

# Experimental Analysis of Fluid Flow Variation Effect to Thermal Performances of Radiator as a Source of Dryer Simulation

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**Abstract**—The purposes of this research was to investigate and analyze the effect of fluid flow variation to the performances of tube and fins radiator type. The research was done experimentally to analyze the performances of radiator. The experiment research was carried out in a simulation system of dryer consist of reservoir water tank, a heater, pump to circulate hot water to the radiator and a cooling fan. The variation of mass flow rate of hot water fluids were 0.09 kg/s and 0.18 kg/s, and the cooling air velocity at a constant rate in 1 m/s. The results showed the temperature of air side radiators were tends to decrease over time. This was in line with the heat dissipation of radiator, where they also tend to decrease over time for both variation of mass flow rate. The average heat transfer rate was higher with the higher water flow rate, which were around 3971.65 Watt. The radiators effectiveness ( $\epsilon$ ) tends to increase with the increasing of time with an average of  $\epsilon = 0.34$  for hot water mas flow rate 0.09 kg/s, and 0.43 for the hot water mass flow rate 0.18 kg/s. The maximum effectiveness value for both mass flow rate variations were obtained at 30 minutes which is 0.32 and 0.45.

**Keywords**—radiator, fluid flow variation, heat transfer, effectiveness

## I. INTRODUCTION

### A. Radiator

Radiator is a heat exchanger device that is used to change the high temperature fluid to make it cooler by transferring heat energy to the environment. In general, radiators are usually used as heat exchangers in vehicle engines, both cars and motorbikes with the purpose to keeping the engine working temperature at its optimal temperature. In the heat dissipation process by the radiator, it produces exhaust heat on the air-side of the radiator, which is a potential energy to be utilized for some heating purposes, such as dryer, heater and many more. In developing countries with a long term of winter, the use of radiators as heaters can help energy efficiency. For the use in dryer or heater system, application of radiator can help increasing the productivity of peoples.

Some previous studies and analyzes have been carried out to determine the performance of radiators in various conditions, experimentally and numerically. This is important to know in designing a dryer from the radiator's heat dissipation.

Experimental analysis of car radiators has been carried out using ethylene glycol/copper as the working fluid, where with the addition of those nanofluids of 0-5%, the heat transfer coefficient will increase [1]. The Other researches that also use nanofluids as a working fluid for radiators are also carried out. By changing the composition ratio of Ethylene Glycol / Water-based TiO<sub>2</sub> nanofluids, an increase in heat transfer rate of up to 37% was obtained at low concentrations of nanofluids against the base fluid ratio [2]. It was similar to the result by using multi-walled carbon nanotubes [3]. Numerical analysis of the performance of car radiators using working fluids from various aluminum and copper-based nanofluids as working fluids has been carried out with a volume fraction ratio of 0.3 with the results obtained that the heat flux will be higher using nanofluids particles from copper compared to aluminum. [4] To determine the effect of the direction of the blowing and positioning of the radiator to the performance of a single plane aluminum radiator, a numerical modeling is carried out using CFD [5][6]. Experimental research was conducted to determine the effect of heating the mass flow rate of the inlet water temperature and the connection position on the panel radiator where it was known that the exhaust heat produced at all joint positions was almost linearly increased with increasing inlet temperature [7]. The effect of mass flow rate variations to the performances of heat exchanger also done by some other researchers. [8] has analyzed the effect of mass flow rate 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 fluid. To determine the effect of mass flow rate on pressure drop and heat transfer in a drying chamber, an experimental experiment was carried out which 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 [9]. The experiment by varying coolant flow rate also carried out to knows the effect to the heat transfer characteristic of automotive radiator, with the result showed that the increasing of coolant flow rate will also increasing the Nusselt number of the coolant [10]. The others experiment of the effect of mass flow rate to the convective heat transfer coefficient also analyzed by [11]. Numerical investigation of mass flow rate effect to the heat transfer rate of automobile radiator has

analyzed using CFD modeling, and the result showed the heat transfer rate as well as efficiency is increased, as the air mass flow rate increases [12].

In this study, an analysis of the performance of the radiator as a source of heat energy for the drying chamber is carried out by varying the speed of the fluid entering the radiator. The performance analyzed is the exhaust heat produced by the radiator, the rate of heat transfer and the effectiveness of the radiator. This information about the exhaust heat generated by the car radiator will be used as an analysis to designing the dryer chamber.

**II. METHODOLOGY**

**A. Experimental Method**

The schematic of the experimental set-up is shown in Fig. 1. It consists of a used radiator system of a car, water tank, a centrifugal pump, water heater, valve, a flow meter and fan system. In this research, water (H<sub>2</sub>O) were used as the working fluid and all the radiator systems are in normal conditions.

In this research, water will be heated by a heater in the water tank. The water is then circulated to the entire system using a pump by adjusting the variation of radiator inlet water velocity by 0.09 kg/s and 0.18 kg/s measured by using a flow meter. The heat transfer process inside the radiator is carried out by forced convection using a blow from the fan with a constant flow rate of 1 m/s. The temperature of the inlet water radiator (T1), the radiator outlet (T2), the air temperature before the radiator (T3) and the air temperature after the radiator (T4) are measured using a thermocouple.

