PROTOTYPE OF A MULTI-STAGE SIFTER FOR MECHANICAL SEPARATION OF LUNAR REGOLITH

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ABSTRACT

The multi-stage sifter was developed as part of the DISTOBEE project for the ESA “2nd Space Resources Challenge”. This system is specifically engineered to separate regolith into three size fractions: below 125 µm, 125–500 µm, and 500–1000 µm, using brushes and vibrations. A systematic parametric study was conducted to identify favorable operating parameters and component geometries.

The examined variables included the number of brush arms per level, brush geometry and contact pressure, vibration frequency, brush rotational speed, and the overall axial inclination of the unit. A key functional feature is the dual-mode operation of the brush system. By reversing the drive shaft direction, the brushes switch between a sifting mode and a discharge mode, actively conveying processed material from the sieve center toward the outlets. The axial inclination ensures controlled material transport across the sieve surfaces, hence brushing and vibrations can sustain effective screening within the sifter without any additional transport mechanisms. The small cameras enable an operator to monitor the sifting process in real time. The experimental phase of our research provided clear guidance on operating ranges and design choices to improve the repeatability and reliability of multi-stage sifting scenarios. The prototype was tested under realistic operational conditions, demonstrating its capability in harsh environments.

OPERATING PRINCIPLE

The three-stage sifter integrates stacked sieves (1) with mesh sizes of 1000 µm, 500 µm, and 125 µm, respectively. The final-stage sieve has a larger surface area to improve the flow of fine particles. Each processing stage is equipped with brushes integrated into custom-shaped rotary arms (2) and vibrators to facilitate material flow. Dedicated discharge chutes (3) route the segregated regolith fractions from the sieves into their corresponding collection containers (4).

The system operates in two consecutive modes. Upon delivery from the DISTOBEE excavator, the **sifting mode** segregates the regolith through the stacked sieves. Subsequently, reversing the drive shaft's rotation activates **discharge mode**, routing the sorted fractions through the outlets into their respective containers. The operator can monitor the sifter's operation using cameras mounted beneath each sieve.

Fig.1 Side view of the multi-stage sifter prototype

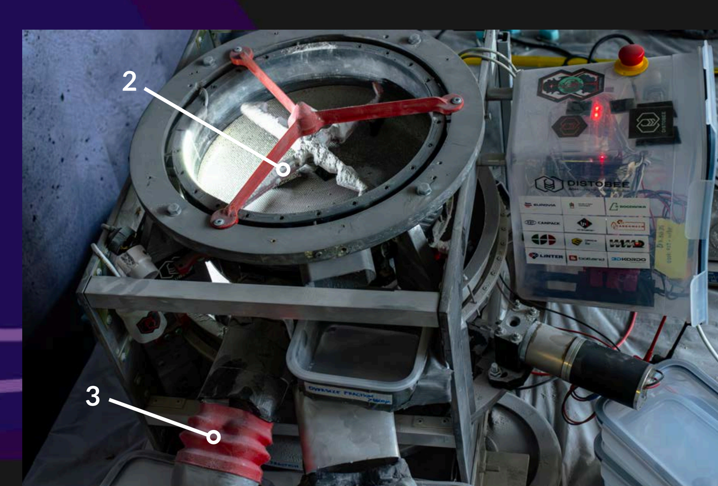

Fig.2 Multi-stage sifter layout highlighting the screening mechanism

DISTOBEE
AGH Lunar Resources Initiative

The DISTOBEE system was developed in response to the requirements of the ESA “The Second Space Resources Challenge”, an international competition focused on technologies for the collection and processing of lunar regolith for in-situ resource utilization (ISRU). The system was engineered to excavate, transport, and mechanically process lunar regolith simulant under strict mass and energy constraints. The sieving module demonstrated high efficiency in fraction separation. The multi-stage sifter, which is a core component of the DISTOBEE system (Fig.3), was successfully presented during the competition finals, where it underwent field testing at the “LUNA” analog facility in Germany under simulated lunar conditions.

