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Analysis of Changes in Heat Exchanger Performance in PK-XXX Aircraft with Material Modification Using Ansys Program

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Abstract

Airplanes are popular transportation for the community in general because they have various advantages over other existing transportation. Airplanes have a relatively short time to travel between islands. Safety and comfort are major factors in the operation of an aircraft. One of the safety factors in an aircraft is the air supply, one of the supporting components of the air supply is a heat exchanger. The heat exchanger keeps the temperature of the air entering the Air Cycle Machine at its operating temperature. The Heat Exchanger in this journal is a type for the Boeing 737-500 aircraft which has a significant decrease in performance which results in damage to ACM components. A plate and frame heat exchanger with aluminum alloy material will be compared with a copper heat exchanger using the Ansys program to determine the effectiveness of both. The analysis will be carried out using the calculation method as well as running tests on the Heat Exchanger, and using Ansys for testing material modification.

Keywords
Airplane; heat exchanger; ansys, modification

I. Introduction

Heat Exchanger has an important role in changing hot air into cold air. The heat exchanger is the first component to encounter hot air coming from the APU when it is grounded or when the engine is in-flight, besides that it is a meeting place for hot air and cold air before entering the Air Cycle Machine so that in a series of components there are two heat exchangers, namely primary heat exchangers and secondary heat exchangers. Although the ACM changes the total change from hot to cold, the heat exchanger is a component that protects the work from the ACM being too heavy and as a preventive measure so that the ACM remains in top condition until the downtime of the component. So it can be said that the heat exchanger is an important component for Air conditioning on aircraft, both Boeing and Airbus types.

There are three zones on the plane, namely the cockpit, forward cabin, and aft cabin. Each of these zones is then broken down into 2 more parts, where each part is regulated by a series of components to produce the cold temperature that is felt in the aircraft cabin. The division is divided into two parts, namely the first part consists of the cockpit and the front half of the cabin, while the second part consists of the remaining half of the rear cabin and the rear galley. As mentioned earlier that each part is governed by a series of components consisting of two heat exchangers, water extraction, reheater, condenser, and ACM or Air Cycle Machine. When the aircraft is grounded, the compressed air comes from the Auxiliary Power Unit or APU, while during flight the compressed air comes from the rotating engine.

The purpose of this study is to identify the causes of decreased performance of the Heat Exchanger, analyze the effects caused by the factors that decrease the heat exchanger so that performance decreases drastically, analyze maintenance on the heat exchanger that can affect performance degradation, modify the cleaning control to find out differences in Heat Exchanger performance, planning to control the Heat Exchanger to overcome existing problems.

Transportation at this time has become a basic need for community activities, especially the activities of the people of North Sumatra. These activities make transportation an important choice with an increasing number of populations using transportation modes, especially public transportation. (Agussani, 2020)

Safety and comfort are important factors for airplanes as one of the modes of air transportation used to travel long distances between cities, islands, and even between continents, both in terms of work, education or even to relieve fatigue for a moment from the existing routine. So do not be surprised if the airplane is the safest mode of transportation to date. In its operation, it is hoped that there will be no damage to each of its components because if there is damage and an error results in fatal things, considering that the aircraft cannot stop for a moment in the air. In connection with this high level of safety, the regulations or regulations that govern are also strict. So that it can create high safety conditions for the operator as the owner of the aircraft or the MRO as a place for aircraft repair so that the aircraft technician must have a verified certificate within a certain period of time to ensure that the aircraft is handled by the right person to produce safety quality that is maintained. In keeping the aircraft in prime condition with a high level of safety, every night a routine check called RON or Remain Over Night with a scheduled task card is always carried out as a preventive maintenance effort to increase safety on the aircraft itself.

II. Review of Literature

2.1 Experimental and Procedures

a. Materials

On the plane, there are 3 zones, namely the cockpit, forward cabin, and aft cabin. Each of these zones is then broken down into 2 more parts, where each part is regulated by a series of components to produce the cold temperature that is felt in the aircraft cabin. The division is divided into two parts, namely the first part consists of the cockpit and the front half of the cabin, while the second part consists of the remaining half of the rear cabin and the rear galley. As mentioned the purpose of the Primary Heat Exchanger is to release heat from compressed air into the compressor section of the Air Cycle Machine (ACM).

The primary plenum or diffuser serves as a place for ram air to flow and enter the primary heat exchanger and exit through the ram air exhaust. The location of the primary heat exchanger and plenum/diffuser on the back, and the outer part of the air conditioning compartment.

The primary heat exchanger consists of an air-to-air, plate-fin, and cross-flow type heat transfer model. Two insulating air flows into the thin-walled channels. Channel walls are made of plates and fins to increase the surface area. The primary plenum /diffuser has an outer duct and an inner duct. The outer duct is in the form of a plenum and the inner duct is in the form of a diffuser. The inner duct has a fan bypass check valve. The fan bypass check valve is attached to the door assembly at the rear bottom of the diffuser. Air from the FCSOV enters the primary heat exchanger. Crossflow from the ram air releases heat before the air enters the Air Cycle Machine in the compressor section.

