Experimental optimisation of lunar regolith beneficiation for the production of an Ilmenite-rich feedstock

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1. Introduction

The space industry is moving towards increasing sustainability for operations of a long duration space mission and eventually a permanent space settlement. In-situ resource utilization (ISRU) technologies will play a major role in realizing this vision. As moon is the current object of interest, the lunar regolith becomes the most abundantly available source of different minerals on the lunar surface. One such mineral is Ilmenite which is an ore of titanium as well as a source for oxygen. Previous research shows that Ilmenite is a more energy efficient source for extraction of oxygen compared to other minerals such as silicates. However, Ilmenite deposits on the lunar surface are scattered and not as high as the silicate minerals.

Therefore, beneficiation of the lunar regolith for increasing the Ilmenite content to maintain process efficiency is important for the potential oxygen process chain. The research published in this poster is a part of the lunar regolith beneficiation project undertaken at the German Aerospace Center in Bremen by the Synergetic Material Utilisation research group. A test setup is developed for beneficiation of lunar regolith to separate Ilmenite from the rest of the particles in the lunar regolith and produce an enriched feedstock that can be further used for extraction of oxygen and/or other metals.

2. Beneficiation test setup

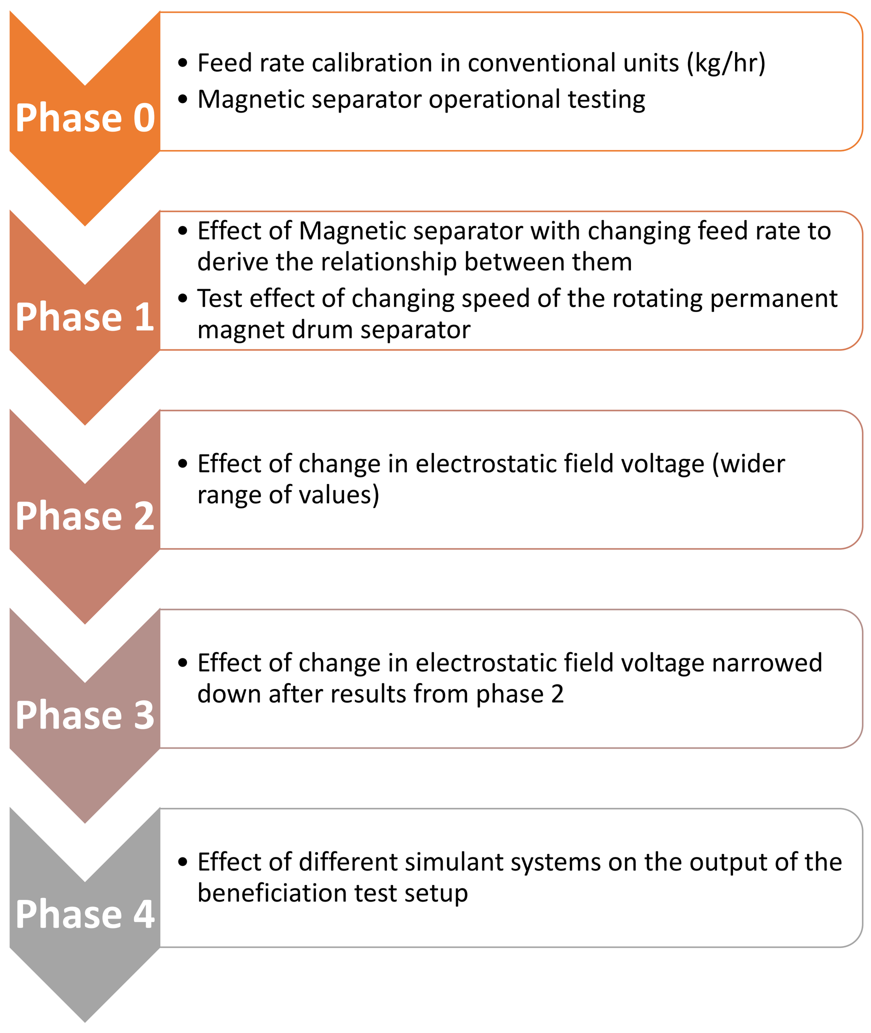
The beneficiation test setup is a multi-stage processing unit that comprises of gravitation, magnetic and electrostatic beneficiation techniques for sequential beneficiation of the input lunar regolith simulant. It starts with a vibratory feeder followed by a horizontal sifter that filters the regolith based on the particle size. The next stage is a permanent magnet rotating drum separator that filters out the ferromagnetic agglutinates and dust particles. The last stage consists of a tribocharging setup with electrostatic plate separator at the bottom which further separates Ilmenite from the other phases present in the lunar regolith. The system schematic and the beneficiation test setup are both shown in the figures below.

