Research on Operation of Optimum Heat Pump for Each Region Climates

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１．Research Objective１

The purpose of this study is to evaluate the performance of Heat Pump Water Heater (HPWH) in areas with some different climate. The working fluid which is used in this HPWH research is R32. The performance referred to in this study is the temperature of the hot water obtained, heat capacity and COP. At this stage, the HPWH performance is obtained from simulation result using EF+M for tropical climates.

２．Major Research Result

2.1 Schematic of Heat Pump Water Heater

Fig. 1 show the scheme of Commercial Heat Pump Water Heater which is used in this research use refrigerant of R32 with heating capacity based on specification divided into 3 condition, that's are: summer condition (4 kW), winter condition (3.5 kW), and Cold condition (4 kW). The component of this HPWH Consist of compressor, condenser, expansion valve, evaporator, accumulator, 4-way valve, water pump, water tank storage and PID Controller to make better performance of the system as seen in Fig. 1. The compressor used in this commercial HPWH is electrical driven scroll compressor with power requirement based on specification about 1.060-1.200 kW. The condenser is coil heat exchanger type. The expansion valve used in this HPWH is Electronic Expansion Valve (EEV) and the evaporator is fin-tube heat exchanger. The capacity of tank in this HPWH is about 318 L with the maximum water temperature at the tank based on specification is 65^{o}C. There are 3 controller that work in this commercial HPWH that are rotation speed controller (PID 1), opening valve controller (PID 2) and water mass flowrate circulation controller (PID 3). The rotation speed controller work based on input of heating capacity. At the lower heating capacity condition, PID 1 will inform compressor to reduce the rotation speed of compressor. The opening valve controller work based on the temperature superheated setting. At the higher superheated temperature, PID 2 will inform EEV to open the valve wider. The water mass flowrate circulation controller work based on setting temperature at the water. At the first time running the water pump will work at maximum condition to circulate water into the coil condenser. As the process goes on, which is the water temperature will be closed to the setting temperature, the PID 3 will inform the water pump to reduce the mass flowrate. The fan flowrate in evaporator is not constant, its divided into 3 classification, that's are: High (about 24.5 m^3/min), medium (about 21.2 m^3/min) and low (about 20.8 m^3/min) based on the outside air temperature.

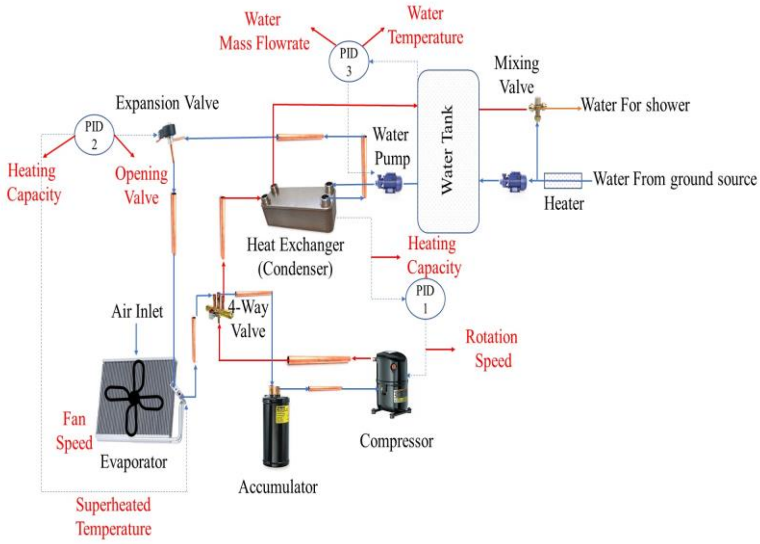

Fig. 1 Scheme of HPWH for EFM Simulation

2.2 Modeling

Table 1. shown the model that use in this simulation for compressor, Condenser, Electronics Expansion Valve, and Evaporator.

