

Effects of Vacuum upon Ball Milling of Lunar Regolith Simulant



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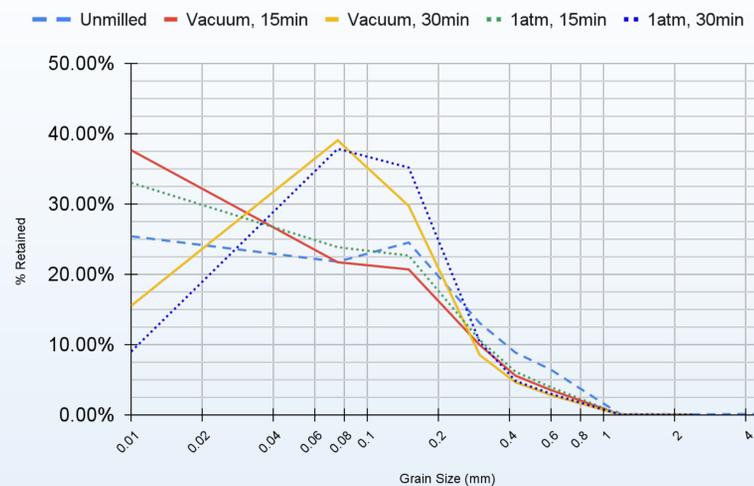
Alaska Space Grant Program

Introduction

The comminution of rocks is a varied set of techniques that has been crafted for thousands of years, through trial and error, to produce the very methods that span the world's mining industry today. As we begin to set out into space, the techniques of grinding rocks we have become so familiar with must be re-examined for their efficacy beyond our atmosphere. Ball milling, an extremely commonplace technique used to grind rock, utilizes a rotating drum filled with (traditionally) steel balls called milling media, which mechanically grind rock as the drum rotates. Our investigation seeks to quantify the effects of an atmosphere upon this mechanical grinding action, in addition to examining a possible alternative to steel milling media.

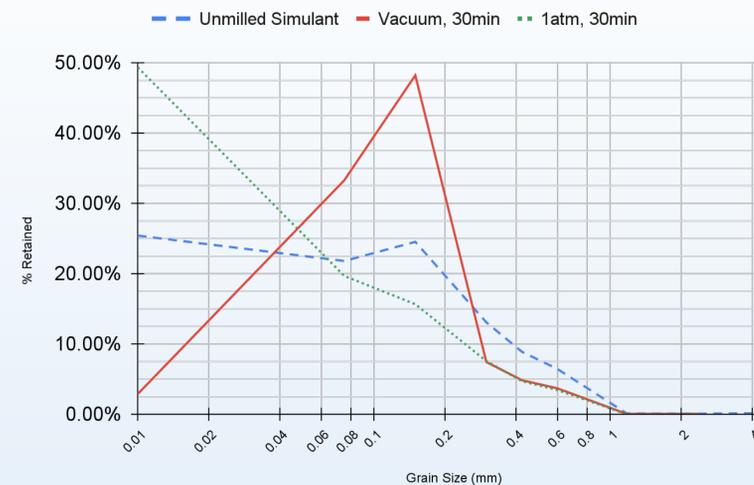
Steel Milling Media

Percent Mass vs. Grain Size (mm)



Ceramic Milling Media

Percent Mass vs. Grain Size (mm)



Milling in Vacuum

The method by which we gauged the efficacy of milling techniques is the degree by which the grain sizes were reduced, relative to a control sample. Mass loss for all samples in both milling and sieving was on the order of individual grams, out of an ideal 300 gram sample size.

To determine the reduction in grain sizes, the collected samples were placed into a series of sieves (*US Standard sieves*), shaken, and massed. A major problem in all of the 30 minute tests is the clumping of grains due to an excess of dry fines. This is evident in the paradoxical reduction of fines after a significant amount of grinding.

Based on physical examination, the tests which are expected to have the greatest grain size reduction, do actually produce grains that are finer than 'less effective' tests despite the indication in the data. Per the Steel tests, with vacuum showing a generally slight increase in grinding efficacy, this slight increase is identical in form to the difference between both 30 minute tests despite presence of clumping. It appears that the degree of fines reduction correlates to the efficacy of grinding, just as well as the increase of fines does.

