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Evaluation of cooling efficiency improvement of the simple office for small factories using heat dissipation with cold water circulation

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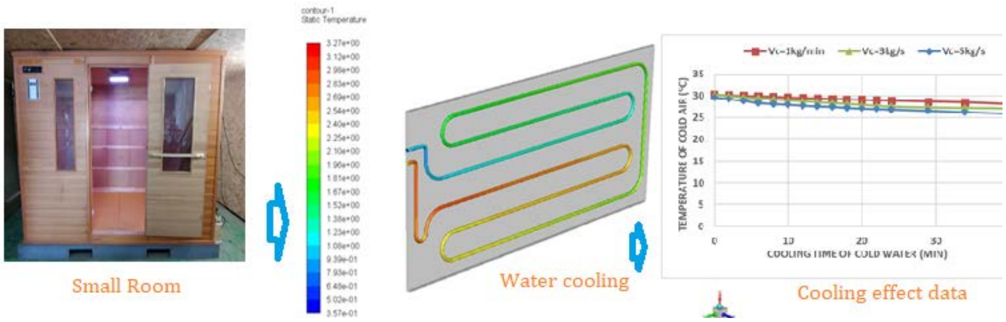
ABSTRACT



This study was conducted to implement the improvement of heating efficiency by the cold water flowing in the X-L pipes inside the walls of a small room according to changes in the mass flow rate of the cold water. More comfortable cooling, which is also beneficial to health, was implemented. The radiant heat transfer cooling was implemented with the absorption of heat energy by the cold water flowing in the X-L pipes inside the walls of the small room without any movement or circulation of the air existing in the interior space of the room. In addition, this study significantly reduced heat energy consumption for radiant cooling and manufacturing costs by investigating accessories for cooling devices suitable for a room not larger than six square meter. As the flow rate of the cold water increased, the heating efficiency of the small room improved proportionally.

Keywords: Heating Efficiency, Polyethylene Tubes, Flow Rate, Wellbeing Cooling, Absorption, Thermal Energy

INTRODUCTION

Recently, as the demand for simple office for small factories has been gradually increasing, studies on cooling device design technologies[1–3] and manufacturing technologies suitable for simple office for small factories are urgently required, however, the current study reports from literature are insufficient to draw firm conclusions.[4] There are many literature reports which indicate that radiant heat transfer cooling can be implemented with the absorption of heat by the cold water flowing in the polyethylene tubes. This cooling effect when used in the walls of simple office for small factories for interior cooling would be beneficial to health of inhabitant. However, studies on implementing cooling with radiant thermal energy by the polyethylene tubes in the walls inside the simple office for small factories are insufficient.[5] Therefore, in this study, the cooling effect beneficial to health was implemented by the polyethylene tubes in the walls of a simple office for small factories, in which cold water flows, inside the cold-water panels to implement the radiant heat energy cooling with the cold water flowing in the polyethylene tubes. As a result of the study as such, compared to the cooling systems in which cooling is implemented with the forced convective heat transfer at the current technical level in which the air is forced to circulate by the air conditioner,[6] more comfortable cooling, which is also beneficial to health,[7] was implemented. The radiant heat transfer cooling was implemented with the absorption of heat energy by the cold water flowing[8] in the polyethylene tubes inside the walls of the simple office for small factories in this study without any movement or circulation of the air existing in the interior space of the simple office for small

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factories. In addition, this study significantly reduced heat energy consumption for radiant heat transfer cooling and manufacturing costs[9] by investigating accessories for cooling devices suitable for simple office not larger than 6 m^2.

EXPERIMENTAL APPARATUS AND METHOD

EXPERIMENTAL APPARATUS

Figure 1 shows an experimental apparatus to measure the cooling performance with radiant heat transfer according to changes in the temperature and flow rate of the cold water circulating in the polyethylene tubes inside the walls of simple office for small factories. Figure 2 shows a 3D schematic diagram of an chiller piping to measure the cooling performance with radiant heat transfer according to changes in the temperature and flow rate of the cold water circulating in the polyethylene tubes inside the walls of simple office for small factories. As shown in Figures 1 and 2, cold-water polyethylene tubes were laid in the walls of the simple office for small factories, and cold-water polyethylene tubes were installed inside the walls to examine the cooling performance with radiant heat energy by the absorption of radiant thermal energy[10] by the cold water leading to the drop of the temperature of the air existing in the internal space of the simple office for small factories. The size of the simple office for small factories is 1600 mm wide, 2100 mm long, and 1800 mm high.

