Three General Lunar Regolith Conveyance Systems Tested in Atmosphere and Vacuum Conditions

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Introduction

With growing interest in ISRU, further development in lunar regolith conveying is essential. This research investigated finding the best ways for conveying regolith into a Molten Regolith Electrolysis (MRE) reactor. To meet the requirements of the NASA GCD grant; 3 different conveyors were tested: screw conveying, piston conveying, and vibratory conveying. The final normalized results from each test can be seen below the normalizing formula used can be seen on the right. Adjacent, each system performance in vacuum and atmosphere is discussed in depth.

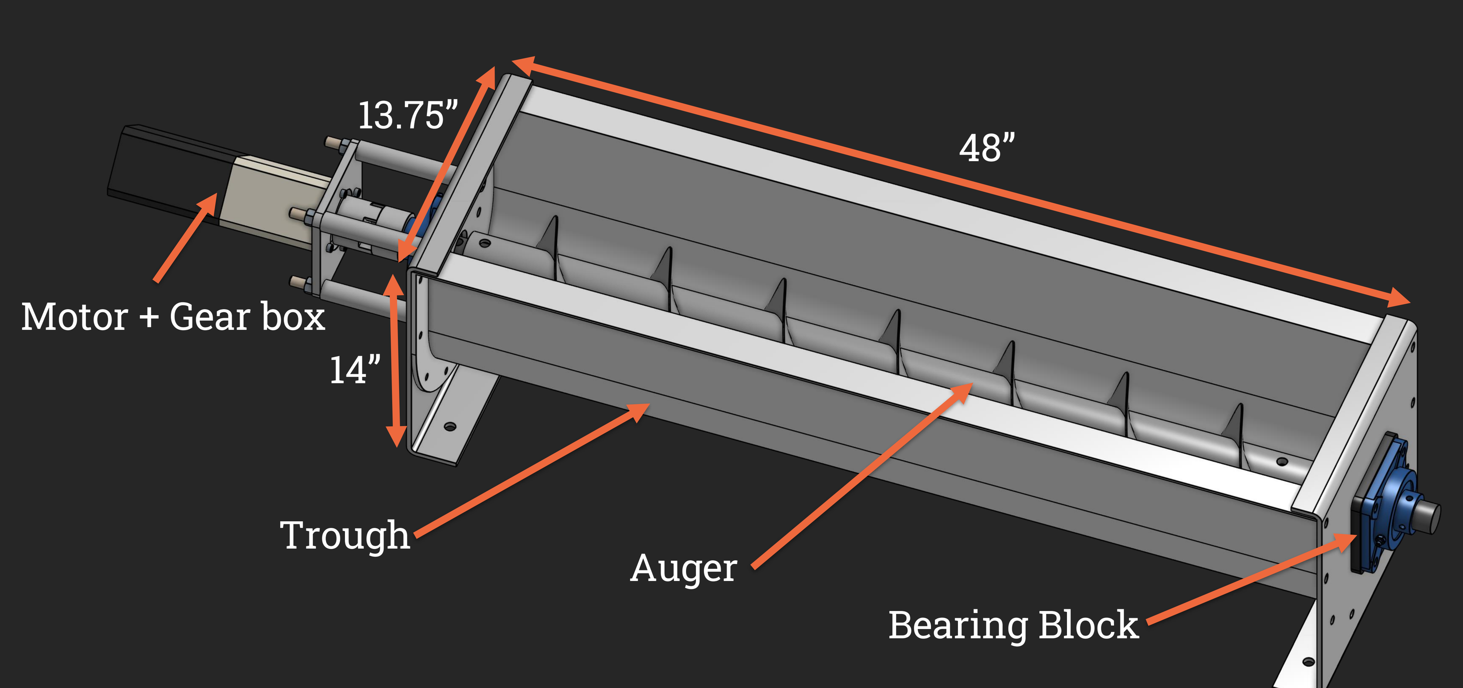
Conclusion

From the tests conducted it was found that out of the three systems tested, the vibratory conveyor had to most significant performance improvement in vacuum from atmosphere, while the other two systems saw a performance decrease in vacuum from atmosphere.

