

# A Novel Self-Extricating Mechanism for Martian Planetary Exploration Rovers



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Wheels that can autonomously increase their contact area with a surface can decrease slippage and sinkage on granular terrain, making Martian planetary rovers independent of ground control in an embedding event.

## Engineering Need:

Planetary rovers on the Martian Surface often get stuck in the loose soil. In these events, the only method of extracting it is through maneuvers controlled by ground-control on Earth, which usually does not have a high success rate.

## Engineering Goal:

The objective of this project is to create an autonomous self-extrication method for planetary rovers that is applicable in various states of embedding in the Martian soil, ensuring that the rover isn't completely reliant on ground-control to get itself out of these situations.

## Background:

### General Information About the Martian Landscape

- Mars' terrain is very **diverse**
- Common rover hazards: soft **sand traps**, **steep slopes**, **rocks**, and **dunes**
  - Can cause wheel **damage** and **sinkage**.

### Rover Mobility and Mechanical Design

- Mobility is crucial for planetary exploration rovers
  - Getting stuck can **end** a mission.
- Embedding occurs due to **sinkage** (wheel sinking) and **slippage** (lost motion).
- Increasing wheel - ground contact area reduces slippage.

### Current Extrication Methods & Limitations

- Stuck rovers currently rely on human commands from Earth - slow and often **ineffective**.
- Delay time between signals from Earth and limited awareness of rover's situation
- E.x. Spirit rover got stuck in Martian soil
- **Autonomous self-recovery** systems could **detect immobilization** and **free the rover** without mission-control intervention.

## Methodology:

### Proof of Concept:

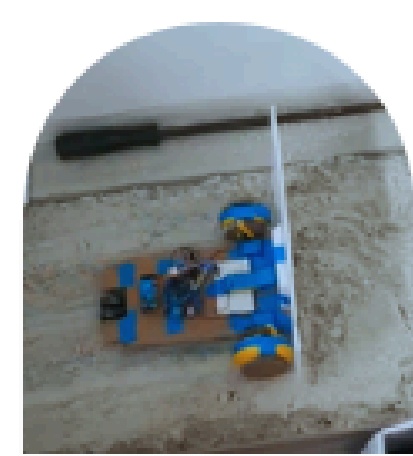
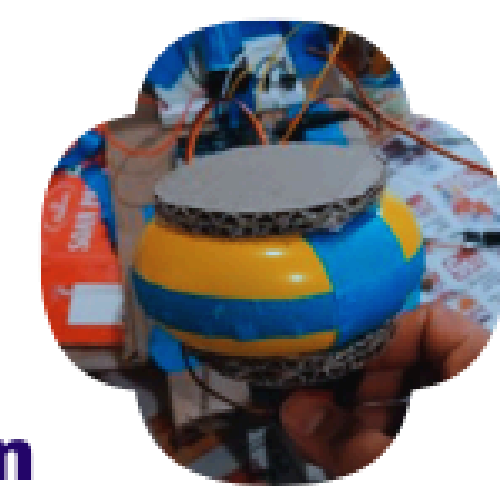


#### Test Bed Setup

- **0.5 x 2 m sand box to drive prototype on**
- **Vernier Go Motion sensor for vehicle velocity**

#### Prototype

- **Made a low fidelity prototype of the flexible wheel**
- **Rigid wheel of similar size for comparison**

