International Research Journal of Innovations in Engineering and Technology (IRJIET)

ISSN (online): 2581-3048
Volume 9, Issue 4, pp 156-160, April-2025
https://doi.org/10.47001/IRJIET/2025.904023

Transient Effectiveness Test of Cross Flow Air Heater Heat Exchanger

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Abstract **- The problem of high electrical energy consumption in HVAC (heating, ventilation, and air conditioning system), makes renewable energy a solution to the problem. Renewable energy sources such as solar, geothermal, and wind energy are used in reducing electrical energy consumption, which is functioned to warm the room (space heating), drying agricultural products, melting snow-filled roads, heating agricultural land (soil heating), greenhouse heating, and hot springs. heat exchanger is a heat conducting device that can transfer energy from a fluid with a hot temperature to a cold temperature fluid or vice versa which can be used in the application of drying products produced by farmers, plantations, and large or small scale fisheries. Due to the function of the heat exchanger as a room heater, an effectiveness performance test was carried out on the air heater heat exchanger research carried out at the Thermofluid Lab, Department of Mechanical Engineering, Diponegoro University. In this test, several variations of water flow rate and air speed were carried out. There are variations of water flow discharge of 5 liters/minute, 2.5 liters/minute, and 0 liters. In the variation of air velocity there are speeds of 3.6 m/s, 2.7 m/s, and 1.8 m/s. The analysis obtained in the study is that the greatest effectiveness value occurs in the variation of water flow discharge of 2.5 liters/minute with an air speed of 1.8 m/s with a maximum effectiveness value of 0.622 and a minimum of 0.521.**

Keywords: air heater; effectiveness; heat exchanger; heat transfer; renewable energy.

I. INTRODUCTION

At present, the energy crisis continues to increase every day, this is because around 40% of the total primary energy consumption worldwide is used only for heating, ventilation, and air conditioning (HVAC) systems. In reducing electrical energy consumption, renewable energy sources such as solar, geothermal, wind, and others are needed to minimize energy consumption (Qin, Liu and Zhang, 2021).

Geothermal heat is a renewable energy source that can be used directly for space heating, drying agricultural products, melting snow-filled roads, heating agricultural soils, greenhouse heating, and utilization for hot springs (Pandey, Kuntjoro and Uksan, 2022).

In western homes, many use heat exchangers as a heating device and the heat source comes from water heated in the boiler (Juliartha, Mirmanto and Okariawan, 2018).

Currently, heat exchangers are used in the application of drying products produced by farmers, plantations, and large-scale fisheries. In small-scale industries, they still use resources from the sun which requires a large amount of land and a long time. This is what encourages the use of heat exchangers to overcome this problem, the use of heat exchangers is currently widely used in large or small industrial fields (Azwinur and Zulkifli, 2019).

This research will test the air heater heat exchanger with renewable energy in the form of hot water fluid by adding variations in the test in the form of fan air speed levels and variations in the level of water pump flow discharge. The purpose of providing variations in this study is to determine the effect of variations on the performance of the effectiveness of the air heater heat exchanger, and it is hoped that this research will get accurate effectiveness results.

II. RESEARCH OBJECT

2.1 Air Heater Heat exchanger

Air heaters are used to improve the performance of the boiler efficiency, which is due to utilizing the heat in the flue gas from combustion to heat the air, such as in the air resulting from the heating process in the air preheater then continued through the air heater for heating for the second time. The heating process that occurs is convection. A picture of the air heater heat exchanger can be seen in Figure 1.

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Figure1: Air Heater Heat Exchanger

The air heater heat exchanger tool has several components that have been installed into one part. The following are the components in Table 1.

