The Effect of Condenser Cooling to Coefficient of Performance (COP) and Electrical Consumption on AC Split

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Abstract: The refrigeration equipment currently available is a split AC with some capacity. One of the processes that occur in cooling machine is condensation which produces water and hot refrigerant. Inside the condenser, some of refrigerant heat must be removed with the help of a blower to avoid the damage of compressor. Seeing this, the condensed water from the evaporator will be reused as a cooling fluid. The purpose of this research is to determine the coefficient of performance (COP) and electrical consumption without and using an additional condenser cooling system. The test was carried out by modified condenser split AC 1 Pk R-410a by installing 9 nozzles, a DC pump where the 3 nozzles horizontal and 3 nozzles vertical. The independent variables of this test are the 3 nozzles horizontal position and the spraying time is 1, 2 and 3 minutes. The room used is a 6 x 6 x 3.5 m as cooling load. From the results, it was found that there was an increase in the performance of the cooling machine with the addition of a cooling system of about 34%, while in the electrical consumption, there was a slight decrease about 5%.

1 INTRODUCTION

Indonesia as a tropical country that gets sunlight almost all year round. This condition has an impact on the air temperature and humidity which is quite high. Along with the human desire to more comfort, the use of cooling systems, air conditioning (AC) for comfort is increasing. In its application, this system is used in various aspects of life, ranging from the food industry, chemical industry, hotels, hospitals, aviation, shipping and even in households.

One type of cooling system that we often find is a split cooling system where the evaporator will be placed inside of the room but the compressor, condenser and the expansion valve are outside which are widely used in households. Generally air conditioning generally work on the principle of vapor compression, where there are several main components, such us compressor, condenser, expansion valve and evaporator. These 4 components form a system to condition the air of a room. In the process, there are two main processes i.e. heat transfer processes, the process of absorption of heat in the evaporator and heat dissipation in the condenser where the heat in the refrigerant is pushed into the environment using air and assisted by blower, where the condensed water from the evaporator will be discharged through the exhaust pipe. This process will not take place perfectly when the outside air temperature is high enough (Patel and Sheth 2015) so that an additional system is needed to cool the condenser and reduce compressor work. In direct evaporative system, water evaporates directly in the air stream, producing an adiabatic process of heat exchange in which the air-dry bulb temperature decreases as its humidity increases. Thus, the amount of heat transferred from the air to the water is the same as the one employed in the evaporation of the water. (Porumb, Bălan, and Porumb 2016) said that the evaporative system allowed the reduction of energy consumption for the fresh air cooling with almost 80% and also (Patel and Sheth 2015) mention that the evaporative system is ecofriendly and is not associated with ozone layer depletion problem because it does not need any refrigerant. Seeing this, the researcher wants to make an innovation, reducing the use of electric power, but the comfort can still be fulfilled.

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Data on electricity usage, especially in its use for air conditioning, has increased quite sharply. The Executive Director of the IEA (International Energy Agency) was said in Asia, respectively ASEAN, that the use of air conditioners had triggered a higher global demand for electricity. (Alhamdo, Theeb, and Abdulhameed 2015) also mention that in air cooled condensers, the power consumption is a major issue in vapor compression cycle. The power consumption concern increased much more if the air-cooled condensers work in area with very high ambient temperature (between 50-60 ^{0}C). Seeing these phenomena, the researchers tried to further examine the use of evaporative cooling systems in Air Conditioning. From a previous study (Ridhuan and Juniawan 2014) said that the highest coefisient of performance (COP) value of cooling with only blower (before modified) was 6.44 while the highest COP after being modified with evaporative cooling systems was 15.43. So it can be said that cooling with water is better than air conditioning. In the otherside (Rif and Km 2016) also said that a decrease in electricity consumption of 0.5 kW without a cooling load and with a loading of 2000w reduced compressor work by 0.4 kW. This proves that the potential for using water as a cooling medium is quite large. In any subsequent research by (Alhamdo et al. 2015) (Silalahi, Ajiwiguna, and Kirom 2018), (Ardita and Subagia 2018) that the use of condensate water can reduce the temperature of the refrigerant entering the condenser by 2.2ºC and decrease the use of electric power by 0.5 kW with 2000W cooling load. So, The purpose of this research is to design a system that is able to reduce the use of electricity consumed by a compressor split AC

2 METHODOLOGY

The design of this research is to modify the AC split condenser by adding an additional system consisting of a water reservoir, condensate water, pump and nozzle as shown in Figure 1 to see the effect of additional cooling on AC split performance. The placement of this additional cooling system is behind the condenser / in front of the cooling blower in the form of water spray through the nozzle. The water used is the result of air condensation from the air conditioner itself, collected, pumped and reused to cool the condenser in the same way.

