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CONDENSOR DESIGN ANALYSIS WITH KAYS AND LONDON SURFACE DIMENSIONS

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Abstract -- *The use of condensers in air conditioning units is more common in large-capacity units than in ones with a smaller capacity. Air conditioning provides comfort and freshness to an air-conditioned room. It should be noted that each room has a different heat load, which affects the specifications of the condenser used. The accuracy with which appropriate condenser specifications are determined affects the performance of the air conditioner. Thus, considering how important condenser needs are, it is necessary to design condensers with optimal performance, which adhere to proven standards. To achieve this, the design of a condenser should be based on the results of the smallest condenser dimensions of three types of surfaces, as they are intended for a limited place. This condenser design uses the standard dimensions of the Kays and London charts. Data is collected by measuring the results of temperature and enthalpy of a refrigerant at desuperheating and condensation, inlet air temperature, outlet air temperature, refrigerant mass flow rate, and air mass flow rate. The results of the compact condenser design are based on existing data, which is obtained from the smallest design results. The result uses the type of Surface CF-8.72(c) with a heat transfer area of 0.259 m^2, a total tube length of 9.5 m, crossing tube length 0.594 m and a pressure drop of 3778 Pascal (Pa) on the side of a tube. This design fulfills the stipulated requirements, as the pressure drop is less than the specified maximum limit in most units.*

Keywords: *Condenser; Air Conditioning; Heat Exchanger*

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INTRODUCTION

The use of condensers in air conditioning units has expanded from small-capacity units to large-capacity ones due to rising temperatures in Indonesia, especially Jakarta, over time. The two laws of thermodynamics contain two terms: refrigeration and air conditioning. It should be noted that the fields of refrigeration and air conditioning are interconnected, but each has a different scope [1], [2]. Air conditioning in the form of temperature regulation, humidity regulation, and air quality. While refrigeration is used for specific process needs such as refrigeration for household, general, and industrial purposes [3], [4].

The condenser is a very important cooling component that functions to maximize efficiency in the cooling engine [5], [6]. In this condenser, heat is released by condensation and sensible heat. In general, using a surface condenser, this type of condenser is a compact type in which refrigerants are circulated through the tube [7], [8]. The outside air condenser usually uses a cooling refrigerant circulation from the which is assisted by the fan to release heat into the atmosphere [9]. The most working fluid flows continuously in a heat exchanger, after exceeding a certain operating time, it will pollute the heat transfer surface [10], [11]. The deposits formed on most surfaces will have a sufficiently low thermal conductivity, which will result in a decrease in the global heat transfer coefficient in the heat exchanger, resulting in a lower exchange rate of heat energy in the heat exchanger [12], [13]. To get the best performance, the heat exchanger must be designed carefully and optimally. Therefore, mastery of the design method of a heat exchanger is very important because it will provide a very large contribution to efforts to improve the performance of industrial installations, which also means efforts to save energy, especially in the industrial sector [14, 15, 16].

The heat exchanger can be called a compact heat exchanger when the area for the volume ratio is quite significant. Namely, the ratio of the surface area of heat transfer to the heat exchanger volume is high. The area of the density of the heat exchanger depends on the phase of the fluid [17], [18]. Whereas for gas to gas and gas to liquid the threshold area value to volume ratio is greater than or equal to 500 m^2/m^3 or 700 m^2/m^3, while for compact heat exchangers from liquid to liquid, the ratio is greater than or equal to 200 m^2/m^3 or 400 m^2/m^3 [19, 20, 21].

Given the need for condensers as heat exchangers that continue to increase in many industries, it is necessary to design condensers efficiently and effectively by using standard dimensions obtained from previous studies. This study aims to design a condenser using three types of surface dimensions from Kays and London and select condensers from the design results that have the smallest dimensions. From this research, it is expected to be able to design a heat exchanger by applicable standards so that heat exchangers can be produced that have high effectiveness.

METHOD

An outline of research activities can be seen in the flow diagram Figure 1.

