

CAE REPORT 2018

Car No.: 21

Team Id: 18185

Team Engines and Demons

Indian Institute of Technology, Indore

Outline

Introduction

- Design Approach
- Role 0f CAE
- Software used

Roll Cage Analysis

- Static Analysis
  - Meshing
  - Boundary Condition Determination
  - Results Without Stiffeners
  - Results Comparison with and without Stiffener
- Dynamic Analysis
  - Front Impact
  - Rear Impact
  - Crushing
  - Roll over and landing on one over head member

Brake System

- Brake Discs
- Brake Caliper

Suspension and Steering Wheel Assembly

- Boundary Condition Determination using ADAMS
- Suspension and Steering System MBD Analysis
- Front Hub Analysis
- Rear Hub Analysis
- Front Knuckle Analysis
- Rear Knuckle Analysis
- Front Wishbone Analysis
- Rear H-Arm Analysis
- Front Wheel Axle
- Steering Arm
- Suspension Mounting Brackets Analysis

Transmission System Components

- Engine Mounting Analysis
- Boundary Condition Determination of Gears and Pinions
- Gears and Pinions Analysis
- Gear box Housing Analysis

Introduction

Design Approach

Objective for this year's design was to design a vehicle with the least weight possible. So, serious efforts were put upon designing of each component possible to reduce the overall weight of the vehicle ranging from Brake discs to Knuckle Hub, Brake Caliper, Hitch Plates.

Role of CAE in Designing

CAE played an important role in designing of the vehicle. Each self designed component is analyzed rigorously under possible extreme conditions to validate its designs, and make proper changes in design beforehand to ensure safety of the driver and Integrity of the vehicle.

Software Used

- Designing: CATIA, Solidworks
- Meshing: Hypermesh, ANSYS
- Solver Tool: Optistruct, Radioss, ANSYS
- MBD Analysis: MotionSolve, ADAMS
- Topology Optimization Tool: Virtual PYXIS

Roll Cage Analysis

Static
Dynamic

Component Importance

- Roll Cage is the prime constituent of the BAJA vehicle which supports all other subsystems and driver.
- Failure of roll cage causes direct effect to the alignment of other sub components and can also cause damage to the driver.

Performance Requirement

- Roll cage should be able to withstand all the possible impact forces and its deformation under such forces must be under the permitted limit. Roll cage's integrity must not be compromised under any possible circumstances.

Tests Planned for validation

- Front Impact
- Rear Impact
- Side Impact
- Bump
- Torsion
- Roll Over

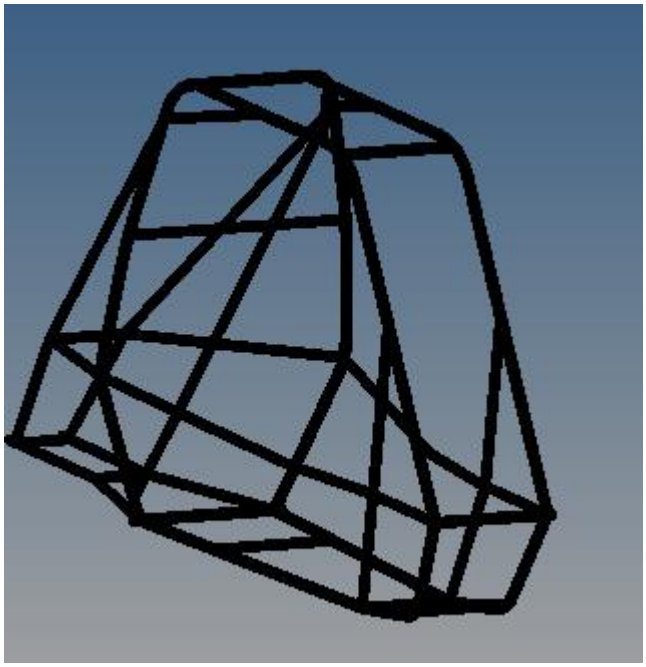
BOUNDARY CONDITION DETERMINATION

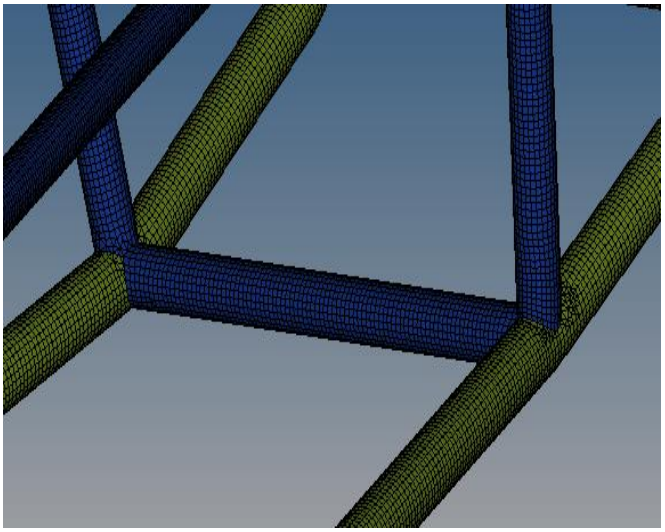
Mass of the full vehicle was estimated to be about 200 Kg.
So, g force=200*10=2000 N.

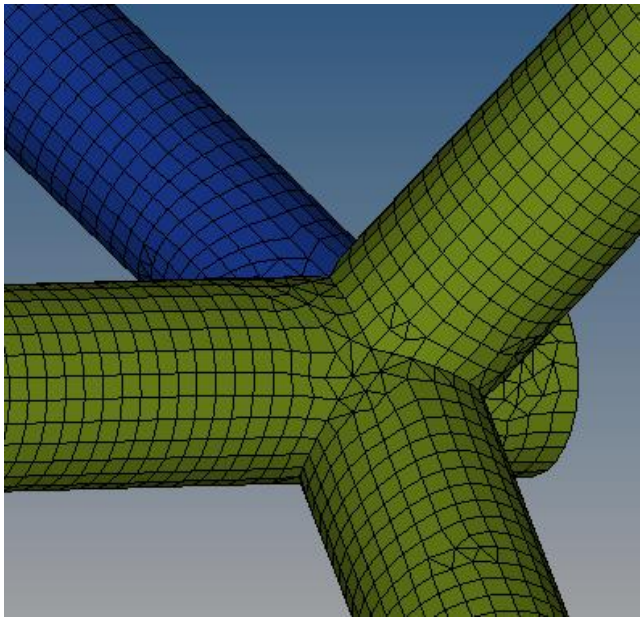
Sr No	CASES	g Force Calculation	BOUNDARY CONDITION DETERMINATION
1	**FRONT IMPACT TEST** (Head on collision while travelling at 45 km/h with another vehicle travelling at same speed)	Impact velocity = 90 km/h (head on) Impact Time=0.7 s Acceleration=Δv/t= 35.71=3.6g≈4g	4g force on the front most member Rear suspension mounting points as fixed supports F=4mg= 8000 N
2	**REAR IMPACT TEST** (Impacted by another vehicle travelling at 45 km/h from rear while standing still)	Impact velocity = 45 km/h Impact Time=0.7 s Acceleration=Δv/t= 17.85 = 1.82g ≈ 2g	2g force on the rear most member Front suspension mounting points as fixed supports F=2mg=4000 N
3	**SIDE IMPACT TEST** (Impacted by another vehicle travelling at 45 km/h from side while standing still)	Impact velocity = 45 km/h Impact Time=0.7 s Acceleration=Δv/t= 17.85 = 1.82g ≈ 2g	2g force on the right/left most member & all suspension mounting points as fixed supports F=2mg=4000 N
4	**BUMP TEST** (Vehicle going over a bump with bump force equivalent to 2g force)	2g force taken from Reference	2g on front suspension mountings and rear suspension mountings fixed F=4mg=4000 N
5	**TORSION TEST** (Only one of the front wheel going over a bump and experiencing force equivalent to 2g.)	Force couple equivalent to 2g force. (From reference.)	2g force couple with respect to center line on front suspension mountings & rear suspension mountings fixed F=2mg=4000 N
6	**ROLL-OVER TEST** (Vehicle rolling over and impacting on overhead members with impact force equivalent to 3g.)	3g force taken from reference	3g force on topmost member & all suspension points fixed F=3mg=6000 N

ROLL CAGE STATIC ANALYSIS

Meshing







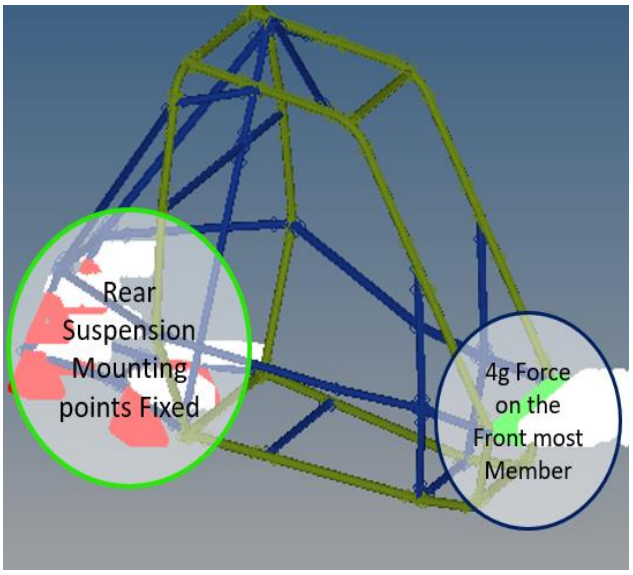
Care has been taken while meshing the roll cage for static and dynamic analysis in order to get more accurate results. Meshing has gone through proper quality checks. And refinement was done wherever necessary.

Final Mesh Quality After Refinement

Mesh Quality Parameter	Value
Meshing type	2D
Warpage (Maximum)	5
Aspect Ratio	2.75
Element Size	4
Skew (Maximum)	41.45
Minimum Length	3.14
Maximum Length	5.23
Minimum Tria-Angle	32.35
Maximum Tria-Angle	106.49
Minimum Quad-Angle	66.54
Maximum Quad-Angle	112.86
Jacobian (Minimum)	0.71

