CFD simulations of particle resuspension due to human walking

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In controlled areas of nuclear facilities, workers could be exposed to radioactive aerosols. One of the airborne contamination sources is particles that are initially seeded on the floor and could be removed by workers while they are walking. In the future, EDF will increase its maintenance operations (*Grand Carénage Project*) which will involve co-activity of the workers. In order to assess occupational exposure and protect the workers, it is suitable to determine accurately the particle resuspension rates which are, up to now, estimated on the basis of empirical considerations. This study aims at improving this estimate by coupling a resuspension model to CFD calculations of airflows under a safety shoe when walking.

Firstly, an experimental study was carried out on the gait cycle. A video analysis of four workers walking with safety shoes on a treadmill allowed several parameters to be characterized (rotation speed and acceleration, angle with the floor, etc.). These parameters were used as input data for CFD calculations, performed with the ANSYS CFX code, on a rigid CAD geometry obtained by a 3D scanning of a shoe. In order to simulate the shoe movement, the immersed solid method was used, with a modified forcing term allowing the boundary layer around the immersed solid to be better described. A RANS approach was employed for modelling the unsteady and incompressible flow, with the SST k-ω turbulence model, well suited for airflows at low Reynolds number near wall. An example of the friction velocity field is presented in Fig. 1, when the shoe reaches the floor.

In order to calculate the particle resuspension due to airflows induced by the shoe movement, an adaptation of the well-known Rock'n'Roll model (Reeks and Hall, 2001) for unsteady flows was introduced in the ANSYS CFX code. The resuspension rate was determined at each cell of the floor, assuming a constant friction velocity during a very small time step (quasi-steady approach). In addition, instead of using the Biasi *et al*. (2001) correlation for the distribution of adhesion forces, we chose to implement experimental distributions obtained by Atomic Force Microscopy for our specific studied particles (alumina, cobalt oxide) and floor surface (epoxy coating, representative of paintings in nuclear plants). Lastly, the transport and deposition of airborne particles was modelled with an Eulerian approach (Nérisson *et al.*, 2011).

This approach was first validated by carrying out analytical experiments on particles suspension in a ventilated box following the fall of an inclined plate on 1 µm alumina particles deposited on an epoxy coating. The time evolution of particle concentration was measured at the exhaust, allowing the airborne released fraction (ARF) to be determined. The value obtained by simulation is in good agreement with the experimental one (ARF about 5.10^{-3}).

Further to this validation, first simulations of resuspension of 5 µm alumina particles during a gait cycle on epoxy coating was performed, and a mean resuspension rate was determined. An illustration of the particle concentration is given on Fig. 2. In next future, the simulation results will be compared to experiments of resuspension due to the human walking in a 30 m^3 ventilated chamber.

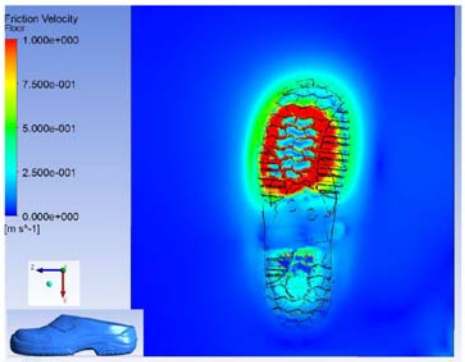

Fig. 1. Friction velocity when the shoe reaches the floor.

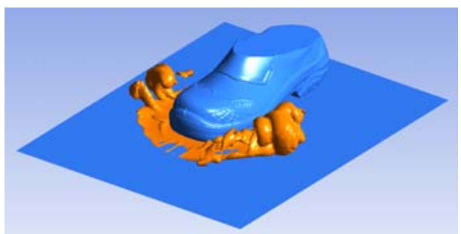

Fig. 2. Iso-surface of 5 µm particle concentration during a gait cycle.

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ANSYS CFX. http://www.ansys.com
Biasi, L., de los Reyes, A., Reeks, M.W. and de Santi, G.F. (2001). *Journal of Aerosol Science*, 32, 1175-1200.
Nérisson, P., Simonin, O., Ricciardi, L., Douce, A. and Fazileabasse, J. (2011). *Computers & Fluids*, 40, 79–91.
Reeks, M.W. and Hall, D. (2001). *Journal of Aerosol Science*, 32, 1-31.