Optimization of Rover Wheel Geometries for Planetary Missions

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Abstract

Rovers have been used extensively on exploration and sample collection missions to the Moon and Mars. Challenging prospective missions require rovers that have reliable wheels to navigate the harsh conditions of the planetary regolith. However, due to the regolith being soft the wheels on the rover start to lose traction and the wheels sink while driving. The goal of this work is to optimize the grouser geometry to improve wheel traction and sinkage simultaneously facilitating better rover maneuvering. This research will be conducted by changing different parameters of the grouser's height, number of grousers, and shape of the grousers. Novel geometries will be analyzed using LIGGGHTS and Paraview software. Recommendations will be made towards optimizing the wheel performance on planetary surface missions. MATLAB will be the first to use to optimize the grouser geometry and then input into LIGGGHTS and processed in Paraview. For validating the work, high-fidelity simulations will be performed along with sensitivity study.

Objectives

1. Research on rover wheel designs, optimization tools, and previous work.
2. Create MATLAB code for optimization parameters
3. Graph results to see if our design makes sense
4. Test LIGGGHTS script using simple cylinder and particles
5. Use LIGGGHTS to simulate the particles and wheel
6. Change grouser design and shape
7. Input in LIGGGHTS
8. Review results and repeat

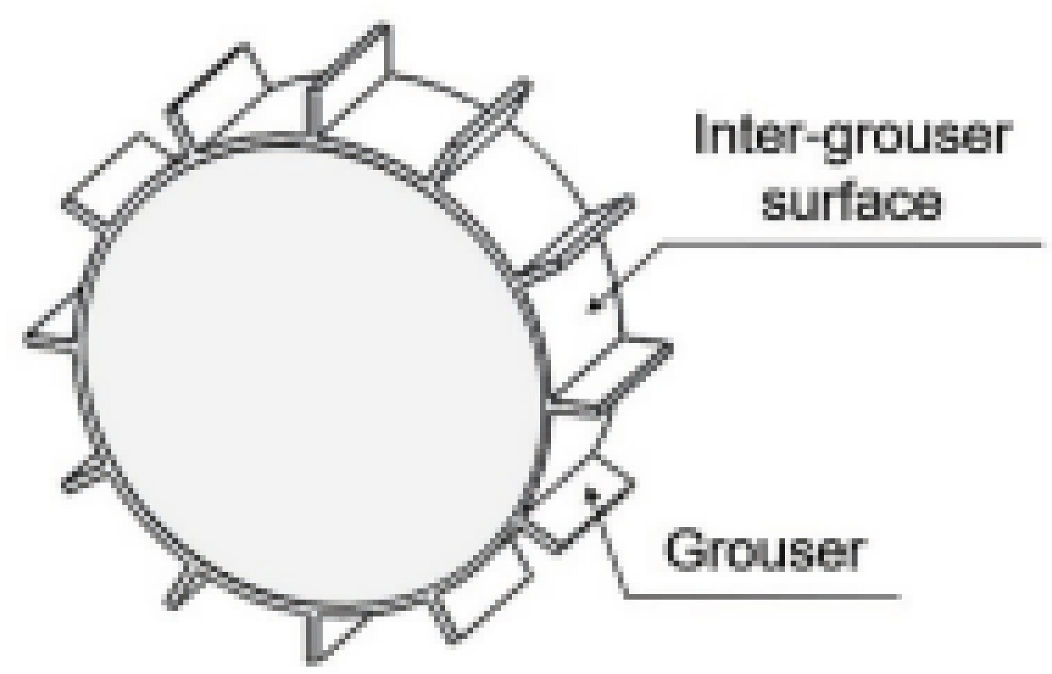

Figure 1: Typical Grouser

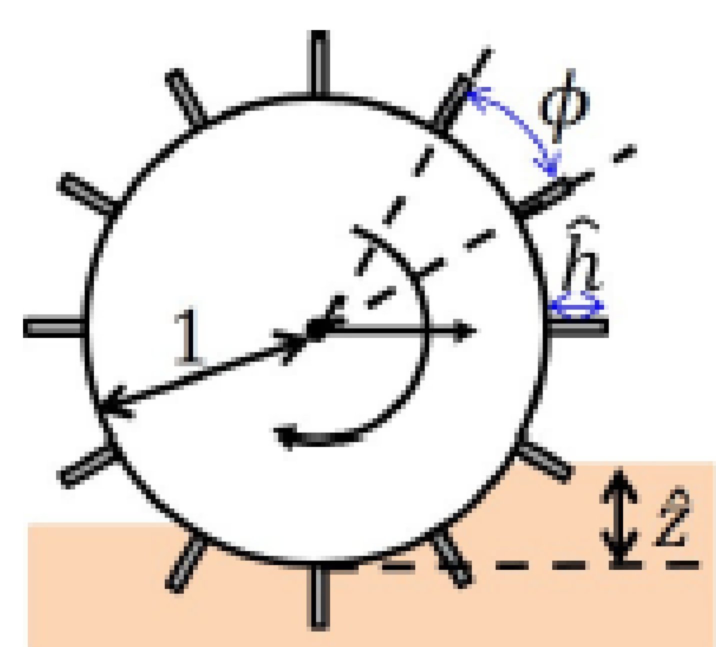

Figure 2: Key parameters

Methodology

After considering all the parameters, the preliminary design will be done using Computer Aided Design (CAD) software. The preliminary design will be created like previous designs from other work. From there, the designs will be put into the LIGGGHTS, where the designs can be analyzed. Another open-source software called LIGGGHTS will also be used. LIGGGHTS can simulate soil particles and a wheel to see if the wheel can travel across the land. For this analysis, the simulation will be for wheeled vehicles operating on a deformable terrain. LIGGGHTS will be used to analyze the tractive performance for the design that was chosen. After running the initial analysis for the preliminary design, the design will be optimized to find better performance.

Optimization

x_1 = Grouser spacing angle
x_2 = Height of grouser
x_3 = Sinkage

Minimize

$$\eta = -\frac{K_u\sqrt{\frac{W_R^3}{bD_R^2}}}{T}\left(\frac{r}{x_1}\right)\left(\sqrt{(1+x_2)^2-(1+x_3)^2}-\sqrt{1-(1-x_3)^2}\right)$$