Table 1. Modeling for EF+M simulation

Component	Continuity	Energy	Pressure Drop
Compressor	$\dot{m}_{r,o} - \dot{m}_{r,i} = 0$	$\dot{m}_{r,o}.h_{r,o} - \dot{m}_{r,i}..h_{r,i} = W$	-
Condenser (R-W)	Refrigerant side $\frac{\partial \rho_R}{\partial t} + \frac{\partial(\rho_R v_R)}{\partial z} = 0$ Water Side $\frac{\partial \rho_W}{\partial t} + \frac{\partial(\rho_W v_W)}{\partial z} = 0$	Refrigerant side $\frac{\partial(\rho_R u_R)}{\partial t} + \frac{\partial(\rho_R v_R h_R)}{\partial z} = -\frac{Lc_{In}}{S_{In}}$ Water side $\frac{\partial(\rho_W u_W)}{\partial t} + \frac{\partial(\rho_W v_W h_W)}{\partial z} = \frac{Lc_{In}}{S_{In}} q$	Refrigerant Side $\frac{\partial P_R}{\partial z} = -f_R \frac{1}{d_H} 2 \rho_R v_R^2$ Water side $\frac{\partial P_W}{\partial z} = 0$
EEV	$\dot{m}_{r,o} - \dot{m}_{r,i} = 0$	$\dot{m}_{r,o}.h_{r,o} - \dot{m}_{r,i}..h_{r,i} = 0$	$\dot{m}_{r,i} = \rho_{r,i}.C_v.A_{exp}\sqrt{\frac{2(P_{r,o} - P_{r,i})}{P_{r,i}}}$
Evaporator	Refrigerant Side $\frac{\partial \rho_R}{\partial t} + \frac{\partial(\rho_R v_R)}{\partial z} = 0$ Air side $\rho_{A,o}.v_{A,o}.X_{A,o} L_{A,o} - \rho_{A,i}.v_{A,i}.X_{A,i}.L_{A,i} = 0$	Refrigerant Side $\frac{\partial(\rho_R u_R)}{\partial t} + \frac{\partial(\rho_R v_R h_R)}{\partial z} = -\frac{Lc_{In}}{S_{In}} q_{In}$ Air Side $\rho_{A,O} v_{A,O} X_{A,O} L_{A,O} - \rho_{A,I} v_{A,I} X_{A,I} L_{A,I} = \frac{A_{Pipe} + \eta_{FIN} A_{FIN}}{L} j_{Out}$	Refrigerant side $\frac{\partial P_R}{\partial z} = -f_R \frac{1}{d_{In}} 2 \rho_R v_R^2$ Air side $P_{A,O} - P_{A,I} = -f_A \frac{2 L_x \rho_A V_{ac}^2}{D_{ec}}$

2.3 Profile of HPWH Performance

In the EFM simulation with the temperature setting conditions at the outlet tank for the user at 38°C with the source water temperature 35.23°C and the environment at 29.6°C. To achieve steady state with a temperature of 38°C at the temperature of the water out for the user takes about 30.000 seconds. At steady state the condenser water temperature comes out at 44°C to maintain the temperature of hot water to the user at 38°C as shown in figure 2. To maintain the water temperature at the steady state condition of the compressor work needed is a rotation of 10.4 RPM with a power of 0.04 kW as shown in Figure 3. It should be noted that this simulation assumes the flow rate of water to the user is constant at 0.0256 kg/s all the time (24 hours).

