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Temperature Distribution Characteristics for Changes in Hot Water Flow in A Small Ocher Jjimjilbang

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소형 황토 찜질방의 온수유량 변화에 대한 온도분포 특성

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ABSTRACT

The ocher jjimjilbang for a single-person household that will be studied in this study is 2.1 m^2 in size, and this study was conducted to implement well-being room heating that is beneficial to health by supplying radiant heat provided by hot water during room heating by embedding hot water panels in the walls of the ocher jjimjilbang to configure a hot water circulating system. In addition, the ocher bed and the ocher walls, which have been verified through many study findings and reference materials, were constructed so that the living life with a bed and the ocher jjimjilbang would be implemented simultaneously. As the mass flow rate of the hot water increased, the magnitude of the wall temperature rise thanks to the hot water increased, and as the flow rate of the hot water increased, the transfer rate of the heat transferred from the wall of the ocher jjimjilbang to the air inside the wall of the ocher jjimjilbang increased.

Keywords : Ocher Jjimjilbang(황토 찜질방), Hot Water Flow(온수유량), Temperature Distribution(온도분포), Heat Transfer(열전달), Performance(성능)

1. Introduction

The number of single-person households is increasing and has reached 5,618,677 households (National Statistical Office, census data). The ratio of single-person households to the entire households is 28.6%, and is gradually increasing. In the case of the houses of such single-person households, the burden of room heating costs is high in cold winter, and some of the people living in single-person households are living hard in the cold season of winter[1~3]. It is judged that, if the results of this study are used to provide the radiant heat of the ocher jjimjilbang, which is beneficial to health, to the elderly who live in single-person households while they are sleeping, the health of the elderly will be improved significantly[4,5]. In addition, whereas the one room (3~4 pyeong) of a single-person household is entirely heated, in the case of the ocher jjimjilbang

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that can be also used as a bed for a single-person household, only 0.64 pyeong may be heated so that the room heating cost can be significantly reduced[6]. At home and abroad, heating apparatuses used in winter (hot water boilers and air conditioners, etc.) for existing houses are mainly supplied to buildings where each heating apparatus is used for a space exceeding 8 pyeong(26.4m^2), and the air is circulated by forced convection to transfer heat according to reports of studies of heating technology[7~9]. Since there are no accessories (circulation pumps, heaters, etc.) for heating apparatuses suitable for building spaces not larger than 2 pyeong, the accessories used in heating apparatuses for spaces larger than 8 pyeong are used in heating apparatuses for spaces not larger than 2 pyeong so that the electric power energy loss is large and the installation cost is high[10,11]. The ocher jjimjilbang for single-person households that will be investigated in this study is 0.64 pyeong(2.1m^2) in size, and will be configured so that hot water will be circulated through the bed and walls when heated in order to implement well-being heating by supplying the radiant heat produced by hot water. In addition, the ocher bed and the ocher walls, which have been verified through many study findings and reference materials, will be constructed so that the living life with a bed and the ocher jjimjilbang would be implemented simultaneously. In addition, electric boilers for hot water supply in winter suitable for 0.64 pyeong(2.1m^2), the size of the ocher jjimjilbang that can be also used as a bed for a single-person household were also studied. Therefore, in this study, the temperature distribution characteristics of the integrated ocher jjimjilbang, which can be used as both a room heater and a jjimjilbang in winter, were studied.

