Lab-7A: Structural Analysis (FEA) of Your Device

Due Monday August 10th

FEA of Mini-car: General Instructions on

There are a number of FEA analyses you could conduct on your solid model, such as:

I. Investigated the **strength** of your chassis:
   → Determine the maximum load that your chassis can handle without yielding.

Or:

II. Optimize your chassis for **minimum mass**:
   → Determine the minimum mass of the chassis without yielding (carrying the motor).

Choose to ***either*** *evaluate the strength* ***or*** *to minimize the weight of the chassis. Additionally you may want to perform an advanced analysis such as Topology (optional).*

General Steps for performing FEA:

STEP-1: Simplify the solid model
STEP-2: Select type of analysis (this assignment: static)
STEP-3: Assign material properties
STEP-4: Assign restraints and apply loads (BCs)
STEP-5: Mesh and run
STEP-6: Extract and analyze results
STEP-7: Optimize the design

Assume you are conducting a FEA on the chassis of the mini-car shown in Fig. 1. The chassis is made of **Acrylic (*medium high impact !*)**.

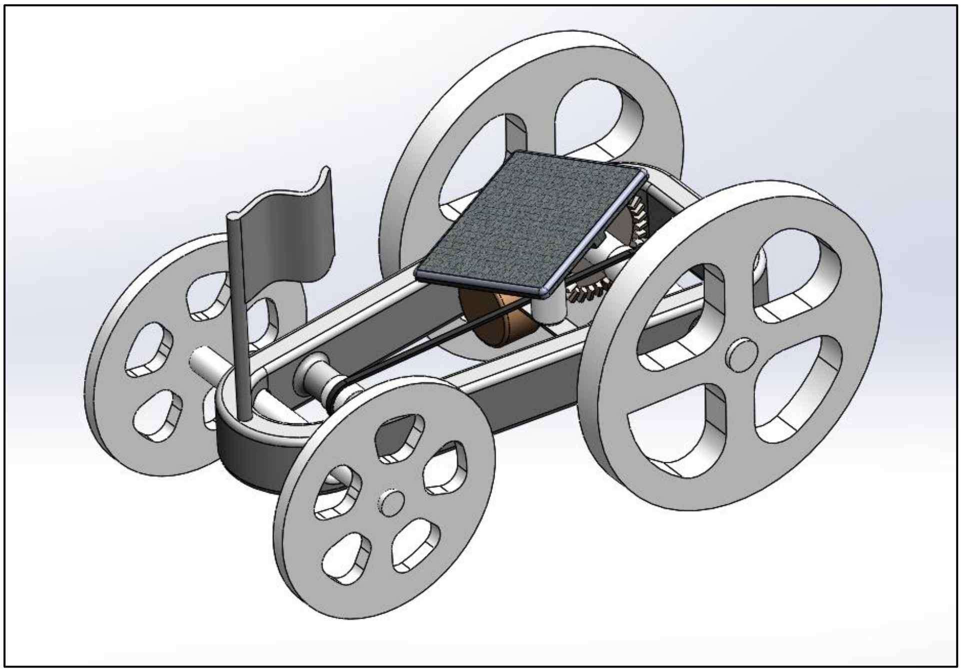


Figure 1: Solid model of a solar- and rubber band powered car

1) Strength of the Chassis

STEP 1: Simplify the solid model for FEA

(a) Suppress features or parts of the assembly that are **not contributing** to the strength of the chassis

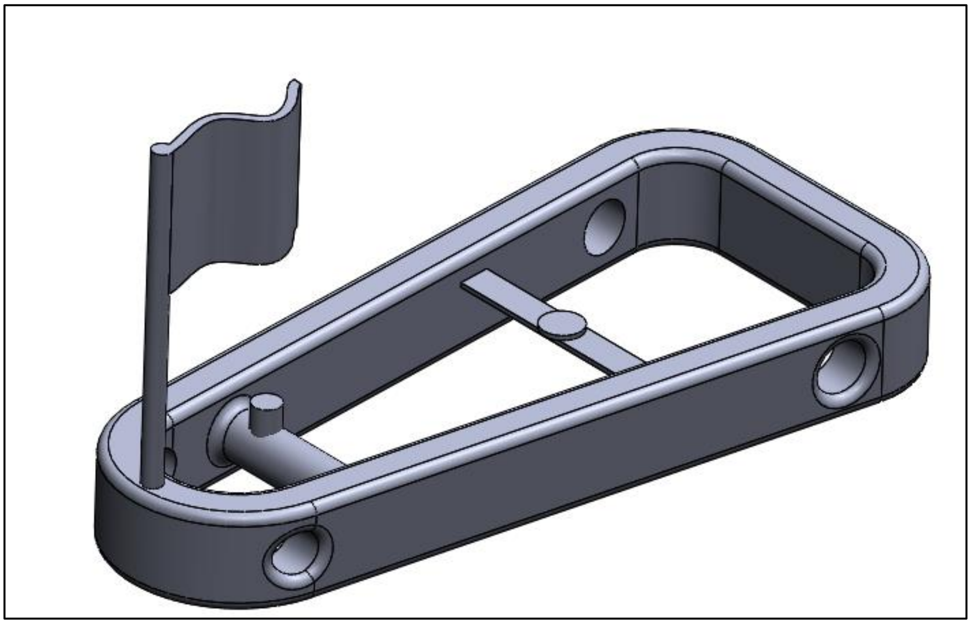


Figure 2: Chassis with removed parts that are not contributing to its strength

(b) Eliminate features that are not critical (**relatively thin structures, rounds, fillets,** …)