Previously that each part is governed by a series of components consisting of two heat exchangers, water extraction, reheater, condenser, and ACM or Air Cycle Machine. When the aircraft is grounded, the compressed air comes from the Auxiliary Power Unit or APU, while during in-flight the compressed air comes from the rotating engine.

Characteristics and Specification

Type	: Air to Air
Proof pressure	: 109 PSIG (752 kPa)
Burst pressure	: 218 PSIG (1,503 kPa)
Operating pressure	: 73 PSIG (503 kPa) at 341oF
Dimension	
Length	: 26.85 inches (682.0 mm)
Wide	: 11.40 inches (289.6 mm)
Height	: 14.5 inches (368 mm)
Weight	: 37.2 lb (16.9kg)

b. Experiment

The heat exchanger is a component made of alluminum where the working flow is hot air and cold air, where this heat exchanger is used on aircraft for cooling systems. The heat exchanger consists of several parts such as a core with 2 pins that are welded for air in and out and consists of 2 flanges which are welded on the top and bottom. At the core, hot compressed air and cold pressurized air are separated by thin plates which then exchange heat with each other in a heat exchanger.

The plate and Frame Heat Exchanger is heat exchangers consist of a package of perpendicular, corrugated, or other profile plates. The separator between the perpendicular plates is installed with a soft insulator (usually made of rubber). The plates and bulkhead are held together by a pressure device in which at each corner of the plate (mostly rectangular) there is a fluid flow hole. Through two of these holes, fluid flows in and out on the other side, while the other fluid flows through the holes and spaces on the other side due to the bulkhead.

Effectiveness of Plate-Frame Heat Exchanger Heat Transfer:

Heat Transfer Rate

$$\dot{Q}h = \dot{Q}c$$

$$\dot{Q}h = \dot{m}h.\ cph.\ (Tho - Thi)$$

Logarithmic Average Temperature Difference (LMTD)

$$\Delta Tlm = \frac{\Delta T1 - \Delta T2}{\ln (\Delta T1 / \Delta T2)}$$

where,

$$\Delta T1 = (Th1 - Tc1)$$

$$\Delta T2 = (Th2 - Tc2)$$

Correction factor for plate – frame counter flow heat exchanger

$$R = \frac{(T1 - T2)}{(t2 - t1)}$$

$$P = \frac{(t2 - t1)}{(T1 - t1)}$$

Coefficient Convection

$$Pr = \frac{\eta\ .\ Cp}{k}$$

$$Re = u\ .\ \rho\ .\ De$$

$$\eta$$

$$Nu = 0{,}664 \cdot Re^{0{,}5} \cdot Pr^{0{,}33}$$

$$\alpha_1 = Nu \cdot (\lambda / De)$$

Heat Capacity Rate (C)

For cold fluid flow:

$$C_c = \dot{m}_c \cdot c_{pc}$$

For hot fluid flow on the plate side:

$$C_h = \dot{m}_h \cdot c_{ph}$$

Maximum Heat Transfer Rate (Qmax)

$$Q_{max} = C_{min} \cdot (T_{h,i} - T_{c,i})$$

Effectiveness of Plate-Frame-Type Heat Exchanger

$$\varepsilon = \frac{Q_{act}}{Q_{max}} \times 100\%$$

Number Transfer Unit

$$NTU = \frac{U \cdot A}{C_{min}}$$

Information:

Re : Number Reynolds

Nu : Number Nusselt

Pr : Number Prandtl

III. Result and Discussion

3.1. Cleaning and Repair Method

In CMM we get information about the material contained in the Heat Exchanger which is in the form of aluminum alloy. As we know that the Heat Exchanger has a role to change the hot air into cold air. With such a large role, the Heat Exchanger can inevitably become corroded so that it will reduce the performance of the Heat Exchanger itself. [12]

Aluminum in general has a high corrosion resistance that makes aluminum not easy to corrode, but like other metals, aluminum can still corrode under certain conditions. In the selection of metal materials for construction, one of the parameters that must be considered is the metal's resistance to corrosion, so that aluminum also requires special treatment to avoid corrosion.

Corrosion that generally occurs in aluminum metal is pitting corrosion. Pitting corrosion forms tiny holes that are visible at first. This corrosion occurs when aluminum metal reacts with moist air.

In this method the heat exchanger as a test tool is given a different repair method with slightly different variations of repair on the core which is still within the limits allowed by the Component Maintenance Manual. The repair steps on the Heat Exchanger are clean the oil, dust, and grease that sticks during a visual inspection, clean the attached paint that is no longer serviceable, clean the existing contamination, disassemble the constituent components of the Heat Exchanger such as Core, Pan, and Flang, then perform the repair method on the cores that have been installed, seen when testing leaks and doing visual inspections if there are cracks that occur in the core after the components have been separated, then the next step is to put the components in a chemical liquid that has been heated to a temperature of 100 oC to clean the remaining dirt on the Heat Exchanger, clean with high-temperature water normal 27 oC to clean the remaining solphy fluid, then dry the Heat Exchanger until it is completely dry to prevent re-corrosion.

