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REDESIGN OF CLOVE DRYER SIMULATION MACHINE USING HEAT WASTE OF RADIATOR AS THE HEAT SOURCE

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Abstract. In this study, a redesign to a clove dryer simulation tool using exhaust heat from radiator as a source of heat energy has been done. The dryer simulation tool consists of reservoir tank, a heater, a pump to circulate the water in the system, a radiator as a heat exchanger and a drying chamber with 2 shelves. The redesign stage is carried out by fixing the piping insulation system, changing the pipe and adding valve controls to vary the velocity of the fluid flow. Variations made are variations in the mass flow rate of 0.09 kg / s and 0.18 kg /s with a constant air flow rate of 1 m/s. The results of the analysis show that at a higher mass flow rate of 0.18 kg/s the average rate of heat transfer from the radiator air side is higher, which is around 3971.65 watts. The effectiveness of the radiator will also be higher at a higher mass flow rate, the average is 0.34 at a mass flow rate of 0.09 kg/s and 0.43 at a mass flow rate of 0.18 kg /s. For drying rates with a load of 2 kg of cloves with a higher flow rate of liquid will be faster, which is about 5 hours with a flow rate of 0.18 kg/s and 6.5 hours at a flow rate of 0.09 kg/s

Keywords : Redesign, Dryer Simulation, Radiator Heat Waste, Fluid Flow Variation.

1. INTRODUCTION

Radiator is a compact heat exchanger that is used to transfer heat energy from one medium to another for the purpose of cooling and heating. As a compact heat exchanger, the radiator has various types depends on the configuration of the radiator core. So far, radiators are widely known in the automotive industries as a tool to control the temperature of the engine so that the engine temperature stays in the optimal condition between 80°C - 90°C. As a heat exchanger, the radiator certainly produces a waste product in the form of exhaust heat which of course can be used for heating or drying purposes.

For a drying purpose, it is important to know the performance of the radiator first, especially those related to the results of the exhaust heat that can be produced by the radiator. Several studies of radiator performance have been carried experimentally and numerically by varying the mass flow rate of fluid flow in the radiator. This is done in several conditions and by using several different working fluids. An experimental research has been analyzed in a corrugated plate type heat exchanger, where the result showed that the heat transfer coefficient increases with the increasing of mass flow rate for various working fluids. [1]. The experiment to knows the effect of the heat transfer characteristic in automotive radiator has been done by varying the coolant flow rate, with the result showed that the increasing of coolant flow rate will also increasing the Nusselt (Nu) number of the coolant. [2]. Experiment to analyze the effect of mass flow rate on the convective heat transfer coefficient also done to a constant velocity on constant area. [3]. An experimental was also carried out to determine the effect of mass flow rate on pressure drop and heat transfer in a drying chamber, which the result showed that the higher the temperature at the drying chamber inlet, the lower the pressure drop. The pressure drop will increase with the increasing of mass flow rate. [4]. Numerical research has also done to analyze mass flow rate effect to the heat transfer rate of automobile radiator using CFD modeling, and the result showed that as the air mass flow rate increases, the heat transfer rate as well as efficiency is also increasing. [5].

Based on the description, in this research will be carried out a simple redesign of existing drying equipment by changing several components of the previous system that have been carried out, such as variations in fluid flow velocity. The performance observed are the effectiveness and also the air-side temperature and heat transfer rate of the radiator, so that it will get a good drying result in the drying chamber.

