Proceedings of the Canadian Society for Mechanical Engineering International Congress 2021
CSME Congress 2021
June 27-30, 2021, Charlottetown, PE, Canada

Computational Fluid Dynamics Modelling of Cough Droplet Trajectories and Mask Material Effectiveness

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Abstract

With rising concerns of virus transmission surrounding the global COVID-19 pandemic, the study of droplet transport via air has become extremely important. One of the most concerning vehicles of virus transmission is the expulsion of droplets in the form of coughs, sneezes, and in some cases, speaking. Larger, heavier droplets fall, landing on the ground or nearby surfaces and are less of a concern for virus transmission as surfaces can be easily disinfected. The remaining particles stay in the air and eventually evaporate, a potentially dangerous situation because it exposes droplet nuclei which may contain viral pathogens from an infected person. The exposed pathogens can be transported through the air and inhaled by others, leading to infection. Because of the high danger associated with particle evaporation in air, exploring the effect of air conditions including temperature, flow and ventilation, and humidity on droplet behaviour is desirable, and can lead to a better understanding of transmission prevention mechanisms, such as distancing and filtration.

To explore droplet patterns, a 2-dimensional computational domain was created to model a room with finite element analysis using commercial software. At one wall of the domain, a mouth was modeled with a circular inlet having a corresponding diameter where a user-defined function was applied to give the particles a velocity profile consistent with that of an average cough. Simulations were conducted to determine the flow field and droplet histories. This data was collected for different air temperatures and humidities. A 3-dimensional model was then created to further observe the spread of droplets. The numerical results were post-processed for interpretation, analysis, and data visualization. Then, working alongside a mask design team and an experimental team, the effectiveness of different mask materials to contain droplets was modelled.

Currently, there is little data available on appropriate safety measures to be followed concerning the spread of viruses within different contexts. There is also little data on the effectiveness of different mask materials to limit the propagation of expelled particles. The particle trajectories and droplet evaporation data under different circumstances will help inform safe distances between people when there is concern for virus transmission. The data collected from cycling through masks of varying materials will inform the public on which materials are best for homemade masks. These recommendations will provide information on how to stay safe during a pandemic, having the potential to reduce the spread of infection on a large scale.