Thermal Performance of Hot Water System Produced by Air Conditioning Coupled with Heat Recovery

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Keywords: Air Conditioning, Heat Recovery, Free Hot Water, Twisted Tapes.

Abstract: Shifting the air conditioning (AC) cycle from conventional to efficiently novel cycle is one of the effective ways to save energy and reach sustainability. In this experimental investigation, an effort had been made in design, fabrication, and evaluated the thermal performance of air conditioning coupled with heat recovery to produce free hot water for residential. It is also investigated the effect of the number of twisted tapes insert inside the heat recovery unit. The experiment was conducted in a 4 x 4 m room with 1 pk compressor power. Heat recovery was used to increase water temperature after coming in contact with hot refrigerant from the discharge of the compressor. This hot water was delivered to the thermal storage tank. The result indicated an increase in temperature and energy of the heat recovery tank by around 0.2%, 6.0%, 6.8%, 17.3% using one, two, three, four twisted tapes.

1 INTRODUCTION

The efficient and conservation energy system for optimization in refrigeration, heating, ventilating, and air conditioning (RHVAC) in building energy involves the employment of a heat exchanger as a thermal recovery unit (Sunu et al., 2020b; 2017a, 2017b). Heat exchanger exchanging the heat of the hot to the cold side and vice versa of the conditioned part/space. From its function in general point of view, the heat exchanger has an important role. Various types of heat exchangers are applied in the RHVAC field. (Sunu et al., 2020c, 2017c, 2017d) this research applied a double pipe heat exchanger which scratched with grooves to optimize heat transfer and pressure losses. It was found that the addition of longitudinal and circumferential grooves on the walls of the heat exchanger gave positive results on heat transfer and pressure losses. Research on the other types of heat exchangers such as plate heat exchanger (Nur et al., 2015). The result shows the increases of plate spacing give effect to the increase of total area on the other hand the rises of plate spacing decrease the fluid pressure drop. Optimization of the heat exchanger shape is done to improve the heat transfer process and hydraulic characteristics in the heat exchanger. (Ji et

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Wijaya Sunu, P., Made Suarta, I., Simon Anakottapary, D., Bambang Dwi Kuncoro, C., Dewa Gede Agus Triputra, I., Dewa Made Cipta Santosa, I., Made Ari Dwi Suta Atmaja, I., Suarsana, K. and Wayan Edi Arsawan, I.
Thermal Performance of Hot Water System Produced by Air Conditioning Coupled with Heat Recovery.
DOI: 10.5220/0010947100003260
In *Proceedings of the 4th International Conference on Applied Science and Technology on Engineering Science (iCAST-ES 2021)*, pages 434-439
ISBN: 978-989-758-615-6; ISSN: 2975-8246

al., 2015) study a complete investigation on heat transfer enhancement techniques special for flow in the pipe. The main purposes of the techniques are to generate vortex inside the flow so as to generate the fluid mixing and advection. The utilization of vortex generators increases the possibility to improve transport phenomena.

To generate the swirl and increase the turbulence flow can be done in several ways, which can be separated into two major ways: one is active methods and the other is passive methods. In the first method the flow activated driven by the force convection using machinery driving the fluid changing its flow direction, another active way is using vibration. Especially in the second method or passive ways, surface variation has been established for increasing the transport of energy and pressure drop in a turbulent flow. This modification method applying surface techniques that induced the formation of the vortex at the secondary flow (Lorenz et al., 1995; Adachi et al., 2001, 2009; Eiamsa-ard et al., 2008, 2009; Jain et al., 2013; Wang et al. 2013; Piriyarungrod et al., 2018; Pan et al., 2020). The heat transport mechanism in heat exchanger equipped with passive technique can actually be developed for producing turbulence in the fluid flow.