Table 1: Components of the air heater

No	Components of the Air Heater
1.	Upper water reservoir
2.	Lower water reservoir
3.	Fan
4.	Pump
5.	Inline pipe
6.	on / off switch

2.2 Effectiveness Equation (ε)

Heat exchanger consists of two words, namely heat or heat and exchanger or exchange. In the process exchange process can be in the form of heating and cooling (Tambunan, 2016). The heat transfer effectiveness of a heat exchanger is the ratio of the heat transfer rate (Q) to the maximum heat transfer rate value obtained from the calculation (Qmax). The use of effectiveness to determine the quality of a heat exchanger (Robiyanyusra, Gani and Taufiqurrahman, 2021). To find the effectiveness of heat exchanger can use the equation (1).

$$\varepsilon = \frac{Q}{Qmax} \qquad (1)$$

Description:

ε = Effectiveness
Q = Heat transfer rate (W)
$Qmax$ = Maximum heat transfer rate (W)

2.2.1 Heat Transfer Rate Equation (Q)

In knowing how much heat transfer in the fluid to be used in equation (1), it can be calculated using equation (2).

$$Q = \dot{m} \times Cp \times \Delta T \qquad (2)$$

Description:

Q = Heat transfer rate (Watt)
C_p = Heat capacity of the fluid (W/kg.K)
ΔT = Difference between fluid temperature and ambient temperature (K)

2.2.2 Maximum Heat Transfer Rate Equation (Qmax)

The maximum heat transfer in the fluid to be used in equation (1) can be calculated using equation (3).

$$Q_{max} = C_{min}\,(T_{hi} - T_{ci}) \qquad (3)$$

Description:

Q_{max} = Maximum heat transfer rate (W)
C_{min} = The smallest value between Ch and Cc values (W/K)
$T_{h,i}$ = Temperature of hot fluid entering the heat exchanger (K)
$T_{h,o}$ = Temperature of cold fluid entering the heat exchanger (K)

2.3 Data Collection

Data collection begins with recording data manually and in real time for 40 minutes, carried out transiently (the temperature in the water is not kept fixed), and the test is given the treatment of variations in fan air speed and variations in water flow rate from the pump. Variations of fan air speed consist of 100% or 3.6 m/s, 75% or 2.7 m/s, and 50% or 1.8 m/s. While the variation of the water flow rate consists of 100% or 5 liters/minute, 50% or 2.5 liters/minute, and 0% or 0 liters (no water flow rate). After finishing taking the data, continue with analyzing the data to calculate the effectiveness value of the tool against the running time. Data collection requires the preparation of a scheme of equipment and materials that can be seen in Table 2, and Figure 2.

Table 2: Tools and material

Tools	Material
• *Air heater heat exchanger* • Laptop • Water heater • DHT22 sensor • DS18B20 sensor • Anemometer digital display • Microprocessor thermistor thermometer • Handphone	▪ Hot water 60 ℃

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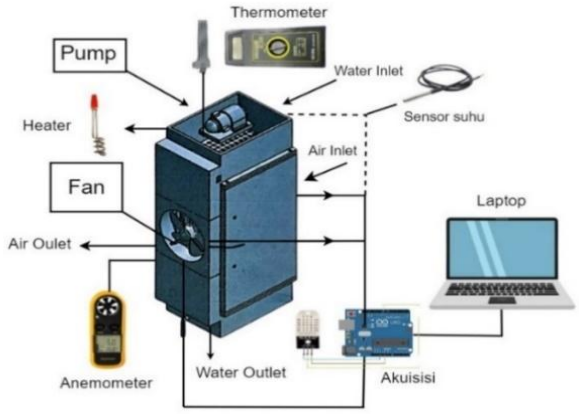

Figure 2: Data Collection Scheme

III. RESULTS AND DISCUSSION

3.1 Test Data Collection Results

The time of taking air heater test data is in the morning starting at 07.00 to 09.30, because according to its function to warm the room, the temperature in the environment around the tool must be quite cold, namely in the morning. The data obtained comes from sensors that are turned on during the test. As for examples of the data obtained as in Figure 3, and Figure 4.

