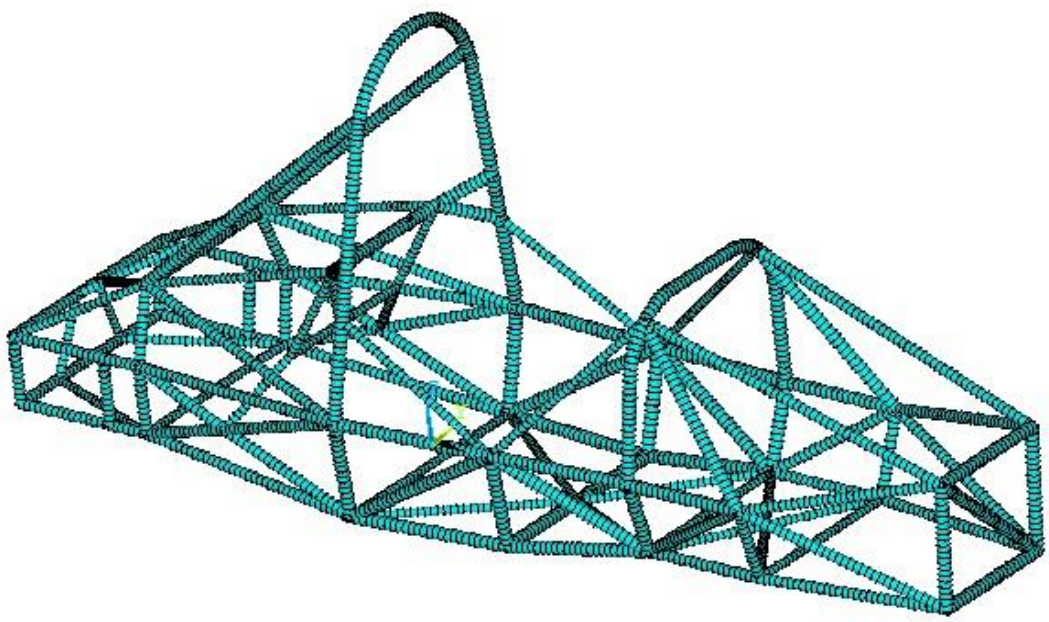
FEA OF THE SPACEFRAME CHASSIS

Material properties: 25CrMo4 (AISI 4130)

YOUNG MODULUS E (GPA)	POISSON COEFFICIENT	YIELD STRENGTH RE (MPA)	ULTIMATE STRENGTH RM (MPA)	FATIGUE STRENGTH RF (MPA)
200	0.3	600	800	310

Mesh

Beam elements (1cm length)



Load cases:

- Loads from suspensions when braking, accelerating or in a bend
- Loads from the differential
- Crash situations (same as alternative frame rules and loads from the engine)
- Torsion

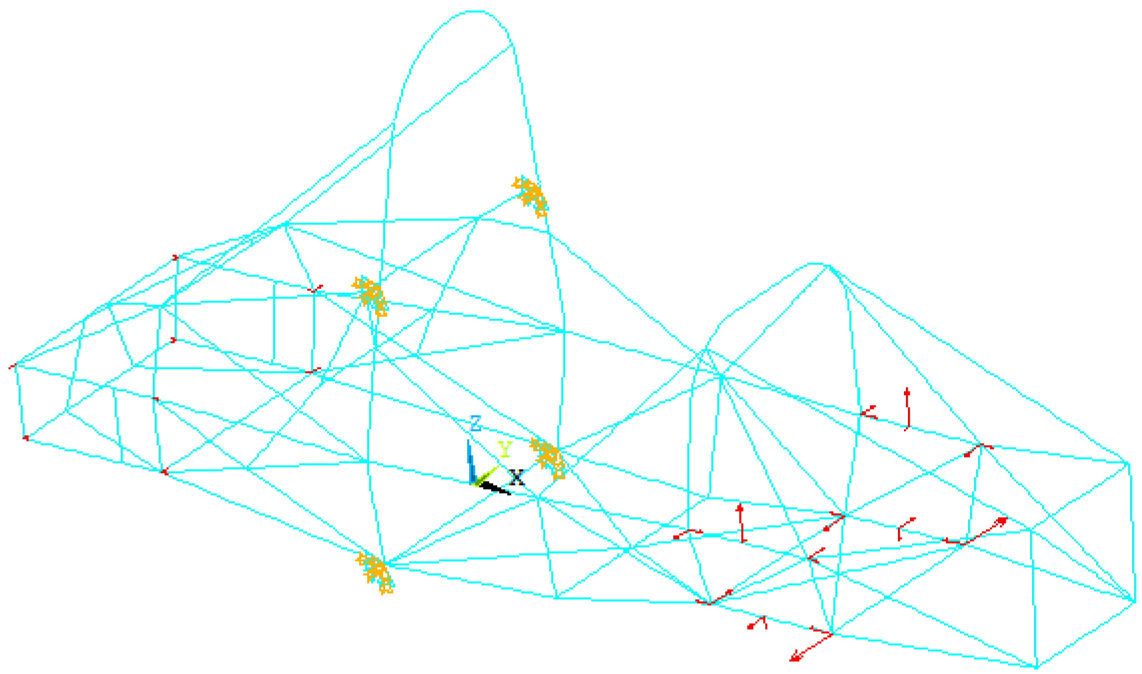
Braking (1.5g)

Loads (on the right part of the chassis - symmetry right/left)

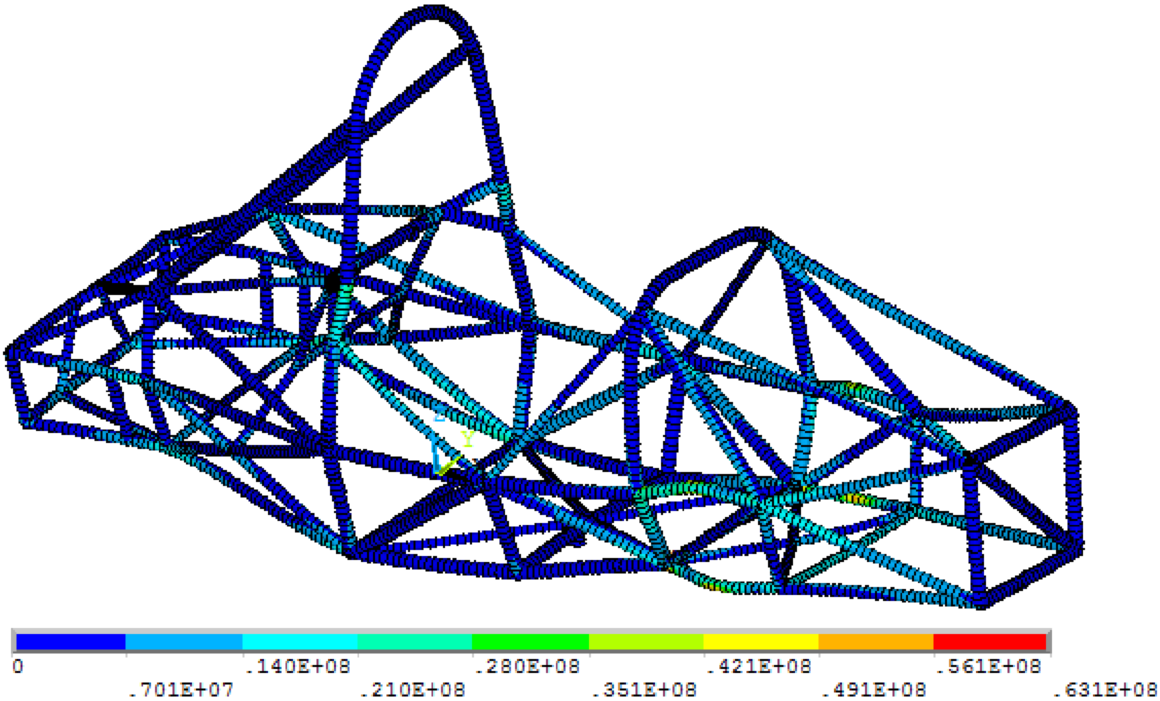
		FRONT	REAR
UPPER A-ARM	Front mounting point	FX=374 N FY=855 N	FX=197 N FY=-360 N
	Rear mounting point	FX=525 N FY=855 N	FX=93 N FY=-341 N
LOWER A-ARM	Front mounting point	FX=-760 N FY=-2110 N	FX=197 N FY=360 N
	Rear mounting point	FX=-518 N FY=-1091 N	FX=93 N FY=-341 N
SUSPENSION	Rocker mounting point	FY=-820 N FZ=-380 N	neglected
	Damper mounting point	FY=220 N FZ=1240 N	neglected

Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



Results



VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
63	12.7	0.5

Design considerations

"Weak" load case => No influence on design

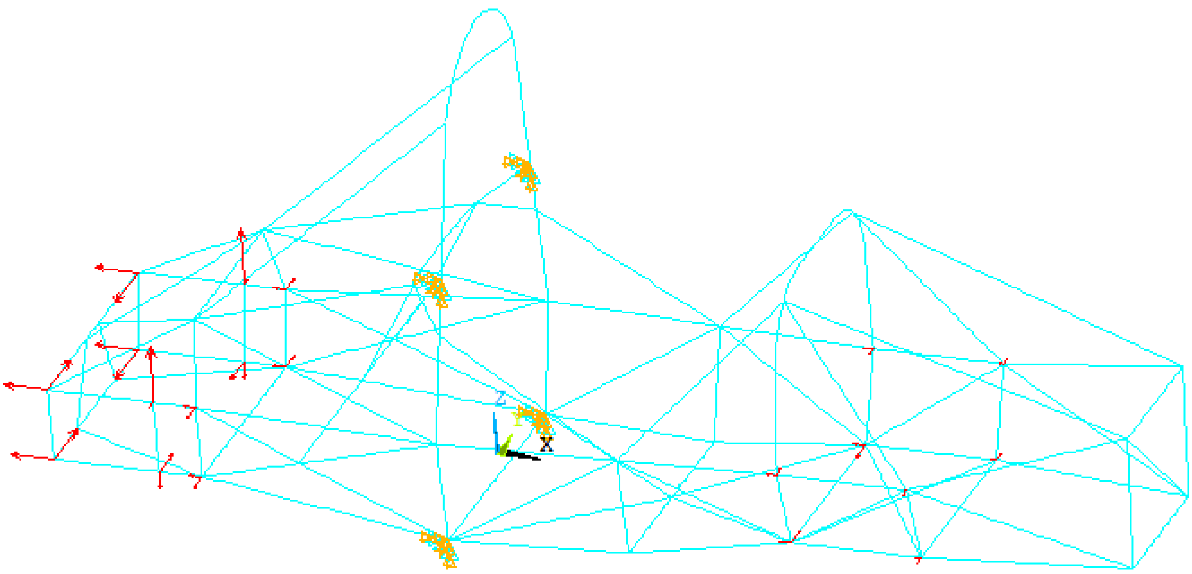
Acceleration (1.5g)

Loads (on the right part of the chassis - symmetry right/left)

