KAZIMIERZ PULASKI UNIVERSITY OF TECHNOLOGY AND HUMANITIES IN RADOM

GREEN AND SAFE ROAD TRANSPORT IN LOCAL COMMUNITIES

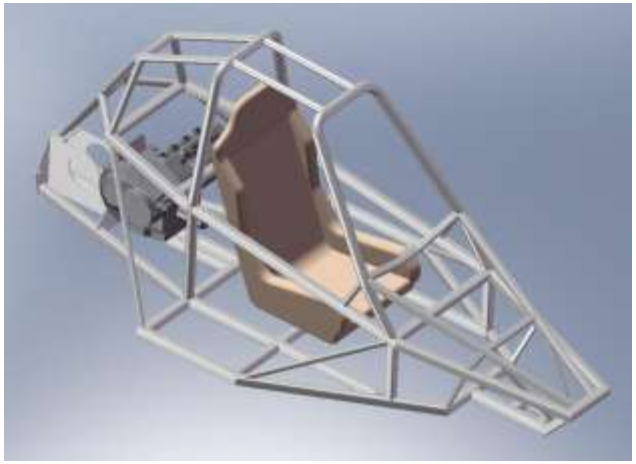
Erasmus Intensive Programme

Radom, 07-20.04.2013

Designing of safe and light weight vehicle body

Krzysztof Olejarczyk

UTH Radom



Contents

1. **Introduction:**
   - Goal of project
   - Review of constructions

2. **Main body:**
   - Construction of safety cage and its durability requirements
   - Steps to prepare a model
   - FEM frame strength analysis

3. **Summary**

Goal of project

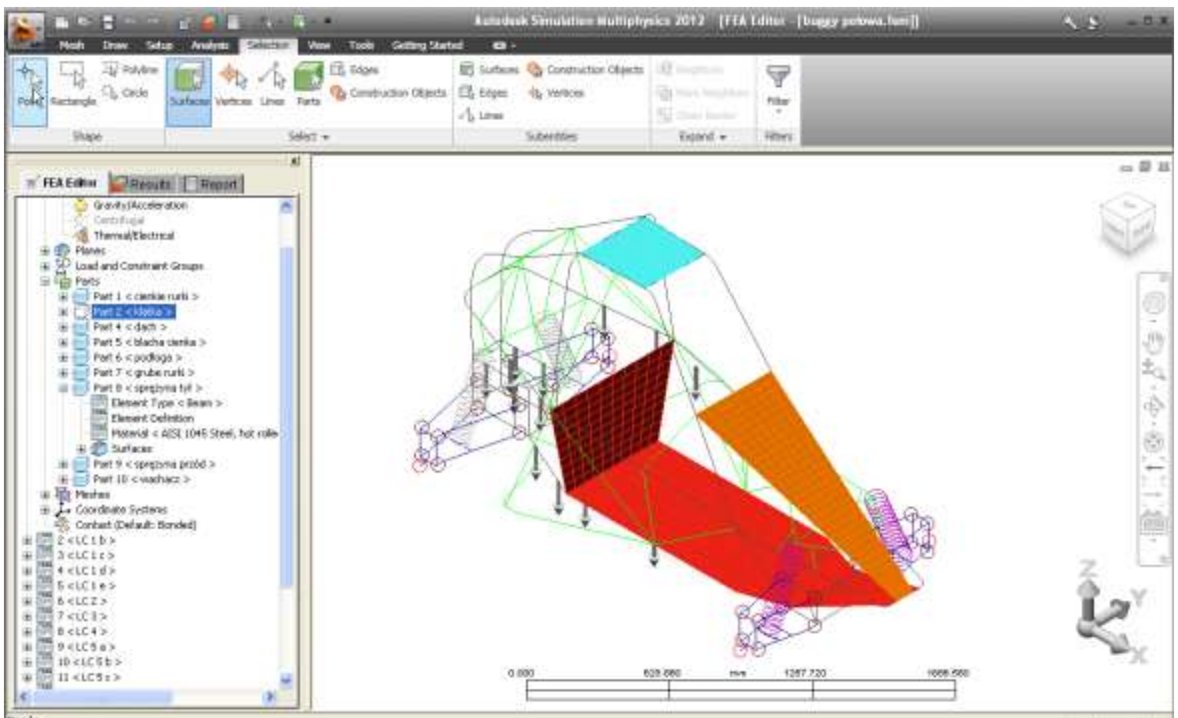
The goal of the project is to design the model frame of the "buggy" vehicle by means of using the selected program which supports the design.

It is also necessary to perform a series of computer calculations in order to simulate the behaviour of the structure under the influence of different load conditions as well as to formulate proposals for the stiffness and strength of the designed construction.

The frame of the vehicle model visualization is performed using Computer Aided Design (CAD) SolidWorks software.

Strength calculations are made by means of the Finite Element Method (FEM) using CAE AUTODESK Symulation Multiphysics – Algor software.

AUTODESK Symulation Multiphysics® – a software package for the realization of the strength calculations, thermal, dynamics, vibrations, electrostatics and visualization of the results of calculations using the FE method



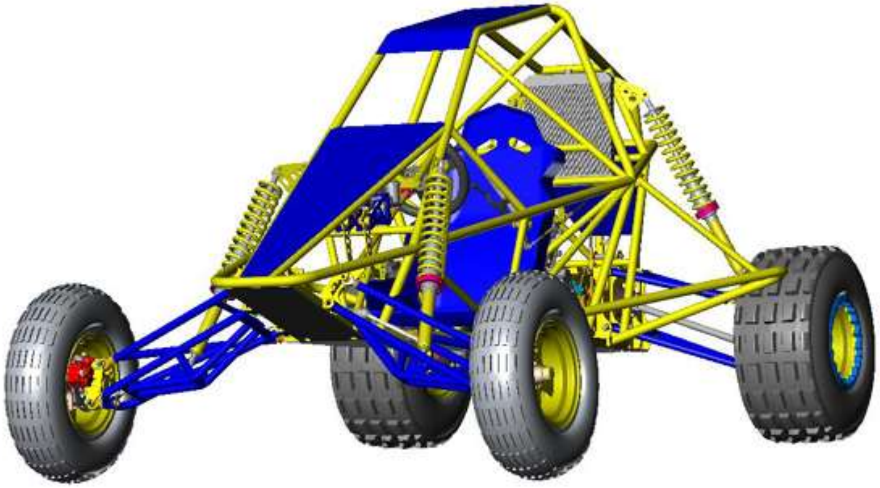
Review of constructions

Badland Buggy

Computer model of
Badland Buggy "ST3” frame

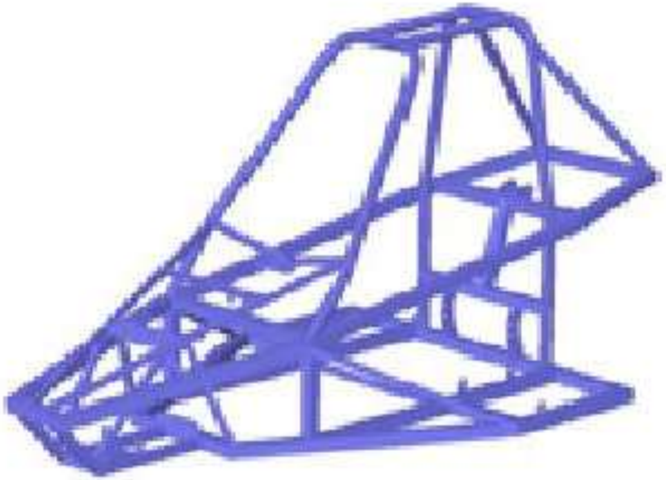
Badland Buggy ST3model
(without engine and gearbox**)**

The Edge



Computer model of
„The Barracuda" buggy

The Edge



"The Sidewinder" buggy
and its model

Chenowth Racing

3D model of the frame's
Chenowth Racing
desert’s buggy

Chenowth Racing's vehicle

Chenowth Racing

Military vehicle's Chenowth Racing

Polish regulations for the design of type buggy vehicles

Basically, there are no regulations for the construction of the buggy frame.

But to be able to take part in official races, the buggy frame construction must satisfy the basic safety criteria for **safety cages** used in racing cars, built according to the guidelines of appendix "J" federation FIA

Objective of a safety cage

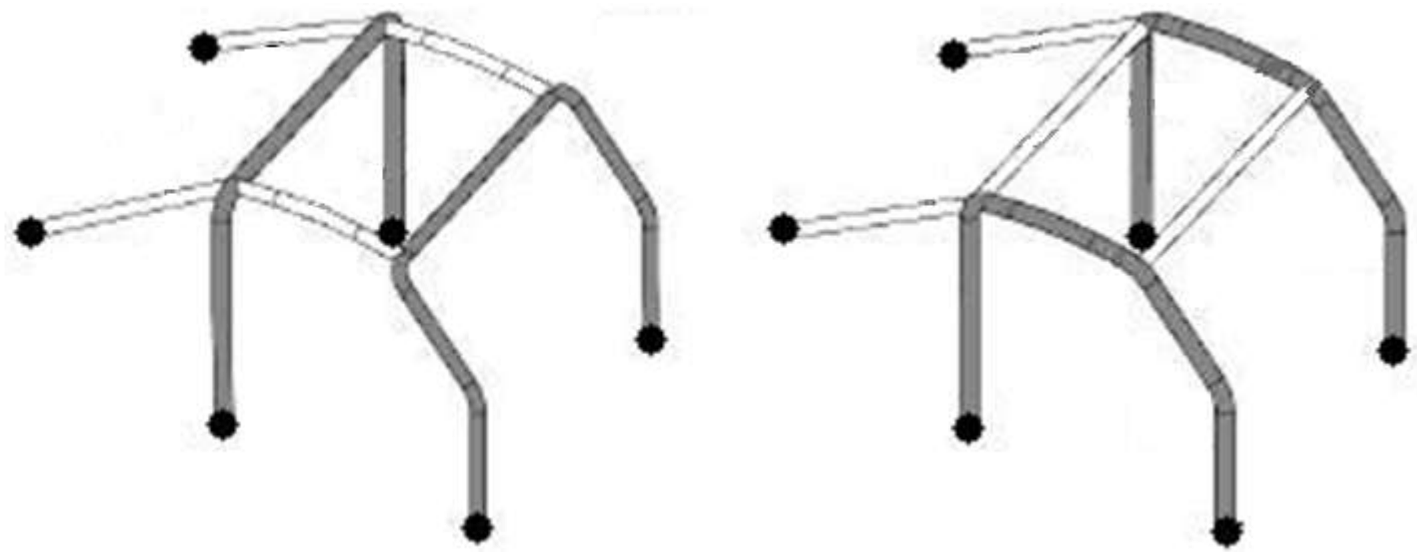
The use of safety cage is designed to protect drivers from crushing and serious injuries induced by hitting an obstacle or a rollover.

Construction of safety cage

The construction of the base frame must contain the following elements:

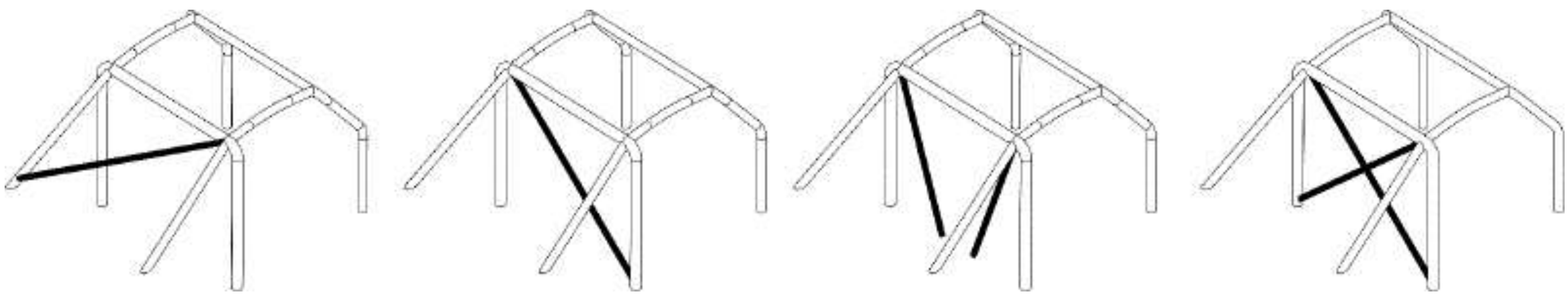
Option I: 1 roll bar main + 1 roll bar front + 2 longitudinal elements + 6 fixing points

Option II: 2 side roll bar + 2 transverse elements + 6 fixing points



Construction of safety cage

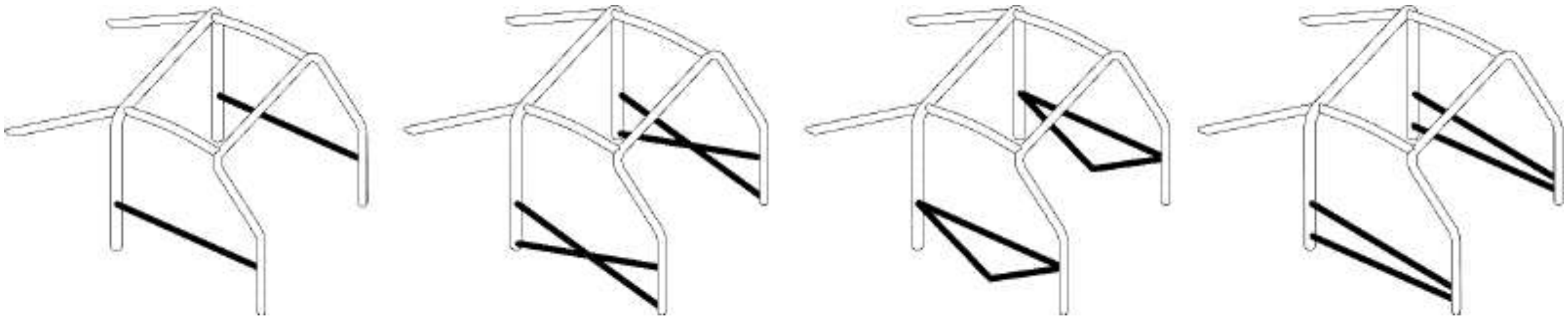
The structure must be complemented by obligatory strengthening element(s) as shown in figure



Places diagonal element(s)

Construction of safety cage

In case of side door strengthening elements, one or more of these elements must be installed on each side of the car as shown in figures



Possible places and methods fix the side door strengthenings

Materials specification used for safety cage construction of buggy

Material:	Minimum tensile strength R_m :	Minimum dimensions (diameter x wall thickness **mm**):	application**:**
Carbon steel, cold drawn, containing up to 0.3% carbon	350 N/mm^2	ø45 x 2.5 or ø50 x 2.0	Main rollbar, rollbar side and its connection to the construction.
		ø38 x 2.5 or ø40 x 2.0	Other elements of the safety cage

Safety cage strength requirements

-Evaluation of the safety cage must cover the whole structure, and therefore the test must be performed on the model of the complete frame.

- The test can be performed using a hammer with minimum dimensions 500x200mm.

- All the tests should be performed for the upper part of the cage.

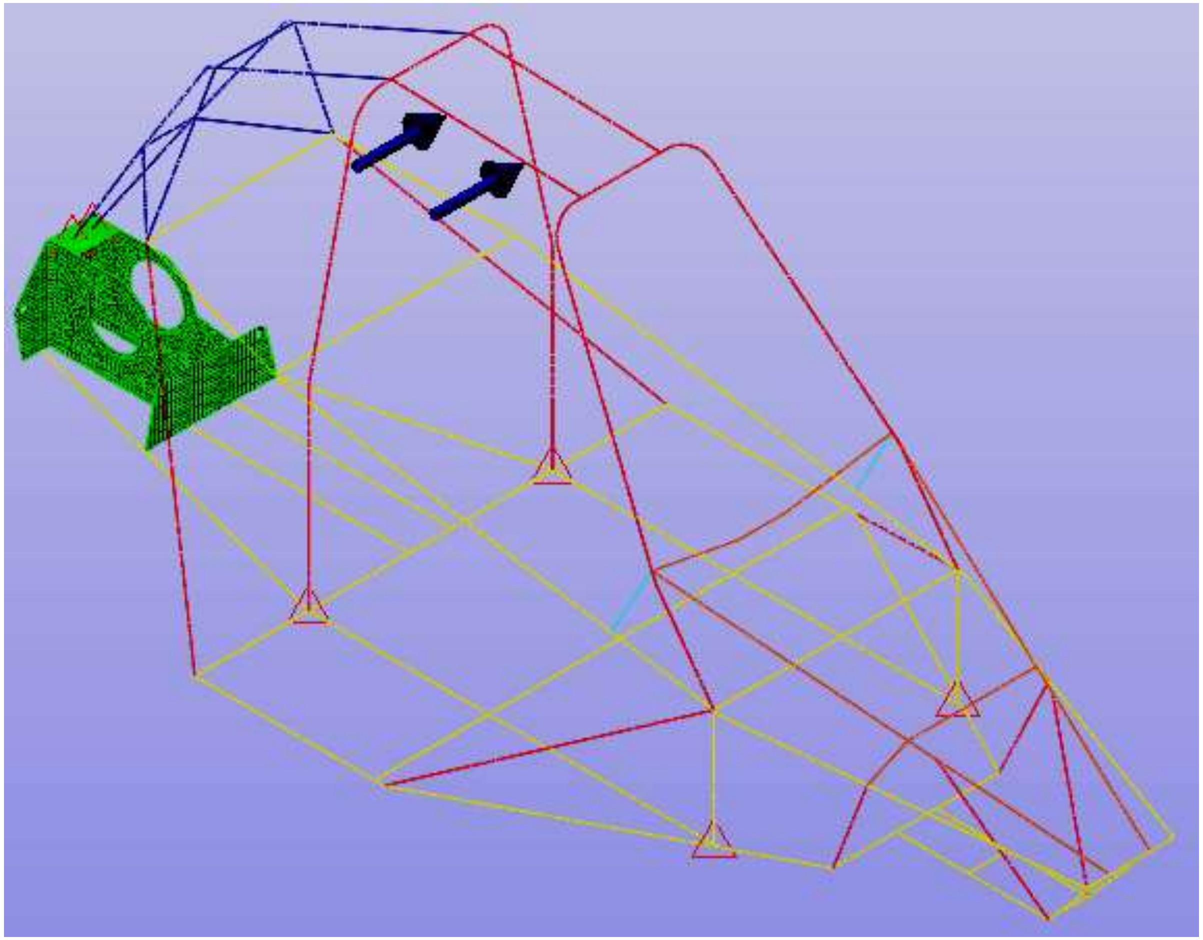
- No cracks or plastic deformation greater than 50mm are allowed in the whole structure after the tests.

Safety cage strength requirements

Because we did not know the total weight of the vehicle, therefore the tests were designed for a mass limit of 400kg.

