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The Effect of the Number of Cooling Pads on the Output Air Condition and Effectiveness of Air Cooler

Wibowo Kusbandono[1,*]

[1]*Department of Mechanical Engineering,Faculty of Science and Technology, Sanata Dharma University, Indonesia*

[*]*Corresponding Author: bowo@usd.ac.id*

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Abstract

To get comfortable air, it can be done by using an air conditioner or air cooler. The electrical power used for the air cooler is relatively lower. This research aims to see the effect of the number of cooling pads on the output air condition and on the effectiveness of the air cooler. The research was conducted experimentally. The research was conducted by varying the number of cooling pads used, thick. The distance between the cooling pads is 1.5 cm. The air temperature inlet of the air cooler has a dry bulb air temperature of $30^{o}C$ with an air humidity (RH) of 60%. The lowest dry bulb air temperature achieved was $24{,}04^{o}C$ when the number of cooling pads was 6 pieces. The highest air cooler effectiveness achieved was 0.99. Research has given satisfactory results. However, research can be developed by varying the cooling pad material or cooling pad pattern in order to obtain a small number of cooling pads.

Keywords: air cooler, effectiveness, cooling pad

1 Introduction

Air cooler is equipment used to produce cool air. Unlike the air conditioner (AC) which uses the working fluid of Freon, the air cooler uses the working fluid of water. Therefore the air cooler is more environmentally friendly. In its operation, the AC engine uses a steam compression cycle to produce cold air, while the air cooler uses an evaporative cooling process to get cold air. In the AC engine, the freon circulation system is in a closed flow system, while in the air cooler, the water flow system is open. In an open flow system, the fluid makes contact with the outside air. The use of the air cooler does not require it to be placed in a closed room, so that the air cooler can be placed in a room with free air circulation. Thus the need for oxygen from the air for users is not lacking. Of course, the air flow in the room is conditioned relatively calmly, it doesn't interfere with the air flow from the air cooler. From the psychrometric chart, it can be seen that for the condition of the air entering the air cooler at a dry bulb air temperature of 35^0C with a relative humidity (RH) of about 46%, the lowest dry bulb air cooler outlet air temperature that can be achieved is around 25^0C. Meanwhile, if the incoming air is with dry bulb air temperature of about 30^0C with a RH of about 60%, the lowest dry-bulb output air temperature can be reached 24^0C.

The air cooler is not used to condition all the air in the room. The air output of the air cooler is intended for users only. The output air flow is only directed to people who want to enjoy the air from the air cooler. With the air cooler, the output dry bulb air temperature can reach 24^0C- 26^0C. At that air temperature, the user can feel the coolness of the air it produces. In the design of the air cooler, in addition to the condition of the output air being in a comfortable area, it must also have high effectiveness. Unlike the AC machine, if the AC machine is designed to produce dry air [1], the air cooler is designed to produce relatively higher air humidity. The higher the RH, the cooler the air produced.

The manufacture of air coolers has actually been done for a long time. It has even been patented a lot [2-8]. But in Indonesia, the new air cooler is known after the air cooler was marketed in the last decade. Besides being cheap, the air cooler can also be carried anywhere (can be moved around). It's just that the condition of the output air produced by the air cooler depends on the condition of the air entering the air cooler [9]. The

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minimum dry bulb output air temperature that the air cooler can produce is equal to the wet bulb air temperature entering the air cooler. When the dry bulb air temperature output reaches the temperature of the wet bulb air entering the air cooler, the relative humidity of the air reaches 100%. Because the RH of the air has reached 100%, it is impossible for water evaporation to occur on the cooling pad which causes a decrease in air temperature again. Unlike AC machines, the air cooler cannot produce the desired air condition. For areas in Indonesia, air coolers are suitable for use in air conditions, with dry bulb ambient air temperatures between 28^0C to 35^0C with low relative humidity (40%-50%). The lower the relative humidity of the air, the more profitable it is because the lowest air temperature produced will be lower.