Conclusions

It was found that, among the steel media tests, the effect of an atmosphere is a small part of total grinding efficacy. However, amongst the ceramic tests, operation in vacuum appears to produce a far greater grinding efficacy than even steel media. Further investigation into alternative milling media may yet yield effective replacements for use in space.

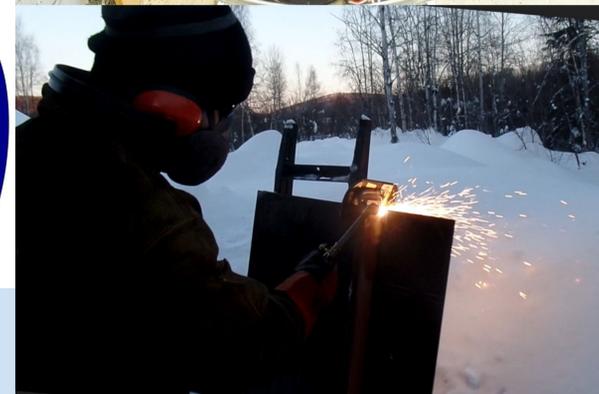
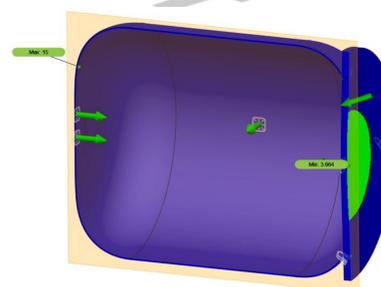
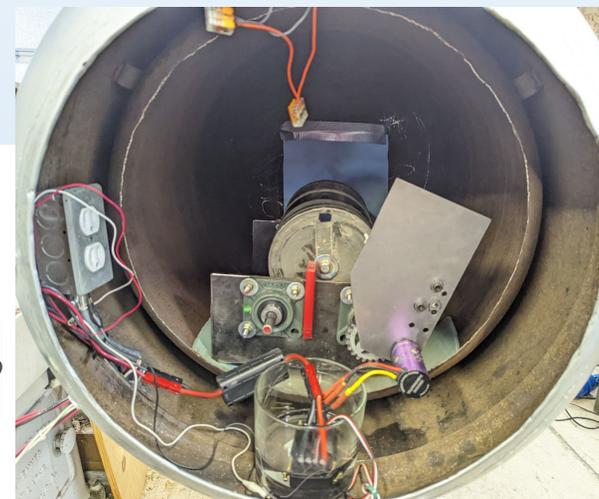
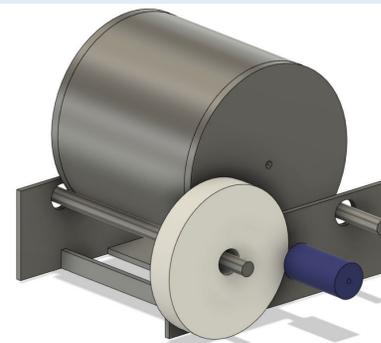
Acknowledgements

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Building a Vacuum Chamber

In order to construct our vacuum chamber, one that was tolerant to dirt and dust, we first began with Autodesk Fusion 360 Finite Element Modeling to ensure our selected vacuum vessel was capable of resisting the pressure load and buckling. The chamber was built from a former well pressure tank, a door cut into the end of the tank and sealed with a silicone, cornstarch, graphite sealant. In order to fit the door to the curve of the tank, extra metal was welded around the plate that was torched out from the tank. Despite the origin of the vacuum chamber, after approximately one hour of pumping with a 2.0CFM pump, a vacuum on the order of 0.5 millibar is attainable.



Building a Ball Mill

The ball mill consists of two 12in wide plates, with holes drilled to support bearing mounts. Two rods, one inch in diameter, act as supporting elements for the drum. The drum was cut from a section of steel pipe, and capped with extra steel plate from the frame. The surface is smooth steel, with an acrylic lid screwed onto one end, so as to view the material inside the drum as the mill operates. The mill spins at approximately 60 rpm.