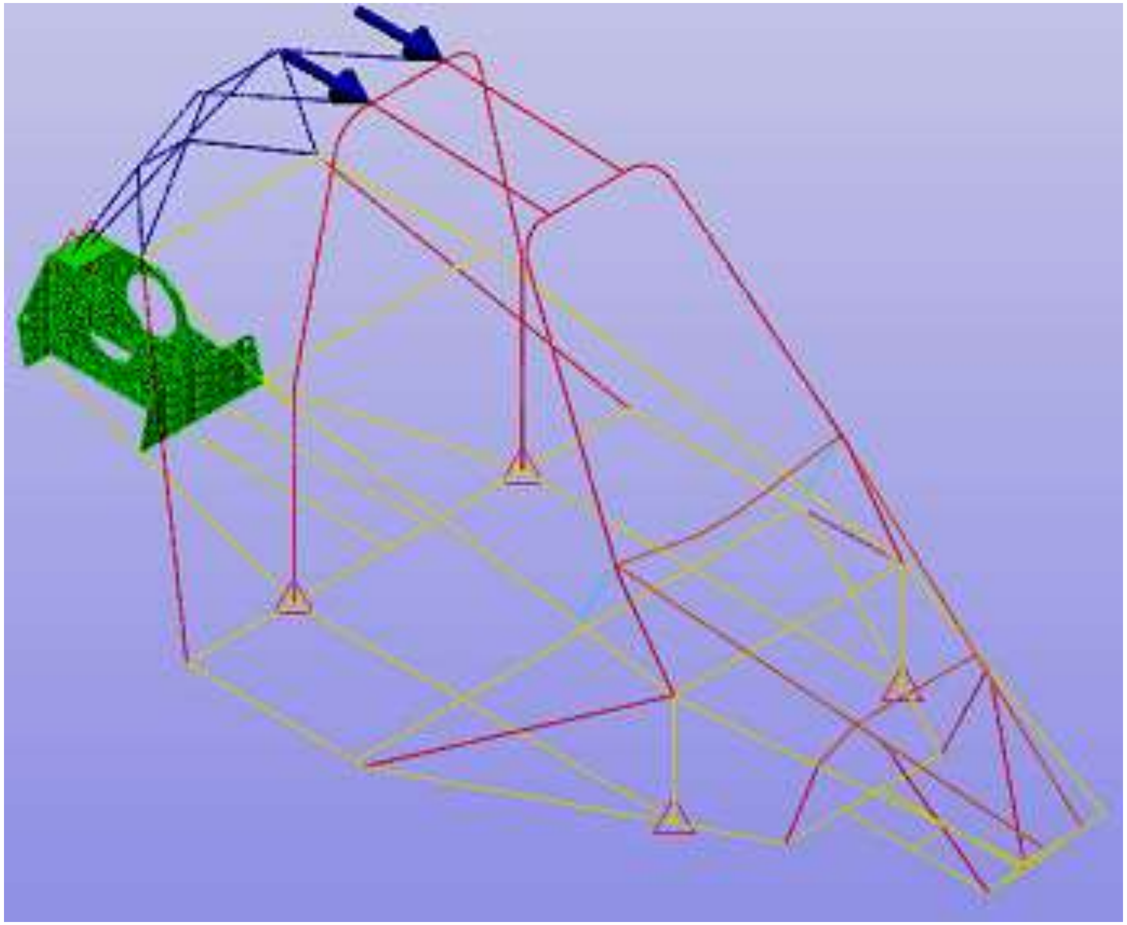
W (kg) = **W**eight of the vehicle (kg) + 150kg)

Safety cage strength requirements – transverse load



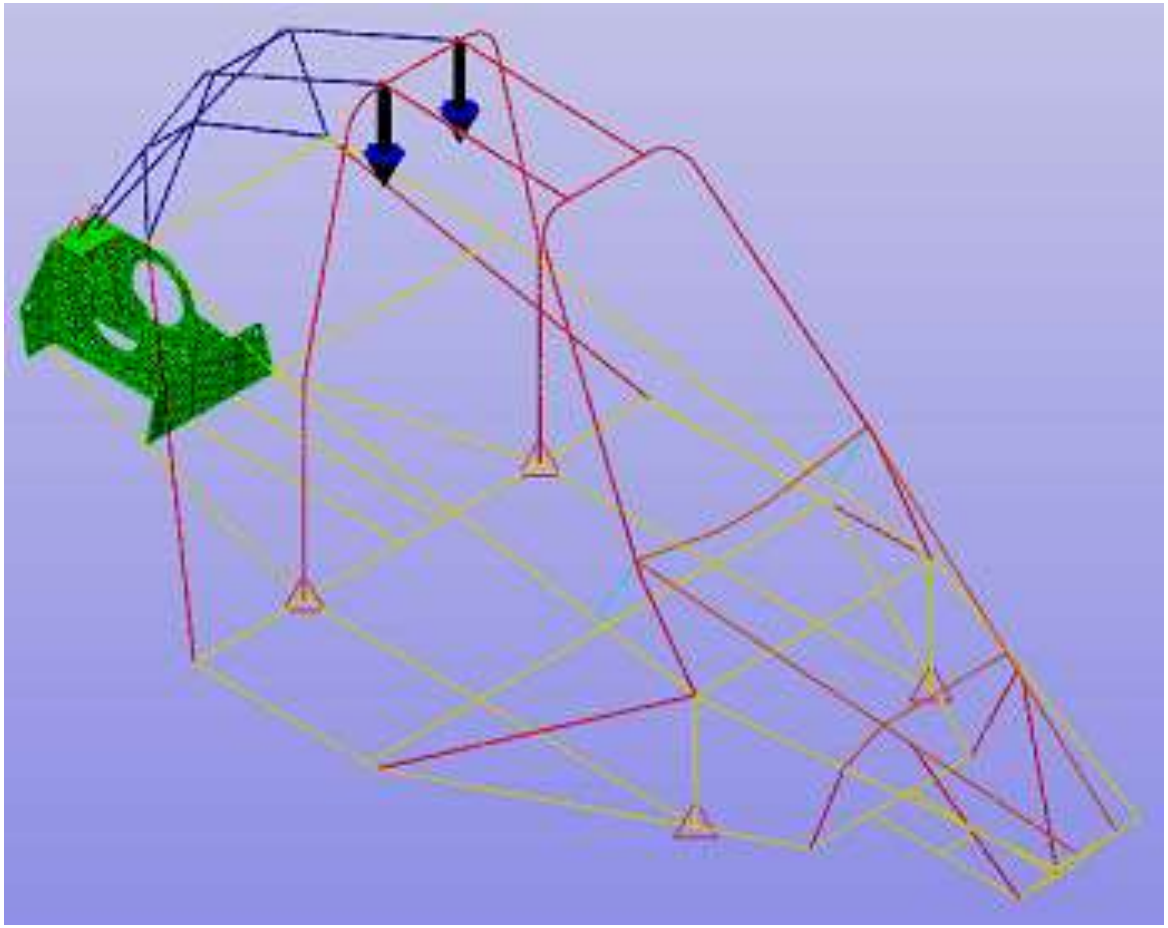
1,5 * W =825kg (≈8250N)

Safety cage strength requirements- longitudinal load



5,5 * W =3025kg (≈30250N)

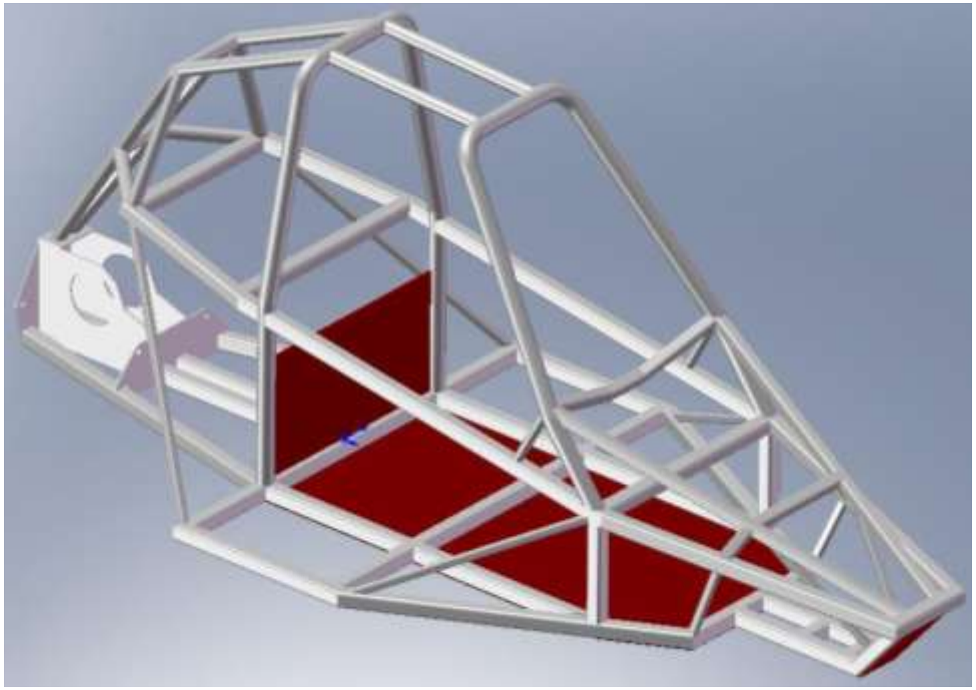
Safety cage strength requirements – vertical load



7,5 * W = 4125kg (≈41250N)

Floor plate - design requirements

The floor must be made of metal and extend from the axis of pedals until the driver's seat. It has the shield of an integral front leg to the height of 30cm and the wall on the engine space to the height of 50cm.



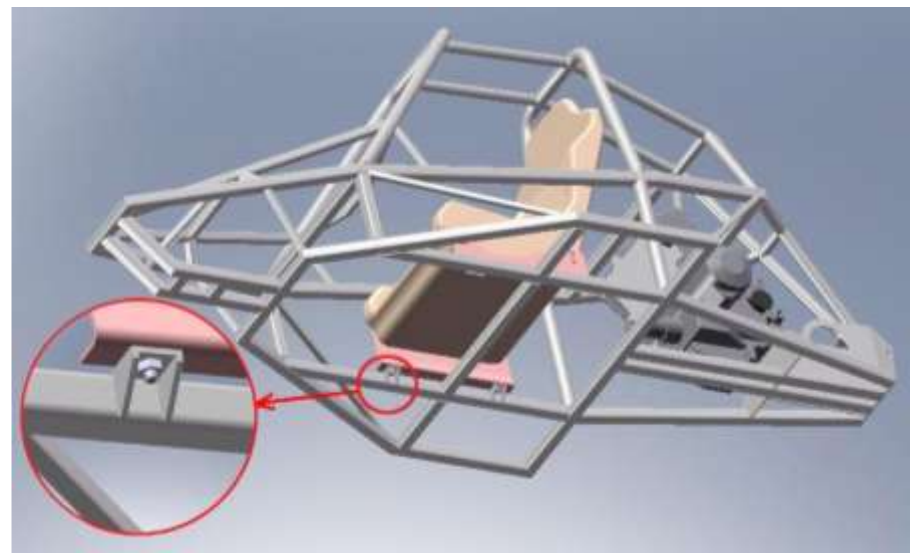
Location of main floor and metal shields - a model made in SolidWorks.

Engine and gearbox

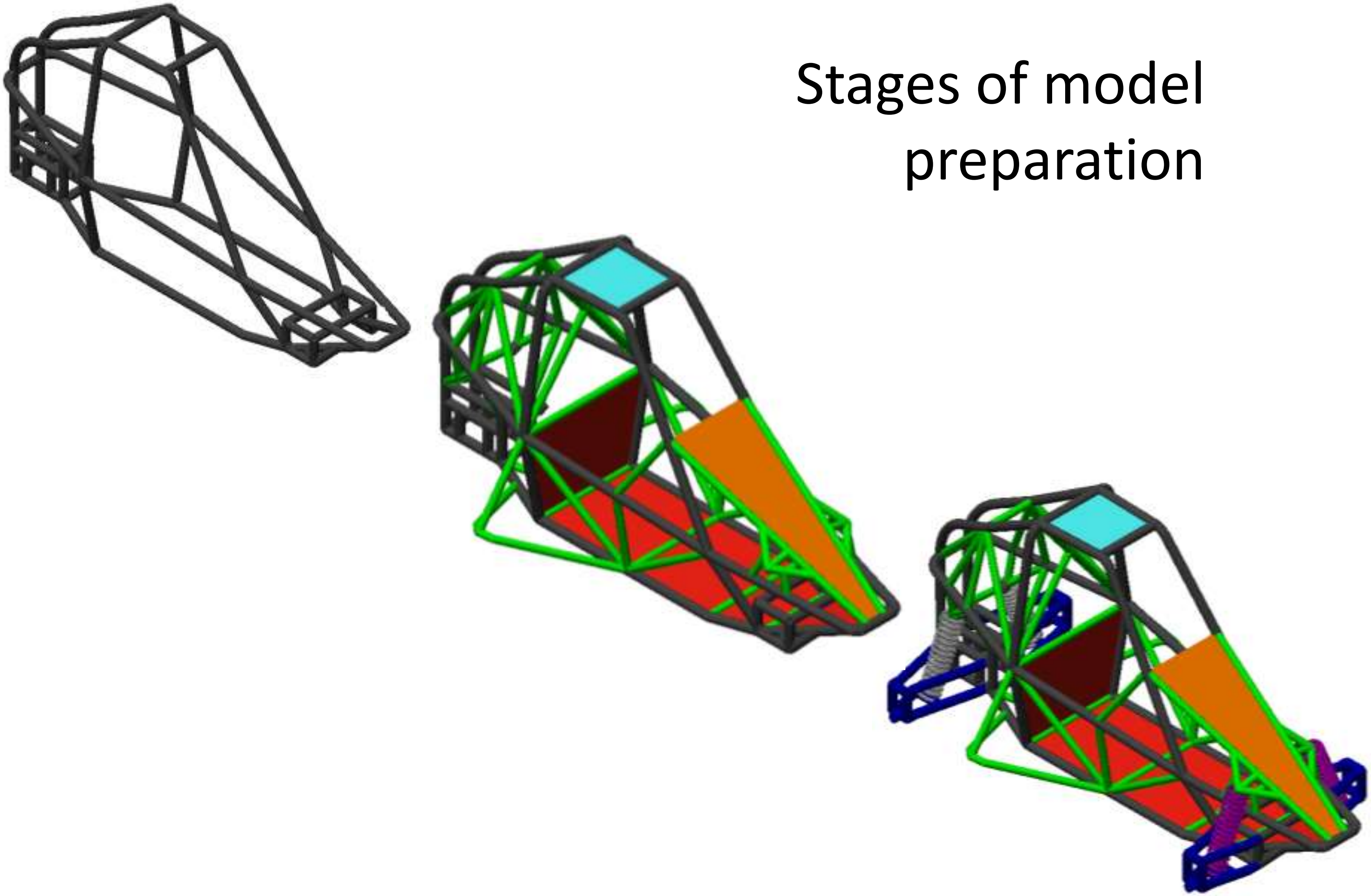
Selection criteria :

- simple location and attachment to the frame (dimensions);
- relatively high power output in relation to its weight and main dimensions;
- not complicated transfer of gear mechanism; low sensitivity of electrical installation to atmospheric conditions;
- low failure rate of the engine and other components while working in hard environments.