3.2. Effectiveness of Heat Exchanger

This study will explain the role of the repair function on the effect of the performance of the heat exchanger itself. Therefore, repair modifications will be carried out and will be tested with 2 different types of tests, namely a leak test to find out the results of the repairs that have been carried out, there is still a leak with a low flow and put into the air, then a flow test will be carried out which functions as the work of the heat exchanger that is conditioned when operating on an aircraft with a pressure greater than that when viewing a test leak.

The test procedure has been adapted to a pre-existing manual issued by the vendor of the component. Where to test the flow test Heat Exchanger that has been treated and then partially assembled until the cores, pans and flanges are installed in the correct and precise position then pressure is fired through the pan inlet

The purpose of this test is to find out whether there is a leak or not after a variation of repair by testing using a leak test, while the running test is carried out to find out the Heat Exchanger performance data obtained during the test such as the Heat Exchanger temperature value, Air Flow, and some other important data that will be used for calculations to find the value of the efficiency of the Heat Exchanger itself.

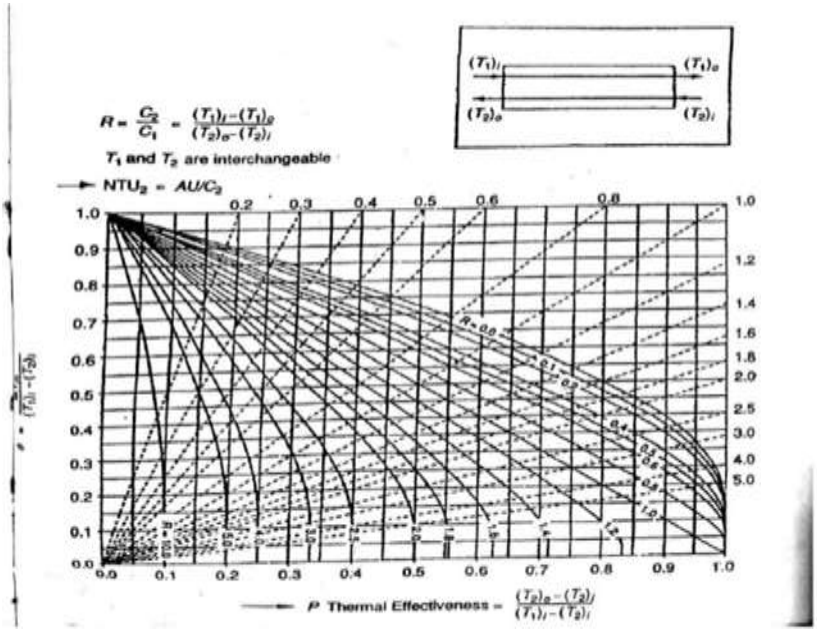

Figure 1. *Graph of Counterflow Plate-Frame LMTD Correction Factor Value*

Table 1. Testing 1 before Treatment

Baro. (inHgA)	Primary Temperature (°C)		Secondary Temperature (°C)		$\dot{m}_c$ (kg/s)	$\dot{m}_h$ (kg/s)	A (m^2)	c_p (kJ/kg °K)	C_{min} (kW/ °K)
	T_{1in}	T_{2out}	t_{1in}	t_{2out}					
29.74	30	34	39	38	0.667	0.683	19.7098	1.009	4.087

Effectiveness of Plate-Frame-Type Heat Exchanger
Ɛ = 11.3776 %

Table 2. Testing 2 Before Treatment

Baro. (inHgA)	Suhu Primary (°C)		Suhu Secondary (°C)		$\dot{m}_c$ (kg/s)	$\dot{m}_h$ (kg/s)	A (m^2)	c_p (kJ/kg °K)	C_{min} (kW/ °k)
	T_{1in}	T_{2out}	t_{1in}	t_{2out}					
29.74	30	35	39	38	0.667	0.683	19.7098	1.009	4.087

Effectiveness of Plate-Frame-Type Heat Exchanger
Ɛ = 11.3776 %

Table 3. Testing 1 After Treatment

Baro. (inHgA)	Suhu Primary (°C)		Suhu Secondary (°C)		$\dot{m}_c$ (kg/s)	$\dot{m}_h$ (kg/s)	A (m^2)	c_p (kJ/kg °C)	C_{min} (kW/ °C)
	T_{1in}	T_{2out}	t_{1in}	t_{2out}					
29.74	30	36	39	37	0.667	0.683	19.7098	1.009	4.087

