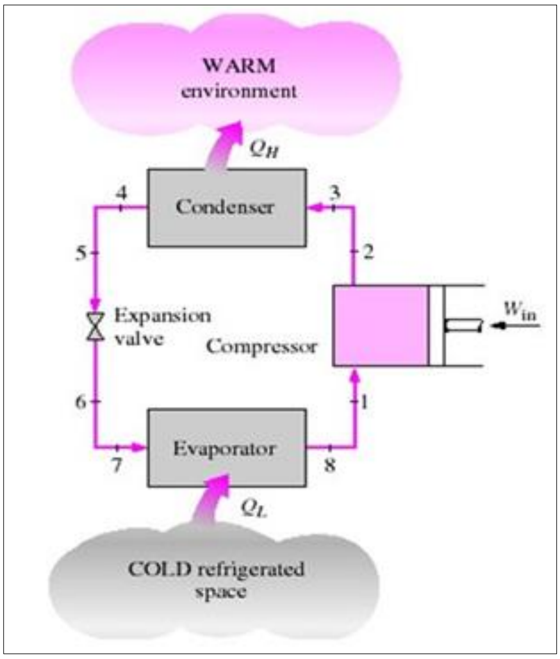

Figure 1 Ideal vapor-compression refrigeration cycle [3]

The condenser functions to remove the compression heat provided by the compressor and the energy absorbed by the evaporator. Increasing the performance coefficient on the cascade system as a result of increasing the high-stage condenser heat release rate [4]. The main function of the condenser is to receive steam from the compressor and condense it. The condenser has the role of maximizing the efficiency of the cooling machine so it is said to be a very important component. The condenser as a heat transfer unit has the function of condensing gas into a liquid state [5]. The condenser is applied in analyzing the heat transfer process through the evaluation of materials and refrigerants, as well as liquid smoke distillation equipment through the cooling arrangement in the condenser [6, 7]. Refrigerant is the main fluid used in the cooling process. Refrigerant is the most sensitive material to the total cooling costs and operating conditions distributed to the condenser [8]. Refrigerant distributed through the condenser has an effect on the temperature in each tube, pressure drop, refrigerant mass, and heat transfer [9]. The fluid flow in the condenser can be gas outside the pipe and refrigerant inside the pipe or vice versa. The heat transfer process takes place in the condenser between two fluids that have different temperatures, so the condenser acts as a heat exchanger. A heat exchanger is an application of the heat transfer process that occurs in two immiscible fluids with different temperatures separated by [2, 10]. The rate of heat transfer in the condenser depends on the condensing and evaporation temperatures, as well as the cooling capacity [11].

Refrigeration is needed in transportation equipment for delivering food to maintain its freshness and durability. The purpose of refrigerating food is to lower the temperature to prevent the growth of microorganisms. This can prevent food from rotting and spoiling. The process of cooling food, especially food that is sent between locations or regions, requires transportation through a refrigeration system. The refrigeration system used for transportation uses a vapor compression cycle. This cycle is most often used for refrigeration and air conditioning. Cooling is the process of transferring heat from a lower temperature to a higher temperature. Several studies on the use of vapor compression refrigeration systems in contact with food, such as refrigerators; cold boxes for eggplant, cucumber, tomato, and beer; as well as for fishing boats [12, 13, 14].

In principle, vapor compression refrigeration uses interconnected components, the evaporator, compressor, condenser, and expansion valve. The cooling fluid is in the form of refrigerant to absorb heat in the room and release it to the environment. This refrigerant circulates in the cooling unit. The temperature difference between the refrigerant and the air results in the process of releasing and absorbing heat. The performance of the cooling system is affected by the condition of the refrigerant. The refrigerant vapor exits the evaporator which has a low pressure sucked by the compressor. The pressure of the steam inside the compressor is increased and a change of form occurs in the form of superheated steam. This steam is circulated to the condenser so that it undergoes a condensation process. Furthermore, it is circulated to the expansion valve for the pressure reduction process so that the fluid easily undergoes the evaporation process in the evaporator. In the condenser and evaporator, a heat transfer process occurs, namely the evaporator absorbs heat from the cooled component and heat is released to the environment by the condenser.

In this study, the evaluation of cooling performance at constant temperature was carried out based on variations in condenser dimensions. The dimensions of the condenser related to its capacity have an influence on the release of heat in the condenser to the environment. This has implications for the heat absorption process by the evaporator from the cooled space.

2. Material and methods

The materials in this study used refrigerant 134a (R134a) and refrigeration oil. The measuring instrument consists of three condenser units with dimensions (L 23 x H 14) inch^2 and thickness respectively 19 mm (condenser-1), 26 mm (condenser-2), and 44 mm (condenser-3), vacuum machine, digital thermometer, manifold gauge, digital tachometer, and digital scales. The research was carried out on a refrigerator truck unit that was attached to a means of transportation with a vapor compression system.