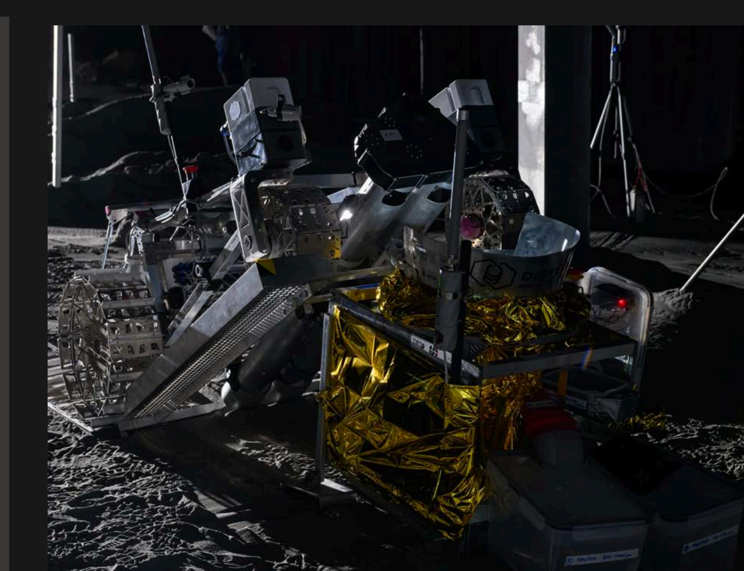

Fig.3 DISTOBEE system during ESA "2nd Space Resources Challenge"

