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Radiant Heat Transfer Performance of a Small Pension

Dong-Hyun Cho

Professor, Department of Mechanical Engineering, Daejin University, South Korea, chodh@daejin.ac.kr

Abstract

In this study, cold water panels were laid in the walls of a small pension, and cold-water tubes were installed inside the cold-water panels to examine the cooling performance with radiant heat transfer by the absorption of radiant thermal energy by the cold water leading to the drop of the temperature of the air existing in the internal space of the small pension. The size of the small pension is 2000 mm wide, 1500 mm long, and 1700 mm high. The cooling area of the small pension experimental apparatus is 3 m^2, and cold-water panels were laid inside the walls of the small pension. As a result of this study as such, unlike the forced convective heat transfer cooling in which the air existing in the interior space of a small pension is forced to circulate by an air conditioner or an electric fan, the radiant heat transfer cooling by the cold water panels laid in the walls of the small pension in this study implemented comfortable radiant heat transfer cooling, which is also well-being beneficial to health have been realized by implementing the radiant heat transfer cooling without any movement or circulation of the air.

Keywords*: Small pension, Radiant heat transfer, Cold-water, Cooling, Thermal energy*

1. Introduction

Recently, as the demand for small pensions has been gradually increasing, studies on cooling device design technologies and manufacturing technologies suitable for small pensions are urgently required, but the current study reports are insufficient, and this study is desperately required because people are relying on air conditioner cooling and electric fans even in hot midsummer [1]. In addition, since there are no appropriate cooling device accessories (chillers, cold water pumps, cold water circulation piping parts, etc.) required for small pensions, accessories suitable for house buildings larger than 24 m^2 are used in small pensions not larger than 6 m^2 leading to large energy losses and great increases in installation costs [2]. In addition, although many studies on cooling technologies for cooling panels in which cold water circulates have been reported, they are mainly for simplified cooling panels and study reports for small pensions are insufficient [3]. In addition, there are many study reports indicating that radiant heat transfer cooling implemented with the absorption of thermal energy by the cold water flowing in the tubes laid in the walls of small pensions is wellbeing cooling beneficial to health [4]. However, reports of studies on implementing cooling with radiant thermal energy by laying cold water panels in the walls inside the small pension are insufficient [5]. Therefore, in this study, wellbeing cooling beneficial to health was implemented by laying cold water panels in the walls of a small pension and installing tubes, in which cold water flows, inside the cold-water panels to implement the radiant thermal energy cooling with the cold water flowing in

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the cold-water tubes. This study was conducted to implement radiant heat transfer cooling with the thermal energy absorbed by the cold water circulating inside the cold-water tubes by laying cold water panels in the two walls of the small pension. 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, more comfortable cooling, which is also wellbeing cooling beneficial to health, was implemented because radiant heat transfer cooling was implemented with the absorption of thermal energy by the cold water flowing in the tubes laid inside the walls of the small pension in this study without any movement or circulation of the air existing in the interior space of the small pension. In addition, this study significantly reduced thermal energy consumption for radiant heat transfer cooling and manufacturing costs by investigating accessories for cooling devices suitable for small pensions not larger than 6 m^2.