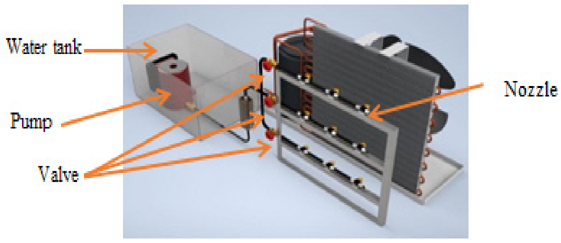

Figure 1: Design.

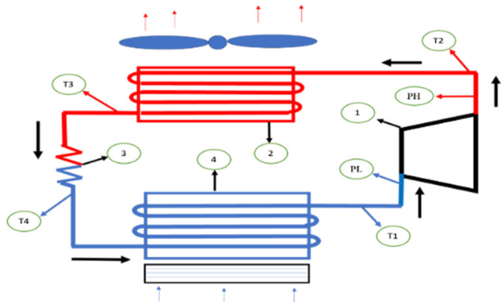

Figure 2: Measurement position design.

The test will be carried out based on variations in horizontal position of the nozzle and the time of spraying. The 3 nozzles horizontal position means; top, middle, and bottom row. The spraying time variation is the length of spraying time the condenser is sprayed, consecutively 1, 2 and 3 minutes. For the data collection will use several instruments, such us thermocouple to take temperature data, voltmeter to take current and voltage data and pressure gauge which is directly added on the refrigeration machine to determine the low and high pressures that’s occur.

The test conditions are:

1. Average room temperature 30^{0}C
2. Room: Applied Refrigeration Laboratory, Mechanical Engineering, Bali State Polytechnic
3. Condition of room: 6 x 6 x 3.5, 2 doors glass, 8 glass windows, 1 x 2 m equipped with curtain
4. Average voltage: 225 Volt
5. Stuffs: 3 bookcases with books inside and several other tools
6. Cos Ø : 0.8
7. Data taken every 5 minutes for 1 hour
8. Layout of nozzle as figure 3

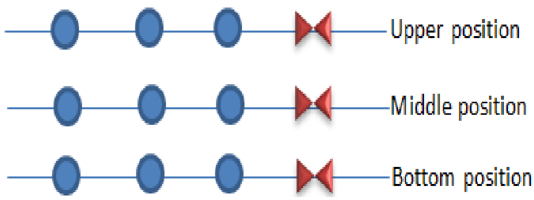

Figure 3: Layout of nozzle.

3 RESULT AND DISCUSSION

The results that have been achieved are a set of test equipment consisting of 1 set of split AC 1 Pk, refrigerant R410a, 840 watts, low pressure 160-170 psi, 4.6 Ampere where these results are in accordance with the specifications of this cooling machine. The installation of the pressure gauge is to determine the high pressure and low pressure that occurs in the system and the thermocouple that has been installed to determine the temperature at each position properly on the test instrument as shown in Figures 4 and 5.

Figure 4: Test equipment.

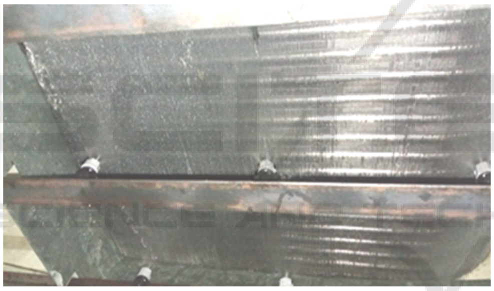

Figure 5: Nozzel.

The next step is to collect data by measuring pressure, temperature, voltage and current. To see the differences that occur, several variations were tested. The variations made for the position of the nozzle and time of spraying where 3rd nozzles will be placed horizontally. For the spraying time, 3rd variations horizontal will be carried out, namely 1, 2 and 3 minutes. The test will take place with 9 variations, when the 1st test without additional coolant to test the initial ability of the cooling machine, 2nd, 5th and 8th for the top horizontal nozzle with a spraying time of 1 minute, 3rd, 6th and 9th for the top horizontal nozzle with a spraying time of 2 minutes and 4th, 7th and 10th for the top horizontal nozzle with a spraying time 3 minutes.

From the results of the tests carried out, the results are as shown in the table and figure below:

Table 1: Comparison ER, Wk and COP.