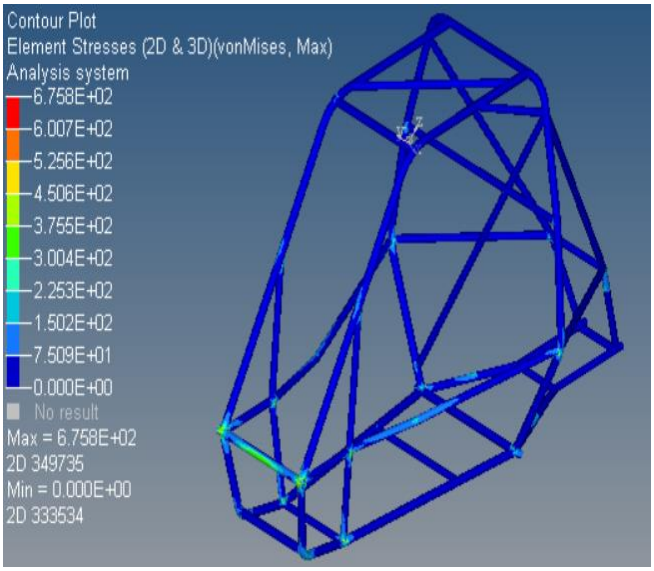
Front Impact Analysis

Boundary Condition



4g force on the front most member and rear suspension mounting points fixed

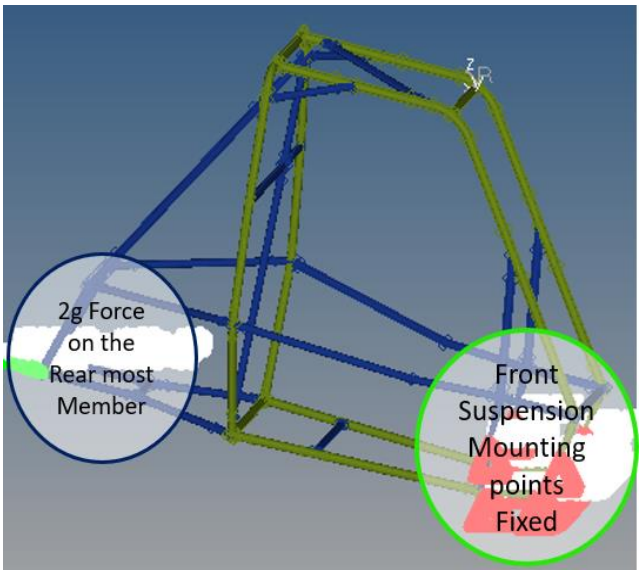
Results



Maximum Stress	675.8 MPa
Yield Strength	607 MPa
Factor of Safety	**0.898**

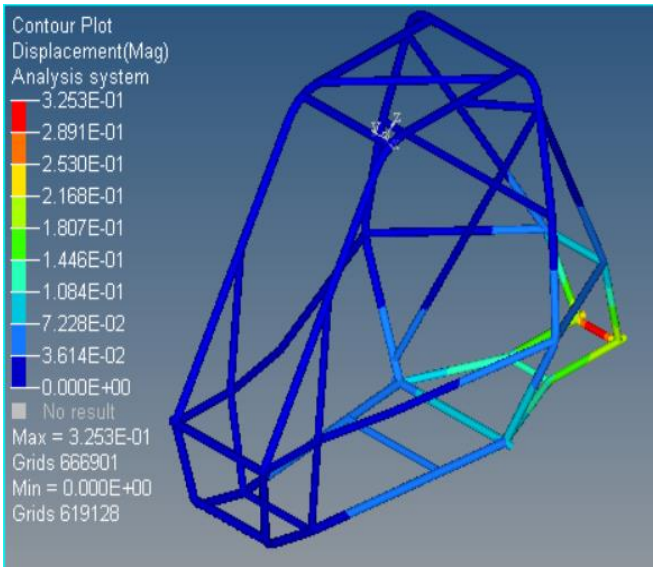
Rear Impact Analysis

Boundary Condition



2g force on the rear most member and front suspension mounting points fixed

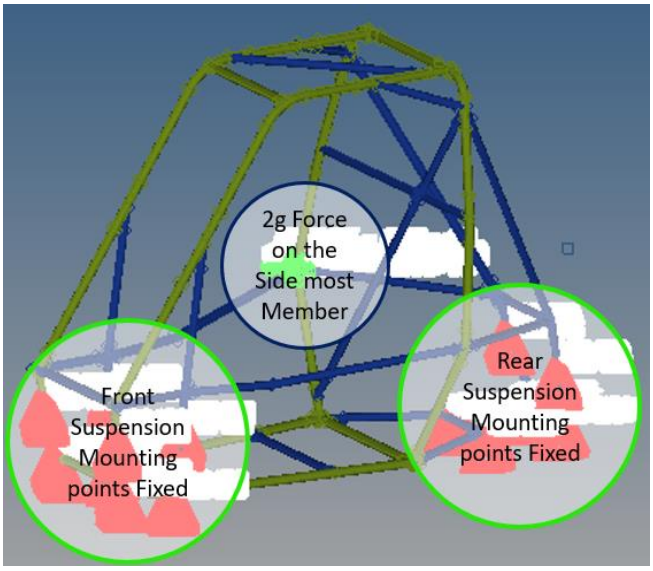
Results



Maximum Deformation	0.3253 mm
Remark	**Permissible**

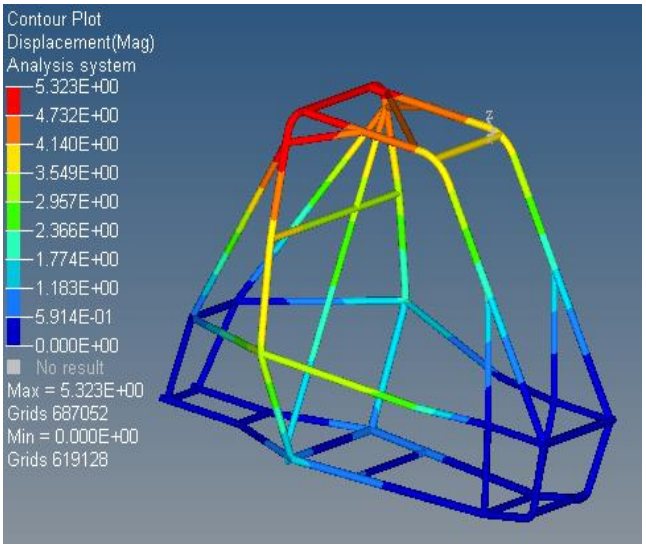
Side Impact Analysis

Boundary Condition



4g force on the front most member and rear suspension mounting points fixed

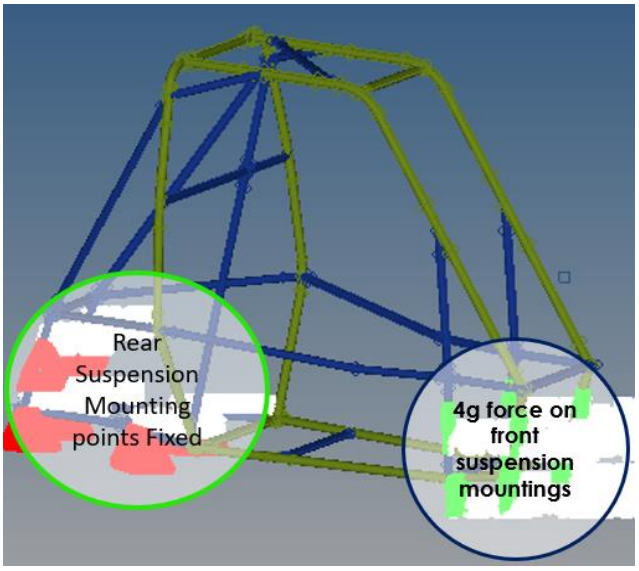
Results



Maximum Displacement	5.323 mm
Remark	**Passed**

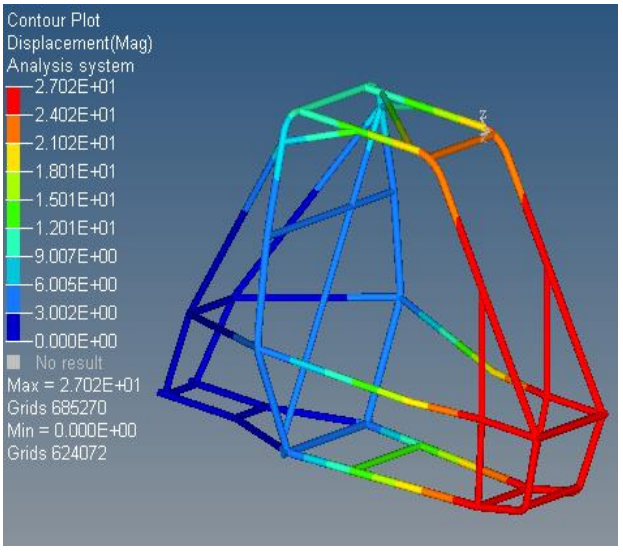
Bump Analysis

Boundary Condition



2g force on the rear most member and front suspension mounting points fixed

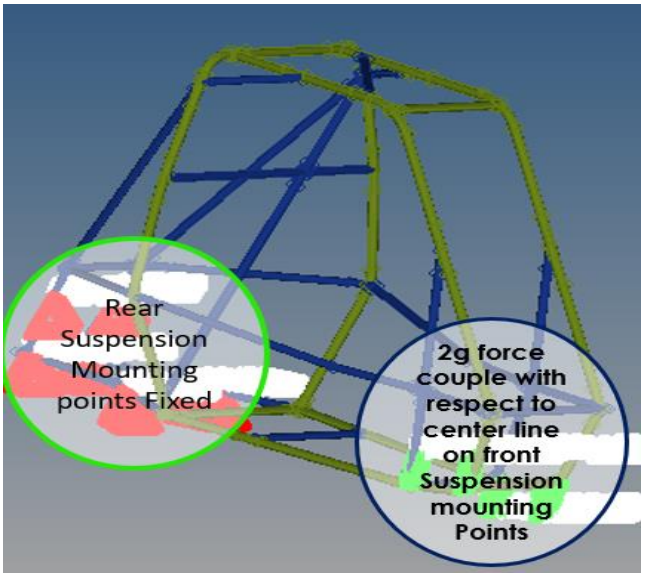
Results



Maximum Displacement	27.02 mm
Remark	**Dangerous**

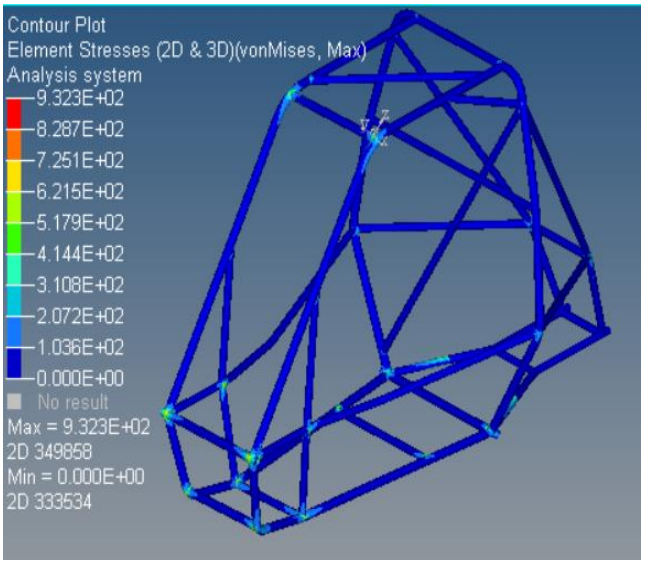
Torsion Analysis

Boundary Condition



2g force couple with respect to center line on front suspension mountings & rear suspension mountings fixed

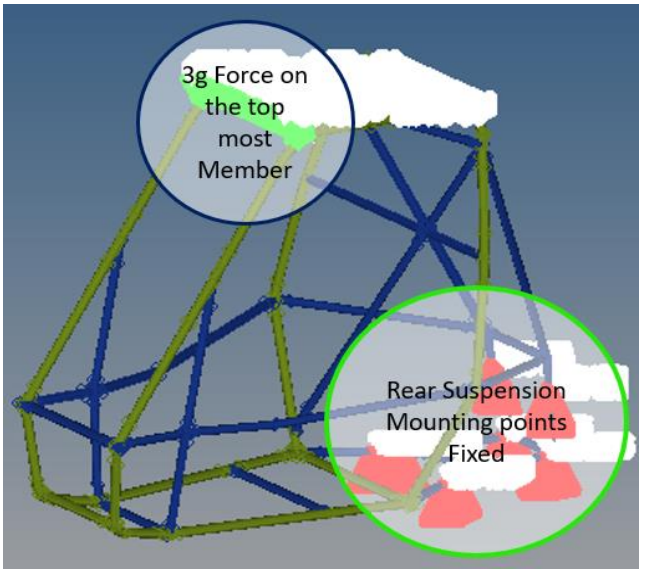
Results



Maximum Stress	932.3 MPa
Yield Strength	607 MPa
Remark	**Failed**

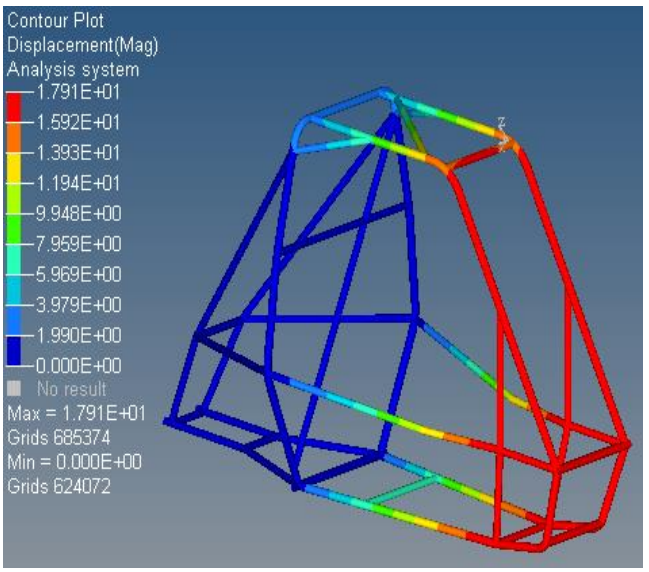
Roll Over Analysis

Boundary Condition



2g force on the rear most member and front suspension mounting points fixed

Results

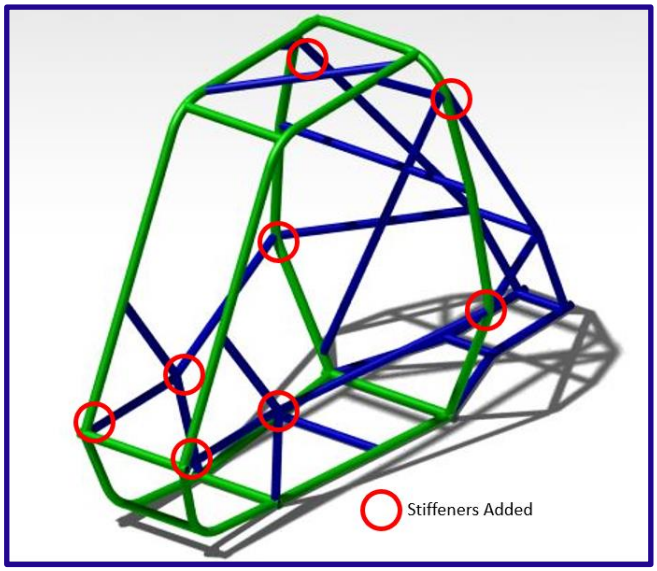


Maximum Deformation	17.91 mm
Remark	**Dangerous**

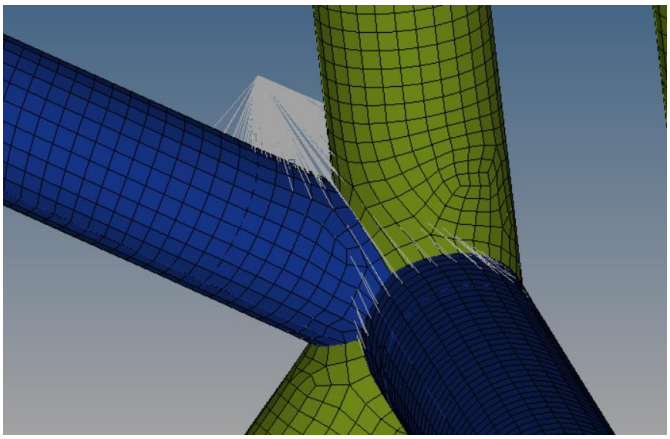
Design Changes Suggested by Analysis

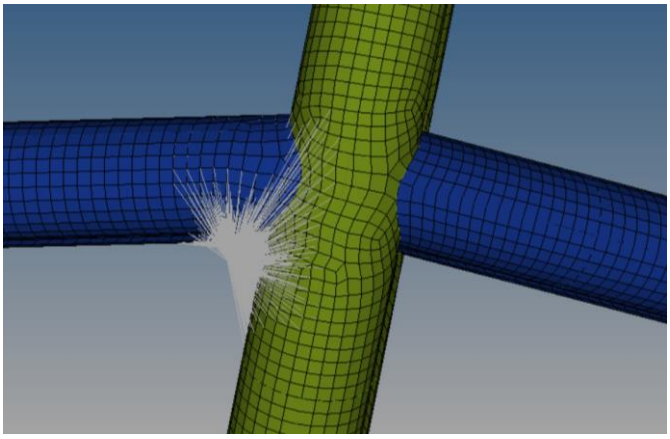
- The Roll cage Fails in the case of Front Impact, Roll over, Torsion and Bump Test.
- To overcome this problem without increasing much weight, we tried to introduce Stiffeners in our design.
- As shown in the figure below, Stiffeners were introduced at some critical joints.
- Stiffeners were added in meshing by introducing rigid body elements RBE3.
- During actual Manufacturing process stiffeners were added by welding metal plates of 3 mm thickness and desired shape near at critical joints.
- Then, we compared the results of the same tests with stiffeners and without stiffeners.
- After the introduction of stiffeners, the maximum stress and deformation in the previously failing cases (i.e. Front Impact, Torsion and Bump), are now under the allowable range.

