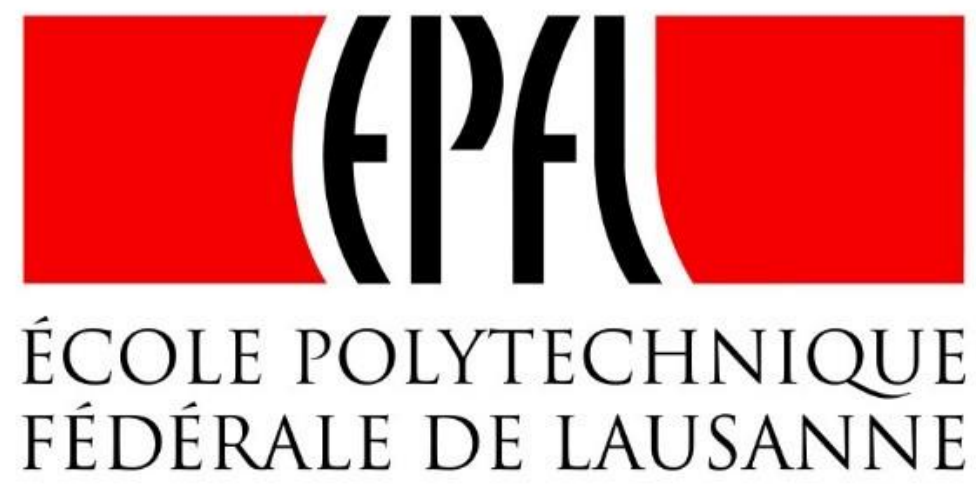


Modeling The *Hyperloop* With COMSOL® : On The Mechanical Design Of The EPFLoop Capsule

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Introduction

The EPFLoop student team from Ecole Polytechnique Fédérale de Lausanne developed a capsule thanks to which it won third place at the SpaceX Hyperloop Pod competition in 2018. During the development of the EPFLoop pod, COMSOL Multiphysics® was used to study the design of the aluminium chassis and the design of the braking system, including the analysis of thermal performance.

