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Application of model based predictive control for water-based floor heating in low energy residential buildings

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ABSTRACT

A model based predictive control method is applied in order to determine the optimal supply fluid temperature in the case of concrete embedded water-based floor heating in low energy residential buildings. The aim of the control is to keep the indoor temperature within a defined comfort interval. The forthcoming supply fluid temperature is obtained through a numerical optimisation based on a prediction of the upcoming heat demand. The elementary response function, which is the basis for the method, is obtained from a numerical control volume model, and as an alternative, from a simplified 2-node lumped model. The accuracy of the results obtained from the simplified model is surprisingly good in comparison to the detailed numerical model. The control method is applied for a single room for which a perfect prognosis of the heat demand exists. The results show a fairly steady optimised supply fluid temperature.

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1. Introduction

The control of water-based floor heating systems is usually divided into two parts; a central control, which considers the external conditions and an individual room control [1]. Commonly in Scandinavian countries, the supply temperature is feed-forward controlled based on the outdoor temperature while a thermostatic on/off control operates on the room level in order to avoid over temperature due to heat gains with unexpected intensity.

A concrete floor slab, which embeds a hydronic pipe circuit, comprises a significant thermal mass that leads to a delay time between the heat supply and the response in indoor temperature. A drawback with conventional control techniques is their inability to compensate for the delay time and to adapt to changing dynamics [2]. Moreover, a careful tuning of PI controller parameters is required for systems with long delay times.

The major benefit of predictive control is that the heat supply can be adjusted in advance due to a prediction of the future heat demand. Hence, predictive control methods counteract the long response time of the embedded floor heating system. Lee et al. (1999) and Cho et al. (2003) [3,4] studied typical on/off control methods for floor heating in Korea (i.e. *Ondol* heating). Lee et al. (1999) [3] developed a predictive control scheme that determines the proper circulation pump on/off time for a floor heating circuit that supplies heat to an apartment room. The thermal characteristics of the studied room are determined in a learning process through the use of artificial neural network technique. Cho et al. (2003) [4] developed a predictive control, which determines the on/off time based on a weather forecast for the next day. Both Lee et al. (1999) and Cho et al. (2003) [3,4] concluded that predictive control is better than the current 2-position on/off control in terms of energy consumption.

Model based predictive control has found wide acceptance in industrial applications [5]. A model based predictive control in our floor heating application would iteratively find, through the use of a model which describes the system, the forthcoming constrained supply heat flux which optimises a certain objective function. The optimal objective function is preferably the minimal indoor temperature deviation. The historical supply heat flux and a prognosis of the forthcoming heat demand are the inputs for the optimisation procedure. Model based predictive control can explicitly take into account constraints on the signals in the system, which is an advantage in comparison to other control techniques (i.e. constraining the supply heat flux within practical limits).

Chen (1997 and 2001) and Pyeongchan (2003) [6,2,7] have applied model based predictive control in floor heating applications. Pyeongchan (2003) [7] considers a water-based system while Chen (1997 and 2001) [6,2] considers an electrical floor heating system. The aim is to improve the utilisation of free heat gains (e.g. solar gains) and to stabilise the indoor temperature within a given comfort interval. Pyeongchan (2003) [7] applies Strand's (1995) [8] heat source/sink conduction transfer function model, which is implemented in the EnergyPlus software in order to iteratively find

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