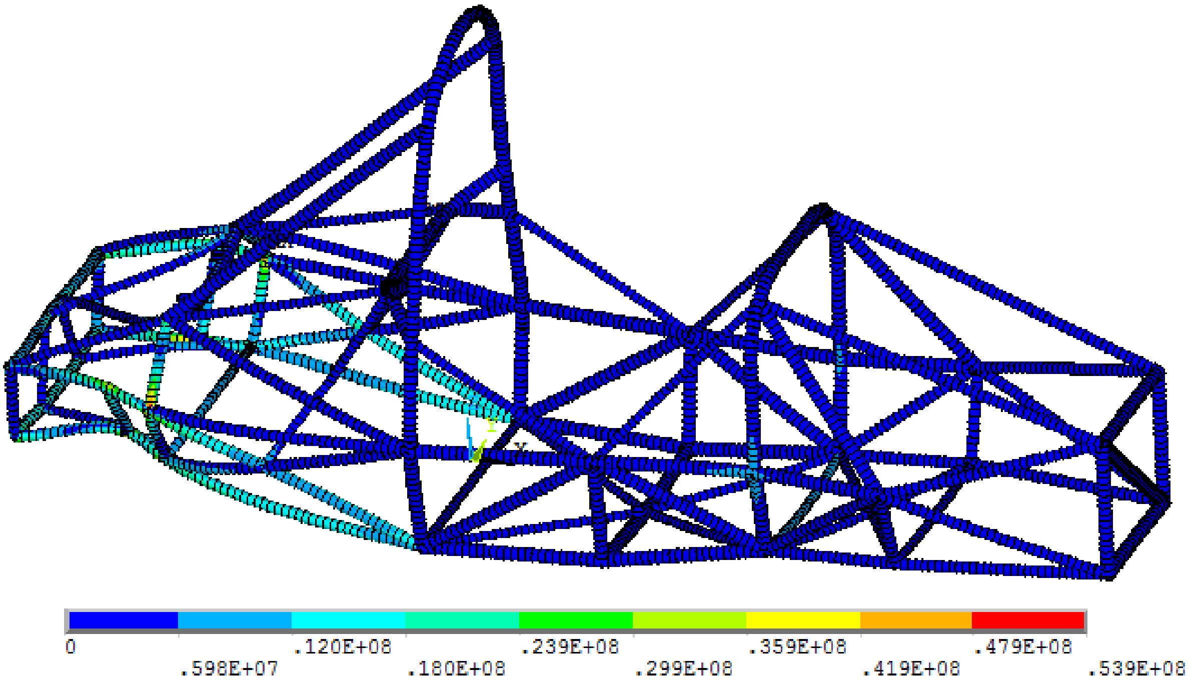
		FRONT	REAR
UPPER A-ARM	Front mounting point	FX=-94 N FY=-214 N	FX=-272 N FY=-497 N
	Rear mounting point	FX=-204 N FY=265 N	FX=-921 N FY=-1395 N
LOWER A-ARM	Front mounting point	FX=-107 N FY=-298 N	FX=-272 N FY=-497 N
	Rear mounting point	FX=-269 N FY=-565 N	FX=-921 N FY=1395 N
SUSPENSION	Rocker mounting point	neglected	FY=1822 N FZ=-768 N
	Damper mounting point	neglected	FY=-381 N FZ=2614 N

Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



LOADS AND BOUNDARY CONDITIONS



Von Mises Stress (Pa)

Max stress (MPa)	Safety factor	Max displacement (mm)
54	14.8	0.2

Design considerations

"Weak" load case => No influence on design

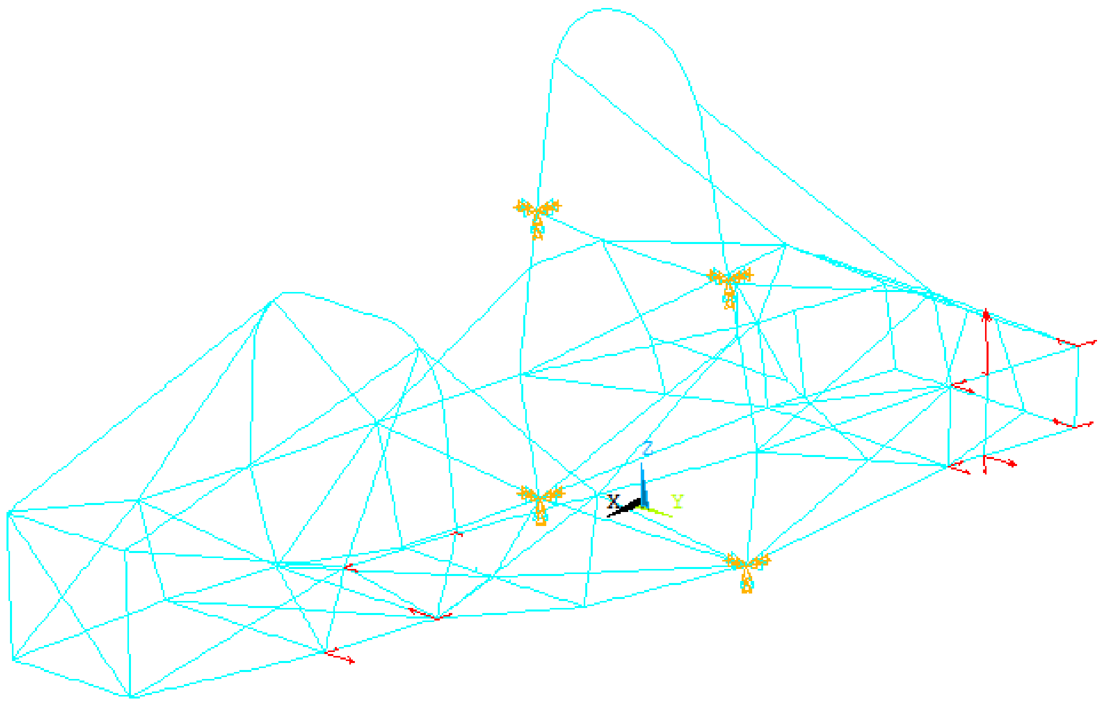
Bend (right turn: 1.5g lateral)

Loads (on the left part of the chassis – loads neglected on the right)

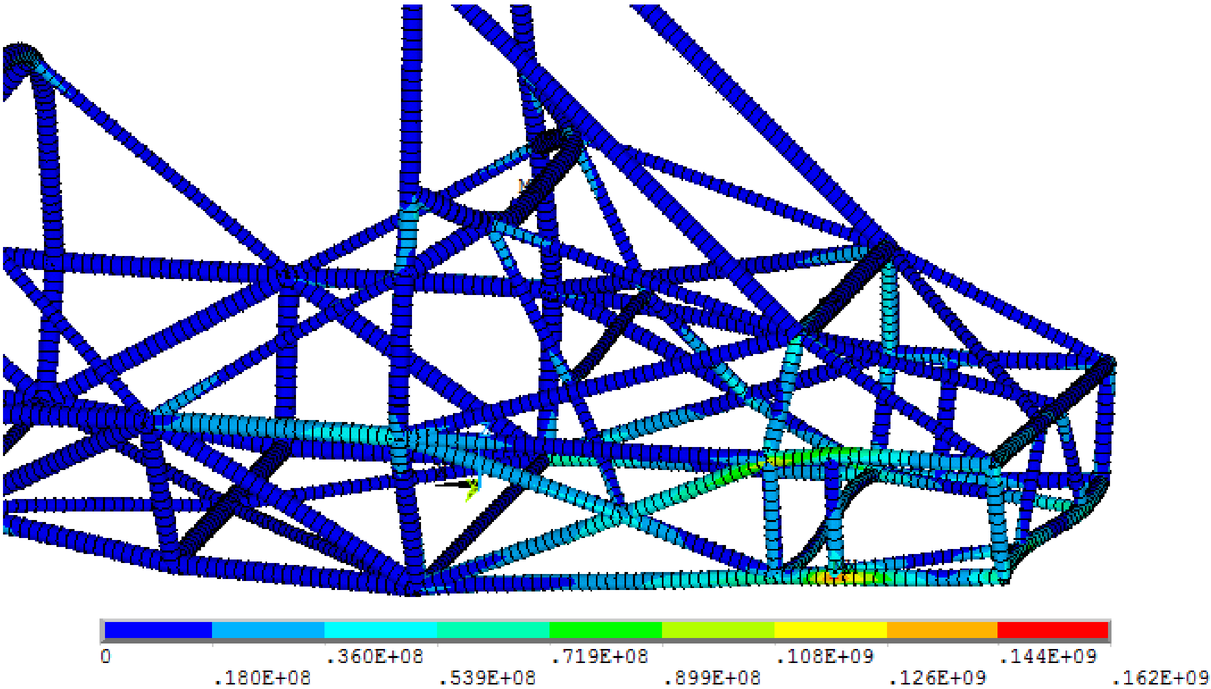
		FRONT	REAR
UPPER A-ARM	Front mounting point	FX=-94 N FY=-214 N	FX=-272 N FY=-497 N
	Rear mounting point	FX=-204 N FY=265 N	FX=-921 N FY=-1395 N
LOWER A-ARM	Front mounting point	FX=-601 N FY=1670 N	FX=-272 N FY=-497 N
	Rear mounting point	FX=-765 N FY=-1610 N	FX=-921 N FY=1395 N
SUSPENSION	Rocker mounting point	FY=1822 N FZ=-768 N	FY=1822 N FZ=-768 N
	Damper mounting point	FY=-381 N FZ=2614 N	FY=-381 N FZ=2614 N

Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



LOADS AND BOUNDARY CONDITIONS

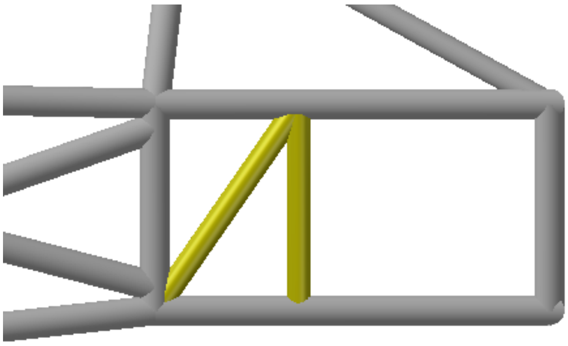


Von Mises Stress (Pa)

Max stress (MPa)	Safety factor	Max displacement (mm)
162	4.9	1.7

Design considerations

Tubes were added near the rear suspension mounting point to limit displacement:



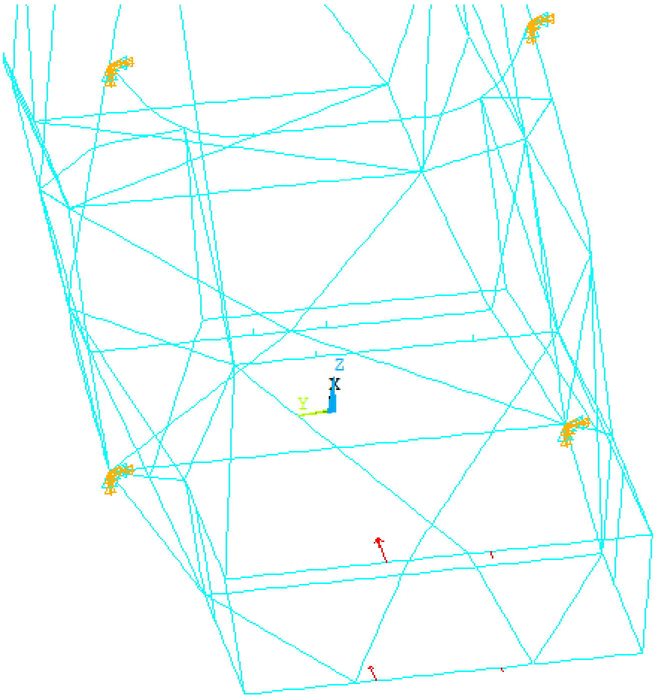
Differential

Load (start with engine at maximum torque)