Research on air cooler has been carried out by several researchers. The difference between the research that has been carried out by the author and that carried out by previous researchers lies in the shape of the cooling pad, cooling pad material, air cooler geometry and research variations. There are studies that vary the intake air temperature [10], there are studies that are carried out by varying the thickness of the cooling pad [11]. Some use a cooling pad made of sponge [11], some use coconut fiber [12,15]. Some vary the flow of air produced by a fan [12]. There are also those that vary the temperature of the water used [13, 14] and there are those that vary the water discharge [15]. In the research that has been done by the author, the cooling pad used is relatively thin, about 1 mm, and with different materials from previous researchers. The research was conducted by varying the number of cooling-pads. In the market, the cooling pad used for the air cooler is quite thick, with a thickness of more than 5 mm, some even more than 4 cm.

Some of the assumptions used in this research that have been carried out are: (1) when the air passes through the cooling pad, the air undergoes an evaporative cooling process (2) when the air undergoes an evaporative cooling process, the wet bulb air temperature remains (starting when the air enters the water). cooler until the air comes out of the air cooler) (3) the evaporative cooling process runs at a constant enthalpy, no energy enters and leaves. In the evaporative cooling process, there is a decrease in dry bulb air temperature, an increase in relative humidity, an increase in specific humidity, and an increase in dew point temperature.

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2 Research Methodology

The research was conducted experimentally. The object under study is a homemade air cooler. Figure 1, presents a schematic of the air cooler used in the study. Figure 2, presents an image of the cooling pad. The maximum number of cooling pads used is 6 pieces. The thickness of the cooling pad moistened with water is 1 mm.

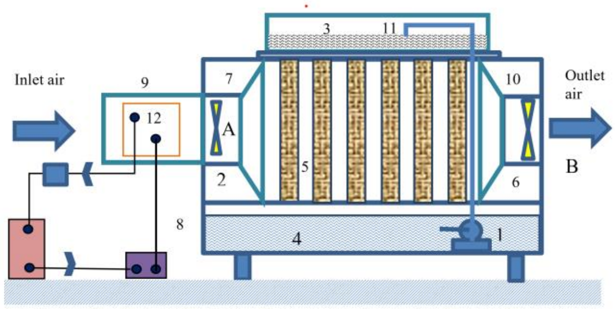

Figure 1. Schematic of an air cooler with 6 cooling pads

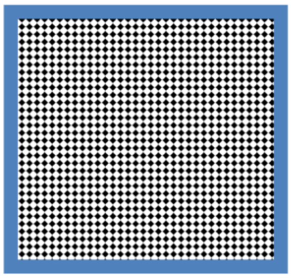

Figure 2. Cooling Pads

Air-cooler components in Figure 1

1. Submersible pump (submersible pump)
2. Air intake fan
3. Upper water reservoir
4. Bottom water reservoir
5. Cooling pad
6. Bottom water reservoir
7. Water cooler frame
8. Case
9. Air inlet
10. Air outlet
11. Water channel
12. Air heater

