Inertial Filtration of Lunar Dust in Reduced Gravity

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We report experimental results on the collection efficiency of an air cyclone operating with a lunar dust simulant under lunar gravity. Microgravity collection efficiency is, to within experimental uncertainty, not different from collection efficiencies obtained in one-g experiments. CFD modeling of cyclone operation in reduced gravity supports this conclusion.

Introduction Lunar dust has been identified as a significant hazard to future lunar missions due to its presumed human toxicity[1]. In the vernacular of physiological effects associated with particulate pollution, approximately 5% of lunar dust by volume is *respirable*, having aerodynamic diameters of less than 4 μm. The adverse effects of lunar dust on machinery has been well-documented. The pervasive presence of respirable dust in the lunar environment necessitates a robust and economical means of filtration. Air cyclones are currently used in a variety of industrial and manufacturing environments as first stage filtration technologies, and may prove suitable in a similar role in lunar habitats. Here, we demonstrate that the reduced gravity of lunar environments does not preclude the use of an air cyclone on the Moon.

Central Question An air cyclone is a device that separates particles from a carrier air stream by means of a centrifugal force acting on the particles. Dust particles, initially entrained in the air flow, enter a tangential inlet near the top of the cyclone, and follow the downward spiral of the air vortex. Centrifugal force and inertial effects act on the particles to move them outward toward the inner wall of the cyclone where they are trapped in the boundary flow. Trapped particles eventually move down the inner wall and are collected in a dust cup at the base of the cyclone while the air flow reverses direction near the base of the cyclone, and exits the through the vortex finder at the top of the cyclone. The viability of air cyclones in the lunar environment is contingent on the degree to which gravitational settling is the dominant mechanism of particle collection. This is the question addressed in the present work.

Results and Discussion To investigate the role of gravitational settling in the performance of an air cyclone, an experiment designed to assess collection efficiency of an air cyclone was flown aboard the *Weightless Wonder*, a modified C-9 aircraft used in the parabolic flight program operated by NASA's Reduced Gravity Office [2]. Lunar dust simulant JSC-1AF (Orbitec, Inc.) was fluidized in an airstream at 10 cfm and pulled through a reverse-flow cyclone separator.

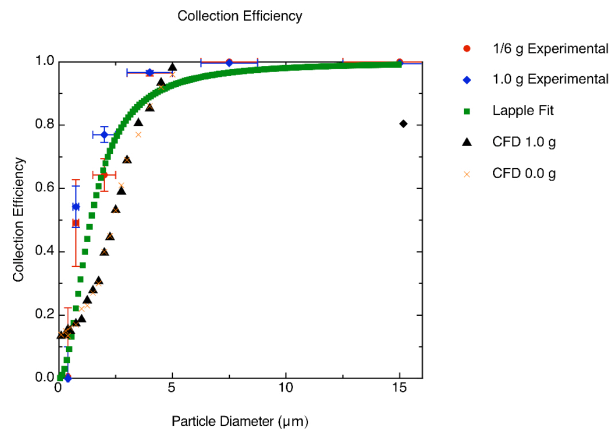

Figure 1: Experimental results (● and ◇), CFD results(▲ and ×), and Lapple Model predictions (■) for the performance of the model cyclone used in this study.

Collection efficiencies across the particle diameter range $0.3\mu m \leq d_p \leq 15\mu m$ were obtained under both 1/6 g and 1.0-g gravitational loading. To within experimental uncertainty, reduced gravity cyclone performance is not significantly different than 1.0-g performance.

CFD calculations and an analytical model of particle motion in cyclone flow were developed to understand this surprising result. Our analysis shows that particle trapping occurs primarily by entrainment of particles in the boundary flow at the cyclone wall and subsequent deposition at wall surface. Gravitational settling in the axial direction does not contribute significantly to particle collection because the time scale for centrifugal motion of particles from the cyclone interior to the wall is much shorter than the axial settling time.

References

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