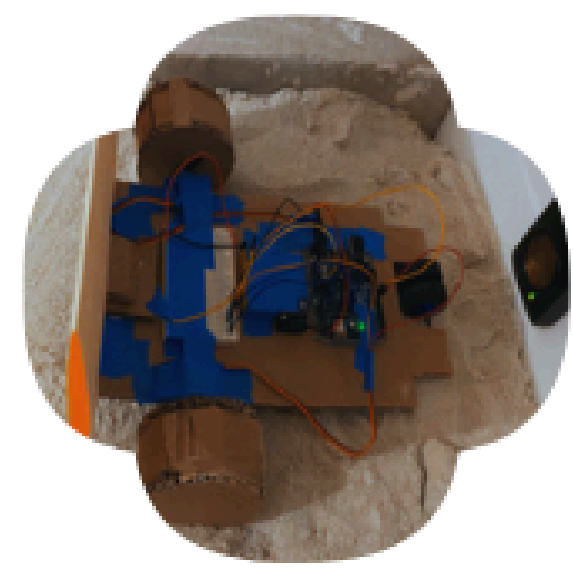


#### Calculate Slippage

- **Slippage = (Wheel Velocity-Vehicle Speed)/Wheel Velocity**
- **Wheel Velocity measured using CapCut**

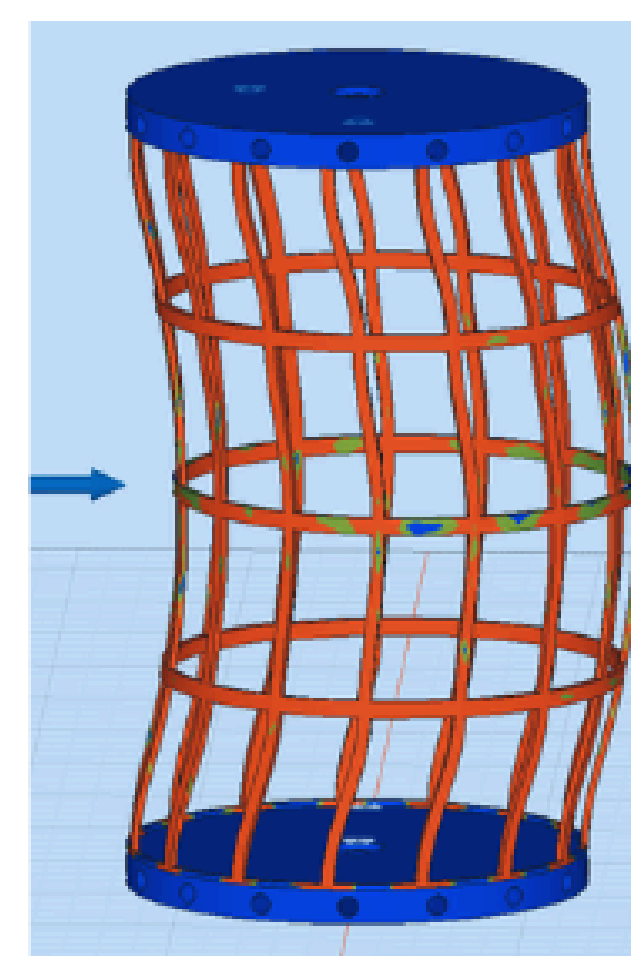
#### Calculate Sinkage

- **Sinkage is distance from bottom of a wheel to top of soil**
- **Measured in cm for both wheels**



### Tensile Test:

1. **Created a CAD model of design when at maximum width**
2. **Simulated a force of 200N acting on the circumferential surface**
3. **Changed material of circumferential surface**
4. **Measured Safety Factor, Displacement, Yield Strength and Contact Force to determine which material would deform best but still retain its shape.**



## Results:



Fig. 1) Position vs. Time Graph for Flexible Wheels

The flexible wheel was **driven 3 times** on the test bed. Each time the position vs time was measured for the vehicle, to help calculate its slippage. Fig. 1) shows the average position of the vehicle for all 3 tests. The trendline gives us an average vehicle **speed of 0.276 m/s**, which also means the **slippage is 49%** (when a **wheel velocity of 0.528m/s** is used in the slip equation). Throughout all 3 tests **no events of sinkage occurred**.

The rigid wheel was **driven 3 times** too. Fig. 2) shows the average position of the vehicle for all tests. The trendline gives us an **average vehicle speed of 0 m/s** with a **wheel velocity of 0.31 m/s**, which also means the **slippage is 100%**. \*Note that this might be due to difference in the amount of voltage supplied to rigid wheel. Additionally, during one of the tests, a **wheel sunk 1.1 cm** into the sand.