2. Experiment

2.1 Experiment Setup and Conditions

Fig. 1 Experimental apparatus for small ocher jjimjilbang

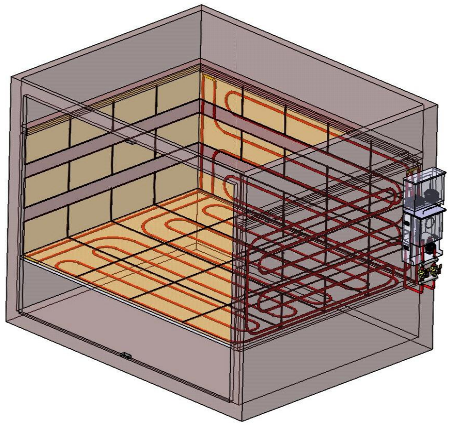


Fig. 2 3D plan of small ocher jjimjilbang

Fig. 1 shows a small ocher jjimjilbang for room heating by supplying the thermal energy possessed by the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang. Fig. 2 shows a 3D plan of the small ocher jjimjilbang for room heating by supplying the thermal energy possessed by the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang. An ocher jjimjilbang that can be used for room heating by radiant heat was developed for the first time at home and abroad by embedding hot water panels in the walls of the ocher jjimjilbang and installing hot water tubes inside the hot water panels. The dimensions of the ocher jjimjilbang are 2000mm wide, 1100mm long, and 1800mm high. The size of the ocher jjimjilbang was determined to be the same as that of a single bed so that the ocher jjimjilbang can be installed in the rooms of single-person households and used as a bed at normal times while being used as a jjimjilbang at home by those who like sauna bath. Those who like sauna bath could enjoy sauna bath in the jjimjilbang installed in large bathhouses. However, this study fabricated an experimental apparatus for the ocher jjimjilbang implemented to enable enjoying sauna bath at home beyond the jjimjilbang culture as such and examined the temperature distribution characteristics of the ocher jjimjilbang. Rroom heating is implemented without air movements or circulation unlike the forced convection heating in which air is circulated by force by the air conditioner. Therefore, comfortable heating and well-being heating beneficial to health is implemented. An experimental apparatus was configured to supply hot water to a hot water tubes embeded in the walls of the ocher jjimjilbang by constructing a hot water boiler and a hot water pump to supply hot water to the hot water panels. Existing small heating apparatuses are for heating of houses or offices that are at least 8 pyeong in size and heat the room by forced convection. However, there is no commercial heating apparatus for the small jjimjilbang not larger than 2 pyeong in size investigated in this study. An ocher jjimjilbang, which can be used for small buildings not larger than 2 pyeong such as pensions was investigated.

2.2 Temperature Measurement and Hot Water Flow Measurement

Fig. 3 shows a temperature measuring sensor for measuring the air temperature inside the ocher jjimjilbang and a temperature measuring sensor for measuring the wall surface temperature. Fig. 4 shows the flow rate measuring device for the hot water supplied to the hot water panel inside the ocher jjimjilbang. As shown in Fig. 3, Pt 100Ω temperature sensors were installed at the hot water

Fig. 3 Measurement of air temperature and wall surface temperature inside the ocher jjimjilbang

Fig. 4 Ocher jjimjilbang hot water flow measuring device

inlet and outlet of the ocher jjimjilbang to measure the temperatures. In addition, temperatures were measured at six points on the wall of the ocher jjimjilbang and three points in the inner space of the ocher jjimjilbang. Furthermore, as shown in Figure 4, a flowmeter was installed in the hot water tube at the entrance of the ocher jjimjilbang to measure the flow of hot water.

3. Results and Discussion

3.1 Heat Transfer Rate of the Ocher Jjimjilbang

Fig. 5 shows the heat transfer rate of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang and the heat transfer rate of the air inside the ocher jjimjilbang in the process through which the thermal energy possessed by the hot water is transferred to the air inside the ocher jjimjilbang. The heat transfer rate of the hot water that supplies thermal energy to the inside of the ocher jjimjilbang was obtained using Equation (1).

$$Q_{r,in} = m_{h,w} Cp_h (T_{r,out} - T_{r,in}) \qquad (1)$$

where, $Q_{r,in}$ represents the heat transfer rate of the hot water that supplies thermal energy to the inside of the ocher jjimjilbang. $\dot{m}_{h,w}$ represents the mass flow rate (kg/s) of the hot water, $T_{r,in}$ represents the temperature(K) of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang at the inlet, and $T_{r,out}$ represents the temperature of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang at the outlet. The heat transfer rate of the air inside the ocher jjimjilbang was obtained using Equation (2).

$$Q_{r,air} = m_a Cp_a (T_{r,2} - T_{r,1}) \qquad (2)$$

where, $Q_{r,air}$ represents the heat transfer rate(W) of the air inside the ocher jjimjilbang. m_a represents the mass flow rate(kg/s) of the air, $T_{r,1}$ represents the initial temperature(K) of the air inside the ocher jjimjilbang, and $T_{r,2}$ represents the final temperature of the air inside the ocher jjimjilbang. As shown in Fig. 5, the heat transfer rate of the heat supplied by the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang and that of the heat absorbed by the air inside the ocher jjimjilbang matched well with $\pm 5\%$ deviations. Therefore, the reliability of the experimental results of this study is considered to have been secured.

