Multimaterial Compliant Wheel Design and Optimisation for Martian Rover

Administrative Info

Project: Multimaterial Compliant Wheel Design and Optimisation for Martian Rover
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1 Context and Motivation

EPFL Xplore is a student-led Swiss association, part of the MAKE initiative at EPFL. Each year the team builds a Martian-like rover to compete in the European Rover Challenge (ERC) in Krakow. The team has around 50 students. The mechanical team is split into Handling Device (robotic arm) and Structure.

The rover is expected to traverse complex, rough, and uneven terrain while retaining grip and limiting vibration. The main point of leverage to improve the behaviour of the rover in this regard is the wheelbase, which directly impacts the rover's ability to overcome obstacles and avoid slipping.

The current wheels are a two-part design of 3D-printed TPU rim and PETg hub, but the geometry makes the system prone to viscoelastic effects and parasitic latent deformation, that compromise wheel roundness and introduce vibration to the system.

2 Technical Background

The wheel design requires consideration of multiple aspects across various disciplines:

- **Material Selection:** Some materials are more appropriate to improve grip across various surfaces, and others have deformation and stiffness properties that lend themselves better to creating a compliant geometry.
- **Structural Mechanics:** The geometry of the wheel has the largest impact on performance and resistance. By correctly exploiting the properties of various geometries, the result can be both resistant enough to undergo repeated loading and impacts, as well as flexible enough to avoid transmitting the resulting vibration through the hub up to the rest of the rover.
- **CAD Design** The design of the wheel is to be done using CAD software, and good handling of the software at hand is essential to efficiently iterate on dimensions and geometries.
- **Manufacturing Methods:** The production process heavily guides the design process. By investigating appropriate (and realistic) manufacturing methods, a broader coverage of possibilities can be undertaken.

3 Research Question and Objectives

Research question. *What materials and geometries allow for the wheel that performs best under the foreseen operating conditions?*

To answer this, the student will:

1. Study the operational rover loading case and extreme limits the wheels undergo.
2. Study the state of the art in flexible materials, their properties and limitations.
3. Design and simulate various wheel designs to minimise weight, transmissibility, and cost, while respecting the operational limits of the design.

4. Derive scaling and similarity laws applicable for testing on scale models of the wheel and validate simulations using scale models on a test bench.

4 Scope and Constraints

To keep the project realistic:
Operational conditions require the following:

- Max. load at least 450 N.
- Outer Diameter no more than 250 mm.
- Hub diameter no less than 65 mm

5 Requirements

We are looking for a highly motivated student who wants to tackle a real materials, manufacturing and mechanical design challenge. Compliant wheels are used more and more in the context of extra-planetary rovers, and staying cutting-edge is a huge asset to keep launch costs low while conserving performance. This project digs into the finer details of practical R&D, in the context of applications where operational requirements frame the design.

- Hands-on experience with Fusion360 or equivalent CAD software.
- Good understanding of strucural behaviour and weaknesses in compliant systems.
- A surface-level knowledge of manufacturing methods and available materials.
- Some experience designing complex geometries and parametric designs.
- Experience and understanding of FEM simulations and their limitations, as well as the types of simulations relevant for this project (harmonic response, nonlinear static stress, dynamic non-conformal loading erc.)

6 Deliverables

- A wheel design that satisfies the operational criteria without the current design's shortcomings.
- A measurement setup and reproducible experiments comparing it to the current wheels.
- A final report covering the analysis, the implementation, and the experimental results.