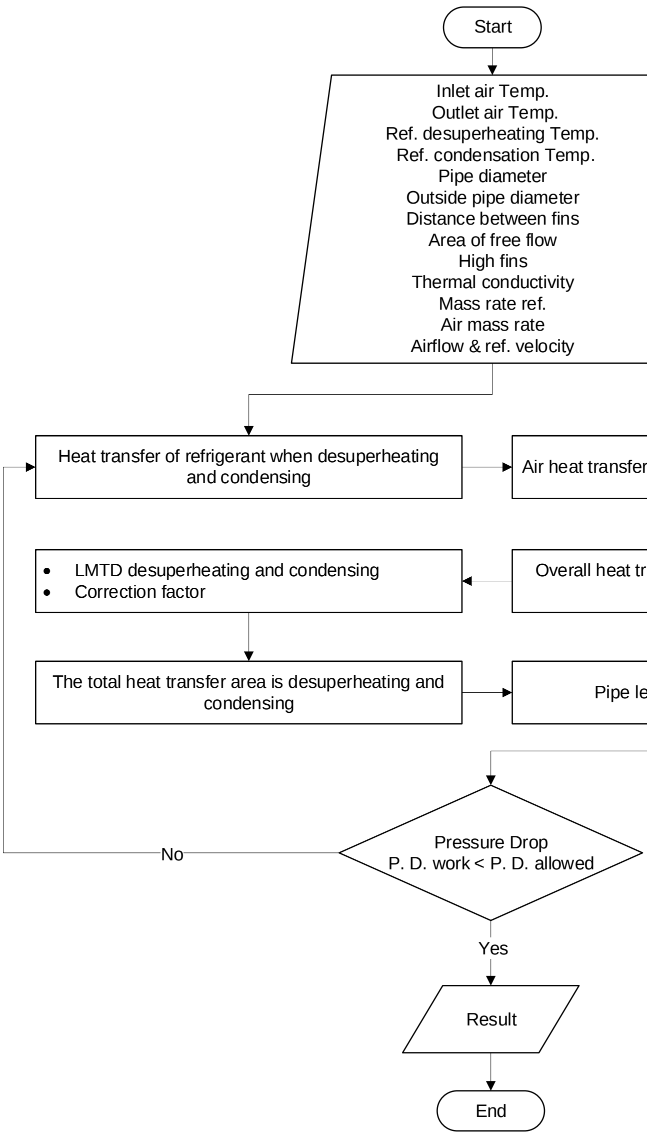

Figure 1. Research Flowchart

The implementation of this research can be divided into several stages. In general, the stages are data collection, calculation, and drawing design results. Initially, with planning, the condenser is designed using standard dimensions with several types of surface variations, so that the maximum design results are obtained. Several data are listed in Table 1.

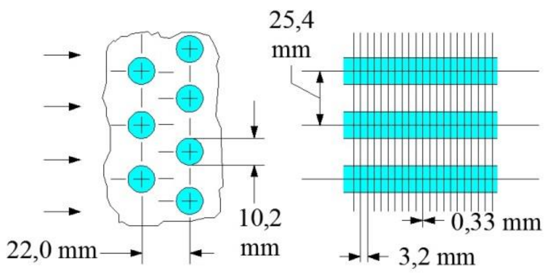

Figure 2. Surface 8.0-3/8 T [19]

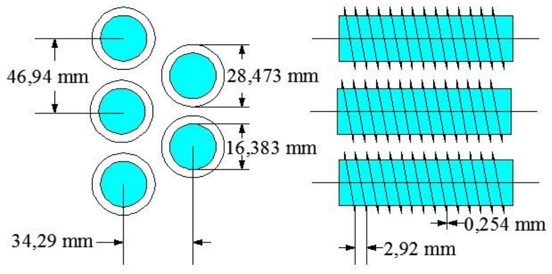

Figure 3. Surface CF-8.7-5/8 J [19]

The design of the condenser uses R-134a type refrigerant. Furthermore, collecting data was obtained from the measurement of temperature and enthalpy of the refrigerant at desuperheating, temperature, and enthalpy of the refrigerant at condensation, intake air temperature, air outlet temperature, refrigerant mass flow rate and airflow rate. The condenser is designed to use a forced convection system with a fan to remove heat.

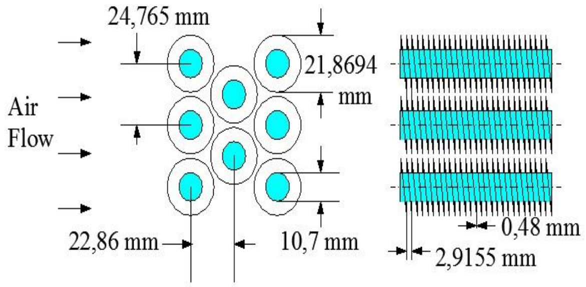

Figure 4. Surface CF-8.72(c) [19]

The condenser tube material will be made from copper and a fin material from aluminum. Based on considerations in terms of construction, the condenser design dimension refers to the graph of heat transfer and friction factor for a continuous fin circular tube heat exchanger with a surface type that is shown in Figure 2, Figure 3, and Figure 4.