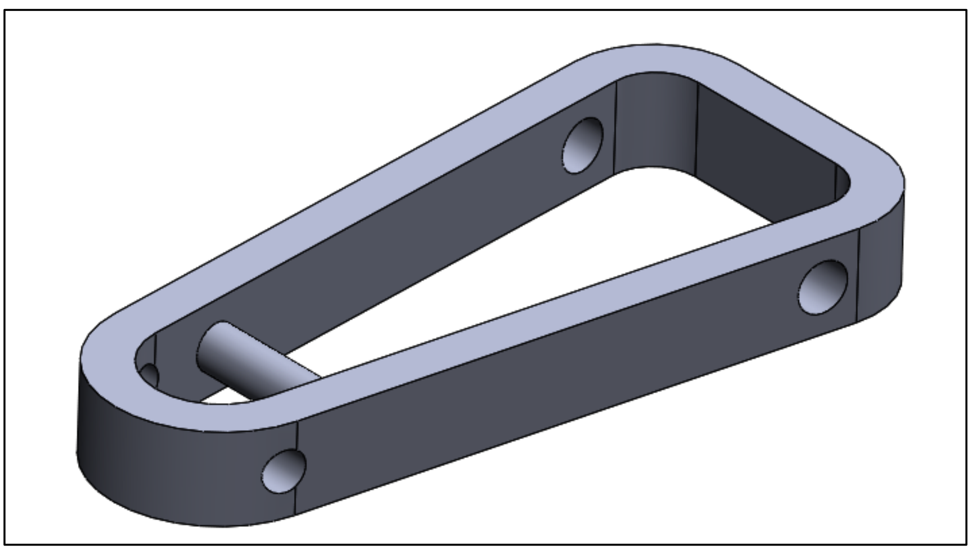


Figure 3: Simplified chassis (removed **thin** cross bar, rounds, and fillets)

STEP 4: Applying BCs: Fixtures and Loads

In order to apply restraints (“fixed” BCs) the model requires **split lines** inside the axle holes. The axles are pushing up against the top face of the axle hole.

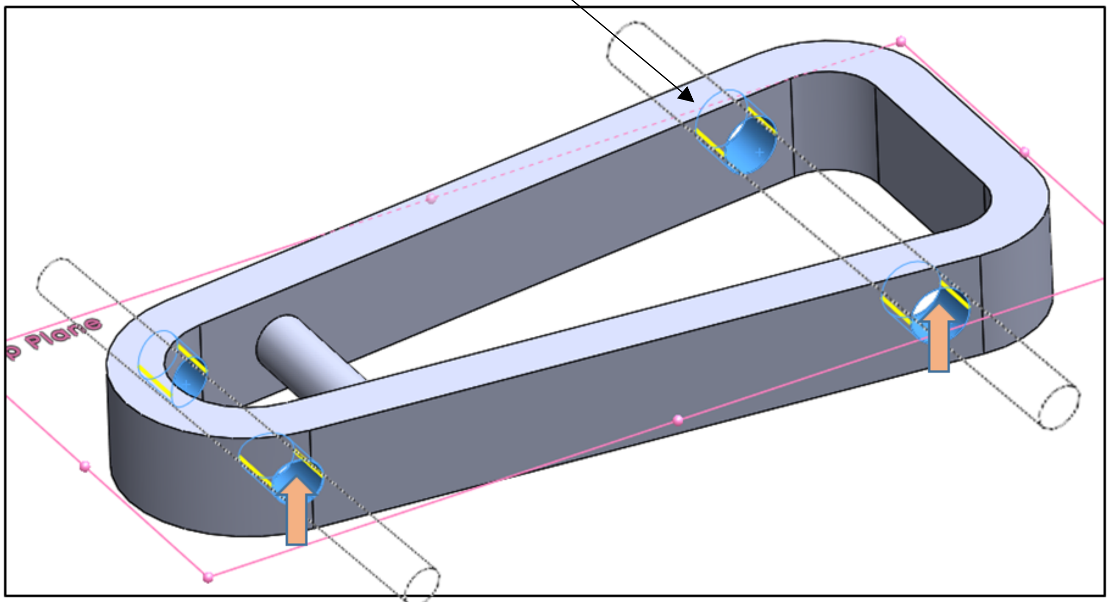


Figure 4: Axles push up against the top face of the axle hole (split lines are shown in yellow).

Assume someone steps on the chassis and we would like to apply a load to represent this situation:

