IMPERIAL

Space Resources Roundtable

Influence of Frequency and Pressure on the Brazil Nut Effect for Size Classification

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Introduction

Background
Lunar habitation and exploration demand effective regolith feedstock preparation with uniform size and composition. Control may be preferable for efficient oxygen and metal production, crucial for In Situ Resource Utilisation (ISRU) on the Moon.

The Brazil Nut Effect (BNE) presents a novel mechanism for size segregation without the need for process fluids.

The BNE is characterised by larger particles rising to the top of a heterogeneous granular column; the Reverse BNE (RBNE) describes opposite, whereby larger particles sink.

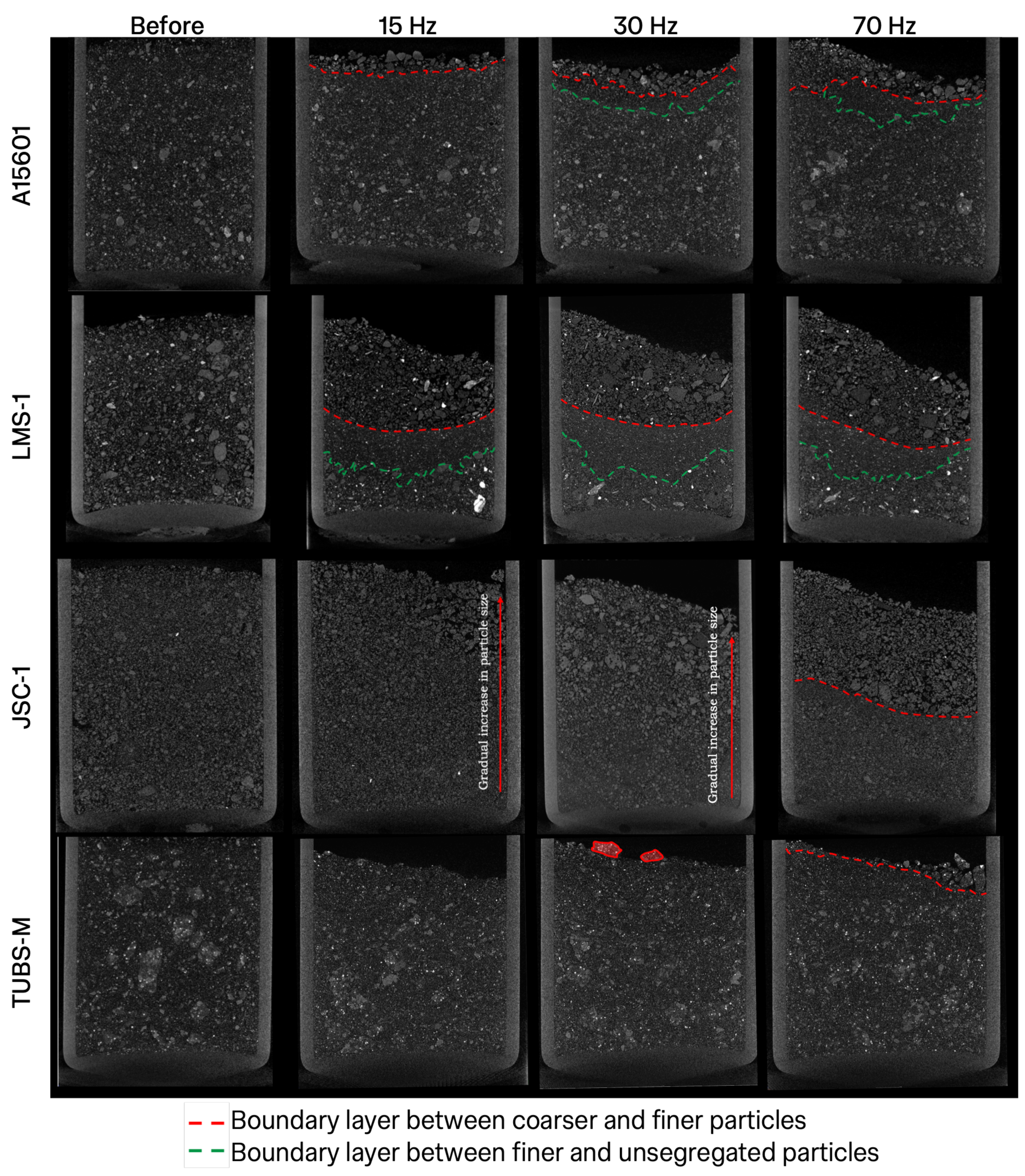

Figure 1: Cross-sectional slices of X-ray micro computed tomography (micro-CT) scans for A15601, LMS-1, JSC-1, and TUBS-M samples shaken at 15, 30, and 70 Hz from our previous investigation. This study looks to understand the role of particle size distribution and environmental conditions on the separation behaviour. Rasera et al. [Submitted for Publication, 2024].

Motivation
An initial investigation into the suitability of the BNE for size segregation used Apollo 15601 regolith and simulants JSC-1, LMS-1, and TUBS-M. Variable segregation performances were observed across the materials tested (Figure 1).

This investigation aims to understand the dynamics of the BNE with a focus on the role of vibrational frequency and vessel pressure. This will facilitate the optimisation of the BNE for ISRU.

Methodology

Soda lime glass beads (one gram, ballotini; D_{50} = 150 μm, Figure 2a) were shaken for 3 minutes under atmospheric and low-pressure (450 mbar) at 15, 30, 70, 125, and 170 Hz (Figure 2b). The peak-to-peak amplitude was 1.3 mm.