3. Experimental evaluation

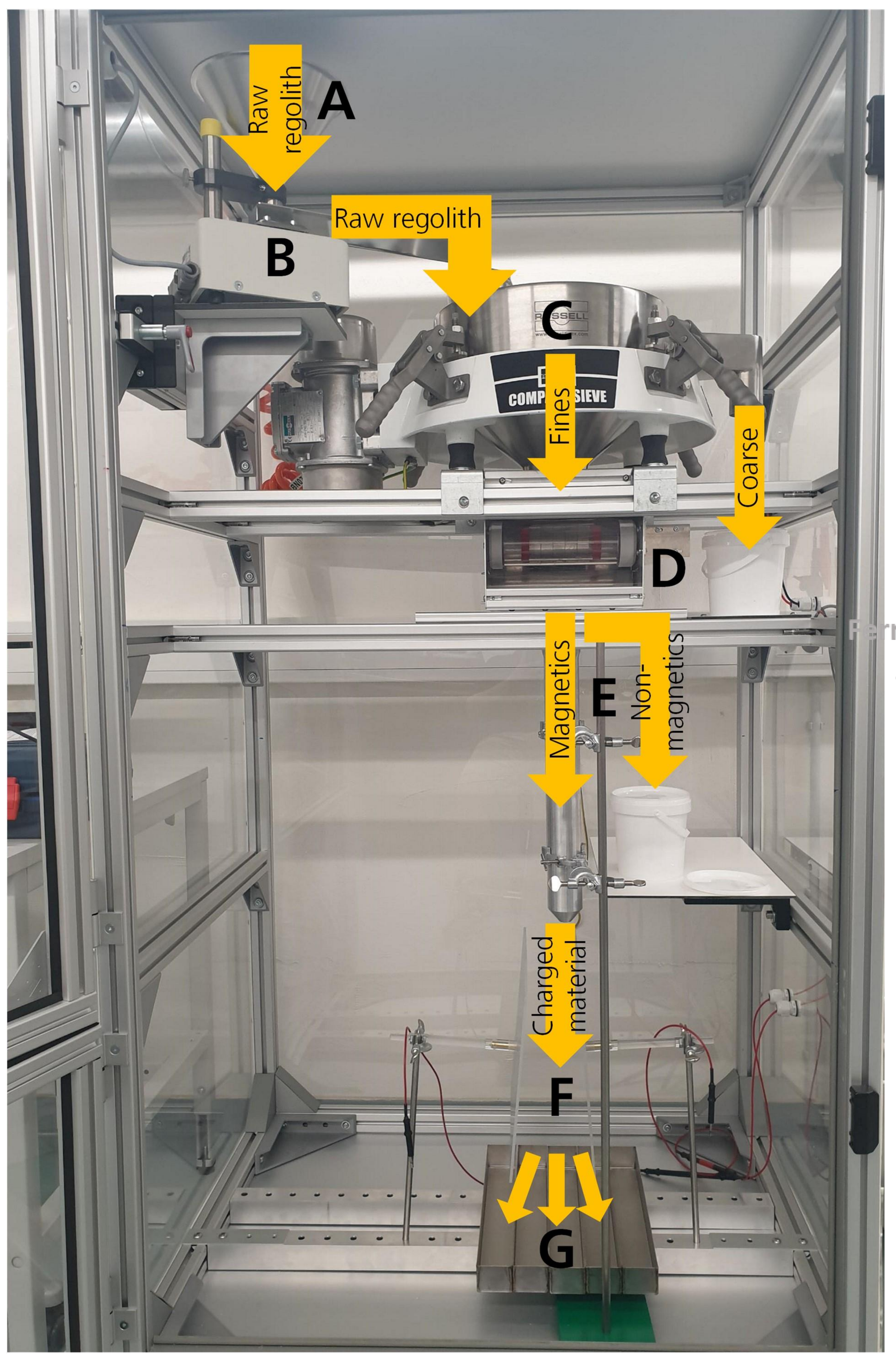
The experimental validation and optimization of the beneficiation test setup is underway currently. The goal of the optimization experiments is two fold:

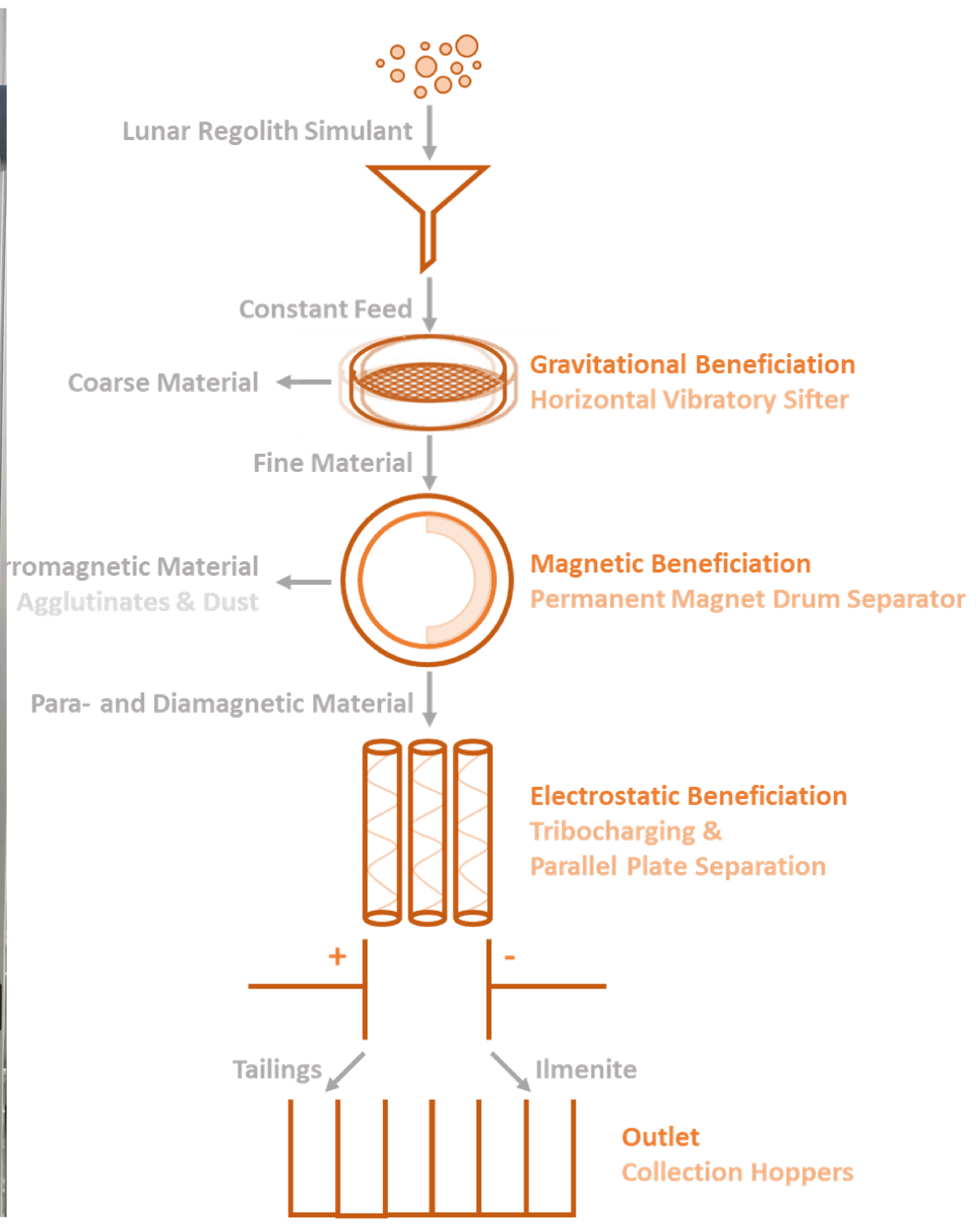
1. Validation of the beneficiation test setup
2. Determination of an optimised configuration of experimental parameters for achieving best possible beneficiation