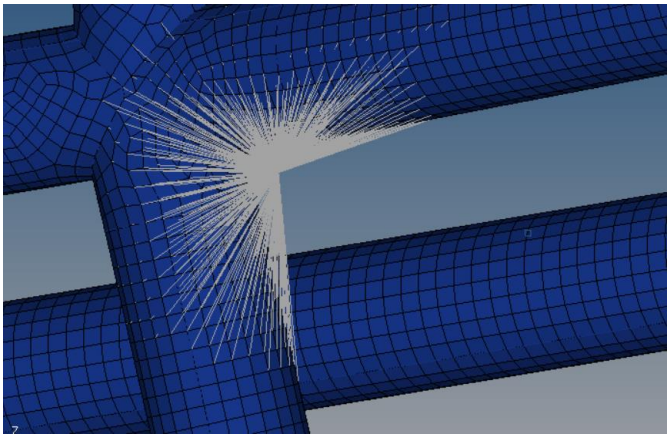
Joints where stiffeners were added

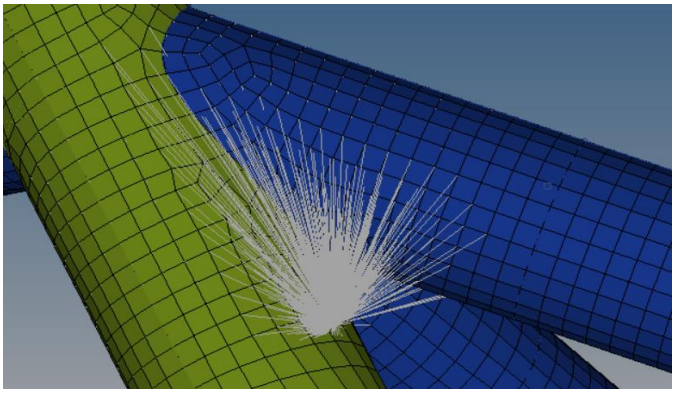


Changes in Meshing: Introduction of Stiffeners as RBE 3 Elements

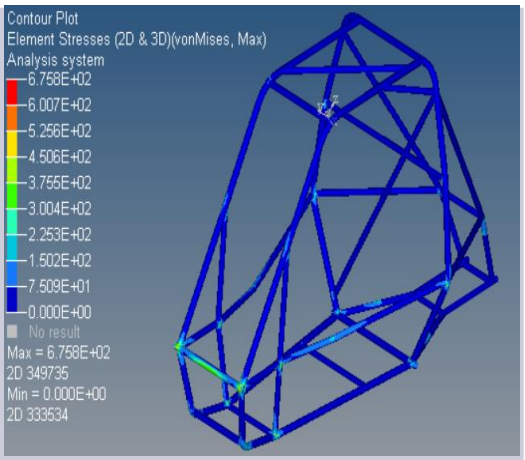
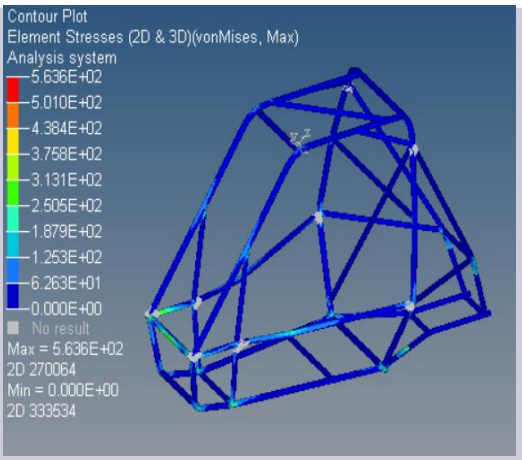
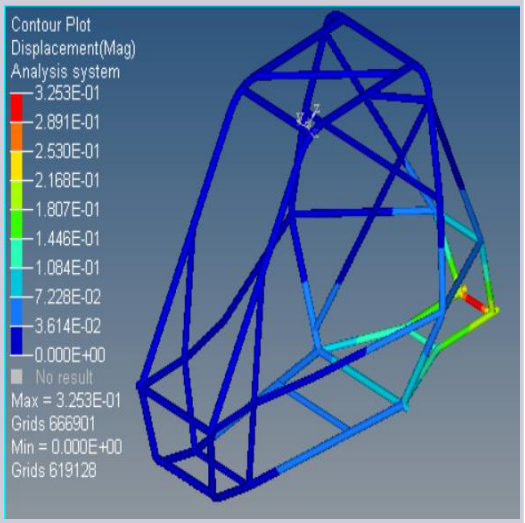
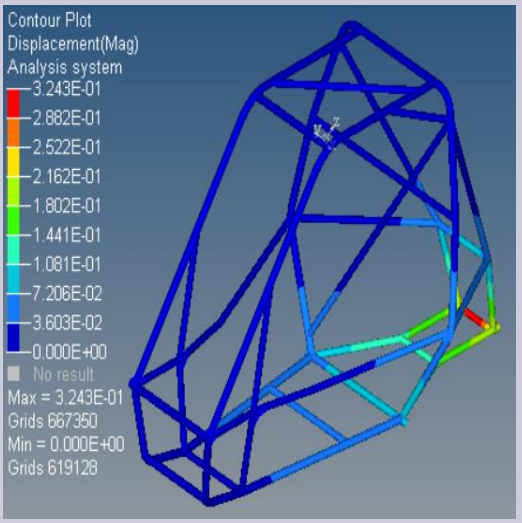




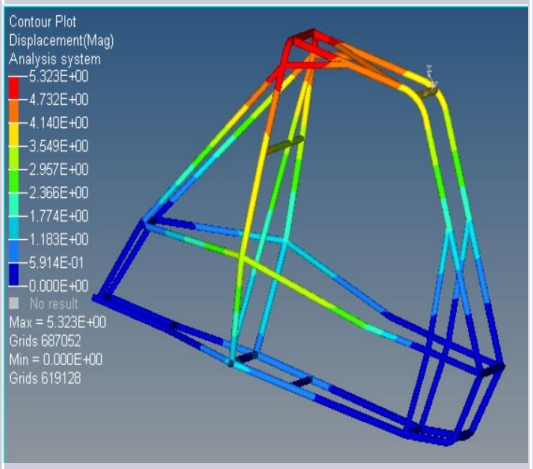
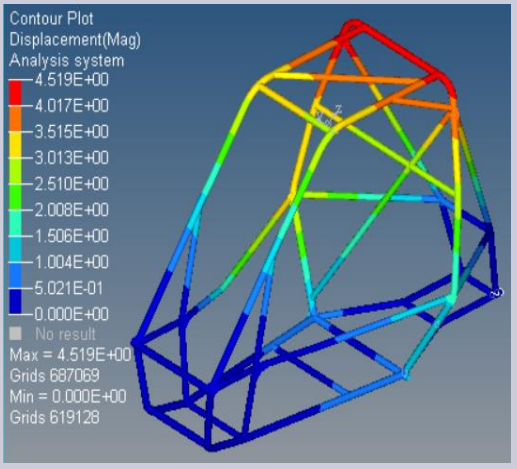
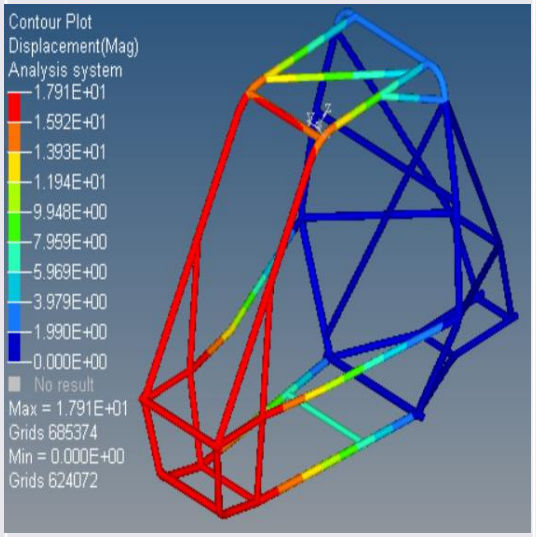
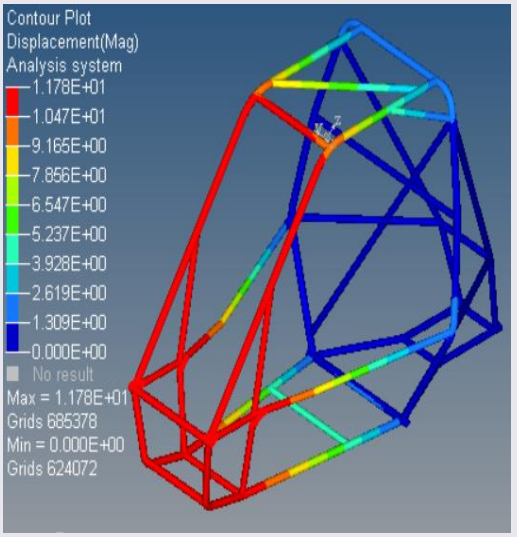




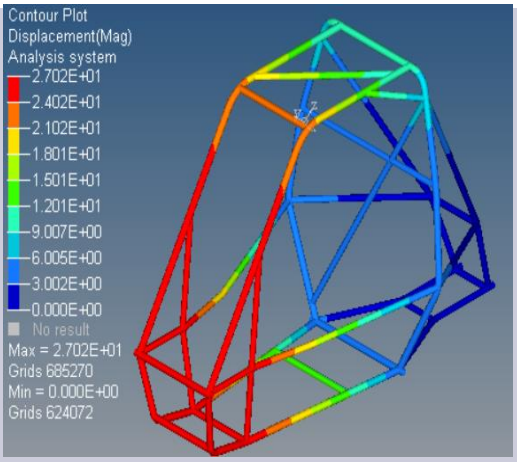
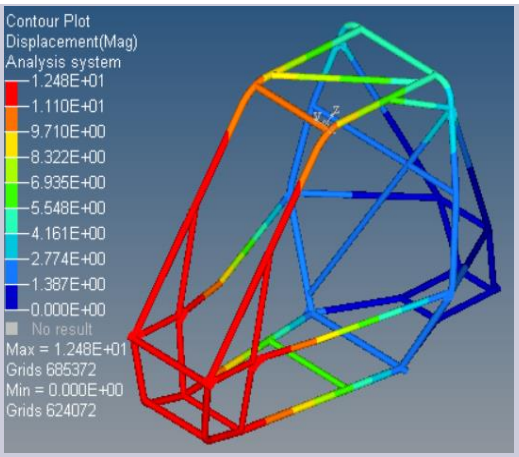
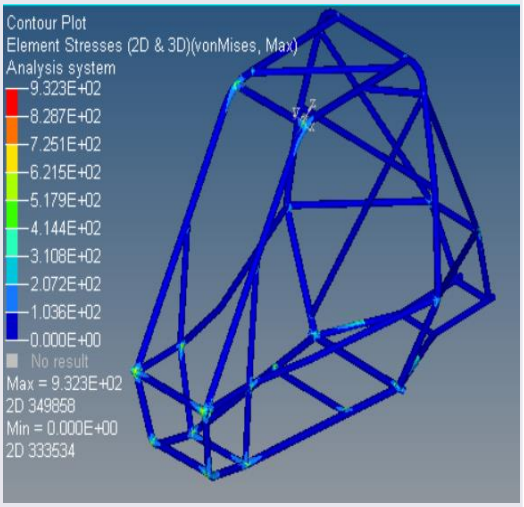
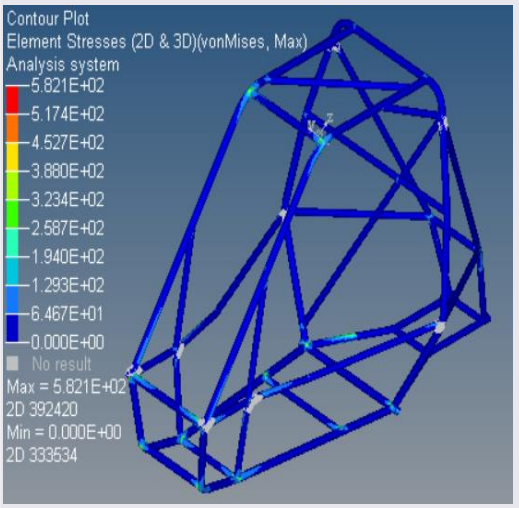
Comparison with and without Stiffener

TEST	WITHOUT STIFFENERS	WITH STIFFENERS
FRONT IMPACT		
Maximum Stress	675.8 MPa	563,6 MPa
Yield Strength	607 MPa	607 MPa
Remark	**Failed**	**Passed**
REAR IMPACT		
Maximum Displacement	32.53 mm	32.43 mm
Remark	**Passed**	**Passed**

Comparison with and without Stiffener

TEST	WITHOUT STIFFENERS	WITH STIFFENERS
SIDE IMPACT		
Maximum Displacement	5.323 mm	4.519 mm
Remark	**Passed**	**Passed**
ROLL OVER		
Maximum Displacement	17.91 mm	11.78 mm
Remark	**Passed**	**Passed**

Comparison with and without Stiffener

TEST	WITHOUT STIFFENERS	WITH STIFFENERS
BUMP		
Maximum Displacement	27.02 mm	12.48 mm
Remark	**Dangerous**	**Passed**
TORSION		
Maximum Stress	932.3 MPa	582.1 MPa
Yield Strength	607 MPa	607 MPa
Remark	**Failed**	**Passed**

Roll Cage Dynamic Analysis

Why Dynamic Analysis?

- Static Analysis includes many assumptions and such assumption leads to only approximate results. So, to increase the reliability of the analysis, dynamic analysis is preferred.

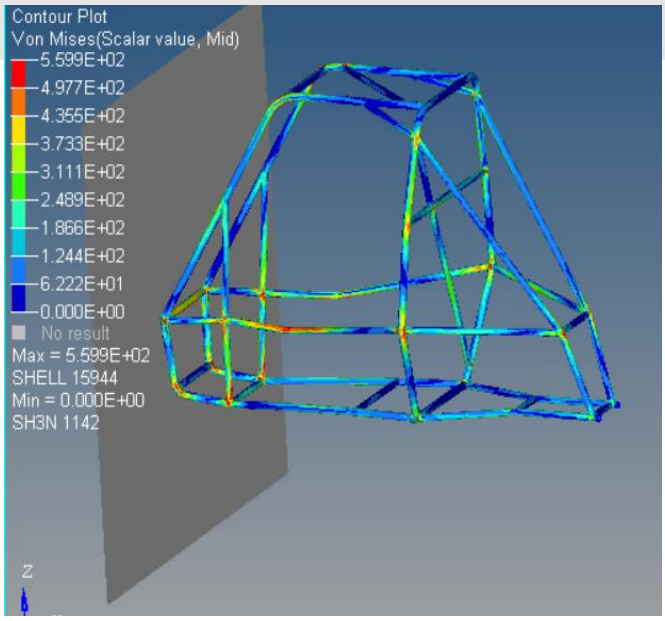
Tests planned

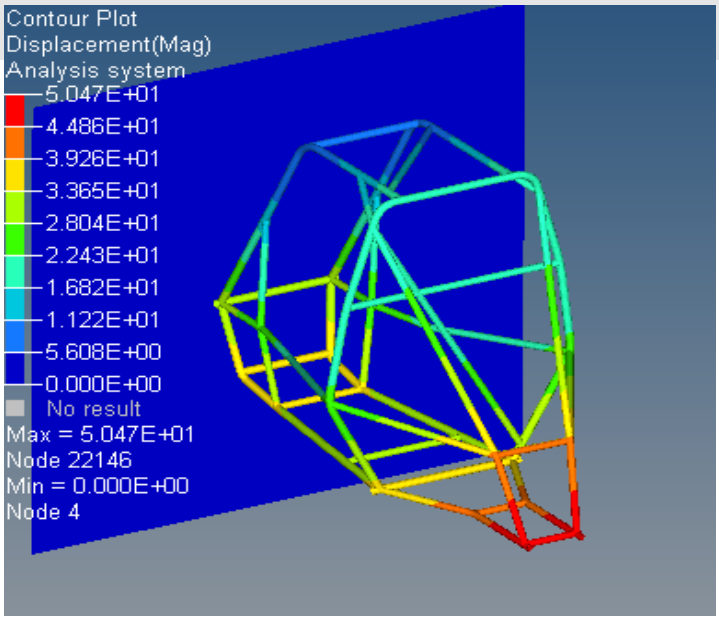
- Front Impact Test at 60 km/h
- Rear Impact Test at 45 km/h
- Side Impact Test at 45 km/h
- Roll over and landing on one of the front over head members.