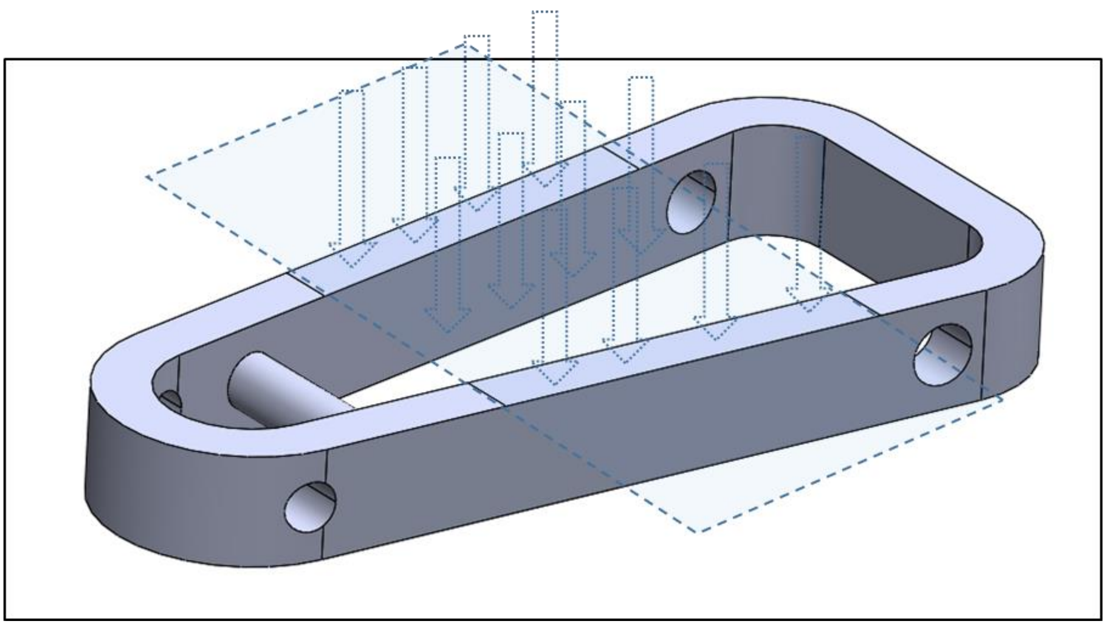


Figure 5: FEA model of chassis showing outline of anticipated load on the structure.

Added split lines representing the boundaries of applied force:

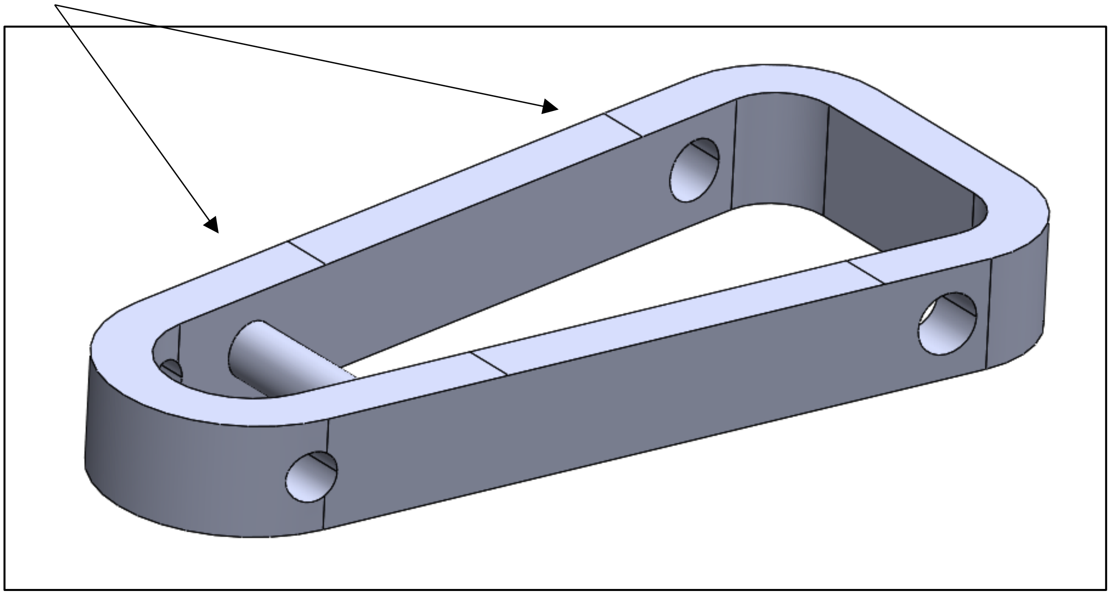


Figure 6: FEA model of chassis showing split lines representing the "footprint" of applied force.

NOTE: The decisions of how and where to apply BCs and Loads are at the designer's discretion. I am showing only one possibility – you might want to analyze a completely different loading scenario.

STEP 4 (continued): **Assign Restraints and Loads**

Only the top halves inside the axle holes are restrained ("fixed"). A load of 500 N was chosen as an initial guess to run the analysis.