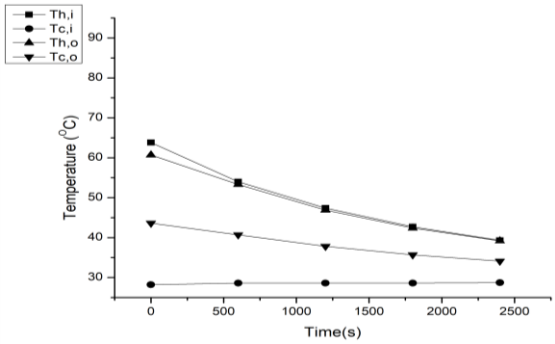

Figure 3: Graph of temperature against time at 5 lt/min flow rate variation, 3.6 m/s air velocity

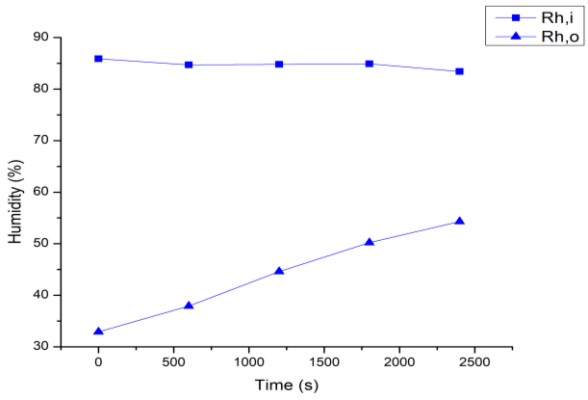

Figure 4: Graph of humidity against time at 5 lt/min flow rate variation, 3.6 m/s air velocity

Based on the data obtained on the Figure 3 and Figure 4, the heat exchanger in this test is quite stable during the 40 minute test. Cross flow type heat exchangers have consistent performance under varying operating conditions. In cross flow, the flow directions of the cold and hot fluid are perpendicular to each other, which causes the fluid to move along different paths (Darliansyah, 2005). The heat obtained by the air that goes out of the fan on this tool is by convection process, as well as the use of air heaters in the industry. in the industry functions as an air heating device (Sinaga, 2019). In its application in industry, to heat the air before entering the combustion chamber, which was previously at ambient temperature. In the combustion process there are influencing factors, namely heat, air, and fuel. Therefore, the air is heated in an air heater or air heater so that it can require less fuel (S and Ghofur, 2019).

3.2 Effectiveness(ε)

Based on the results of data collection that has been obtained, then can proceed to the calculation using equation (1). In Figure 5 to Figure 7 is a graph of the results of the calculation of the effectiveness of the air heater tool obtained from the table of test data collection results in each variation.

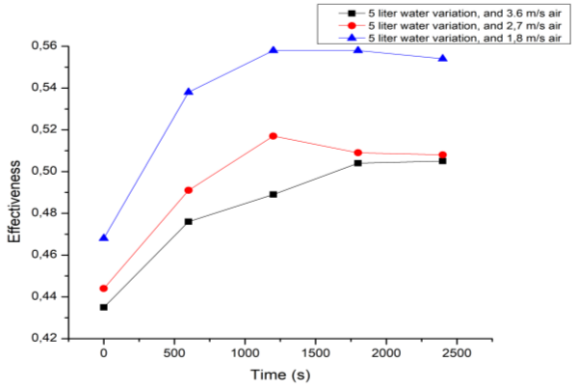

Figure 5: Graph of effectiveness(ε)against time at a water discharge variation of 5 liters/minute