	LEFT MOUNTING POINT	RIGHT MOUNTING POINT
UPPER TUBE	FX=8100 N	FX=-1900 N
LOWER TUBE	FX=5000 N	FX=-1200 N

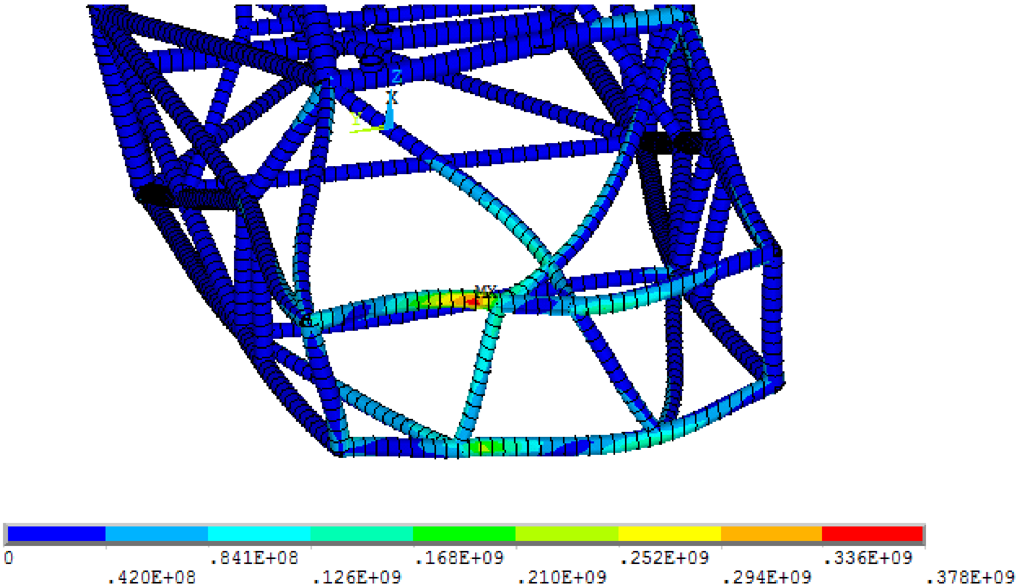
Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



LOADS AND BOUNDARY CONDITIONS

Results

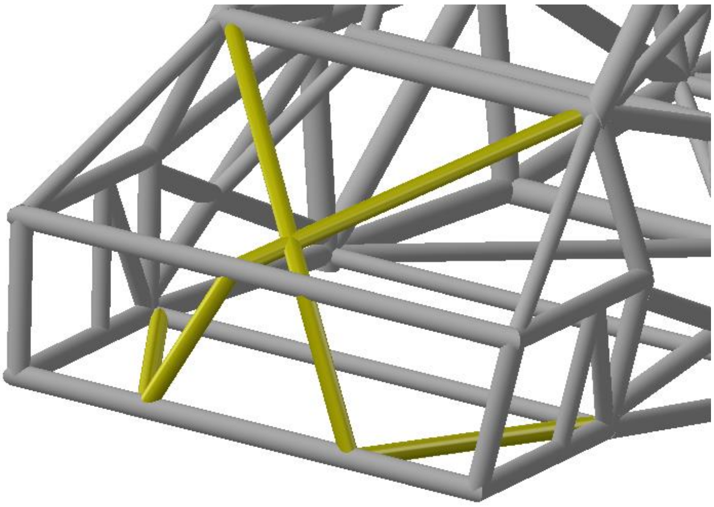


VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
378	2.1	1.3

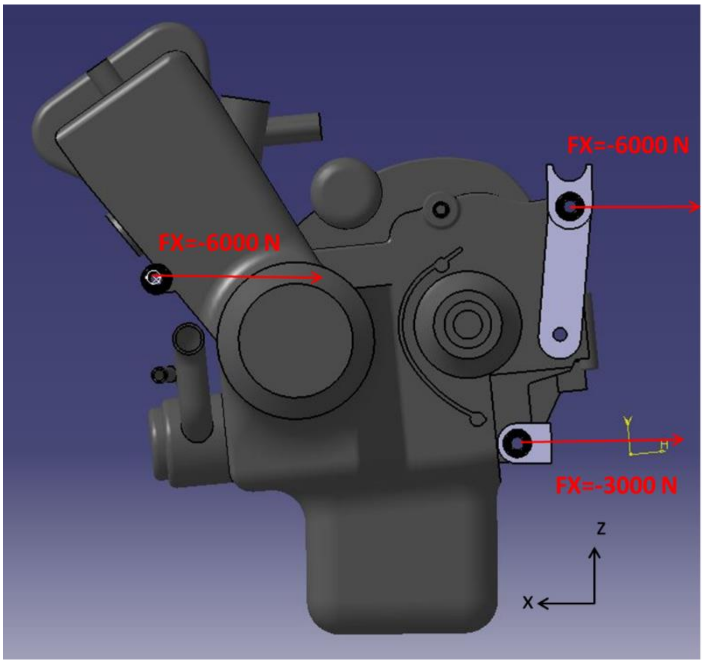
Design considerations

The "rear cell" was reinforced to limit high stresses:



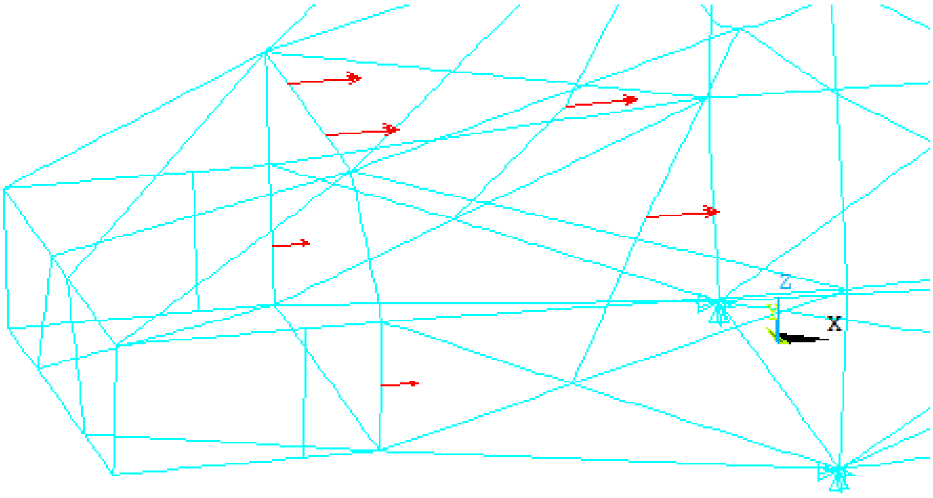
Engine (front impact)

Loads



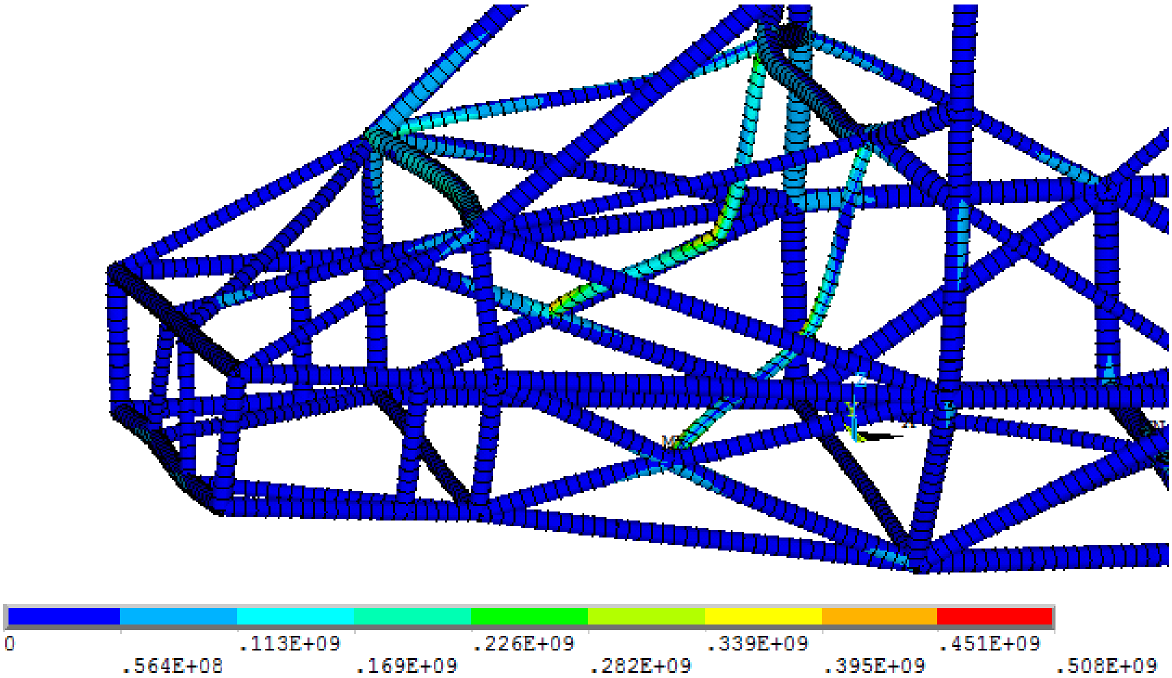
Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



Loads and Boundary conditions

Results

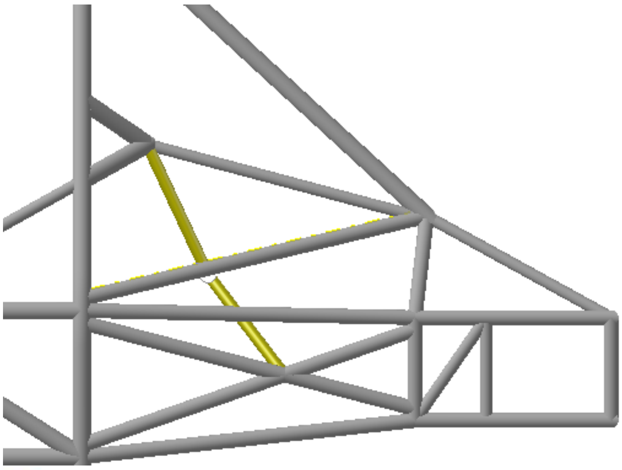


VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
508	1.6	4

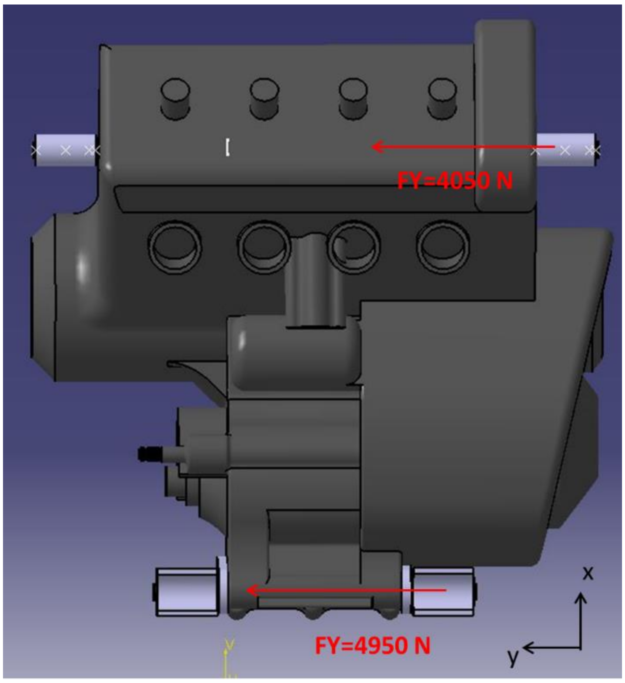
Design considerations

The current configuration should be safe in a crash condition:



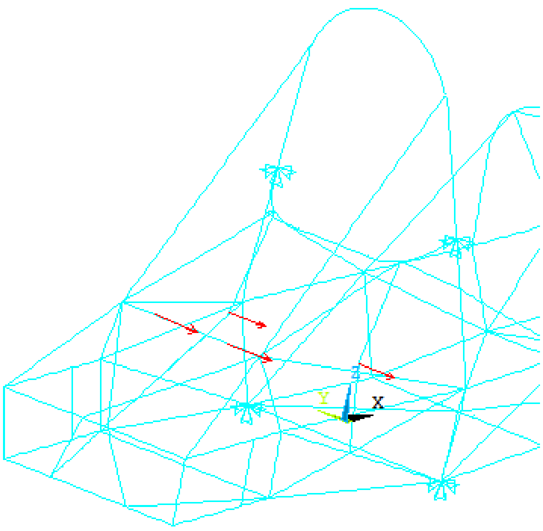
Engine (lateral impact)

Loads



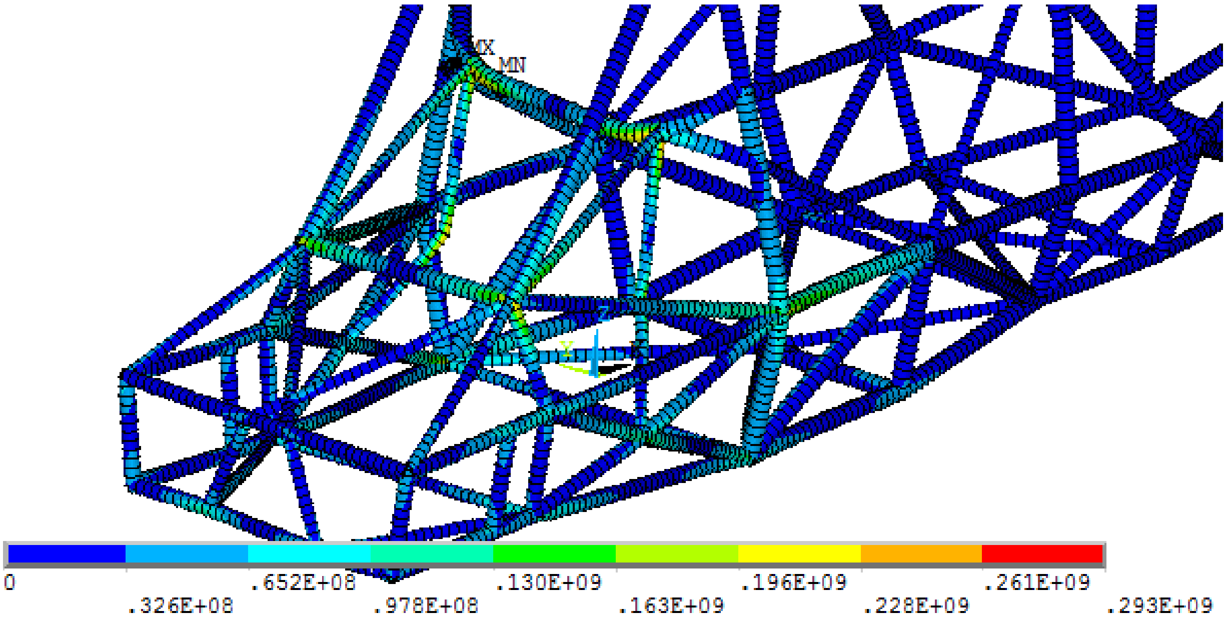
Boundary conditions

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect. (The main hoop is supposed to be the stiffest part of the frame)



LOADS AND BOUNDARY CONDITIONS

Results



VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
293	2.7	5

Design considerations

The current configuration should be safe in a crash condition.

Main hoop impact

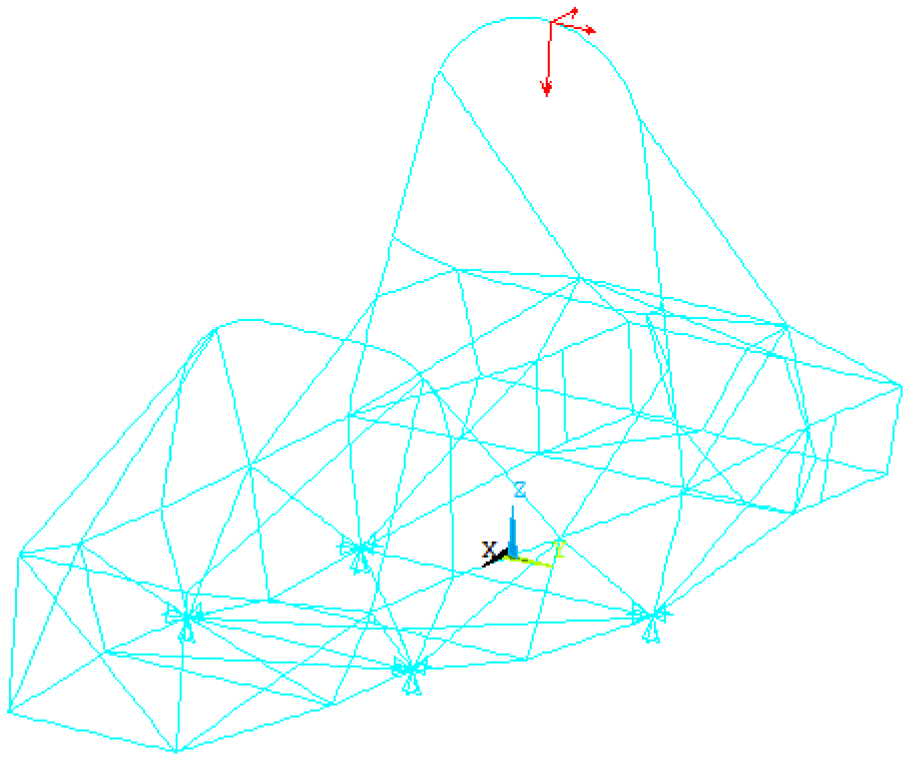
Loads (from alternative frame rules)

At the top of the main roll hoop:

FX=-6000 N
FY=5000 N
FZ=-9000 N

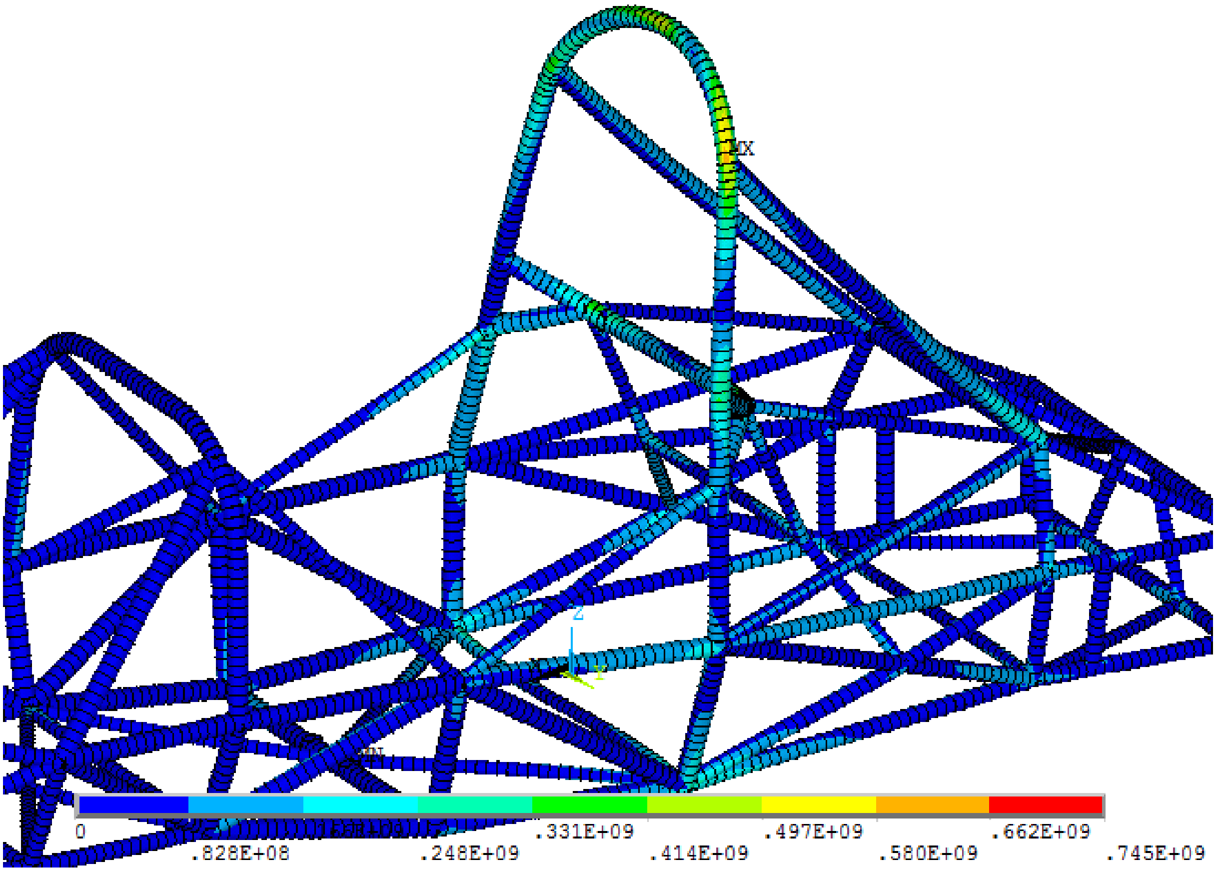
Boundary conditions (from alternative frame rules)

Fixed displacements of the bottom nodes of both sides of the front and main roll hoops.



LOADS AND BOUNDARY CONDITIONS

Results



Von Mises Stress (Pa)

Max stress (MPa)	Safety factor	Max displacement (mm)
745	1.07	18

Design considerations

Plastic deformation occurs (Re=600MPa) but there is no failure.