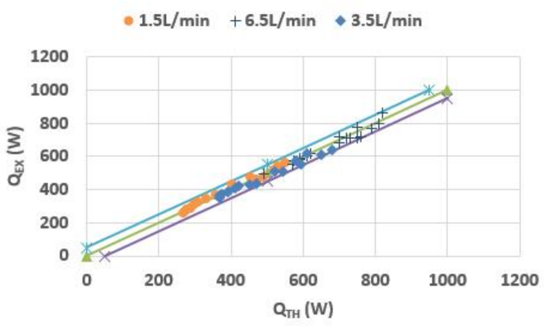


Fig. 5 Comparison of heat transfer rates in the ocher jjimjilbang

3.2 Characteristics of Temperature Distribution in the Ocher Jjimjilbang

Fig. 6 shows the temperature distribution of the hot water in relation to the flow rate changes of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang. The experiment was carried out under three hot water flow rate conditions: 1.5 L/min, 3.5 L/min, and 6.5 L/min. As shown in Fig. 6, the temperature of the hot water increased proportionally with the elapse of the hot water boiler operation time. Therefore, it is considered that the heating of the ocher jjimjilbang is operating normally. In addition, as the mass flow rate of the hot water increased, the temperature of the hot water increased. Therefore, it is considered that the

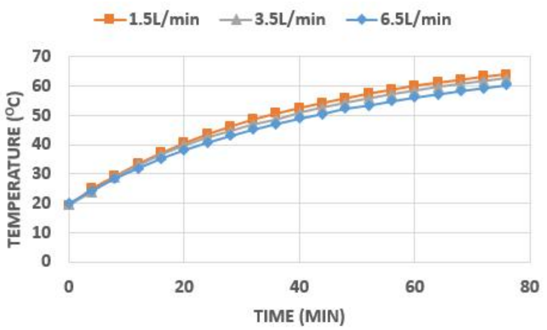
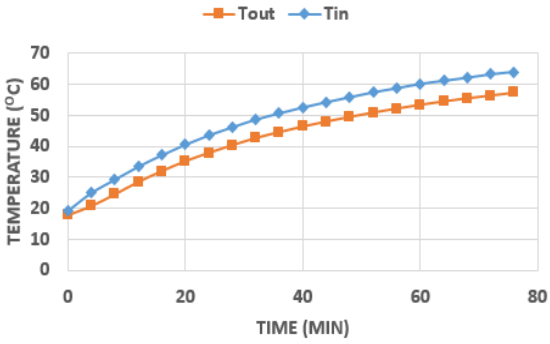


Fig. 6 Temperature distribution of the hot water circulating in the walls of the ocher jjimjilbang

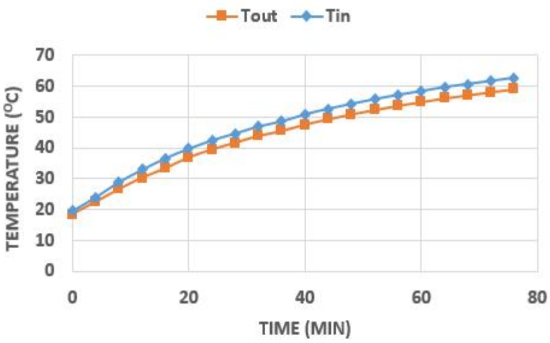
heating performance improves as the flow of the hot water increases.