2. METHODS

The research was carried out experimentally by redesigning the system in the simulation of the previous dryer that made by [6]. The redesign is done by varying the speed of fluid flow inlet the radiator system by using a valve and flowmeter, so that the radiator can get optimal heat dissipation performance. The other components in previous dryer tools such as used tube and fins type radiators, water reservoir tanks, heaters, hot water pumps, thermostat, and cooling fans are still used by checking and repairing several components that have been broken, such as the thermostat, and replaced piping insulation system to get more effectiveness in radiator performance. The schematic of the system are shown in figure. 1 below

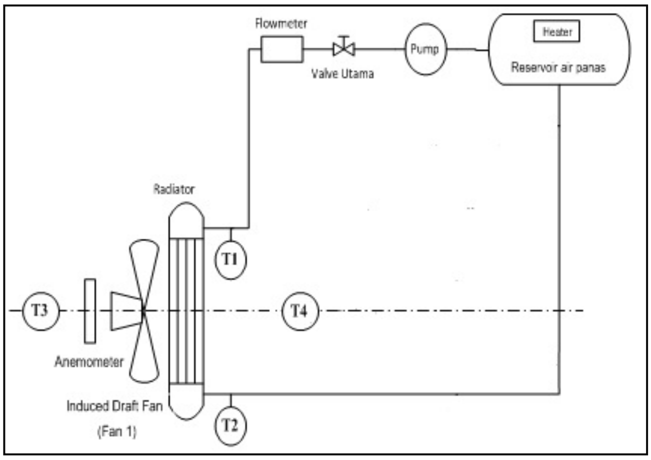

Figure 1 Schematic experimental set-up

The radiator's specification used in this research showed in table 1 below

Table 1 Specification of Radiator

No	Data	Values
1.	Radiator's type	*Compact heat exchanger- circular tube continuous fin*
2.	Radiator's volume	P x L x T= 500mm x 30 mm x 550 mm
3.	Tube diameter	10 mm
4.	Tube length	330 mm
5.	Number of row	2
6.	Number of tube per row	22
7.	Pitch	11 mm

Analysis of radiator performance is done by using the equation for compact heat exchanger analysis as in the following equation [7], [8] there were:

Coefficient convection (hcold) :

$$h_{cold} = St.\ G.\ Cp \quad (1)$$

Heat transfer rate (qcold) :

$$q_{cold} = h_{cold}.A_{cold}\ (\ Tc_{in} - Tc_{out}\ ) \quad (2)$$

Effectiveness radiator (ε) :

$$\varepsilon = \frac{q_c}{q_{max}} = \frac{Ch\ (Thi\text{-}Tho)}{Tmin\ (Thi\text{-}\ Tci)} = \frac{Cc\ (Tco\text{-}Tci)}{Cmin\ (Thi\text{-}Tci)} \quad (3)$$

where :

$$q_{max} = Cmin \,.\, (Th_{,i} - Tc_{,i}) \quad (4)$$

$$Ccold = \dot{m}_c \,.\, Cp_c \text{ and } Ch = \dot{m}_h \,.\, Cp_h \quad (5)$$

3. RESULTS AND DISCUSSION

3.1 Redesigning Clove Dryer

Before redesigning the dryer, an analysis is first carried out to calculate the inlet radiator water flow rate to produce the most effective heat exhaust for clove drying. According to [9], the drying room temperature is 40-60 ˚C with an average of 52.02 ˚C for drying cloves. From the data, the initial calculation is done to determine the velocity of the fluid flow inlet the radiator using the effectiveness radiator's analysis from equation above.

T = 40°-60°
Average Temperature = 52,02° C
Assuming :
T1 = 70° C -> 343 K
T2 = 50° C -> 323 K
T3 = 30° C -> 303 K
T4 = 42° C -> 315 K
Radiator's effectiveness

$$\varepsilon = \frac{Tco - Tci}{Thi - Tci} => \frac{T4 - T3}{T1 - T3}$$

$$\varepsilon = \frac{315-303}{343-303} = \frac{12}{40} = 0{,}3$$

$$\varepsilon = \frac{q}{q_{max}} = \frac{\dot{m}c \,.\, Cc \,.\, (Tco - Tci)}{\dot{m}h \,.\, Ch\, (Thi - Tci)}$$

Air flow rate ($\dot{m}_c$) => V = 1 m/s

$\dot{m}c = \rho \bullet V \bullet Afr$
T = 303 k -> ρ = 1,151416. Kg/m^3 ; Cp= 1,007 kj/kg . K