Performance Requirements

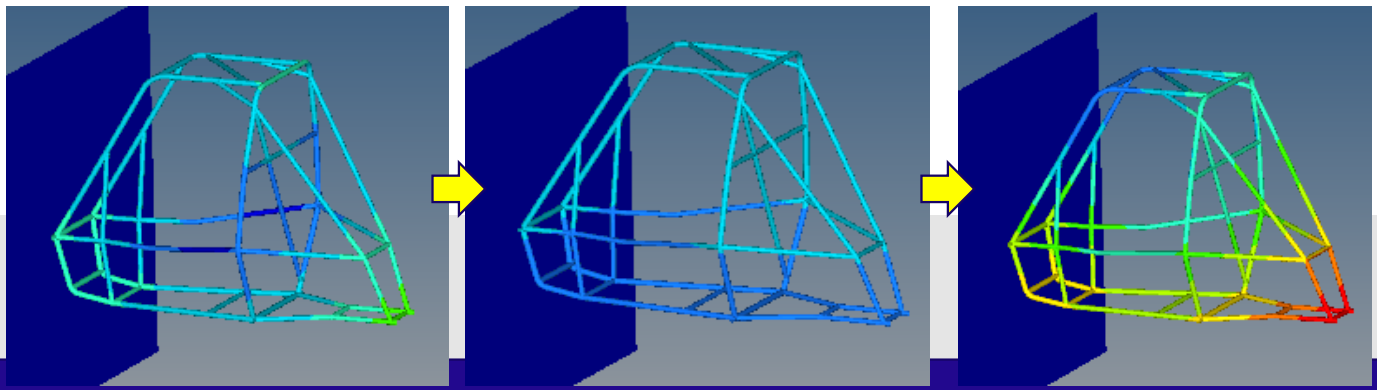
- Stresses must not exceed yield strength of the material causing material to fail. Not much factor of safety required, as the assumptions are comparable to actual scenarios.
- Deformation of the roll cage must be under permissible range

DYNAMIC FRONT IMPACT ANALYSIS

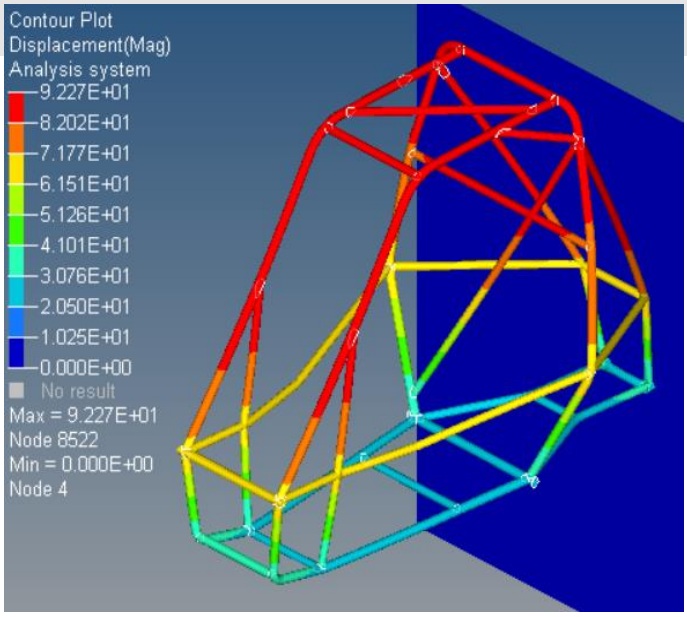


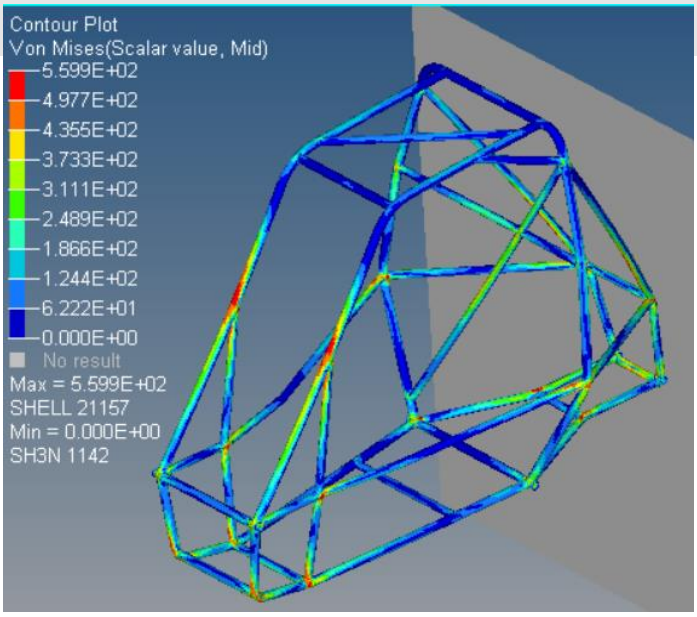


Parameter	Value
Test Case	Vehicle collided with another vehicle at relative speed of 60 km/h.
Vehicle/ wall relative speed	60 km/h
Maximum Deformation	50.47 mm
Maximum Stress	559.9 MPa
Yield Strength of the material	607 MPa
Remark	Safe Sufficient gap is kept between transmission components and the Rear FAB.

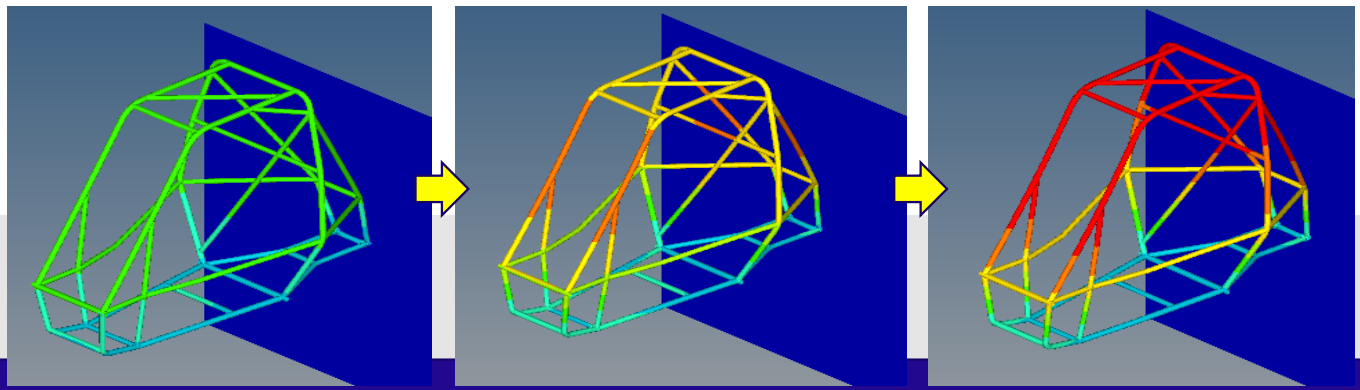


DYNAMIC REAR IMPACT ANALYSIS

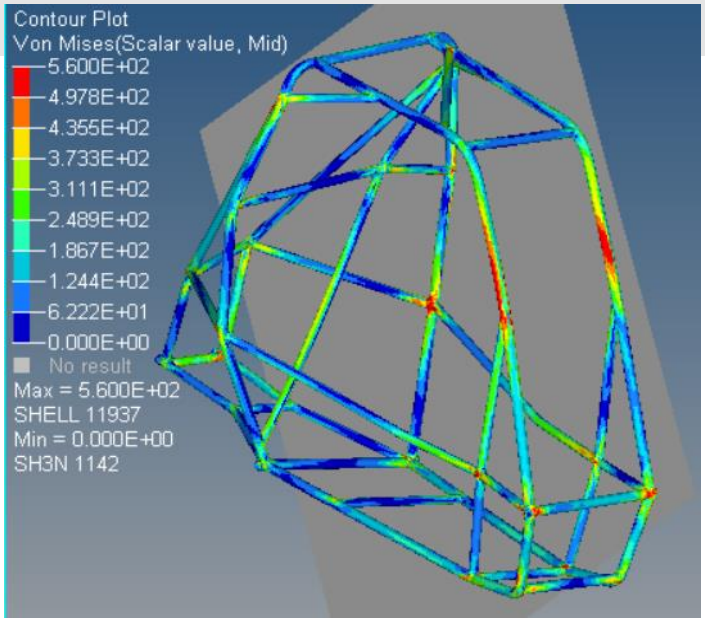


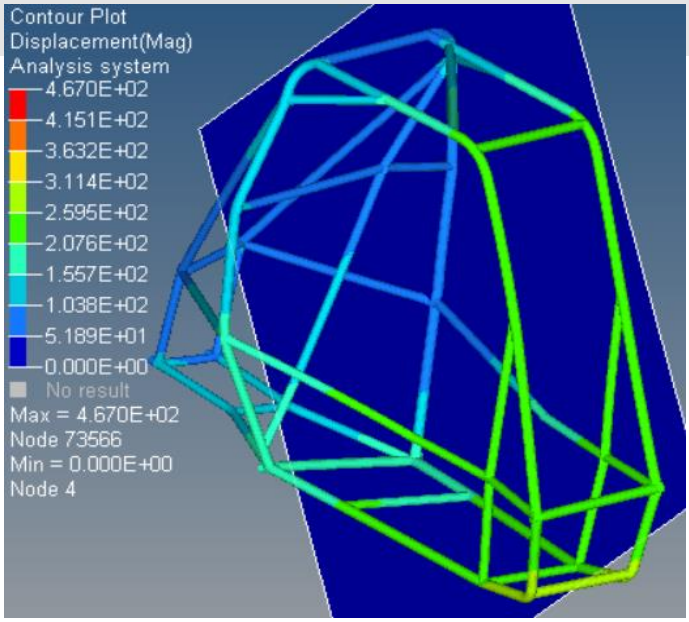


Parameter	Value
Test Case	Vehicle Impacted by another vehicle travelling at 45 km/h from the rear in stand still position
Vehicle/ wall relative speed	45 km/h
Maximum Deformation	92.27 mm
Maximum Stress	559.9 MPa
Yield Strength of the material	607 MPa
Remark	Safe Sufficient gap is kept between transmission components and the Rear FAB.

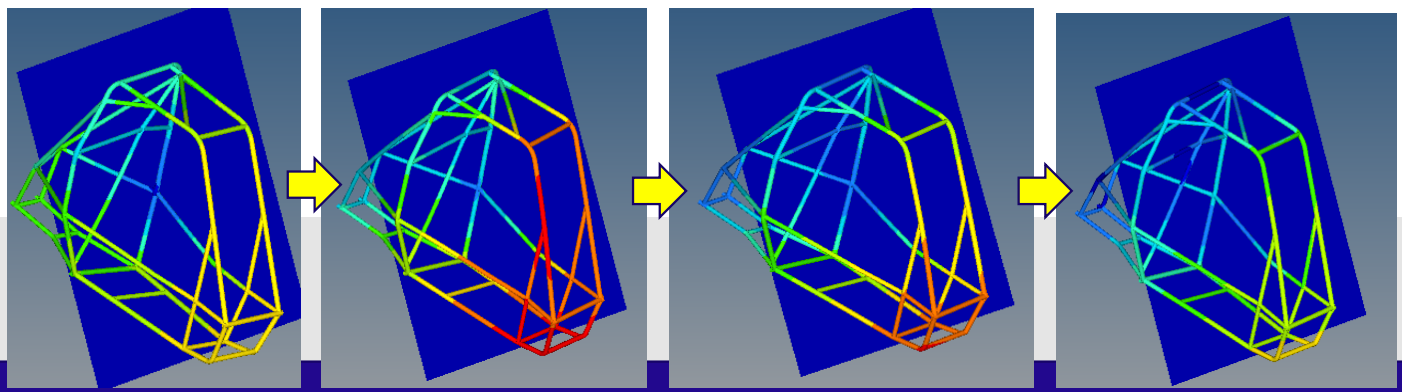


DYNAMIC SIDE IMPACT ANALYSIS

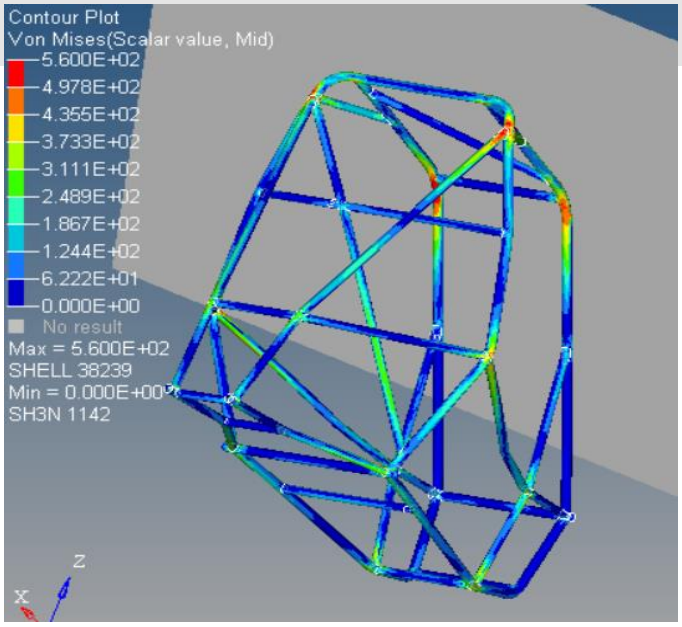


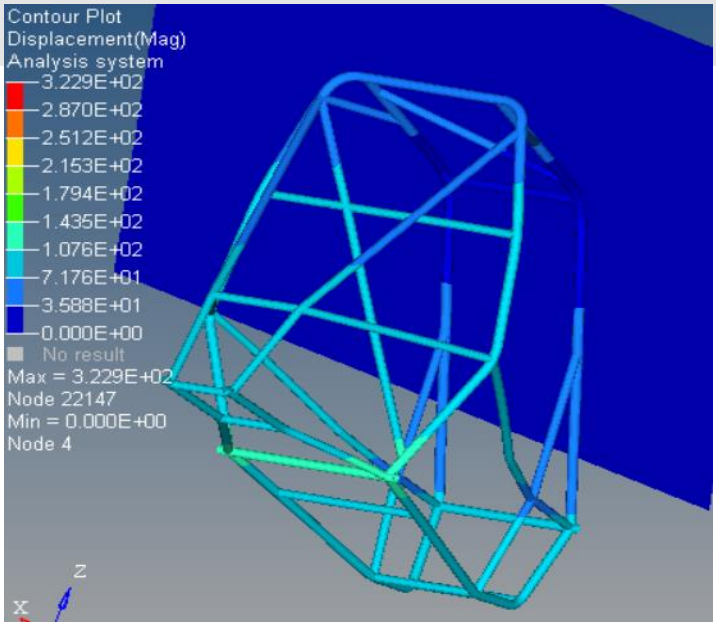


Parameter	Value
Test Case	Roll cage impacted by some other vehicle travelling at maximum speed of 45 km/h.
Vehicle/ wall relative speed	45 km/h
Maximum Deformation	4.67 cm
Maximum Stress	560 MPa
Yield Strength of the material	607 MPa
Remark	Safe 3 in = 7.62 cm gap between the limbs of driver and the SIM member.