Seat and its attachment



Stages of model preparation

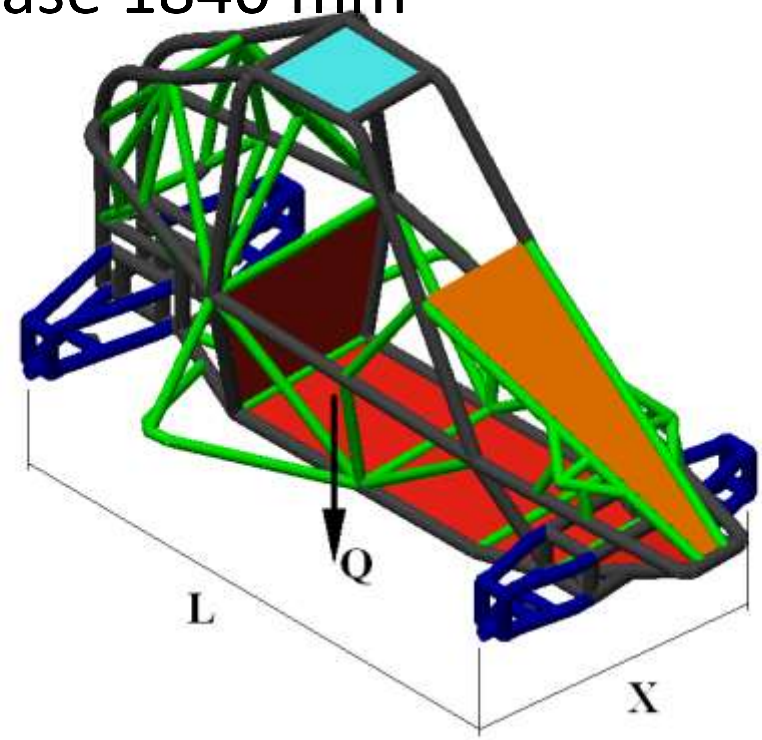


Initial project assumptions

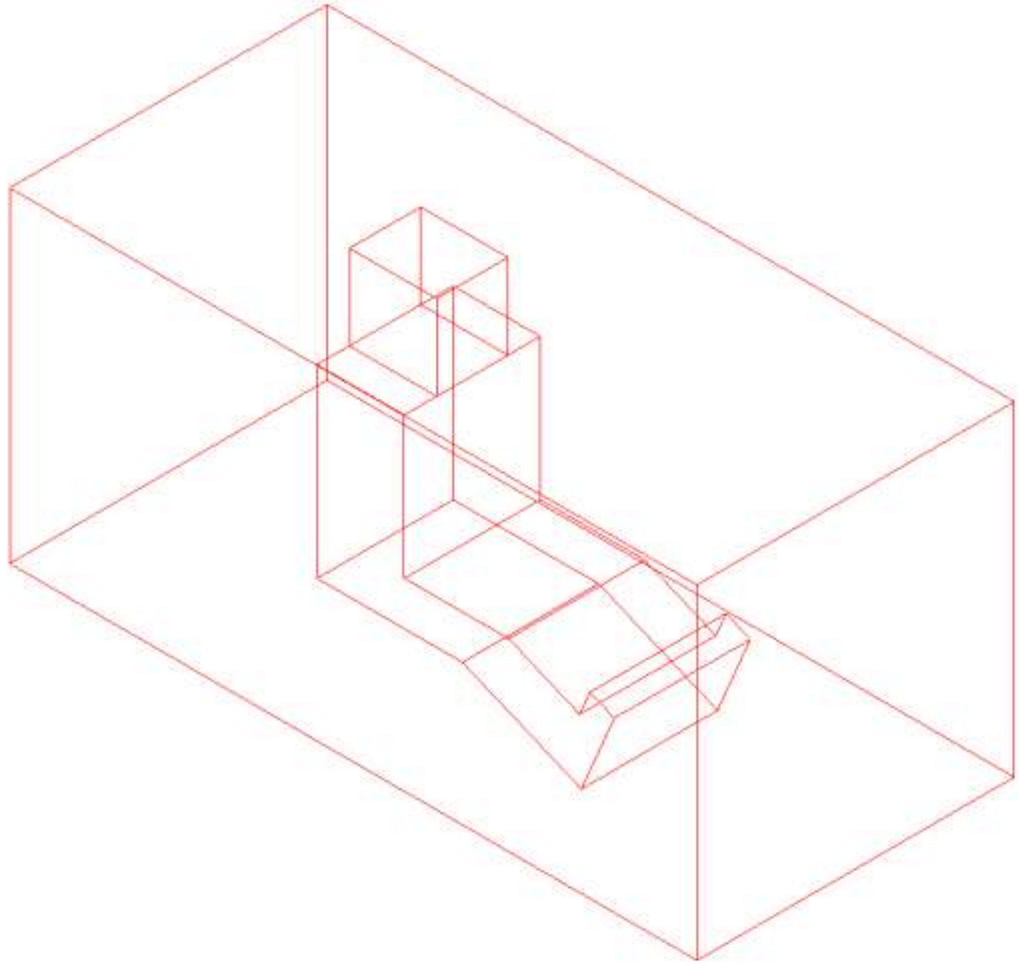
Q - Vehicle mass 400 kg

X - Maximum wheel truck 1300mm

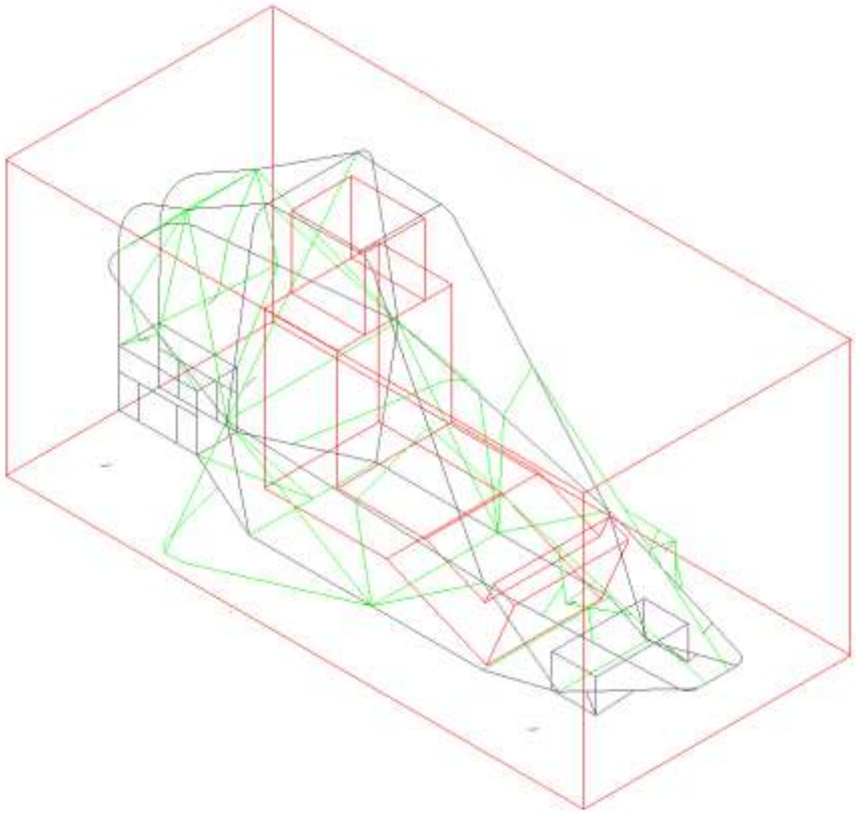
L - Vehicle wheelbase 1840 mm

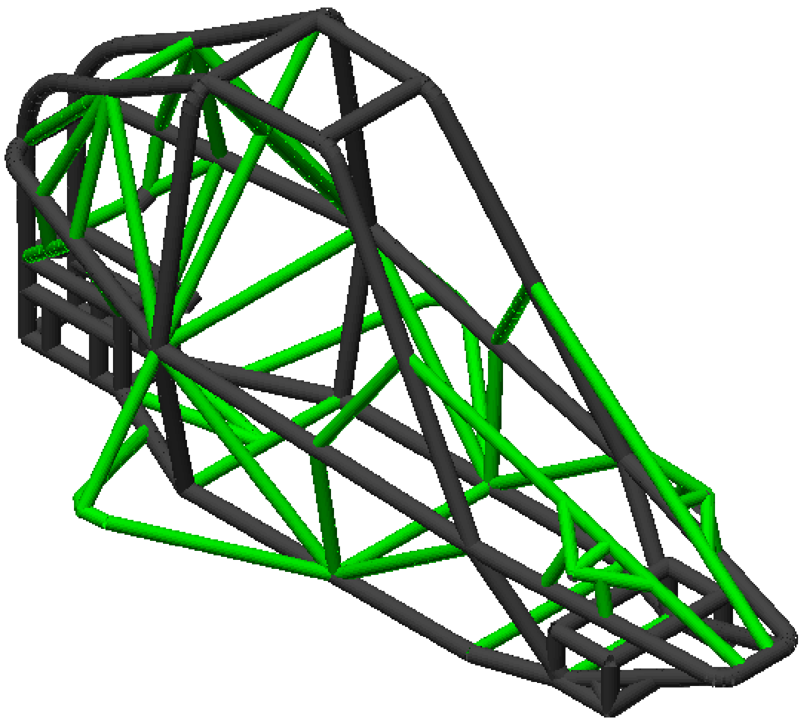


1. Draw protected space and a rectangular where you want to fit a model of the vehicle



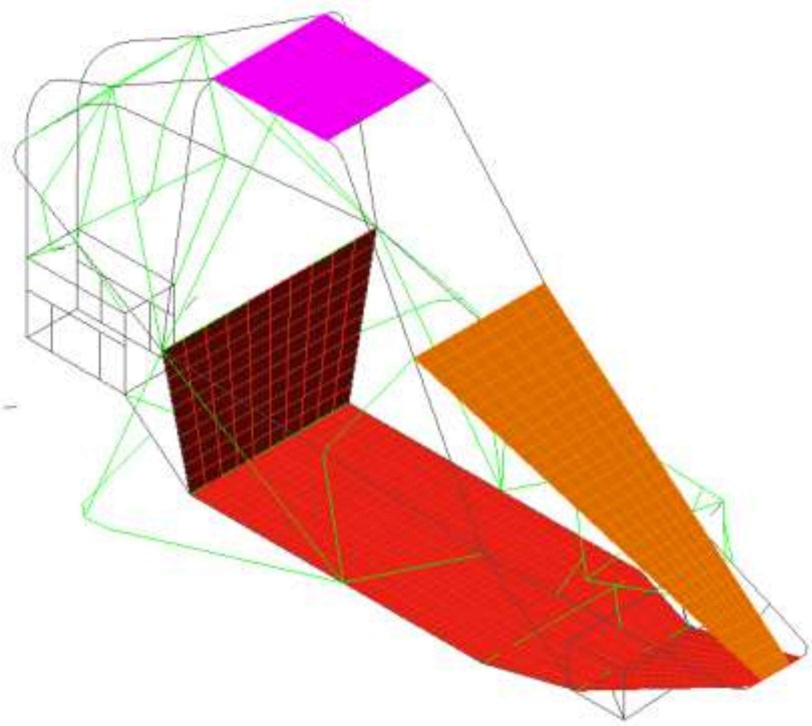
2. Draw a safety cage, the structure of fixing and protecting engine and the driver's legs

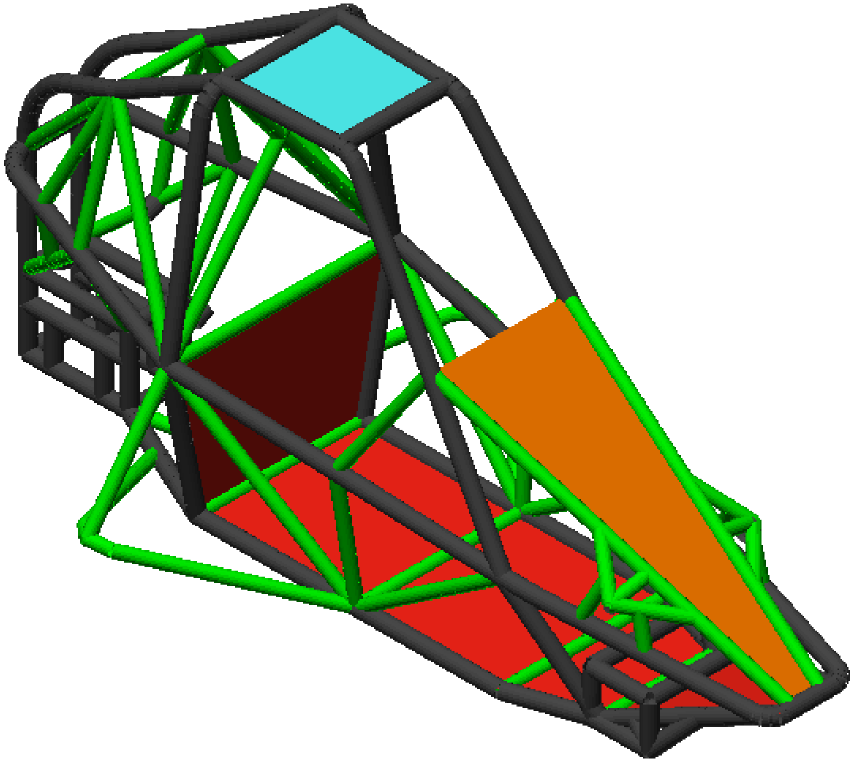




Enabled 3D visualization

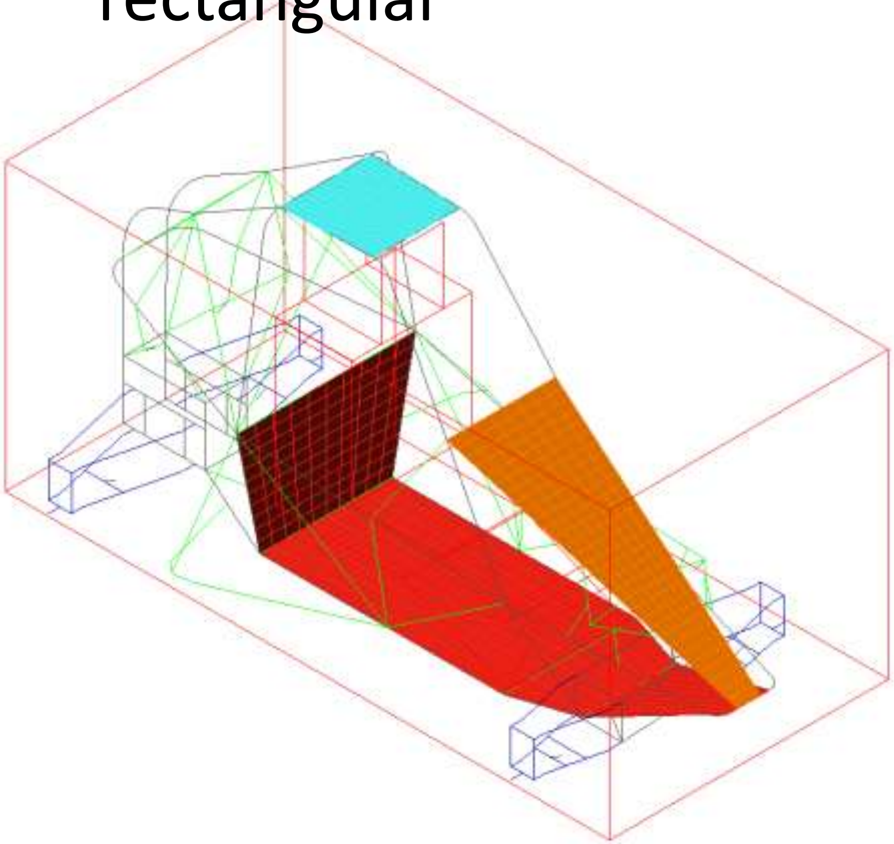
3. The plate finite elements are used to draw the vehicle roof and to build the floor and the rear barrier separating the driver from the engine compartment

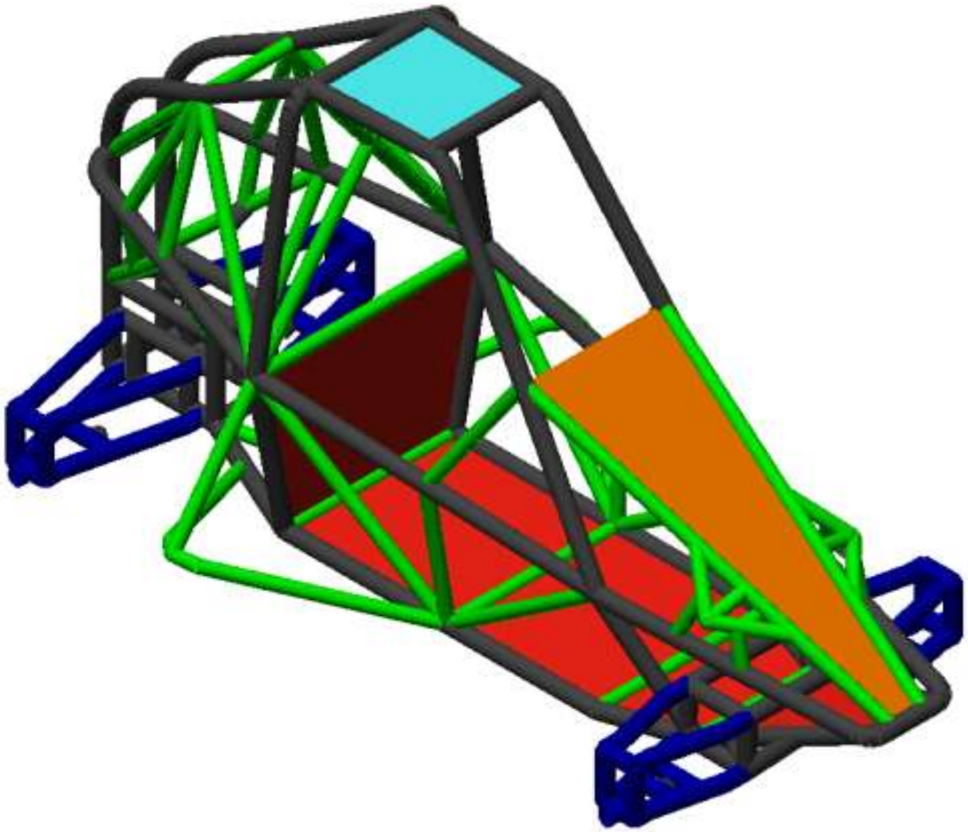




Enabled 3D visualization

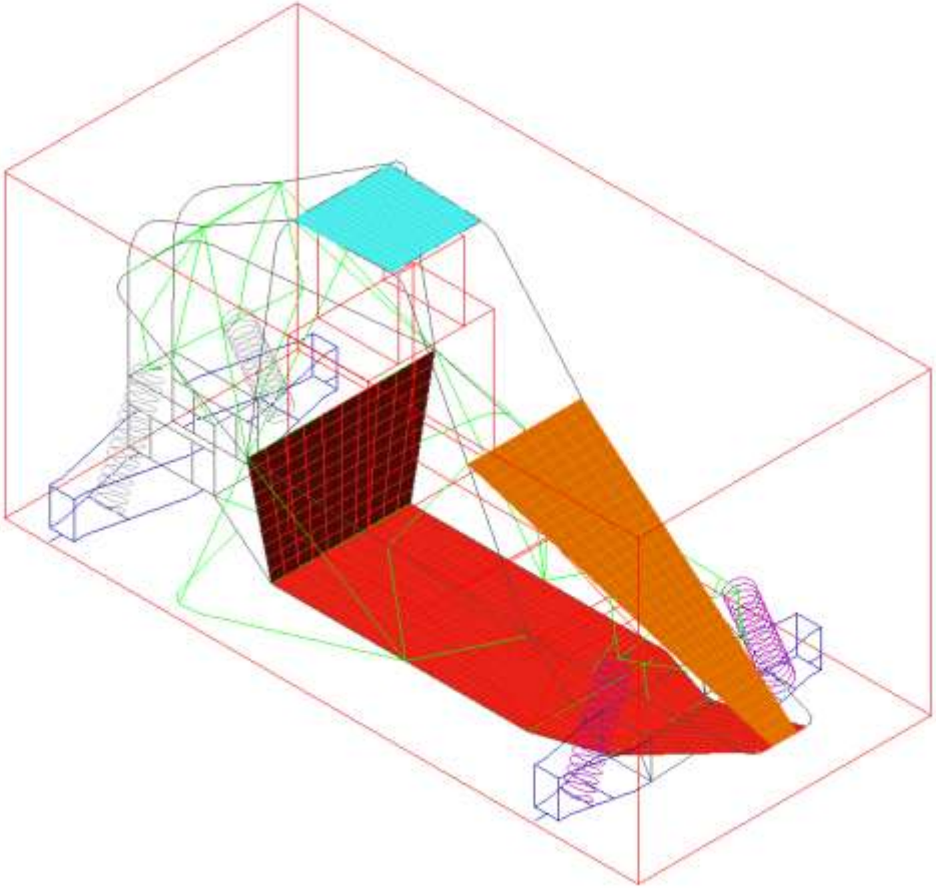
4. Draw the suspension arms and the front axle and rear axle of the vehicle using the width of the rectangular