The different stages of experimental optimisation are shown in the figure below.



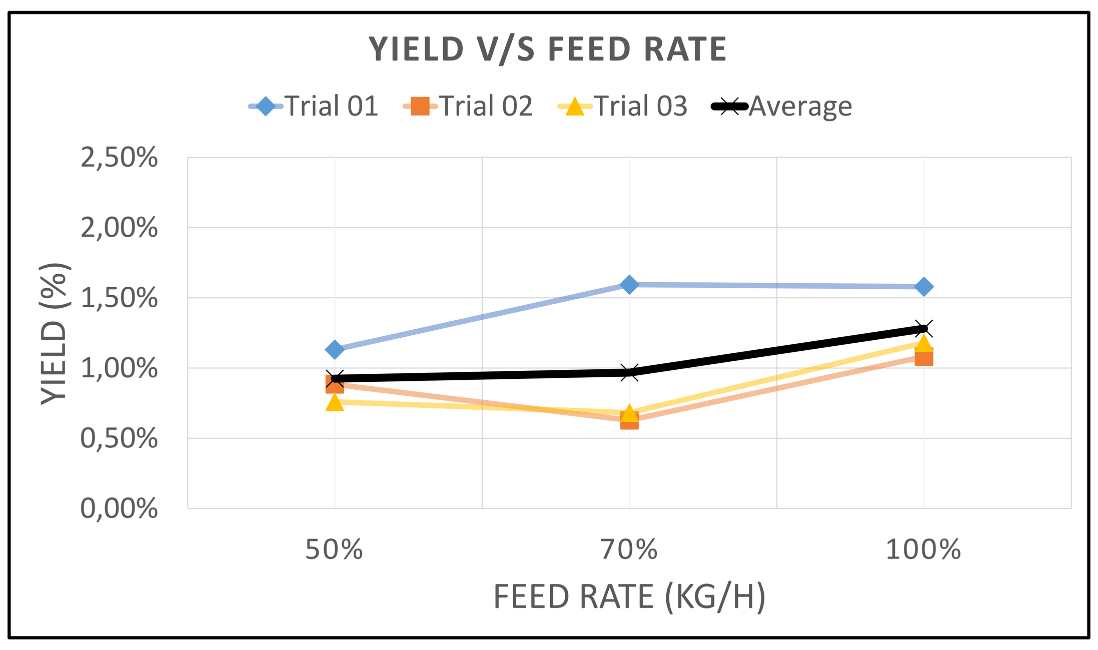
Beneficiation setup and system schematic