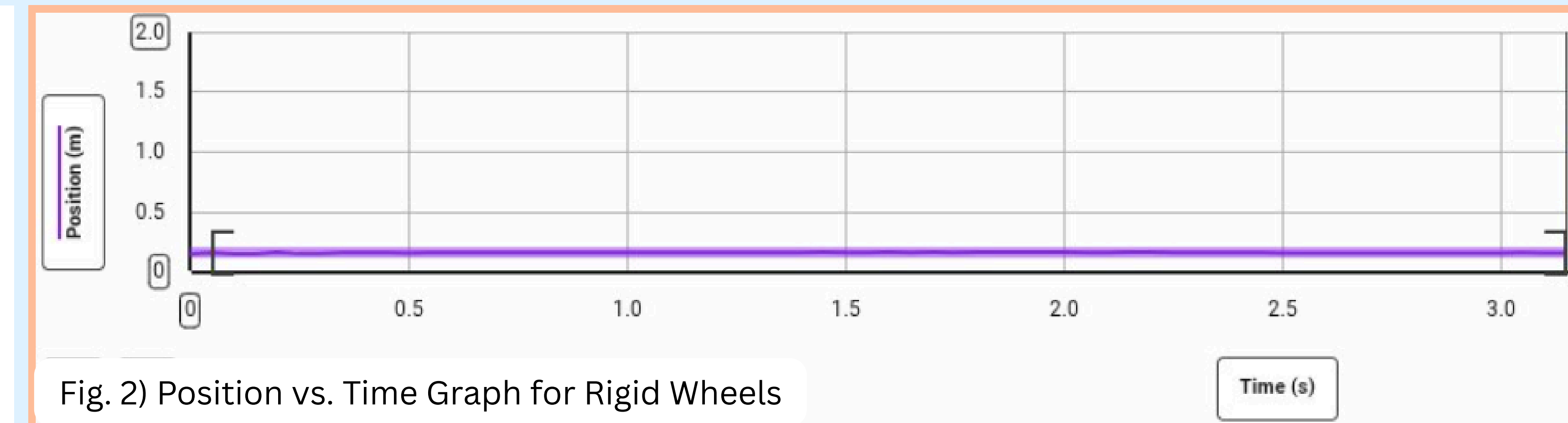


Fig. 2) Position vs. Time Graph for Rigid Wheels

**Implication:** This experiment shows that flexible/deformable wheels **reduce the slippage of the vehicle and its sinkage**, verifying that **inflatable wheels perform better on sandy terrain** than rigid wheels. Current Martian rover's rigid wheels can be replaced with a **flexible wheel that can vary its geometry** based on the vehicle's slippage and sinkage, **ensuring that the rover can safely traverse rough terrain**.