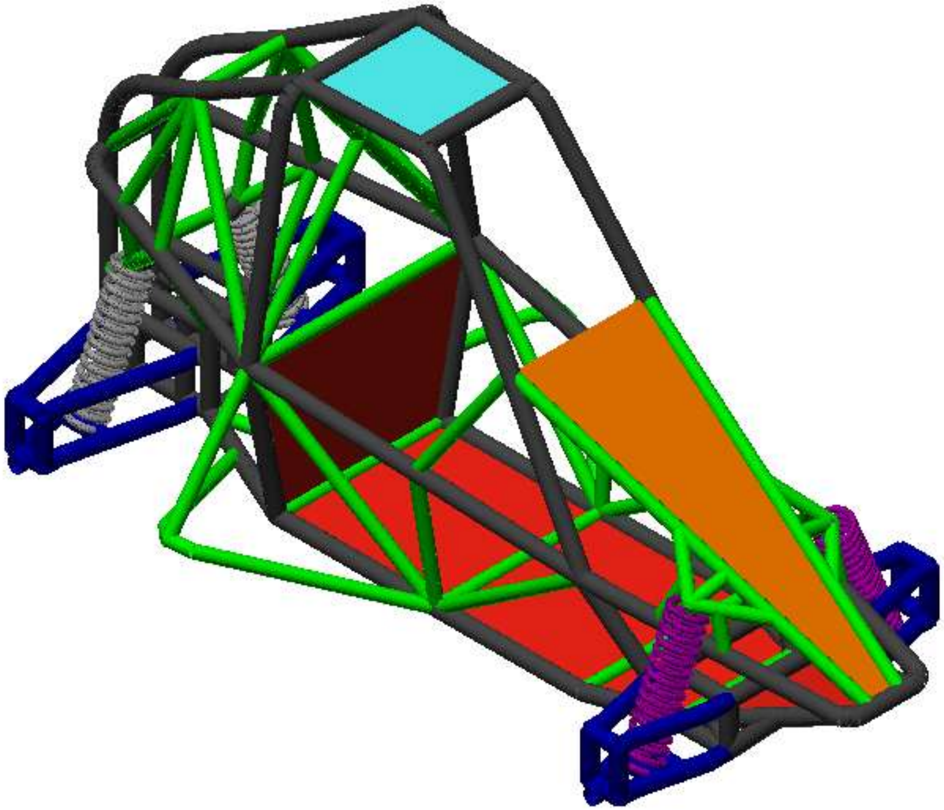




Enabled 3D visualization

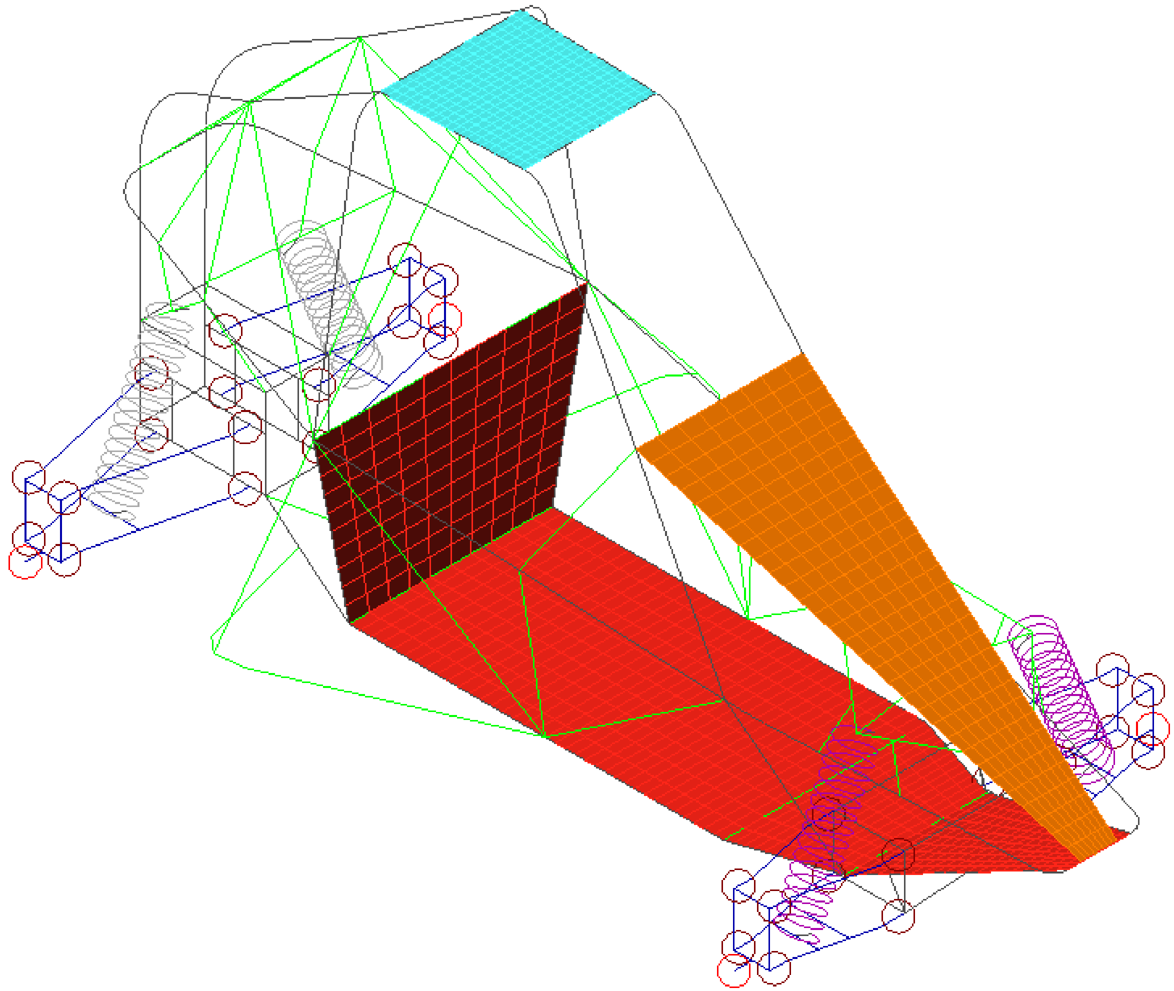
5. Draw a suspension spring



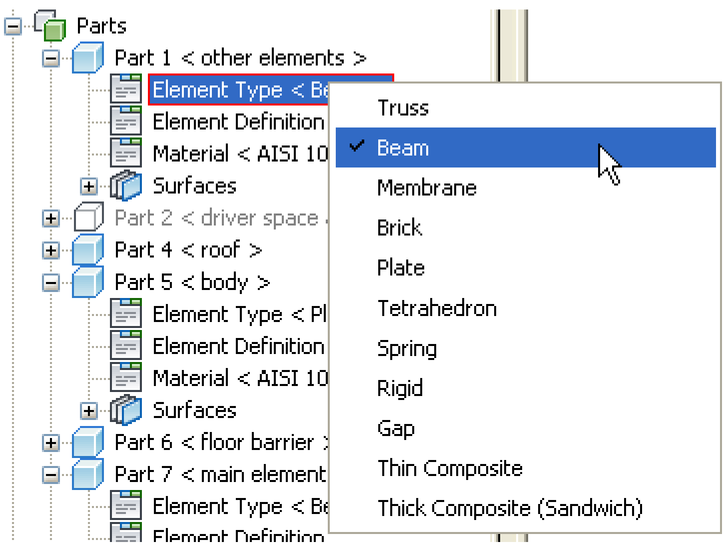


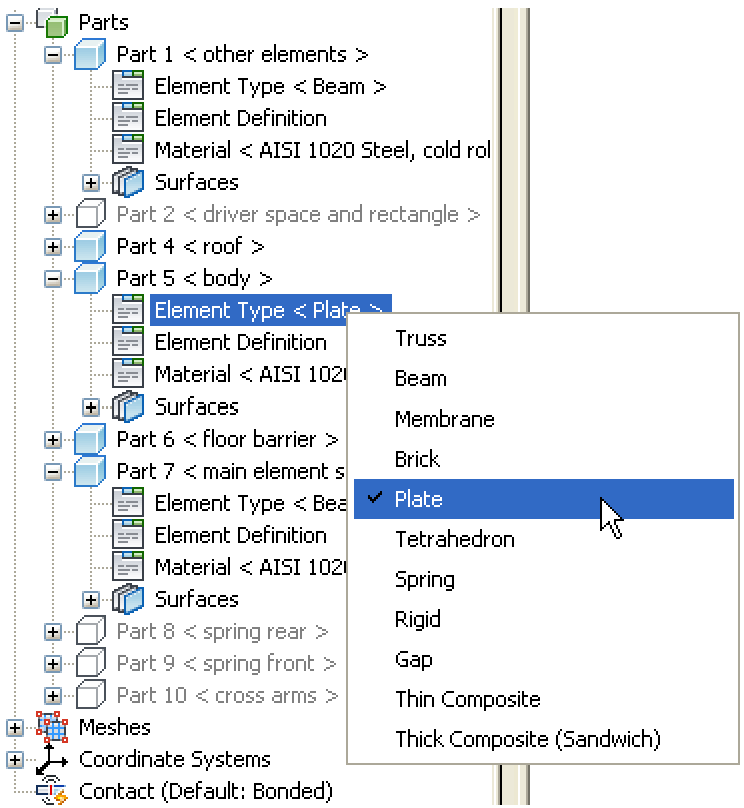
Enabled 3D visualization

6. Apply the boundary conditions and beam end relations

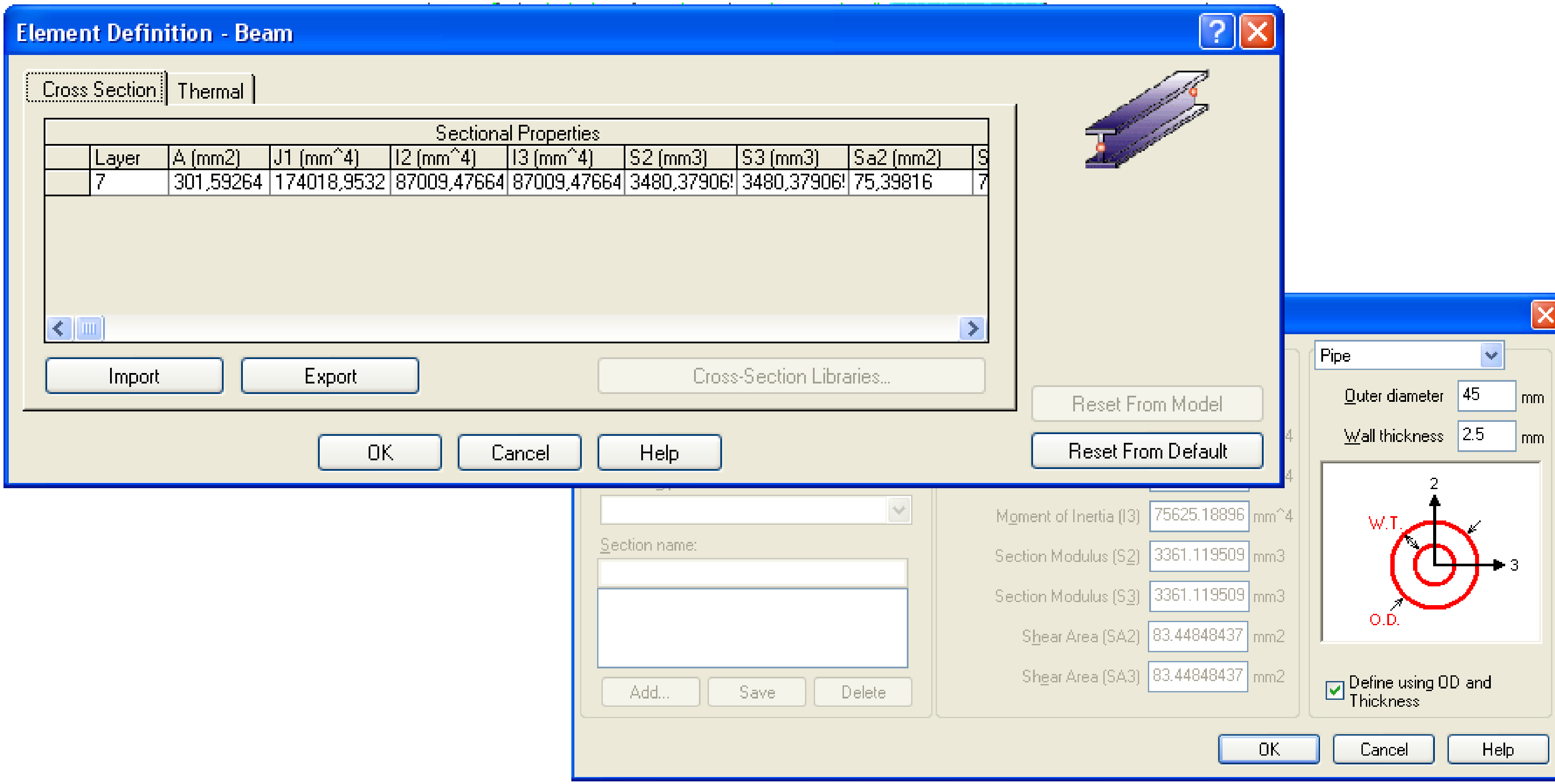


7. Choose a finite element type.

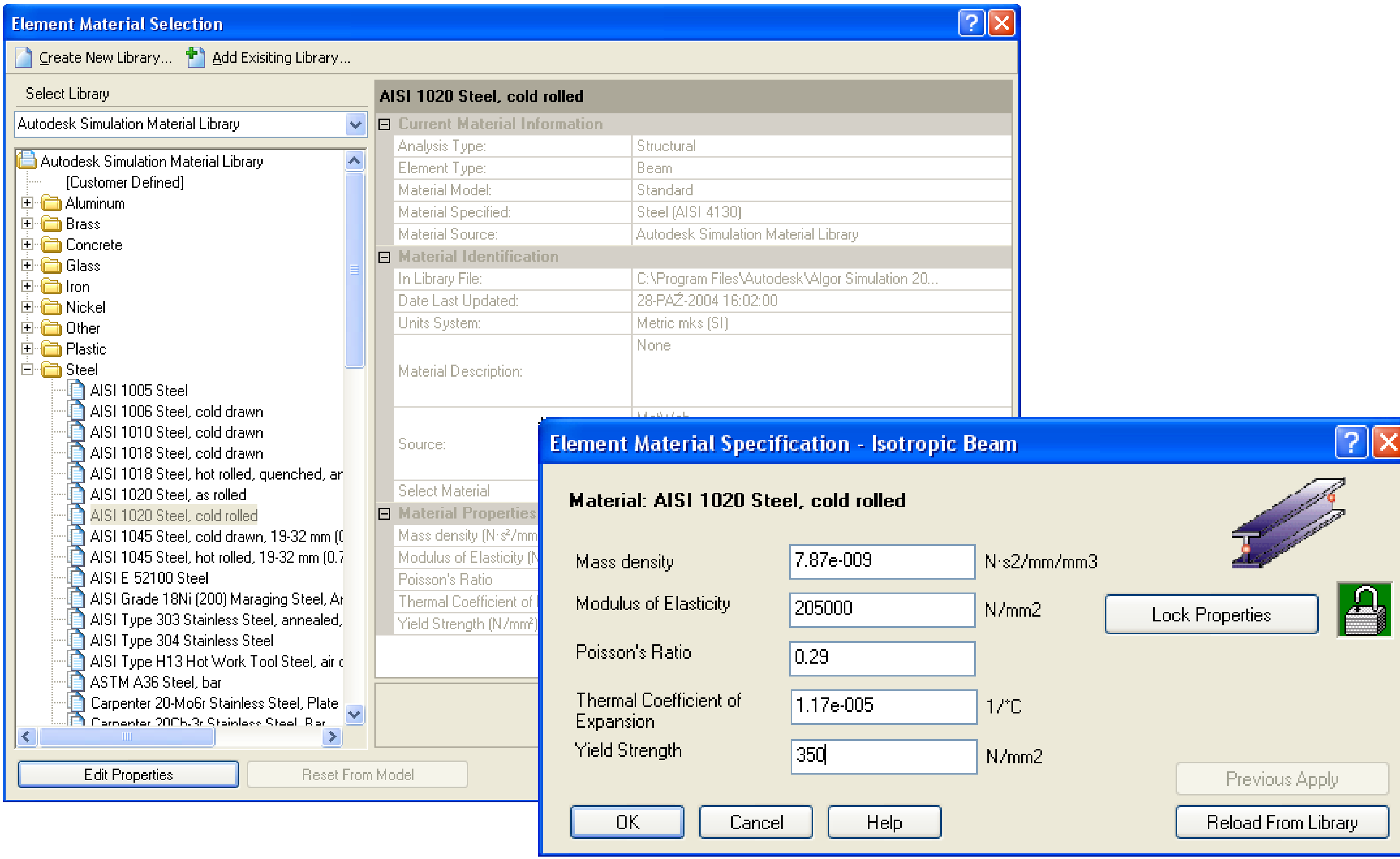




8. Identify cross-sectional dimensions (beam) or thickness (plate).



9.Choose a material.



10. The load model

- The type of a load model frame depends on the stress analysis.
- Basically, the load model will be a dead weight and nodal forces which replace the interaction of major components such as: engine, fuel tank, gearbox, the driver and his seat on the frame of the vehicle.

FEM strength frame analysis

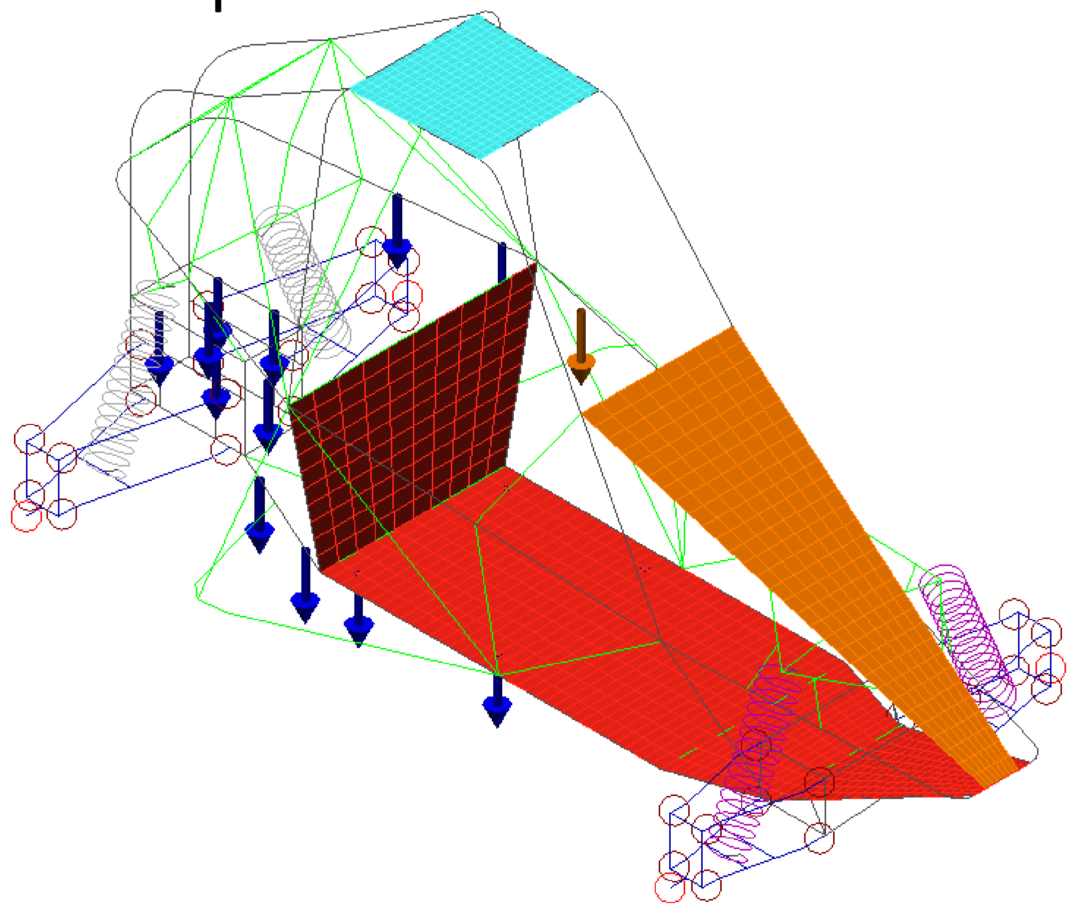
The frame model was subjected to a series of stress tests designed to verify the correctness of its construction and selection of materials, from which it was made.

