BUILD SIMUL (2011) 4: 335 – 340
DOI 10.1007/s12273-011-0051-6

Optimization of variables in air conditioning control systems: Applications of simulations integrating CFD analysis and response factor method

Kyosuke Hiyama (✉), Shinsuke Kato

Institute of Industrial Science, The University of Tokyo, 4-6-1 Komaba, Meguro-ku, Tokyo 153-8505, Japan

Technical Note

Indoor/Outdoor Airflow and Air Quality

Abstract

The integration of three-dimensional spatial distributions into building simulations is of significant interest, and computational fluid dynamics (CFD) analysis is widely employed in building design processes. For example, based on the experience of architects and engineers, CFD analyses are often conducted under steady boundary conditions to determine the degree of attainment of indoor environments. However, CFD analyses have large calculation costs and cannot be often used for simulations with unsteady boundary conditions such as energy simulations in the building design processes. Thus, we developed a method that calculates sensitivities from heat sources to an arbitrary point in an indoor environment and integrates them into simulations with unsteady boundary conditions. In the proposed method, CFD analysis is employed under steady boundary conditions to calculate the response factors, and the resulting sensitivities are integrated into simulations under unsteady boundary conditions. In the present study, the proposed method was applied to optimize the variables of an air conditioning control system. With our method, temperature changes at a sensor over time are calculated from the time series of air supply temperature. In total, 800 calculations were conducted, and the optimal variables that allow the temperature at the sensor to reach the target value quickly were obtained. Except for the time required to calculate the response factors, the optimization in the present study took only a few seconds. If only CFD analysis was used for the optimization, the calculations would take a year. Thus, calculating the sensitivities via CFD analysis and utilizing the results in simulations is a useful approach for solving optimization problems. Moreover, the proposed method is applicable to simulations that require three-dimensional spatial distributions to enhance the accuracy of the calculation such as energy simulations.

Keywords

response factor,
CFD,
optimization,
temperature distribution,
air conditioning control,
thermal environment

Article History

Received: 5 July 2011
Revised: 9 September 2011
Accepted: 13 October 2011

© Tsinghua University Press and Springer-Verlag Berlin Heidelberg 2011

1 Introduction

Indoor climates have a three-dimensional spatial distribution because airflow is three-dimensional. To understand building performance, spatial distributions must be integrated into building simulations. Thus, in recent years, many attempts have been made to integrate spatial distributions (Zhai et al. 2002; Bartak et al. 2002; Takemasa et al. 2007). For example, researchers have developed methods to combine computational fluid dynamics (CFD) analysis with energy simulations. However, in the majority of these studies, a CFD analysis directory was employed, which has the same limitations as CFD analysis under unsteady boundary conditions (Chen 2011). Due to the dramatic development of computational technology, CFD analysis has become a common tool for architectural design. However, the method is difficult to apply, and usage is limited to verifying the performance of a building's design. Moreover, CFD analysis is not suitable for calculations that require repeated analysis for optimization. Nevertheless, design quality increases when CFD analysis is used to assess three-dimensional spatial distributions (Suga et al. 2010). One method of employing CFD analysis in the design process is to utilize the technique under limited boundary conditions. However, the number of cases must correspond to an acceptable calculation cost. Thus, a method that can be applied to a limited number of cases is needed.

To meet the aforementioned requirements, we developed

E-mail: hiyama@iis.u-tokyo.ac.jp