Applied Thermal Engineering 40 (2012) 267–274

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Toward integrated building design: A parametric method for evaluating heating demand

Issa Jaffal*, Christian Inard, Emmanuel Bozonnet

LaSIE, University of La Rochelle, Avenue Michel Crépeau, 17042 La Rochelle, France

ARTICLE INFO

Article history:
Received 1 July 2011
Accepted 2 February 2012
Available online 9 February 2012

Keywords:
Building energy efficiency
Building simulation
Design of experiments
Energy demand
Low-energy buildings
Overall building design
Parametric model
Statistical model

ABSTRACT

In this study, we describe a novel method for evaluating building heating demand based on a statistical approach. Our aim is to support integrated building design by providing fast modeling with accuracy close to that of dynamic simulations. A general parametric model encompassing overall building design is proposed based on the analysis of heat transfer. The method is subsequently applied to evaluate the heating demand of a single-family house in a cold French climate. Several polynomial functions are derived from the general model as functions of the amounts of heat transferred by different mechanisms and the physical and geometric building parameters. The model is identified with a small number of dynamic simulations using the design of experiments. The model illustrates how the weighting factors for the various amounts of heat are much higher in cold climates than in hot ones. We demonstrate that building heating demand can be accurately analyzed using the design parameters of the developed model. This analysis highlights the potential of this approach for supporting building energy designers in the choice of energy-efficient solutions.

1. Introduction

The building sector has a significant potential for mitigating problems linked to energy demand and its subsequent climatic, environmental and economic issues. The development of low-energy buildings is currently one of the most important objectives in many environmental programs worldwide [1–3]. These programs consider a sharp decrease in heating demand to be a key factor for improving building energy efficiency.

Energy-efficient solutions can be obtained by combining various energy-saving building components with high-performance equipment and optimally controlled operations. However, this holistic approach, once adopted, can lead designers to make complex choices considering the numerous constraints on overall building design, due to such requirements as occupants' needs (functionality, comfort, aesthetics, etc.), acceptable investment costs, and low environmental impact.

Due to the high number of requirements and building components that influence energy performance, an integrated building design is an inherently difficult problem to formulate and solve. To date, a systematic approach to integrated building design has not yet been reported, and building design has been based instead on experience and intuition [4].

An integrated design approach begins with an investigation of the building design targets and the possible forms and solutions of the building project. This is the intelligence, the first phase of Simon's decision-making process [5], which is followed by design, choice, and review. Specific decision tools should be used to assess energy-performance aptitude, which is crucial for the design, the second decision-making phase, conducted prior to making and validating design choices [5]. The development of these decision-support tools can be aided by the development of rapid and accurate building energy-assessment tools.

The aim of this study is to present a general parametric method for evaluating building heating demand that will be useful in the further development of decision tools for integrated building design. Such parametric models, obtained by regression from dynamic simulation results, combine the speed of simplified models and the accuracy of dynamic models [6,7].

The relevant model coefficients can be identified, as in the case studied in this work, with the design of experiments [8–12]. This statistical method is used to obtain detailed information about the effect of the inputs of a system on the corresponding output. It allows for choosing a small number of experiments to be performed to identify a parametric model.

The design of experiments has been used previously in building energy performance [13–15], thermal comfort [16], HVAC systems [17,18], and urban heat islands [19] studies. In an initial approach, we developed a model for the evaluation of building heating demand

* Corresponding author. Tel.: +33 5 46 45 86 24; fax: +33 5 46 45 82 41.
E-mail address: issa.jaffal@univ-lr.fr (I. Jaffal).

1359-4311/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2012.02.005