Front roll hoop impact

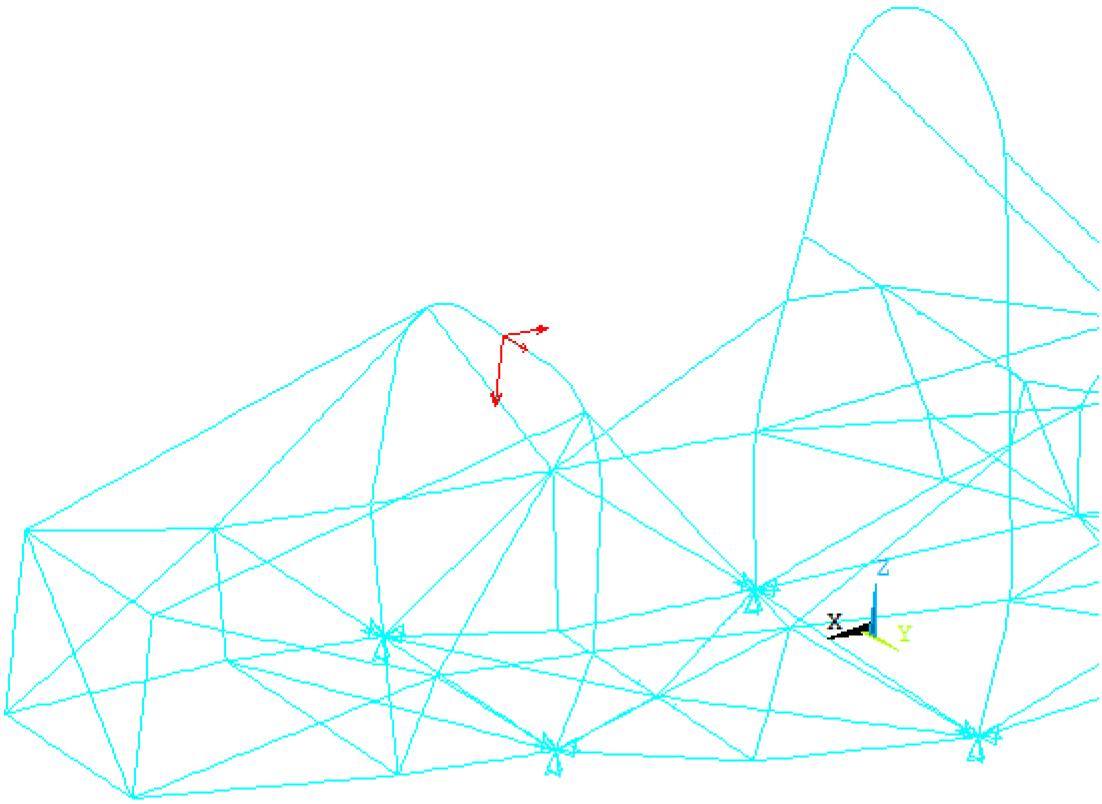
Loads (from alternative frame rules)

At the top of the front roll hoop:

FX=-6000 N
FY=5000 N
FZ=-9000 N

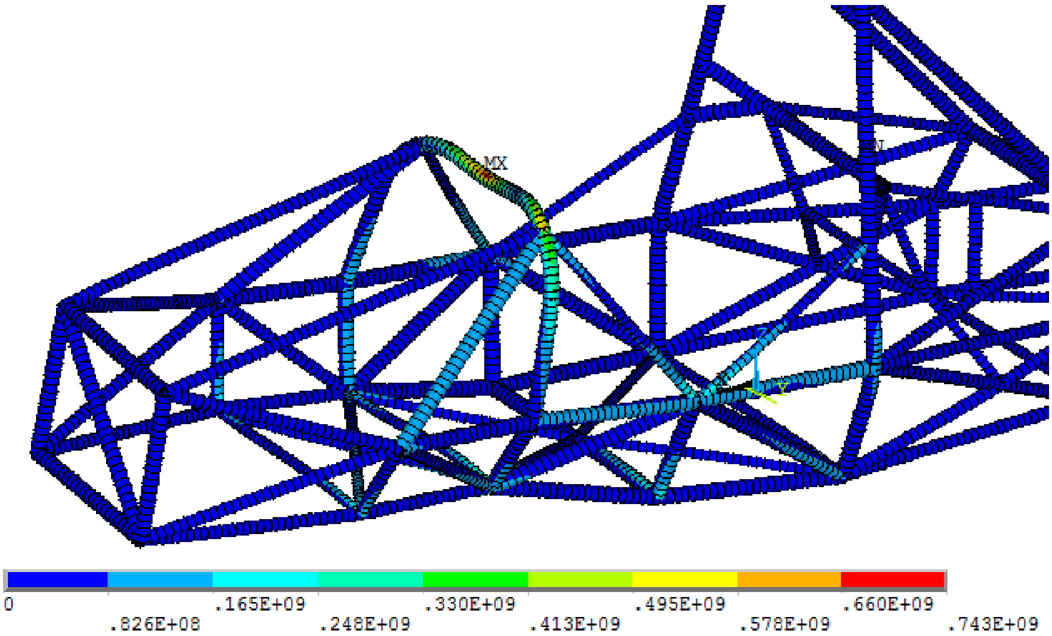
Boundary conditions (from alternative frame rules)

Fixed displacements of the bottom nodes of both sides of the front and main roll hoops.



Loads and Boundary conditions

Results

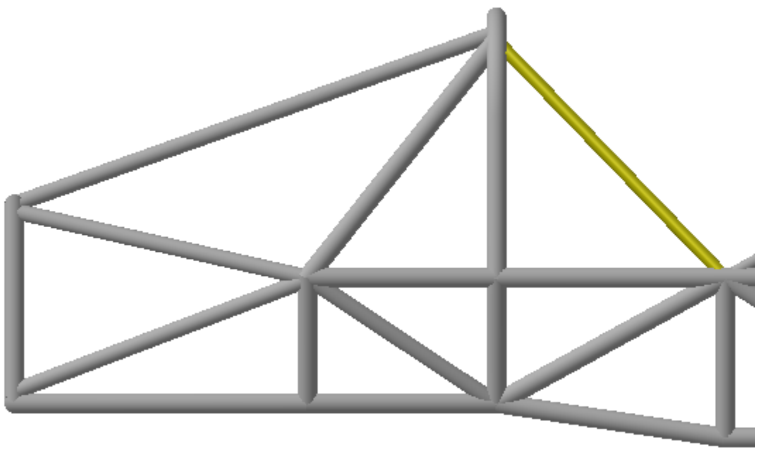


VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
743	1.08	11

Design considerations

Plastic deformation occurs (Re=600MPa) but there is no failure. An additional front hoop brace extending in the backward direction limits the displacements:



Side impact

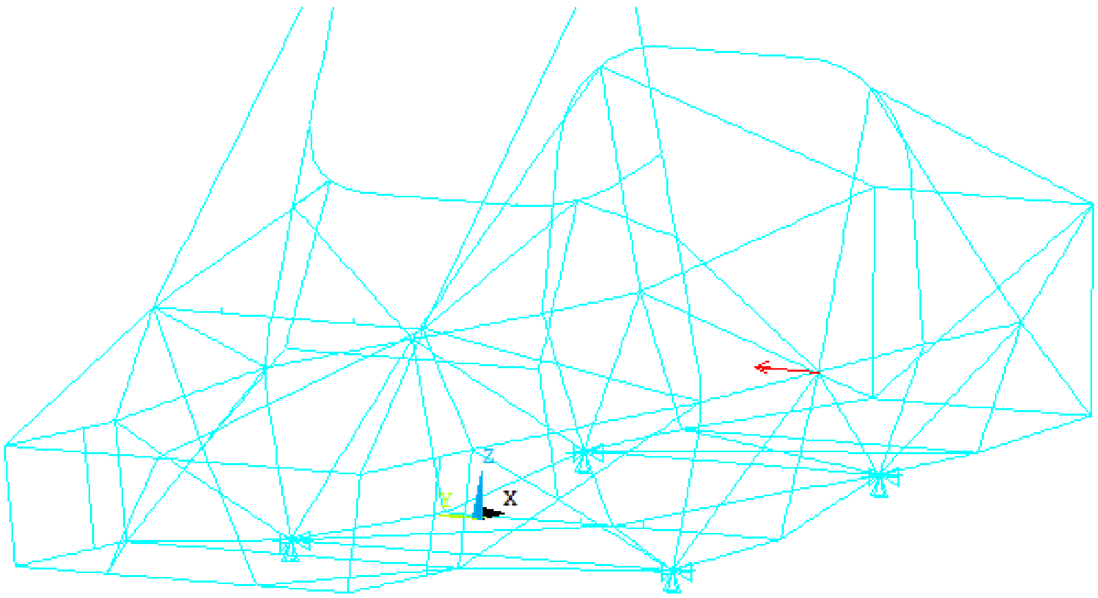
Loads (from alternative frame rules)

At the worst-case location:

FY=7000 N

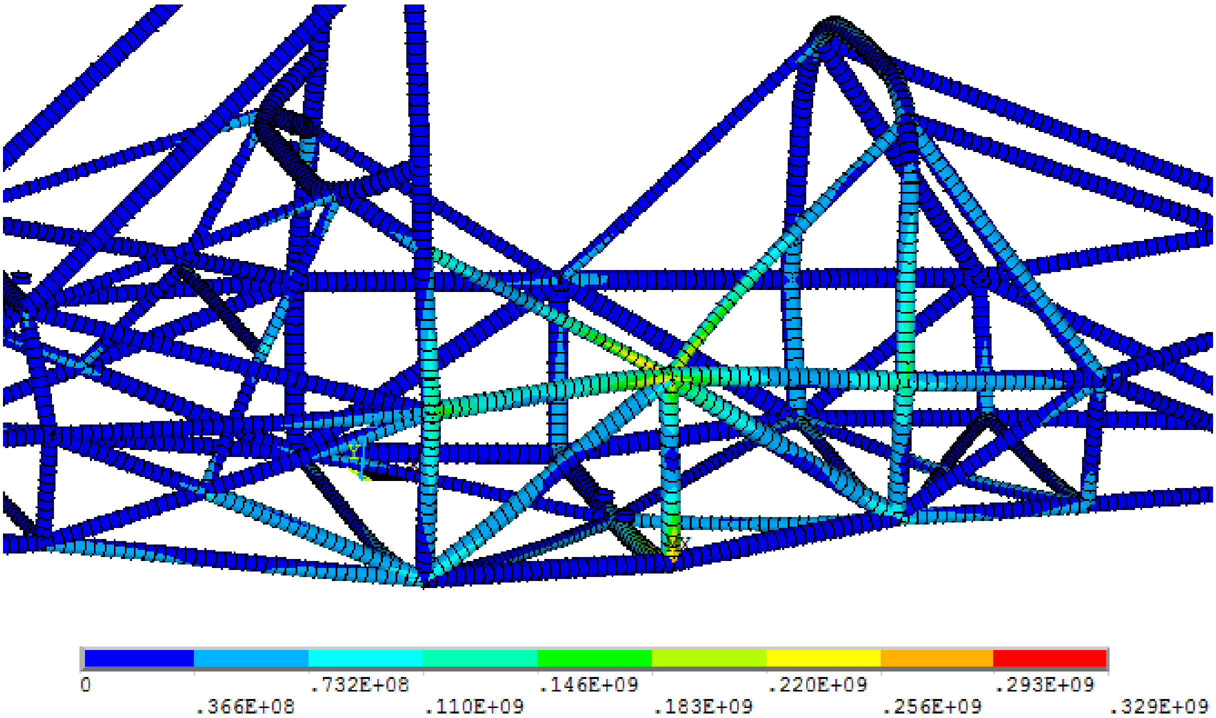
Boundary conditions (from alternative frame rules)

Fixed displacements of the bottom nodes of both sides of the front and main roll hoops.