Using computer strength analysis, the behaviour of the structure under two different load cases was examined:

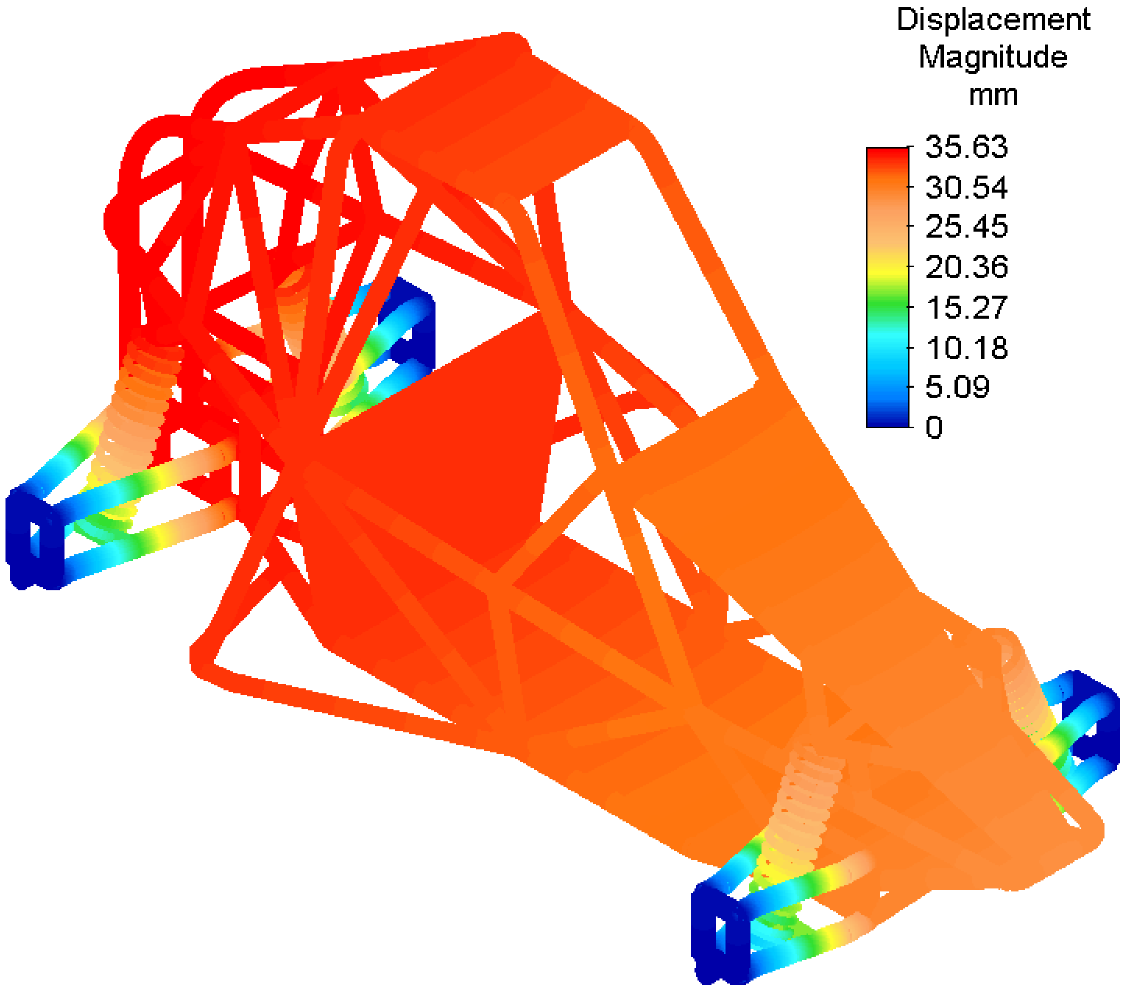
- loads generated during the normal use of the vehicle
- strength tests simulating the frame turnover

Analysis type– Static stress with linear material model

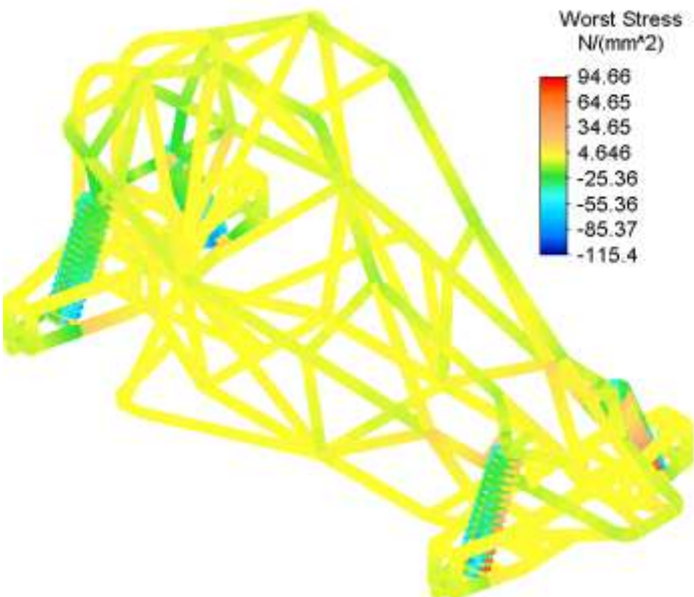
Stress calculation under the dead load and the weight of the main components and the driver

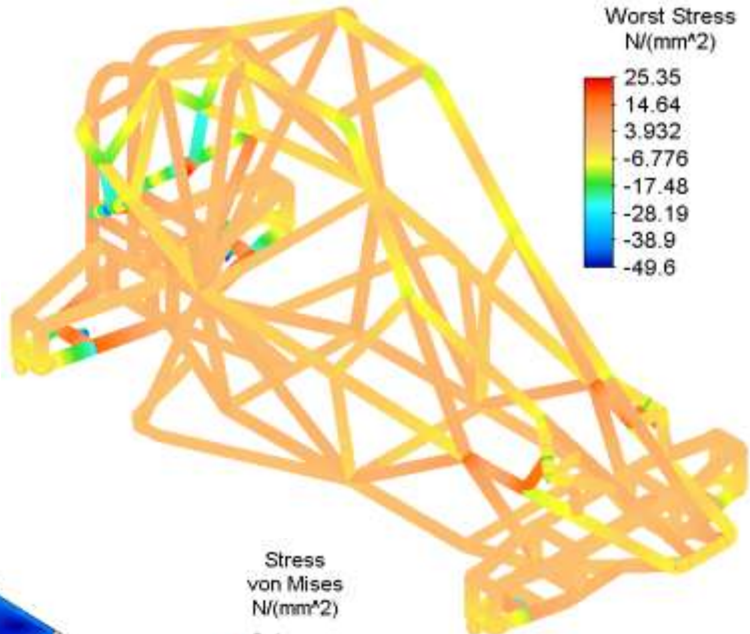


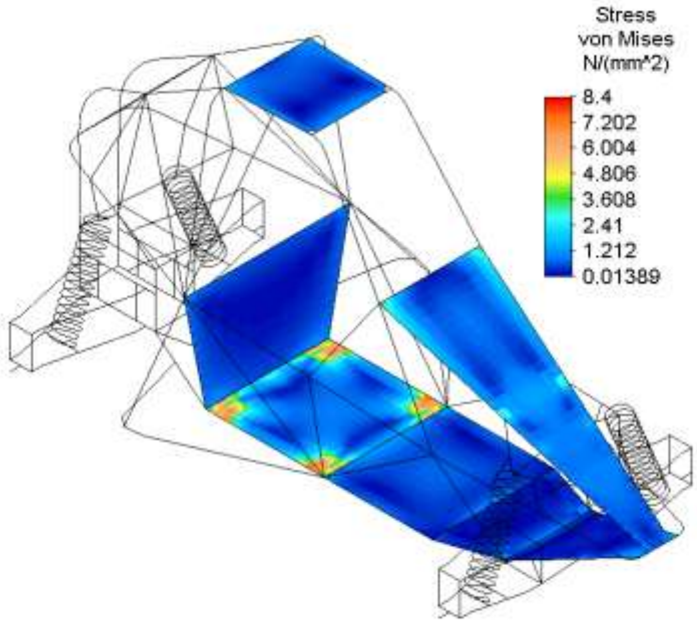
The results in the form of contour magnitude displacements



The results in the form of contour stress







Appointment of stiffness in all directions and the torsional stiffness:

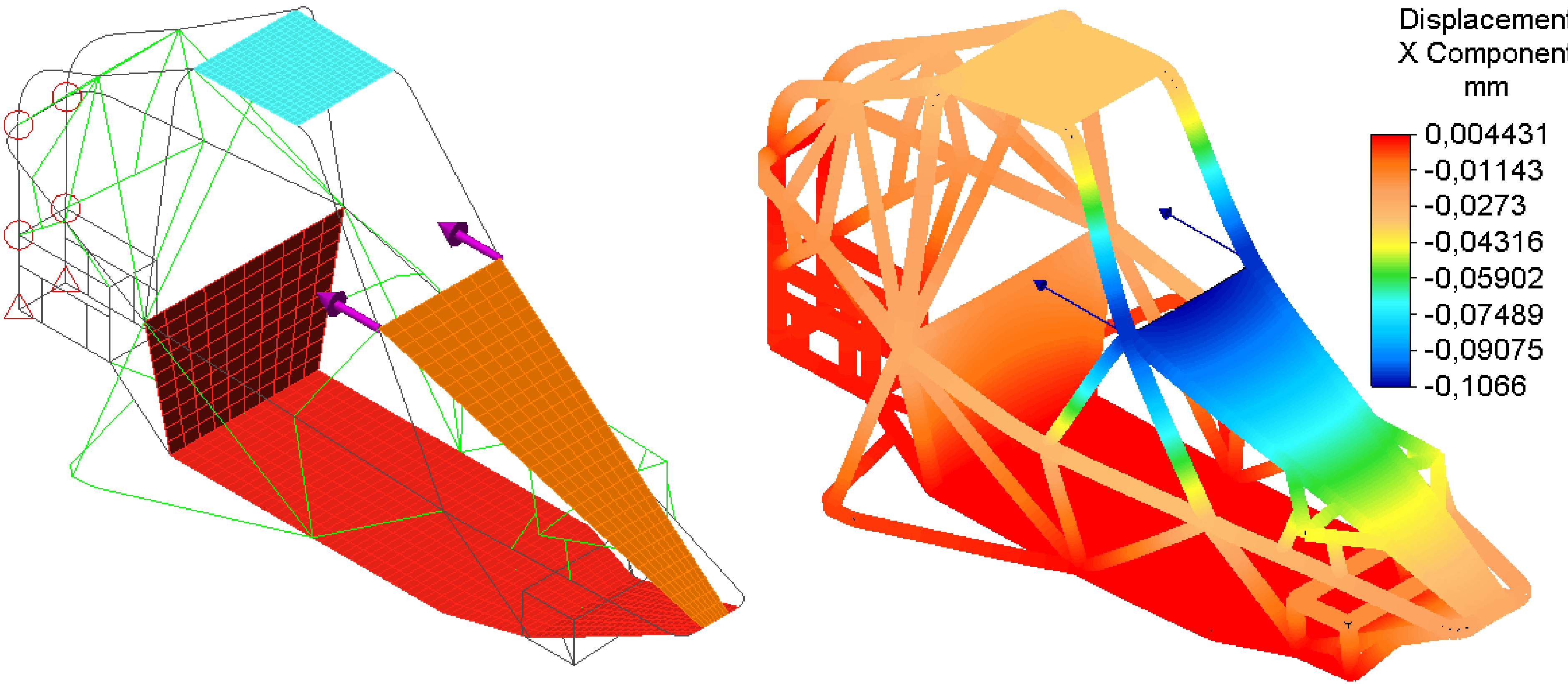
$$c_x = P_x / u_x \quad [N/mm]$$

$$c_y = P_y / u_y \quad [N/mm]$$

$$c_z = P_z / u_z \quad [N/mm]$$

$$c_\alpha = M_{z(or\ x,y)} / \alpha \quad [Nmm/deg]$$

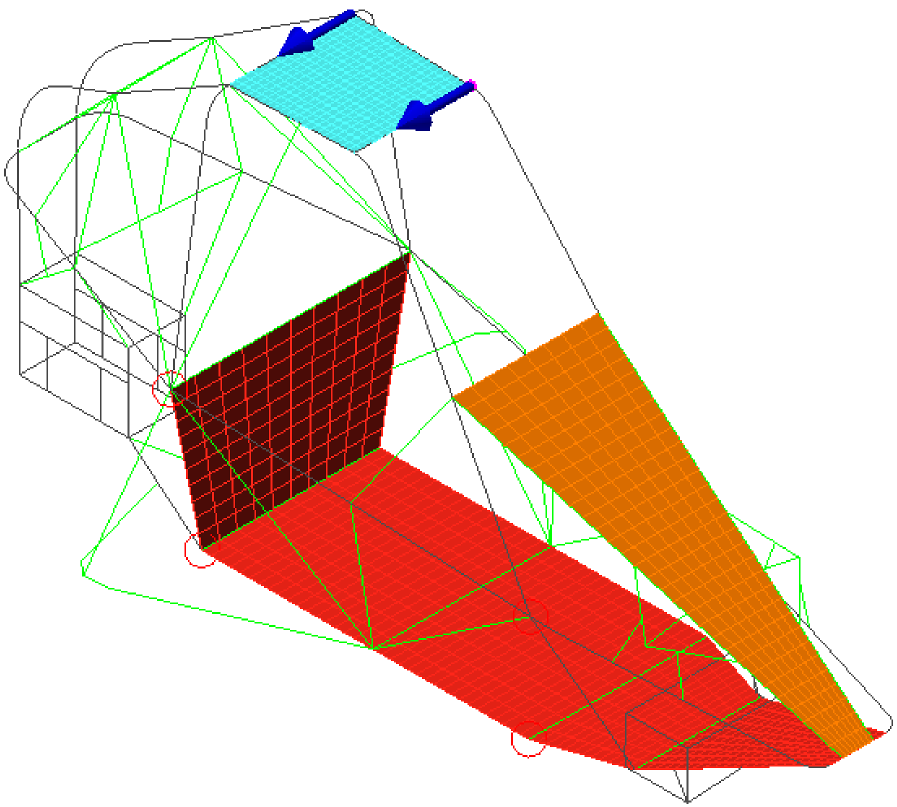
Appointment of stiffness in X direction

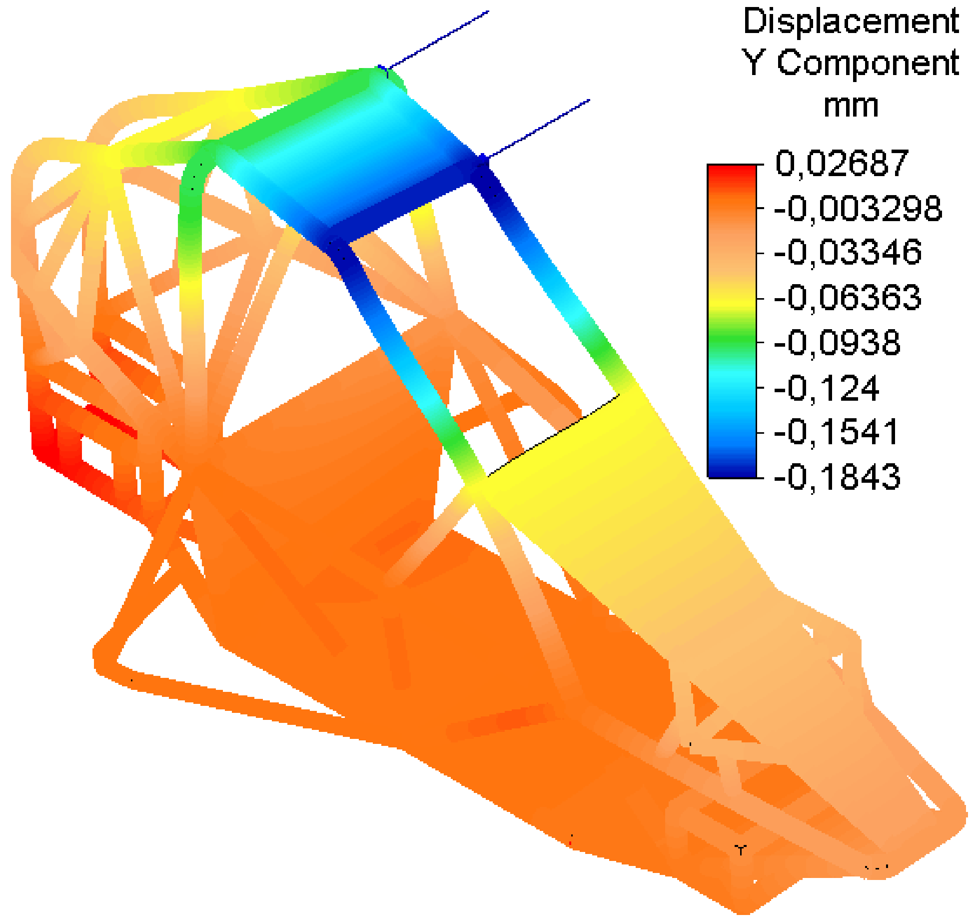


$P_x = 1000$ [N]

$c_x = P_x / u_x$ [N/mm]