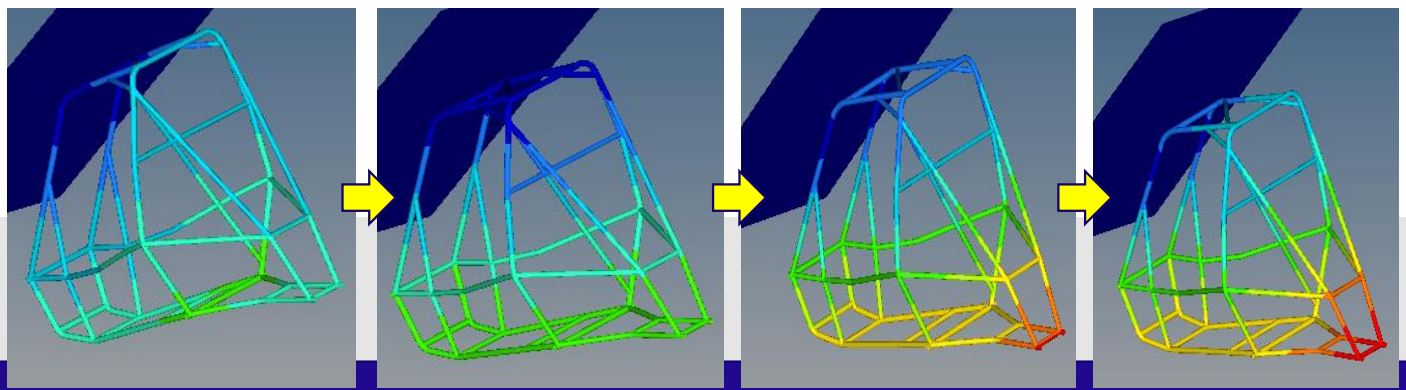


DYNAMIC ROLL OVER ANALYSIS



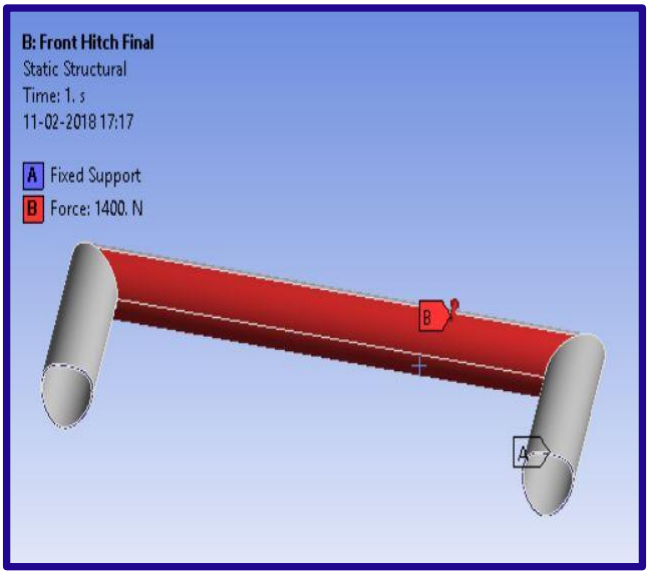


Parameter	Value
Test Case	Vehicle rolled over and landed on one of the Roll cage over head members. 3 degree angle between plane of the FAB members and the wall
Vehicle/ wall relative speed	45 km/h
Maximum Deformation	3.23 cm
Maximum Stress	560 MPa
Yield Strength of the material	607 MPa
Remark	Safe Sufficient clearance between roll cage members and important sub component systems.



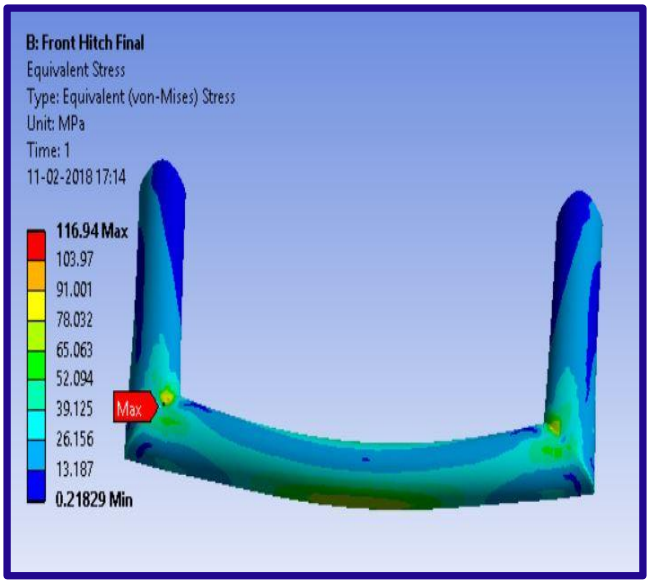
Front Hitch Plate

Boundary Condition



F = μ*Weight of the Vehicle with driver
= 0.7*200*10=1400 N

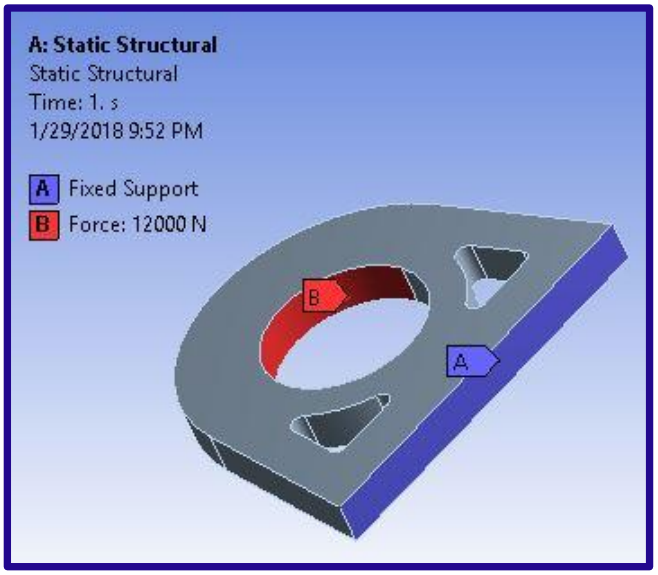
Results



Maximum Stress	229.25 MPa
Material Selected	AISI 4130
Yield Strength	560 MPa
Factor of Safety	2.44

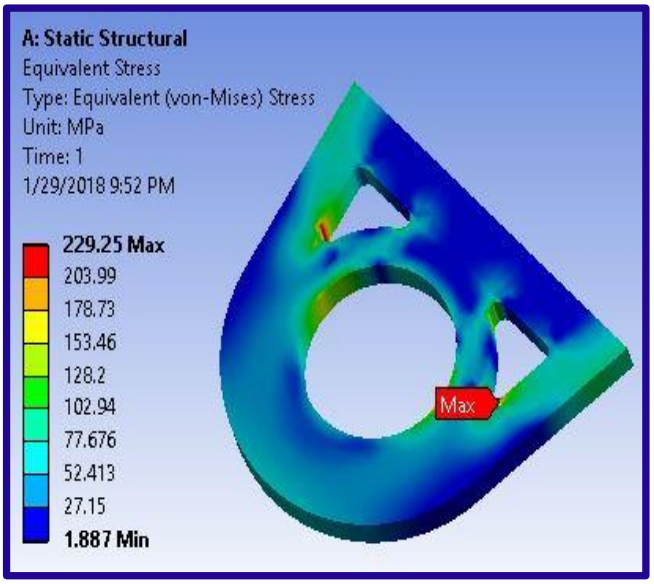
Rear Hitch Plate

Boundary Condition



F = μ*Weight of the Sledge
= 0.7*1500*10=10500 N ≈ 12000 N

Results



Maximum Stress	229.25 MPa
Material Selected	Mild Steel
Yield Strength	370 MPa
Factor of Safety	1.61

Brake System

Brake Disc

Brake Caliper

Brake Disc Analysis

Component Importance

- Brake Discs are the key component of the brake system as it experiences the maximum force that is the force exerted on the wheels to lock them in their position.

Performance Requirement

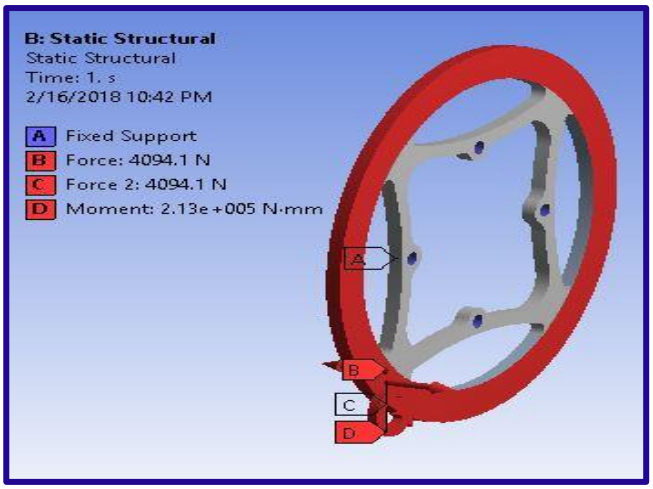
- Since Brake Discs experience the maximum braking force, it must be able to withstand it.
- Friction of the brake pads generate high amount of heat. So, the induced thermal strains must also be analyzed.

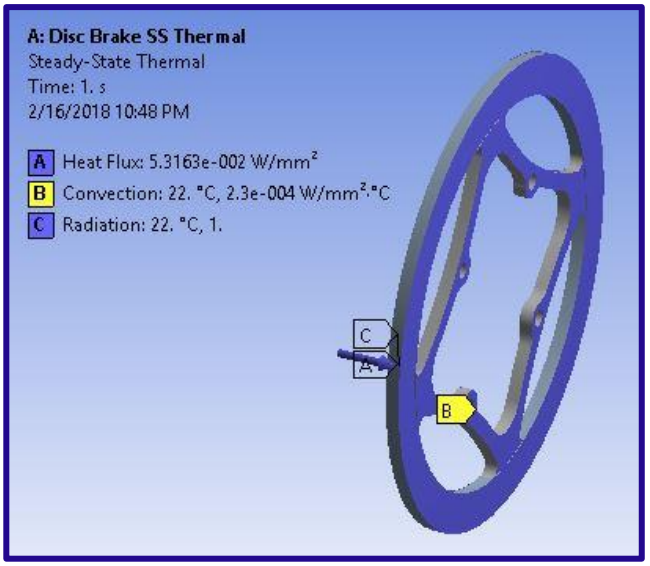
Tests Planned

- Static Force Analysis
- Thermal analysis

Brake Disc

Boundary Conditions



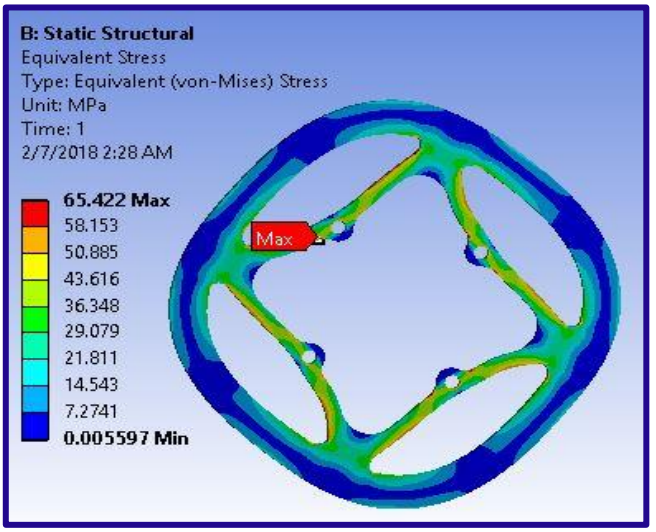


- 4 Fastening Points with the Hub fixed
- Reaction forces from brake pads on frictional surface
- required moment to generate braking force on the outer ring with respect to the center-line.

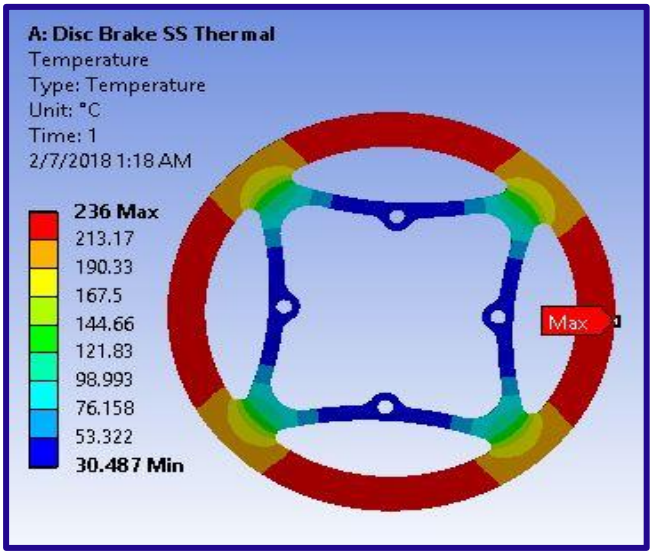
Moment M = P*d
=μ*(Reaction from brake pads) *(radius of the disc)
= 213 Nm

- Heat flux = Kinetic energy of the vehicle / 3*area under brake pads

Equivalent Von-Mises Stresses



Results: Thermal Temperature



Maximum Stress	65.422 MPa
Material Selected	SS 304
Yield Strength	215 MPa
Factor of Safety	3.28
Maximum Temperature	236 °C
Continuous service Temperature for SS 304	915 °C
Remarks	Safe

Brake Caliper Analysis

Component Importance

- Brake Caliper is the part that accommodates the Caliper Assembly.
- We have used floating type of Caliper so it is also a part of the brake disc locking mechanism.

Performance Requirement

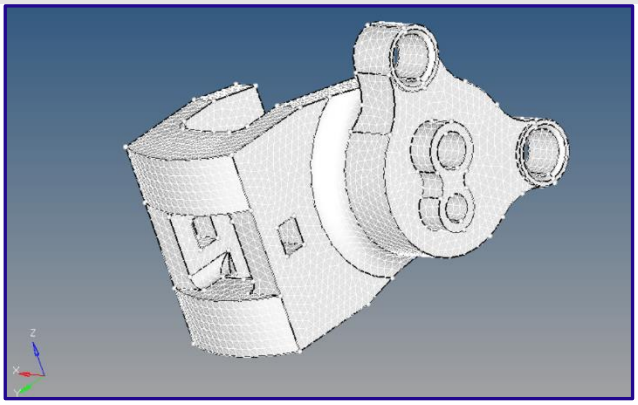
- Failure of it would directly cause failure of brake system. Replacement of it will be the only way to restore the breaking system. That process is quite time consuming. So Higher factor of safety and fatigue life is desired under normal working conditions.
- It should be able to withstand the reaction of brake pads while they generate braking force to lock the brakes.

Tests Planned

- Static and Fatigue life Analysis under possible extreme conditions.