Screw Conveyor

A screw conveyor is a transportation method that uses a screw to push regolith. Regolith could be metered by RPM of the auger/screw. It can likely survive high temperatures and break the molten crust of an MRE.

From the graphics the power requirement for the screw conveyor in vacuum, at 50% fill, at 12 RPM is about 10 W higher than it is in atmosphere. It can also be seen that at higher RPM's and at high fill percentages, the power usage for the screw conveyor increases initially. As the screw conveyor empties, the power requirements for RPM's converge to ~30 W.



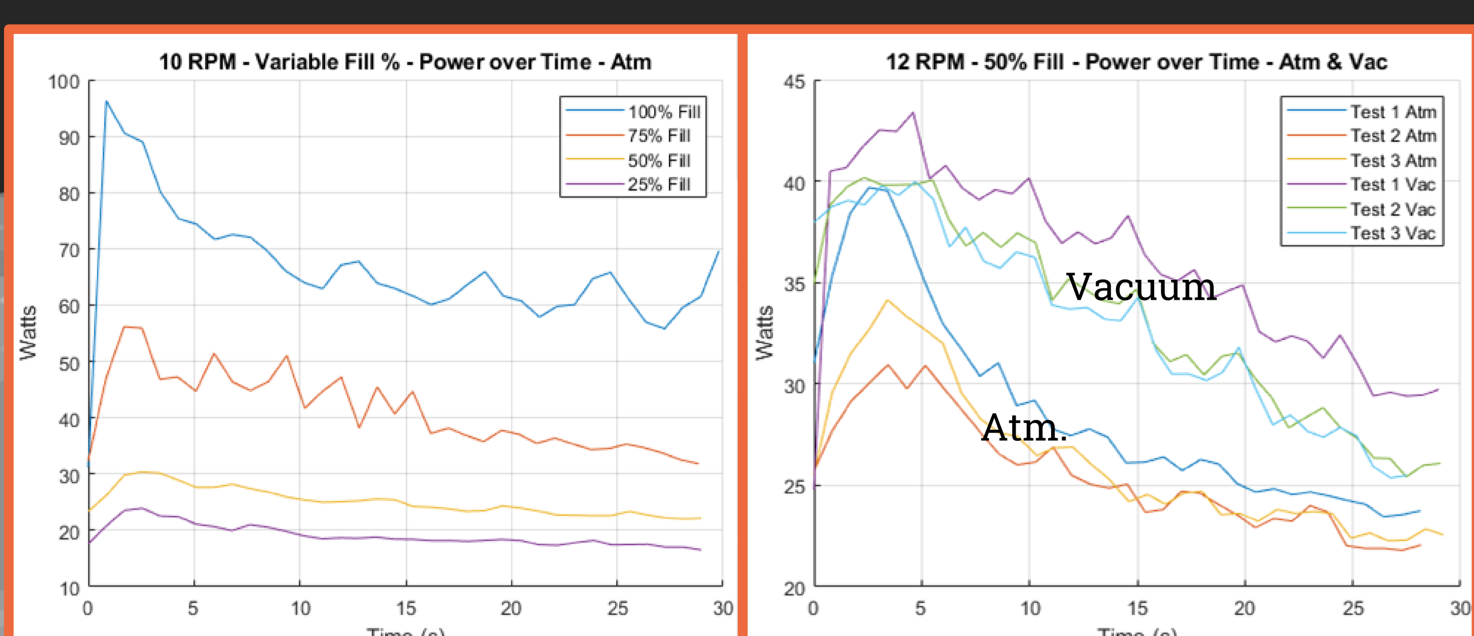
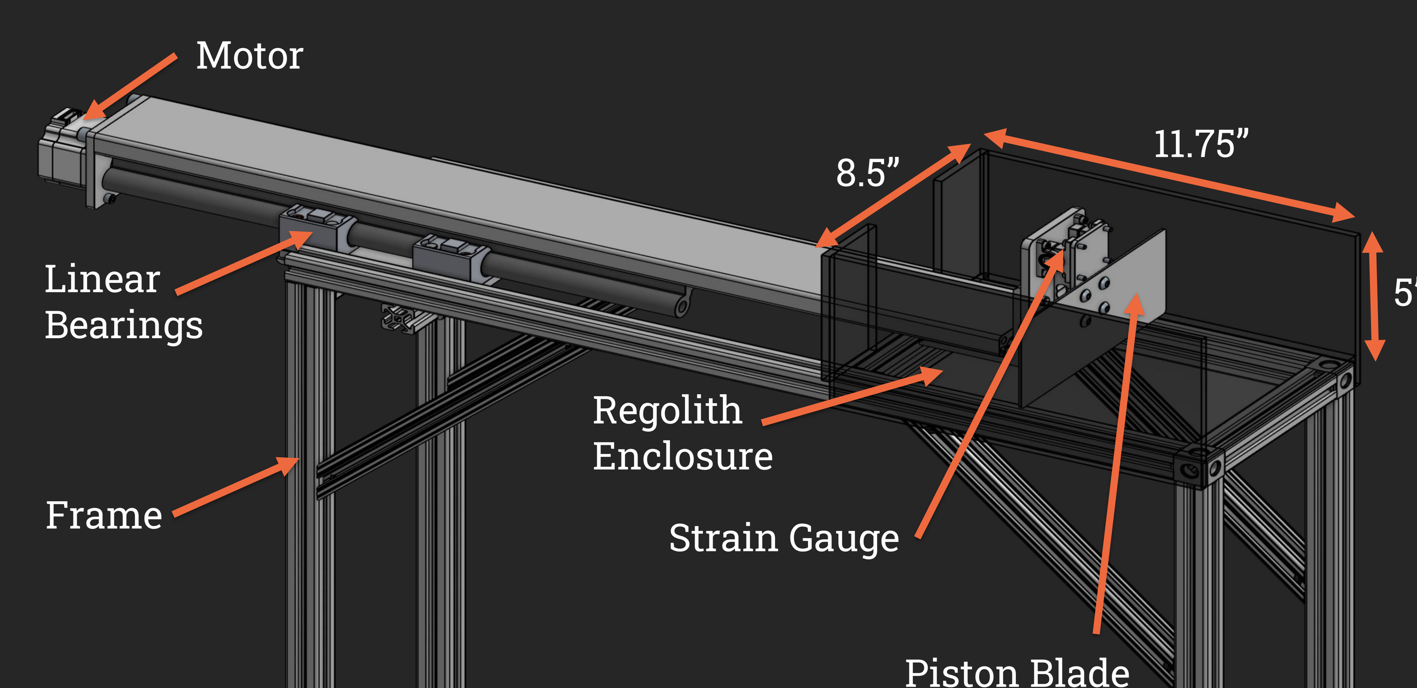