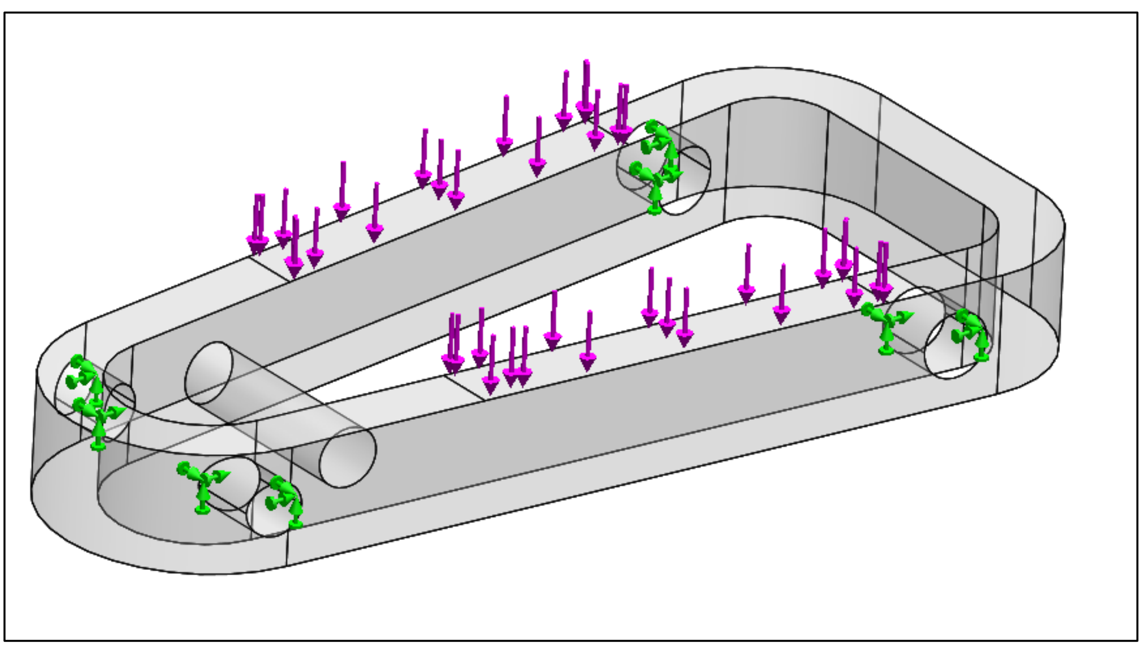


Figure 7: FEA model of chassis showing applied loads and restraints (BCs).

STEP 5: Mesh and Run the analysis

STEP 6: Extract and review results

No part of the chassis experiences a stress of more than 18 MPa, which means he chassis is not yielding to the Load of 500 N.

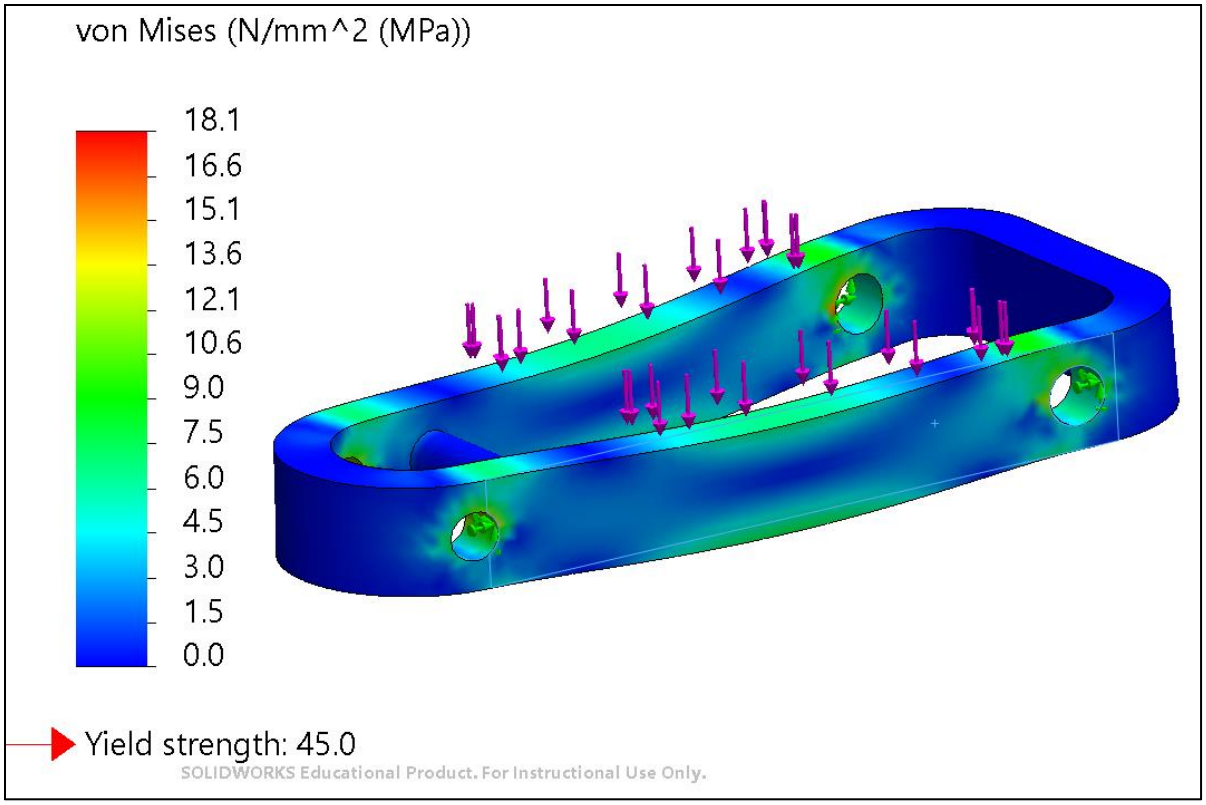


Figure 8: Chassis stress contours resulting from an applied load of 500 N (maximum stress is 18 MPa; yield strength is 45 MPa)

STEP 7: Optimize the Design

In this STEP-7, we are **<u>not optimizing</u>** the design, we are only trying to establish what the maximum stress is that the chassis can withstand without yielding.

To determine the maximum load we can incrementally increase the applied load and run the analysis until parts of the chassis result in yielding (yield strength is 45 MPa).

As a first guess, we triple the load from 500 N to 1500 N and run the analysis.

