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Analytical solution for heat transfer in a multilayer floor of a radiant floor system

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Abstract

In radiant floor systems, the distribution of the floor surface temperature, which can be used to determine the mean temperature and the lowest/highest temperature of the floor surface, is an important parameter. The mean temperature of the floor surface determines cooling/heating capacity and indoor thermal comfort. The lowest surface temperature, which considers the dew point in an indoor environment, is a crucial factor in the prevention of condensation on a floor surface. The highest surface temperature is typically considered for local thermal comfort. In this paper, an analytical solution for heat transfer in a multilayer floor structure of a radiant floor system is proposed based on the analysis of the heat transfer process of a multilayer floor, equivalent thermal resistance and separation of variables method. The corresponding formulas are derived to estimate the distribution of floor surface temperature. The calculation results are validated by experiments. The calculation and experimental results show good accordance. The absolute error between the calculation and experimental results for floor surface temperature is within 0.3ºC. A method for the calculation of the dimensionless temperature of the floor surface, which can be used for radiant heating and cooling systems, is provided. Using this proposed method, the distribution of floor surface temperature and the influence of floor structure parameters on the thermal performance of floors can be estimated and analyzed.

Keywords

radiant floor,
analytical solution,
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equivalent thermal resistance

Article History

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1 Introduction

Due to the heat transfer between the heated or cooled floor, the space and the people in the space is mainly by radiation efficiently, the radiant floor system can work with a low temperature for heating and high temperature for cooling economically. The use of radiant floor heating/cooling systems has expanded in recent years due to energy savings, comfort and health (Olesen 1997, 2008; Simmonds et al. 2000).

Substantial research on the thermal performance of radiant floors has been performed in recent years:

(1) Analysis of the heat transfer of radiant floors. Kilkis et al. (1994) presented a composite fin model to approximate the distribution of floor surface temperature in cooling and heating panels under quasi steady-state conditions. Koschenz and Dorer (1999) presented an analytical solution for a homogenous slab with an embedded array of parallel circular pipes. The model can be employed to illustrate transient 2D heat flow in a homogenous slab. Olesen and Michel (2000) examined the cooling capacity of a radiant floor with various structural parameters using an experimental method provided in BS EN1264-5 (2008) and proposed different heat exchange coefficients between floor surface and indoor space according to different reference temperature. Holopainen et al. (2007) examined the use of uneven nodal network in a floor heating simulation with a finite difference heat balance method and concluded that a sufficient level of accuracy can be achieved with a reduced total number of nodes by uneven nodal network. Jin et al. (2010a) assumed that the floor was divided into two layers and correlated the thermal conductivity of the lower layer based on the numerical model to simply obtain the temperature of the floor surface. The effects of the thermal resistance of pipes and water velocity were evaluated using numerical simulation of a radiant floor cooling system (Jin et al.

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