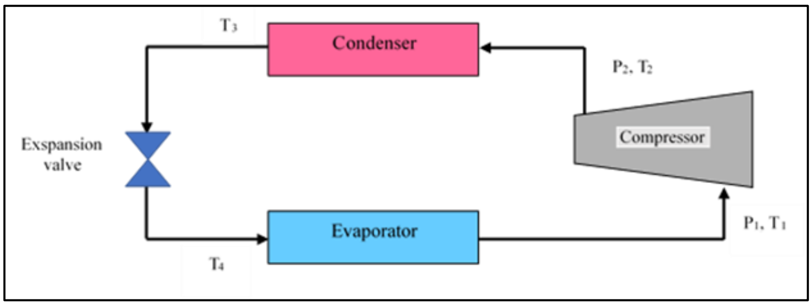

Figure 2 Research schematic

Tests were carried out for constant cooling load and room temperature of 2000 Watt and 10^{o}C respectively. Variables measured include refrigerant pressure and temperature at the compressor inlet pipe (P_1 and T_1), refrigerant pressure at the condenser inlet pipe (P_2 and T_2), and refrigerant temperature at the condenser outlet pipe (T_3). The research scheme is shown in Figure 2. Absolute pressure (Pabs) in units of kPa is calculated using the average value of each repetition with the following Equation.

$$P_{abs} = P_{gauge} + P_{atm}\text{..................}(1)$$

P_{atm} is atmospheric pressure (kPa) = 101.325 kPa and P_{gauge} is measuring pressure (P_{sig}). Furthermore, the average temperature value is determined from each digital thermometer. Based on the pressure and temperature values, the enthalpy values at each point can be obtained using Table R134a. The enthalpy value is used to calculate compression work (W_c), refrigeration effect (q_r), and coefficient of performance (COP). Compression work using Equation 2.

$$W_c = h_1 - h_2\text{......................}(2)$$

W_c is compression work (kJ/kg), $\dot{m}$ is the mass flow rate (kg/s), h_1 is the initial enthalpy of compression (kJ/kg), and h_2 is the final enthalpy of compression (kJ/kg).

The Refrigeration Effect (q_r) is the heat absorbed in the evaporator in process 4-1 as shown in Equation 3.

$$q_r = h_1 - h_4\text{.......................}(3)$$

q_r is the refrigeration effect (kJ/kg), h_1 is the initial enthalpy of compression (kJ/kg), and h_4 is the final enthalpy of expansion (kJ/kg). The coefficient of performance (COP) of a standard vapor compression cycle is the refrigeration effect divided by the compression work.

$$COP = \frac{q_r}{W_c} = \frac{h_1 - h_4}{h_2 - h_1} \text{.......(4)}$$

3. Results and discussion

The dimensions of the condenser (P 23 x H 14) inch^2 x 44 mm (condenser-3) produce the fastest cold time when compared to condenser-1 (P 23 x H 14) inch^2 x 19 mm and condenser-2 (P 23 x T 14) inch^2 x 23mm. Condenser-3 requires 660 seconds for cold reaching time, while condenser-1 and condenser-2 require 1320 seconds and 960 seconds for cold reaching time respectively. The cold-reaching time is faster as a result of the lower pressure that occurs in the condenser-3 so the compressor work is also lower. The lower the compressor work, the greater the amount of heat released (qout) by condenser-3 compared to condenser-2 and 1. This is in accordance with previous research by Bawa Susana and Santosa, that the largest condenser dimensions provide the most optimum thermal performance results [16]. To reach a temperature of 10ºC in the cool box, condenser-3 provides the fastest cooling time. This affects the heat transferred or absorbed by the evaporator getting bigger. The condenser's dimensions influence the time to reach cold as shown in Figure 3.

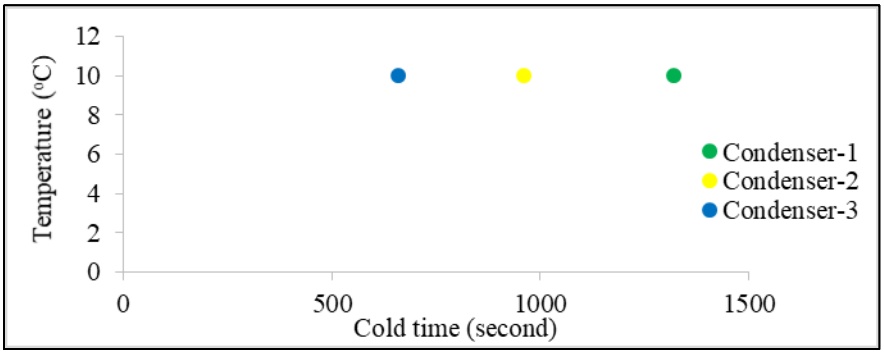

Figure 3 Cooling time for a temperature of 10ºC

Compression work is influenced by the dimensions of the condenser and affects the room temperature. This is shown in Figure 4, namely the relationship between room temperature and compression work.