The thermal performance of a heat exchanger for heat recovery application can be enhanced by various heat transfer enhancement techniques either active or passive technique. One of the applications in the industrial is by applying the system of heat recovery using a heat pipe heat exchanger (HPHE) (Remeli et al., 2015). Modification via surface scraped apply in heat exchanger have been conducted for the fluid with high viscosity pharmaceutical, food, and chemical industries (Dehkordi et al., 2015). Nowadays, high energy-efficient buildings, the deficit of world energy, and carbon footprint and emission have strong demand on the residential energy efficiencies (Yang et al., 2014). To make the advantages of mechanical air conditioning for residential, air conditioning coupled with heat recovery was introduced. Heat recovery application in air conditioning systems has become more popular in these recent years as an economical-effective method. It reuses the waste thermal energy in refrigerant flowing through the condenser and thereby produce free hot water (Sunu et al., 2020a). This system needs an additional heat exchanger which exchanges the heat of refrigerant-to-water and places between compressor and condenser for heat recovery (Jie et al., 2015). This installation mechanism can assist combined space conditioning and free water heating and is very suitable in tropical regions like Indonesia. There has been a fast movement of use and optimization of the waste heat recovery unit integrated with air conditioning since the last few decades (Lee et al., 1996). (Ji et al., 2003) propose the use of a tank of thermal storage as energy storage to enhanced heat recovery room air-conditioner. (Monerasinghe et al., 1982) conducted a study and feasibility of heat recovery integrated with room air-conditioning. The use of storage-enhanced heat recovery from room air-conditioner to produce free hot water and offer a space air conditioning system for energy conservation. On the other hand, the additional heat recovery process makes the fluctuations of pressure (Jie et al., 2015). The result shows the overall COP of TEV found 12.5–20.9% higher than the capillary tube.

According to relevant research works above are none, to identify all of the passive technique for heat transfer is chosen for use as optimized heat that is applicated in residential building. A twist tape is quite a promising passive technique. A prototype of a heat recovery unit equipped with the twist tape devices was arranged for experimental investigation. In the prototype, the twisted tape could be activating the turbulence flow and increase the advection inside the heat recovery. In this experiment, the operational working parameters on the heat recovery unit were monitored. Based on the experimental marks, the performances of the four-case twisted heat recovery systems and a system without heat recovery were determined and compared.

2 EXPERIMENTAL METHODS

Prototype of heat recovery unit equipped with twist tape was built in the laboratory, as a sketch in Fig. 1. The experimental test rig comprises an outdoor and an indoor unit, a shell and coil HX, and a water centrifugal pump. The nominal evaporator cooling capacity of 9000 Btu/h and the power compressor consumption of 0.75 kW. Refrigerant 22 (R22) is used as a working fluid. A DX evaporator as an indoor unit comprises a copper tube and aluminium fins. Meanwhile, the outdoor unit includes a capillary tube, a tube-and-fin air-cooled condenser, and a hermetic rotary compressor.

This research aims to reveal the performance of the heat recovery unit equipped with a number twist tape. The heat recovery unit is installed in the discharge line of the compressor i.e., between the compressor and condenser. In heat recovery, the heat exchange occurs between refrigerant and water at a specified temperature without direct contacting. The specifications of the indoor unit, outdoor unit, heat recovery unit, and the centrifugal pump are presented in Table 1. The temperature controlling for cooling the room conditioned is only on-off control accordance to temperature set point on the thermostat. There is a gate valve to adjust the refrigerant flow whether using heat recovery or not. This mechanism provided a by-pass loop for refrigerant flow. To control the level of water inside the heat recovery unit, an electrical DC controlling mechanism was proposed.

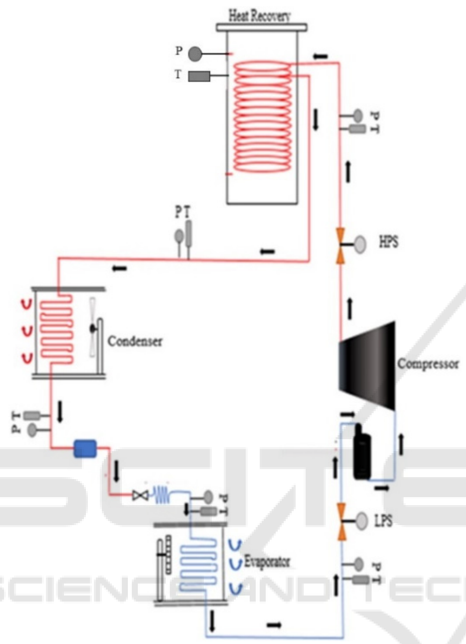

Figure 1: Experimental setup.

