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Numerical investigation of influence of human walking on dispersion and deposition of expiratory droplets in airborne infection isolation room

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ABSTRACT

This paper introduces a numerical simulation model for investigating the influence of moving subjects on the dispersion and deposition of expiratory droplets, rather than on the dispersion of surrogate gaseous counterparts generally adopted in related research works. In our work, the Lagrangian discrete trajectory model is used for tracing the motion of droplets, the Eulerian RANS method is used for solving the airflow field, and the dynamic mesh model for describing the human movement. The model validation was performed through result comparisons with published data from literatures. A case study on the influence of human walking on the dispersion and deposition of expiratory droplets in an airborne infection isolation room (AIIR) is then presented. Our findings show that the human walking disturbs the local velocity field with wake formation. The increase of walking speed could effectively reduce the overall number of suspended droplets, which may have a positive impact on releasing the infection risk of health workers in AIIR.

1. Introduction

Saliva droplets coughed out by patients with infectious respiratory diseases are considered to be the main transporters in the droplet infection of diseases such as SARS, influenza etc. due to the viruses adhering to their surfaces [1]. A multidisciplinary systematic review by Li et al. [2], suggested that ventilation rate and airflow pattern have direct contribution to the airborne spread of infectious agents. On the other hand, the experimental work of Bjørn and Nielsen [3] indicated that a moving person could create quite strong air movement due to the wake behind the person. Micallef et al.'s field monitoring showed that airborne particulate concentration correlated well with human movement [4]. Mazumdar and Chen [5] found that airflow and contaminant transport inside a commercial airliner cabin could be influenced by moving crew and passengers. In addition, the research done by Matsumoto et al. [6,7] as well as Mattsson and Sandberg [8] also indicated that moving objects could have large influence on indoor airflow and contaminant transport. Nevertheless, so far the investigations on human respiratory droplets transport have been mostly performed without considering human movement [9–14].

The application of dynamic mesh techniques has aroused considerable interests in recent years, ranging from internal combustion engine, flapping airfoil and design of chemical mixing vessel to sports performance optimization and so on [15–18]. In some recent works, there have been attempts to involve human movement on studying indoor airflow pattern and contaminant distribution, like the dynamic mesh method adopted by Shih et al. [19,20]. Mazumdar et al. [21] studied the effects of moving objects such as walking visitor, changing of sheet, swinging of door on the contaminant concentration distribution in a single inpatient ward. However, in all these research works, researchers substituted gaseous contaminant such as carbon dioxide for patient respiratory droplets. Their results could be more credible if they used expiratory droplets rather than surrogate gaseous counterparts.

When a patient coughs, sneezes, talks or breathes, pathogen-laden droplets are released. The exhaled droplets are in the polydisperse form. Depending on the different expiratory modes of the patient, the size distribution of droplets can be quite different. In literatures, there are discrepancies in the report of droplet size range. The early studies [22–24] indicated that the diameters of droplets exhaled by human are in majority in the supermicron ranges. On the contrary, researches conducted by Papineni and Rosenthal [25] and Morawska et al. [26] showed that the majority of droplets exhaled by human are in submicron ranges. Recent research done by Chao et al. [27] revealed that the mean diameters

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