Brake Caliper

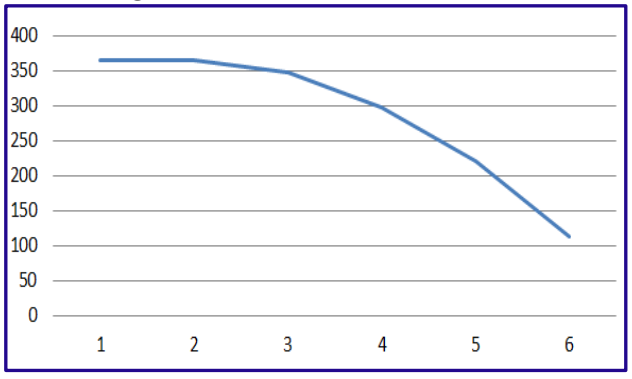
Mesh Quality



Quality factor (2D)	Value
Aspect Ratio(Max)	1.58
Jacobian (Min)	1
Skewness (Max)	37.19
Tria-angle(Min/Max)	22.67/112.1

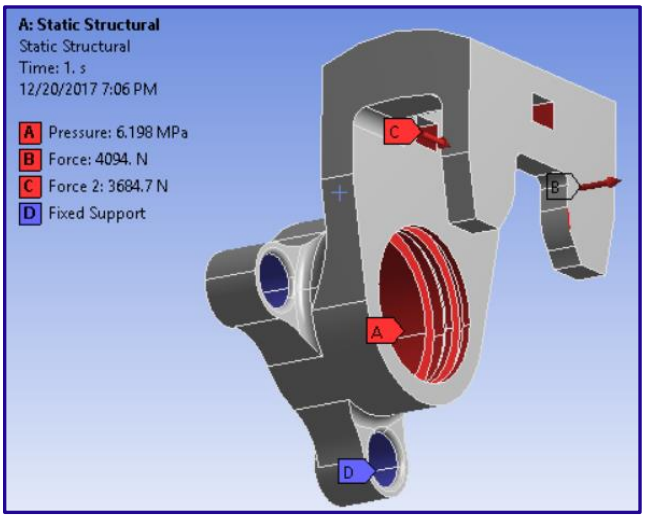
Quality factor(3D)	Value
Aspect Ratio(Max)	1.98
Tet-collapse(Min)	0.35
Jacobian(Min)	1

Convergence Curve:

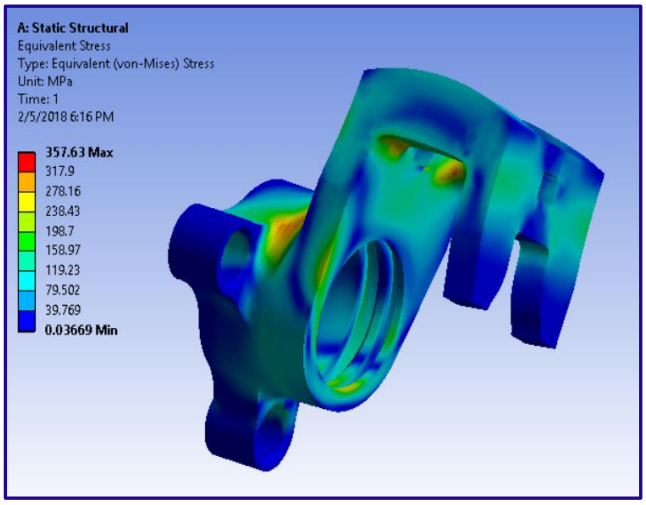


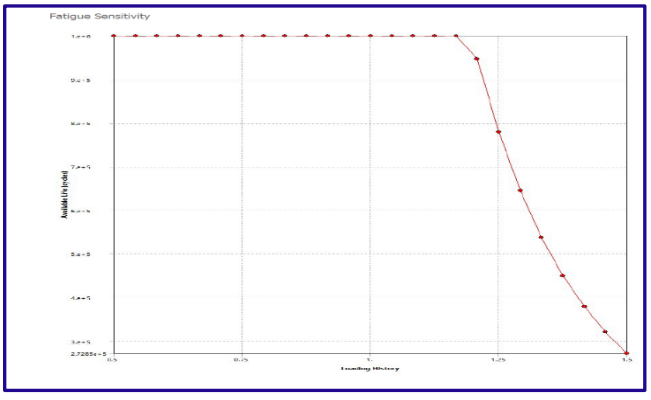
Boundary Conditions

Pressure: Pressure in the Slave Cylinder of the Brake Oil
Force 1: Reaction Force of Brake Pads = 4094 N
Force 2: 3684.7 N : Reaction at Sliding Pins
Fixed Support at Fastening Points.



Results



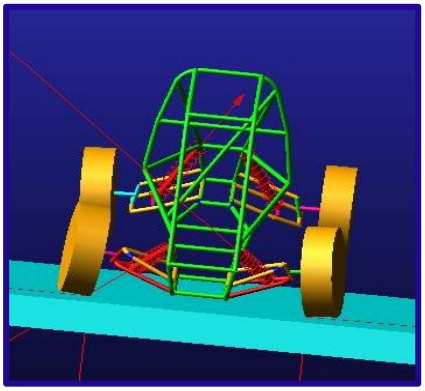


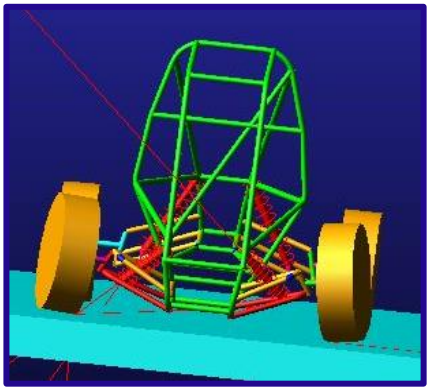
Maximum Stress	357.63 MPa
Fatigue Life	infinite
Material Selected	Al 7050
Yield Strength	490 MPa
Factor of Safety	1.37

Suspension Steering and Wheel Assembly

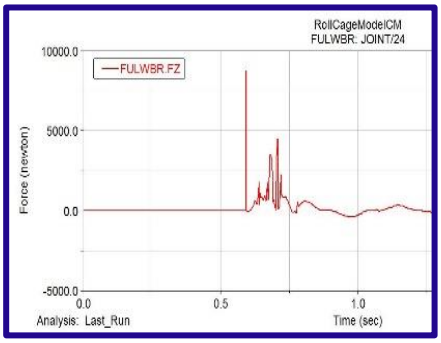
- Knuckle
- Hub
- Wishbones
- Tie Rod
- Vehicle Dynamic Analysis
- Suspension Geometry Analysis

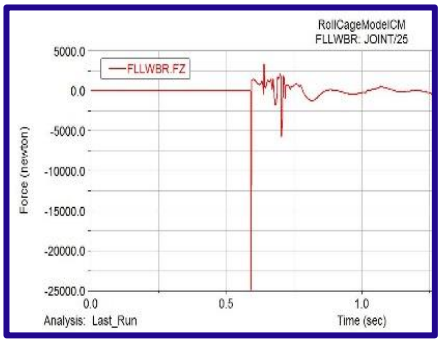
Boundary Condition Determination Using ADAMS Analysis

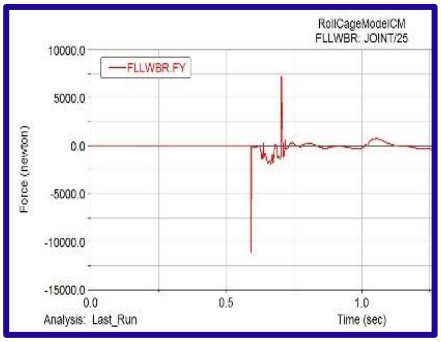


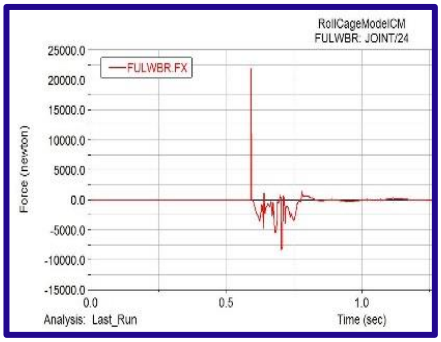


An Multibody Dynamic analysis in ADAMS was carried out to determine forces on Knuckle Hub. Simulation of Dropping of vehicle from 1.5 m on front wheels was done and the forces on ball joints was determined. Ball bearings to be used as the ball joints were determined accordingly.





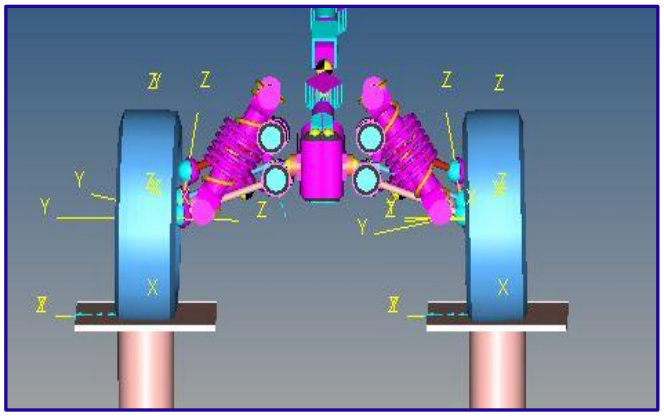




Vehicle Dynamics Analysis

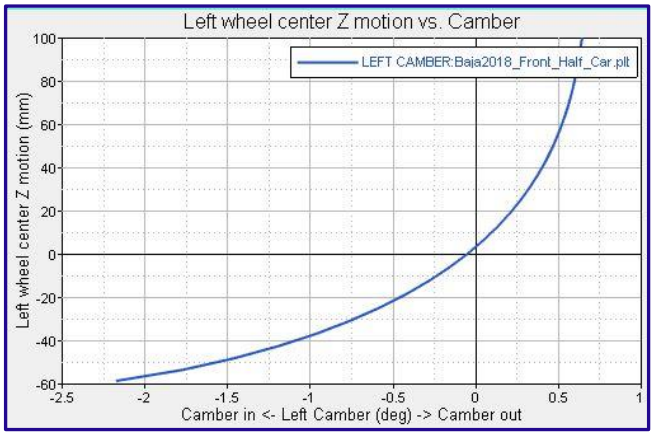
Suspension and Wheel Geometry Analysis

Front suspension vehicle dynamic analysis was car to analyse comfort of the vehicle under various situation and suspension feedback given by the car. Also it was used to decide whether suspension geometry is able to fulfil the required ride comfort condition.

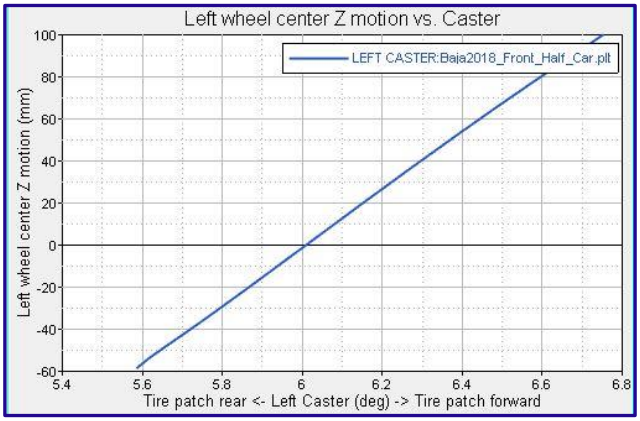


Camber

To ensure ride comfort without compromising traction, minimal Camber change rate was desired. From the analysis, we are getting Camber change rate of 0.3 degree/in , which is under desired range.

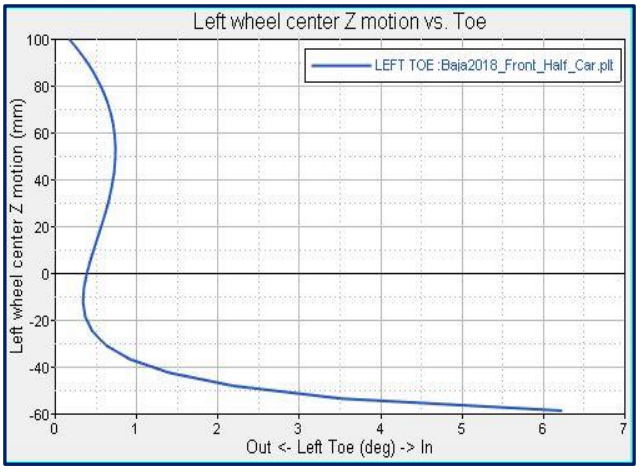


Caster

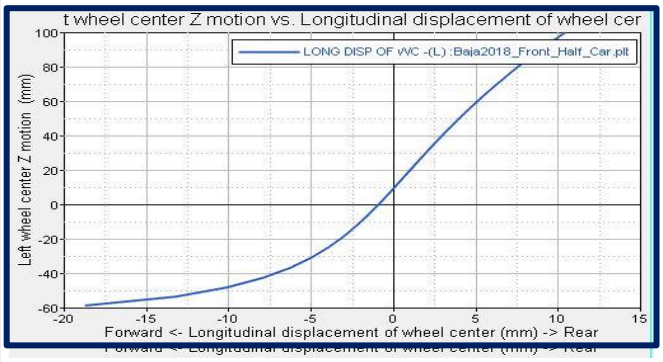


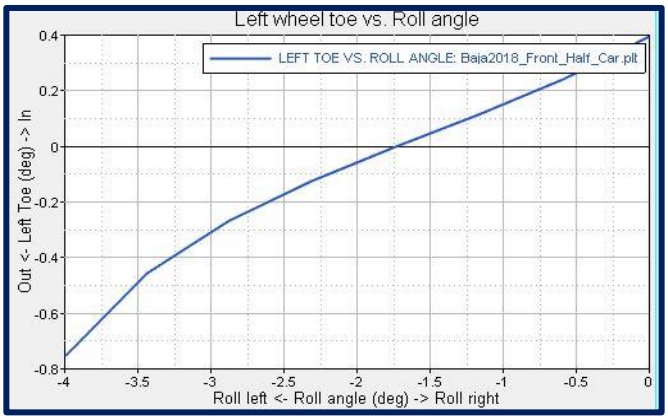
Caster is maintained almost constant (1 degree change throughout the wheel travel) to direct the vehicle forward with minimum forces on upright.