Appointment of stiffness in Y direction

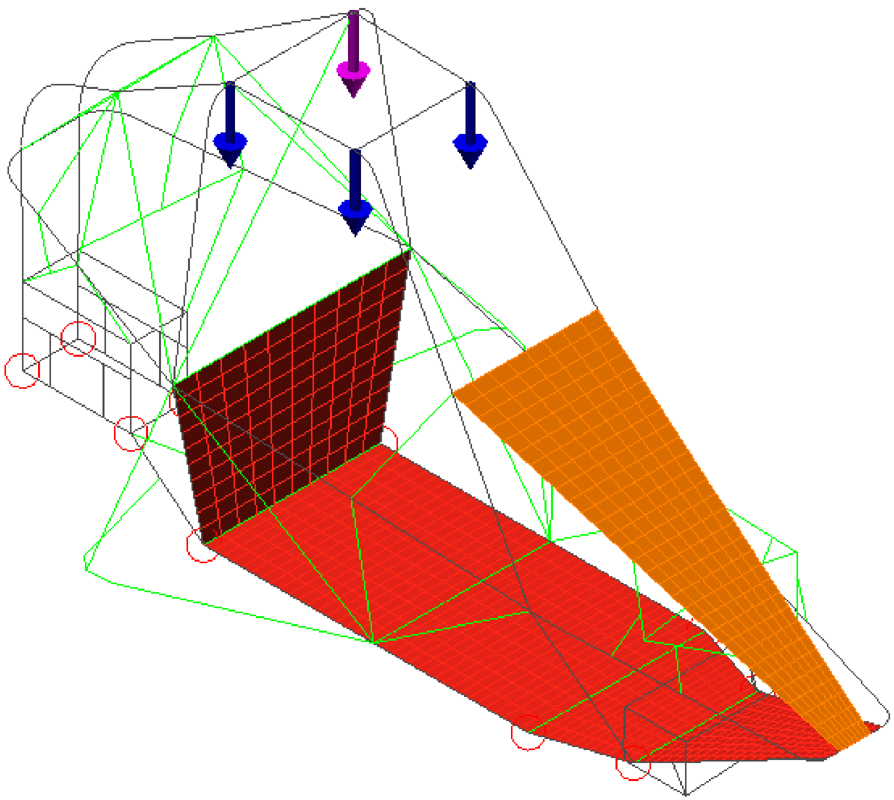


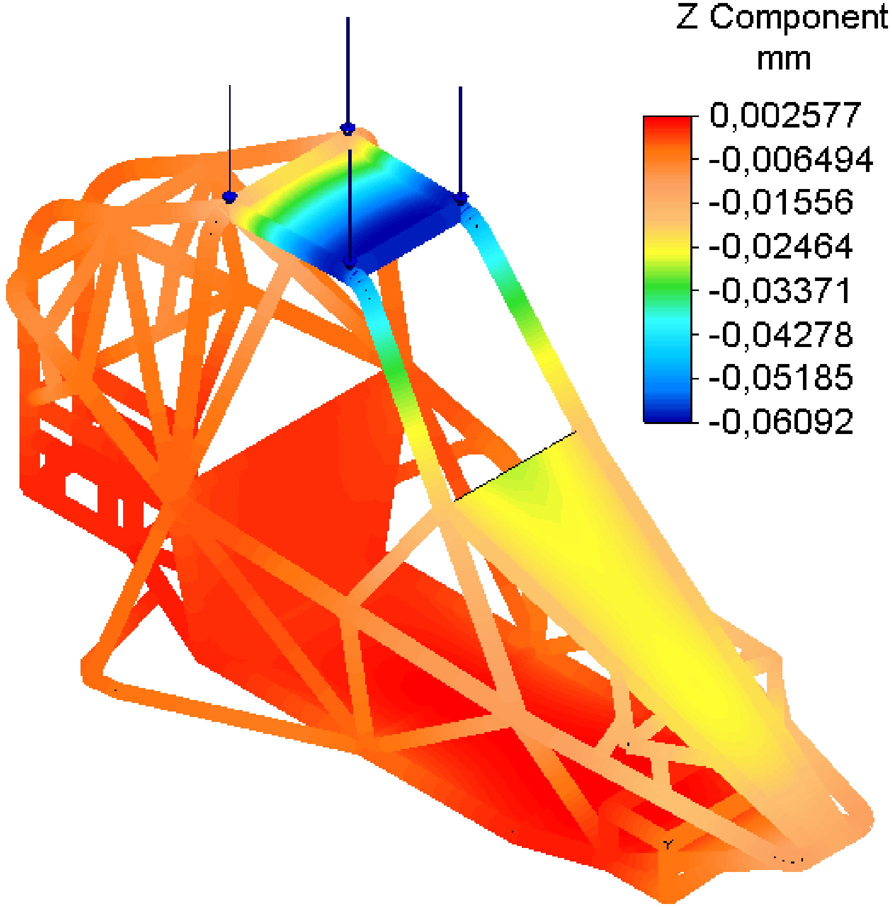


$P_y = 1000$ *[N]*

$c_y = P_y / u_y$ *[N/mm]*

Appointment of stiffness in Z direction

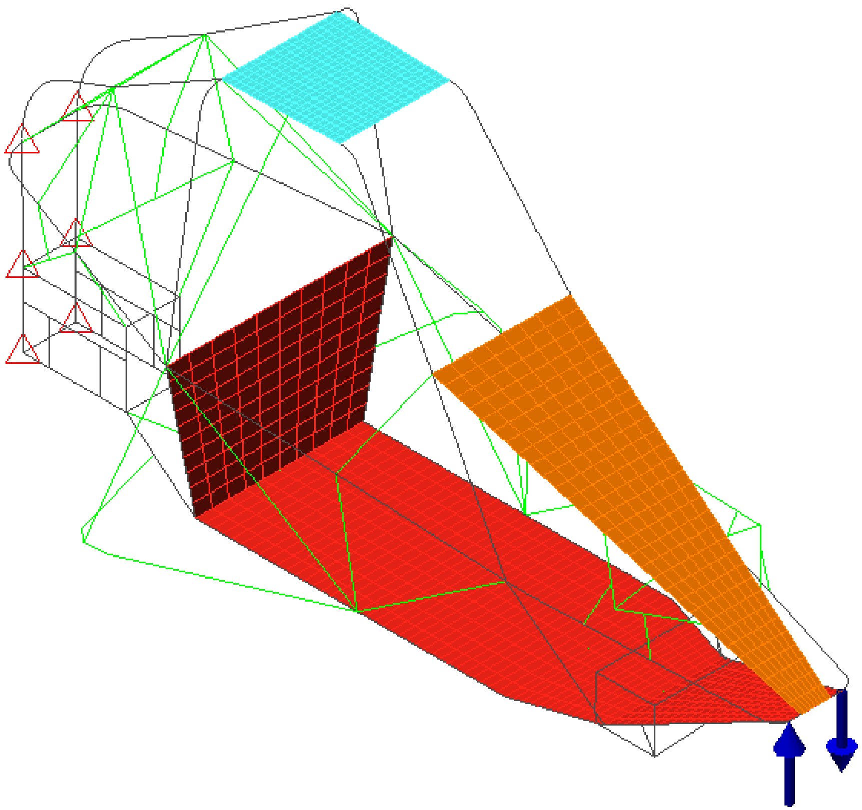


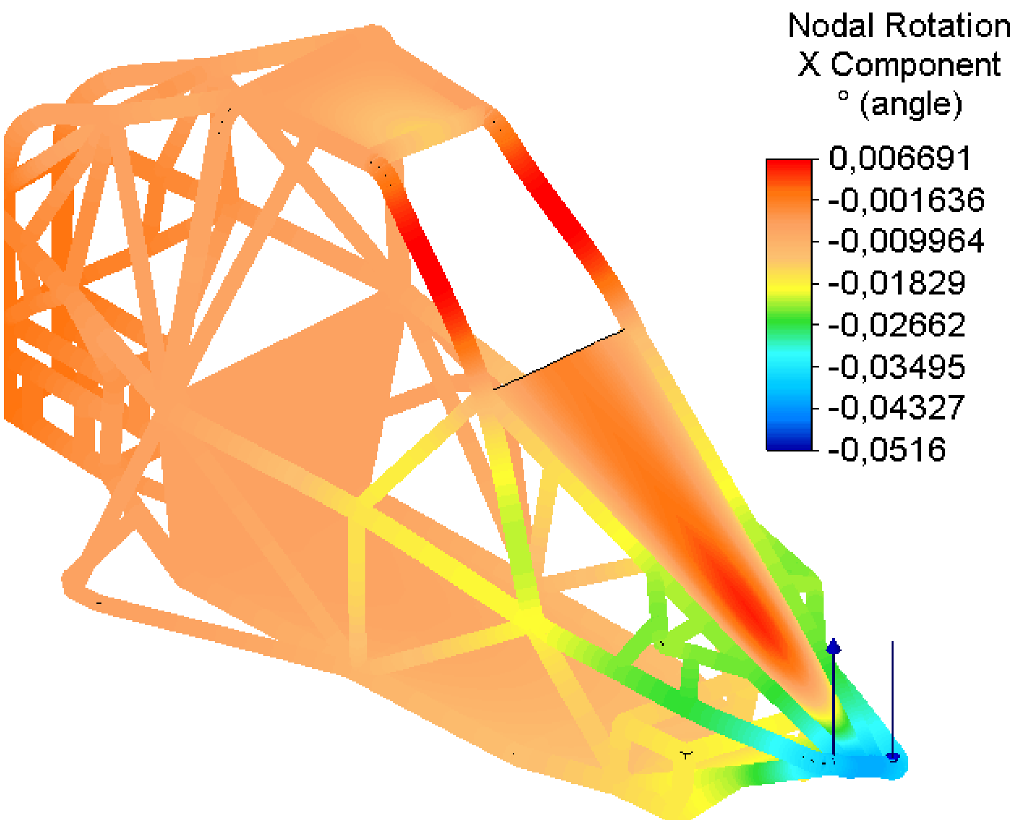


$P_z = 1000$ [N]

$c_z = P_z / u_z$ [N/mm]

Appointment of torsional stiffness

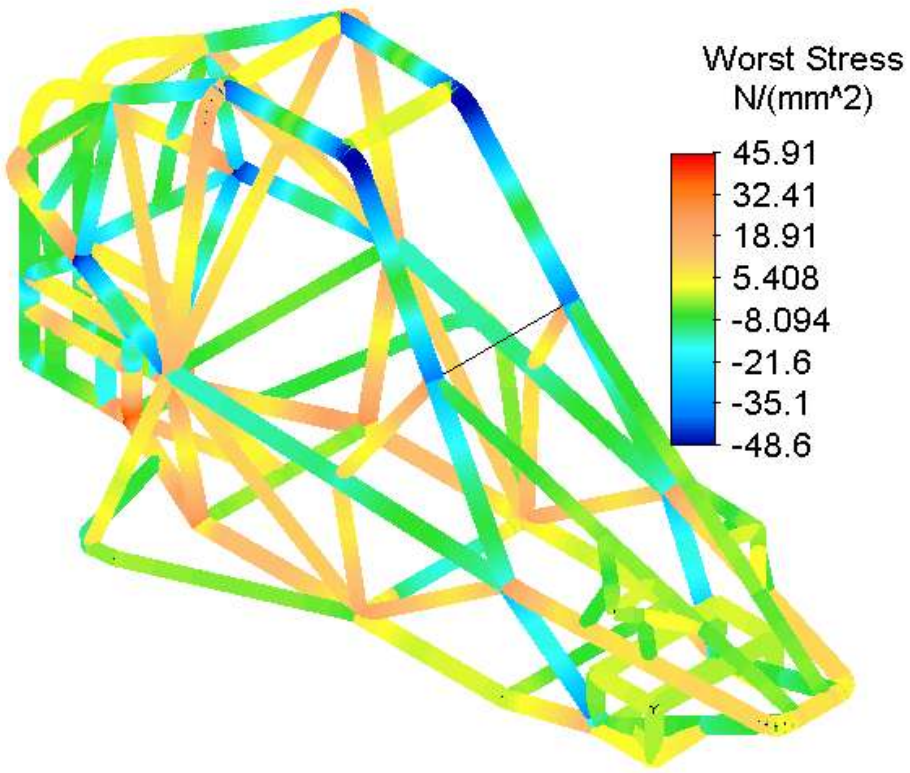


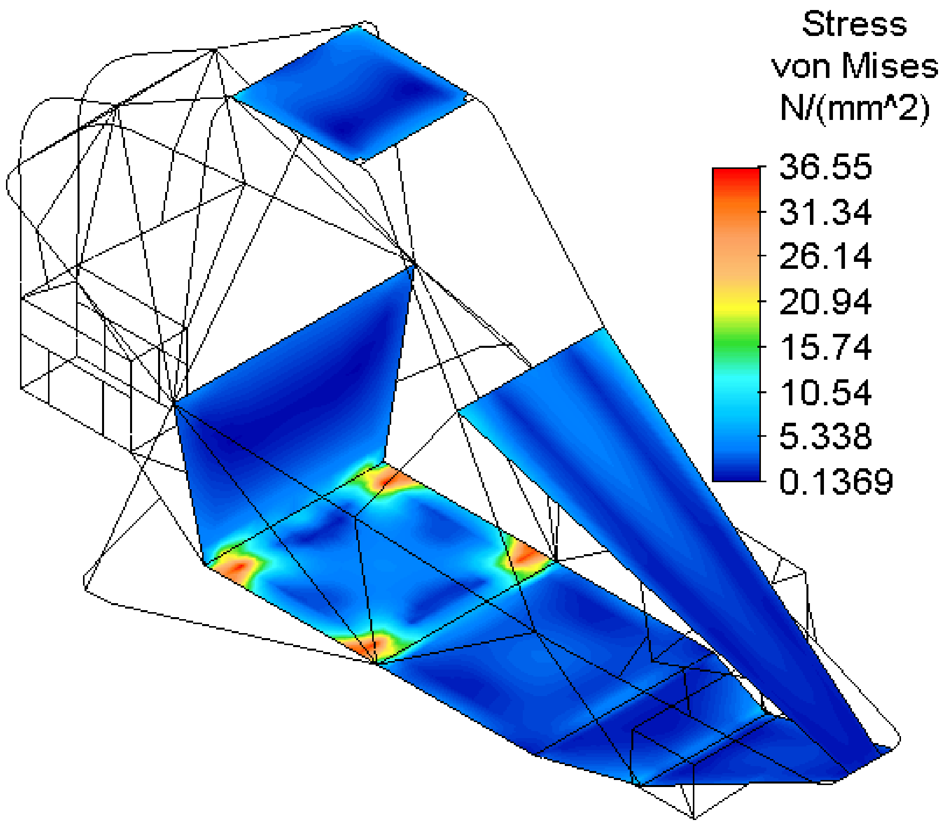


$M_x = 27[Nm]$

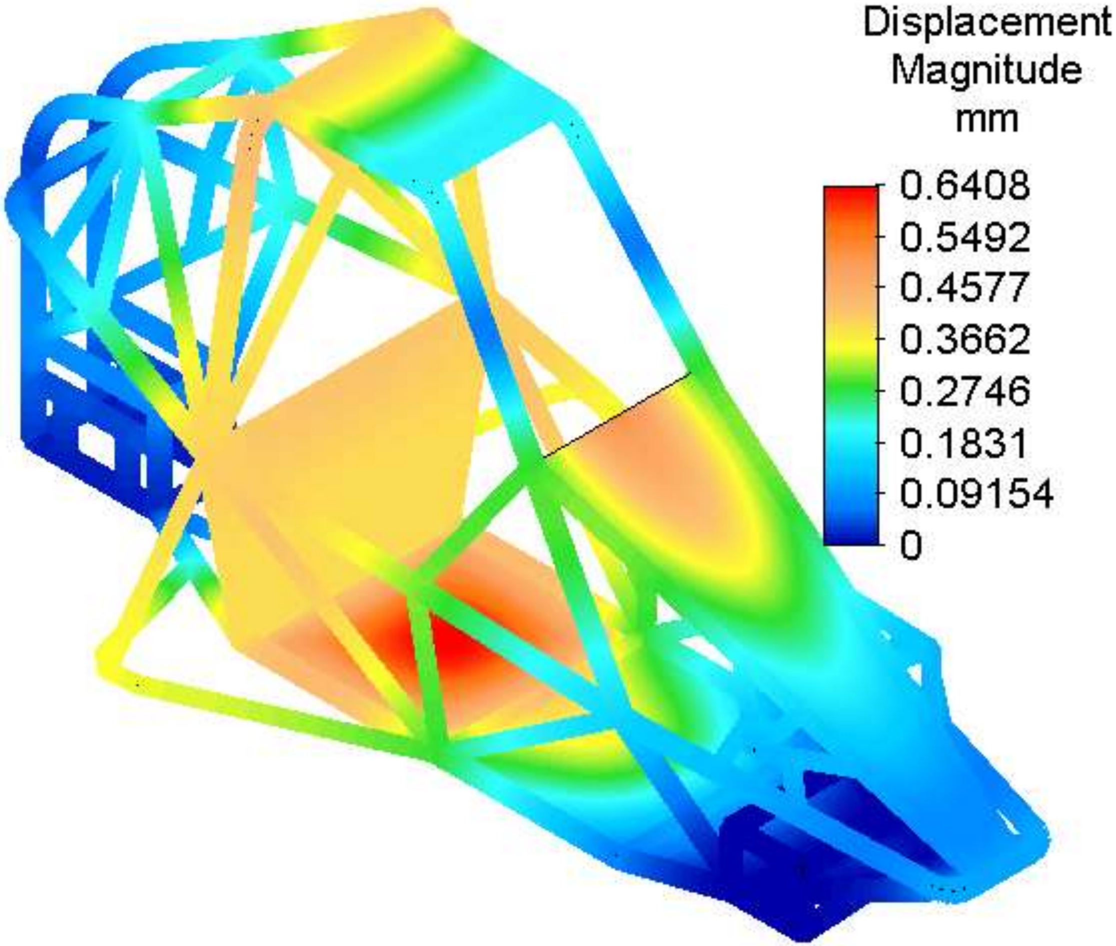
$c_\alpha = M_{z(or\ x,y)} / \alpha$ [Nmm/deg]

Appointment of strains and stresses on overload 5G vertical (frame, equipment, driver)

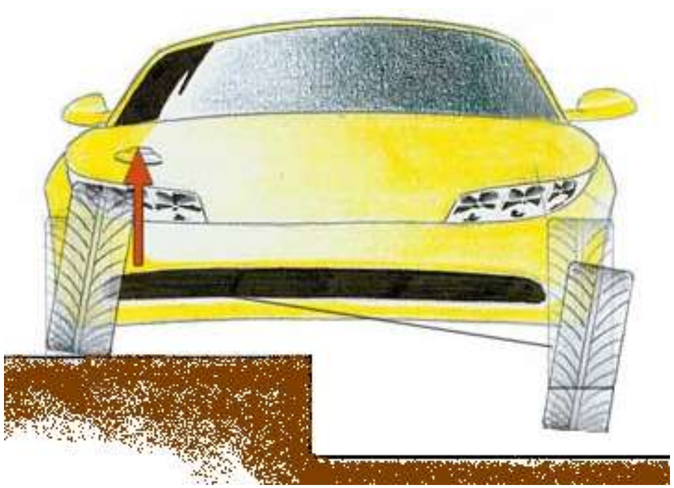


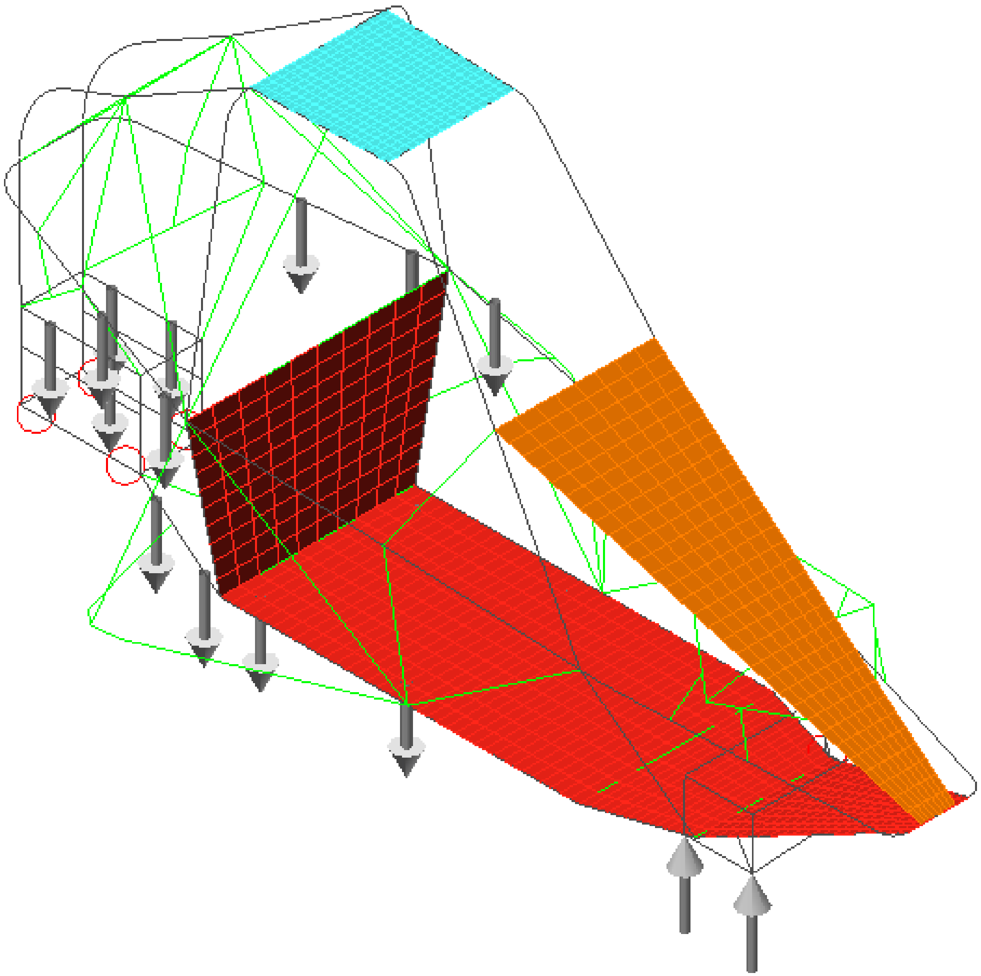


The results in the form of contour magnitude displacements (load 5G)