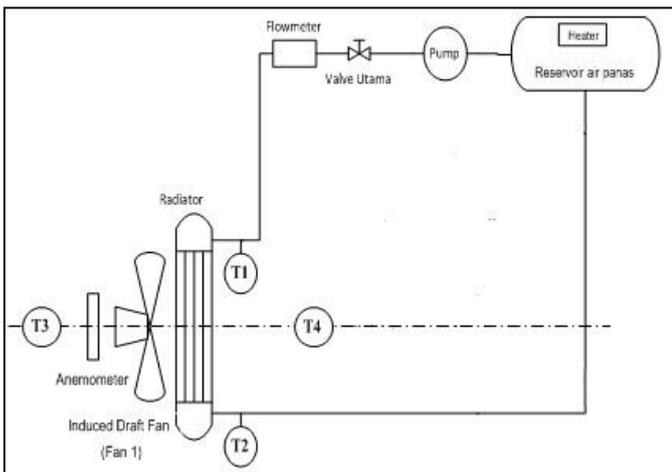


Fig.1. Experimental set-up schematic

The physical properties of the radiator used in this research are shown in table 1.

TABLE I. PHYSICAL PROPERTIES OF RADIATOR

No	Data	Value
1.	Radiator's type	Compact heat exchanger- circular tube continuous fin
2.	Radiator's volume	P × L × T= 500 mm × 30 mm × 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.	Pit length	11 mm

**B. Analysis of Radiator System**

Analysis of radiator performance is done by using the equation for compact heat exchanger analysis as in the following equation [13][14] there were:

- *Coefficient convection (h<sub>cold</sub>) :*

$$h_{cold} = St \cdot G \cdot Cp \tag{1}$$

- *Heat transfer rate (q<sub>cold</sub>) :*

$$q_{cold} = h_{cold} \cdot A_{cold} (T_{Cin} - T_{Cout}) \tag{2}$$

- *Effectiveness radiator (ε) :*

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

where:

$$q_{max} = C_{min} \cdot (Th_{,i} - Tc_{,i}) \tag{4}$$

$$C_{cold} = \dot{m}_c \cdot Cp_c \text{ and } Ch = \dot{m}_h \cdot Cp_h \tag{5}$$

**III. RESULT AND DISCUSSION**

By using the equation above, the analysis of the radiator performance in the dryer simulation tool has been carried out. The results of the radiator performances are shown in Table II and III below

**TABLE II. RADIATOR PERFORMANCE ( $\dot{M} = 0.09 \text{ kg/s}$ )**

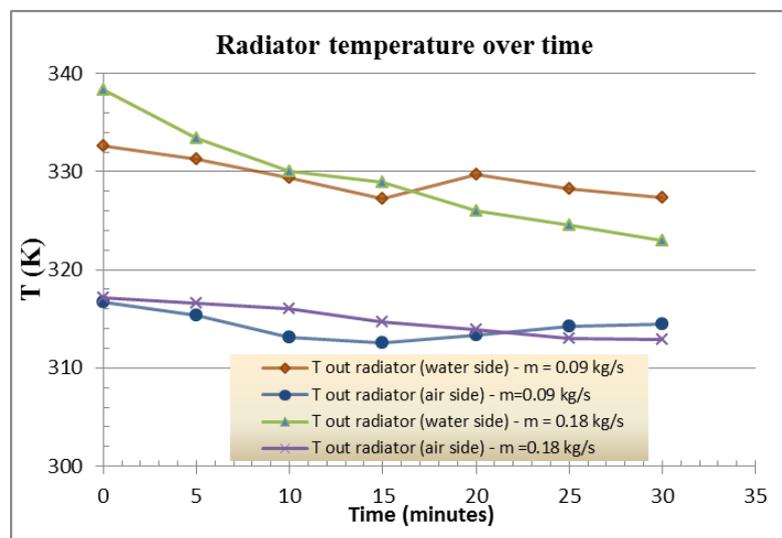
NO	Time (minutes)	T1 (K)	T2 (K)	T3 (K)	T4 (K)	m air (kg/s)	qc (Watt)	$\epsilon$
1	0	354.5	332.6	302	316.7	0.097	4504.565	0.28
2	5	353	331.3	302	315.4	0.097	4122.055	0.26
3	10	335	329.4	302	313.1	0.098	3437.767	0.34
4	15	332.3	327.2	302	312.6	0.098	3287.734	0.35
5	20	335.4	329.7	302	313.3	0.098	3497.652	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 III. RADIATOR PERFORMANCE ( $\dot{M} = 0.18 \text{ kg/s}$ )**

NO	Time (minutes)	T1 (K)	T2 (K)	T3 (K)	T4 (K)	m air (kg/s)	qc (Watt)	$\epsilon$
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 this calculation, a graphical analysis of the performance of the radiator against time is performed as shown in "Fig. 2", "Fig. 3" and "Fig. 4". From the results of the analysis, it can be seen that the exhaust heat generated by the radiator from the air side (T4) is initially quite high at beginning. This can happen because the radiator system just began to release or transferred the heat from the hot water entering the radiator to the outside environment by convection. Heat dissipation into the environment will tend to be stable after the system operated for 25 minutes, and the resulting heat dissipation temperature is about 314 K for both variations of hot water mass flow rate.