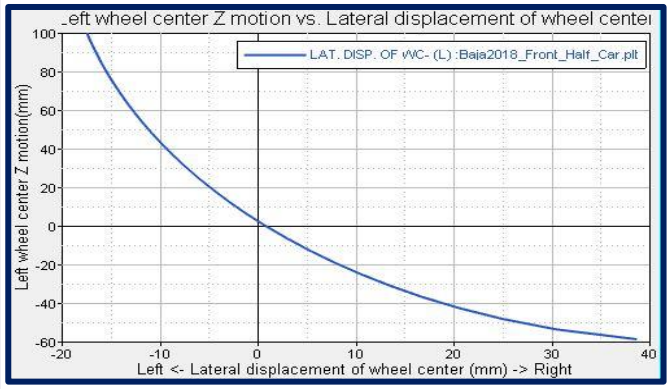
Toe

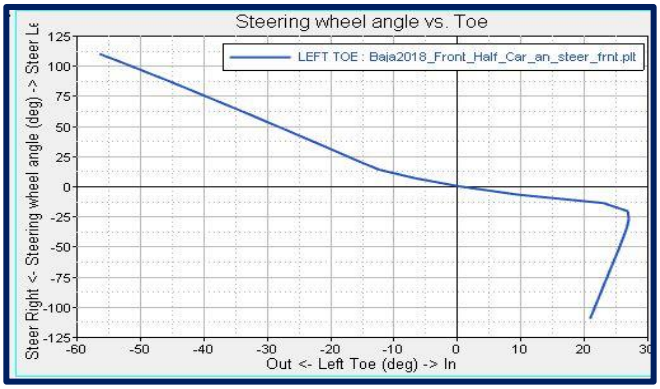


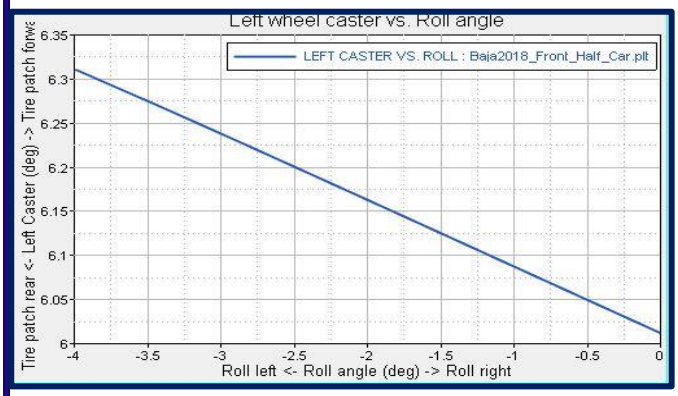
Other Vehicle Dynamic Graphs

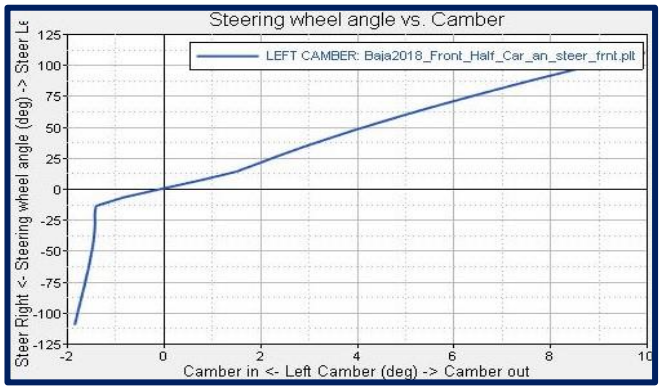


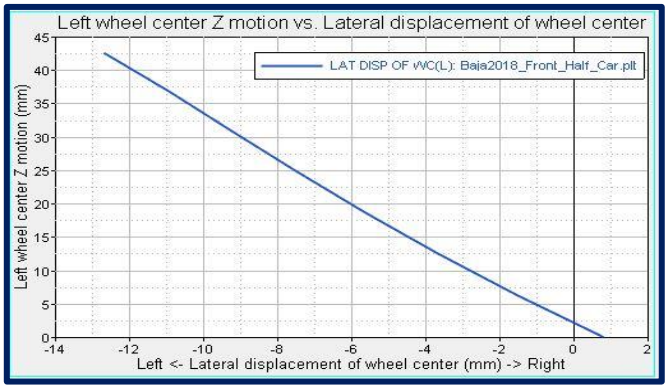


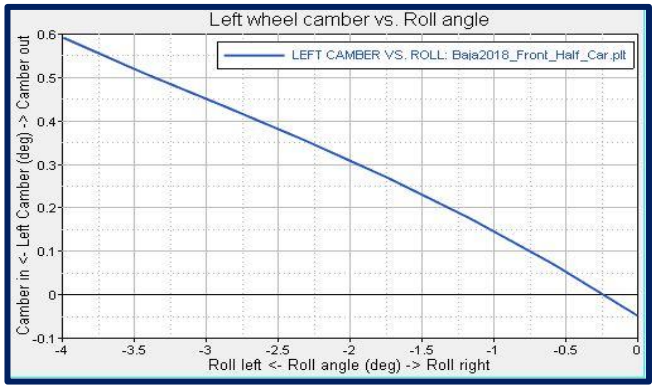






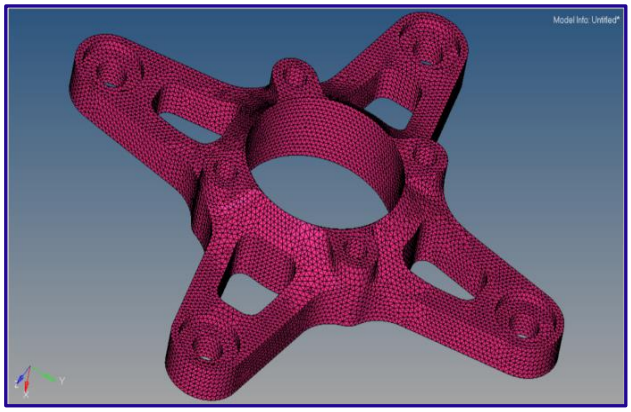






Front Hub

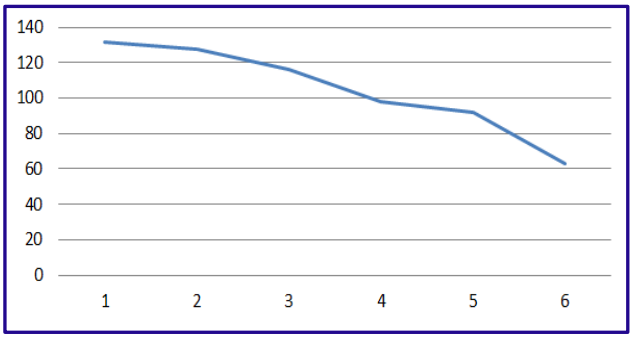
Mesh Quality



Quality factor (2D)	Value
Aspect Ratio(Max)	1.83
Jacobian (Min)	1
Skewness (Max)	42.38
Tria-angle(Min/Max)	25.17/116.8

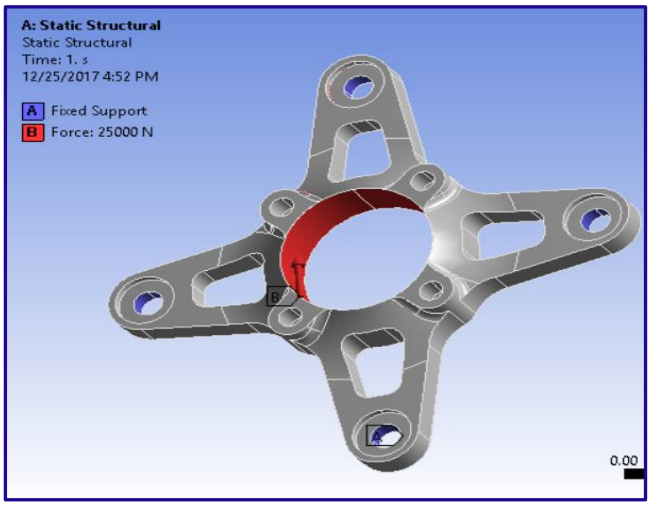
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Aspect Ratio(Max)	2.11
Tet-collapse(Min)	0.38
Jacobian(Min)	1

Convergence Curve:

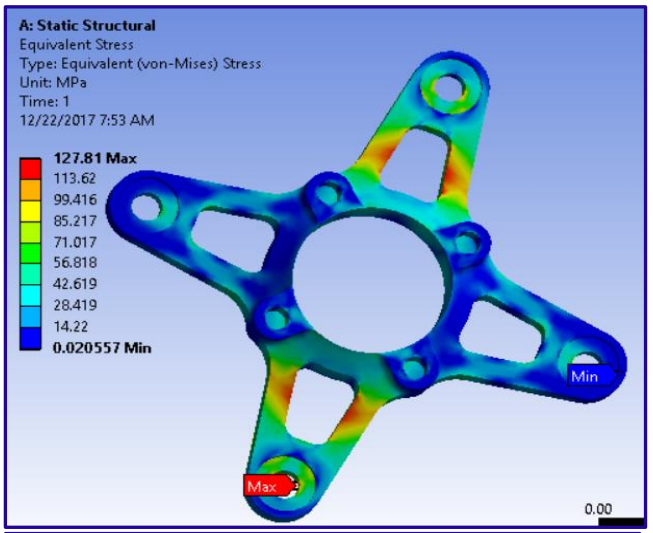


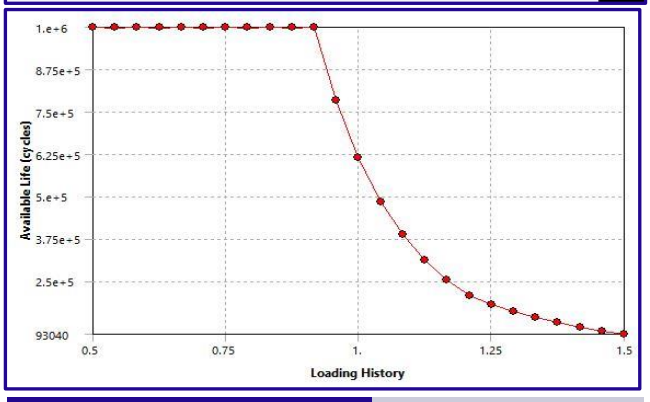
Boundary Conditions

Hub will be under extreme condition when the vehicle will land on any one wheel. At that time, the weight of the vehicle would come on the axle and the wheel fastening points would be fixed. Applying the force obtained from the ADAMS analysis, which turned out to be equal to 25 kN.



Results

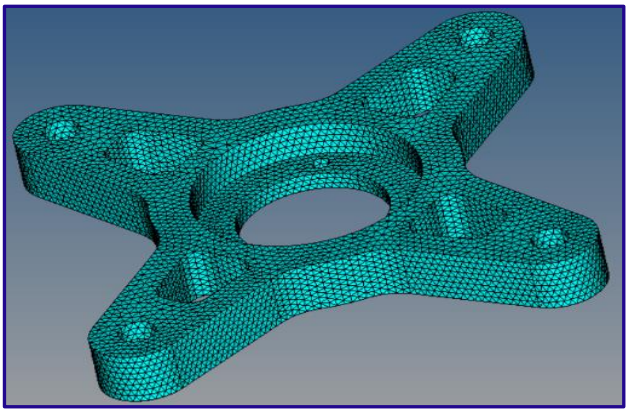




Maximum Stress	127.81 MPa
Fatigue Life	6.14e5 cycles
Material Selected	Al 7075
Yield Strength	503 MPa
Factor of Safety	3.94

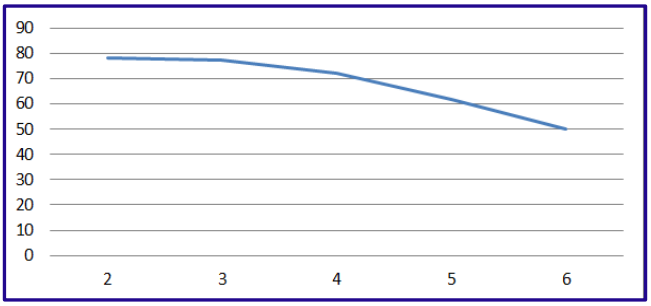
Rear Hub

Mesh Quality



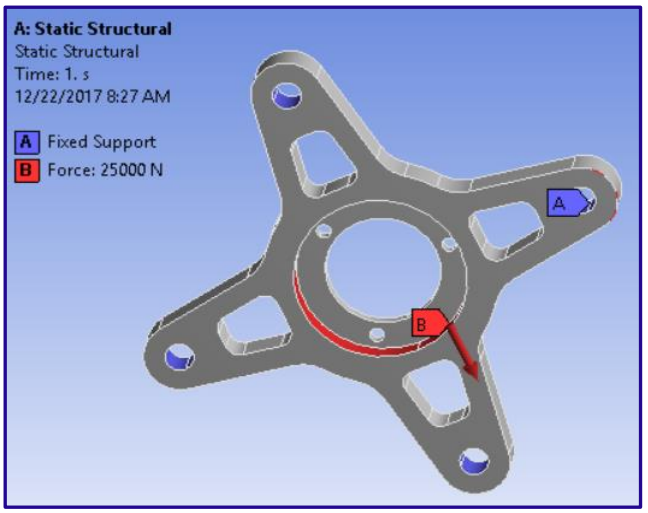
Quality factor (2D)	Value
Aspect Ratio(Max)	1.58
Jacobian (Min)	1
Skewness (Max)	37.19
Tria-angle(Min/Max)	22.67/112.1
Quality factor(3D)	**Value**
Aspect Ratio(Max)	1.98
Tet-collapse(Min)	0.35
Jacobian(Min)	1

Convergence Curve:

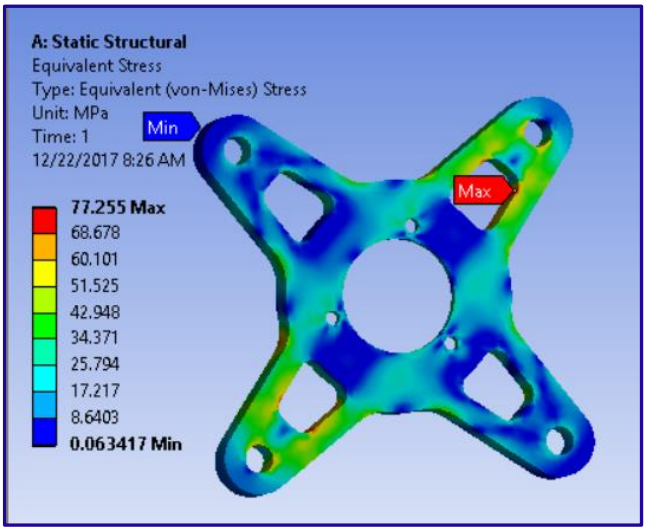


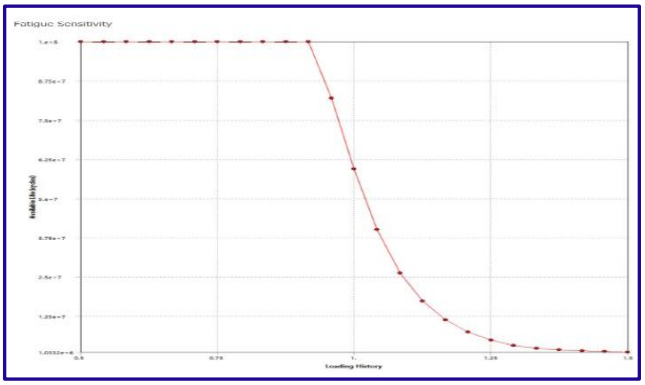
Boundary Conditions

Hub will be under extreme condition when the vehicle will land on any one wheel. At that time, the weight of the vehicle would come on the axle and the wheel fastening points would be fixed. Applying the force obtained from the ADAMS analysis, which turned out to be equal to 25 kN.



