# Measurement of the size-resolved filtration efficiency of various face mask materials up to 5 micrometres using the Aerodynamic Aerosol Classifier

S.D. Payne[1], T.J. Johnson[2] and J.P.R. Symonds[1]

[1]Cambustion Ltd, J6 The Paddocks, 347 Cherry Hinton Road, Cambridge. CB1 8DH. UK
[2]Department of Engineering, University of Cambridge, Cambridge, CB2 1PZ. UK
Keywords: Aerodynamic Diameter, Classifier, Face Masks, Filtration Efficiency, Particle Size
Presenting author email: spayne@cambustion.com

## Background

Face coverings are widely worn in public spaces under many countries' COVID-19 laws and guidelines. The intention is that coverings over the mouth and nose will protect others against the spread of infection by capturing virus-laden particles produced by the wearer. While the World Health Organisation defines aerosols as <5 µm and droplets as ≥5-10 µm in diameter, both can be generated as a continuum of particle sizes during various respiratory activities including coughing, talking and singing.

It is therefore of interest to investigate the particle size-resolved filtration properties of various face mask materials, for both inhalation and exhalation flows and across a wide range of particle sizes. The Aerodynamic Aerosol Classifier (AAC) can select particle sizes between 25 nm and >5 µm by using a rotating cylinder to classify particles with the desired aerodynamic diameter (i.e. a set ratio of centrifugal and drag forces) so that particles move across the AAC's sheath flow to its outlet. This principle of aerosol selection is independent of particle charge state and produces a truly monodisperse aerosol with a high transmission efficiency limited only by diffusion and impaction losses.

## Method

Face covering samples were mounted and sealed in a 47mm filter holder. These coverings included:

- Disposable filtering half masks conforming to the FFP1, FFP2 and FFP3 classes specified in EN 149
- Disposable surgical masks consisting of non-woven fabrics
- Cloth face coverings consisting of woven fabrics

Each sample was placed downstream of the AAC which was run at a series of rotational speeds to select aerodynamic diameters in the range 50 nm – 5 µm from a dioctyl sebacate (DOS) aerosol. For particle sizes up to 2 µm, the aerosol generator and detector were a Collison nebuliser and TSI Condensation Particle Counter 3775 respectively; beyond this size a Topas SLG-250 Condensation Aerosol Generator and a Palas Welas 1000 light scattering spectrometer were used instead.

Particle penetration tests were conducted for filter face velocities corresponding to 30 lpm and 95 lpm for inhalation and 160 lpm for exhalation through the entire mask, which are specified in EN 149 for steady-state breathing resistance tests. Subsequently, the pressure drop versus flow rate characteristic of each material sample was measured and the trade-off between filtration efficiency and breathing resistance was evaluated.

## Results

Selected filtration efficiency measurements for exhalation flow are plotted in Fig. 1 for samples cut from six commercially available face coverings.

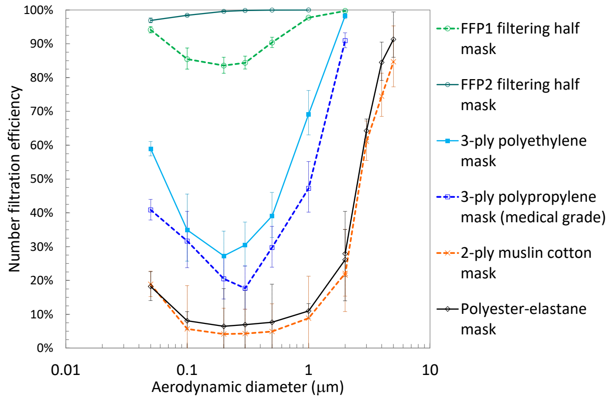


Figure 1. Number filtration of AAC-classified DOS particles through various face mask materials at 160 lpm equivalent through the entire mask

The groupings of filtration efficiency by mask material type that emerge are likely due to the different filtering fibre widths and spacings that determine efficiency of particle capture by the interception mechanism, for which the aerodynamic diameter is the most useful measure of size. The impact of interception increases as particle size approaches the fibre width and proper characterisation of the woven fabric materials in particular is reliant on the ability to classify particles up to 5 µm (it is only at this larger size range where filtration efficiency for the cloth coverings approaches 90%).

Previously, the AAC transmission efficiency and transfer function width have been characterised for particle sizes up to 3 µm (Johnson *et al.* (2018)) using a tandem AAC configuration. This study expands the AAC characterization up to 5 µm using the Palas Welas.

## Reference

Johnson, T.J., Irwin, M., Symonds, J.P.R., Olfert, J.S., and Boies, A.M. *Aerosol Science and Technology* 52 (2018) 655-665.