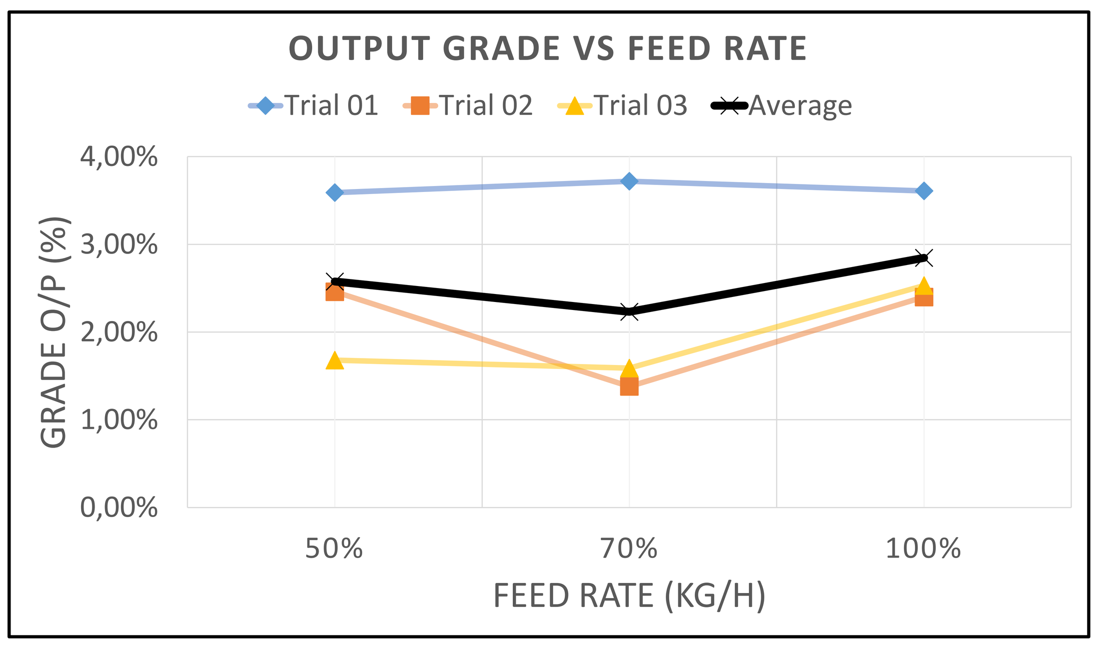




4. Sample Phase Analysis

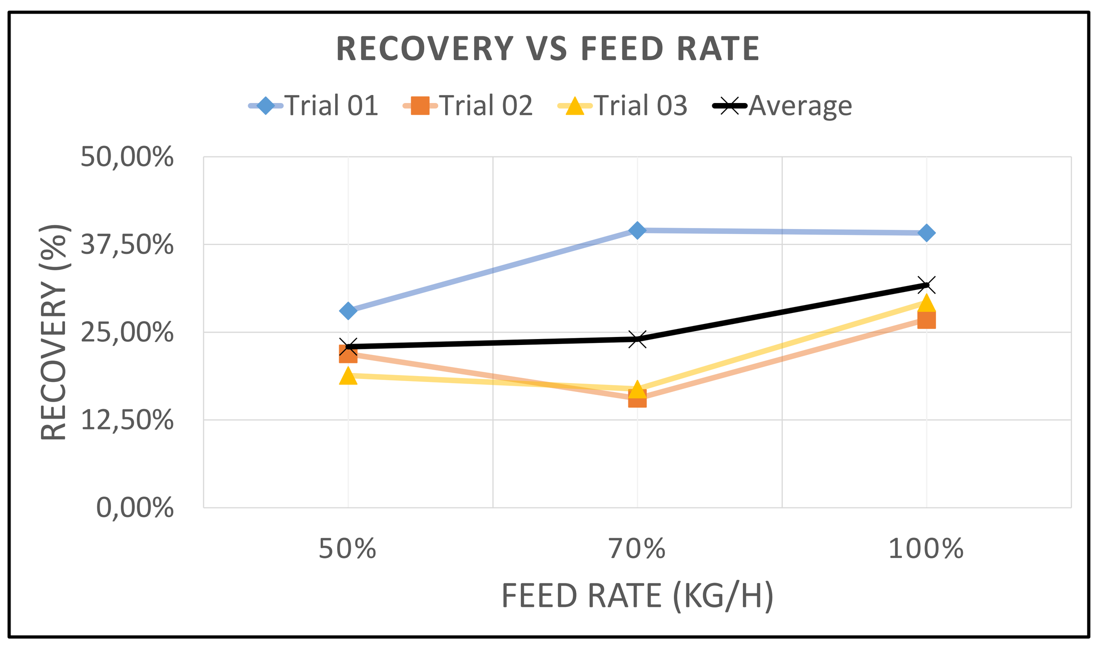
The samples collected during the optimization experiments were analysed using X-ray diffractometry (XRD) at the Department of Crystallography in the University of Bremen. The qualitative phase analysis for the samples is done using X'pert HighScore software tool while the quantitative phase analysis is done on TOPAS software that used rietveld refinement approach for analysis.