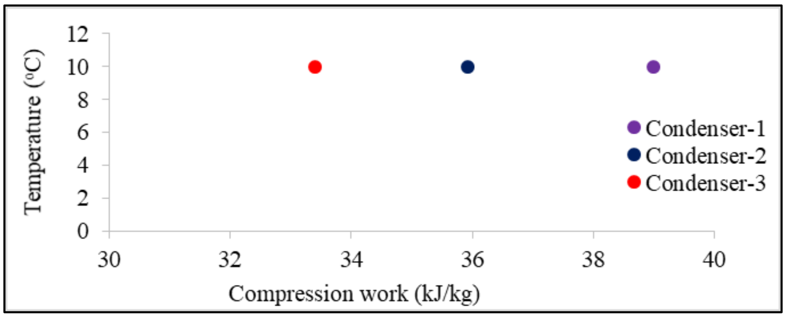

Figure 4 Compression work at a temperature of 10ºC

The lowest compression work occurs in the condenser with the largest dimension (condenser-3), which is to reach a room temperature of 10ºC. The highest compression work occurs in the smallest condenser dimension (condenser-1). The compression work on condenser-1, condenser-2, and condenser-3 is 38.984 kJ/kg, 35.923 kJ/kg, and 33.408 kJ/kg, respectively. This shows that the compressor outlet pressure is inversely proportional to the dimensions of the condenser. The smaller the dimensions of the condenser have an impact on the higher the compressor outlet pressure. The relationship between the room refrigerator temperature of 10ºC and the coefficient of performance (COP) is presented in Figure 5.

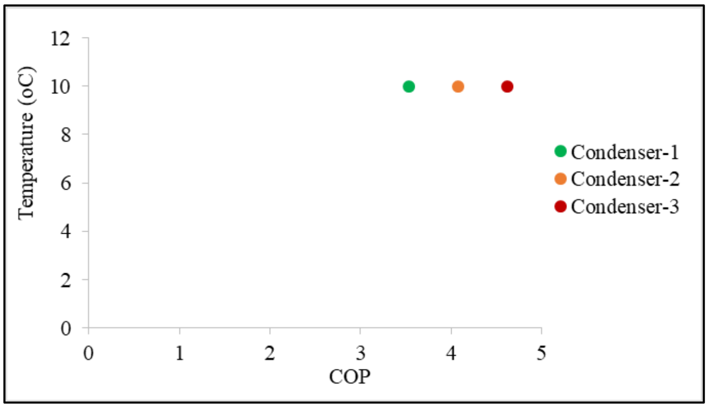

Figure 5 Coefficient of performance (COP) at a temperature of 10^{o}C

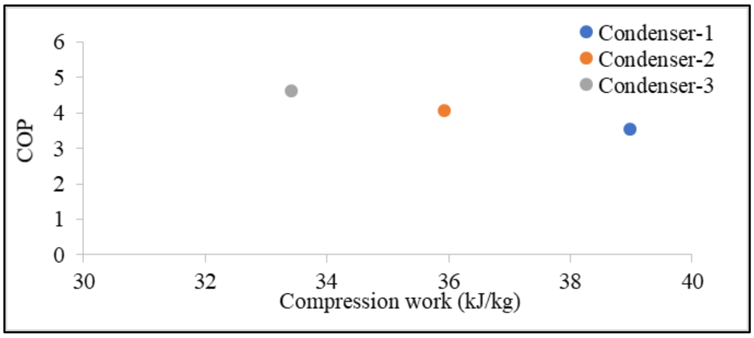

Figure 6 The relationship between the coefficient of performance (COP) and compression work at a temperature of 10^{o}C

The highest COP occurs in the largest condenser dimension application, namely condenser-3. This is because the lowest compression work occurs in condenser-3. The compression work in the cooling system affects the COP value. The lower the compression work has an impact the higher the COP value, and vice versa. The COP values for condenser-1, condenser-2, and condenser-3 were 3.531, 4.081, and 4.622, respectively. The COP value is directly proportional to the area of the condenser and inversely proportional to the compression work. Compression work affects the COP value as presented in Figure 6. The lowest COP value occurs at high compression work, while the highest COP value occurs at the lowest compression work. The compression power required for refrigeration is inversely related to COP. An efficient refrigeration system has a high COP with low compression power. The longer the condenser, the more effective the heat transfer occurs because the shorter the fluid mechanism process that occurs to return the fluid from the condenser to the evaporator [16].