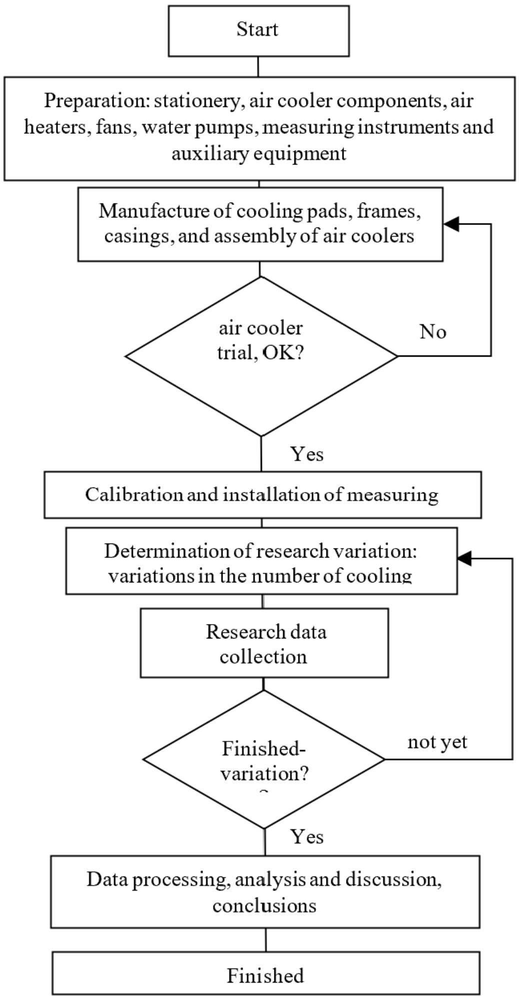

Figure 3. Research Flow

In this study, the air entering the air cooler was conditioned at a dry bulb air temperature of 30^0C, with a relative humidity of 60%. If the dry bulb air temperature does not reach 30^0C the air is preheated by the air heater before entering the air cooler, as desired. The air flow velocity is 1.5 m/s. The research implementation follows the research flow as presented in Figure 3. The research was conducted by varying the number of cooling pads, using 3 cooling pads, 4 cooling pads, 5 cooling pads and 6 cooling pads. To determine the air condition, a dry bulb thermometer and a wet bulb thermometer were used. Meanwhile, to measure the velocity of air flow used anemometer. Other air conditions can be searched by using psychrometric charts, such as relative humidity, absolute humidity, specific volume and air enthalpy.

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The data from the research results are used to get the effectiveness of the air cooler. The effectiveness of the air cooler (∈) is the ratio between the actual (actual) decrease in dry bulb air temperature and the possible or ideal decrease in dry bulb air temperature [9]. The equation used to calculate the effectiveness of the air cooler is expressed by Equation (1).

$$\in = \frac{(T_{db,A} - T_{db,B})}{(T_{db,A} - T_{db,C})} \ldots..(1)$$

In Equation (1)

∈ **:** air-cooler effectiveness

$T_{db,A}$: dry bulb air temperature entering air-cooler, ^{0}C

$T_{db,B}$: dry bulb air temperature out of air-cooler, ^{0}C.

$T_{db,C}$: lowest achievable dry bulb air temperature air-cooler, ^{0}C.

$T_{db,D}$: wet bulb air temperature in process evaporative-cooling, ^{0}C

3 Results and Discussions

The results of the study are presented in Table 1. It appears that the condition of the output air from the air cooler is influenced by the number of cooling pads used. For air coolers with 6 cooling pads, the air cooler output air conditions produce the lowest dry bulb air temperature. As for the air cooler with 3 cooling pads, the air condition of the air cooler output produces the highest dry bulb air temperature. This is probably due to the large surface area of the water in contact with the air passing through the cooling pad. The more the number of cooling pads on the air cooler, the more surface area of the water in contact with the air when the water flows through the cooling pad. The larger the surface area of the water in contact with the air, the more water can evaporate into the air. Unlike the boiling process, the evaporation process can take place not at the boiling point temperature. The evaporation process can take place at any temperature. As long as the humidity has not reached 100% RH, the water flowing on the cooling pad can still evaporate into the air. The process of evaporation of water requires heat. In the process of evaporation of water in the cooling pad, heat is taken from the environment. In this case the environment is air. The heat is taken from the air flowing through the cooling

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pad. The more water that evaporates, the greater the heat of vaporization required to change the water from the liquid phase to the vapor phase. The greater the heat taken by water from the air, the lower the air temperature. The amount of heat taken from the air is equal to the amount of heat used to change the liquid phase from the water to the water vapor phase. During the evaporative cooling process, the enthalpy value of the air remains constant. The heat taken from the air is sensible heat, while the heat used to change water from the liquid phase to the vapor is latent heat. In this case, it is assumed that no heat is taken from the water used to change the phase from water to steam.