At a load of 1500 N the chassis yields!

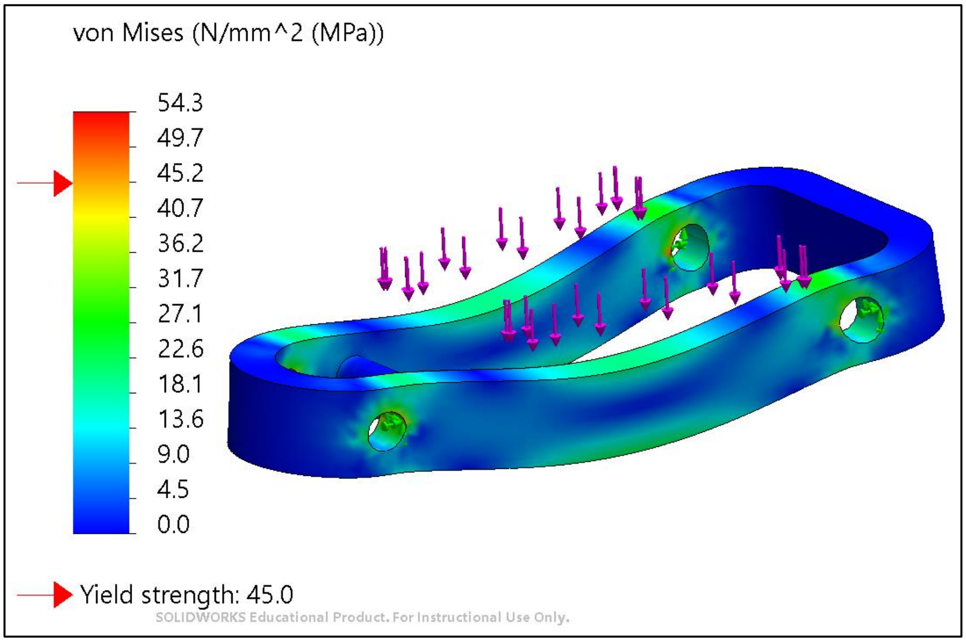


Figure 9: Chassis stress contours with an applied load of 500 N (maximum stress =18 MPa; yield strength = 45 MPa)

Because segments of the chassis are experiencing yielding (Fig. 9), we reduced the load to 1000 N and ran the analysis, which resulted in no yielding. Next, we increased the load to 1300 N, then back down to 1150, then up to 1200 N, and thus established the maximum allowable load without yielding to be 1200 N.

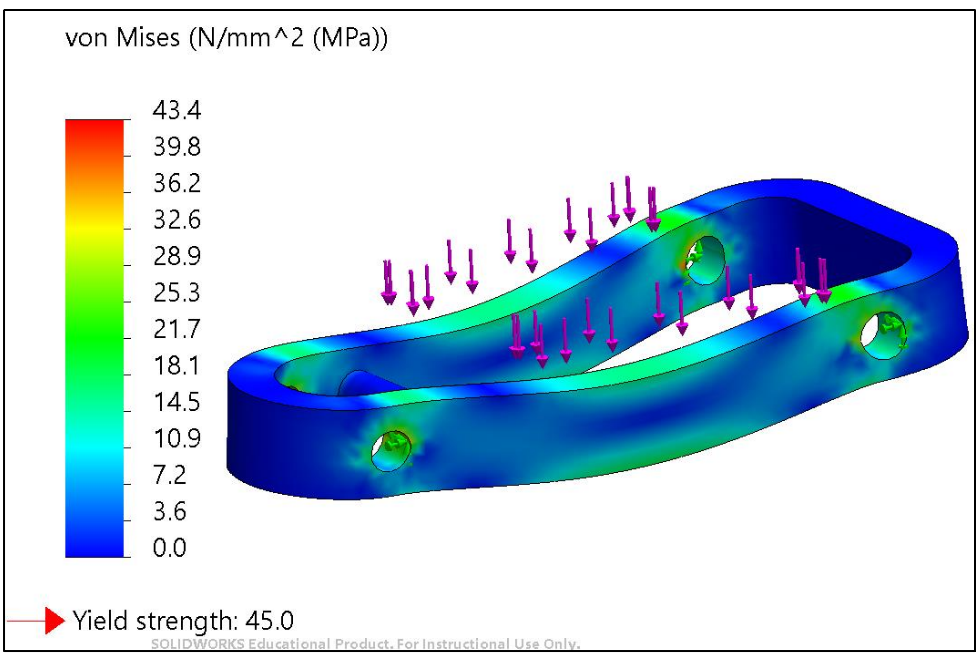


Figure 10: FEA analysis of the chassis showing stress contours with an applied load of 1200 N before yielding sets in.

2) FEA Analysis to Minimize the Mass of the Chassis

First attempt: reduce the thickness of the chassis from 10 mm to 5 mm!