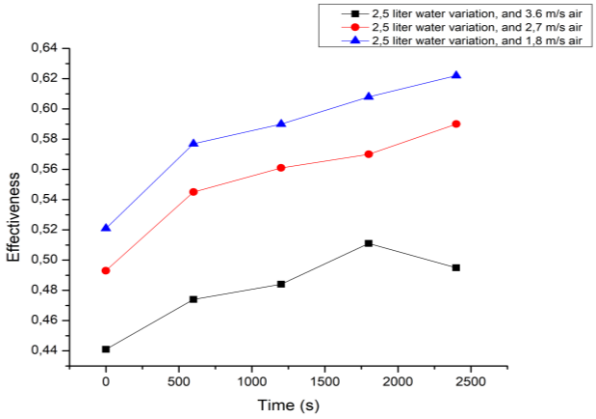

Figure 6: Graph of effectiveness(ε)against time at a water discharge variation of 2,5 liter/menit

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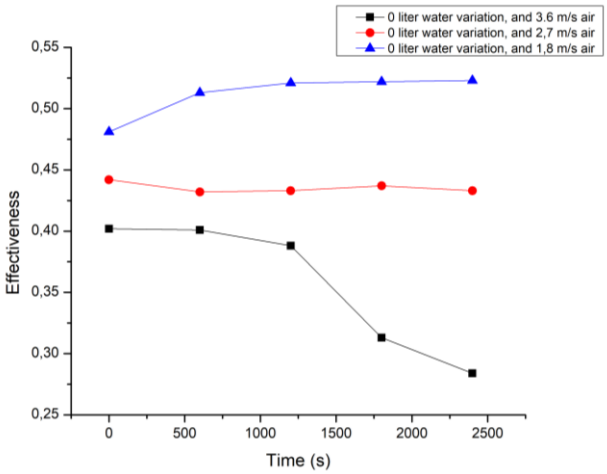

Figure 7: Graph of effectiveness(ε)against time at a water discharge variation of 0 liter

Based on the effectiveness graphs in Figure 5 to Figure 7, that the effect of the water flow discharge is seen from each graph, on the graph the water flow discharge of 5 liters/minute has a smaller effectiveness compared to 2.5 liters/minute, then the flow discharge of 0 liters has a smaller effectiveness than the others, giving an explanation that the flow discharge makes a difference in the results of this test. However, not only from the water flow rate, the air speed on the fan also affects the results of the effectiveness obtained. In each effectiveness graph above, the air speed of 1.8 m/s has the advantage of good effectiveness and stability values, compared to the maximum speed of 3.6 m/s which only has the maximum effectiveness value of 0.505, while 1.8 m/s air has a maximum effectiveness value of 0.622, and 2.6 m/s air has a maximum effectiveness value of 0.590.The results of the above research produce a good effectiveness value because it has a good thermal conductivity material from aluminum properties as an inline pipe that delivers hot water temperature to the air sucked by the fan to the surrounding environment (Ratnawati and Salim, 2018).

IV. CONCLUSION

Based on the results of testing and analysis on the transient air heater, the following are the results:

1. The application of different variations of water flow discharge and air velocity both have an influence on the effectiveness results obtained. The smaller the water flow rate and air velocity, the greater the effectiveness obtained. However, if the air speed is small but the water flow is turned off, it will get a small effectiveness value due to the absence of even circulation of water temperature from the upper water reservoir to the lower water reservoir.
2. The best variation in testing the air heater heat exchanger tool is in the variation of flow discharge of 2.5 liters / minute, which is 50% of the maximum water pump performance with an air speed of 1.8 m / s, which is 50% of the maximum fan performance, obtained a maximum effectiveness value of 0.622 and a minimum of 0.521. This research produces a good effectiveness value because it has a good thermal conductivity material from the nature of aluminum as an inline pipe that delivers hot water temperature to the air sucked by the fan to the surrounding environment.

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Citation of this Article:

Muchammad, Akmal Hafidh Purnomo, & Budi Setiyana. (2025). Transient Effectiveness Test of Cross Flow Air Heater Heat Exchanger. *International Research Journal of Innovations in Engineering and Technology - IRJIET*, 9(4), 156-160. Article DOI https://doi.org/10.47001/IRJIET/2025.904023

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