2. Experimental apparatus

[Figure 1] shows an experimental apparatus to measure the cooling performance with radiant heat transfer according to changes in the temperature and mass flow rate of the cold water circulating in the tubes of the cold water panels laid inside the walls of a small pension. As shown in [Figure 1] in this study, cold water panels were laid in the walls of a small pension, and cold water tubes were installed inside the cold water panels to examine the cooling performance with radiant heat transfer by the absorption of radiant thermal energy by the cold water leading to the drop of the temperature of the air existing in the internal space of the small pension. The size of the small pension is 2000 mm wide, 1500 mm long, and 1700 mm high. The cooling area of the small pension experimental apparatus is 3 m^2, and cold water panels were laid inside the walls of the small pension. The experimental apparatus was configured so that cold water is circulated in the tubes for cold water circulation installed inside the cold water panels. Therefore, radiant heat transfer cooling is implemented as the cold water flowing in the cold water tubes installed inside the cold water panels absorbs the thermal energy held by the air existing in the interior space of the small pension, and 3D simulation studies and experimental studies were carried out to implement welling cooling beneficial to health. As a result of this study as such, unlike the forced convective heat transfer cooling in which the air existing in the interior space of a small pension is forced to circulate by an air conditioner or an electric fan, the radiant heat transfer cooling by the cold water panels laid in the walls of the small pension in this study implemented comfortable radiant heat transfer cooling, which is also well-being beneficial to health have been realized by implementing the radiant heat transfer cooling without any movement or circulation of the air. A chiller to absorb the thermal energy of the cold water circulating in the cold water panel and a cold water pump were constructed to configure the experimental apparatus so that the cold water flowing in the cold water tubes laid in the walls of the small pension would absorb the thermal energy held by the air existing in the interior space of the small pension. Existing small cooling devices are for cooling of houses and offices not smaller than 26 m^2 and carry out cooling by the forced convection heat transfer method. However, study reports on cooling accessories for small pensions not larger than 3 m^2 examined in this study are insufficient. Therefore, in this study, accessories for cooling devices that can be used in small pensions not larger than 3 m^2 were investigated. Fig. 2 shows a chiller to absorb the thermal energy of the cold water circulating in the cold water tube installed inside the cold water panels laid inside the walls of a small pension. As shown in Fig. 3, a chiller for the absorption of the heat of the cold water circulating inside the cold water tubes laid inside the walls of the small pension was installed to comduct an experimental study. The noise of the chiller to absorb the thermal energy held by the cold water was studied not to exceed 40 dB, so that no sleep disturbance would be caused by the noise when conducting activities or sleeping at night in the small pension. As such, by developing the chiller technology to take away the thermal energy held by the cold water, the study was conducted to reduce energy losses by at least 3% compared to existing technologies for the chiller installed outdoors when considering outdoor heat absorption losses and pipeline losses.

Figure 1. Experimental apparatus for the cooling performance of a small pension by radiant heat transfer

Figure 2. A chiller to take the thermal energy held by the cold water circulating inside the cold-water tubes

3. Results

3.1. Result of 3D simulation regarding the radiant heat transfer performance of a small pension

[Figure 3] shows a shape of 3D simulation of a cooling water panel for a small pension. Figures 4 and 5 show the hexahedral+tetrahehedral mixed unstructured mesh of the cold-water panel. The 3D simulation was carried out with 648,7000 cells. The size of the cold-water panel is 1,700 mm wide, 850 mm long, and 23.5 mm thick. As shown in Fig 3 and Fig. 4, the simulation was performed at a temperature of 0.3°C of the cold water flowing into the inlet of the cold-water panels laid inside the walls of the small pension. In addition, the 3D simulation was carried out under the conditions of a mass flow rate of cold water of 3 kg/min and an outdoor temperature of 32°C. ANSYS FLUENT R19 was used as analysis software. A 3D simulation study was conducted on convective heat transfer in the process through which the cold water flowing inside the tubes laid in the walls of the small pension absorbs the thermal energy held by the air existing in the interior space of the small pension. The 3D simulation of heat transfer from the air existing in the interior space of the small pension to the walls of the small pension was carried out under the conditions of natural convective heat transfer, gravity, and incompressible ideal gas air.

[Figure 5] shows a 3D simulation of the process through which cold water panels are installed inside the wall of a small pension, cold water tubes are installed inside the cold-water panels, and the cold water flowing in the cold-water tubes absorbs radiant thermal 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 panels is 0.3°C. The simulation was carried out when the mass flow rate of cold water was 3 kg/min. The mass flow of cold water is a turbulent steady flow, and the forced convective heat transfer of cold water in the cold-water panel is conjugated heat transfer, which the cold water takes the thermal energy of the air existing in the space inside the small pension. Through the process as such, the thermal energy held by the air existing inside the small size decreases leading to the drop of the temperature of the air existing inside the small pension so that radiant heat transfer cooling is implemented.