Afr = 50 cm x 55 cm = 0,275 m^2 Cp = 1007 J/Kg . K

$\dot{m}c$ = 1,151416 Kj/m m/s . 0,275 m^2

$\dot{m}c$ = 0,316 Kg/s

T1 = 343 K ; ρ = 978,47 Kg/m^3 ; Cp = 4189 J/Kg . K

$$\circ{>}\varepsilon = \frac{\dot{m}c \,.\, Cc\,(Tco-Tci)}{\dot{m}h \,.Ch\,(Thi-Tci)} = \frac{\dot{m}c \,.\, Cc\,(T4 - T3)}{\dot{m}h \,.\, Ch\,(T1 - T3)}$$

$$= \frac{0{,}316\frac{kg}{s}.1007\frac{j}{kg}.\,k(315-303)k}{\dot{m}h \,.\, 4189\frac{j}{kg}.\,k\,.\,(343-303)k} = \frac{3818{,}\,544 \text{ j/s}}{\dot{m}h \,.\, 167560 \text{ j/kg}}$$

$$0{,}3 = \frac{3818{,}544\ j/s}{\dot{m}h \,.\, 167560\ j/s} => 50268\ \dot{m}h = 3818{,}544$$

$$\dot{m}h = 0{,}075 \text{ kg/s}$$

From the above calculations, in order to get optimal results, a clove dryer simulation tool was redesigned by adding a flowmeter and valve, replacing the previous 3/8 inch diameter pipe, to 1/2 inch diameter. This clove dryer simulation tool uses a pump with a maximum capacity of 30 l/ min.

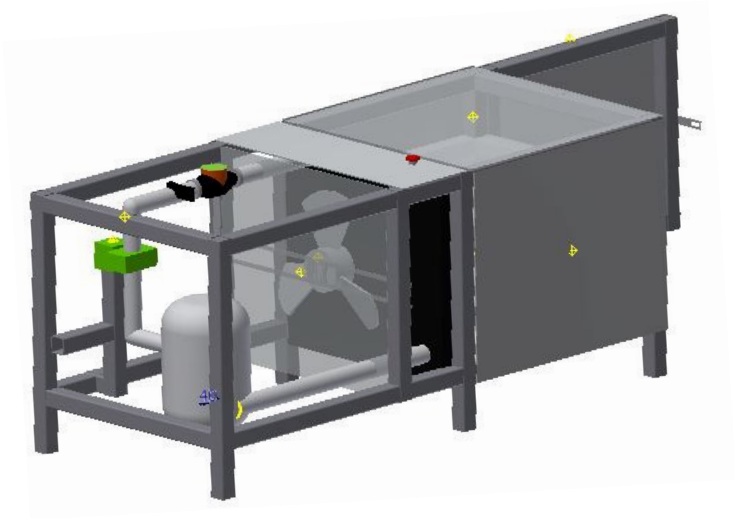

Figure 2. redesign of clove dryers

3.2. Performance of Clove Dryer

The performance of radiator as a source of the clove dryer has been tested experimentally. The water as the working fluid has been heated by the heater in the reservoir tank and will be circulated to the radiator by a pump with a flow rate of 30ℓ / min. The mass flow rate of water inlet radiator are measured using a flow meter which the speed control using a valve. The heat transfer process of the radiator is carried out by forced convection using air blowing from the fan with a flow rate of 1 m/s. The temperature of the water enters the radiator, exits the radiator, the air temperature before the radiator, and the air temperature after the radiator is measured using a thermocouple. The test results on the temperature of radiator exhaust heat are shown as table 2 and table 3 below

Table 2 Performance of Dryer ($\dot{m} = 0.09\ kg/s$)