LOADS AND BOUNDARY CONDITIONS

Results

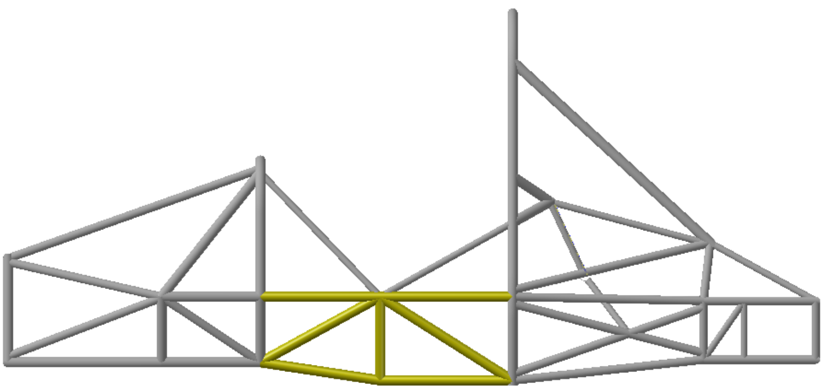


Von Mises Stress (Pa)

Max stress (MPa)	Safety factor	Max displacement (mm)
329	2.4	5

Design considerations

The side impact structure composed of 6 tubes limits the stress:



Front bulkhead impact

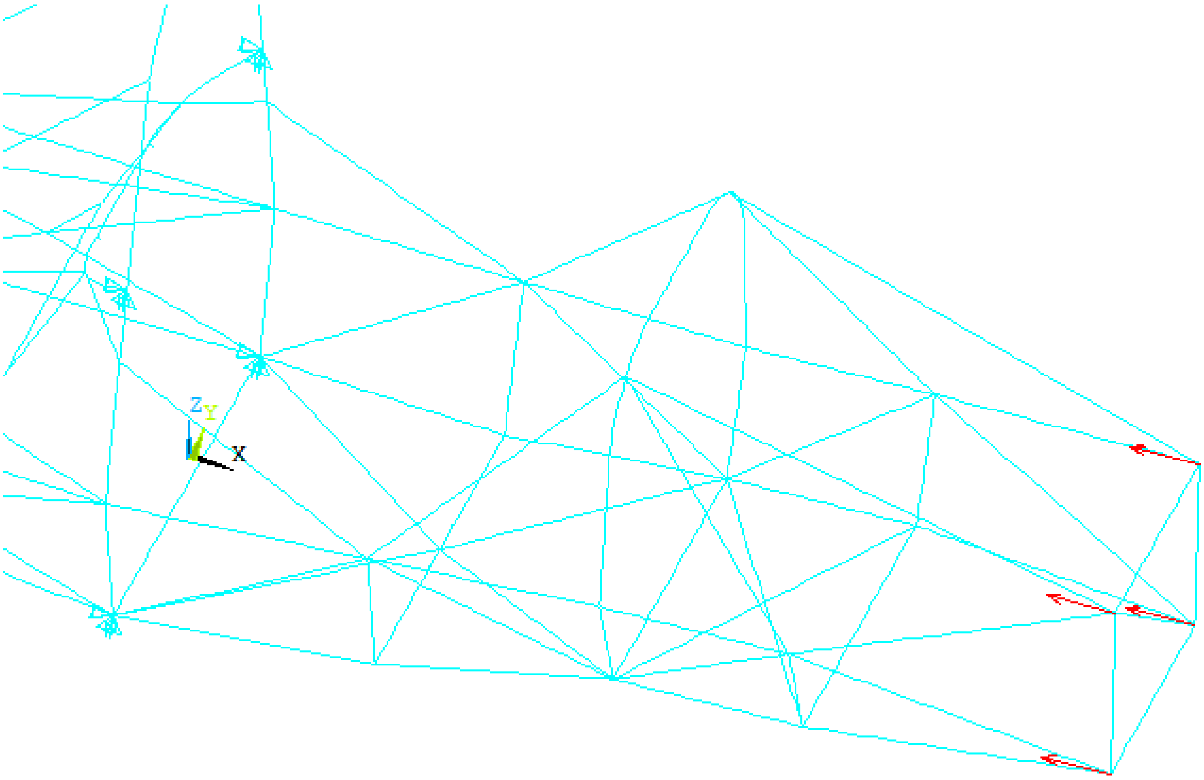
Loads

Distributed at the 4 vertex of the front bulkhead:

FX=-150 kN

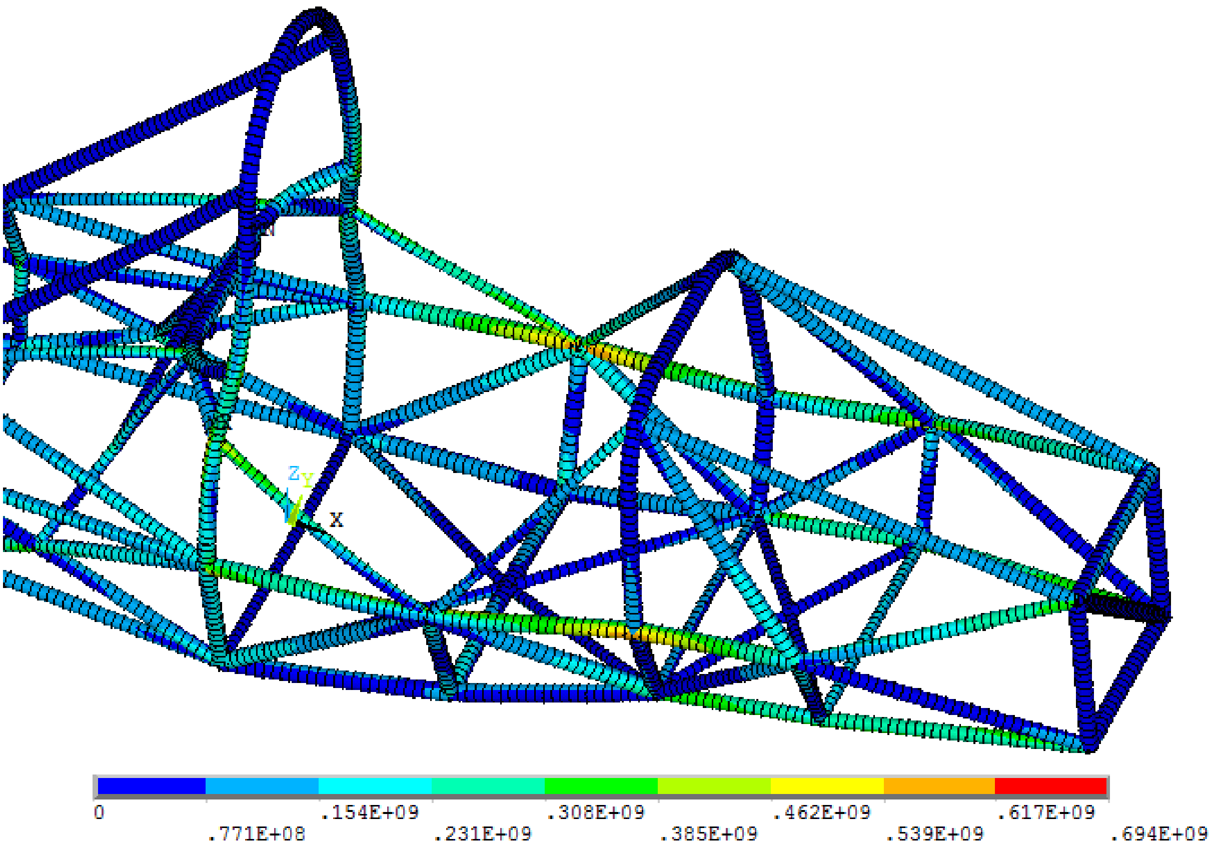
Boundary conditions (from alternative frame rules)

Fixed displacements of the bottom nodes of both sides of the main roll hoop and both locations where the main hoop and shoulder harness tube connect.



LOADS AND BOUNDARY CONDITIONS

Results



VON MISES STRESS (PA)

Max stress (MPa)	Safety factor	Max displacement (mm)
694	1.15	5

Design considerations

Plastic deformation occurs (Re=600MPa) but there is no failure.

Shoulder harness attachment

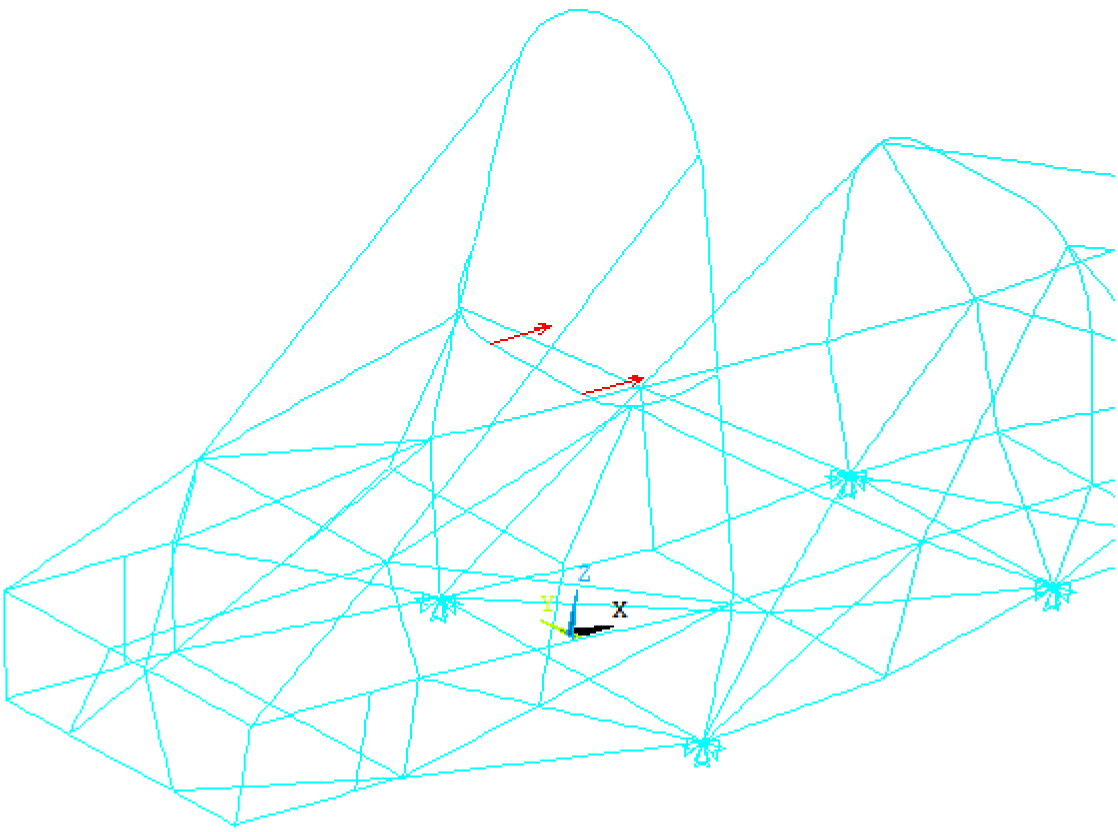
Loads (from alternative frame rules)

At each harness attachment point:

FX=13200 N

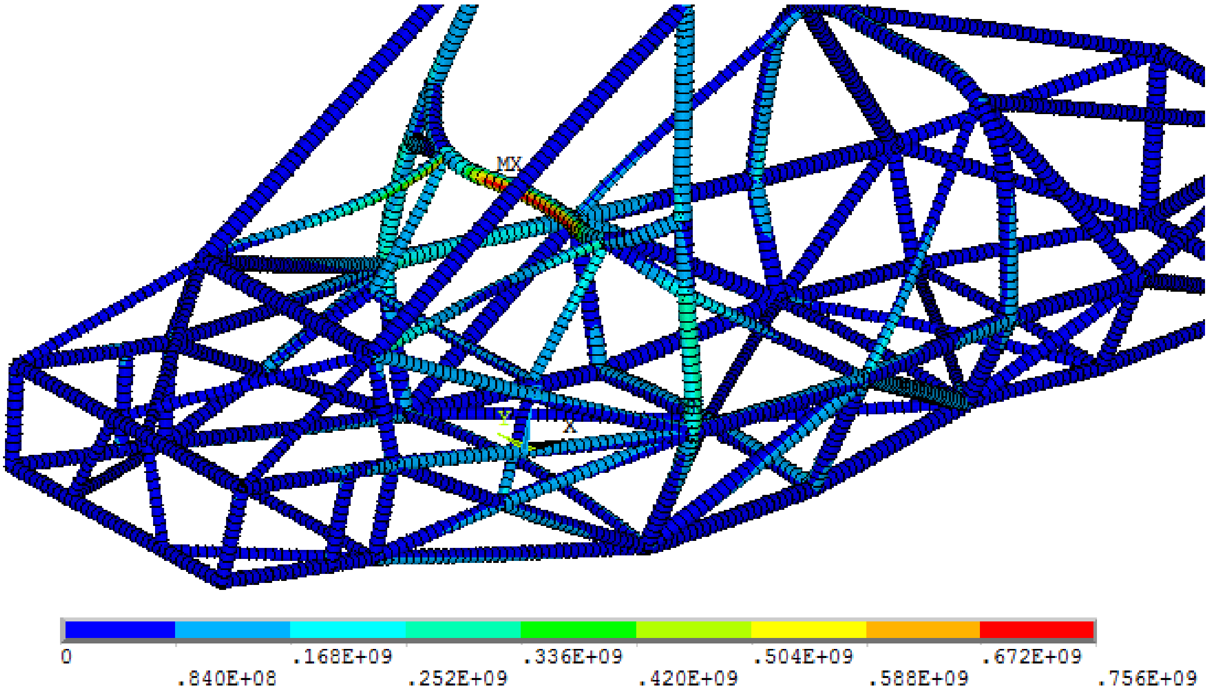
Boundary conditions (from alternative frame rules)

Fixed displacements of the bottom nodes of both sides of the front and main roll hoops.