### Safety Factor of Potential Materials

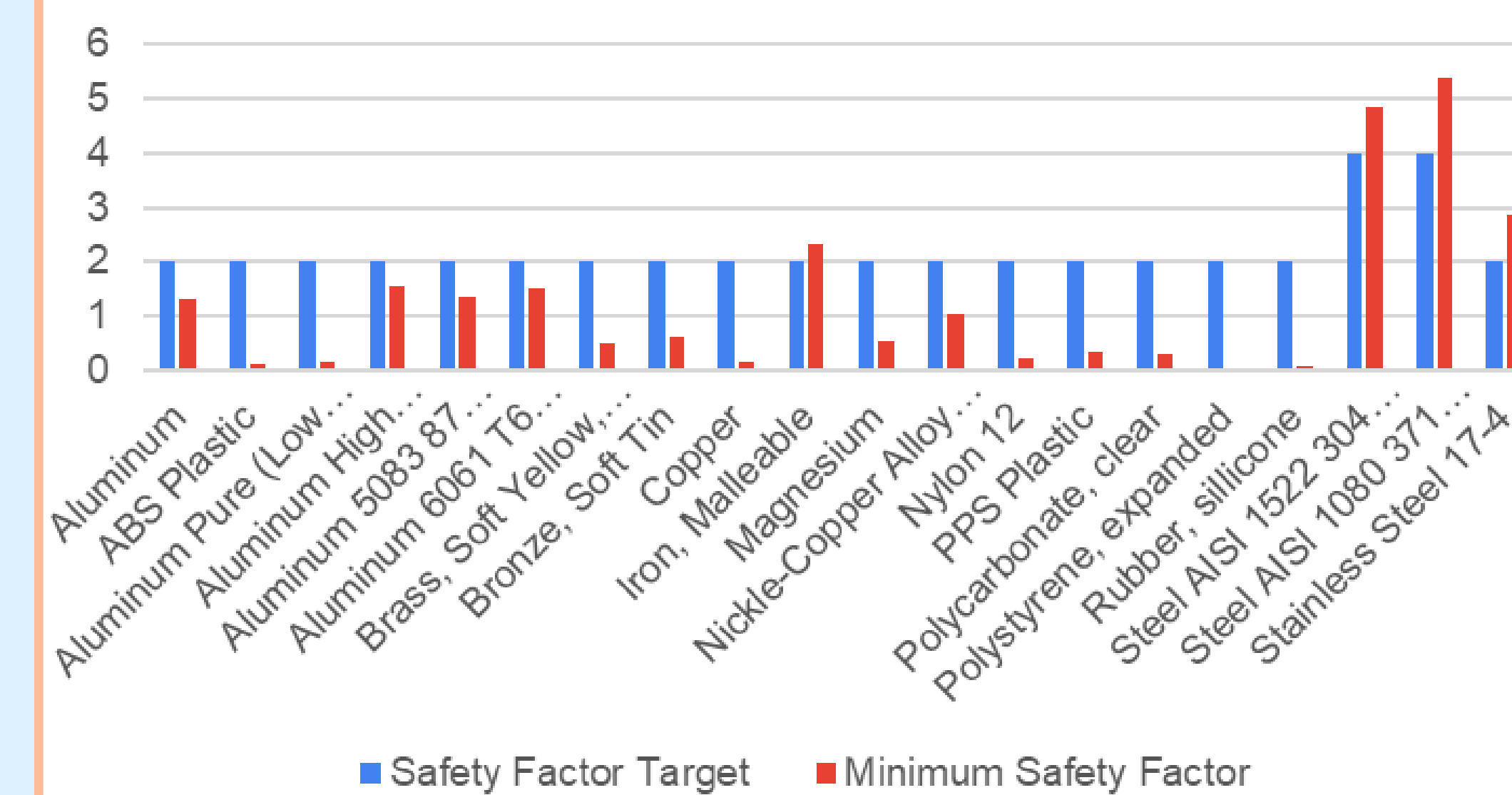


Fig. 3) Minimum and Target Safety Factor Graph for Potential Materials

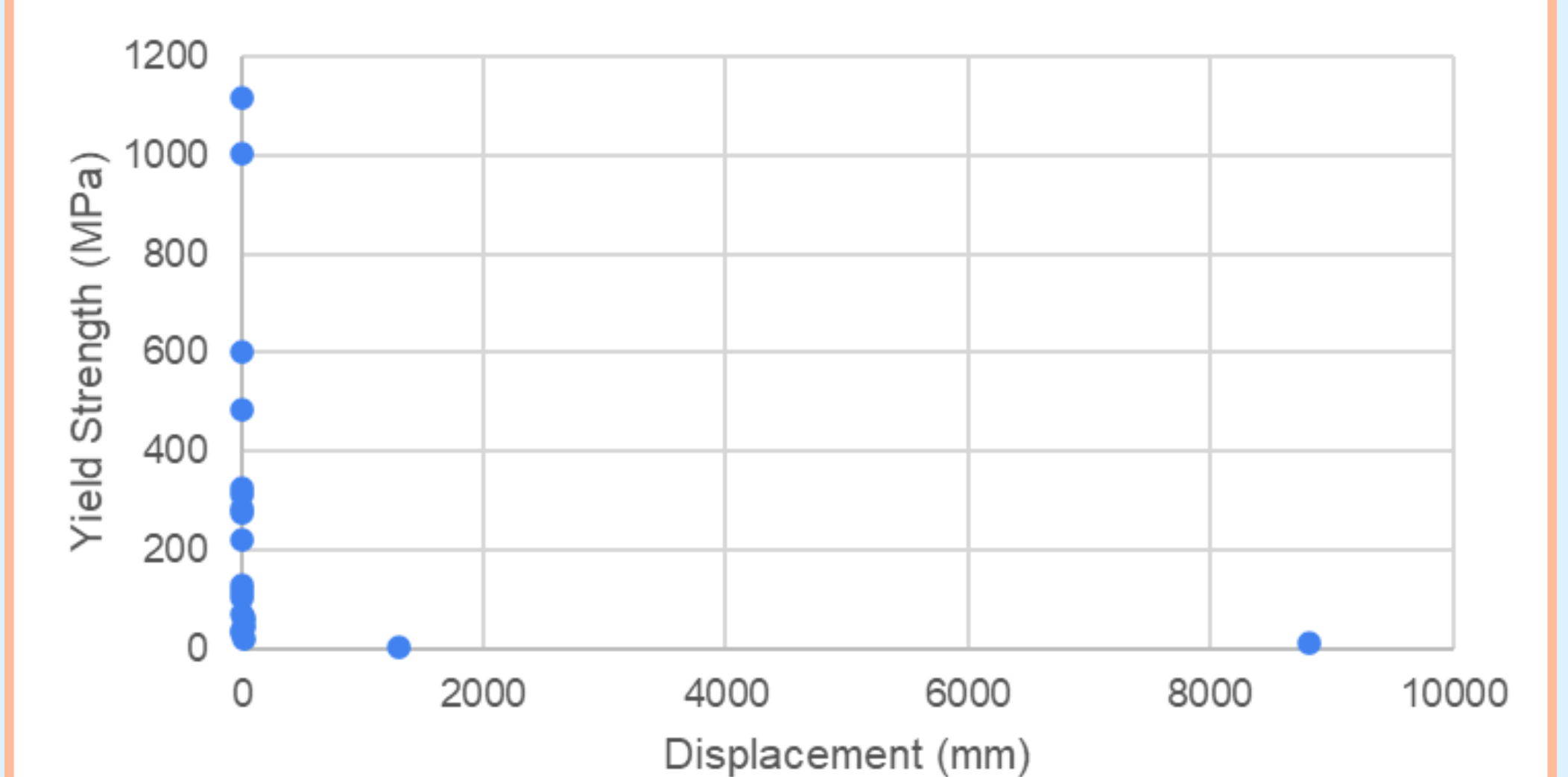


Fig. 4) Displacement vs. Yield Strength Potential Materials

**Implication:** The final material should have a **minimum safety factor greater than the target**, to prevent it from permanently deforming. Only 4 of the materials meet this criterion. Then we want the **material to have a high yield strength but not displace too much that it causes a plastic deformation**. Iron (malleable) had the **highest displacement** of the four materials (0.328mm) and a yield strength of **483MPa**, similar to others. Thus, an **iron wire mesh** would be the best material to construct the circumferential surface of the wheel.

## Future Steps:

- Finish **debugging circuit** and adding a battery to it
- **Build a prototype** of wheel with a malleable Iron mesh for the circumferential surface
- Integrate **Arduino code** to physical prototype and test on Martian soil simulant or fine sand
  - Add a **swaying motion** function for when rover gets stuck
  - Refine autonomy of mechanism using machine learning
- Refine prototype design to cause **less wiring issues**

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