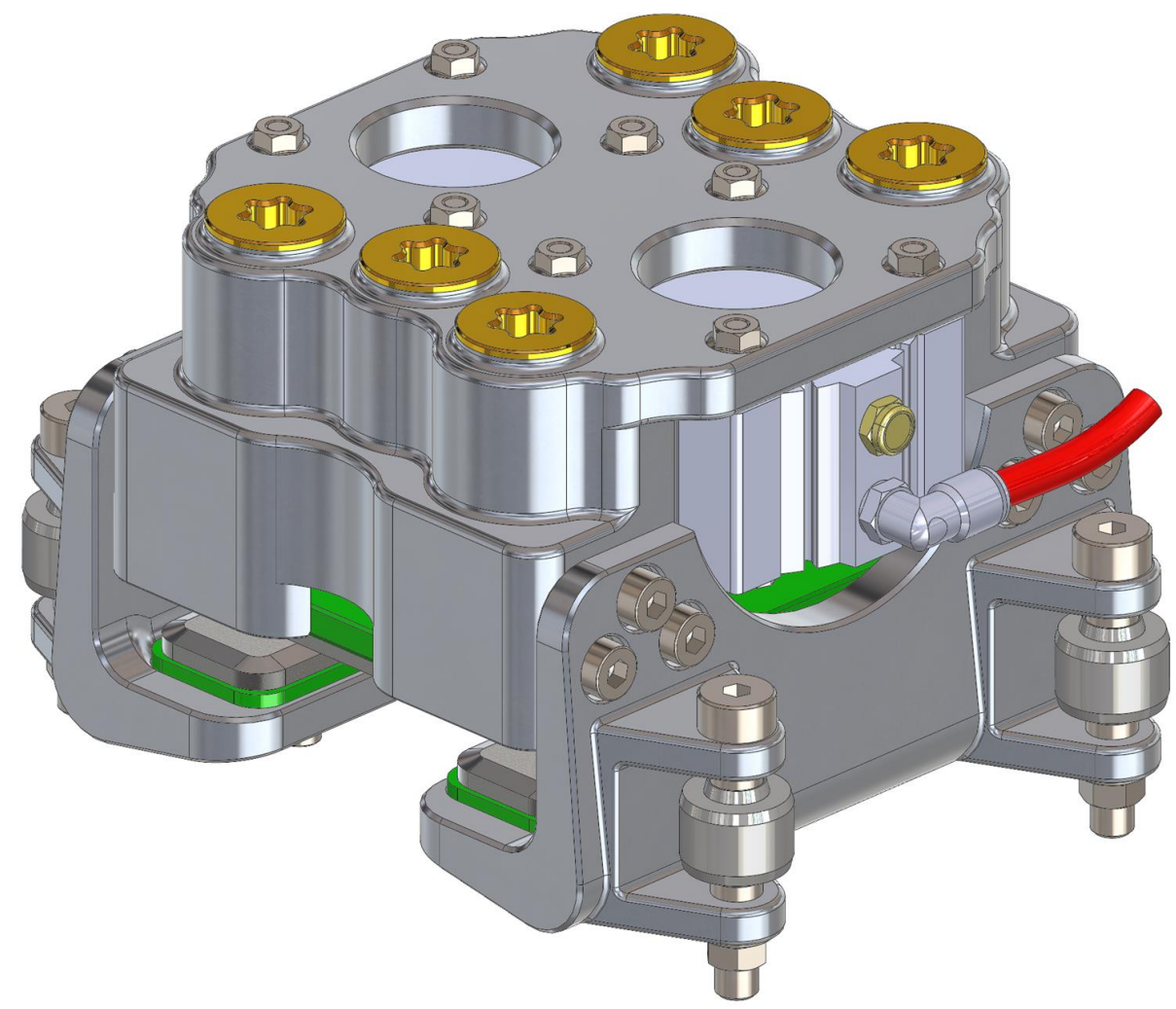


Figure 1. CAD of one brake

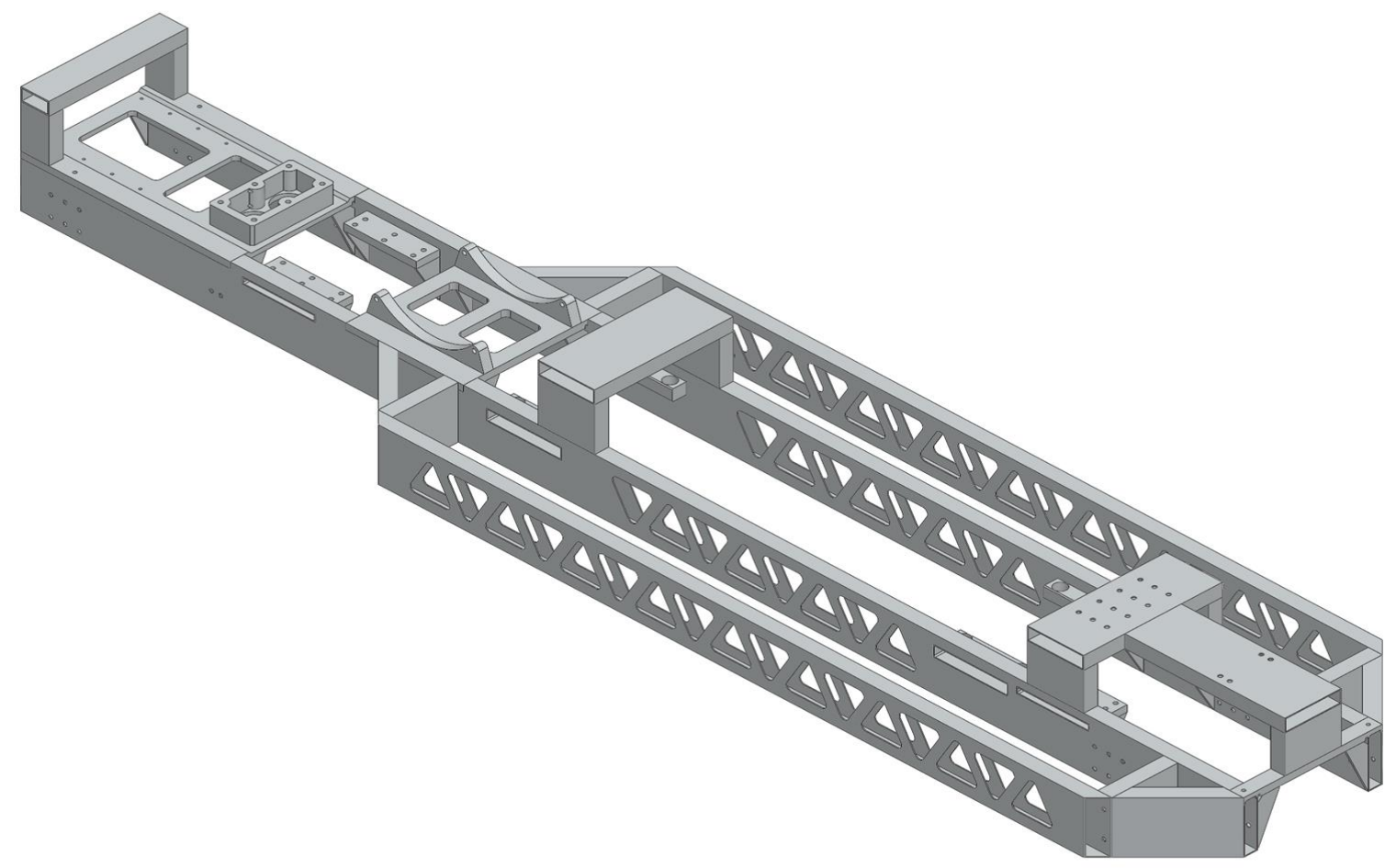


Figure 2. CAD the chassis

Thermal Profile of the Braking System

Problem

The amount of kinetic energy carried by the pod at top speed requires an efficient braking system. To avoid excessive increase of temperature, the material constituting the brakes pads must be chosen accordingly.

Computational Methods

- The module used is **Heat Transfer in Solid with Translational Motion**. Inserting the decelerating profile speed in the simulation, a material sweep was performed to choose the ideal one.
- COMSOL® enabled us to use an **infinite domain** and **contact with friction** that simulates the movement along the rail, without simulating the entire rail.