Effectiveness of Plate-Frame-Type Heat Exchanger
Ɛ = 22.7553 %

Table 4. Testing 2 After Treatment

Baro. (inHgA)	Suhu Primary (°C)		Suhu Secondary (°C)		$\dot{m}_c$ (kg/s)	$\dot{m}_h$ (kg/s)	A (m^2)	c_p (kJ/kg °C)	C_{min} (kW/ °C)
	T_{1in}	T_{2out}	t_{1in}	t_{2out}					
29.74	30	35.5	39	37.3	0.667	0.683	19.7098	1.009	4.087

Effectiveness of Plate-Frame-Type Heat Exchanger
Ɛ = 19.342 %

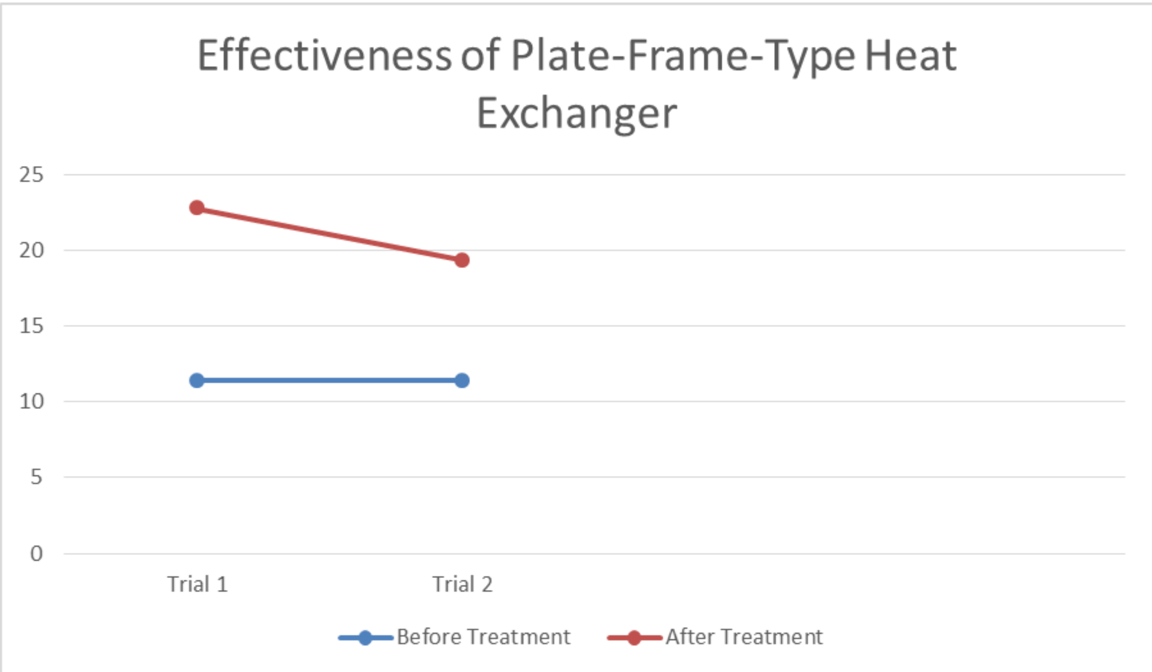

Figure 2. *Graph Effectiveness of Plate-Frame type Heat Exchanger*

3.3. Compare Alluminium Alloy with Copper

Copper is one of the most widely used light metals by humans because of its great abundance in nature is also due to the properties possessed by copper. Copper has superior properties, among others, has a slow corrosion rate, thermal and electrical conductivity good quality, relatively soft, and easy to work with for example being molded, extruded, drawn, pressed, forged, and rolled.

Copper has many good properties that are advantageous to be developed in the industrial field electricity, among others: one of the lightest metals, weighing about 8906 kg/m^3. Therefore copper has replaced the role of steel in many ways such as in vehicles, home appliances, in addition, power Its heat conductivity is also high, therefore copper is also used for the completeness of radiator materials, boiler, and heating fittings.

Figure 3. *Copper Heat Exchanger*

Pure aluminum is a soft, durable, lightweight, and malleable metal with good looks the outer surface varies from silvery to gray, depending on the roughness of the surface. Tensile strength pure aluminum is 90 MPa, while aluminum alloys have tensile strengths ranging up to 600 MPa. Aluminum has a weight.

The engineering properties of pure aluminum and aluminum alloy materials are affected by the concentration of the materials and the treatment given to the material. Aluminum is well known as a material that is resistant to corrosion. This is caused by the passivation phenomenon, which is the process of forming an aluminum oxide layer on the surface aluminum metal surface as soon as the metal is exposed to free air. This layer of aluminum oxide prevents further oxidation. However, passivation can occur more slowly when combined with metal that is more cathodic, because it can prevent the oxidation of aluminum.