Subjected to

$$1 < x_1 < 360$$
$$0.1 < x_2 < r$$
$$0.05r \le x_3 \le 0.15r$$

Preliminary Results

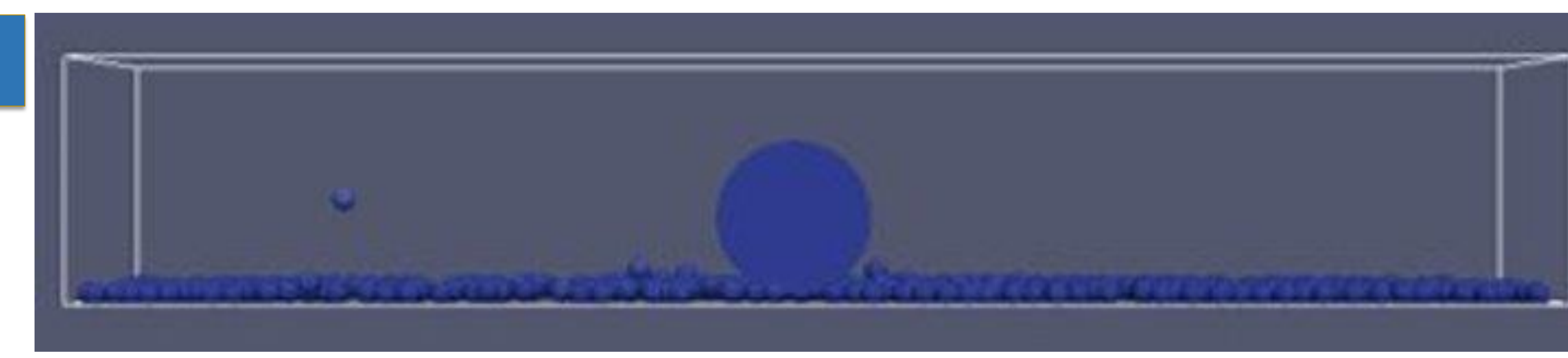

Figure 3: LIGGGHTS initial setup

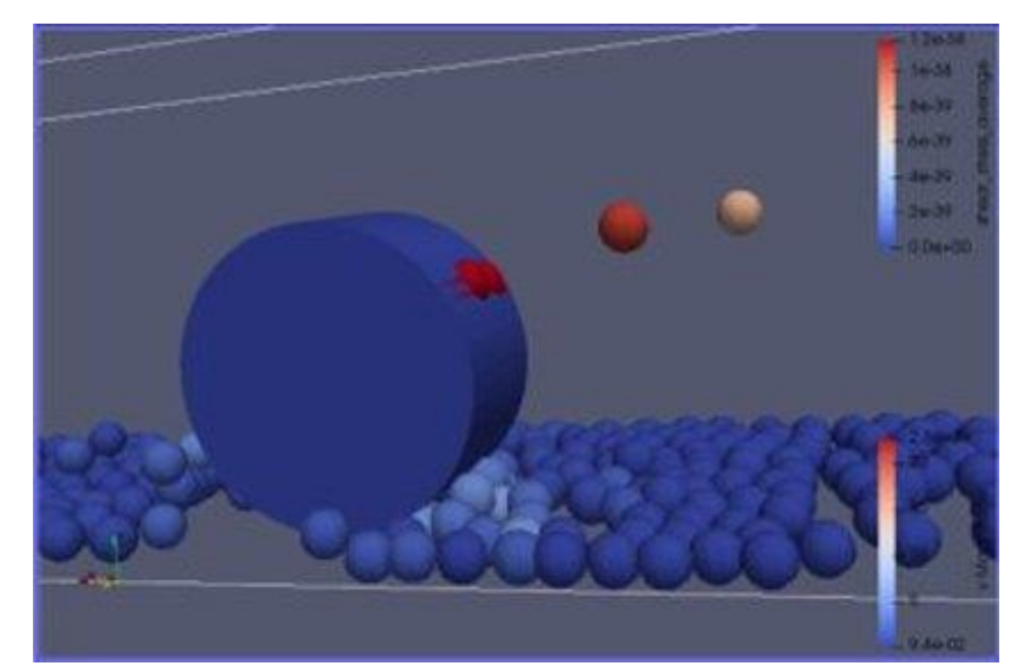

Figure 4: Shear Stress acting on Wheel

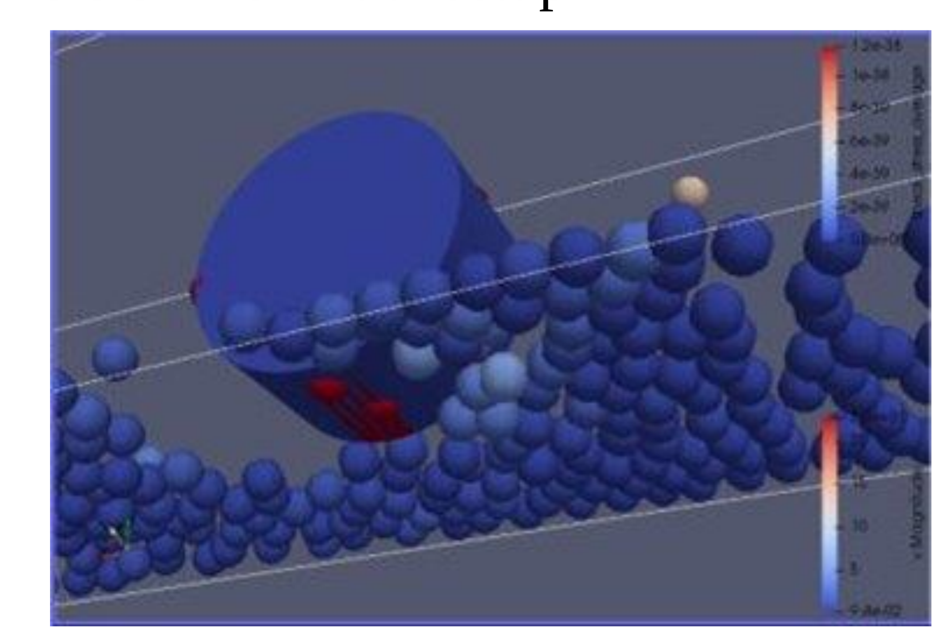