Table 1. Conditions of air inlet and outlet of air cooler and effectiveness of air cooler

Number of *cooling pad*	**Intake air condition *air cooler***				**Air condition out of *air cooler***			**Effectiveness of *air cooler* (ε)**
	$T_{db,A}$ (ºC)	**$T_{wb,A}$ (ºC)**	**RH_A (%)**	**W_A (gr/kg)**	**$T_{db,B}$ (ºC)**	**$T_{wb,B}$ (ºC)**	**W_B (gr/kg)**	
3	30ºC	24ºC	60%	16,1	25,15 ºC	24ºC	18,19	0,81
4	30ºC	24ºC	60%	16,1	24,77 ºC	24ºC	18,35	0,87
5	30ºC	24ºC	60%	16,1	24,38 ºC	24ºC	18,52	0,94
6	30ºC	24ºC	60%	16,1	24,04ºC	24ºC	18,66	0,99

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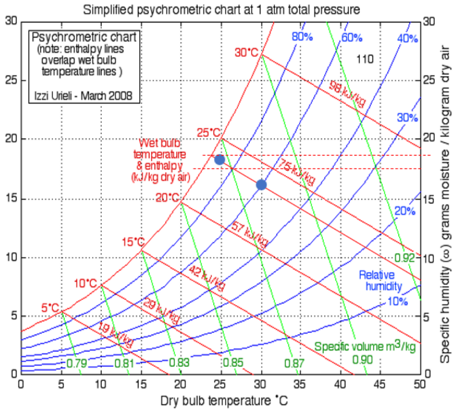

Figure a. *Air cooler* with 3 *cooling pads*

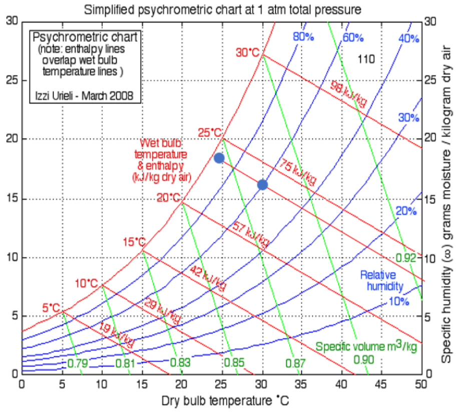

Figure b. *Air cooler* with 4 *cooling pads*

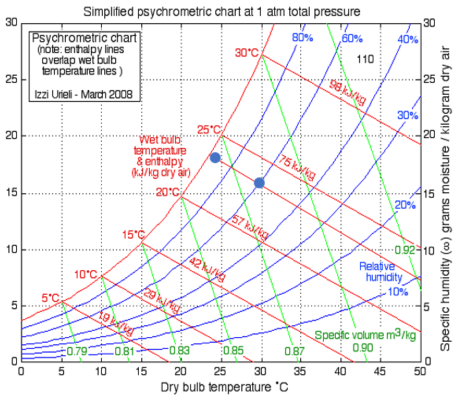

Figure c. *Air cooler* with 5 *cooling pads*

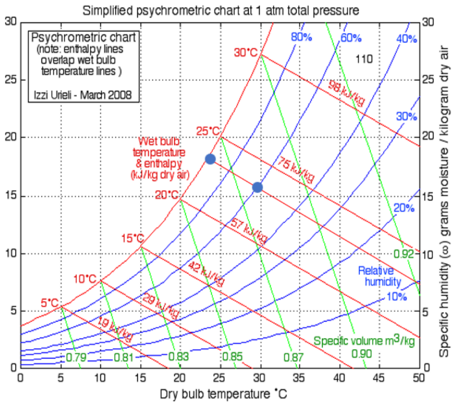

Figure d. *Air cooler* with 6 *cooling pads*

Figure 4. Conditions of air inlet and outlet of air cooler and effectiveness of air cooler with different number of pads. a. Air cooler with 3 cooling pads. b. Air cooler with 4 cooling pads. c. Air cooler with 5 cooling pads. d. Air cooler with 6 cooling pads