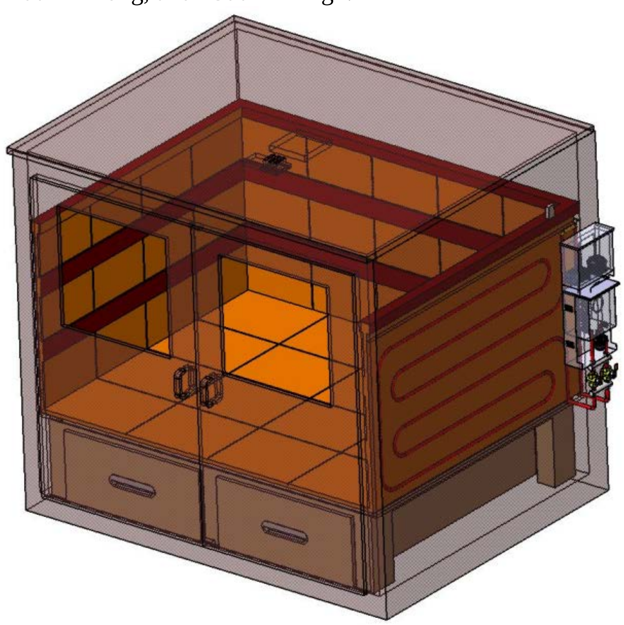

Figure 1 Experimental apparatus for the cooling performance of simple office for small factories by radiant heat transfer

The cooling area of the simple office for small factories experimental apparatus is 3 m^2, and cold-water polyethylene tubes were laid inside the walls of the simple office for small factories. The experimental apparatus was configured so that cold water is circulated in the polyethylene tubes for cold water circulation installed inside the cold-water panels.[11] Therefore, radiant heat energy cooling is implemented as the cold water flowing in the cold-water polyethylene tubes inside the walls absorbs the heat energy held by the air existing in the interior space of the simple office for small factories, and 3D simulation studies and experimental studies were carried out to implement well-being cooling beneficial to health. A chiller to absorb the thermal energy of the cold water circulating in the cold-water polyethylene tubes and a cold-water pump were constructed to configure the experimental apparatus so that the cold water flowing in the cold-water polyethylene tubes in the walls of the simple office for small factories would absorb the heat energy held by the air existing in the interior space of simple office for small factories.

Existing small cooling devices meant for cooling of simple office for small factories and offices not smaller than 26 m^2 and carry out cooling by the forced convection heat transfer method.[8] However, study reports on cooling accessories for simple office for small factories not larger than 3 m^2 examined in this study are insufficient. Figure 3 shows a chiller to absorb the thermal energy of the cold water circulating in the cold water polyethylene tubes installed inside the walls of simple office for small factories. As shown in Figure 3, a chiller for the absorption of the heat of the cold water circulating inside the cold water polyethylene tubes inside the walls of the simple office for small factories was installed to conduct an experimental study.

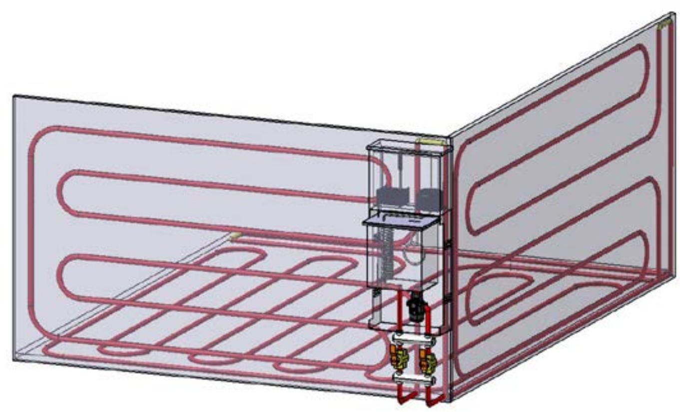

Figure 2. 3D schematic diagram of chiller piping for the cooling performance of simple office for small factories with radiant heat transfer

Figure 3. The experimental apparatus for natural convective radiative heat transfer cooling load of simple office for small factories

Experimental Method

Figure 4 shows the temperature and temperature controller in the interior space of simple office for small factories.[12] The temperature of the air existing inside the simple office for small factories[13] was controlled to be constant by proportionally controlling the flow rate and the temperature of the cold water.[8]

Figure 5 shows the temperature sensors and thermometers to measure the air temperature and wall temperature inside simple office for small factories. The wall temperature of simple office for small factories was measured by attaching three resistance temperature sensors each on the upper, middle, and lower areas of the right and middle walls[14] of the simple office for small factories, respectively. In addition, three resistance temperature sensors were installed at equal spaces, one each in the upper, middle, and lower areas of the interior space of simple office for small factories to measure the air temperature in the indoor space of simple office for small factories.[15] Figure 6 shows a flowmeter to measure the flow rate of the cold water flowing in the cold water polyethylene tubes inside simple office for small factories.