Fig. 7 shows the distribution of the temperatures of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang at the inlet and the outlet. The experiment was carried out under three hot water flow rate conditions: 1.5 L/min, 3.5 L/min, and 6.5 L/min. As shown in (a) to (c) of Fig. 7, the inlet temperature and outlet temperature of the hot water increased proportionally with the elapse of hot water boiler operating time. Therefore, the inlet temperature and outlet temperature of the hot water supplied to the ocher jjimjilbang are considered to rise normally. In addition, as the mass flow rate of the hot water increased, the magnitudes of changes in the inlet and outlet temperatures of the hot water increased. Therefore, it is considered that the transfer rate of the heat supplied to the ocher jjimjilbang improves as the hot water flow increases.

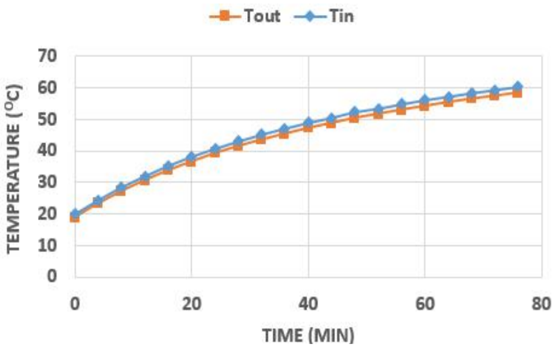
Fig. 8 shows the distribution of the temperatures of the wall surface of the ocher jjimjilbang with respect to the changes in the flow rate of the hot water circulating in the hot water panel embedded in the walls of the ocher jjimjilbang. The experiment was carried out under three hot water flow rate conditions: 1.5 L/min, 3.5 L/min, and 6.5 L/min. As shown in Fig. 8, the temperature of the wall surface of the ocher jjimjilbang increased proportionally with the elapse of operating time of the hot water boiler. Therefore, the temperature of the wall surface of the



(a) V_1 = 1.5 L/min



(b) V_2 = 3.5 L/min



(c) V_3 = 6.5 L/min

Fig. 7 Distribution of the temperatures of the hot water circulating in the walls of the ocher jjimjilbang at the inlet and outlet in relation to changes in the flow of the hot water

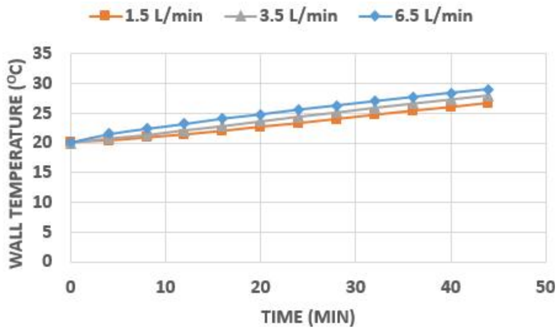


Fig. 8 Distribution of the temperatures of the wall surface of the ocher jjimjilbang with respect to the changes in the flow rate of the hot water circulating in the walls of the ocher jjimjilbang

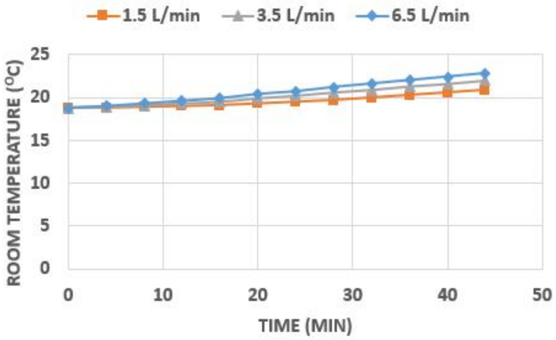


Fig. 9 Distribution of air temperatures inside the ocher jjimjilbang in relation to changes in the flow rate of the hot water circulating in the walls of the ocher jjimjilbang

ocher jjimjilbang is considered to rise normally. In addition, as the mass flow rate of hot water increased, the magnitude of the rise of the temperatures of the wall surface of the ocher jjimjilbang increased. Therefore, it is considered that the transfer rate of the heat transferred from the wall surface of the ocher jjimjilbang to the air inside the walls of the ocher jjimjilbang increases as the hot water flow rate increases.