The point of comparison in this experiment is the present of a number of twist tape inside the heat recovery. The water pumped by a 125 W centrifugal pump from the storage tank to heat recovery and flowing back to the storage tank. The main component for refrigeration was listed below,

Table 1: Specification of main component.

Component	Specification
Compressor unit	Hermetic, Rotary 750 W, R22
Condenser unit	Fin and tube with air cooled system.
Expansion device unit	Capillary tube
Evaporator unit	Fin and tube exchanger
Heat recovery unit	Shell and coil exchanger

According to this investigation, as shown in Fig.1, the flow of recovery heat can be divided into two portions: first capturing waste heat by heat transfer process between refrigerant and water inside heat recovery, and the second storing the absorbed heat in the thermal storage tank. Four different numbers of twist tape used are one twist, two twists, three twists, and four twists. It is important to have sufficient information and analysis of the effect of the presence of twist tape inside the heat recovery to the absorbing waste heat. These variables will correlate to the performance of the heat recovery system.

The circulating water to heat recovery from the thermal storage tank was maintained at 12 liters per minute. The water absorbed heat in heat recovery. The temperature of circulating water increased by the contacted process with refrigerant tube and then entered the storage tank through the connection pipeline. In the storage tank, the water releasing the heat to the storage water by heat exchanged process. The circulating water is sucked by the pump for flowing back to the heat recovery. In this experiment, the operating parameters on the overall systems were recorded using instrumentation equipment. Thermocouples (K type) with frequency 1 Hz for 3600 s measured the refrigerant temperatures. The water flow rate was measured by a rotameter and maintain at 12 lpm.

3 RESULT AND DISCUSSION

The result and discussion section deliberate the performance of the operated heat recovery (HR) without twist tape compared to heat recovery with a number of twist tape under the same water volume rate condition. The performance is determined on the operation constraints on the water heating temperature inside heat recovery and the energy absorbed by the heat recovery system. Temperature comparisons of with and without twist tape of the systems are presented below.

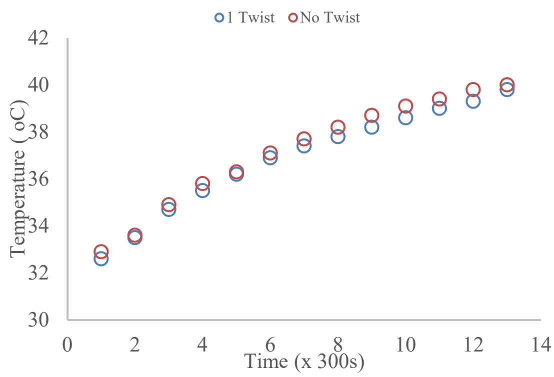

Figure 2: The time series temperature of one twist tape.

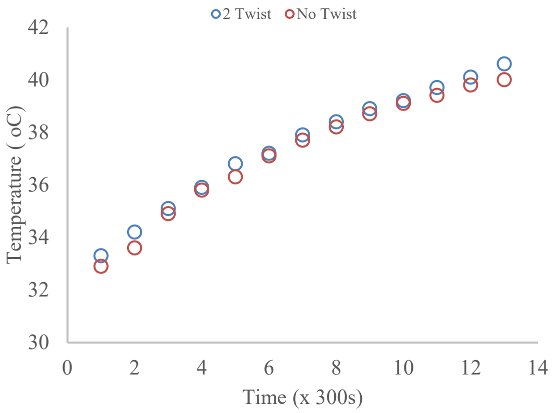

Figure 3: The time series temperature of two twist tape.

Fig. 2 to 5 compares the temperature of heat recovery for the systems with/without twist tape. The temperature of HR without twist tape was taken as the temperature reference to calculate the performance of the heat recovery system with the twisted tape.

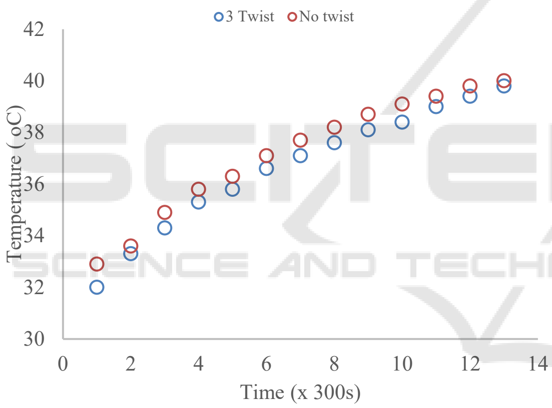

Figure 4: The time series temperature of three twist tape.