The entire data is calculated to determine the total tube length and cross-section area of the smallest condenser.

Table 1. Design Data

Meaning	Symbol	Quantity
Refrigerant mass flow rate	$\dot{m}_{R134a}$	0.0012 kg/s
Air mass flow rate	$\dot{m}_{air}$	0.0029 kg/s
Thermal conductivity	k_m	237 W/mK
Free air flow speed	v_∞	10 m/s
Inlet air temperature	$T_{u(in)}$	27º C
Outlet air temperature	$T_{u(out)}$	40º C
Refrigerant desuperheating temperature		75º C
Refrigerant condensation temperature		50º C

This design is said to be successful if the results of the design produce a significant decrease in pressure less than the amount of pressure drop allowed. The final step is to draw the design results so that the main condenser dimensions are in the form of tube length, condenser cross-sectional area, and tube bends.

RESULTS AND DISCUSSION

Design Model

The results of the design calculations are then drawn using a computer aided design application to obtain three-dimensional images of each surface type. Figure 5 is the design of the 8.0-3 / 8T surface type. This compact design has the smallest diameter tube characteristics compared to other types. This design also has a high density between the tubes, and it has a plate fin type.

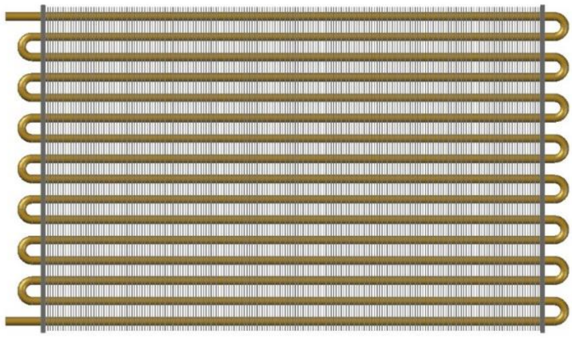

Figure 5. 8.0-3/8T Surface Model

The surface type CF-8.7-5 / 8J (b) has the largest tube diameter, as shown in Figure 6. This design has the farthest distance between the tubes. The type of fin used is a circular fin. While the CF-8.72 (c) surface as shown in Figure 7 has a design dimension that is almost the same as the 8.0-3 / 8 T surface. Significant differences occur in fin types. It uses a circular fin.

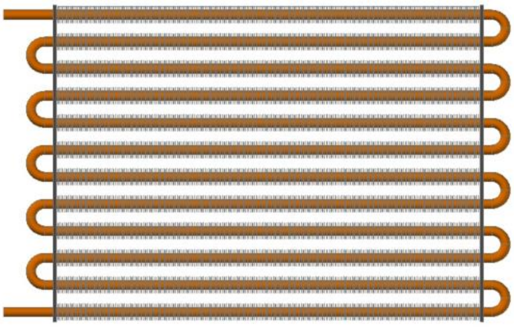

Figure 6. CF-8.7-5/8J(b) Surface Model

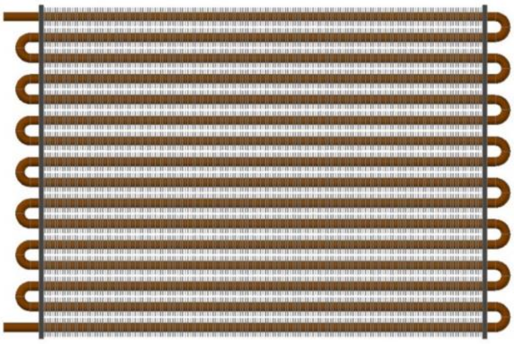

Figure 7. CF-8.72(c) Surface Model

Design Analysis

In variations of the heat exchanger surface design in Figure 8, surface CF-8.72(c) has the largest overall heat transfer coefficient, which is 41.218 W/m^{2}K at desuperheating, 35.699 W/m^{2}K at condensation. In another side, for 8.0-3/8T surface types has a coefficient heat transfer of 38.52 W/m^{2}K at desuperheating, 33,621 W/m^{2}K at condensation and type CF-8.7-5/8J(b) has the lowest overall heat transfer coefficient of 24,958 W/m^{2}K when desuperheating, 21.843 W/m^{2}K at the time of condensation.