Fig. 9 shows the temperature distribution inside the ocher jjimjilbang. The experiment was carried out under three hot water flow rate conditions: 1.5 L/min, 3.5 L/min, and 6.5 L/min. As shown in Fig. 9, the air temperature distributed inside the ocher jjimjilbang increased proportionally with the elapse of operating time of the hot water boiler. Therefore, it is considered that the heating performance increases because the heat transfer rate of the ocher jjimjilbang increases as the hot water flow rate increases.

4. Conclusion

In this study, the distribution of the temperatures of hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang, the distribution of the temperature of the wall surface of the ocher jjimjilbang, and the distribution of the temperature of the air inside the ocher jjimjilbang in relation to changes in the flow rate of the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang were investigated and the following results were derived.

1. The transfer rate of the heat supplied by the hot water circulating in the hot water panels embedded in the walls of the ocher jjimjilbang and that of the heat absorbed by the air inside the ocher jjimjilbang matched well with ±5% deviations. Therefore, the reliability of the experimental results of this study was verified.
2. As the mass flow rate of hot water increased, the magnitude of wall temperature rise increased.
3. As the flow rate of hot water increased, the rate of transfer of heat from the wall of the ocher jjimjilbang to the air inside the wall of the ocher jjimjilbang increased.
4. As the mass flow rate of hot water increased, the magnitude of changes in the inlet and outlet temperatures of the hot water increased. Therefore, as the flow rate of hot water increased, the rate of transfer of the heat supplied to the ocher jjimjilbang improved.
5. The air temperatures distributed inside the ocher jjimjilbang increased proportionally with the elapse of the hot water boiler operation time.

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References

1. Mendes, N., Winkelmann, F. C., Lamberts, R., and Philippi, P. C., "Moisture Effects on Conduction Loads," Energy and Buildings, Vol.

35, No. 7, pp. 631-644, 2003.
2. Woods, J., Winkler J., and Christensen, D., “Evaluation of the Effective Moisture Penetration Depth Model for Estimating Moisture Buffering in Buildings, NREL Technical Report,” NREL /TP-5500-57441, 2013.
3. Barbosa, R. M., and Mendes, N., “Combined Simulation of Central HVAC Systems with a whole-building Hygrothermal Model,” Energy and Buildings, Vol. 40, No. 3, pp. 276-288, 2008.
4. Steeman, M., Janssens, A., Steeman, H. J., Van Belleghem, M., and De Paepe, M., “On Coupling 1D Non-isothermal Heat and Mass Transfer in Porous Materials with a Multizone Building Energy Simulation Model,” Building and Environment, Vol. 45, No. 4, pp. 865-877, 2010.
5. Francesca, C., Anderea G., Piercarlo, R., Paolo, B., “Analysis of the Influence of Installation Thermal Bridges on Windows Performance: The Case of Clay Block Walls", Journal of Energy and Buildings, Vol. 43, No. 6, pp. 1435-1442, 2011.
6. Cho, S. H. and Ho, S. H., “Modernized Energy Integrated Management Technology of Distric Heating for Apartment Houses,” Magazine of the SAREK, Vol. 42, No. 5, pp. 40-47, 2013.
7. Kim, Y. O., “Design Variables Optimization of Edge Welded Metal Bellows by Using Taguchi Method,” Inha Univ., Master’s Thesis, 2016.
8. Lee, S. W., Hong, H. K. and Kim, Y. K., “Ondol Heating Simulation of District Heating, Proceedings of the SAREK 2012 Winter Conference, pp. 105-108, 2012.
9. Woon, D. H. and Kim, H. G., “The economics value of residential heating systems in house price, Korean Energy Economic Review, Vol. 7, No. 2, pp75-101, 2008.
10. Park, C. I. and Kim, R. H., “A Study for energy Comsumption Efficiency Test Method of Domestic Gas Boiler, Proceeding of The Korea Society for Energy Engineering, pp. 157, 2012.
11. Korea Boiler Engineering Assoc., “The Concerns about the Side Effects of the High Efficiency Policy on the Gas Boile, Korea Boiler Engineering Axxoc., No. 73, No. 73, pp. 60-63. 2000.