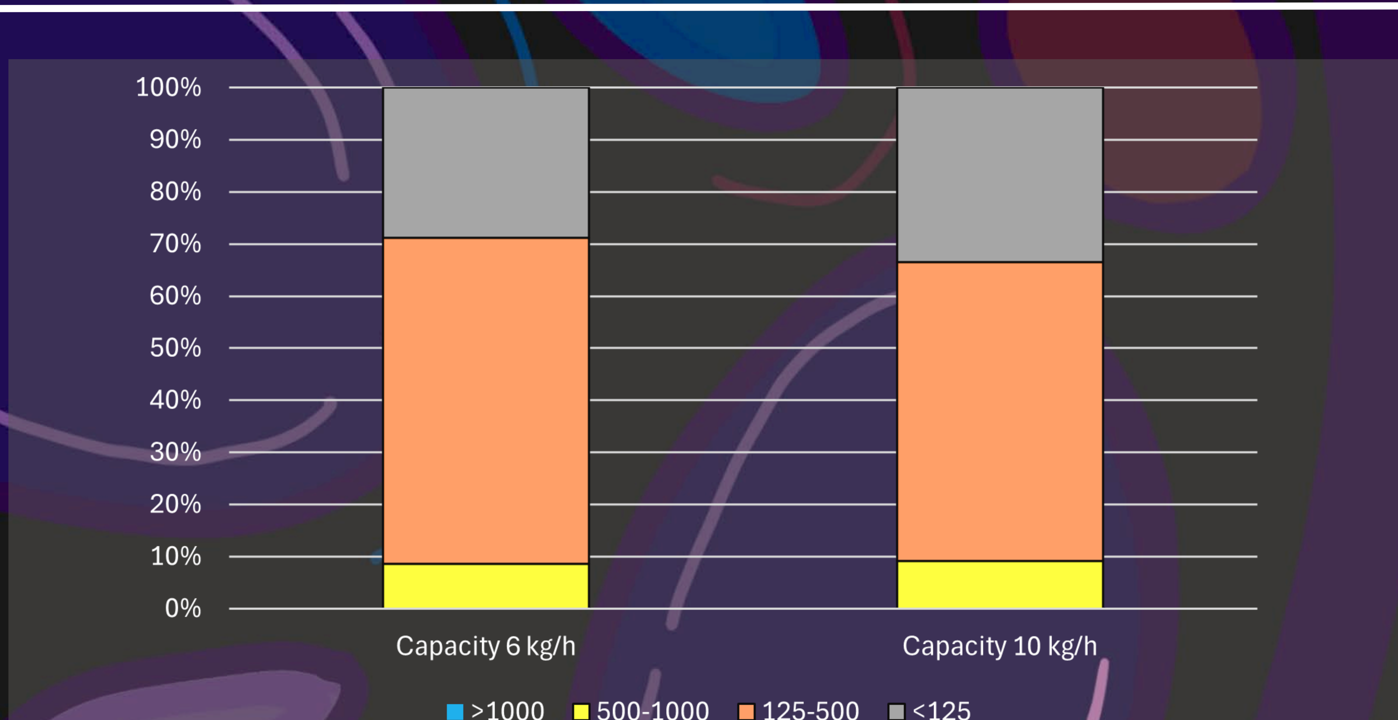

Fig.5 Effect of capacity on screening efficiency

LABORATORY TESTS

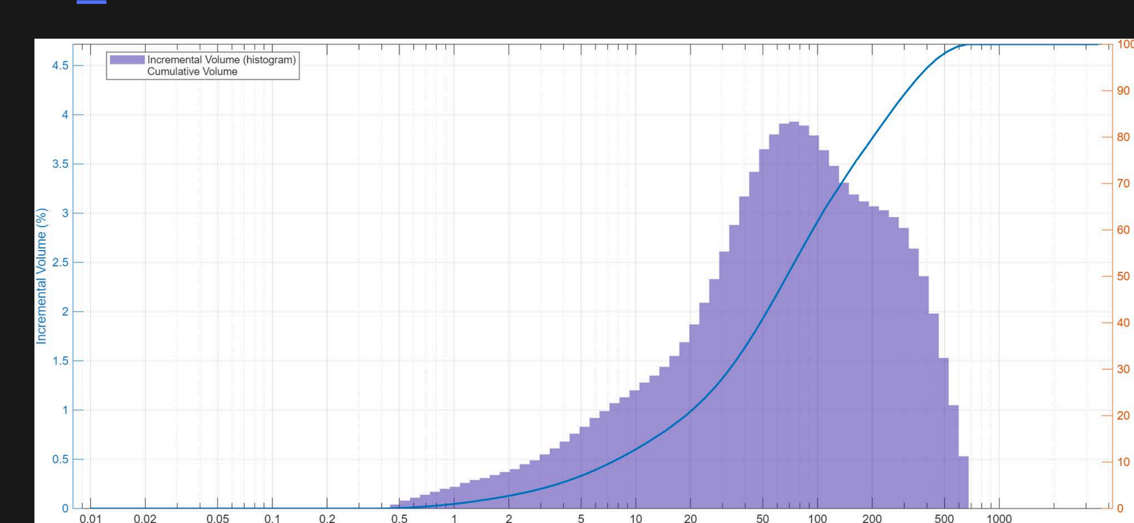

Fig.4 Particle size distribution of the tested lunar regolith simulant

The analysis presented in Fig. 4 utilized a lunar regolith simulant pre-screened through a 1000 µm sieve, with its particle size distribution determined via laser diffraction. The results indicate that the cumulative share of the fine fraction (particles < 125 µm) reached approximately 68%. This value establishes a critical benchmark for the theoretical maximum screening efficiency, as it defines the total mass fraction capable of passing through the finest sieve apertures.

To evaluate the time-dependent screening efficiency, a laboratory test was conducted by feeding material pre-screened below 500 µm onto a 125 µm sieve. During the experiment, the mass of the undersized fraction was recorded at increasing time intervals, starting at 30 seconds. Testing continued until the cumulative mass approached the fine fraction content previously determined via laser diffraction analysis, which was 68%. After 9 minutes of operation, the collected undersized material reached 63% of the initial feed mass. This corresponds to a screening efficiency of 95% relative to the laser-derived reference value.

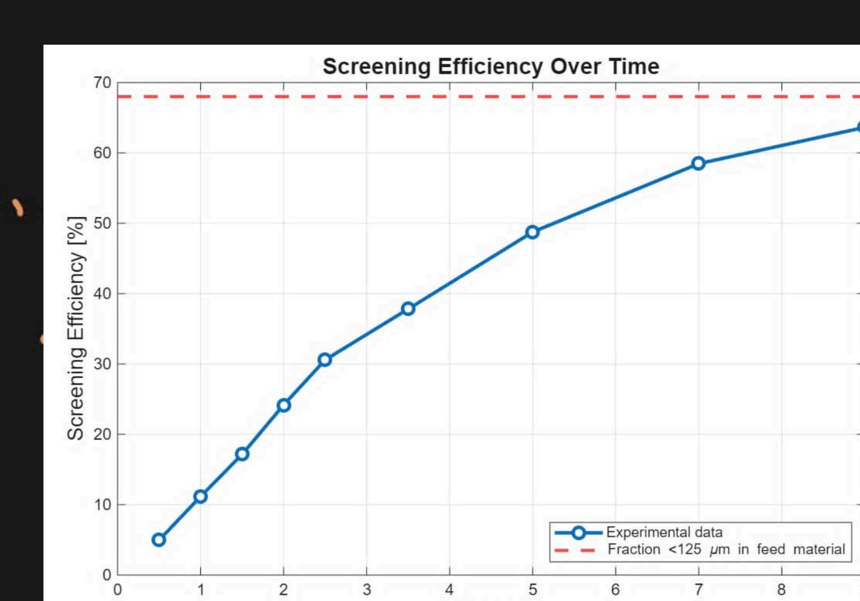

Fig.6 Sifting efficiency of the 125 µm screen for the initial regolith simulant

CONCLUSION

The purity of the obtained regolith fractions depends primarily on processing time - extended sifting durations enhance separation efficiency. This relationship allows for optimization between fraction quality and operational throughput based on specific mission requirements. However, the improvement gradually approaches an asymptotic limit, where further sifting does not lead to any significant mass flow through the sieve.