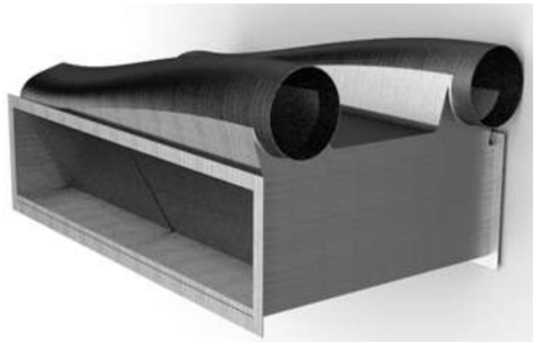

Figure 4. *Alluminium Alloy Heat Exchanger*

In the heat exchanger, there is heat exchange between hot air and relatively cold air. Hot air comes from the APU or Auxillary Power Unit which has a temperature of 39 oC with a pressure of 30 PSIG. While the relatively cold air comes from the outside air which is then increased in pressure by a booster with a final pressure of 50 PSIG and a temperature of 30 oC.

Comparison of heat exchangers made of aluminum and copper will use Ansys software to determine the difference in the effectiveness of heat transfer between the two. The chart below shows a copper-based heat exchanger giving better results.

The heat exchanger on the Ansys is a form of simplification in the actual conditions on the plane. The purpose of this simplification makes it easier for us to know the effectiveness of heat transfer. The picture shows the temperature transfer, the red hot temperature decreases the temperature to orange.

