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Scaling Effects on Inertial Particle Separator Performance

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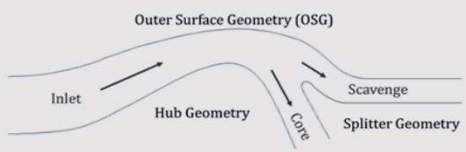
Introduction

An Inertial Particle Separator (IPS) is a filtration system that is installed at the inlet of air-breathing engines to minimize the ingestion of foreign objects, including dust and debris. As engines—and IPS systems by extension—continue to grow larger, it is important to quantify the flowpath scaling effects on particle filtration efficiency.

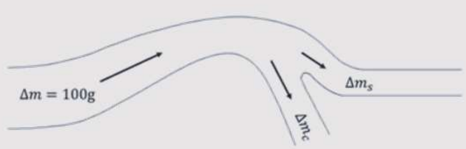


IPS Geometry and Components. *An IPS is comprised of an Outer Surface Geometry (OSG), a hub geometry, and a Splitter Geometry (also called the Inner Surface Geometry, or ISG).*

Objective

This study will investigate the effect of scaling IPS geometries on its particle separation performance using 2D Computational Fluid Dynamics (CFD). The particle separation efficiency, η, will be used to quantify filtration performance where:

$$\eta = \frac{\Delta m_s}{\Delta m_s + \Delta m_c}$$



Particle separation efficiency, η, of an IPS. *The incoming particulate mass, Δm, is separated at the bifurcation region where a fraction of it enters the scavenge, Δm_s, and the rest enters the engine core, Δm_c.*

Design

Three baseline IPS geometries, each using a different OSG, and their double-scale counterparts were studied. Each OSG featured a different scavenge channel height (quantified by s/H). An example baseline IPS geometry (left) and its double-scale counterpart (right) are shown below.

Methods

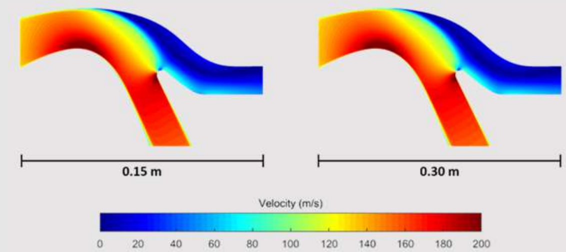
- For computational results, a mesh was generated for each IPS using ANSYS Workbench.
- The flowfields for each IPS geometry were computed using Reynolds Averaged Navier Stokes (RANS) modelling in ANSYS Fluent, using the sst-kω turbulence model.
- Particle injections were then simulated using ANSYS Fluent. Particle diameters ranging from 0.82 μm to 352.00 μm were injected allowing for separation efficiencies to be plotted against particle diameter and Stokes number.

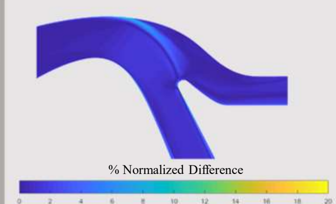
Particle Stokes Number

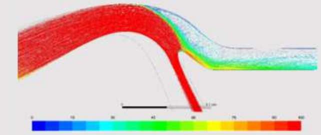
The Stokes number of a particle, St, is a non-dimensional parameter that is used to characterize how a particle moves within a fluid. The Stokes number is the ratio between the time for a particle to respond to fluid forces and the time it takes for the fluid to move across a characteristic domain.

$$St = \frac{\rho_p d_p^2}{18\mu_{air} f}\frac{u_D}{D}$$

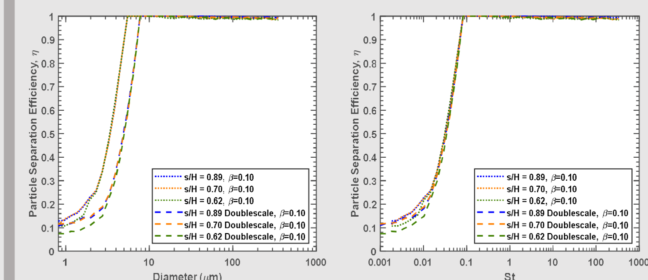
Results







Example particle track image with 3.27 μm particles.



Findings

- 2D scaling did not significantly affect the flow field characteristics of the IPS, but it is nonzero.
- As the geometry was scaled up, there was a decrease in particle separation efficiency.
- Stokes number is an effective tool for non-dimensionalization.