Figure 1: Screw Conveyor Mass Fill % (atm) and Atm. Vs. Vac. Power Usage.

Piston Conveyor

A piston conveyor is a system similar to a coin pusher in an arcade. Regolith would come down from a hopper into a chamber. The chamber would then fill up with regolith, a blade would then extend out and push the regolith into the reactor. The blade would retract, and the chamber would fill again.

From the graphics it can be seen that power usage for the piston conveyor is higher in vacuum than in atmosphere but the push force is lower. It can also be seen that there is little power difference when the mass or the speed is changed in atmosphere.



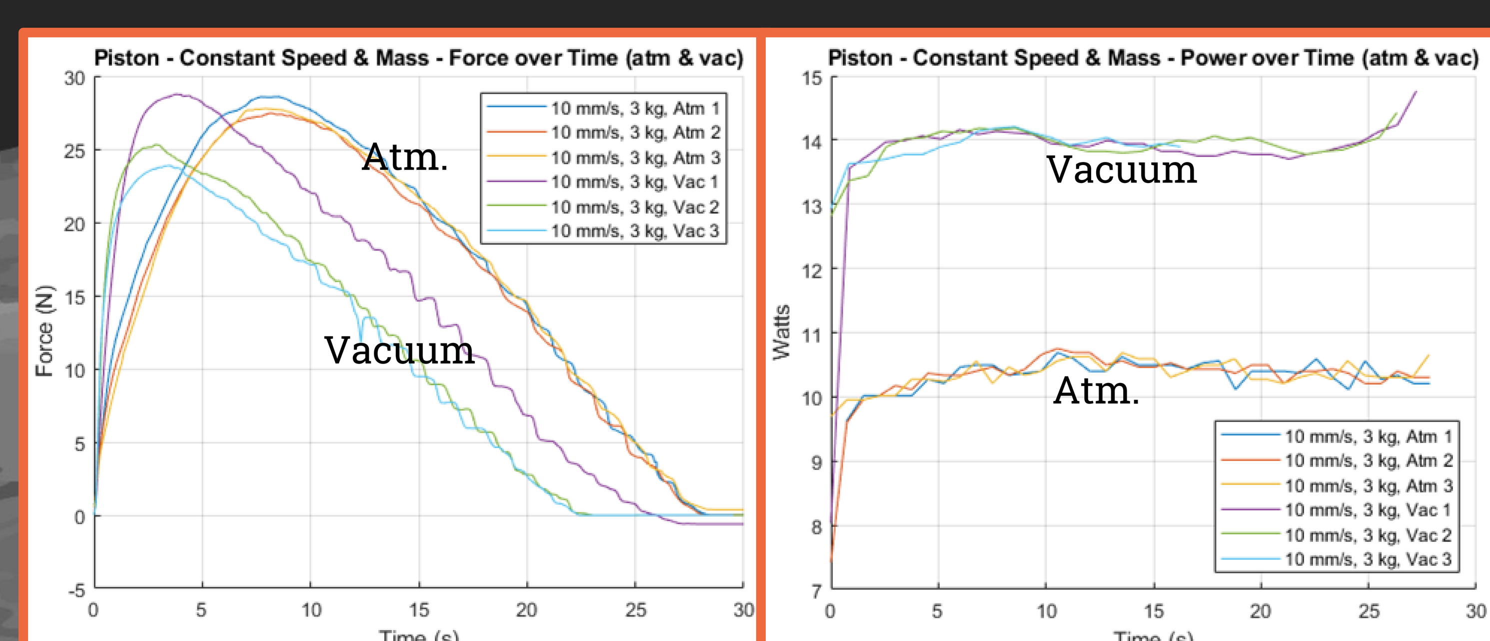
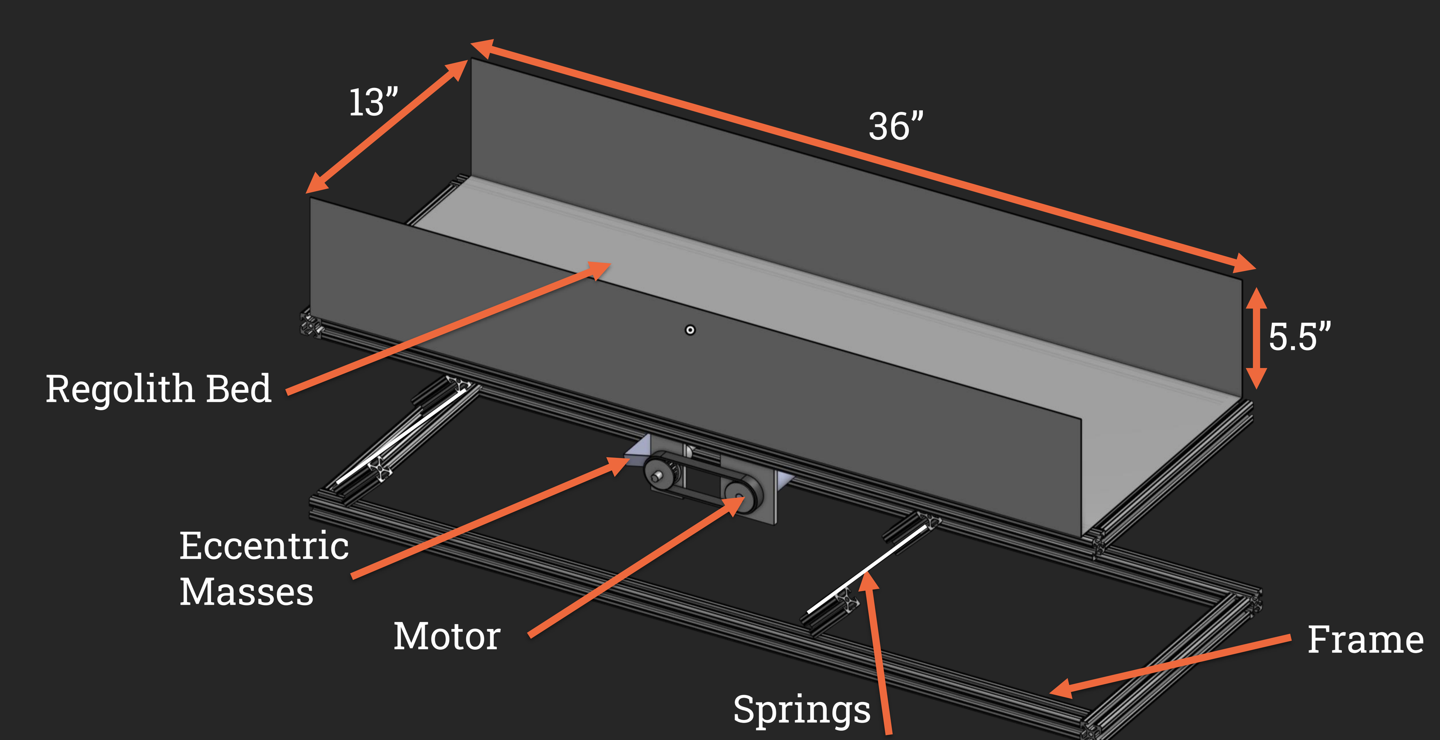


