Building and Environment 46 (2011) 245–252

Contents lists available at ScienceDirect

Building and Environment

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

Modeling deposition of particles in vertical square ventilation duct flows

Ran Gao, Angui Li*

School of Environmental and Municipal Engineering, Xi'an University of Architecture and Technology, 710055, Shaanxi, Xi'an, PR China

ARTICLE INFO

Article history:
Received 20 May 2010
Received in revised form
19 July 2010
Accepted 20 July 2010

Keywords:
Particles
Ventilation ducts
Computational fluid dynamics
Lagrangian eddy lifetime model
Dimensionless deposition velocities of particles
Reynolds-averaged Navier–Stokes equations

ABSTRACT

The presence, flow, and distribution of particle in heating, ventilation, and air-conditioning (HVAC) ducts influence the quality of air in buildings and hence the health of building occupants. To shed a better light on the flow of particles in HVAC ducts this a paper has considered the effects of drag, lift force, gravity, Brownian diffusion, and turbulent diffusion on the dimensionless deposition velocity of particles in smooth vertical ventilation ducts using fully developed and developing velocity profiles. Based on the Reynolds stress transport model (RSM) at two different air velocities, 3.0 m/s and 7.0 m/s, the aforementioned effects were predicted using Reynolds-averaged Navier–Stokes (RANS)–Lagrangian simulation on square shaped ducts under vertical flows.

Preliminary results suggest that the gravity of particles does not directly change the dimensionless deposition velocity in vertical flows. Nevertheless, the gravity of particles contributes to changing the Saffman lift force. It is thus the Saffman lift force that directly changes the dimensionless deposition velocity of particles in vertical flows. In addition, the difference in the dimensionless deposition velocities between fully developed and developing flows is owing to the turbulent diffusion, turbulent intensity, and needless to say, the Saffman lift force under different dimensionless particle relaxation time.

1. Introduction

The mechanisms of deposition of particle in ducts can be applied to a number of fields including contaminants control, filtration, and aerosol sampling. Particle deposition can influence the size distribution of particles along ducts as a result of drag, lift force, gravity, Brownian diffusion, and turbulent diffusion. Knowing the particle size distribution in ducts can help estimate the exposure of building occupants in HVAC-supported buildings.

Size distributions of deposited particles in HVAC ducts have not been fully investigated. One study showed that the total mass of the deposited particles in an HVAC duct was likely to be dominated by large particles, debris, and fibers [1]. Other studies have reported that particle deposition alters the quality of indoor air in HVAC-based buildings. M.S. Zuraimia (2007) and Chaosheng Liu (2006) suggested that particle deposition on the interior surfaces of ducts can lead to more microorganisms and secondary pollutants generations hence affecting the quality of indoor air occupants breathe [2,3]. In addition, for small size ducts, particle deposition reduces the airflow rate and hence degrades the efficiency of the ventilation system. Therefore, predicting particle deposition in HVAC ducts is important to improve the indoor air quality, and to increase the efficiency of the ventilation system.

Particle deposition on the HVAC ducts of the History Museum in Shaanxi, China was investigated by our research team. The average density of particles studied was 1800 kg/m^3. It was found that the distribution frequency of deposited particles lesser and larger than 10 μm in diameter was 55% and 45%, respectively. Since particles with different diameters have different aerodynamics mechanisms, our research team has studied the deposition of particles diameters smaller than 10 μm (0.1–10 μm) in both horizontal and vertical ducts [4]. The research team has also investigated deposition of particles larger than 10 μm (10–200 μm) in horizontal ducts [5,6]. In this paper, we will focus on the deposition of particles ranging from 10 to 200 μm in vertical ducts.

Uijttewaal and Oliemans (1996) performed Lagrangian simulation of particle deposition in the inertia-moderated regime in vertical cylindrical-tube flows generated by both direct numerical simulation (DNS) and large eddy simulation (LES) [7]. Zhang and Ahmadi (2000) analyzed particle deposition on vertical and horizontal floor surfaces in a directly numerical simulation (DNS) generated channel flow [8]. The latter study is the only DNS Lagrangian simulation that includes deposition of particles on a horizontal floor surface. However, few investigations have been found using Lagrangian simulation to study the deposition mechanism in vertical ducts with the analysis of gravity, lift force and turbulent development.

Over the past two decades, empirical equations, Eulerian models and Lagrangian simulations were developed to predict

* Corresponding author. Tel.: +86 29 82202507; fax: +86 29 82202729.
E-mail address: liag@xauat.edu.cn (A. Li).

0360-1323/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.buildenv.2010.07.020