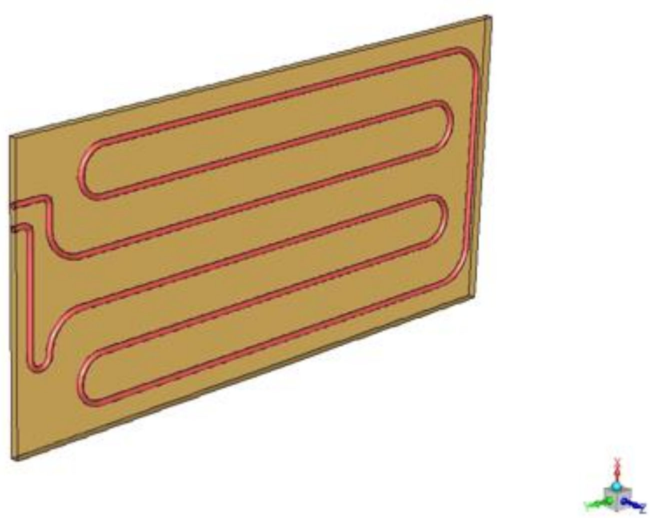
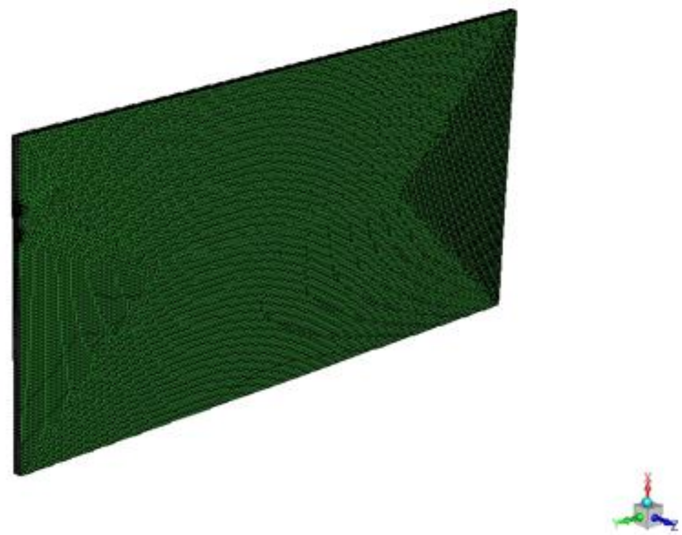


Figure 3. Shape of 3D simulation of a cold-water panel for cooling of small pensions



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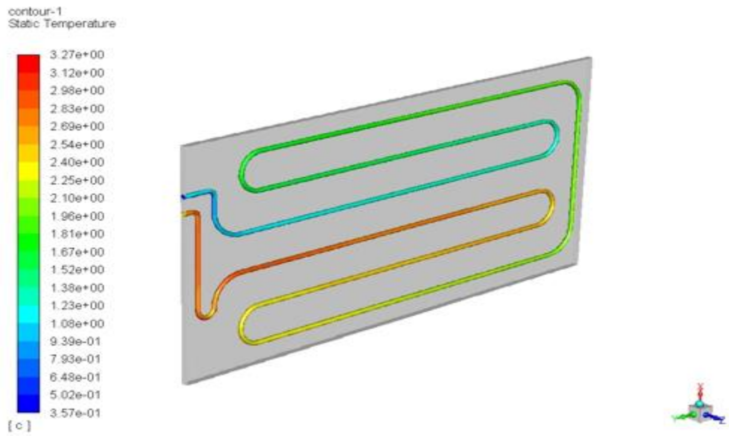
From the results of the 3D simulation, it can be seen that the temperature of the cold water flowing inside the cold-water tubes increased linearly. Based on the results of simulation as such, the thermal energy held by the air existing in the interior space of the small pension was normally transferred to the cold water. In addition, it was thought that as the mass flow rate of the cold water increased, the radiant heat transfer rate performance increased linearly. In this study, the cooling performance value of the radiant heat transfer rate measured in the experimental study and the cooling performance value of the radiant heat transfer rate shown in the simulation result matched well with each other.