To get a cooler dry bulb air temperature from the air cooler, it can be done by increasing the use of cooling pads. The more the cooling pad is used, the lower the output dry bulb air temperature will be. But of course the number of cooling pads used has a limit. The limitation is, if the use of n number of cooling pads can produce output air with a relative humidity (RH) of 100%, then the addition of a cooling pad is no longer needed. The addition of a cooling pad will no longer reduce the dry bulb air temperature from the air cooler, because it is no longer possible to change the phase from water to steam anymore. In other words, the amount of water that evaporates is equal to the amount of water that

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condenses. On the other hand, the more cooling pads used, the lower the output airflow rate. This is because the more the cooling pad is used, the greater the air resistance that occurs. Seeing the results of this study, the use of 6 cooling pads is sufficient. Because the relative humidity value of the resulting air is close to 100%. It is no longer necessary to add a cooling pad. Even if one additional cooling pad is added, the minimum output dry ball air that can be achieved is only 24 ^{0}C. Not so influential.

From Table 1 and Figure 4a-d, it appears that the lowest dry bulb air temperature that the air cooler can achieve is 24,04 ^{0}C. The air cooler is able to reduce the dry bulb air temperature by about 5,96^{0}C, from the initial temperature of 30^{0}C. Close to the decrease in the maximum dry bulb air temperature that the air cooler can achieve, by 6^{0}C (with air intake conditions of 30 ^{0}C and 60% RH). For air humidity, the greater the number of cooling pads, the greater the specific humidity value (ω) produced. The specific humidity of the air increased from 16.1 grams of water/kg dry air to a maximum of 18.66 grams of water/kg dry air. This is because the water content in the air increases from the evaporation of water passing through the cooling pad. Likewise, the value of the relative humidity of the air (RH), increased from the original 60% to all above 90%. The highest produced by the air cooler, the air output of the air cooler has a RH of almost 100%.

The effectiveness of the air cooler depends on the number of cooling pads used. In this study, the effectiveness of the air cooler from the lowest value to the highest value, for the air cooler with a total of 3 cooling pads, 4 cooling pads, 5 cooling pads and 6 cooling pads, respectively, was 0.81; 0.87; 0.94; 0.99. This is understandable because the effectiveness value depends on the dry bulb air temperature from the air cooler outlet. The lower the dry bulb air temperature, the higher the effectiveness value (Equation (1)). Due to the difference in temperature between the dry bulb air temperature entering the air cooler and the dry bulb air temperature, the air cooler output is getting bigger. The effectiveness of the air cooler is directly proportional to the difference between the dry bulb air temperature inlet and the output. As is known, the difference between the lowest dry bulb air temperature that can be achieved by the air cooler (the temperature at which the air has a 100% RH) and the dry bulb air temperature entering the air cooler remains constant. From the results of this study, research can be developed with the target of producing outdoor air conditions that have a relative humidity of 100% of the air but with

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a number of cooling pads that are smaller than 6 cooling pads. It can be done by using another cooling pad, it can be with a different cooling pad material or with a different cooling pad pattern.

4 Conclusions

The study resulted in conclusions (a) for air coolers with 3, 4, 5, 6 cooling pads, respectively producing dry bulb air temperatures of: 25,15^{0}C; 24,77^{0}C; 24,38^{0}C and 24,04 ^{0}C. (b) for air coolers with 3, 4, 5, 6 cooling pads, respectively, the effectiveness of the air cooler is 0.81; 0.87; 0.94 and 0.99. Research can be developed by minimizing the number of cooling pads, for example by using a cooling pad material or a different cooling pad pattern.

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