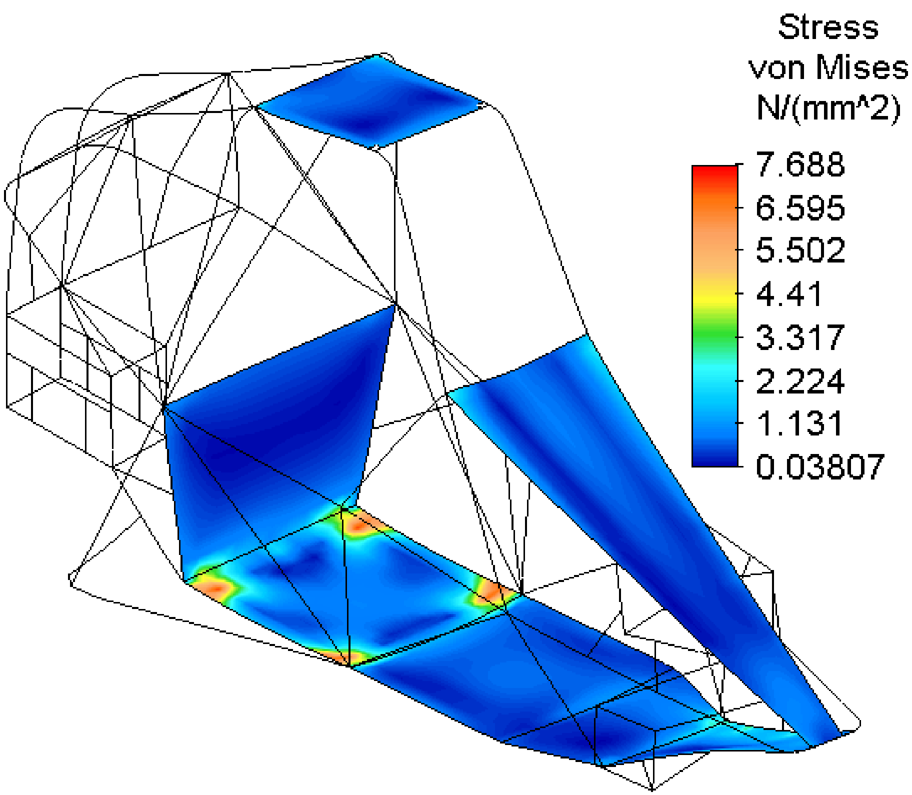


Appointment of strains and stresses on vertical overload of the single wheel (1.8G) after moving to the inequality

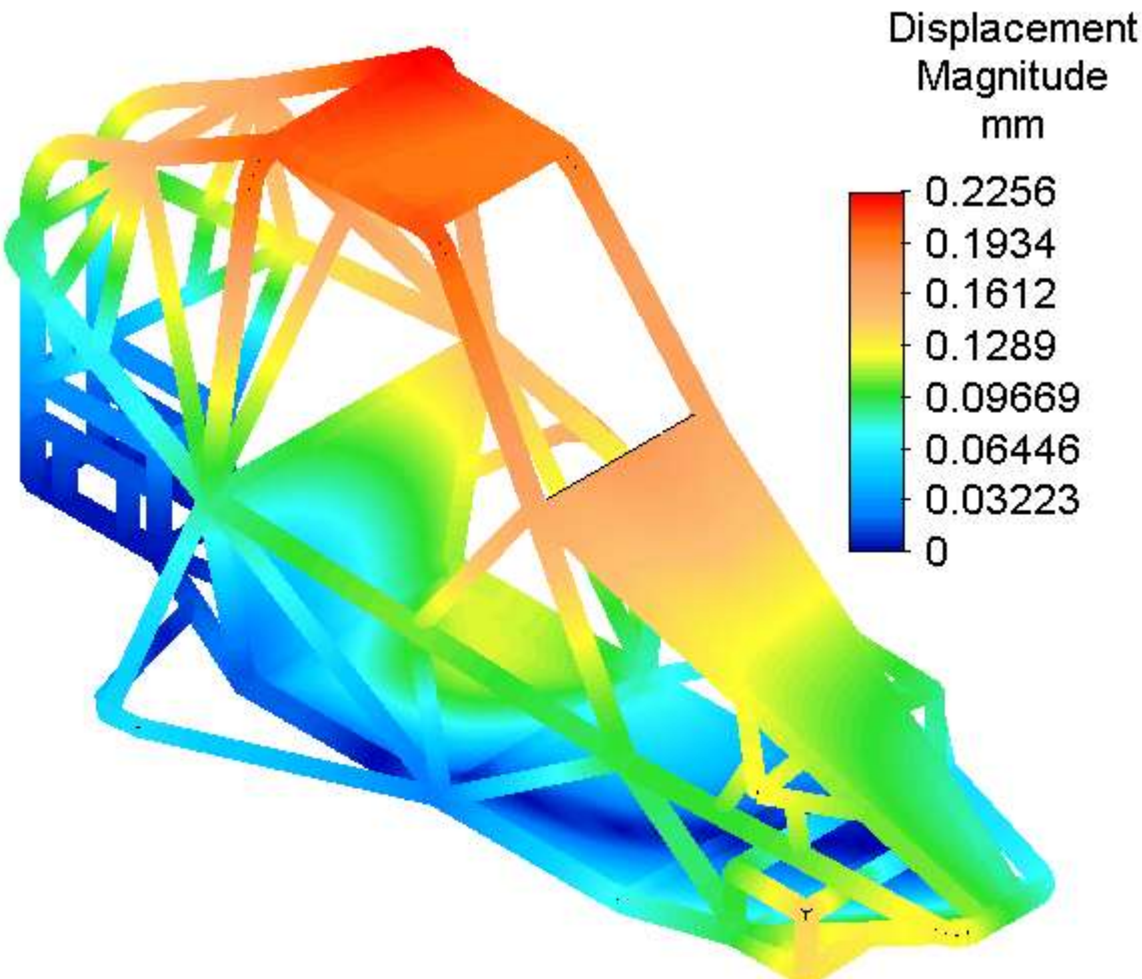




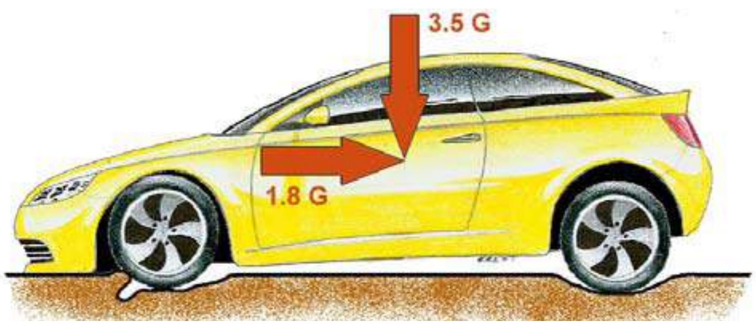
The results in the form of contour stress (vertical overload 1.8G)

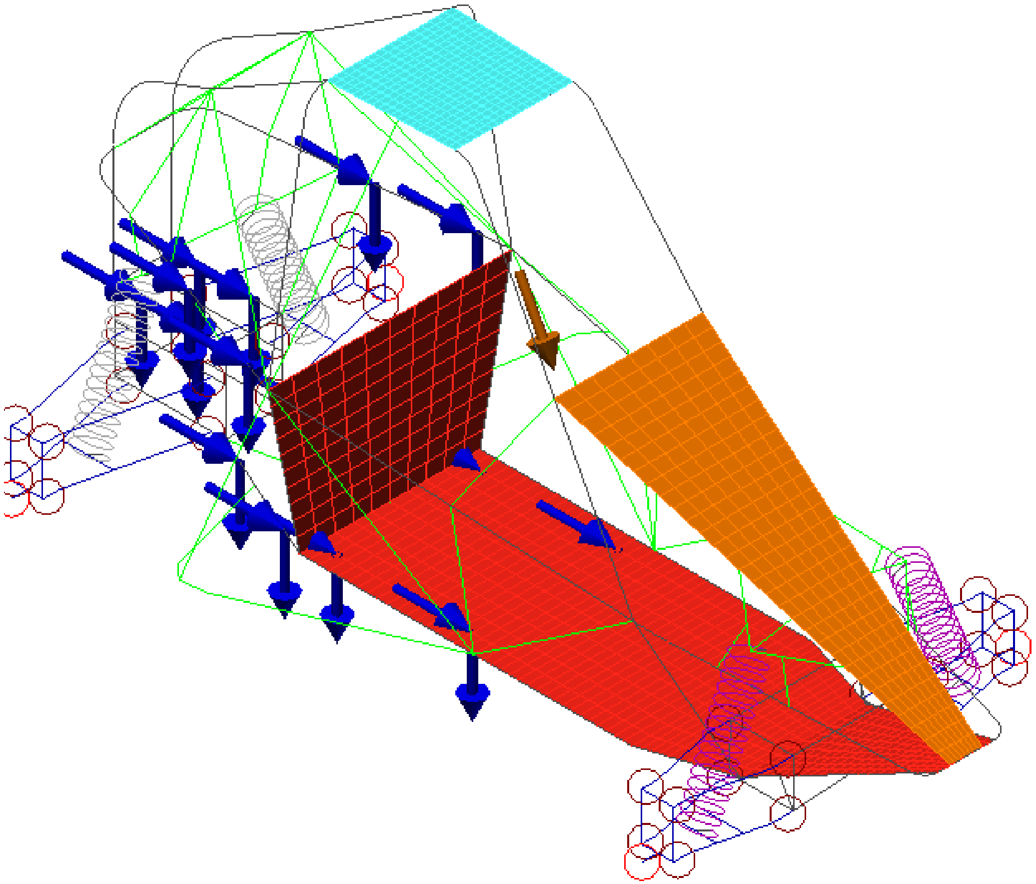


The results in the form of contour magnitude displacements (vertical overload 1.8G)



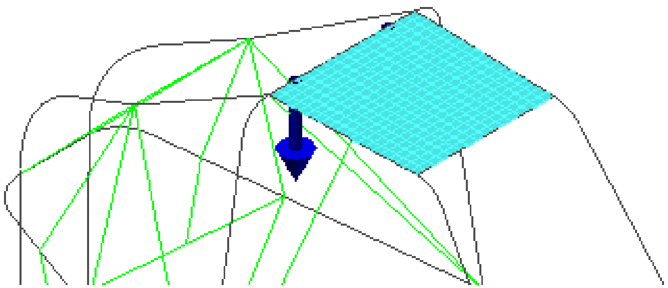
Appointment of strains and stresses on overload in vertical direction 3.5G and horizontal direction 1.8G while simultaneous braking and invasion of inequality

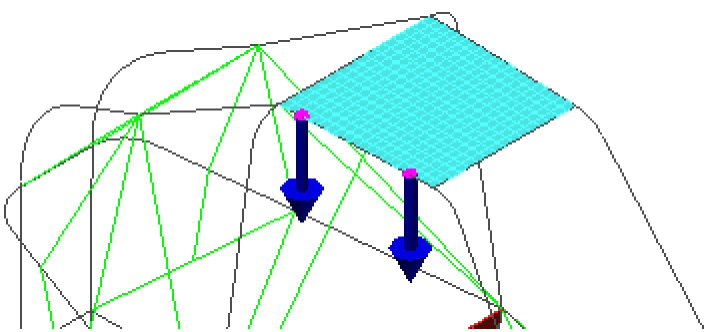


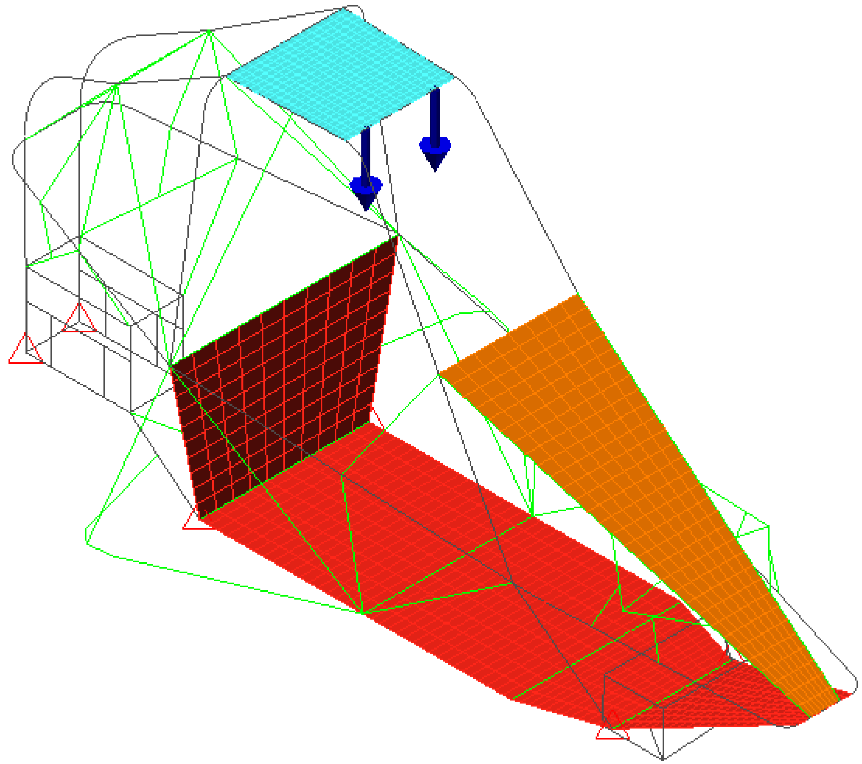


Static analysis – rollover tests

Vertical overload of the roof (the sum of forces is 7.5W)

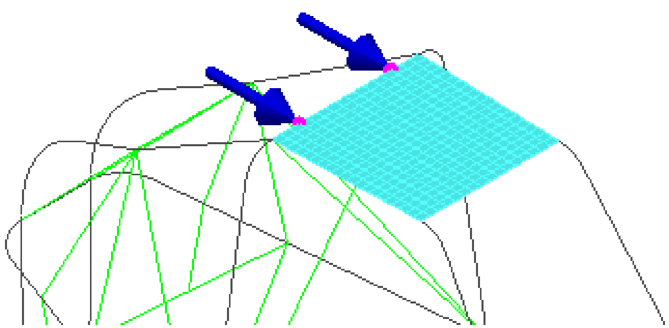


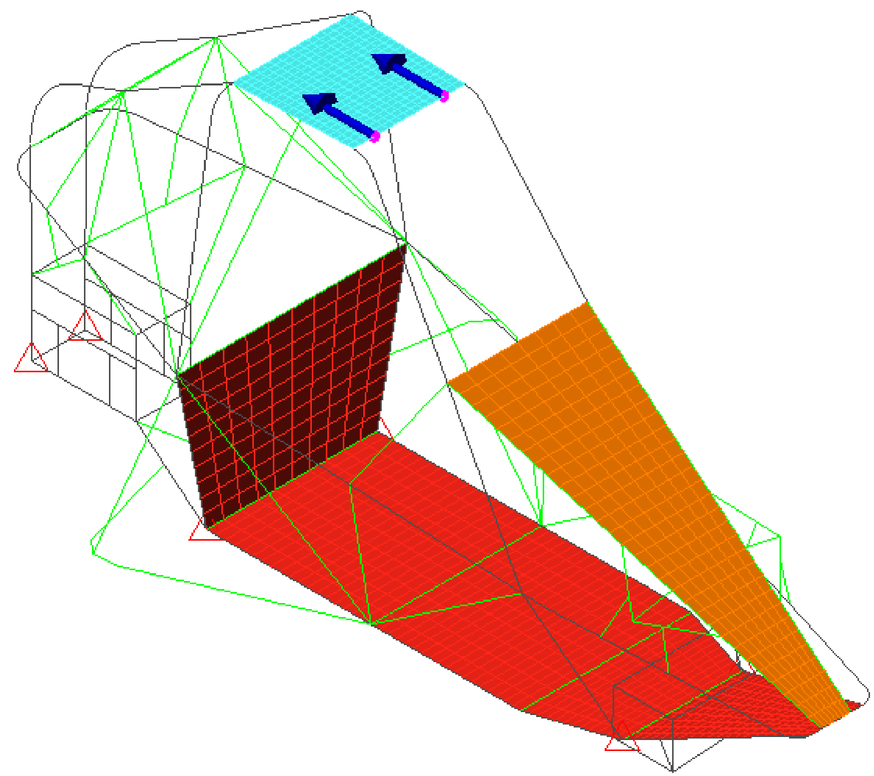




Static analysis – rollover tests

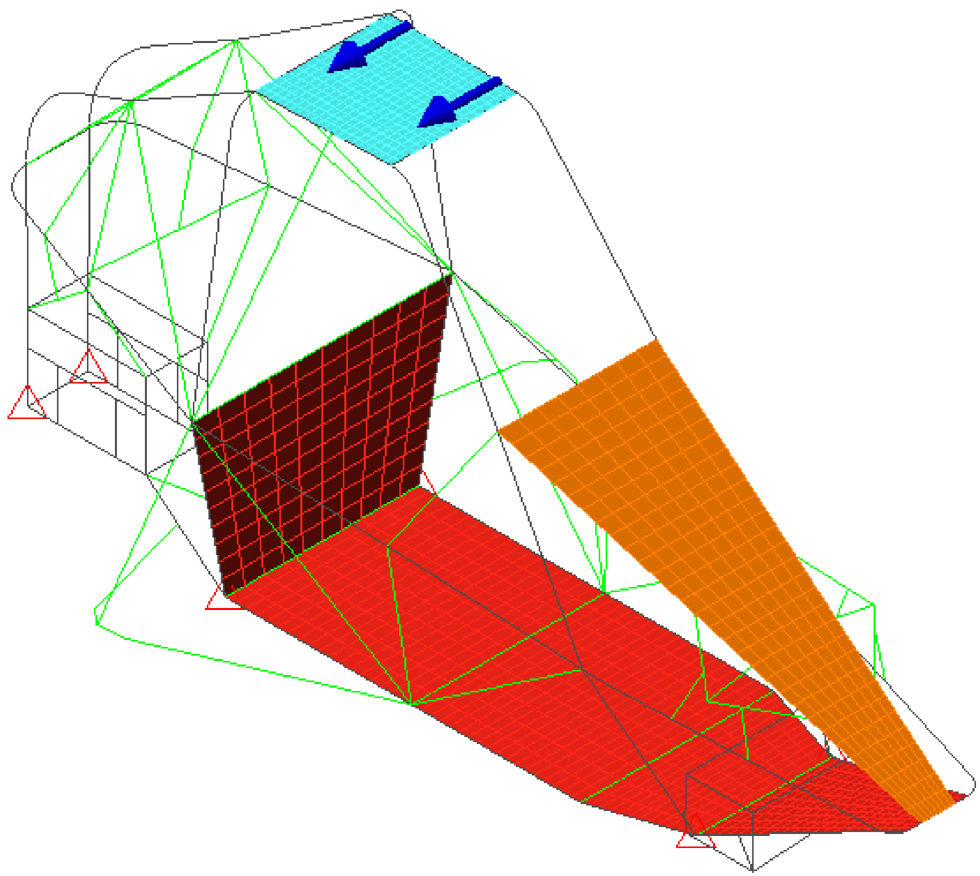
Horizontal longitudinal overload of the roof (the sum of forces acting on the frame has a value of 5.5W)





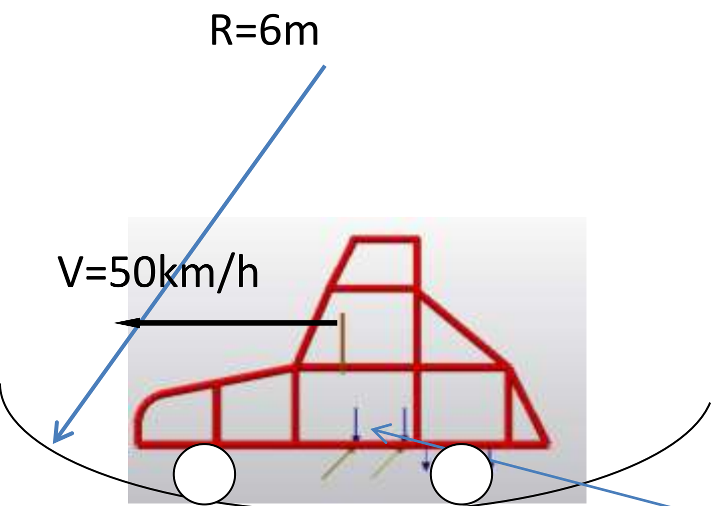
Static analysis – rollover tests

Horizontal side overload of the roof (the sum of the forces is 1.5W)

