

Heat Transfer Study on Fan Coil Unit Of Water Chiller With Nanofluid Al_2O_3 as Chilled Water

Putu Wijaya Sunu¹, Daud S. Anakottapary², I D.M.
Susila³

Mechanical Engineering,
Bali State Polytechnic
Bali, Indonesia

¹wijayasunu@pnb.ac.id

Lukiyanto Y.B.⁴

Mechanical Engineering
Sanata Dharma University
Yogyakarta, Indonesia

⁴Ylukiyanto101@gmail.com

Abstract— Heat exchanger has wide use in many application such as in food industries, chemical, transportation, and refrigeration and air conditioning. Fan coil unit (FCU), one class of heat exchanger which is heat transfer occur by chilled water flowing across a series of finned tube bank for decreasing the air temperature to be cooled. Thermal conductivity of working fluid in heat exchanger was the main issue recently. Enhancement of convective heat transfer and thermal conductivity of working fluid made possible by mixing nanosize particle into base fluid. The aims of this research is to revealed the enhanced of heat transfer by nanofluid Al_2O_3 on FCU unit of chiller system. 0,2% of nanoparticles were added to chilled water. The analysis shows that added small part of nanoparticles induced heat transfer. The total heat transfer enhancement of nanofluid chilled water was about 8.0% - 11.1% compare to that of chilled water without nanoparticles. Finally, the application of nanoparticles give benefit of heat transfer process.

Keywords— FCU; heat transfer; nanoparticles; Al_2O_3 -water nanofluid

I. INTRODUCTION

Heat exchanger plays an important role in energy transfer, conservation, conversion and recovery. Their function for handling the thermal energy in many industrial applications, such as refrigeration and air conditioning power plants, waste heat recovery, chemical, automotive, food handling and many other application [1-3]. Inlet and outlet temperature of heat heat exchanger and mass flowrate of each fluid became two important parameters to see the heat exchanger performance. Another reason to consider the heat exchanger application is ratio of heat transfer and dimension of itself. Special attention has been given to designing small but efficient methods of heat transfer [4-5]. To accomodate this reason, many technique has been developed especially passive technique. One of this method is suspended small part of nanoparticles to the basic fluid became nanofluid. As a new form of fluid, nanofluid can be defined as a fluid in which solid particles with the sizes 1-100 nm are suspended and dispersed uniformly in a base fluid such as water, oil, ethylene glycol [6]. Nanofluid increase the thermal conductivity of basic fluid and growth the energy transfer of heat exchanger [7-10]. Many researchers observed the phenomenon of higher thermal conductivity of various nanofluids compared to that of the base fluids [11-13].

In the refrigeration, heating, ventilating and air conditioning (RHVAC), it is challenging to optimize the energy consumption for all of equipment facilities [14]. Fan coil unit (FCU) is one of the heat exchanger equipment in water chiller air conditioning system that consist of fan and a series of finned tube bank, for decreasing the air temperature [15]. For fan coil units, load of the system induced degradation in the water temperature difference across the fan coil, which results in inefficiencies of heat transfer and unnecessary pump power consumption [16]. To apply the nanofluid (alumina-water) to practical heat transfer processes, more studies on its flow and heat transfer feature are needed, [17] in their studies with alumina water water nanofluids in a turbulent flow. Rea et al. [18] observed up to 27% enhancement with 6% volume fraction alumina-water nanofluid. [19] investigated thermal performances of nanofluids silicone dioxide -water on various concentration in industrial type heat exchangers.

From the literature above known that nanofluid plays important role to increase heat transfer in heat exchanger. This study fills an important gap in the literature for heat exchanger application of nanofluid especially alumina-water in fan coil unit (FCU). The objective of this investigation is to evaluate the amount of heat transfer between ambient air and chilled water (alumina-water) by fan coil unit.

II. EXPERIMENTAL APPARATUS AND METHOD

The experimental apparatus is manufacture for analysis purpose. Figure 1 shown the schematic of the experiment apparatus. It consist four major component of refrigeration namely compressor, condenser, thermostatic expansion device, evaporator. The auxiliary component i.g. fan coil unit (FCU) and pump for pumping the alumina-water suspension as chilled water of the water chiller. Rotameter used to control the volume flowrate of chilled water.