Micro-CT characterises segregation patterns and PSDs. A cylindrical core is extracted from each column centre and divided into subdomains (Figure 2c). The PSD is extracted for each subdomain.

Atmospheric pressure results in the RBNE regime at low frequencies, moving to the BNE at higher frequencies. The opposite behaviour is observed at low pressure. This observed in Figure 2e.

This behaviour is not explained by existing phenomenological models.

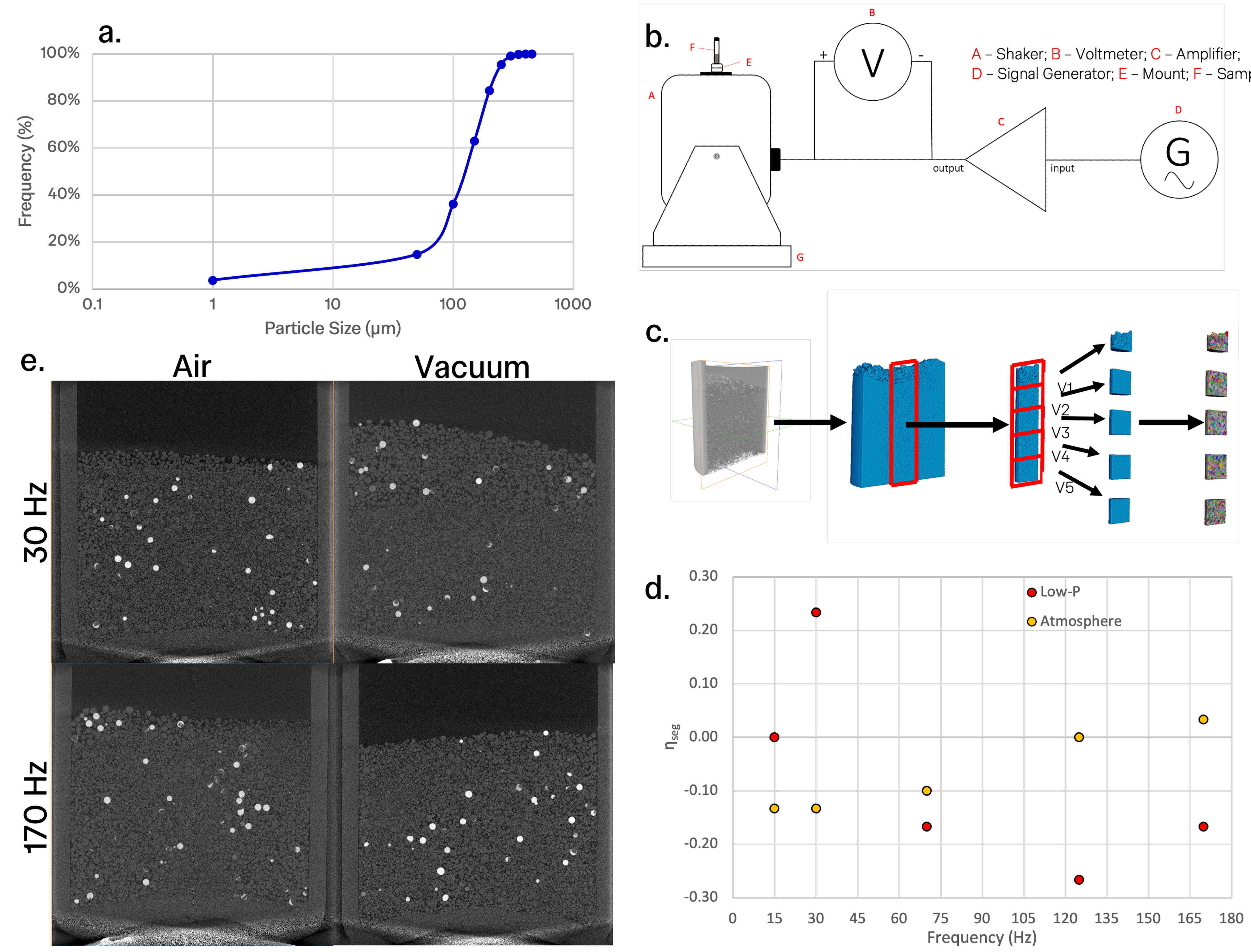

Figure 2: (a) PSD of the ballotini sample; (b) schematic of the shaker apparatus; (c) micro-CT segmentation methodology; (d) particle size distributions measured from micro-CT images; (e) micro-CT cross-sections of the 30 and 170 Hz experimental conditions.

The segregation efficiency is calculated by:

$$\eta_{seg} = \frac{D_{50,top} - D_{50,bottom}}{D_{50,net}} \qquad (1)$$

Positive values indicate a BNE-driven size segregation; negatives indicate RBNE.

Results & Discussion

Table 1 and Figure 2d summarises the delta between the top and bottom subdomains.

Table 1: Segregation efficiency at different frequencies for atmospheric and low-pressure conditions.

	Frequency (Hz)				
P	15	30	70	125	170
Atm.	-0.13	-0.13	-0.10	0.00	0.03
Low	0.00	0.23	-0.17	-0.27	-0.17

Increasing frequency resulted in appreciable bed compaction; the bed height reduced by 40% between 70 and 170 Hz.

Conclusions

The pressure within the sample vial has a direct impact on the segregation behaviour of a mixed granular medium. Segregation mode is frequency dependent. The observed behaviour **is not** explained by existing models.

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