Building and Environment 46 (2011) 82–88

Contents lists available at ScienceDirect

Building and Environment

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

On the effect of turbulent intensity towards the accuracy of the zero-equation turbulence model for indoor airflow application

K.C. Ng [a,*], M.A. Abdul Aziz [a], E.Y.K. Ng [b]

[a] Department of Research and Applications, O.Y.L. R&D Center, Lot 4739, Jalan BRP 8/2, Taman Bukit Rahman Putra, 47000 Sungai Buloh, Selangor Darul Ehsan, Malaysia
[b] School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Singapore

ARTICLE INFO

Article history:
Received 24 May 2010
Received in revised form
5 July 2010
Accepted 5 July 2010

Keywords:
Indoor airflow
Zero-equation turbulence model
CFD
HVAC

ABSTRACT

The zero-equation turbulence model for indoor airflow applications proposed by Chen and Xu [4] has obtained immense popularity amongst the CFD practitioners in HVAC industry. A uniform turbulent intensity of 10% has been assumed in their model. In this paper, following the analogy of Chen and Xu [4] in deriving the coefficient of their zero-equation turbulence model (0.03874) which is indeed expressed as a function of turbulent intensity, the effect of turbulent intensity value assumed in the model towards the solution accuracy is investigated in this paper. Three indoor airflow cases, i.e. forced convection, natural convection and mixed convection problems are studied. It has been discovered that as the assumed uniform turbulent intensity T_i is reduced, the solution accuracy is significantly improved and the prediction comes closer to those of the two-equation standard k-ε model, LES model as well as the experimental data.

1. Introduction

Since the first proposal of the zero-equation turbulence model (thereafter denoted as CHENXU model in the rest of the paper) for indoor airflow simulation by Chen and Xu [4], this model has been gaining immense popularity amongst the CFD practitioners in HVAC industry. The subsequent validation examples demonstrated by Srebric et al. [14] further show that the computed air velocity and temperature distributions by using the CHENXU turbulence model agree considerably well with the measured data, even in those complex indoor airflow scenarios. Nowadays, CHENXU model has been adopted in a wide range of airflow applications.

Concerning on the use of CHENXU model in the coupling of Energy Simulation (ES) and CFD, Zhai et al. [16] have described some efficient approaches to integrate both ES and CFD. Following this, Zhai and Chen [17] integrated ES with a CFD program and studied the existence, uniqueness, convergence and stability of the numerical solutions from the coupled programs. They have also outlined briefly a coupled ES and CFD program with different coupling methods in a separate paper [18]. As reported in their work, CHENXU model was used in the ES–CFD coupling program mainly to reduce the computing time of CFD. Bartak et al. [1], on the other hand, have utilized results of CHENXU model to initialize the field variables computed using the standard k-ε model. This is similar to the adaptive conflation controller implemented in the ESP-r program by Morrison [11], whereby the controller incorporates the CHENXU model in investigative simulation stage to approximate the flow regime in order to establish appropriate modeling approaches. Djunaedy et al. [7] have adopted the CHENXU model during the implementation of external coupling between ES and CFD, mainly because it requires less computational resources.

Besides that, CHENXU model has been widely applied as well in studying the dispersion of particle. For example, Zhao et al. [23] have investigated the diffusion characteristics of aerosol particles. In year 2005, Zhao et al. [26] have computed the distribution of particles generated by normal respiration and coughing. Zhang and Zhao [21] have simulated the indoor particle pollution from coal combustion for a typical home in Xuanwei, China. Dispersion of particles with aerodynamic diameter of 0.5–10 mm in a room ventilated by a personalized ventilation system has been computed by Zhao and Guan [27]. Factors influencing the particle deposition in indoor environments have been analysed as well by Zhao and Wu [28]. By using the Lagrangian Discrete Random Walk model and mixture models, indoor particle dispersion in a three-dimensional ventilated room has been simulated by Zhao et al. [29]. Following this, a model has been developed by Zhao and Wu [30] to predict particle fate in the entire ventilation system by calculating the particle concentration and deposited particle quantity. In a separate

* Corresponding author.
E-mail address: ngkhaiching2000@yahoo.com (K.C. Ng).

0360-1323/$ – see front matter
doi:10.1016/j.buildenv.2010.07.002