NO	Time (minutes)	T1 (K)	T2 (K)	T3 (K)	T4 (K)	m air (kg/s)	qc (Watt)	Dryer Effectiveness (ε)
1	0	354.5	332.6	302	316.7	0.097	4504.565	0.28
2	5	353	331.3	302	315.4	0.097	4122.055	0.26
3	10	335	329.4	302	313.1	0.098	3437.767	0.34
4	15	332.3	327.2	302	312.6	0.098	3287.734	0.35
5	20	335.4	329.7	302	313.3	0.098	3497.652	0.34
6	25	333	328.3	302	314.2	0.098	3766.237	0.39
7	30	332.1	327.4	302	314.5	0.098	3855.437	0.42

Table 3 Performance of Dryer ($\dot{m} = 0.18\ kg/s$)

NO	Time (minutes)	T1 (K)	T2 (K)	T3 (K)	T4 (K)	m air (kg/s)	qc (Watt)	Dryer Effectiveness (ε)
1	0	343	338.3	302	317.2	0.186	4650.773	0.37
2	5	336.2	333.4	302	316.6	0.187	4475.037	0.43
3	10	333.3	330	302	316	0.187	4298.485	0.45
4	15	332.1	328.9	302	314.7	0.187	3914.486	0.42
5	20	328.9	326	302	313.9	0.186	3676.785	0.44
6	25	327.1	324.6	302	313	0.186	3407.959	0.44
7	30	326	323	302	312.9	0.186	3378.023	0.45

From the results of these calculations, the graphical analysis of the radiator performances shows in Figure 3, Figure 4 and Figure 5. The results show that the radiator output temperature on the air side (T4) is initially high at the beginning, because the radiator has just began to work dissipate the heat into the environment, so that the heat dissipation of the radiator was not too effective. The temperature then will tend to be stable in the range of 314 K for both mass flow rates after 25 minutes. This shows that the heat dissipation process from the radiator has run quite well, where the heat from the water will be transferred into the environment by the radiator so that the water temperature will tend to be stable. These were similar to the radiator output temperatures on the water side (T2) where at the beginning it's initially high then it will tend to stabilize in the range of 329 K after 18 minutes work for both mass flow rates.

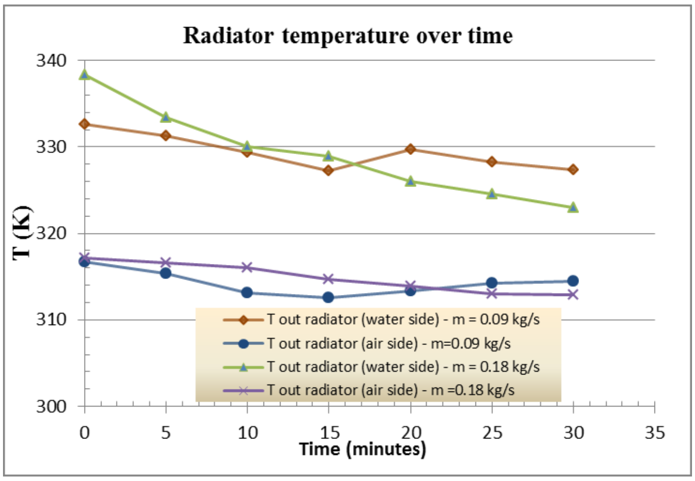

Figure 3. Radiator temperatures over time

The results of the calculation of the heat transfer rate on the air side (qc) over time shows that at the beginning the heat transfer rate is high and will tend to decrease. This is in line with the outside radiator temperature on the air side which tends to decrease compared to the start for both of mass flow rates. The heat transfer rate will tend to be stable after the 25th minute with an average qc of 3781.64 watts for the mass flow rate of 0.09 kg/s and 3971.65 watts for mass flow rate 0.18 kg/s. The maximum heat transfer rate values were 4680 watts for the hot water mass flow rate of 0.18 kg/s. From the analysis shows that the effect of mass flow rate to the performance of radiator's heat transfer was quite significant. The heat transfer rate of air-side radiator will higher with the higher of mass flow rate.