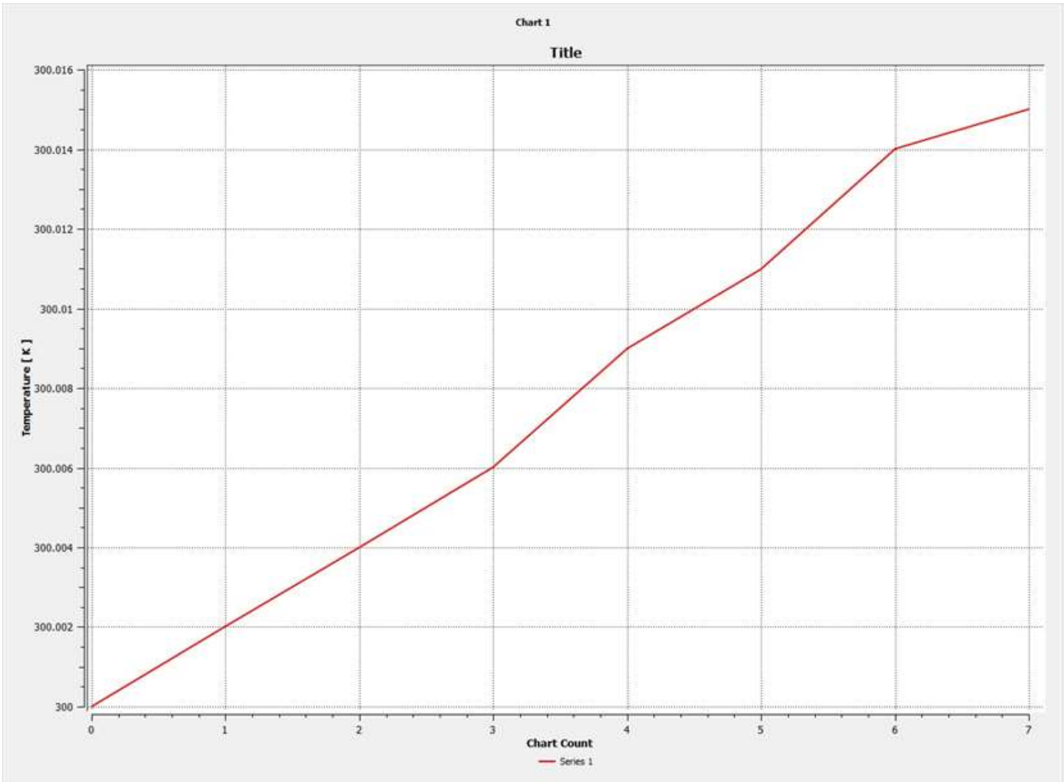

Figure 5. *Graph of Changes RAM Air Temperature on Alluminium Alloy Using Ansys*

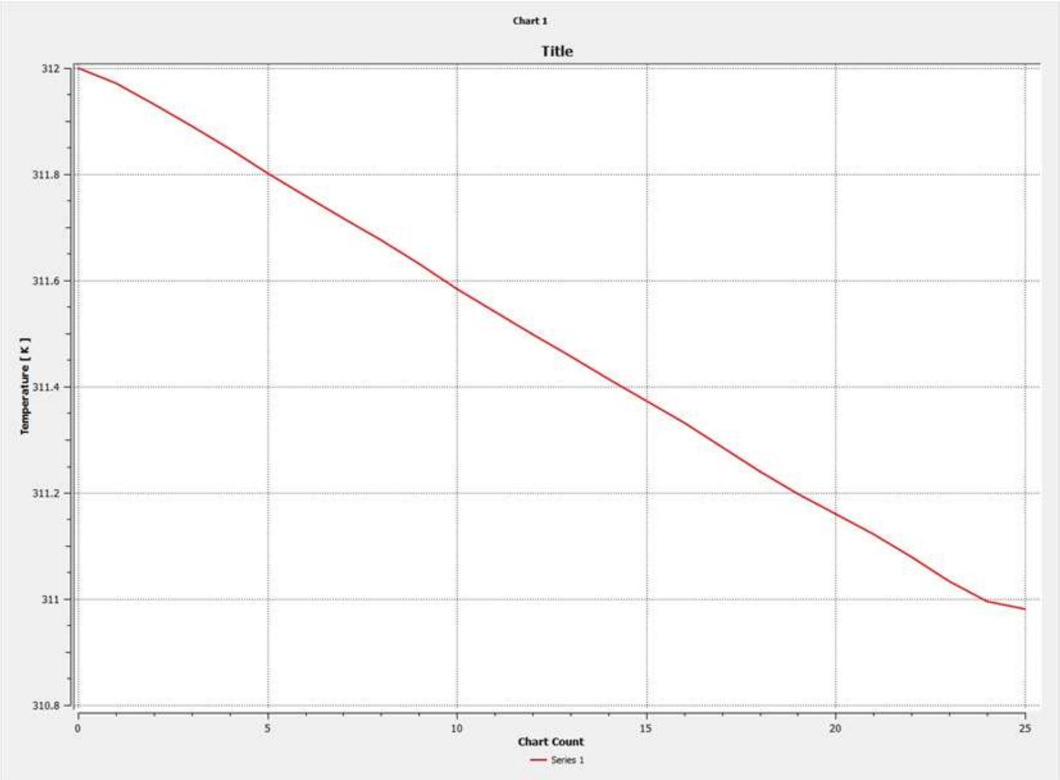

Figure 6. *Graph of Changes Bleed Air Temperature on Alluminium Alloy Using Ansys*