4. Conclusion

Means of transportation used in food delivery to keep it fresh require a cooler box with a temperature according to the condition of the food. To obtain a temperature of 10oC in this study an evaluation was carried out on variations in the dimensions of the condenser. Of the three variations of the dimensions of the condenser used, namely the 1st dimension is (P 23 x H 14) inch^2 x 19 mm, the 2nd dimension is (P 23 x H 14) inch^2 x 26 mm, and the 3rd dimension is (P 23 x H 14) inch^2 x 44 mm, the largest condenser dimension is obtained to provide optimum thermal performance. This can be seen from the value of the coefficient of performance (COP) on the largest condenser dimension (condenser-3) of 4.622 compared to condenser-1 and 2 of 3.531 and 4.081. The highest COP was obtained with the smallest compression work, namely, 33.408 kJ/kg when compared to condensers-1 and 2, respectively 38.984 kJ/kg and 35.923 kJ/kg. The largest condenser dimension application (condenser-3) requires 660 seconds to reach a cold time at 10^{o}C, while condenser-1 and condenser-2 require 1320 seconds and 960 seconds. The largest condenser dimension has low compression power, high COP, and the fastest time to cool down at 10^{o}C.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflict of interest.

References

[1] Putri SWK, Yushardi, Supriadi B. Analysis of variations in the type of condenser air conditioning (AC) on the amount of temperature rise produced. Jurnal Pembelajaran Fisika. 2018; 7(3): 293-298.

[2] Bergman TL, Lavine AS, Incropera FP, Dewitt DP. Fundamentals of Heat and Mass Transfer. 7th. 2011. John Wiley & Sons.

[3] Çengel YA, Boles MA. Thermodynamics: An Engineering Approach. 5th. 2006. McGraw-Hill.

[4] Firdaus R, Putra ABK. Study of variations in the heat release rate of high-stage condensers of cascade refrigeration systems R22 and R404a with concentric tube-type heat exchangers. Jurnal Teknik Pomits. 2014; 3(1): 64-69.

[5] Alus M, Elrawemi M, Eldabee F. Thermoeconomic optimisation of steam condenser for combined cycle power plant. International Journal of Science and Engineering Applications. 2017; 6(3): 70-75.

[6] Pukoliwutang R, Sompie SRUA, Allo EK. Cooling arrangement on condenser for liquid smoke distillation apparatus. E-Journal Teknik Elektro dan Komputer. 2017; 6(1): 27-34.

[7] Nwasuka NC, Nwaiwu U, Nwadinobi CP, Echidebe C, Ikeh VC. Design and performance evaluation of a condenser for refrigeration and air-conditioning system using R-134a. International Journal of Mechanical and Production Engineering Research and Development. 2020; 10(3): 6435-6450.

[8] Chen X, Li Z, Zhao Y, Jiang H, Liang K, Chen J. Modelling of refrigerant distribution in an oil-free refrigeration system using R134a. Energies. 2019; 12(24): 1-15.

[9] Uttariyani I GA. Design optimization of evaporator and condenser for cooling system of passenger vehicle cabin. M.P.I. 2016; 10(2): 195-200.

[10] Çengel YA. Heat Transfer: A Practical Approach. 2nd ed. 2002. McGraw-Hill, New York.

[11] Stoecker WF, Jones JW, Hara S. Refrigeration and Air Conditioning. Second Edition. 1987. Erlangga, Jakarta.

[12] Al-Ajmi ENRM. Coefficient of performance enhancement of refrigeration cycles. Int. Journal of Engineering Research and Applications. 2015; 5(3): 117-125.

[13] Al hasbi G, Budiarto U, Amiruddin W. Analysis of the design performance of a vapor compression refrigeration system on a 5 GT fishing boat in the Rembang area. Jurnal Teknik Perkapalan. 2016; 4(4): 768-778.

[14] Buntu TR, Sappu FP, Maluegha BL. Analysis of the cooling load of food products using the LUCAS NULLE type RCC2 refrigeration machine cold box. Jurnal Online Poros Teknik Mesin. 2017; 6(1): 20-31.

[15] Bawa Susana I G, Santosa I G. Thermal performance evaluation of the variation of condenser dimension for foodstuffs transportation cooling systems. Logic. 2021; 21(3): 184-189.

[16] Fachrudin AR. Effect of condenser length on heat pipe thermal performance. Jurnal INTEKNA. 2020; 20(1): 47-52.