Figure 4. Temperature measurement inside simple office for small factories and temperature controller

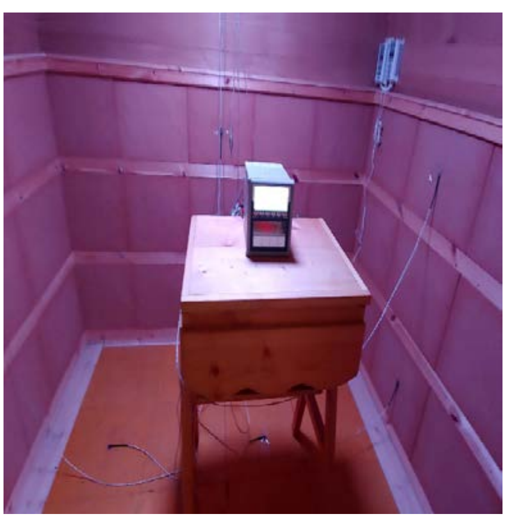

Figure 5. Temperature sensors and thermometers to measure the air temperature and wall temperature inside the room

Figure 6. Flowmeter to measure the flow rate of cold water and temperature sensor to measure the temperature of cold water of simple office for small factories

RESULTS

3D simulation of cooling load in relation to changes in the air temperature inside

Figure 7 shows a shape of 3D simulation of a cooling water polyethylene tubes for simple office for small factories.[13] Figures 8 and 9 shows the hexahedral+tetrahedral mixed unstructured mesh of the cold water polyethylene tubes. The 3D simulation was carried out with 648,7000 cells.[16] A 3D simulation study was conducted on convective heat transfer in the process through which the cold water flowing inside the polyethylene tubes in the walls of simple office for small factories absorbs the heat energy held by the air existing in the interior space of simple office for small factories. The 3D simulation of heat transfer from the air existing in the interior space of the room to the walls of simple office for small factories was carried out under the conditions of convective heat transfer, gravity.[17] Figure 10 shows a 3D simulation[18] of the process through which cold water polyethylene tubes are installed inside the wall of simple office for small factories, cold water X-L pipes are installed inside the cold water panels,[19] and the cold water flowing in the cold water polyethylene tubes absorbs radiant heat energy so that the temperature of the cold water drops. As shown in Figure 10, the temperature of the cold water flowing into the inlet of the cold water polyethylene tubes is 0.3°C. The simulation was carried out when the mass flow rate of cold water was 3 kg/min. The flow of cold water is a turbulent steady flow, and the forced convective heat transfer of cold water in the cold water polyethylene tubes is conjugated heat transfer, which the cold water takes the heat energy of the air existing in the space inside simple office[19] for small factories. Through this process, the heat energy held by the air existing inside the small size decreases leading to the drop of the temperature of the air existing inside simple office for small factories so that radiant heat transfer cooling is implemented.[20] From the results of the 3D simulation, it can be seen that the temperature of the cold water flowing inside the cold water polyethylene tubes increased linearly.

Thermal energy balance between cold water and cold polyethylene tubes of the simple office for small factories

Figure 11 shows the accuracy of matching between the heat energy per unit time[19] obtained by the cold water flowing inside the cold water polyethylene tubes in the walls of simple office for small factories and the heat energy per unit time lost by the air existing

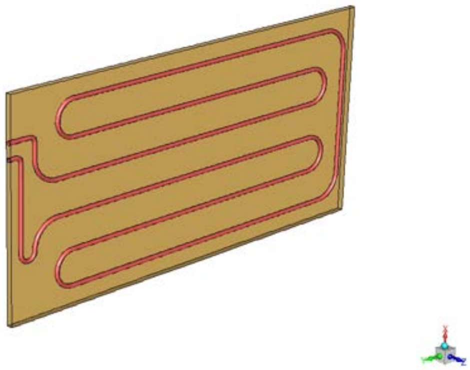

Figure 7. Shape of 3D simulation of a cold water panel for cooling of simple office for small factories

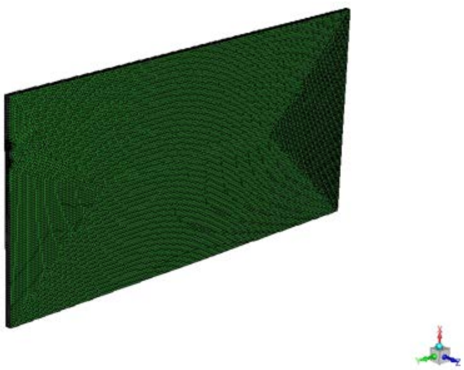

Figure 8. 3D shape simulation of wall for simple office for small factories

Figure 9. Another format of 3D simulation of X-L pipes for simple office for small factories