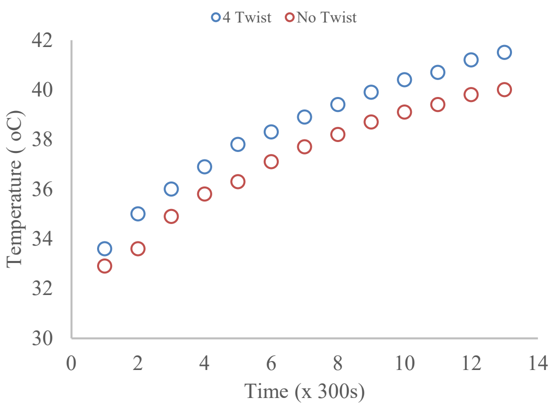

Figure 5: The time series temperature of four twist tape.

For the heat recovery system without twist tape, the fluid flow inside HR flowing from the bottom region to the upper region without disturbance. The fluid flow in smooth line and relatively constant velocity to the discharge section. Meanwhile, in the heat recovery with twist tape, the fluid flow from the bottom region to the upper region starting disturbance with the presence of twist tape. The twisted tape induced the flow condition inside the heat recovery unit. They increase the turbulence strength, recirculation region, and fluid momentum. These phenomena will tear the thermal boundary layer outside the copper coil tube so that the thermal obstacle will be thinner. The disturbance caused by the presence of twist tape will increase as increase the number of twist tape. In this investigation for four number of twist-tape has the highest heat recovery temperature. This phenomenon proves that the highest number of twist tape has the highest randomness of fluid flow.

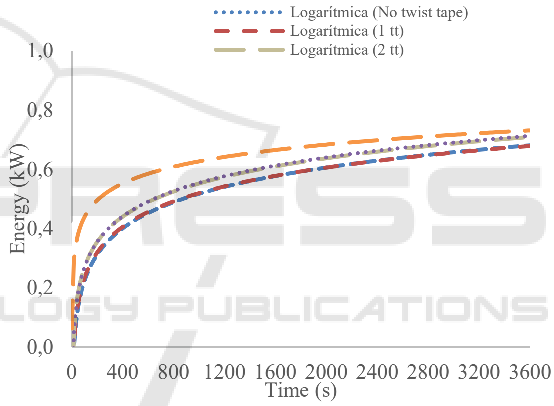

Figure 6: The time series of energy absorbed by heat recovery.

The presence of twist tape the heat recovery will give additional flow disturbance inside it. The temperature of the fluid inside heat recovery will increase and has considered an increase the efficiency. The energy absorbed shows in Fig.6 and follow the equation below,

$$Q = \dot{m}.Cp.dt \qquad \text{eq.1}$$

where Q is the heat absorbed by fluid inside the heat recovery (kW); $\dot{m}$ is the mass flow rate (kg/s); Cp is the heat capacity at constant pressure (kJ/kg. K); dt is temperature different of fluid (°C).

Fig. 6 compares the energy of each case in this investigation for interval 3600 s. It is described that the heat recovery equipped with four twist tape has the highest energy absorbed from the refrigerant tube. The explanation why the energy absorbed by twisttaped heat recovery is the same way with the temperature phenomena.

4 CONCLUSIONS

The objective of this research is to increase the waste heat absorbed by the heat recovery using additional twist tape. An experimental setup has been developed to validate the effect of number of twist tape on the heat absorbed parameter. It can be concluded from the results of this study that:

1. It is possible to apply the proposed system to increasing the temperature of heat recovery.
2. Based on concern operating condition the average heat absorbed 0.56, 0.59, 0.59, 0.65 kW for modified heat recovery.

ACKNOWLEDGEMENTS

The authors would like to express sincere gratitude to DRPM, Kemdikbud-Ristek, Republic of Indonesia for research fund with No. 249/E4.1/AK.04.PT/2021. Also Politeknik Negeri Bali with research project number is No. 42/PG/PL8/2021.

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