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On-line parameter estimation and optimal control strategy of a double-skin system

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A B S T R A C T

To reduce the potential problems of window systems such as undesired heat gain (loss), glare, and thermal discomfort due to asymmetric radiation, double-skin systems have been introduced. The current problem with double-skin systems is that their operation requires an adequate simulation model to realize optimal control of the system. The estimation of the parameters in the lumped model developed in a previous study [1] was based on 'laborious' off-line calibration procedure. This effort has to be repeated for every different size, different type, or differently oriented façade system. Different façade components are characterized by different thermal and optical properties of glazing and blind slats, system configurations [height, width, depth], other simulation variables, etc. For each type the parameter set in the lumped model has to be established through a calibration procedure. In view of micro climate variations even same type systems within one façade but on different heights may have to be calibrated separately. In order to avoid the laborious off-line calibration of every single façade component, an on-line self-calibrating procedure is developed in this paper. The true advantage of the technique is that every component can be pre-wired and ready to be hooked to the calibration set-up when it is brought to the site. The paper will explain the simulation model, selection of calibration parameters, and the process of on-line self-calibration, model validation and application of optimal control. It is shown that the on-line self-calibrating simulation model far outperforms the off-line calibrated model. Consequently, the plug and play self-calibration technique will render the current *in-situ* 'laborious' off-line calibration process obsolete.

1. Introduction

Concerns about the earth's environment such as the depletion of fossil fuels, global warming, and greenhouse gas have stimulated the effort of reducing building energy use. As a part of these efforts to save energy, there have been many studies on optimal HVAC system control and Building Energy Management System (BEMS) control [2–5]. Even though these efforts help to minimize building energy use, they cannot lessen the excessive heat gain (loss) through the building envelope. Therefore, in order to reduce the total energy use, there should be a way to reduce heating/cooling load from the building envelope. In particular, transparent envelopes should be carefully designed due to high U-values. A double-skin system can be a solution to the aforementioned issues and has already been applied to many buildings.

The current problem of a double-skin system is that the applied control is not model-based dynamic control but a straightforward rule-based control [6]. The fundamental principle of rule-based control is "if this, do that" under certain circumstances, and the rule is generally based on expert knowledge. But the disadvantage of this approach is that the rule-based control cannot exactly reflect the dynamic behavior of the system. This is only based on the current state information. However, this approach is widely used in the industry since it is simple and straightforward [6]. In contrast, the model-based dynamic control provides more accurate and better control since it is based on the predicted response of the system [7,8]. In order to achieve the dynamic control, a simple model but accurate enough is required.

Hence, the objectives of the paper are (1) to develop a self-calibrating simulation model required for optimal control, and (2) using the model, to achieve the real-time optimal control of a double-skin system. To accomplish the aforementioned objectives, it is necessary

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