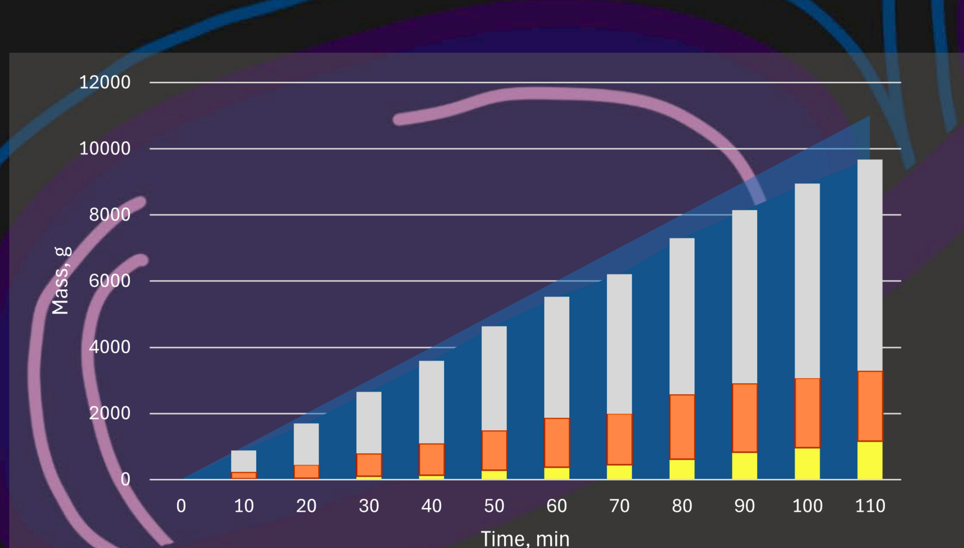

Fig.7 Mass balance and material distribution into individual fractions

The time-course of the experiment is illustrated in Fig. 7, with the specific shaded areas representing the total input feed mass compared against the final total output mass. The data indicate material losses occurring during the process, primarily due to regolith retention within the sifter and losses to the environment.

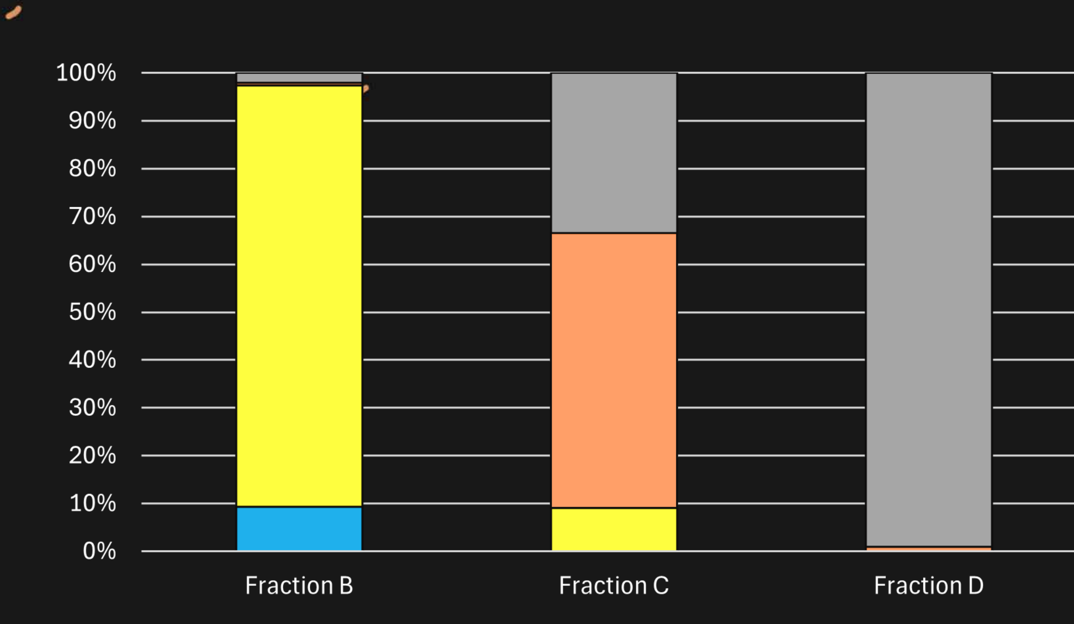

Fig.8 Purity of obtained fractions at capacity of 6 kg/h

The lunar regolith simulant was processed in 10-minute cycles, consisting of a 9-minute sieving phase followed by a 1-minute discharge. Post-experiment particle size analysis (Fig.8) revealed varying purity levels across the recovered materials - 88.11% for Fraction B, 57.40% for Fraction C, and 99.07% for Fraction D. Fraction A was not recovered during this specific test.

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