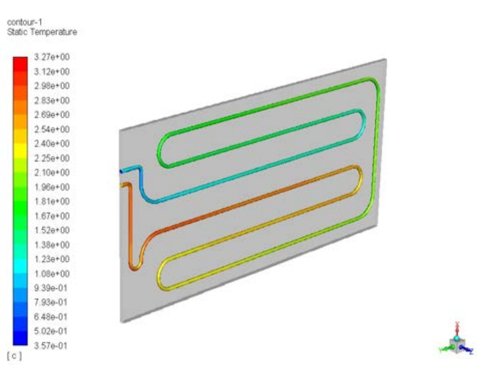

Figure 10. Simulation of heat flow in X-L pipes of simple office for small factories

in the interior space of simple office for small factories. The heat energy per unit time obtained from the cold water flowing inside the cold water polyethylene tubes in the walls of simple office for small factories was obtained with Equation (1).

$$Q_{c,w} = m_{c,w}Cp_c\,(T_{c,2} - T_{c,1}) \quad (1)$$

where, $Q_{c,w}$ represents the heat energy per unit time obtained by the cold water flowing inside the cold water polyethylene tubes in the walls of simple office,[21] $m_{c,w}$ represents the mass (kg) of cold water flowing per unit time, $T_{c,2}$ denotes the inlet temperature (K) of cold water, and $T_{c,1}$ denotes the outlet temperature of cold water. The heat energy lost per unit time by the air existing in the space inside the room was obtained with Equation (2).

$$Q_{c,a} = m_{c,a}Cp_c\,(T_{h,2} - T_{h,1}) \quad (2)$$

where, $Q_{c,a}$ denotes the heat energy (W) lost by the air inside simple office for small factories per unit time, $m_{c,a}$ denotes the mass of air (kg), $T_{h,2}$ denotes the initial temperature (K) of the air existing in the space inside the room, and $T_{h,1}$ denotes the final temperature of the air existing in the space inside simple office for small factories. As shown in Figure 11, the heat energy per unit time obtained by the cold water flowing inside the cold water polyethylene tubes in the walls of the room and the heat energy per unit time lost by the air existing in the interior space of simple office for small factories coincided well at the accuracy of ±5% . Therefore, the accuracy of the experimental results on the cooling performance of simple office for small factories in this study is very high and therefore, the reliability of the cooling performance experimental results is considered to have been secured.

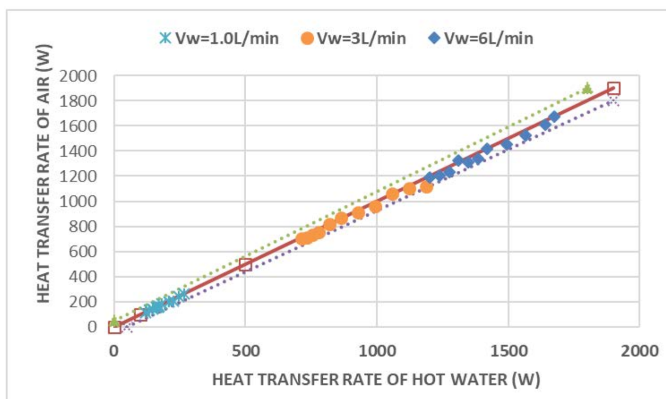

Figure 11. Accuracy of matching between the thermal energy per unit time obtained by the cold water and the thermal energy per unit time lost by the air of simple office for small factories

Natural convective heat transfer coefficient for cooling load of simple office for small factories

Figure 12 shows the comparative values of the theoretical natural convective heat transfer. It show the changes in the radiant heat transfer rate in relation to changes in the flow rate of the cold water flowing inside the cold water polyethylene tubes inside the walls of simple office for small factories. As shown in Figure 12, the cooling performance of the cold water