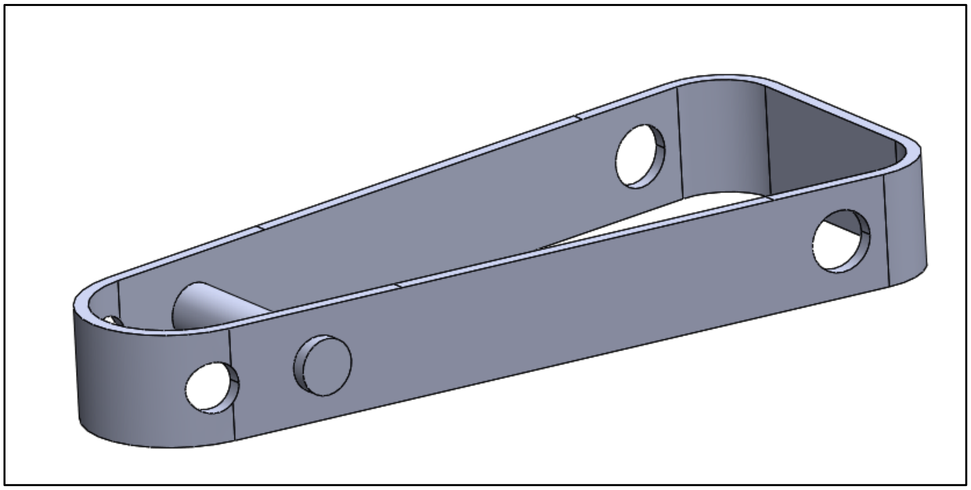


Figure 11: Simplified chassis model with a thickness of 5 mm for FEA (removed thin cross bar, rounds, and fillets)

The total mass that the chassis needs to support is that of the motor (~ 50 g) and solar panel (~15 g). Including wires and a switch we use a total mass of 100 g. Therefore, for the analysis we apply a load of **1N to the chassis.**

The same fixed BCs from the previous analysis and the same split-lines are used to apply a load of 1 N. The analysis is meshed and run and results are shown in Fig. 12.

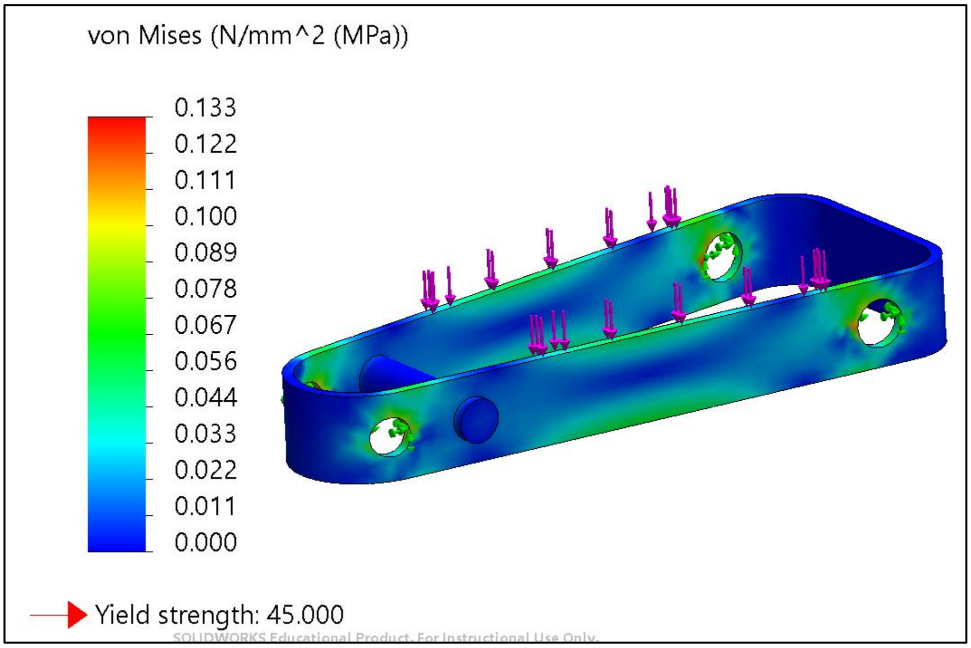


Figure 12: Chassis stress contours resulting from an applied load of 1 N (maximum stress is < 0.15 MPa; yield strength is 45 MPa)

Clearly the chassis is over-designed – in order to save material the height of the chassis is reduced.

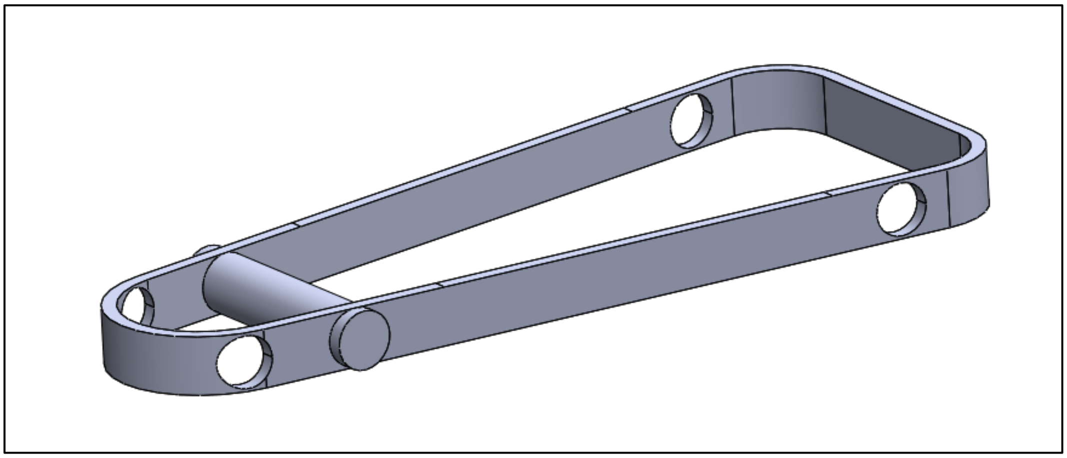


Figure 13: Chassis model with a reduce height from 20 mm to 10 mm

Running the analysis with the same load of 1N:

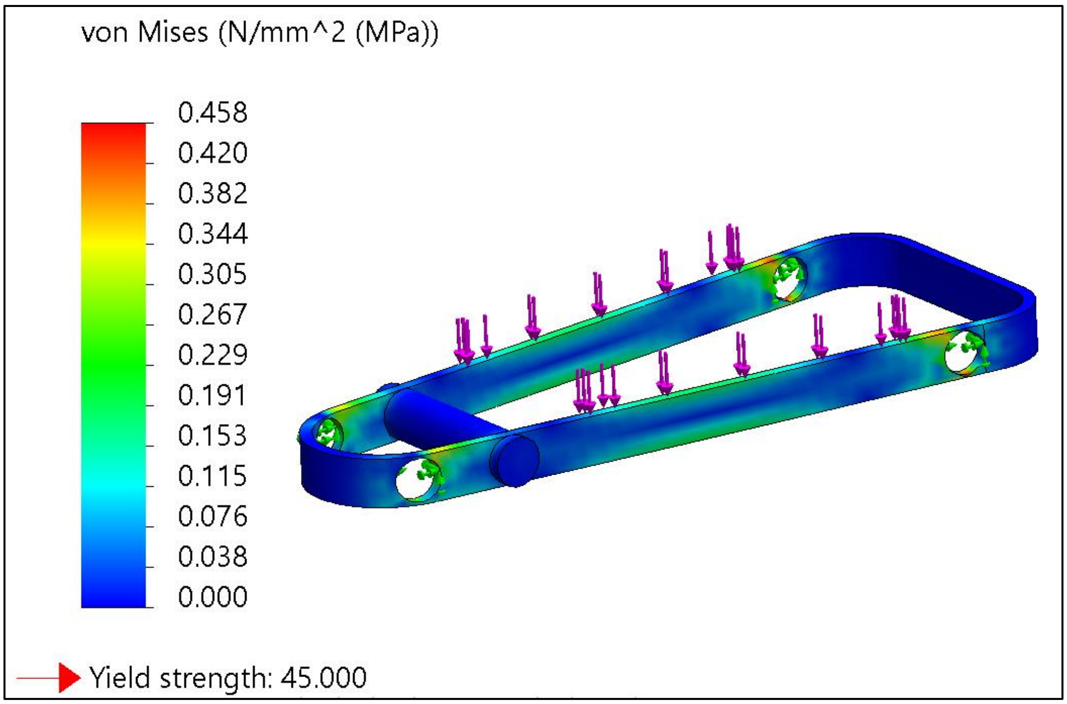


Figure 14: Reduced height chassis stress contours resulting from an applied load of 1 N (maximum stress is < 0.5 MPA)

Modifying the chassis further:

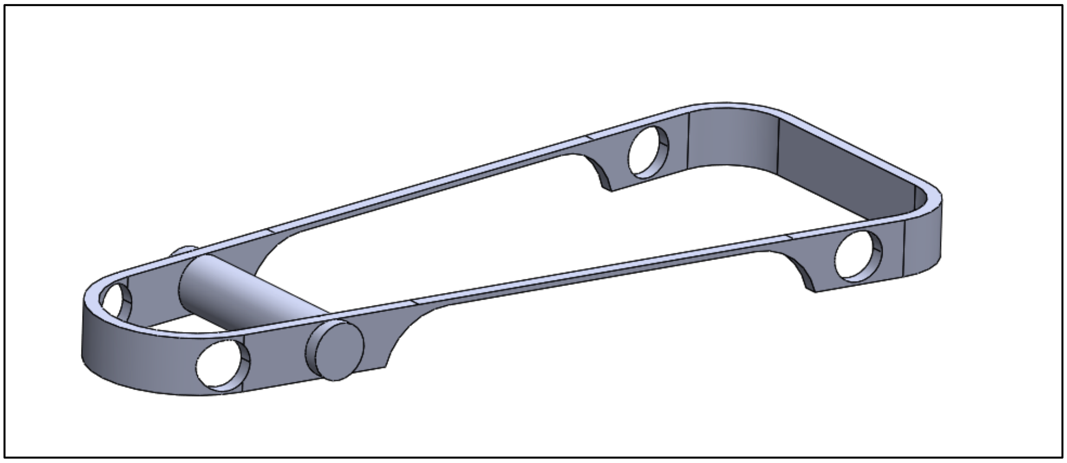


Figure 15: Chassis model showing additional reduction of mass.