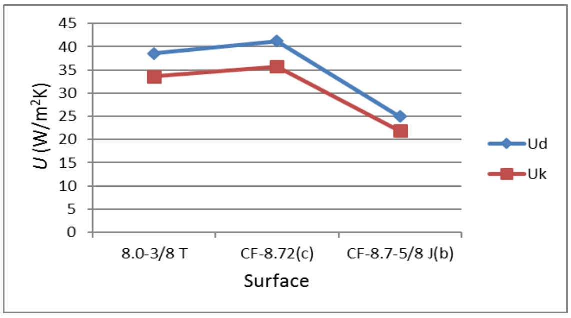

Figure 8. Relationship between a surface area with a heat transfer coefficient

In Figure 9, the calculation of the largest fin efficiency is indicated by the type 8.0-3/8T surface, which is 0.94 while the surface CF-8.72(c) and CF-8.7-5/8J(b) overall fin efficiency values are 0, 93. The fin efficiency value depends on the dimensions and fin material.

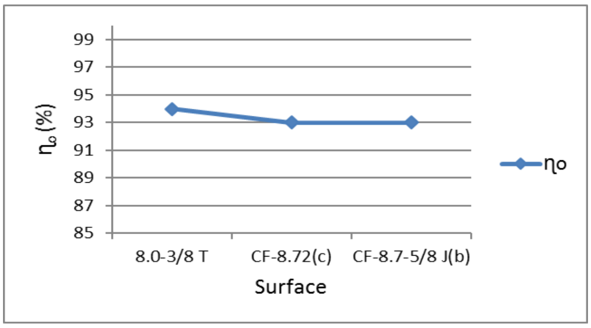

Figure 9. Relationship between the overall efficiency value of fins with surface

The thickness of the fins will affect the heat transfer coefficient on the airside because it is related to the efficiency of fins, the greater the efficiency of the fins, the greater the heat transfer coefficient on the airside. The greater the value of thermal conductivity of the material, the greater the efficiency of a fin.

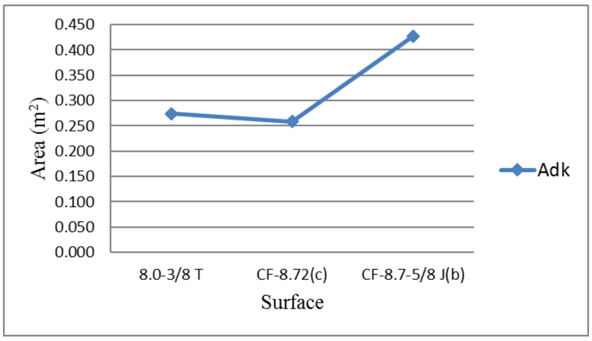

Figure 10. Heat transfer area relationship with the surface

Figure 10 concludes that the largest heat transfer area is shown by surface CF-8.7-5/8J type (b), which is 0.423 meter^2, while surface type 8.0-3/8T has a heat transfer area of 0.274 meter^2 and surface type CF-8.72(c) has the smallest heat transfer area which is 0.259 meter^2.

The results of the comparison in Figure 11 show that the heat transfer area is inversely proportional to the overall heat transfer coefficient. The greater the overall heat transfer coefficient, the greater the total heat transfer area. The greater the overall heat transfer coefficient, the smaller the total length of the tube.

The magnitude of the overall heat transfer coefficient is influenced by the heat transfer coefficient, overall fin efficiency, and fouling factor. If the fin efficiency and heat transfer coefficient are greater, the overall heat transfer coefficient will be even greater. The greater the value of the fouling factor, the overall heat transfer coefficient becomes smaller.

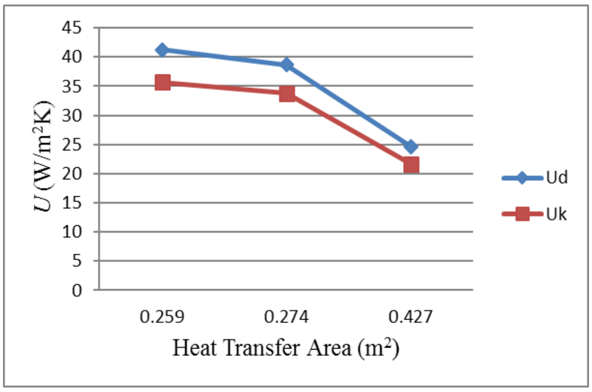

Figure 11. Relationship between heat transfer area and overall heat transfer coefficient