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3.3. Cooling performance of small pensions by radiant heat transfer

[Figure 6] shows 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 tubes laid inside the walls of the small pension. The experiment was carried out under three conditions of the mass flow rate of the cold water: 1.0 kg/min, 3.0 kg/min, and 5 kg/min. As shown in Fig. 6, the heat transfer rate of the cold water decreased in proportion to the increase in the mass 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 thermal energy held by the air existing in the space inside the small pension is normally transferred to the cold water flowing inside the tubes through convective heat transfer. In addition, it is thought that as the mass flow rate of the cold-water increases, the radiant heat transfer rate performance of the small pension increases. In addition, the thermal energy balance was well achieved based on the results of the experiment of the radiant heat transfer performance of the small pension. Therefore, the reliability of the experimental results in this study was verified.

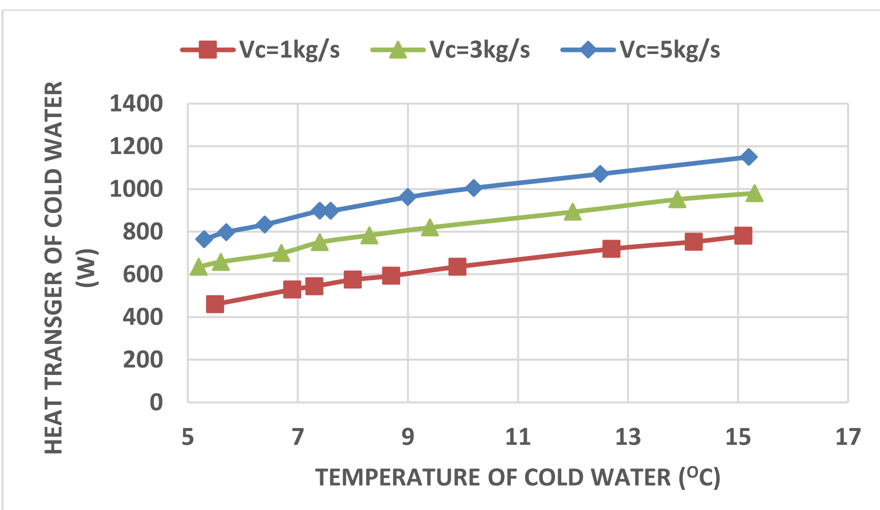

Figure 6. Changes in the radiant heat transfer rate in relation to changes in the mass flow rate of the cold water flowing inside the cold-water tubes

4. Conclusions

This study examined the radiant heat transfer rate performance of a small pension according to changes in the temperature and mass flow rate of the cold water circulating in the tubes in the cold-water panels laid inside the walls of a small pension, and the following results were derived.

The thermal energy obtained by the cold water per unit time and the radiant thermal energy lost by the air inside the small pension per unit time coincided well at the accuracy of $\pm 5\%$.

As the cold-water temperature decreased, the air temperature inside the small pension decreased proportionally. Therefore, as the mass flow rate of the cold water increased, the radiant heat transfer rate performance of the small pension improved proportionally.

In the future, studies on the convective heat transfer coefficient of small pension is required.

References

[1] V. Verda and F. Colella, "Primary energy savings through thermal storage in district heating networks," Energy, vol.36, no.7, pp.4278-4286, **(2011)**

[2] M. A. Ancona, I. Branchini, P. De and F. Melino, "Smart district heating: Distributed generation system' effects on the network," Energy Procecha, vol.75, pp.1208-1213, **(2015)**

[3] M. H. Kim, D. W. J. H. Heo, and D. W. Lee, "Energy performance investigation of net plus energy town: Energy balance of the Juncheon eco-friendly energy town," Renewable Energy, vol.147, pp.1784-1800, **(2020)**

[4] V. F. Sanchez, A. Branchim, E. Barreiro and M. Porta, "Smart dural thermal network," Int. J. Energy, Production Management, vol.30, no.4, pp.315-326, **(2017)**

[5] J. K. Cho, B. Y. Park, Y. J. Lee and W. H. Chung, "Experimental study on a low-temperature hot water capillary radiant floor heating system," Korean Journal of Air-Conditioning and Refrigeration Engineering, vol.30, no.2, pp.62-82. **(2018)**

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