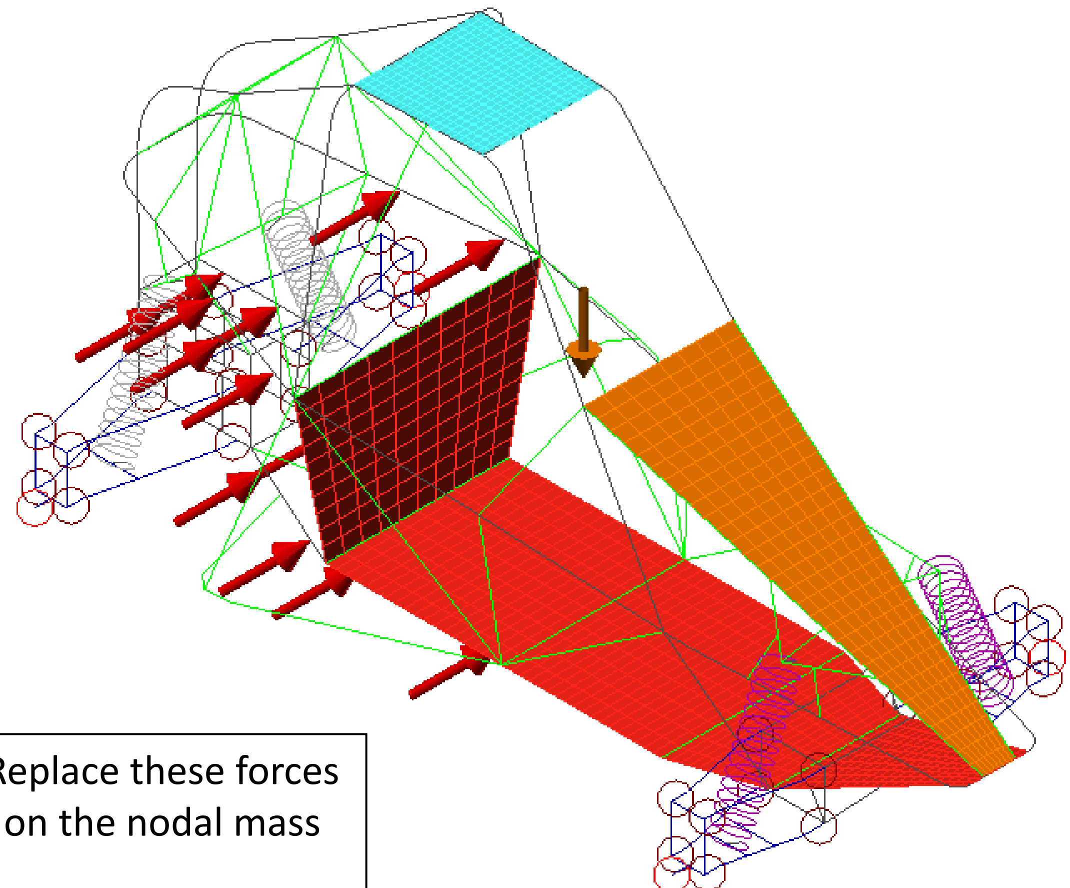


Static analysis – Static stress with linear material model (*Centrifugal)*

Load in the vertical plane when a vehicle is moving in hilly area

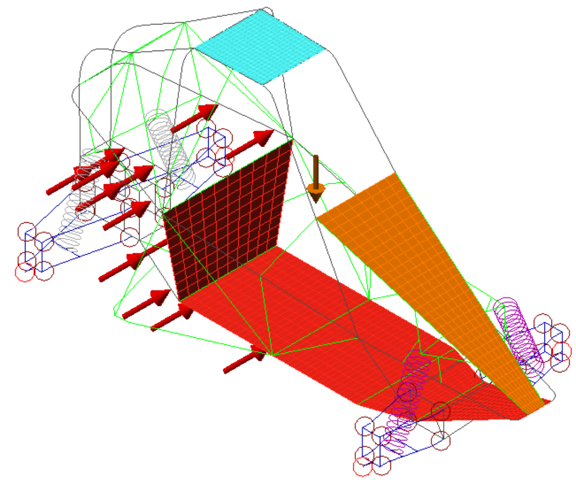


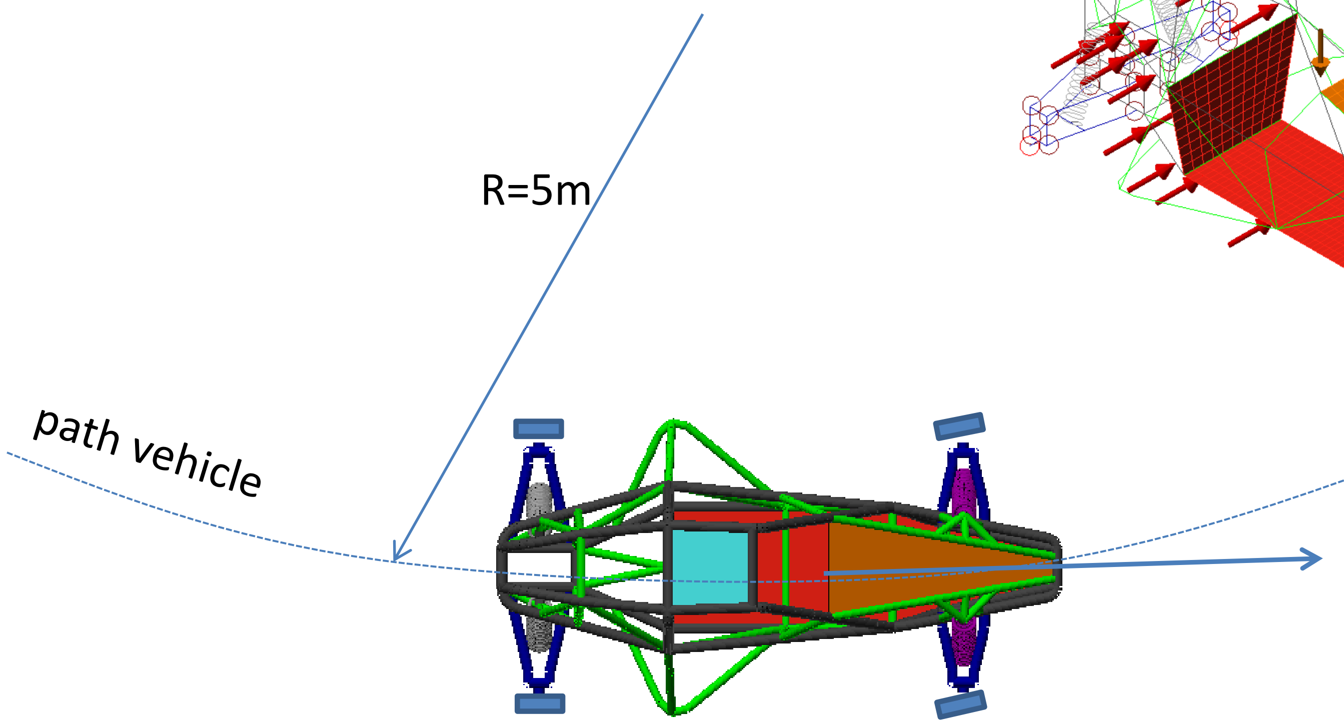
Replace these forces on the nodal mass



Static analysis – Static stress with linear material model (*Centrifugal)*

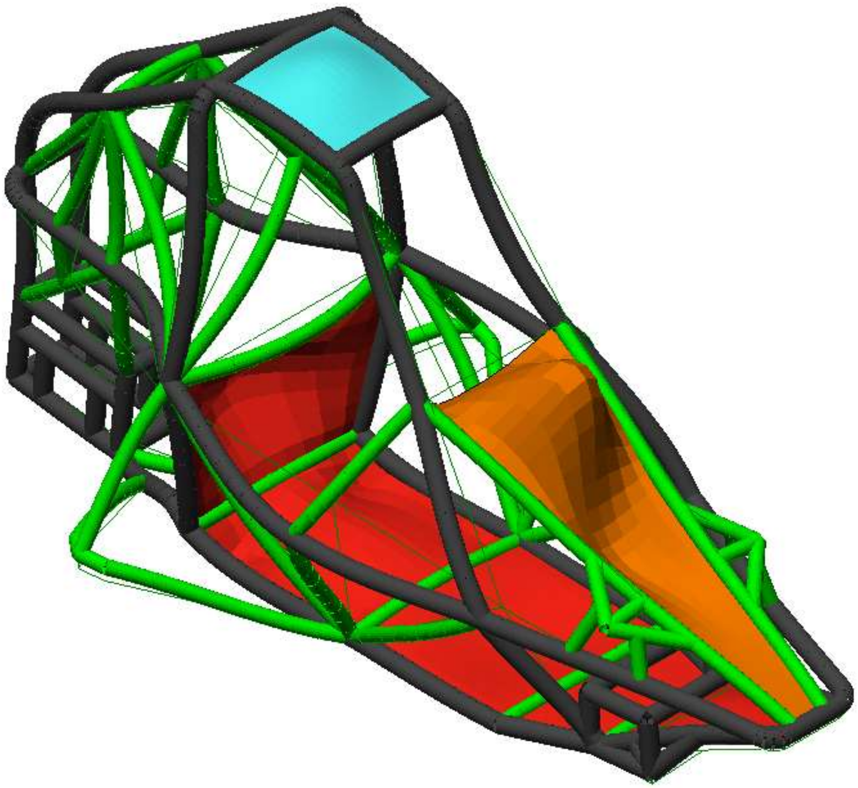
Load in the horizontal plane when the vehicle is moving on the road



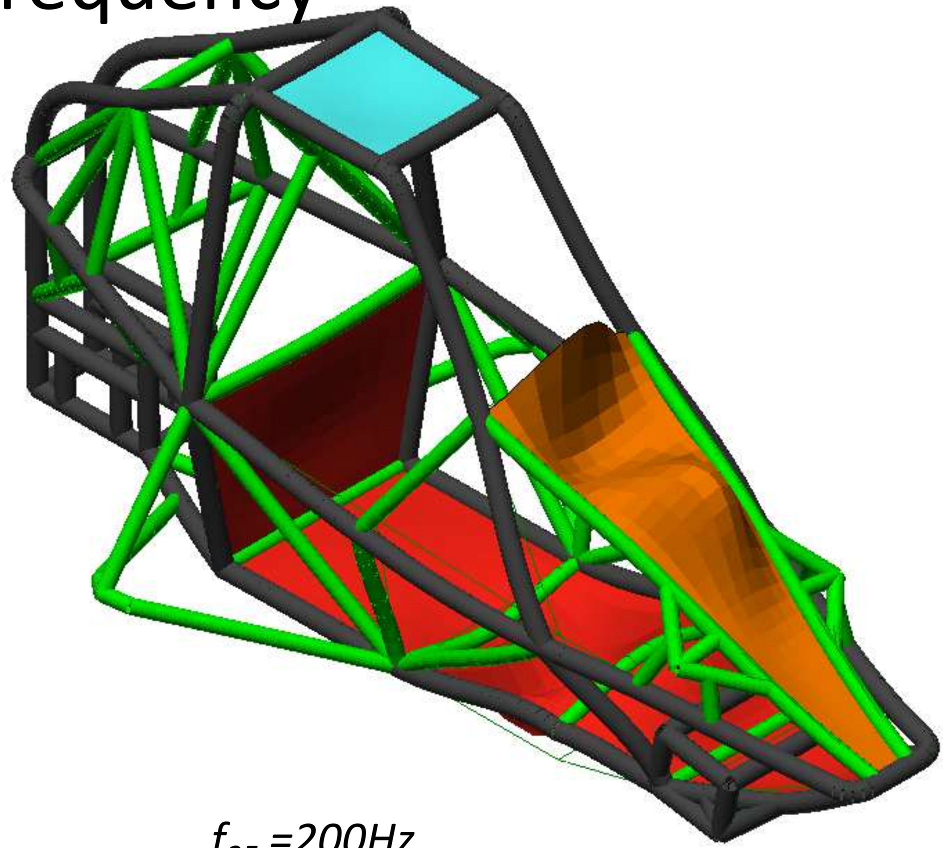


Modal analysis -*Natural Frequency*

Determination of natural frequency and mode shape frequency



f_{21} =175Hz



f_{25} =200Hz

Test: impact on the roof

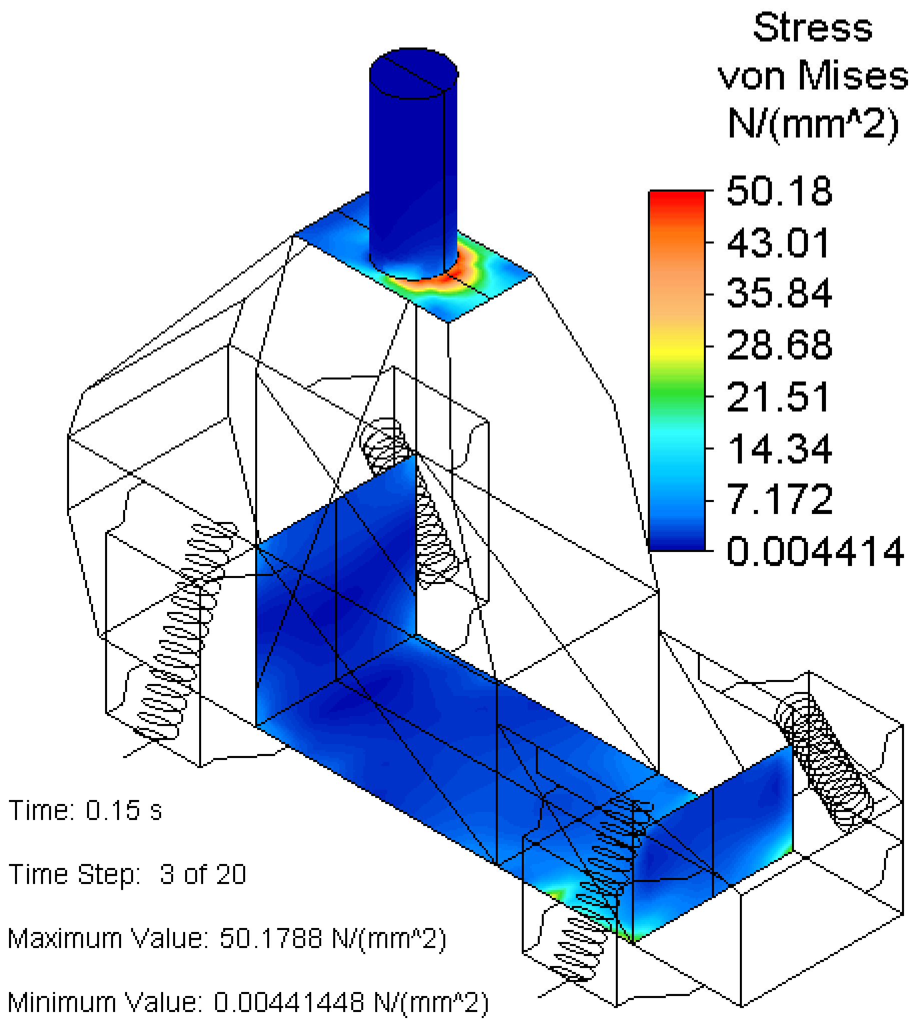
$E_{impact}=11600[J];$

diameter of the impact surface:

$d_{impact}=200[mm];$

velocity of the weight:

$V_{weight}=10{,}04[m/s]$ for $m_{weight}=230[kg]$.



The energy accumulated in the construction

$$E_{accumulated}=0,5 \cdot c_z \cdot u_z^2 \geq E_{impact}$$

SUMMARY

The load bearing element of a vehicle is the frame, which should be designed so as to allow the installation and ensure the optimal placement of individual parts and complete systems. The frame construction should :

- allow to install all the systems required for the vehicle
- meet the basic principles of ergonomics and user comfort;
- ensure the effective protection for the driver both: while driving and in case of an accident;
- enable the most effective transmission of torque to the wheels;
- ensure the best traction parameters.

SUMMARY

The frame strength analysis allowed to conclude that the load bearing structure of the vehicle has a low susceptibility to the effects of external forces.

Very small plastic deformations occured during the strength tests simulating the frame turnover.

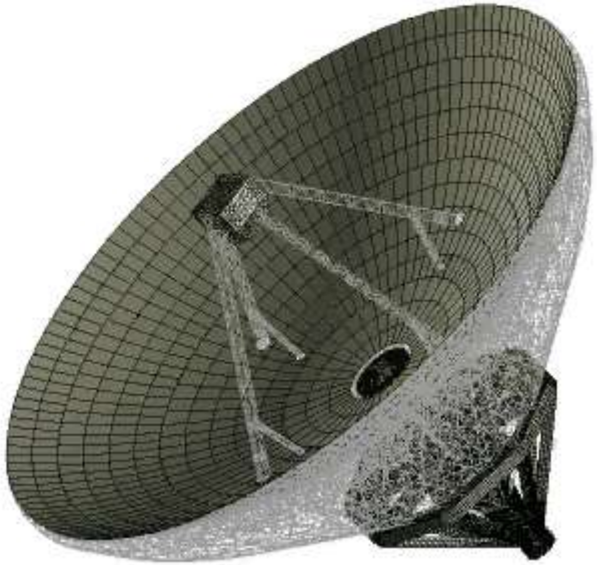
Therefore, the process of frame optimization should be focused on the use of steel profiles with different dimensions.

Sources

1. Autodesk Algor's materials on: www.autodesk.algor.com
2. http://www.beach-buggy.pl/building-buggy.html - marzec 2008
3. http://strefa4x4.pl/index.php?m=buggy.php - marzec 2008
4. http://www.beach-buggy.pl/history.html - marzec 2008
5. http://www.beach-buggy.pl/function.html - marzec 2008
6. http://www.chenowth.com/index.php - kwiecień 2008
7. http://www.badlandbuggy.com/buggy_st3.html - kwiecień 2008
8. http://www.git.com.au/~theedge/Barracuda.htm - kwiecień 2008
9. http://www.git.com.au/~theedge/buggies_sidewinder.htm - kwiecień 2008
10. http://www.git.com.au/~theedge/buggies_ballistic.htm - kwiecień 2008
11. http://www.beach-buggy.pl/autodynamics.html - kwiecień 2008
12. http://www.git.com.au/~theedge/ - kwiecień 2008
13. http://www.rallycross.pl/szayowozy/pobierz/regulaminramowy.pdf - maj 2008
14. http://cbr600.webd.pl/images/pc31_3.jpg - marzec 2008
15. http://bimarco.pl/laser.html# - maj 2008
16. Spyrakos C.; „Finite Element Modeling In Engineering Practice Includes Examples with ALGOR® ", West Virginia University Press, WV.
17. Zieliński A.; „Konstrukcja nadwozi samochodów osobowych i pochodnych", WKŁ Warszawa 2003.
18.http://www.rucker.pl/dydaktyka/wyklady/3.1_konstrukcje_cienkoscienne_i_ramy_nadwoziowe.pdf – czerwiec 2008

Thank you for your attention

For further information please contact:



Ph.D. Olejarczyk Krzysztof
Phone +48 48 361 71 16
mobile +48 606 142 641
e-mail: k.olejarczyk@pr.radom.pl