This is consistent with the process of heat dissipation on the water side radiator, where the temperature of the water outlet of the radiator is quite high at beginning, and then over time the temperature will decrease and tend to be stable in the range 329 K after the system runs for 18 minutes for both variations of mass flow rate. This means that the heat dissipation process carried out by the radiator has been running well, where the stability of the temperature is achieved and resulting a high exhaust heat on the air side of radiator. This is shown in Figure 2. "Below.


**Fig. 2. Radiator temperature over time**

The results of the calculation of the heat transfer rate on the air side ( $q_c$ ) 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  $q_c$  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 obtained 4680 watts for the hot water mass flow rate of 0.18 kg/s. This was shown in "Fig. 3".

From the analysis shows that the effect of mass flow rate to the performance of radiator's heat transfer was quite significant. it was in-line, which the higher mass flow rate of the hot water entering the radiator, the higher the heat dissipate from radiator to the environment.

The results of the radiator's effectiveness ( $\epsilon$ ) 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. This was shown in "Fig. 4".

From the results of these analysis can be known the effect of mass flow rate on the effectiveness of the radiator, that the average effectiveness of the radiator will be higher at a higher mass flow rate. This is in line with the heat transfer rate produced by the radiator.

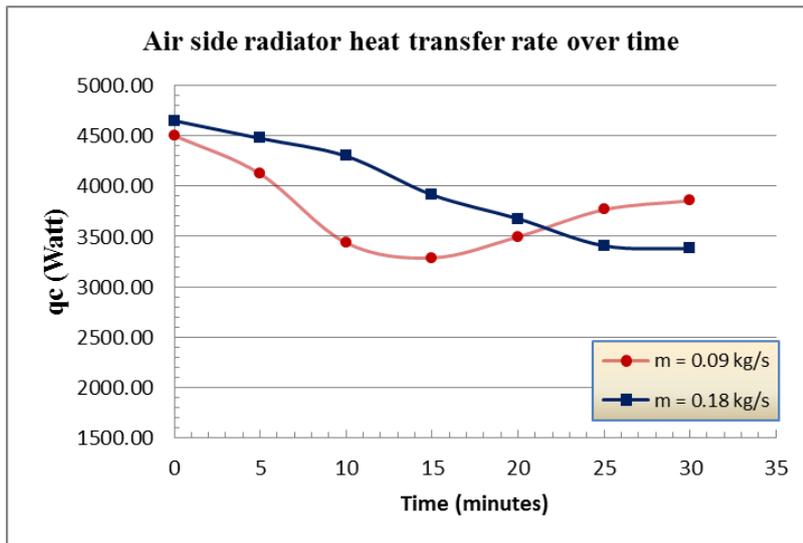


Fig. 3. Heat transfer rate of radiator over time

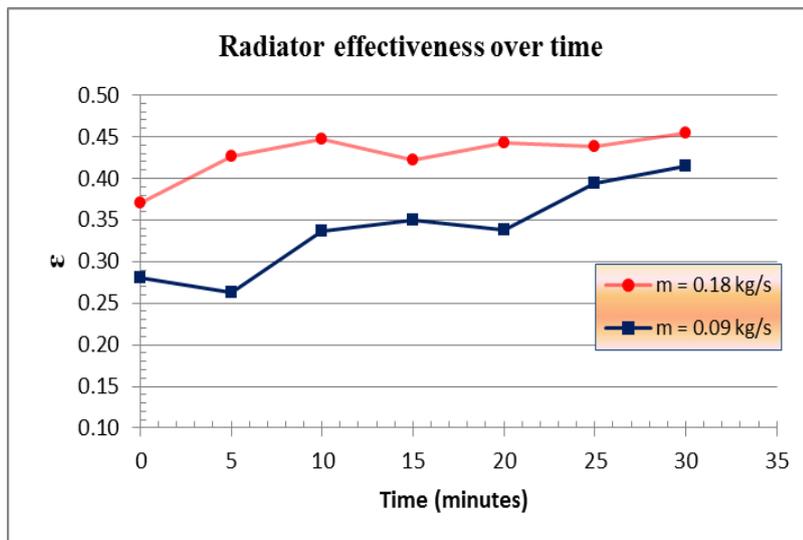


Fig. 4. Radiator effectiveness over time

#### IV. CONCLUSION

From the results of the analysis of the performance of the radiator by varying the flow rate of the mass of water entering the radiator, showed that the effect of mass flow rate to the performance of the radiator is quite significant. The results show that with a higher mass flow rate, the rate of heat transfer generated by the radiator on the air side will higher, this was in line to the radiator effectiveness. This has the similarities trend to the exhaust heat temperature generated from radiator. They was initially high in the beginning and will decreases over time and 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 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.

For a dryer simulation tools, this heat dissipation exhaust from radiator system can be used to designing the dryer room, insulation, and the material of the chamber depends to the average load and the type of the material to be dried.

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