Figure 3. Manufactured Brakes

Results

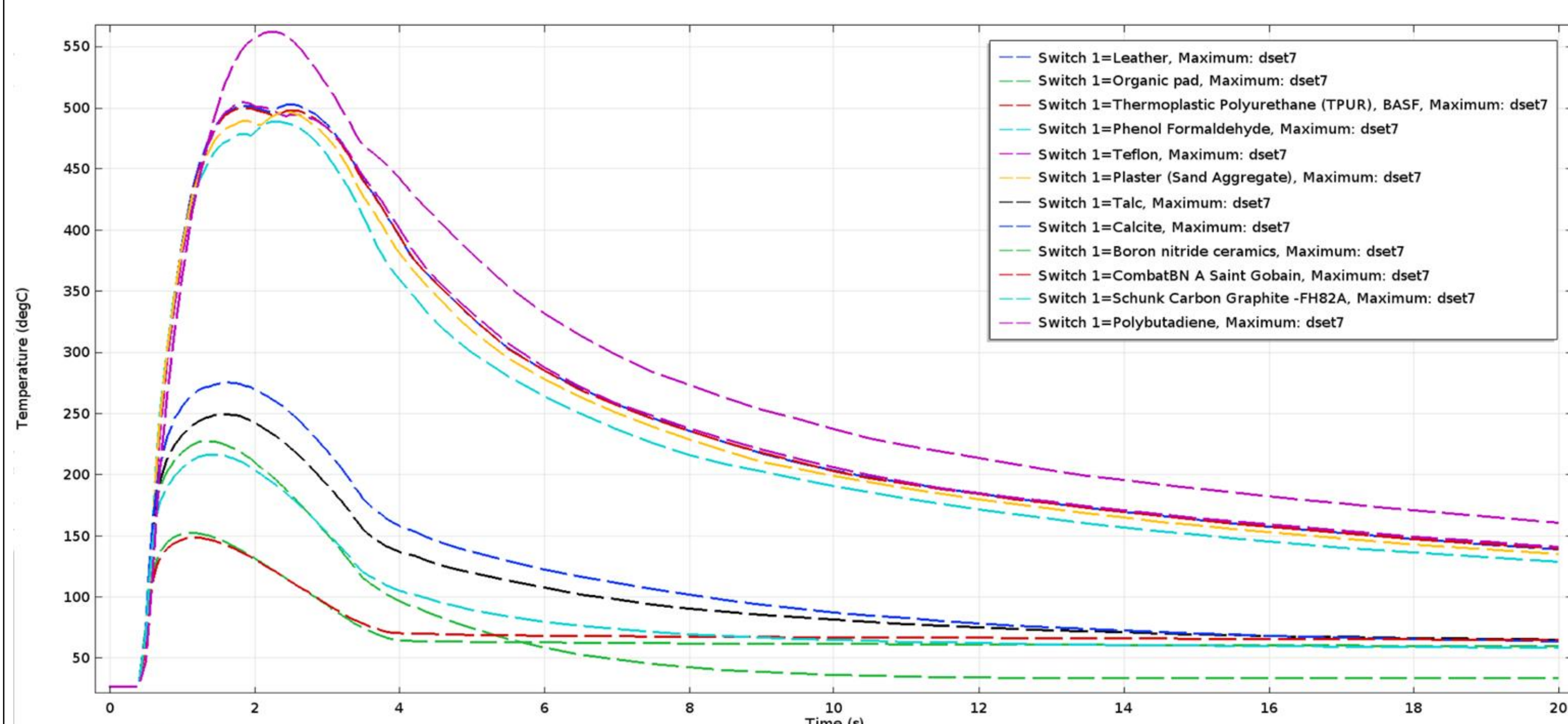


Figure 4. Thermal profile of the brakes

- The thermal profile curve shows a sudden increase of temperature at the braking stage and, then, an exponential decrease in time.
- It is possible to identify two families of curves, mainly dependent from the thermal conductivity and the friction parameter.
- The thermal profile of the material constituting the brakes shown that the ideal solution would be ceramic (Schunk Carbon Graphite, 213 degC) or boron nitrate (CombatBN Saint Gobain, 148 degC).
- The brakes pads have been prepared by Furka, using a recycled plastic fiber based material which properties are close to the analysis best results.