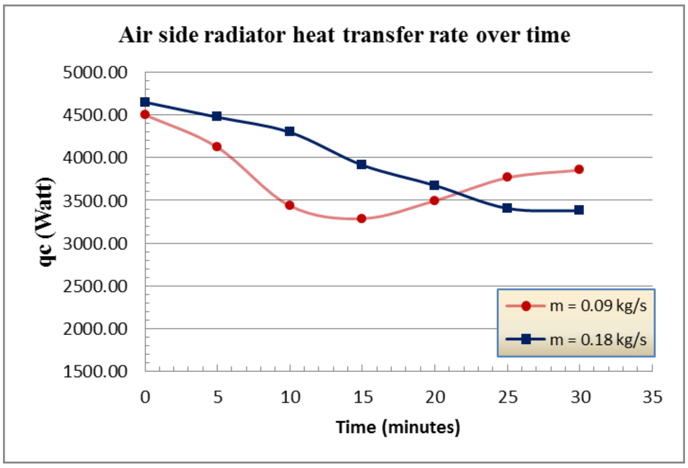

Figure 4. Heat transfer rate of radiator over time

The results of the radiator's effectiveness (ε) as the source of the clove dryer over time showed a tendency to increase. This can occur because the circulation process and heat dissipation of the radiator goes very well. The performance of radiator to circulate the hot water was quite good enough. Radiators are able to produce exhaust heat that is significant enough to be used as a heat source for drying. The average effectiveness of the radiator is 0.34 for the mass flow rate of hot water 0.09 kg/s and 0.43 for the mass flow rate of hot water 0.18 kg/s. From this analysis shows that the average radiator's effectiveness were higher with the higher of mass flow rate. This was similar with the air-side heat transfer rate of radiator.

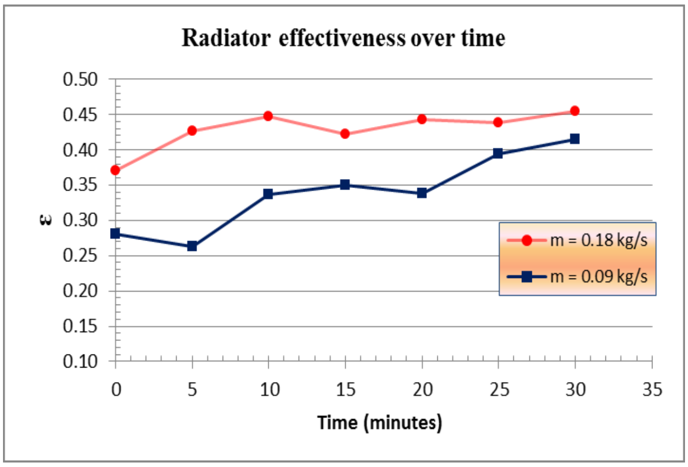

Figure 5. Radiator effectiveness over time

This clove dryer was also tested with a load of 1 kg of wet clove. The drying time for 1 kg clove is 5 hours 30 minutes with a fluid flow rate of 0.18 kg/s. The average heat dissipation of the radiator is 314.87 K with the effectiveness of 0.42. For the fluid flow rate 0.09 kg/s, the drying time of 1 kg clove is 6 hours with the average heat of 314.54 K and the effectiveness of 0.33.

Figure 6. Clove before drying with the dryer tools

Figure 7. Clove after drying with the dryer tools

4. CONCLUSION

From the analysis of thermal radiator's performances shows the effect of mass flow rates to thermal radiator's performances quite significant. The results of the redesign of the clove dryer using a radiator as a heat source can run well. The system produces the heat exhaust with average temperature 314.87 K with the effectiveness of 0.42 for the water mass flow rate 0.18 kg/s, and the average temperature 314.54 K for the water mass flow rate 0.09 kg/s with the effectiveness of 0.33. The clove dryer using a radiator as the heat source also can drying the clove properly. For the load of 1 kg wet clove, the drying time are 5 hours and 30 minutes for the variation of water flow rate 0.18 kg/s and 6 hours for the water mass flow rate 0.09 kg/s.

5. ACKNOWLEDGEMENT

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