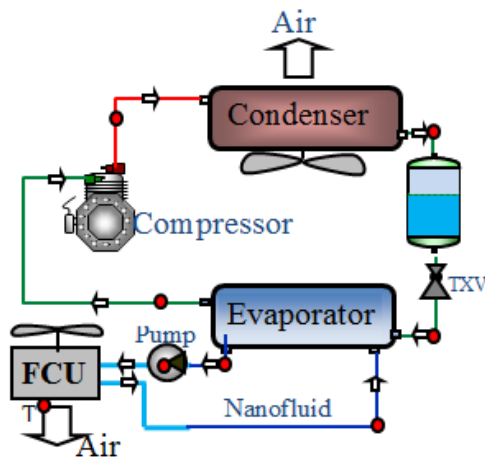


Fig. 1. The experimental apparatus

The specification of refrigeration system component are listed on table 1.

TABLE I. TEST RIG SPECIFICATION

No	Equipment	Description
1	Compressor	Hermetically sealed, Rotary 2 pk, R22 refrigerant
2	Condenser	Air cooled, finned coil.
3	Expansion device	Capillary tube 0.7 mm; thermostatic expansion valve.
4	Evaporator	Shell and tube heat exchanger
5	Fan coil unit (FCU)	Finned coil
6	Pump	Centrifugal, 125 W

The γ Al_2O_3 nanoparticles size of 20-50 nm were used. Nanofluid was prepared by dispersing Al_2O_3 nanoparticles in distilled water as base fluid. The mechanical mixer (magnetic-stirring) and ultrasonic processor was used for dispersing nanoparticles. In this study, the Al_2O_3 – water nanofluid particles volume concentration of 0.1% is used to evaluate the heat transfer performance of chilled water in the fan coil unit.

A. Instrumentation

The temperatures of refrigerant R-22, the ambient air temperatures and nanofluid temperatures were measured by k-type thermocouples, attached to the copper pipe wall, inlet outlet side of the FCU and nanofluid chilled water. The pressure of the refrigeration system were measured by pressure gauge which placed at four point of refrigeration cycle system. The temperatures data were digitalized using data logger and recorded in computer memory and the current of compressor was measured by digital ampere meter.

B. Data processing

The aim of this current investigation is to determine the real amount of heat transfer in the fan coil unit (FCU) of the water

chiller air conditioning. The most important parameters of interest is heat transfer (Q) describe below,

$$Q = \dot{m} \cdot C_p \cdot \Delta T \quad (1)$$

Effectiveness follow the equation as,

$$\varepsilon = \frac{1 - \exp[-NTU(1 - c)]}{1 - c \exp[-NTU(1 - c)]} \quad (2)$$

III. RESULTS AND DISCUSSIONS

Preliminary experiments were done using no nanofluid as chilled water. This data was then used as a comparison to that of nanofluid as chilled water.

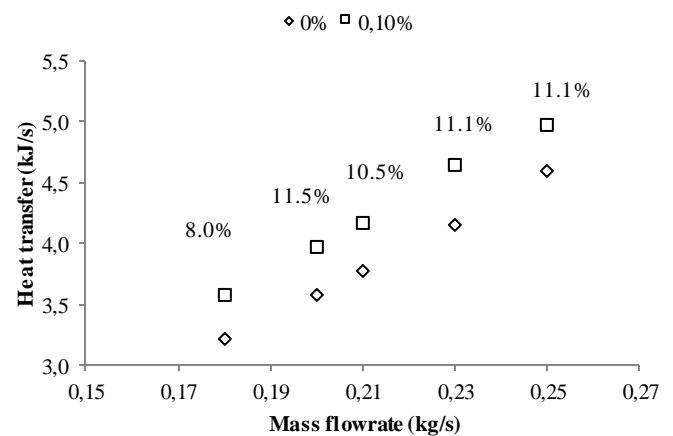


Fig. 2. Real heat transfer of each mass flowrate

Figure 2 shows the overall heat transfer at various mass flowrate of chilled water. The result indicates that the average convective heat transfer increased by increasing the mass flowrate of chilled water. It can be observed that the application of alumina-water as chilled water lead to a significant increase on heat transfer about 8% to 11.5% compared to that of chilled water with no nanofluid. The process of energy transport between pipe wall and flowing nanoscopic particles mostly affected by the type and size of particles. Alumina with particles size 20-50 nm greatly increase the energy transport in fan coil unit. Nanofluid provided the enhancement in the heat transfer by increasing the thermal conductivity of chilled water.