Structural Analysis of the Chassis

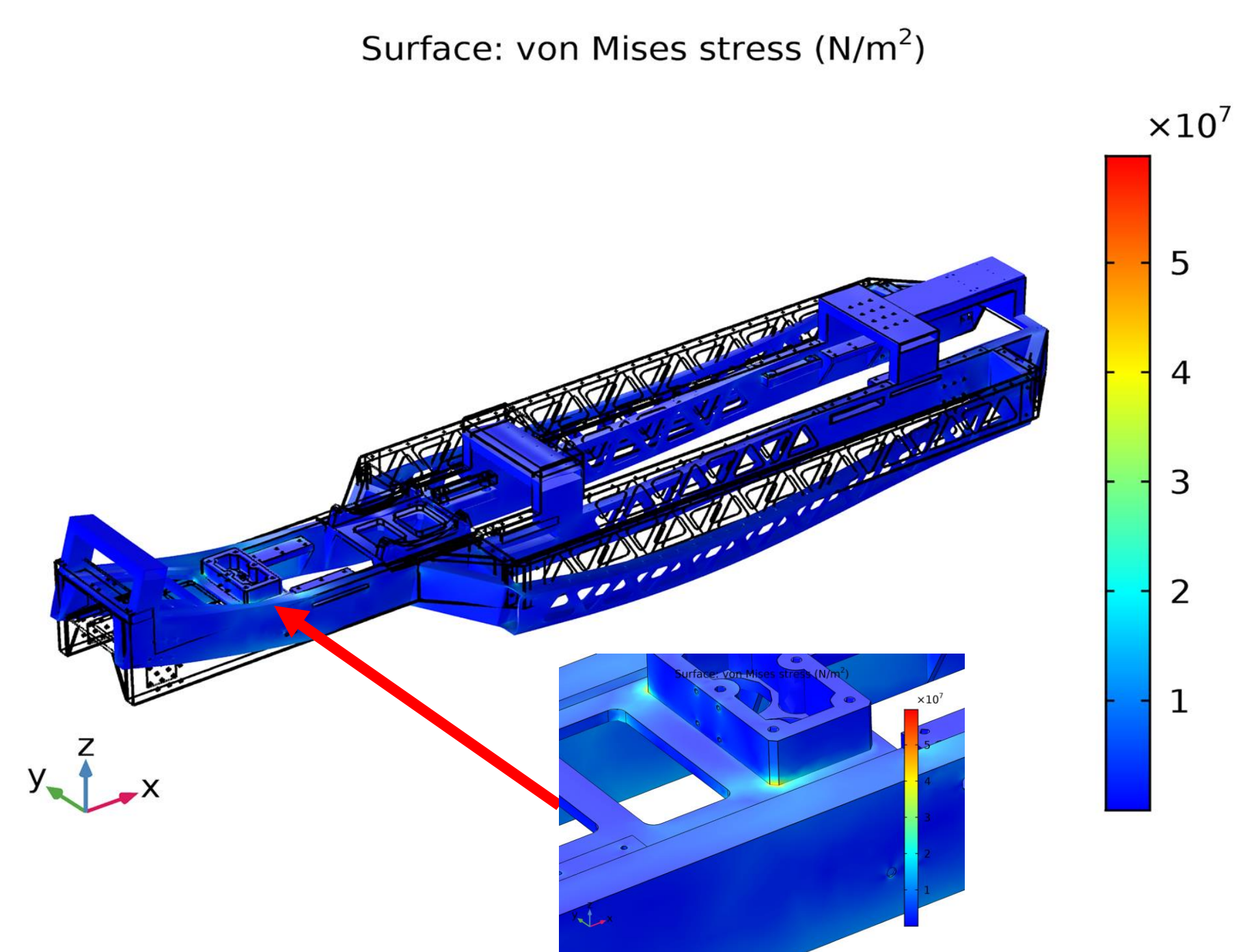
Problem

The mechanical loads acting on the POD require a careful design of the chassis. In order to avoid mechanical failure, structural analyses were performed.

Computational Methods

The module used is **Solid Mechanics**, where the applied loads are the ones nominally given by the sub-systems (pressure vessels, brakes, aeroshell, etc). Afterwards, a **linear buckling study** has been performed, in order to evaluate the maximum acceleration the chassis can sustain.

Results



The selected aluminum has an ultimate strength of 190 MPa and a yield strength of 160 MPa. Taking into account the shear strength, the Von Mises stresses should not be above 63 MPa on the structure. Eventually, the buckling linear system found that the chassis can withstand up to 15 times the loads with a safety factor of 2.