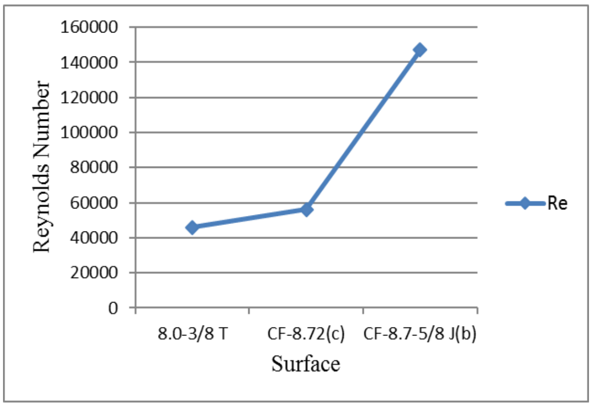

Figure 12. Relationship between variations in surface type with Reynolds numbers

Figure 12 shows that the surface CF-8.7-5/8J(b) type with a tube diameter of 14.097 mm has the largest Reynolds (Re) number, which is 147173.82. The Re number on the surface CF-8.72(c) type with a tube diameter of 8.9074 mm is 56026.47, and the surface type 8.0-3/8T with a tube diameter of 8.4074 mm has the smallest Re number of 45946.76. It can be concluded that the Re number is directly proportional to the diameter of the tube. The larger tube diameter, then the numbers Re is getting bigger, and bigger numbers Re, better for tubes due to the smaller contact area that occurs between the fluid to the tube wall causing friction factor is also getting smaller.

In Figure 13 the calculation results show that the type surface CF-8.7-5/8J(b) with a tube diameter of 14,097 mm produces the smallest pressure drop of 2163.17 Pa. The CF-8.72(c) in diameter 8.9074 mm produces a pressure drop of 3777.56 Pa, and surface 8.0-3/8 T produces the largest pressure drop with a tube diameter of 8.4074 mm which is equal to 4367.03 Pa.

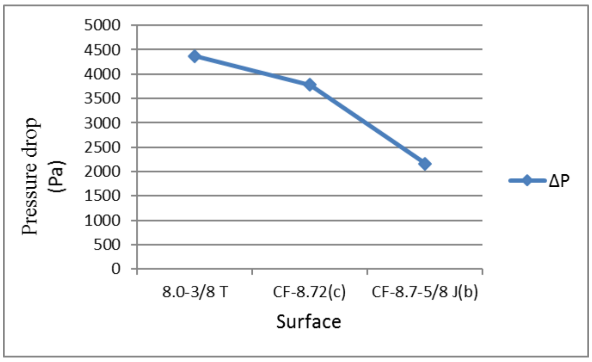

Figure 13. Relationship between surface with a pressure drop

The diameter of the tube is inversely proportional to the pressure drop. The larger diameter in the tube than smaller pressure drops produced. For energy savings and tube resistance, it is recommended to choose a design that produces the smallest pressure drop.

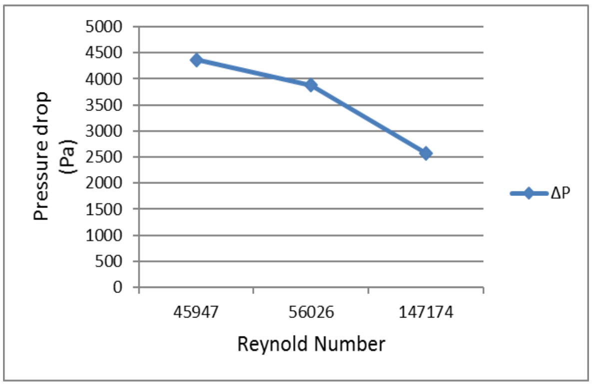

Figure 14. Relationship between pressure drop and Reynold number on the surface

Figure 14 shows that Re numbers are inversely proportional to pressure drop. The greater the value of the Re, the smaller the pressure drop. Thus, the consideration of the pressure drop takes precedence over the Re number, because the pressure drop has more influence on energy-saving and resistance to the tube.

CONCLUSION

The results of the compact type condenser design based on existing data obtained the smallest design results, namely on the type of surface CF-8.72(c). The condenser design has a heat transfer area of 0.259 m^2, a total tube length of 9.5 m, crossing tube length 0.594 m, and pressure drop on the side in a tube of 3778 Pa. This design fulfills the stipulated requirements; in large numbers, the pressure drop is less than the specified maximum limit.

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