Load = 1N

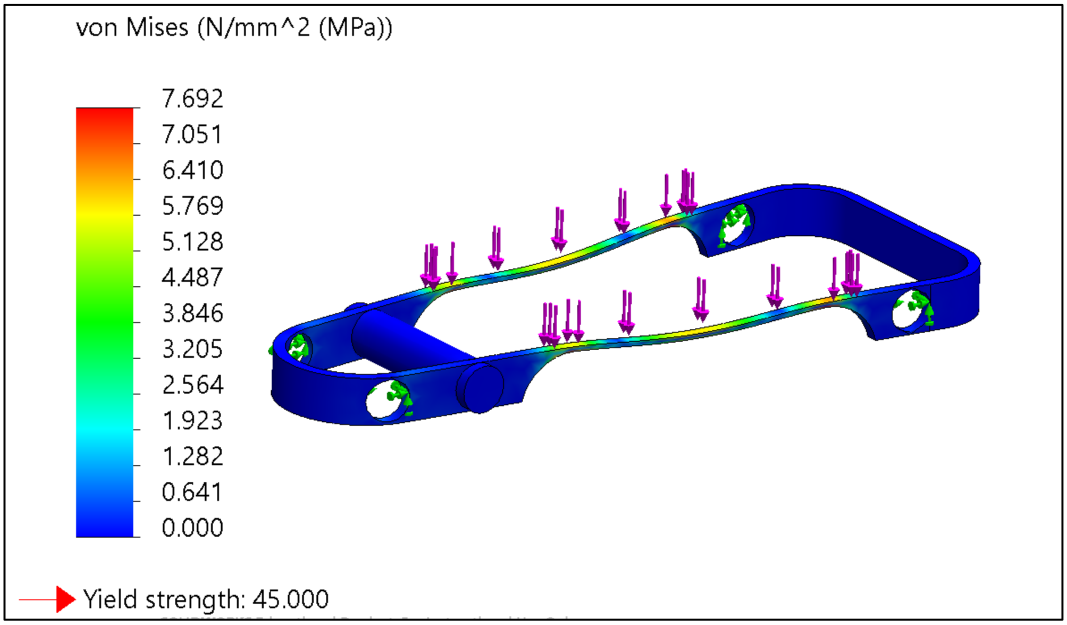
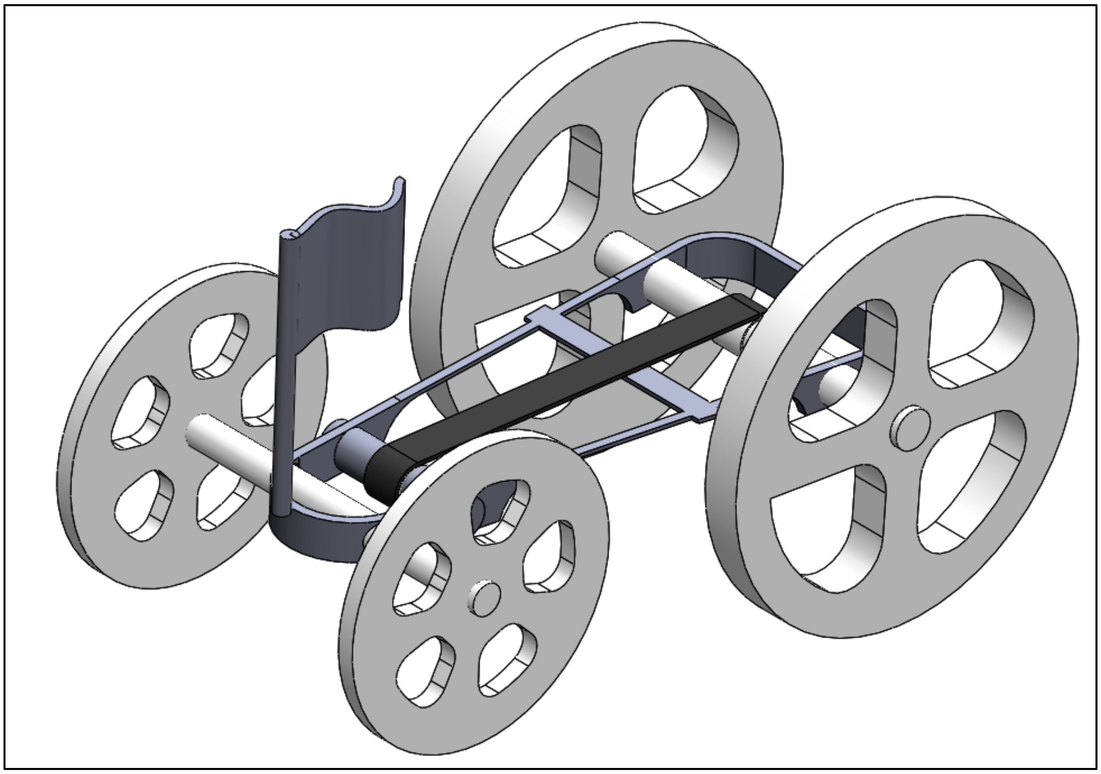


Figure 16: Stress contours of chassis with "minimized mass" and an applied load of 1 N (maximum stress is < 8 MPA)

OPTIMIZED Chassis can carry the load of the motor, solar panel, wires, and a switch without yielding:

The chassis can handle the 1 N load even when its thickness is reduced to about 1x1 mm^2.

Mini-car Chassis Optimized for Minimum Chassis Mass•



- This is not a comprehensive optimization of the mini car – a number of other modifications are possible, such as minimizing the thick interconnecting rod in the front of the chassis, the size and thickness of the wheels, the diameters of the axles, etc.

DELIVERABLES:

Pick either the "maximum load" or the "minimized chassis" analysis. Conduct the FEA on the chassis of your mini-car and present a short report with figures and results showing the initial model, the model with applied BCs, and results (always write the maximum stress in the figure caption. End the report with a short statement stating what the maximum load is or what the lowest-mass chassis is that your device could handle.

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