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Dust Loading and Pressure Drop of Fibrous Filters for Atmospheric In-Situ Resource Utilisation on Mars 2020

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Abstract

The Mars Oxygen In-Situ Resource Utilisation Experiment (MOXIE) on the Mars 2020 rover will produce oxygen from atmospheric carbon dioxide. Dust presents a risk to MOXIE as it may clog the inlet filter. We report the results of an experimental investigation into the dust loading and pressure drop of a MOXIE flight filter and several other filter configurations in simulated Mars conditions. Dust loadings of up to 44 g m^{-2} were achieved at which a doubling of pressure drop across the filter and ground support equipment was observed. This establishes a quantitative relationship between dust loading and pressure drop for the MOXIE flight filter media.

Introduction

In-Situ Resource Utilisation (ISRU) will be demonstrated by the Mars Oxygen ISRU Experiment (MOXIE) on NASA's Mars 2020 rover [1]. MOXIE will produce O_2 by solid oxide electrolysis of Mars' atmospheric CO_2. To protect MOXIE from dust, a High Efficiency Particulate Arrestance (HEPA) filter is fitted at the intake. As the filter dust loading (dust mass per unit filter media area) increases, the filter pressure drop also increases. HEPA filter performance in Mars conditions is poorly understood. Previous work [3] achieved a modest dust loading of 0.03 g m^{-2} and detected no increase in filter pressure drop, concluding that dust is unlikely to pose a problem during MOXIE's operational lifetime (~30 hr), but left open the question of filter performance over the longer term (1200 hr, extensibility goal). The current investigation addresses two objectives using simulated Mars atmospheric conditions (10 mbar CO_2): (1) determine the dust loading as a function of time for a range of dust particle sizes and filter configurations; and (2) determine the filter pressure drop as a function of dust loading.

Equipment

The Mars Simulation Laboratory at the University of Aarhus has several recirculating wind tunnels to study dust transport [2]. The first objective (dust loading vs. time) was addressed using the large wind tunnel (Fig. 1). Five filter configurations were tested: one pleated flight filter (in position 3), and four flat filters. To investigate the effect of pumping on dust loading, filters in positions 3, 4, and 5 were connected to a pump, whereas filters in positions 1 and 2 were not. Filters in positions 1, 3, and 5 were fitted with baffles to examine their effectiveness at reducing dust load.

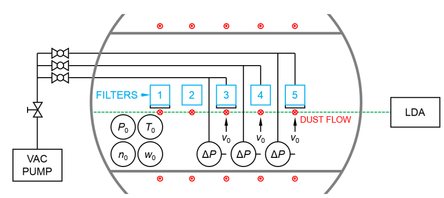

Figure 1: Experimental set-up, large wind tunnel.

The second objective (pressure drop vs. dust loading) was addressed using the small wind tunnel (Fig. 2). Three flat filters were tested: one using flight filter media (position 3), and two using an equivalent media (positions 2 and 4). Filters in positions 2 and 3 were connected to a pump. A calibration plate (position 1) was included to monitor dust loading.

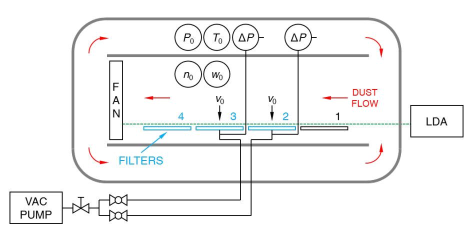

Figure 2: Experimental set-up, small wind tunnel.

Procedure

Clean filters were weighed and the pressure drops ΔP across them measured for inlet face velocities v_0 representative of MOXIE (0–8 cm s^{-1}) and above (up to 18 cm s^{-1}). Filters were then loaded with dust. Filters in the large wind tunnel were exposed to the equivalent of 1200 hours at an average dust particle number density n_0 of 4 cm^{-3} in CO_2 at a pressure P_0 of 10.3 mbar and horizontal wind speed w_0 of 3 m s^{-1}, for each dust Particle Size Distribution (PSD): the Martian dust analogue Salten Skov, mean diameter 2 µm [4], and soda-lime glass microspheres, mean diameters 4 µm and 10 µm. Filters in the small wind tunnel were loaded as rapidly as possible with Salten Skov only. The pressure drops ΔP across the loaded filters were measured, and the loaded filters weighed. All experiments were at room temperature T_0 (295 K).

Results

Dust loading rates for filters in the large wind tunnel are reported in Table 1. Pressure drops before and after dust exposure are plotted in Fig. 4. Images of filters are shown in Fig. 3 and Fig. 4.

Table 1: Dust loading rates, large wind tunnel. Passive filters (positions 1 and 2, not connected to a pump) saw negligible dust accumulation.

Filter position and type	Equivalent dust loading rate (mg m^{-2} hr^{-1})		
	Salten Skov simulant $d_p \approx 2$ µm	Soda-lime glass microspheres $d_p \approx 4$ µm	Soda-lime glass microspheres $d_p \approx 10$ µm
3: Flight, baffled	$(44 \pm 30)\times10^{-3}$	$(180 \pm 50)\times10^{-3}$	$(88 \pm 40)\times10^{-3}$
4: Flat, unbaffled	3.6 ± 0.4	2.3 ± 0.4	0.45 ± 0.4
5: Flat, baffled	2.7 ± 0.4	1.8 ± 0.4	0.45 ± 0.4

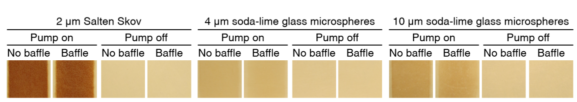

Figure 3: Colouration of filters after exposure to dust in the large wind tunnel.

Discussion

Dust loading rates for smaller dust particles were generally higher than for larger dust particles.

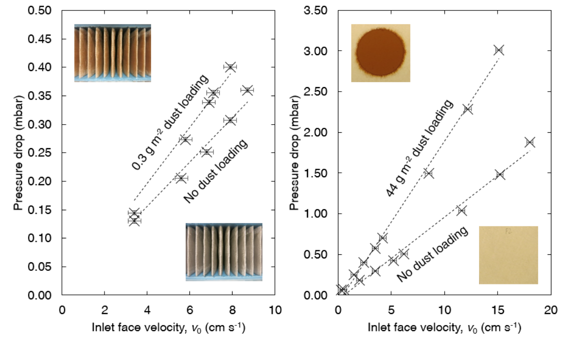

Figure 4: Pressure drop across filter and ground support equipment versus inlet face velocity, before and after dust loading, for the pleated flight filter (left, position 3, large wind tunnel) and flat flight filter media (right, position 3, small wind tunnel).

Passive filters saw negligible dust accumulation. The most heavily loaded flat filter (44 g m^{-2}) appeared caked and a doubling of pressure drop (including ground support equipment) was seen (Fig. 4). Future work has been proposed to examine dust loadings between 0 and 44 g m^{-2} to detect the onset of filter caking, the sizing case for atmospheric ISRU.

Acknowledgements

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