Figure 5: Shear Stress acting on Wheel

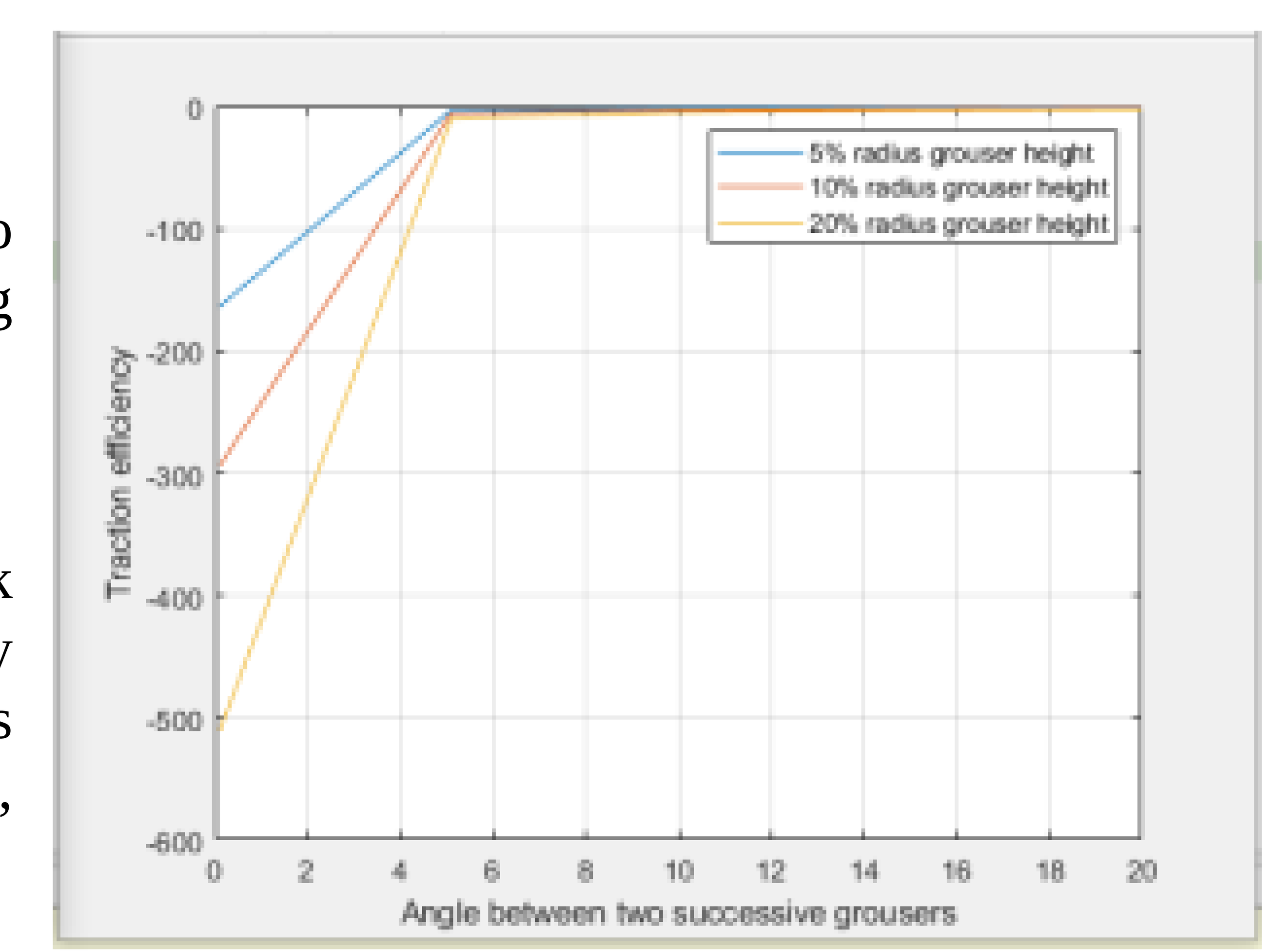

Figure 6: Angle vs Traction efficiency

Future Work

1. Validation of optimization formula.
2. Use a different software called EDEM to better simulate these particles. Will be doing more research on that software.

What is EDEM?

EDEM is high-performance software for bulk and granular material simulation. Powered by DEM, EDEM quickly and accurately simulates and analyzes the behavior of coal, mined ores, soils, fibers, grains, tablets, powders, and more.