

A Mathematical Framework to Calculate Facemask's Effective Filtration Efficiency in Large Population

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Abstract:

Recent studies have shown that the airborne transmission of Coronavirus Disease (COVID-19) is possible via an infected individual's release of respiratory droplets during sneezing, coughing, or talking. Due to airborne transmission of COVID-19, the use of face masks has effectively diminished the spread of the virus. However, the extent to which a mask can provide protection depends on how well the mask “fit” on the wearer's face and the mask material. The fit of a simple cloth mask is expected to vary from one face to another as each wearer has a unique facial topology resulting in unique trends of peripheral leakage and face mask efficacy. Nevertheless, this effect has not been examined and quantified so far. Here, we propose a framework to study the dynamics of peripheral leakage on a large virtual population of subjects generated from a 3D morphable face model; the mask deployment study is performed for more than 1000 distinct morphable faces and different mask shapes. We developed an analytical integral boundary layer solution to quantify the flow field in the interface region between face and mask. Face and mask are interconnected by several linearly inter-connected channels extending from the inner mouth/nose region to mask's outer edge. The top surface of each channel is porous, allowing the fluid to enter for respiration while blocking the large droplets. The compatibility condition of inlet pressure determines the flow distribution in the high-pressure region and each channel. The flow is redistributed at the entrance of each channel. The model is validated with a detailed high-fidelity flow simulation. The results show a relationship between fitness, porosity, and leakage through the mask. The inward and outward protection levels of masks are explored. Furthermore, we discuss the statistics of peripheral leakage patterns in a large cohort of faces obtained from the model.