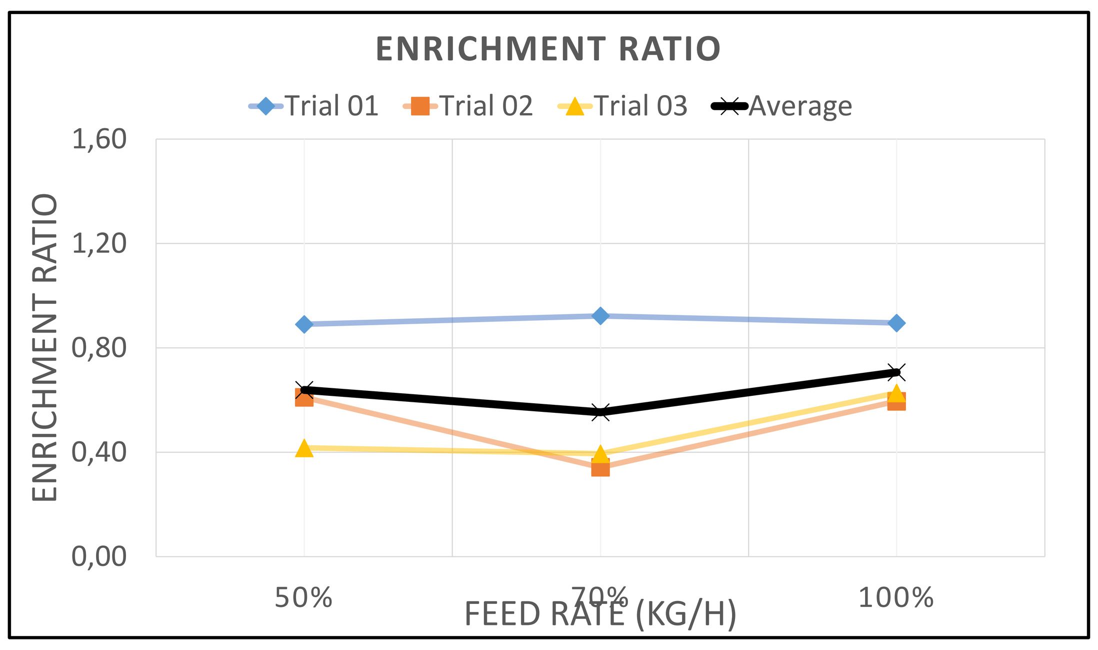




5. Preliminary results

The initial data derived from the analysis of collected samples is used to calculate the essential beneficiation parameters that give clarity about the effective beneficiation. The parameters are yield, recovery, grade and enrichment ratio. All of these are calculated for Ilmenite in the output samples. Each experiment is conducted three times and the average is then considered as a result for further consideration to account for inconsistencies in the experiments. The preliminary results from Phase 1 are shown that show the effect of feed rate on the beneficiation parameters.





5. Conclusion

The preliminary results show the effectiveness of magnetic beneficiation stage when considered independently. The current efforts are focused on the electrostatic beneficiation stage, particularly on the electrostatic plate separator. The initial results of the electrostatic separation show positive results with enrichment ratios up to 2.9 and about 33% recovery and 12% grade of Ilmenite in the output. Further experiments and optimization will provide better insights about the effect of electrostatic separator stages on the beneficiation parameters. Eventually, a more comprehensive analysis of results will provide the final optimal configuration such that the best possible beneficiation is achieved while also taking into account secondary parameters such as power consumption, maintenance requirement, etc.

This work is part of the DLR internally funded young investigator group "Synergetic Material Utilization" (SMU) established 2021 at the Institute of Space Systems in Bremen, Germany. The group focuses on research and development of ISRU technologies for Moon and Mars exploration.

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