Condition	ER	Wk (kj/kg)	COP
Without	122.99	28.13	4.37
Upper 1	138.86	23.6	5.88
Middle 1	136.71	23.66	5.78
Bottom 1	130.33	25.74	5.06
Upper 2	144.39	22.40	6.44
Middle 2	141.39	22.68	6.23
Bottom 2	130.56	25.31	5.16
Upper 3	145.77	22.02	6.62
Middle 3	143.61	22.62	6.35
Bottom 3	133.40	24.56	5.43

Table 2: Comparison Electrical Consumption & COP.

Condition	Electrical Consumption	COP
Without	840	4.37
Upper 1	790	5.88
Middle 1	790	5.78
Bottom 1	810	5.06
Upper 2	780	6.44
Middle 2	780	6.23
Bottom 2	810	5.16
Upper 3	780	6.62
Middle 3	780	6.35
Bottom 3	810	5.43

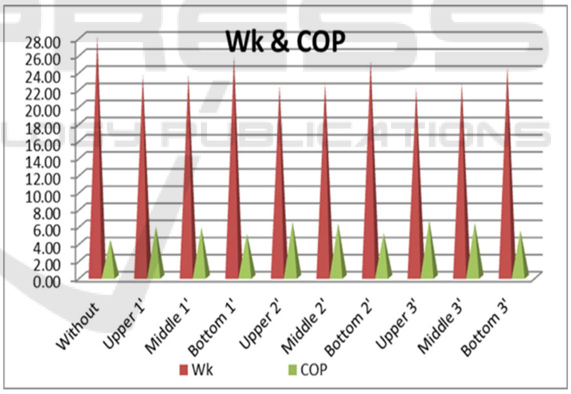

Figure 6: Comparison Work of Compression (Wk) & Coefficient of Performance (COP).

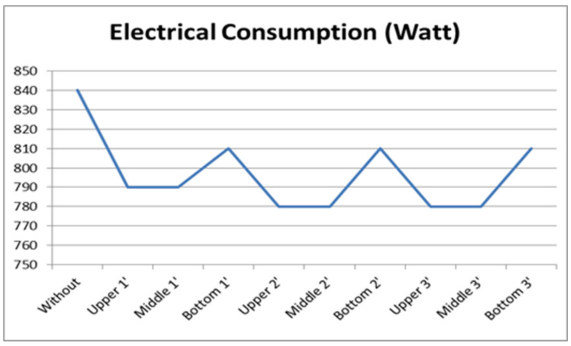

Figure 7: Electrical Consumption.

Based on table 1 and Figure 6 above, it is known that the COP value of the 1 Pk R410a split AC system before the additional cooling system on the condenser is turned on the COP result of 4.37. After the additional cooling system is turned on, the horizontal nozzle on top, middle and bottom rows for 1 minute spray the COP results of 5.88, 5.78 and 5.06. In the 5th variation where the additional cooling system will spray water for 2 minutes, the COP is 6.44, 6.23 and 5.16, respectively. In the 8th variation where the additional cooling system will spray water for 3 minutes, the COP values are 6.62, 6.35, and 5.43. The changes the values of COP with the addition of cooling system in condenser are quite significant due to the reduced compression work which affects the COP value.

Based on Figure 7, it's known that the power consumption of the 1 PK R410a split system before the additional condenser cooling system is turn on, the power consumption is 0.84 watts and after the condenser additional cooling system is turn on in the top and middle horizontal nozzles for 1 minute, the power consumption decrease to 0.79 watts but the value of power consumption is 0.81 watts at the bottom row horizontal of the nozzle. Similarly, for spraying 2 minutes, the top row and the middle horizontal nozzles are 0.78 watts but in the bottom row it increases to 0.81 watts. In 3 minutes of spraying, the power consumption is 0.78 watts on the top and middle horizontal nozzles while the bottom row is 0.81. So in general the value of power consumption after the condenser auxiliary cooling system is turned on is smaller than when the condenser auxiliary cooling system is turned off. These changes occur because the compressions work (Wk) decreases where the compression work is the work done by the compressor using electric power.

4 CONCLUSIONS

Within the limitations of materials and time to experiment, the results obtained in this work, can be summarized that there is an increase in AC performance by 34% in the additional cooling system working especially on the horizontal upper nozzle which sprays water for 1, 2 and 3 minutes with a decrease in electrical consumption of 3Watt hour in average. From the results above, the test will be continued by testing the spray with the nozzle in the vertical direction and adding cooling fins to the compressor.

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