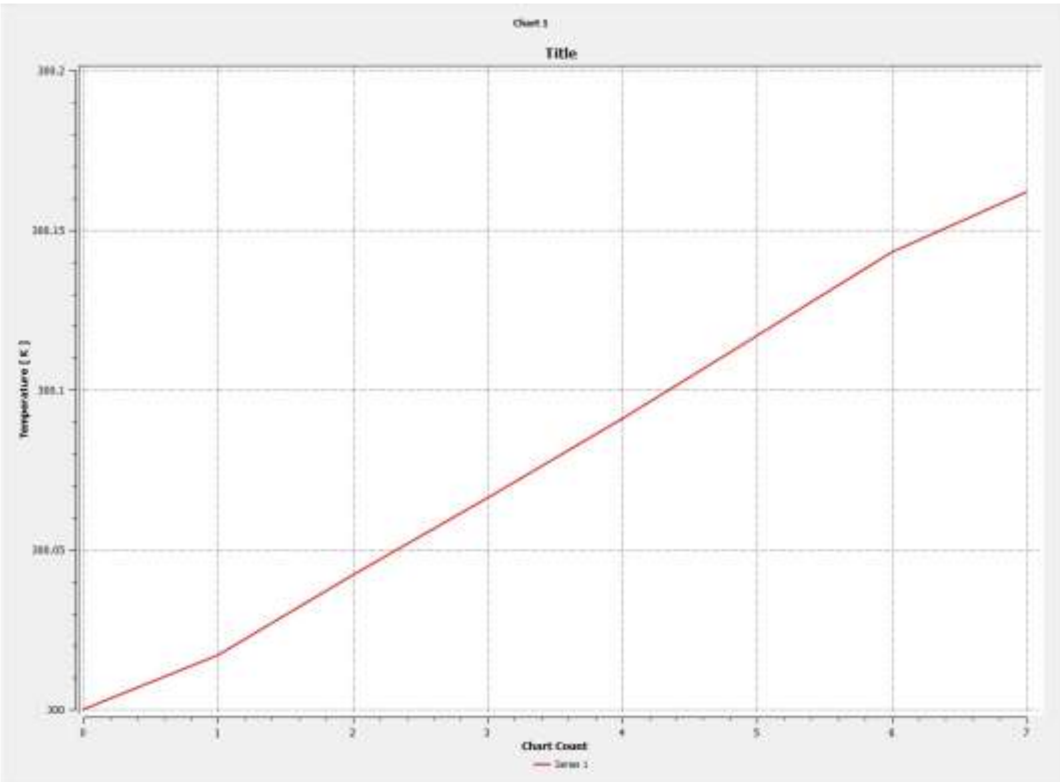

Figure 7. *Graph of Changes RAM Air Temperature on Copper Using Ansys*

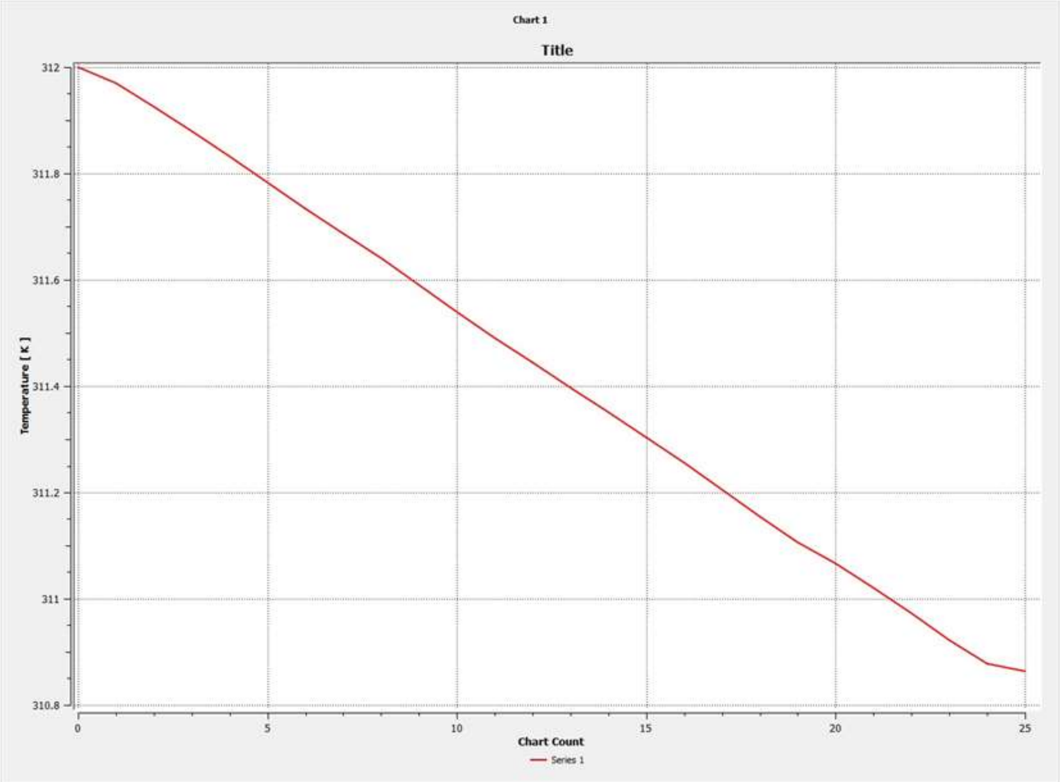

Figure 8. *Graph of Changes Bleed Air Temperature on Copper Using Ansys*

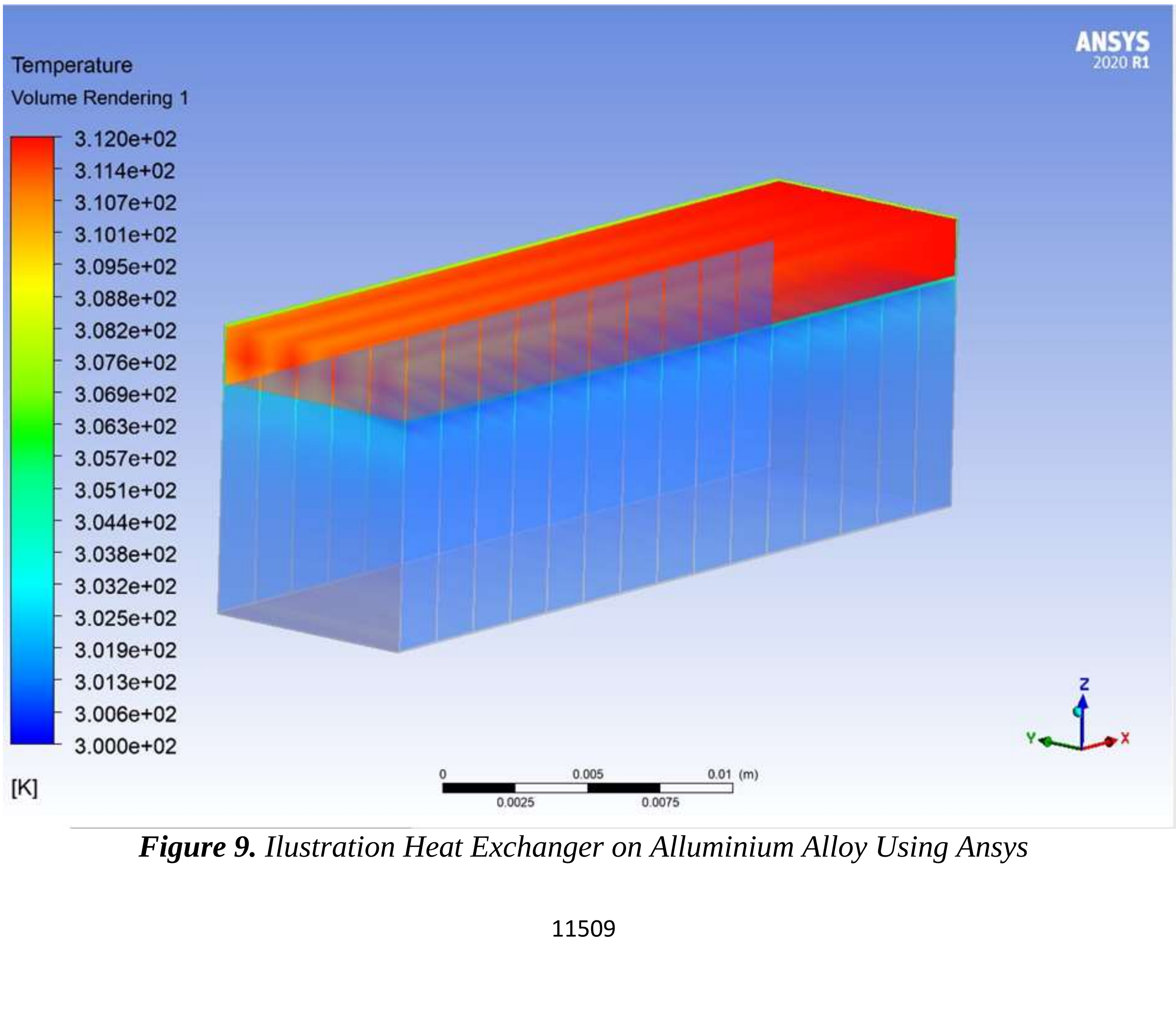

Figure 9. *Ilustration Heat Exchanger on Alluminium Alloy Using Ansys*

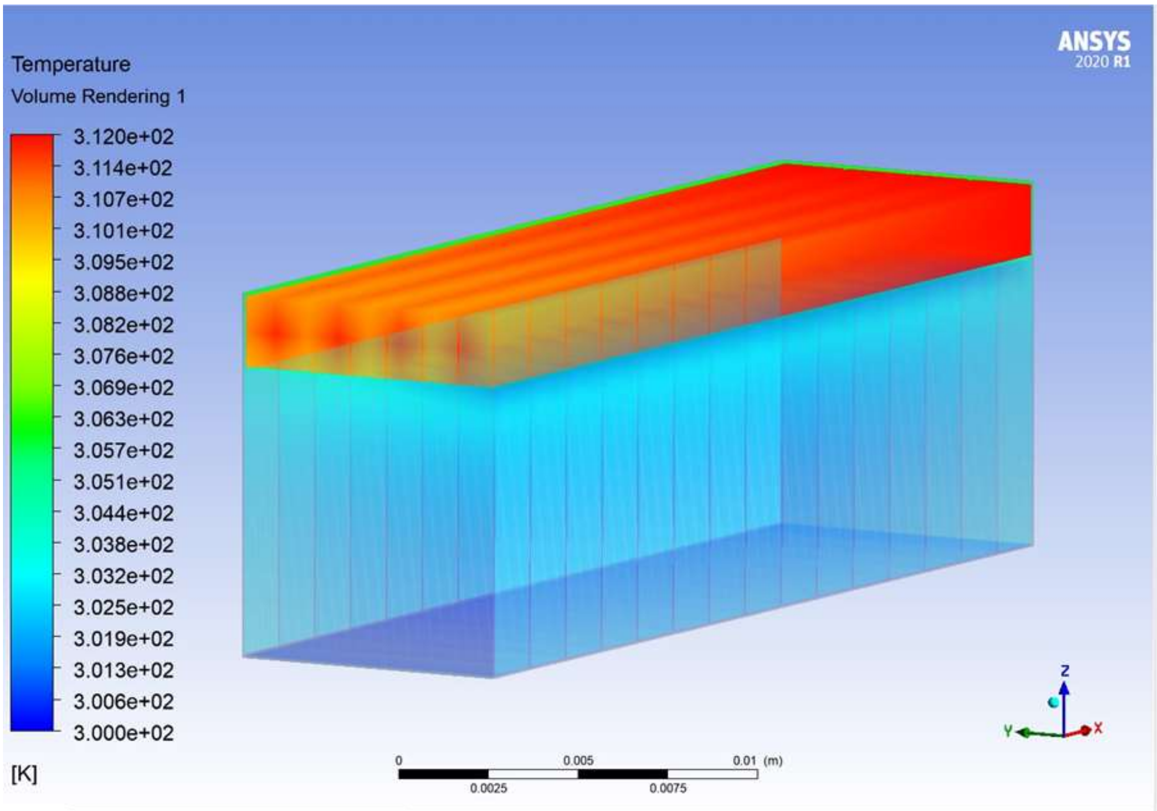

Figure 10. *Ilustration Heat Exchanger on Copper Using Ansys*

IV. Conclusion

The cleaning and repair method on the Alluminium Alloy Heat Exchanger has succeeded in increasing the effectiveness of the Heat Exchanger. With this increase, a test using Ansys was then carried out to determine the difference in efficiency between Alluminium and Copper, the results showed that Copper had better effectiveness than Alluminium.

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This paper and the research behind it would not have been possible without the exceptional support of my family, my colleague and my head of the master program mechanical engineering department of Mercu Buana University. They enthusiasm, knowledge and great care have inspired and kept my work on track and able to complete this research well.

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