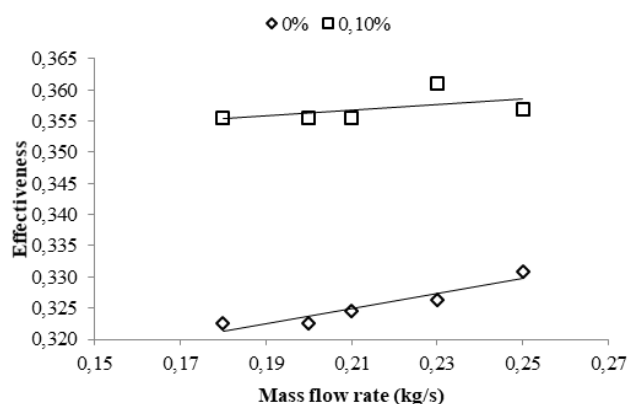


Fig. 3. Effectiveness of the heat transfer of each mass flowrate

The mass flowrate and effectiveness relationship of the investigation were presented in Figure 3. The effectiveness of the nanofluid chilled water were compared to that of the no nanofluid chilled water. It was found out that the mass flowrate and the presence of nanofluid influenced the effectiveness. Figure 3 shows that the increases mass flowrate cause a increase in effectiveness. At the same mass flow rate, the effectiveness of nanofluid chilled water were higher than those of the no nanofluid chilled water. The increase of effectiveness is indicated by the increased rate of the actual heat transfer (see fig.2). The alumina nanoparticles lead to increase thermal conductivity of chilled water and made the FCU more effective

III. CONCLUSION

An experimental investigation was carried out for heat transfer enhancement by Alumina-water nanofluid, effectiveness (ϵ) and overall heat transfer of fan coil unit of water chiller AC. The main objective of this study was to compare with/without nanofluid chilled water. The result can be summarized as,

- The heat transfer increased with increase of mass flowrate of chilled water. At a specified mass flowrate, the heat transfer enhancement of nanofluid chilled water about 8.0 – 11.1% compare to that of no nanofluid chilled water.
- The effectiveness increased with increase of mass flowrate. The effectiveness of nanofluid chilled water have a good agreement with heat transfer enhancement.

LIST OF SYMBOLS

\dot{m}	mass flowrate [kg/s]
ΔT	temperature difference of hot/cold fluid in time period [$^{\circ}\text{C.s}$]
Q	heat transfer [J]
C_p	specific heat [J/kg $^{\circ}\text{C}$]
ϵ	effectiveness
c	heat capacity ratio
NTU	number of transfer unit

ACKNOWLEDGMENT

The authors would like to express the great thank to Directorate General for Research strengthening and

Development, Ministry of Research, Technology and Higher Education, Republic of Indonesia as the sponsor of this research through grant No. 00923/PL8/LT/2018

