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Performance Evaluation of a Heat Recovery System Combined with a Helical-Type Heat Exchanger as a Water Heater

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A B S T R A C T

A heat recovery system is a form of reuse of wasted heat energy as a water heater. The water heater is an effort to utilize heat from the work of the compressor without reducing the function of the air conditioner as a room cooler. This study aimed to evaluate the coefficient of performance between standard air conditioners and modified air conditioners with heat recovery systems using a helical-type heat exchanger with a distance of 0 cm between coils. This was an experimental study on a helical-type heat exchanger. Tests were carried out on standard split air conditioners and modified split air conditioners with heat exchangers. The independent variables in this study are variations of the helical type heat exchanger with a distance of 0 cm between the coil and variations in the air setting at the evaporator output. 16°C, 20°C and 24°C. The dependent variable in this study is the coefficient of performance. The evaporator outlet air temperature setting of 16°C has the greatest heat recovery system value, and this is because the evaporator outlet air temperature setting of 16°C has the largest h2 value compared to other evaporator outlet air temperature settings. The greater the evaporator output air temperature setting, the greater the value of the resulting heat recovery system. In conclusion, the highest coefficient of performance is found at the evaporation exit temperature of 24°C, and the variation in the distance between the coil is 0 cm. Meanwhile, the hottest water temperature is found in the evaporator air setting of 16°C with a variation of the distance between the coil of 0 cm.

1. Introduction

Efforts to save energy are currently intensively carried out in every element of human life. Indonesia, which is in a tropical climate with warm air temperatures and high humidity, encourages residents to use air conditioners. In addition to the cool air, in some places, a water heater is also needed for bathing (water heater). There is an alternative that can be done besides using a commercial water heater, namely by utilizing the heat generated by the AC compressor by adding a heat recovery system (HRS).[1-3]

Heat recovery systems in air conditioning systems have been widely applied to both split air conditioners and water chillers. A heat recovery system is a form of reuse of wasted heat energy as a water heater. The water heater is an effort to utilize heat from the work of the compressor without reducing the function of the air conditioner as a room cooler. The working principle of the water heater uses a vapor compression cycle. Namely, the evaporator side is used to cool the room, while the side between the compressor and condenser is used for the heating process.[4,5] In this system, the tool added is a water heater (heat exchanger) which is installed between the compressor and the condenser. This heat exchanger plays an important role in the transfer of heat from the refrigerant so that a pressure drop does not occur, which affects the work of the cooling system. By varying the distance between the coil, the heat exchanger can release and obtain COP well pada heat recovery system because the less distance between the coil, the more heat can be released from the water in the heat recovery tank.[6-8]

Previous studies stated that the use of a helical type heat exchanger has a good heat transfer coefficient compared to standard split air conditioners.[9] Comparison of standard air conditioners and modified air conditioners with the addition of a helical type heat exchanger affects the coefficient of performance (COP). This study aimed to evaluate the coefficient of performance between standard air conditioners and modified air conditioners with heat recovery systems using a helical-type heat exchanger with a distance between coils of 0 cm.

2. Methods

This study was an experimental study on a helical-type heat exchanger. Tests were carried out on standard split air conditioners and modified split air conditioners with heat exchangers. The independent variables in this study are variations of the helical type heat exchanger with a distance of 0 cm between the coil and variations in the air setting at the evaporator output. 16°C, 20°C and 24°C. The dependent variable in this study is the coefficient of performance. The control variable in this study was refrigerant filling up to a suction pressure of 80 psi and a volume of water in the tank of 20 L. This study used a helical type heat exchanger with a copper pipe size of ¼ inch, a copper pipe length of 4 meters, and each heat exchanger coil totaling 7 coils, a heat exchanger height of 20 cm, with a distance between coils of 0 cm (Figure 1).

Figure 1. Helical-type heat exchanger with 0 cm distance between coils.

The experimental procedure is as follows; The split AC used is a standard AC with a compressor system capacity of 1 PK. The system is vacuumed with a vacuum pump for 30 minutes until the blue analyzer needle on the manifold is at -30 psi. Then, refrigerant R22 is filled with a pressure of 80 psi according to the capacity of the AC compressor. After the air conditioner is turned on, the initial pressure and temperature are measured. For every drop of 1°C on the thermistor, observe pressure (P1 and P2) and temperature (T1, T2, T3, T4, and T5). The study was stopped if the evaporator outlet temperature reached 24°C. After the room temperature and split AC system is normal, the same steps are carried out for temperature testing at 16°C and 20°C.