LOADS AND BOUNDARY CONDITIONS

Results

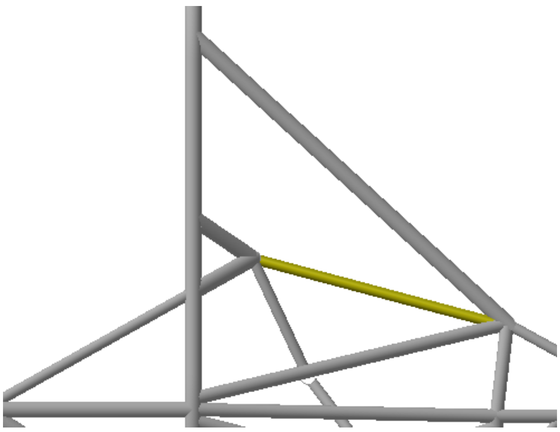


Von Mises Stress (Pa)

Max stress (MPa)	Safety factor	Max displacement (mm)
756	1.06	10

Design considerations

Plastic deformation occurs (Re=600MPa) but there is no failure. An additional tube in the rearward direction limits the displacements:



Torsion test

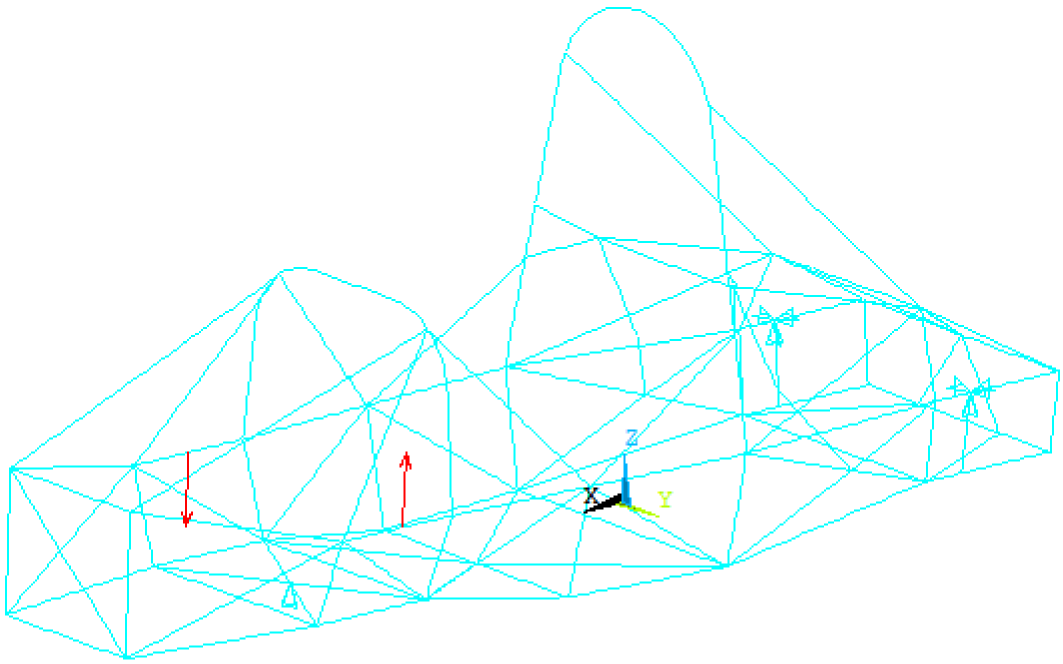
Loads

Loads placed at the mounting of the suspension where the load is highest in the z direction in the bend case => Loads placed at the damper mounting points:

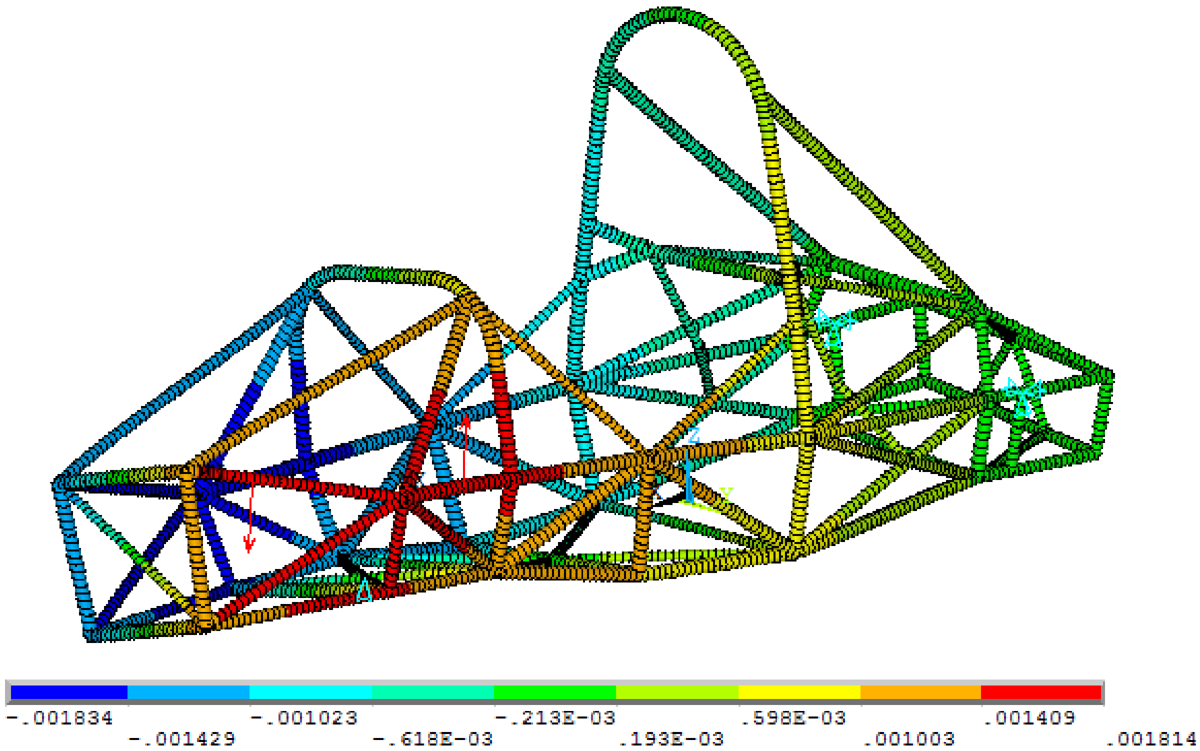
FZ=1000 N on the left
FZ=-1000 N on the right

Boundary conditions

The displacements are fixed on the rear cell at the mounting point of the rear damper. The z displacement is fixed in the middle of the front cell to have an isostatic model.
This configuration gives the same stiffness as when the displacements are fixed on the front cell and forces are imposed on the rear suspension.



Results

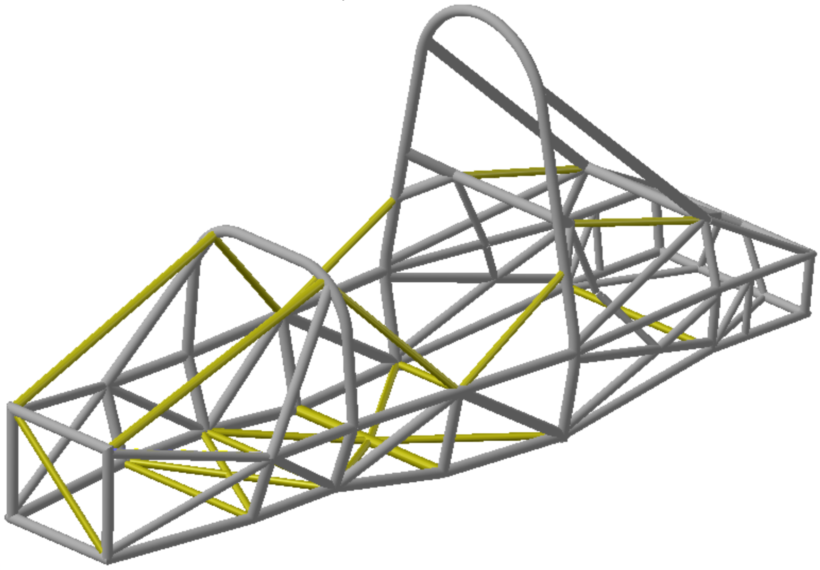


Z-COMPONENT OF DISPLACEMENT

Torsion angle=0.32°
Moment=620 N.m
⇨ **Torsional Stiffness=1915 N.m/deg**

Design considerations

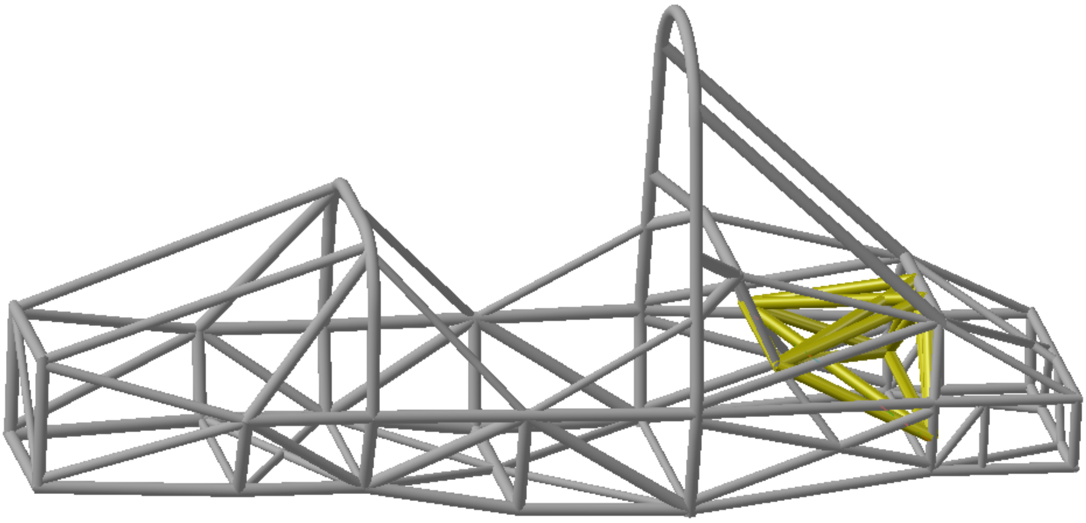
Several additional tubes increase the stiffness/weight ratio:



Torsion test with engine

Model

The engine is simulated by 14 rigid beams that join the 6 engine mounting points:



Loads

Loads placed at the mounting of the suspension where the load is highest in the z direction in the bend case => Loads placed at the damper mounting points:

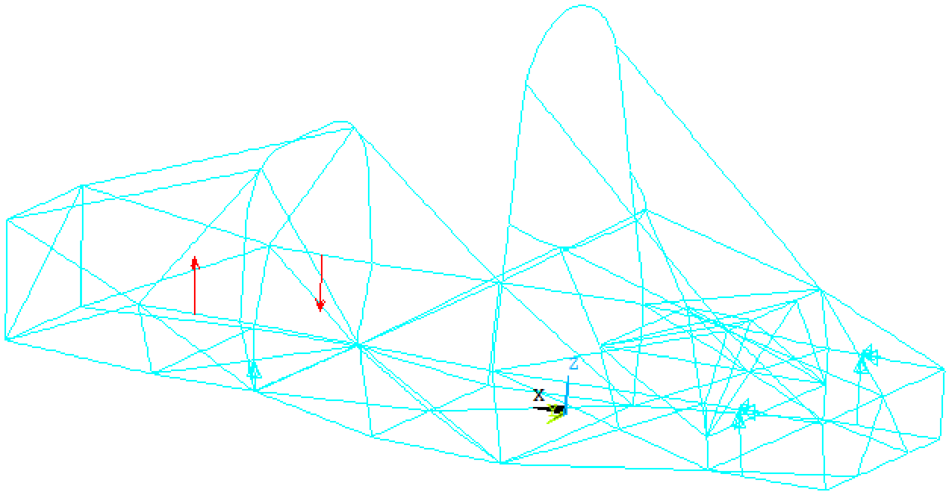
FZ=1000 N on the left

FZ=-1000 N on the right

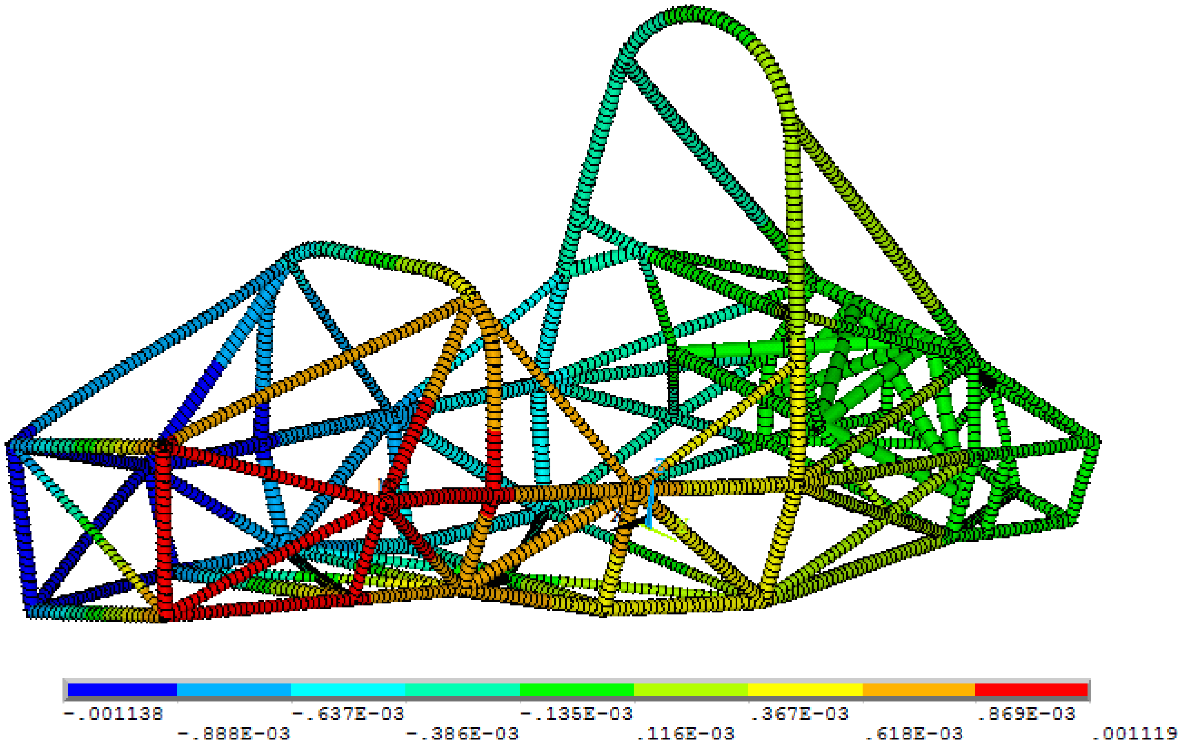
Boundary conditions

The displacements are fixed on the rear cell at the mounting point of the rear damper. The z displacement is fixed in the middle of the front cell to have an isostatic model.

This configuration gives the same stiffness as when the displacements are fixed on the front cell and forces are imposed on the rear suspension.



Results



Z-COMPONENT OF DISPLACEMENT

Torsion angle=0.20°
Moment=620 N.m

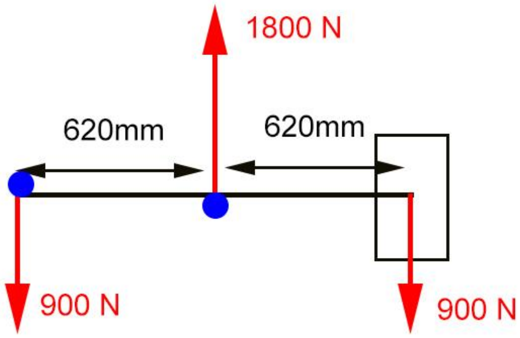
⇨ **Torsional Stiffness=3060 N.m/deg**

Design considerations

The test without engine gave 1915 N.m/deg.
Therefore, the engine increase the stiffness by 60%.

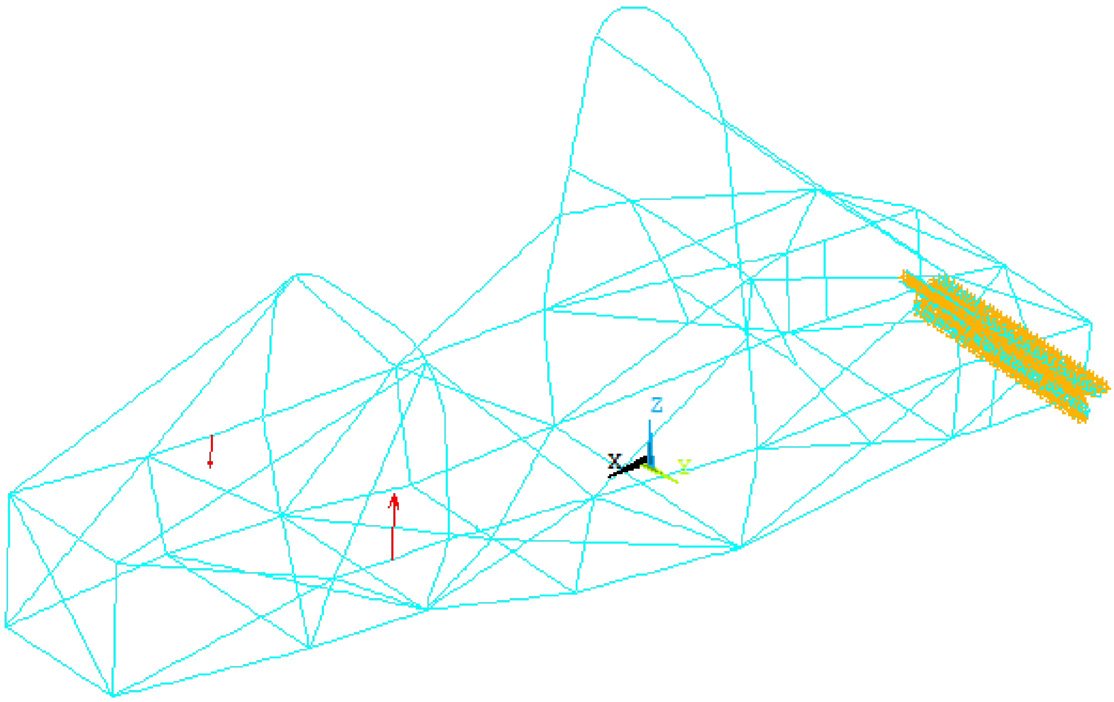
Torsion test as physical test

Loads (same as physical testing)



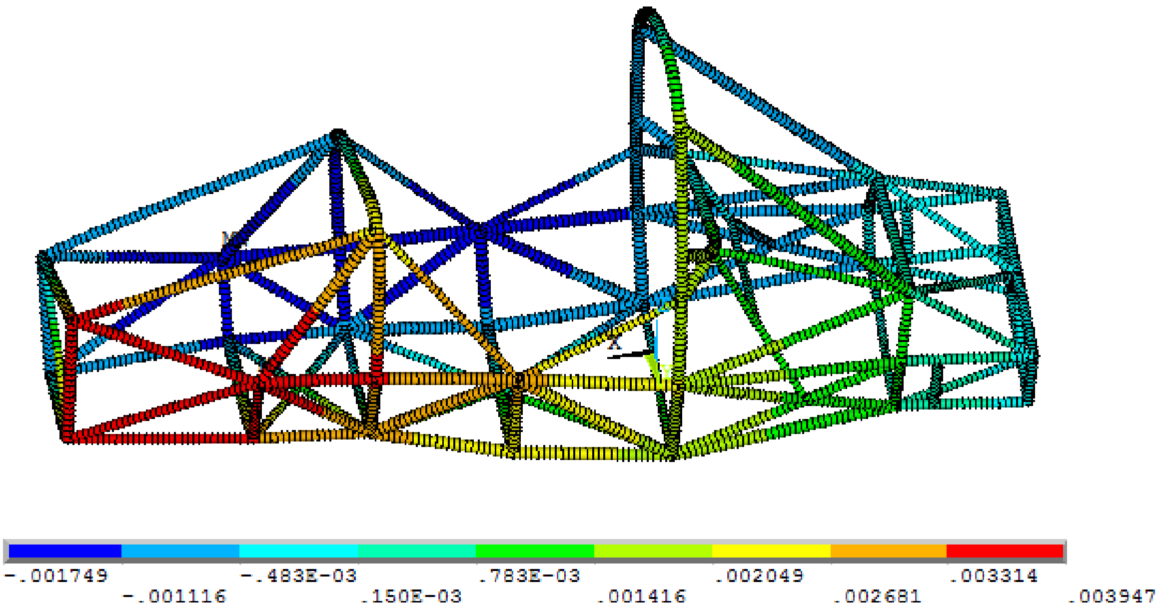
Boundary conditions (same as physical testing)

Fixed displacements of the lowest rear tube of the frame.



Loads and Boundary conditions

Results



Z-COMPONENT OF DISPLACEMENT

Zleft=3.1 mm
Zright=1.1 mm
Torsion angle=0.5deg
Moment=837 N.m

⇨ **Torsional Stiffness=1625 N.m/deg**

Design considerations

The physical test gave 1060N.m/deg.

The ANSYS test in the same conditions gives 1625 N.m/deg.
A more representative ANSYS test with symmetric conditions gives 1915 N.m/deg (18% increase).
Therefore, assuming that the percentage difference would be the same for a symmetric physical test, its stiffness would be 1060x1.18=1248 N.m/deg.

The ANSYS test with the engine gives 3060 N.m/deg (60% increase).
Assuming that the percentage difference between the simulation cases with and without the engine is the same for a physical test, the stiffness of the frame with the engine can be predicted to be approximately 1248x1.6≈**2000 N.m/deg, which is 3.9 times the roll rate of the suspension (514 N.m/deg).**