Figure 2: Piston Conveyor Force and Power Usage, Atm. Vs. Vac.

Vibratory Conveyor

The vibratory conveyor is the most complex conveyance system tested utilizing a method that transports regolith using vibration to launch particles in a forward arc. The frequency to convey the simulant was unknown and needed to be determined experimentally. It was found that the frequencies of 3.46 & 9.6 Hz were the most efficient. The vibratory system was then verified in Simulink where a 1-D model was created to predict bed vibration frequencies.

From testing it was also found that the mass flow rate were higher, and the power usage was lower in vacuum. Additionally, high power usages were found at higher eccentric mass RPMs.



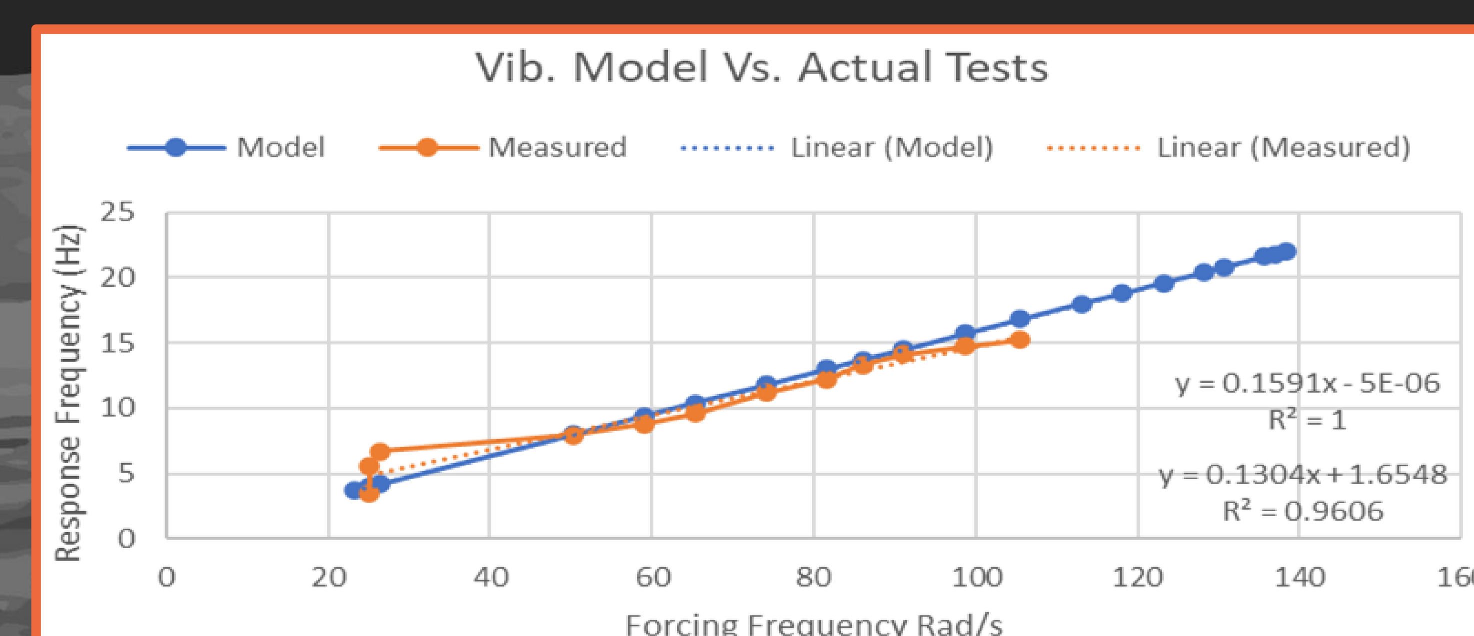


Figure 3: 1D Model Vs. Experimental Data for Vibratory Conveyor. (Equation Used for Model: $\ddot{x} + c\dot{x} + kx = w^2 mr * \sin(w,t)$)

Table 1. Screw Conveyor

	RPM	Fill %	Run Time (s)	Flowed Mass (kg)	Avg. Mass Flow Rate (g/s)	Avg. Power Draw (W)	Kg/Wh
Atmosphere	30	50	30	17.866	617.8	38.52	**57.74**
Atmosphere	12	50	30	8.759	298.35	26.81	**41.26**
Vacuum	12	50	30	6.14	215.71	34.06	**22.93**

Table 2. Piston Conveyor

	Linear Speed (mm/s)	Initial Mass (kg)	Flow Time (s)	Flowed Mass (kg)	Avg. Mass Flow Rate (g/s)	Avg. Power Draw (W)	Kg/Wh
Atmosphere	25	3.000	10.98	2.846	273.22	13.23	**70.53**
Atmosphere	10	3.005	29.33	2.780	94.78	10.31	**33.11**
Vacuum	10	2.717	26.68	2.633	103.33	13.86	**26.83**

Table 3. Vibratory Conveyor

	Bed Freq. (Hz)	Reg. Mass (kg)	Flow Time (s)	Flowed Mass (kg)	Avg. Mass Flow Rate (g/s)	Avg. Power Draw (W)	Kg/Wh
Atmosphere	3.46	3.002	20	1.966	98.3	6.6482	**53.23**
Atmosphere	9.6	3.004	18	2.990	166.111	10.972	**54.5**
Vacuum	3.46	3.000	14	2.938	209.86	5.83	**129.58**