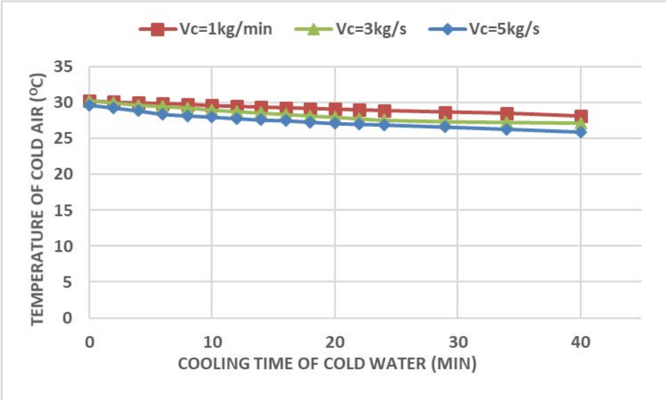

Figure 12 Changes in the radiant heat transfer rate in relation to changes in the mass flow rate of the cold water flowing inside the cold water X-L pipes of simple office for small factories

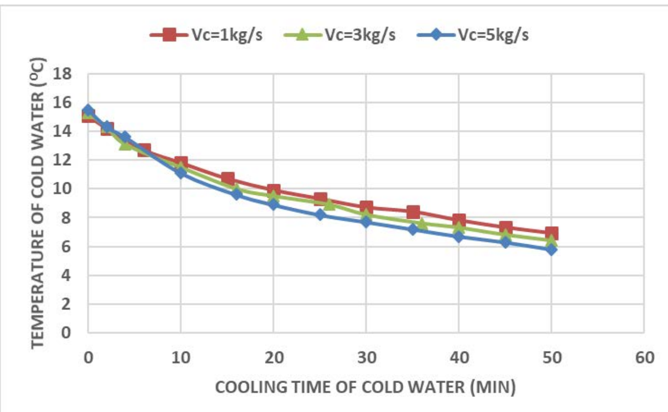

Figure 13. Changes in the temperature of the air existing in the space inside the room according to changes in the cooling time of the cold water circulating in the cold water polyethylene tubes of simple office for small factories

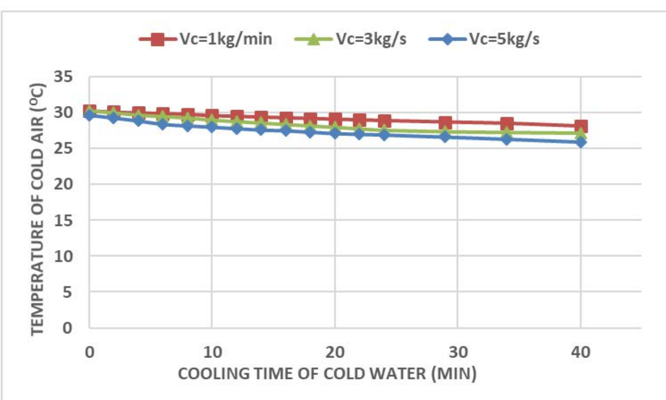

Figure 14. Changes in the temperature of the cold water circulating in the cold water polyethylene tubes according to cooling time of cold water for simple office for small factories

decreased in proportion to the increase in the flow rate of cold water. In addition, the amount of heat energy reduction per unit time decreased in proportion to the cooling time. Therefore, it is considered that the heat energy held by the air existing in the space inside the room is normally transferred to the cold water flowing inside the polyethylene tubes through convective heat transfer. Furthermore, the thermal energy balance was well achieved based on the results of the experiment of the cooling performance of simple office for small factories.

Figures 13 and 14 show changes in the temperature of the air existing in the space[22] inside simple office for small factories according to changes in the cooling time and the temperature of the cold water circulating in the cold water polyethylene tubes inside simple office for small factories, respectively. As shown in Figures. 13 and 14, as the temperature of the cold water decreased, the temperature of the air existing in the space inside the room decreased linearly. Therefore, based on the results of experiment of the cooling performance of simple office for small factories with radiant heat transfer, it is considered that radiant heat transfer occurs normally.[23] Thus, it is thought that as the flow rate of cold water increases, the cooling performance of simple office for small factories increases proportionally.[24] This method conclusively evaluated the application of indirect cooling system for a room or part of a building for comfort living.[25]

Conclusion

This study examined the radiant heat transfer rate performance of simple office for small factories according to changes in the temperature and flow rate of the cold water circulating in the polyethylene tubes inside the walls of room, and the following results were derived.

From the results of the 3D simulation of the cooling load of simple office for small factories according to changes in the temperature and flow rate of the cold water circulating in the polyethylene tubes inside the walls of simple office for small factories, it can be seen that the heat energy held by the air in the interior space of the simple office for small factories was transferred normally to the cold water. The heat energy obtained by the cold water per unit time and the radiant energy lost by the air inside the room per unit time coincided well at the accuracy of ±5% of simple office for small factories.

As the cold water temperature decreases, the air temperature inside the room decreased proportionally for simple office for small factories.

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