REFERENCES

- [1] P.W. Sunu and I.M. Rasta, "Heat Transfer Enhancement and Pressure Drop of Grooved Annulus of Double Pipe Heat Exchanger," *Acta Polytechnica*, vol 57, no. 2, pp. 125–130, 2017.
- [2] P.W. Sunu, I.N.G. Wardana, A.A. Sonief, and N. Hamidi, "Flow Behavior and Friction Factor in Internally Grooved Pipe Wall," *Adv. Stud. Theor. Phys.*, vol. 8, no.14, pp. 643-647, 2014.
- [3] P.W. Sunu, "The Characteristics of Increased Pressure Drop in Pipes with Grooves," *Adv. Stud. Theor. Phys.*, vol.9, no. 2, pp. 57–61, 2015.
- [4] P.W. Sunu, I.N.G. Wardana, A.A. Sonief, and N. Hamidi, "The Effect of Wall Groove Numbers on Pressure Drop in Pipe Flows," *Int. J. Fluid Mech. Res.*, vol 42, no. 2, pp.119 – 130, 2015.
- [5] P.W. Sunu, D.S. Anakottapary, W.G. Santika, "Temperature Approach Optimization in the Double Pipe Heat Exchanger with Groove," *Matec web of conference* 58, 04006, 2016.
- [6] S. Choi, "Enhancing Thermal Conductivity of Fluids with Nanoparticles, Developments and applications of Non-Newtonian Flows," *ASME FED 231/MD*, vol. 66, pp. 99–103, 1995.
- [7] S.Z. Heris, S.G. Etemad, and M.N. Esfahany, "Experimental Investigation of Oxide Nanofluids Laminar Flow Convective Heat Transfer," *Int. Commun. Heat Mass Transfer*, vol.33, no. 4, pp. 529–535, 2006.
- [8] D. Wen and Y. Ding, "Experimental Investigation Into Convective Heat Transfer of Nanofluids at the Entrance Region Under Laminar Flow Conditions," *Int. J. Heat Mass Transfer*, vol. 47, no. 24, pp. 5181–5188, 2004.
- [9] W. Daungthongsuk and S. Wongwises, "A Critical Review of Convective Heat Transfer of Nanofluids," *Renew. Sustain. Energy Rev.*, vol. 11, no. 5, pp. 797–817, 2007.
- [10] S. Kakaç and A. Pramuanjaroenkij, "Review of Convective Heat Transfer Enhancement with Nanofluids," *Int. J. Heat Mass Transfer*, vol. 52, no. 13–14, pp. 3187–3196, 2009.
- [11] W. Daungthongsuk and S. Wongwises, "Measurement of Temperature-Dependent Thermal Conductivity and Viscosity of TiO_2 -Water Nanofluids," *Exp. Therm. Fluid Sci.*, vol. 33, no. 4, pp. 706–714, 2009.
- [12] H.A. Mohammed, G. Bhaskaran, N.H. Shuaib, and R. Saidur, "Heat Transfer and Fluid Flow Characteristics in Microchannels Heat Exchanger Using Nanofluids: A Review," *Renew. Sustain. Energy Rev.*, vol. 15, pp.1502–1512, 2011.
- [13] A.T. Utomo, H. Poth, P.T. Robbins, and A.W. Pacek, "Experimental and Theoretical Studies of Thermal Conductivity, Viscosity and Heat Transfer Coefficient of Titania and Alumina Nanofluids," *Int. J. Heat Mass Transfer*, vol. 55, pp. 7772–7781, 2012.
- [14] P.W. Sunu, D.S. Anakottapary, A.A.N.B. Mulawarman, I.D.M.C. Santosa, I.P.S. Negara, "Heat Transfer Characteristics of Fan Coil Unit (FCU) Under the Effect of Chilled Water Volume Flowrate," *IOP Conf. Series: Journal of Physics: Conf. Series* 953, 012058, 2017.
- [15] P.W. Sunu, I.M. Rasta, D.S. Anakottapary, I.M. Suarta, I.D.M.C. Santosa, "Capillary Tube and Thermostatic Expansion Valve Comparative Analysis in Water Chiller Air Conditioning" *IOP Conf. Series: Journal of Physics: Conf. Series* 953, 012063, 2017.
- [16] G.P. Henze and A.G. Floss, "Evaluation of temperature degradation in hydraulic flow networks," *Energy and Buildings*, vol. 43, pp. 1820–1828, 2011.
- [17] W. Williams, J. Buongiorno, L.W. Hu, "Experimental investigation of Turbulent Convective Heat Transfer and Pressure Loss of Alumina/Water and Zirconia/Water Nanoparticle Colloids (Nanofluids) in Horizontal Tubes," *J. Heat Transf.*, vol. 130, no. 4, pp. 1-7, 2008.
- [18] U. Rea, T. McKrell, L. W. Hu, and J. Buongiorno, "Laminar Convective Heat Transfer and Viscous Pressure Loss of Alumina–Water and Zirconia–Water Nanofluids," *Int. J. Heat Mass Transfer*, vol. 52, pp. 2042–2048, 2009.
- [19] A. Kanjirakat, J. Cox, and R. Sadr, "Thermal evaluation of nanofluids in Heat Exchangers Thermal Evaluation of Nanofluids in Heat Exchanger," *Int. Communicat. in Heat Mass Transfer*, vol. 49, pp. 5–9, 2013.