Heat Transfer Characteristics of Fan Coil Unit (FCU) Under The Effect of Chilled Water Volume Flowrate

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Abstract. In this paper, the volume flowrate of chilled water in the water chiller simulation apparatus was optimized using experimental studied. The experimental analysis was performed on the fan coil unit (FCU) of the system. The chilled water flows in tube side and the air as a hot fluid flows throughout the tube and fin of FCU. The thermal performance and analysis of the heat transfer is examined using various chilled water flowrate e.g. 11, 12, 13, 14, 15 lpm. The effect of the flowrate to the important parameter such as LMTD temperature, heat absorb used for investigate the heat transfer characteristics. The result showed that the heat transfer characteristics has been increased with the increased of chilled water volume flowrate.

1. Introduction

Air conditioning system is a sequence of air movement, air cleanliness, controlling temperature, humidifying and dehumidifying in order to reach the human comfort.

Figure 1. Schematic diagram of water chiller
All of the process mentioned use a refrigeration cycle system which uses heat exchanger as equipment to absorb/reject heat from the conditioned room to the ambient. The heat exchanger play a major role not only in HVAC [1,2,3,4] but also in other field of engineering such as power plant, chemical, automotive, food processing etc. In refrigeration system, there are four major component e.g compressor, condenser, expansion device and evaporator. For chiller system which use secondary loop to circulate the chilled water as shown in figure 1, there are additional component namely pump and fan coil unit (FCU). Auxiliary components, such as circulation pumps and fan coil units, can consume a significant proportion of the total energy used [5]. The improper fan coil unit can result in degradation chilled water temperature difference across the coils [6]. For fan coil unit, control the speed of fan during on/off cycle using variable speed to reduce the energy consumption [6]. A complex system using PID control used to maintain the water temperature [7, 8]. [9] Suggest controlling either the chilled water temperature or water volume flow rate to reduce the supplied load to the building at part-load to reduced unnecessary pump power consumption [10]. Volume flowrate of chilled water through the FCU play an important role not only power consumption but also the heat absorb in the FCU itself. Thus, this study fills an important gap in the literature by investigating the phenomenon of chilled water volume flowrate in a secondary loop. The specific objective and the scope of this presented work are to evaluate the energy absorbed by the fan coil unit (FCU) in the heat transfer process between air ambient and the chilled water.

2. Experimental Apparatus And Method

The schematic test rig of the experiment shown in figure 2.

![Figure 2](image-url)

**Figure 2.** The sketch of experimental apparatus with the measurement point

Rotameter used to control the volume flowrate of chilled water. This measurement component equipped with hand shut off valve for varying the flow. The specification of the experiment list components shown in table 1.
Table 1. Test rig specification.

| No | Equipment            | Description                                      |
|----|----------------------|--------------------------------------------------|
| 1  | Compressor           | Hermetically sealed, Rotary 2 pk, R22 refrigerant|
| 2  | Condenser            | Air cooled, finned coil.                         |
| 3  | Expansion device     | Thermostatic expansion valve (TEV)               |
| 4  | Evaporator (HX)      | Shell and tube heat exchanger                    |
| 5  | Fan coil unit (FCU)  | Finned and tube                                 |
| 6  | Chilled water pump   | Centrifugal, 125 W                              |

The refrigerant temperatures and air temperatures were measured by k-type thermocouples which placed at four point of refrigeration cycle system and chilled water loop. The temperatures data were digitalized using data logger and recorded in computer memory.

3. Data Processing

The aim of this current investigation is to determine the Logarithmic Mean Temperature Difference (LMTD) and the heat absorb in the fan coil unit (FCU).

\[
LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}
\]  

with,

\[
\Delta T_1 = t_{h, in} - t_{c, out}
\]  

\[
\Delta T_2 = t_{h, out} - t_{c, in}
\]

The heat transfer in the FCU define as,

\[
Q = \dot{m}.C_p.\Delta T
\]

4. Result and Discussion

Through the counter flow approach, the LMTD in the FCU for flowrate 11 lpm calculated below as:

\[
\Delta T_1 = t_{h, in} - t_{c, out} = 28.93 - 18.1 \text{ (°C)} = 10.82 \text{ °C}
\]

\[
\Delta T_2 = t_{h, out} - t_{c, in} = 19.58 - 13.1 \text{ (°C)} = 6.47 \text{ °C}
\]

\[
LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)} = \frac{10.82 - 6.47}{\ln\left(\frac{10.82}{6.47}\right)}
\]
8.46

For various flowrate the LMTD presented in figure 3.

Figure 3. LMTD on various volume flowrate

Figure 3 shows the logarithmic mean temperature difference (LMTD) from the fan coil unit on various volume flowrate of chilled water. LMTD is the driven of the heat transfer in the FCU. It is found that, the LMTD increased with increased of chilled water volume flowrate and the 15 lpm flowrate gave higher than those of other flowrate. Polynomial statistical approach applied into the data to find the pattern of the data. The significant LMTD increased found at 14 lpm. Here, the chilled water have enough time to contact with the wall and made the FCU more effective.

Figure 4. Heat absorp by FCU on various volume flowrate
The calculation of heat absorbed by the chilled water describe as,

\[ Q = \dot{m} \cdot C_p \cdot \Delta T_{\text{actual}} \]

\[ = 0.18 \cdot 4.187 \cdot 5 \ (kJ/s) \]

\[ = 3.83 \ (kJ/s) \]

The correlation of volume flowrate and the total heat absorbed by the chilled water describe on figure 4. It is found that the heat absorbed by the FCU increased with the increased of chilled water flowrate. Increased the flowrate of chilled water increased the mass flowrate of it. The momentum transfer generated by increased of mass flow responsible for thinning the thermal boundary layer and made the heat absorb by the chilled water higher.

5. Conclusions
An experimental investigation on air cooled chiller with various volume flowrate was carried out for LMTD analysis for describing the heat transfer absorb characteristics at Fan Coil Unit (FCU). The result can be summarized as,

a) The LMTD increased with increased of chilled water volume flowrate.
b) The heat absorbed by the FCU increased with the increased of chilled water flowrate.

6. List of symbols

- \( LMTD \): Logarithmic Mean Temperature Difference
- \( t_h \): temperature of hot fluid [°C]
- \( t_c \): temperature of cold fluid [°C]
- \( Q \): heat absorb in FCU [kJ/s]
- \( \dot{m} \): mass flowrate [kg/s]
- \( \Delta T \): temperature difference of chilled water in/out FCU [°C]
- \( C_p \): specific heat [kJ/kg °C]

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