Meanwhile, the testing steps for a split AC integrated with a heat recovery system (HRS) are as follows; The equipment prepared is a heat recovery system that has been installed with a helical type heat exchanger with a variation of the distance between the coil of 0 cm. The system is vacuumed with a vacuum pump for 30 minutes until the blue analyzer needle on the manifold is at -30 psi. Then, refrigerant R22 is filled with a pressure of 80 psi according to the capacity of the AC compressor. Next, prepare the water to be put into the HRS tank with a volume of 20 L. The split AC is then turned on at 24°C with a helical-type heat exchanger with a coil variation of 0 cm. For every drop of 1°C on the thermistor, observe pressure (P1 and P2), temperature (T1, T2, T3, T4, and T5), and water temperature in the HRS tank. The study was stopped if the evaporator outlet temperature reached 24°C. After the room temperature, the split AC system and the water temperature in the tank are normal, and the same steps are carried out for variations in the evaporator output temperature, which is set at 20°C and 16°C. Enthalpy values, refrigeration effects, compressor work, condenser, and coefficient of performance are calculated and presented in tables and graphs.

3. Results and Discussion

Split AC experiment standards and a heat recovery system combined with a helical type heat exchanger were carried out with various evaporator output temperature settings at 24°C, 20°C, and 16°C. Measurements were made at several points using a thermocouple. The enthalpy values for each experiment are presented in Table 1.

Table 1. Enthalpy values for standard and modified split AC.

Evaporator output air temperature (°C)	Enthalpy value (kJ/kg)				
	h1	h2	h2'	h3	h4
Standard split AC					
24	411.84	435.47	-	240.15	240.15
20	410.67	447.50	-	240.29	240.29
16	408.62	449.14	-	240.44	240.44
Helical-type heat exchanger with 0 cm distance between coils					
24	411.99	435.45	416.79	240.27	240.27
20	410.92	446.88	417.46	240.08	240.08
16	408.85	449.05	417.56	240.41	240.41

Table 2. Performance evaluation of helical-type heat exchanger.

Setting the output temperature of the evaporator in the room (°C)	Refrigeration effect (kJ/kg)	Compressor work (kJ/kg)	Condenser work (kJ/kg)	Heat recovery system (kJ/kg)	Coefficient of performance	Compressor actual power (watt)
		Variation of the distance between coils 0 cm				
24	171.72	23.47	195.19	18.66	8.11	652.63
20	170.84	35.96	206.79	29.42	5.57	688.16
16	168.44	40.21	208.65	31.50	4.97	740.52
		Standard split AC				
24	171.69	23.63	195.32		7.27	675.07
20	170.38	36.83	207.21		4.63	691.90
16	168.18	40.52	208.70		4.15	744.26

A heat recovery system is a form of reuse of wasted heat energy as a water heater. The heat recovery system uses a vapor compression cycle, which is the difference between the vapor compression cycle in a standard split AC and the heat recovery system.[10,11] In a standard split air conditioner, the refrigerant that comes out of the compressor goes to the condenser as a heat remover, but in the heat recovery system, the refrigerant that comes out of the compressor goes to the heat exchanger to release heat which is then absorbed by the water in the heat recovery tank.

The use of evaporator outlet air temperature settings has a different heat recovery system. The smaller the evaporator outlet air temperature setting, the greater the value of the heat recovery system. The evaporator outlet air temperature setting of 16°C has the greatest heat recovery system value. This is because the evaporator outlet air temperature setting of 16°C has the largest h2 value compared to other evaporator outlet air temperature settings. The greater the evaporator output air temperature setting, the greater the value of the resulting heat recovery system.

The coefficient of performance (COP) is a coefficient that is equal to the refrigeration effect divided by the compression work.[12] The higher the COP value, the better the refrigeration system.[13] Table 2 shows the highest COP value at the evaporation exit temperature of 24°C, and the variation in the distance between the coil is 0 cm.

Table 3. Comparison of temperature and time of heating water using a heat exchanger.

Evaporator output temperature (°C)	Variation of the distance between heat exchanger coil	Highest hot water temperature (°C)	Reached time(s)
24	0 cm	32.63	400
20		45.50	1320
16		75.66	15130

A heat exchanger is a tool that is used for the transfer of heat between two fluids that have different temperatures without mixing between one fluid and another. This process is used to transfer heat from a high-temperature fluid to a low-temperature fluid in a system, which usually functions as a cooler or heater.[13] In this study, the hottest water temperature was obtained at the evaporator air setting of 16°C with a variation of the distance between the coil of 0 cm (Table 3).

4. Conclusion

The highest COP value is found at the evaporation exit temperature of 24°C, and the variation of the distance between the coil is 0 cm. Meanwhile, the hottest water temperature is found in the evaporator air setting at 16°C with a variation of the distance between the coil of 0 cm.

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