Dynamical Stability Analysis of the POD

Problem

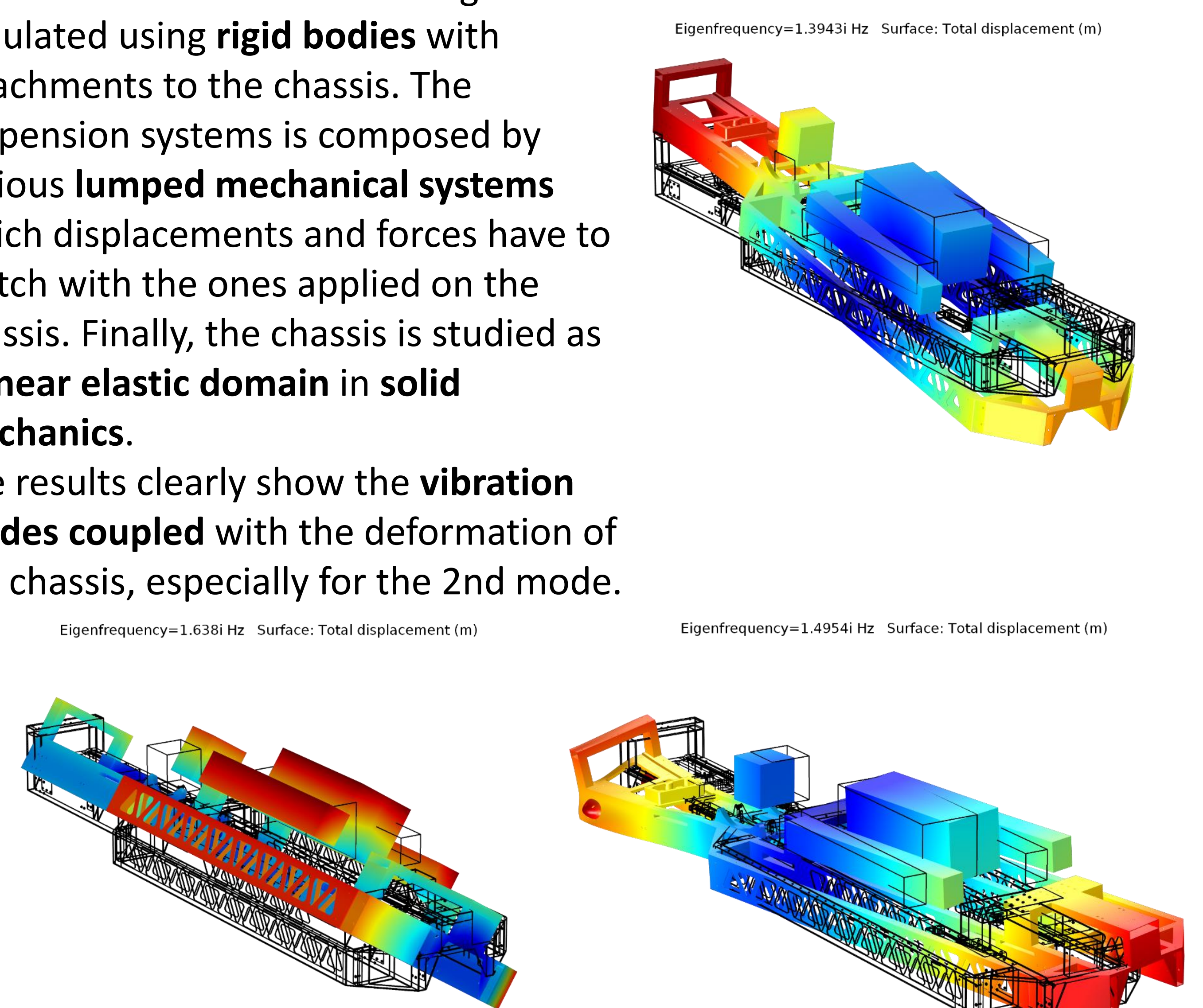
The stability of the pod during the test runs is of crucial importance, since it will allow to provide the maximum performance, ensuring continuous adherence to the rail and complete use of the torque characteristics of the motor.

Computational Methods

In order to simulate the complexity of the suspension system and the effect of the mass distribution on the pod, the following modules has been used: **Multibody dynamics, Lumped mechanical systems** and **Solid mechanics**.

The presence of the three pressure vessels and the motor are being simulated using **rigid bodies** with attachments to the chassis. The suspension systems is composed by various **lumped mechanical systems** which displacements and forces have to match with the ones applied on the chassis. Finally, the chassis is studied as a **linear elastic domain in solid mechanics**.

The results clearly show the **vibration modes coupled** with the deformation of the chassis, especially for the 2nd mode.



Conclusions:

This work pointed out how it is possible to study the complete structure of a transportation system prototype such as the EPFLoop pod. The thermal performance of the braking setup and the stresses on the structure due to loads and vibrations were easily calculated in COMSOL, even if the problem is strongly coupled. We acknowledge EPFL, EE and COMSOL®.