S3.4.2 Numerical Modeling of Air Flow Field in V-panel Intake Air Filters

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Intake air filtration system is critical for protecting turbine engines from particles, liquids, and dissolved contaminants. Different forms of air filters exist, with the most common being panels, cylindrical, and conical cartridges. The designs of these filters can influence the filter performance, such as pressure loss, filter collection efficiency, and service lifetime. In this work, we used numerical modeling based on computational fluid dynamics (CFD) to study the turbulent airflow through the V-panel filters in an attempt to understand the flow distribution. The pleated filter media in these device-level simulations were assumed to be porous blocks with the model input Darcy permeability estimated using correlations of flow velocity and pressure drop obtained through in-house experiments. The turbulent airflow field was determined by solving the Reynolds Averaged Navier-Stokes (RANS) equations. In addition to the porous-block models, we developed models of pleated filters to determine flow through the pleat and test the validity of assuming the pleated media as a porous block. Darcy permeability for these cases were obtained from flat-sheet testing of the media. Because flow characteristics were inherently laminar in the vicinity of the pleated region, a combination of Navier-Stokes and RANS equations were solved to determine the entire flow field. The CFD models were developed in ANSYS CFX and Fluent using the Workbench platform and simulations were run on our in-house high performance computing cluster. Model validation was performed by comparing the predicted pressure drops for given inlet flow rates with experimental test data. Model predictions were found to be within 5-8% of the experimental data. Results showed that there was significant non-uniformity in flow patterns and in turn, in the filter area utilization. Additionally, we found that flow patterns upstream of the filter media did not change significantly with the inclusion of pleats. However, there was a visible change in downstream flow patterns with the pleats compared to the porous block model. The models were also used to study various "what-if" scenarios, such as the effect of change in media permeability, pleat density, glue beads, adjacent filter panels, and other variables on the flow patterns. To summarize, mechanistic modeling was successfully used to understand complex flow patterns in commonly used V-panel air-intake filters. More importantly, the modeling framework can be potentially used for design optimization to accelerate product development and aid in reducing prototyping and experimental testing costs.