Influence of Real Breathing Conditions on the Filtration Characteristics of Respirator Filters

A.J.C. King[1,2], S. Abishek[2,3], B.J. Mullins[2,3], R. Mead-Hunter[2,3]

[1] Department of Mechanical Engineering, Curtin University, Australia
[2] Fluid Dynamics Research Group, Curtin Institute of Computing, Curtin University, Australia
[3] Department of Occupation and Environment, School of Public Health, Curtin University, Australia
Keywords: respirator, filter, pulsatile flow, CFD
* Presenting author email: b.mullins@curtin.edu.au

Passive respirators such as the N95 type Respirator, which are designed to provide protection from particulate suspensions in air are certified using NIOSH (42 CFR 84) or similar test standards. These tests typically utilize an aerosol around the expected Maximum Penetrating Particle Size (MPPS) for the filter - approximately 0.3 microns, and a constant flow rate of air (85 litres/min for the N95 test - at 95% or better capture efficiency).

However, the wearers of respirators do not inhale at a constant flow rate. The adult human breathing rate can be typically characterized as a quasi-sinusoidal pulsatile flow with frequencies in the range 10-30 breaths per minute depending on factors such as age and activity. While there is a significant body of quality research on respirators, much of this is focused on testing respirator fit and performance for specific aerosols (Vo et al. (2015)), or tests based on constant inhalation rates (Martin-Jr and Moyer (2000); Eninger et al. (2008)). The influence of the pulsatile nature of the flow through the respirator has received little attention as such flows are difficult to generate in a laboratory.

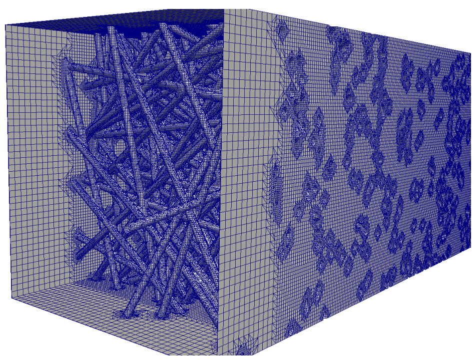

Figure 1: Representative computational surface mesh on the generated respirator filter (fibrous) media

In the present study, computational simulations are carried out to examine the (respirator) filter performance under pulsatile flow conditions which represent realistic human breathing patterns. The CFD simulations are carried out using the open source CFD package OpenFOAM with customized subroutines integrated with the solver for accurately evaluating particle-filter interactions such as particle capture. The results from the present simulations under steady and pulsatile breathing rates are compared with the corresponding predictions obtained from Single Fibre Efficiency (SFE) theory using the equivalent mean (steady) flow for each case.

A section of the representative computational domain and mesh (only surface-mesh is shown for clarity) employed for the present study is shown in Fig. 1. The realistic respirator filter geometry used for the present study is generated using an in-house code that is customizable based on filter-properties such as filter size (fibre diameter), shape, porosity, etc.

Figure 2 shows the instantaneous particle collection statistics along the direction of flow (air + particles) through the respirator filter at different instants of time, obtained from a representative simulation carried out using steady flow of air with mono-dispersed particles.

Acknowledgement
The authors acknowledge the support of Australian Research Council under Linkage Grant (LP140100919). This work was also supported by the Pawsey Supercomputing Centre, Perth, Western Australia through the use of its advanced computing facility and resources.

Eninger, R. M., Honda, T., Adhikari, A., Heinonen-Tanski, H., Reponen, T., and Grinshpun, S. A. (2008). *Ann. Occup. Hyg.*, **52**(5):385–396.

Martin-Jr, S. B. and Moyer, E. S. (2000). *App. Occup. Env. Hyg.*, **15**(8):609–617.

Vo, E., Z Zhuang, M. H., Liu, Y., He, X., and Rengasamy, S. (2015). *Ann. Occup. Hyg.*, **59**(8):1012–1021.

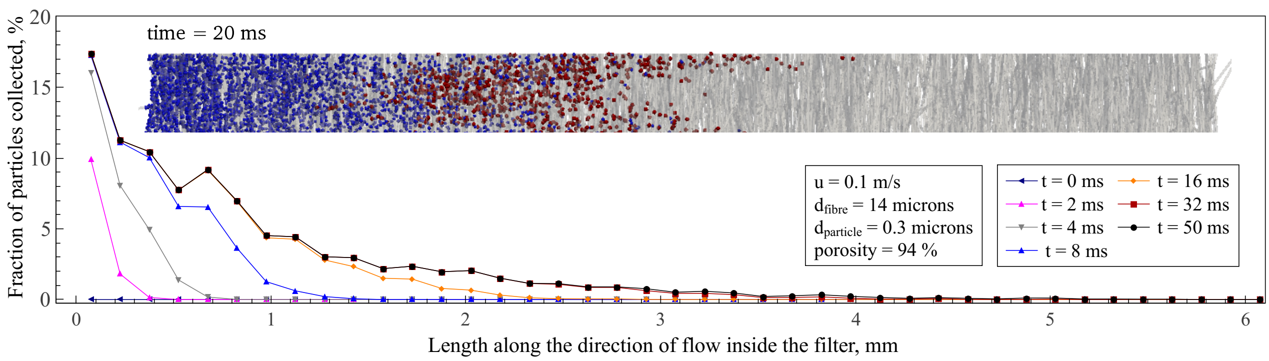

Figure 2: Instantaneous spatial variation in particle collection/ capture along the length of the fibre; blue and red color in the image indicate the particles that are in transit and that are collected, respectively