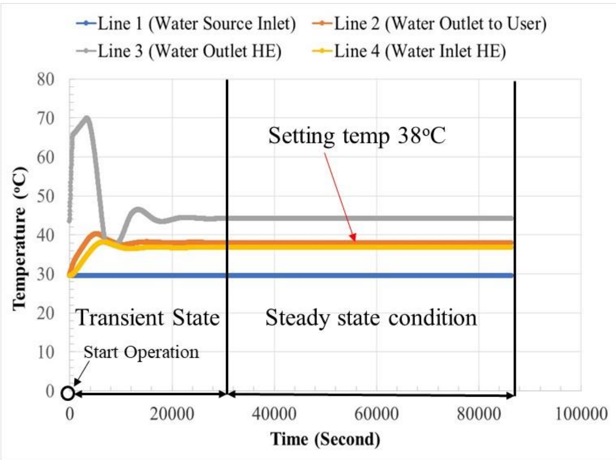

Fig. 2 Profile water temperature at tank

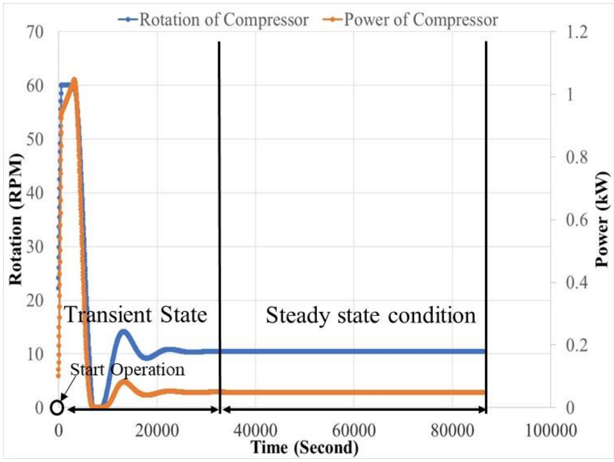

Fig. 3 Profile of Compressor Performance

Initially the heat capacity will reach its maximum condition, after the passage of time in which the water temperature has begun to increase near the temperature setting, the heat capacity will decrease to as much as 0.79 kW during steady state conditions. This proves that the heat capacity and work of the compressor will be reduced when the temperature setting has been reached (Smallest Delta T HE). The average Coefficient of Performance (COP) for tropical climate with this condition is about 5.96

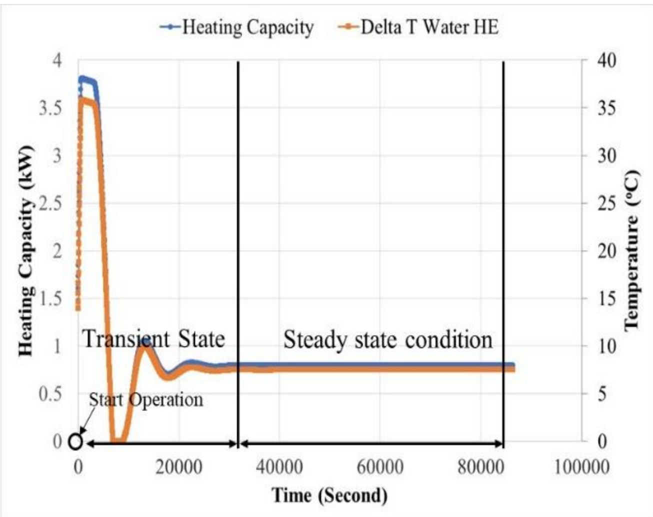

Fig. 3 Profile of Heat Capacity

3. Collaborator

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4. Research Achievement

4.1 Academic and Social Activities

"14th IIR-Gustav Lorentzen Conference on Natural Refrigeration" Submitted Paper of International Conference, December 6-9 2020

5. Issues and Prospect of Research Activities

water heating technology using a Heat Pump or commonly called HPWH is a technology that is proven to be the most efficient at this time although some things are still being developed including being related to climate conditions and CO_2 emissions. In connection with this, several innovations were carried out between optimization in the working fluid and HPWH engine components. In this study, next year research is to change the equation in the refrigerant-water condenser (Heat Exchanger) by using the smooth and spiral method. In addition, the possibility of using CO_2 as a working fluid will be considered. All these researches will be analyses their performance in all prevailing climatic conditions in several countries and their effect on CO_2 emissions through an analysis of LCCP (Life Cycle Climate Performance)