Results

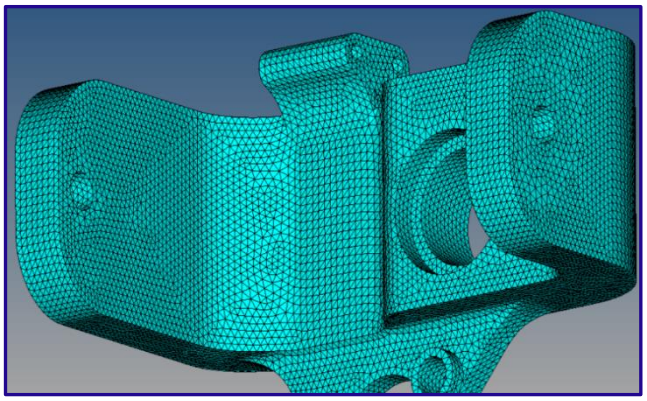




Maximum Stress	71.255 MPa
Fatigue Life	infinite
Material Selected	Al 6061
Yield Strength	276 MPa
Factor of Safety	3.87

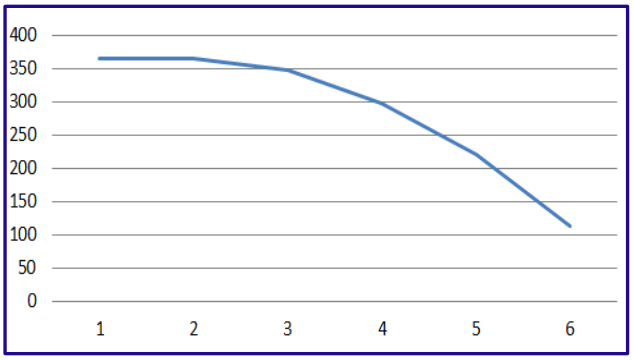
Front Knuckle

Mesh Quality



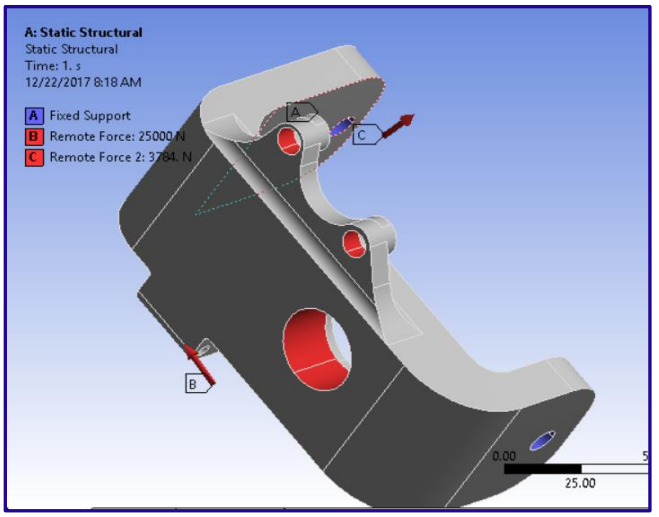
Quality factor (2D)	Value
Aspect Ratio(Max)	1.76
Jacobian (Min)	1
Skewness (Max)	43.46
Tria-angle(Min/Max)	22.47/109.8
Quality factor(3D)	**Value**
Aspect Ratio(Max)	2.81
Tet-collapse(Min)	0.36
Jacobian(Min)	1

Convergence Curve:

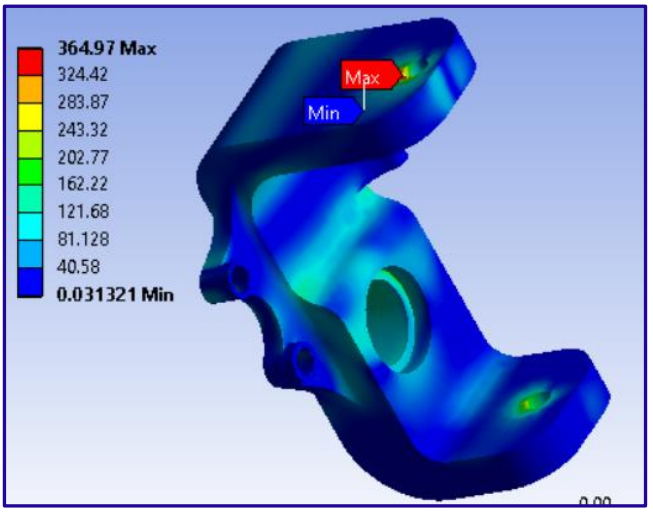


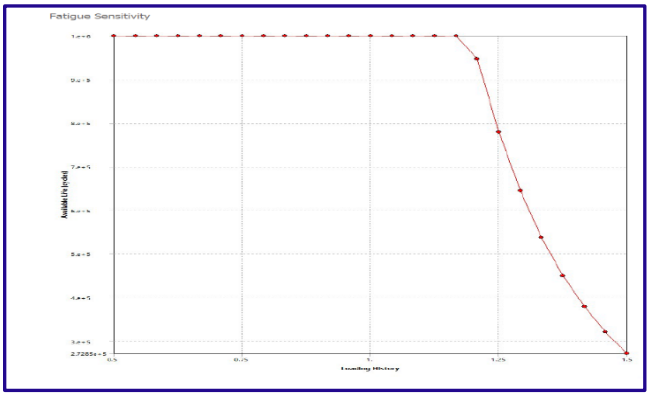
Boundary Conditions

Hub will be under extreme condition when the vehicle will land on any one wheel. At that time, the weight of the vehicle would come on the axle and the wheel fastening points would be fixed. Applying the force obtained from the ADAMS analysis, which turned out to be equal to 25 kN.



Results

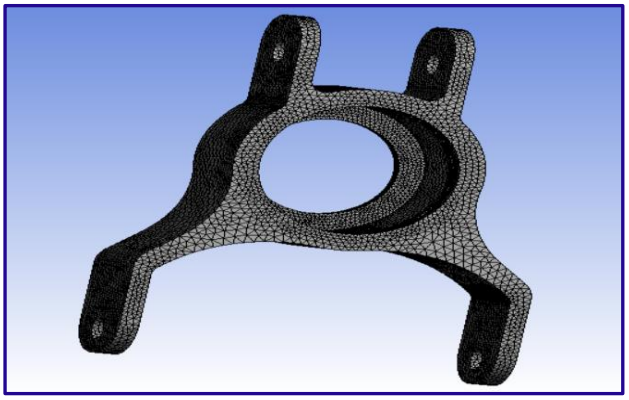




Maximum Stress	364.97 MPa
Fatigue Life	Infinite
Material Selected	Al 7075
Yield Strength	503 MPa
Factor of Safety	1.38

Rear Knuckle

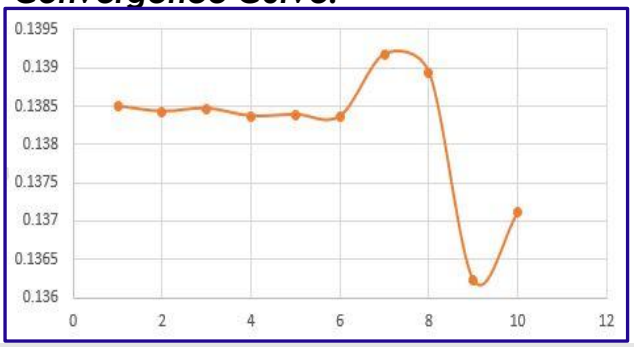
Mesh Quality



Quality factor (2D)	Value
Aspect Ratio(Max)	2.31
Jacobian (Min)	1.21
Skewness (Max)	40.57
Tria-angle(Min/Max)	22.57/112.9

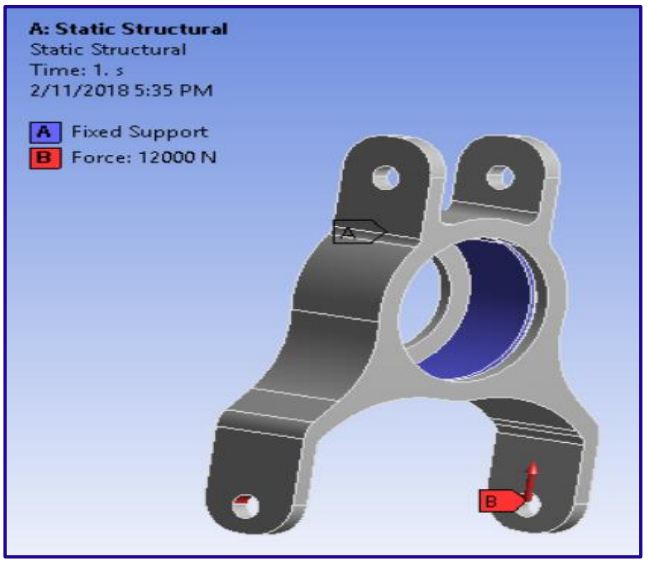
Quality factor(3D)	Value
Aspect Ratio(Max)	3.38
Tet-collapse(Min)	0.43
Jacobian(Min)	1

Convergence Curve:

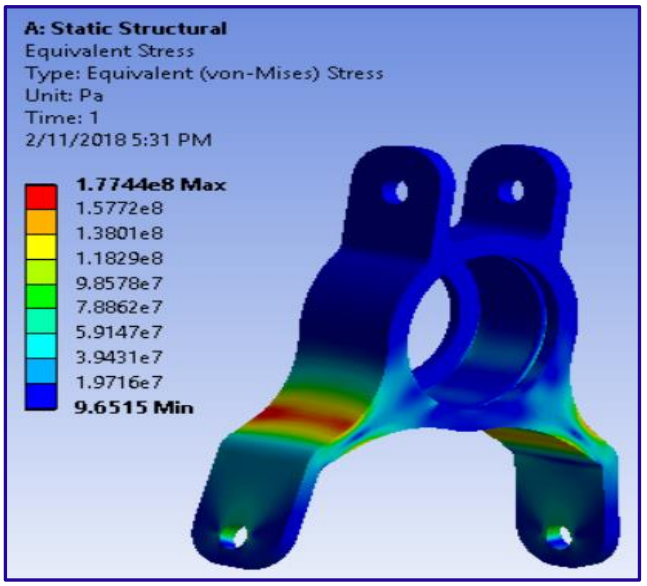


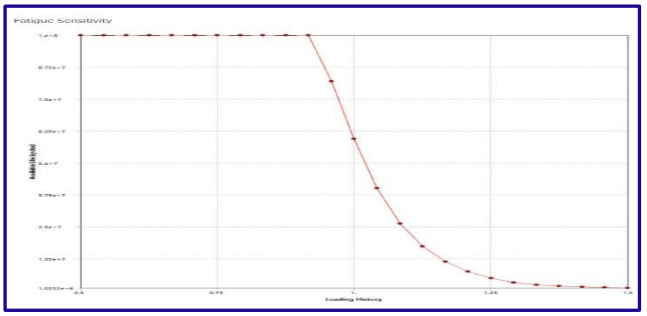
Boundary Conditions

Extreme loading condition for the rear knuckle will be during free fall of roll cage from a height of 1.5 m. Force at that condition is determined using MBD analysis which turns out to be around 12000 N. So upward force of 12000 N on the rear lower H- arm mounting points is applied keeping bearing mounting face fixed.



Results

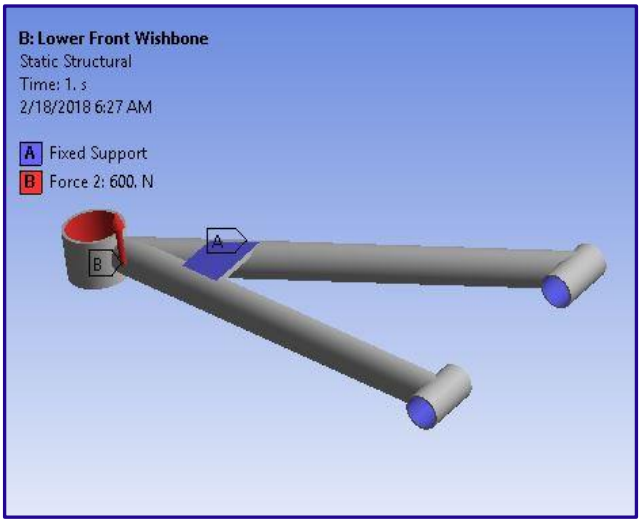




Maximum Stress	177.44 MPa
Fatigue Life	Infinite
Material Selected	Al 6061
Yield Strength	276 MPa
Factor of Safety	1.56

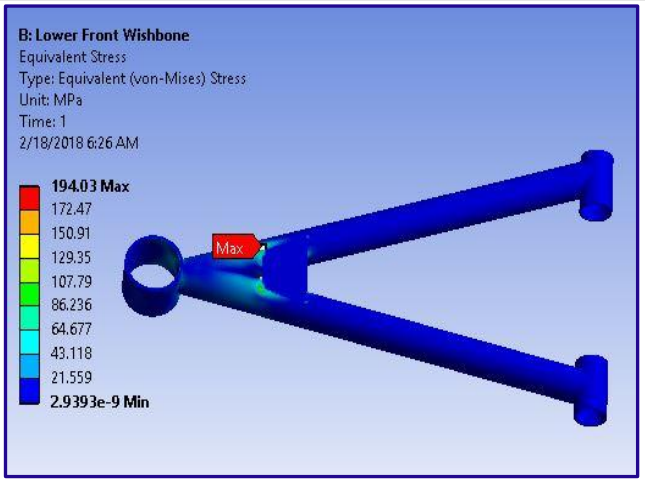
Lower Front Wishbone

Boundary Condition



F = 600 N by approximating the weight distribution on one of the front tires. It would jointly act at wishbone mounting and fox mounting points. But keeping those points fixed and applying the same force on wheels would also generate the same effect.

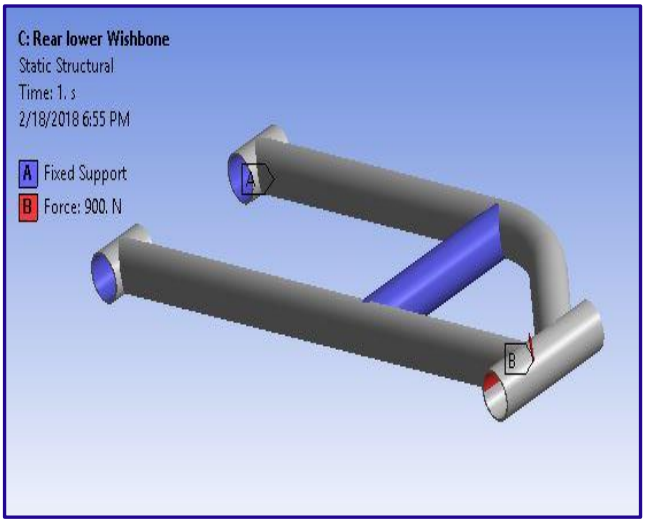
Results



Maximum Stress	194.03 MPa
Material Selected	AISI 4130
Yield Strength	560 MPa
Factor of Safety	2.89

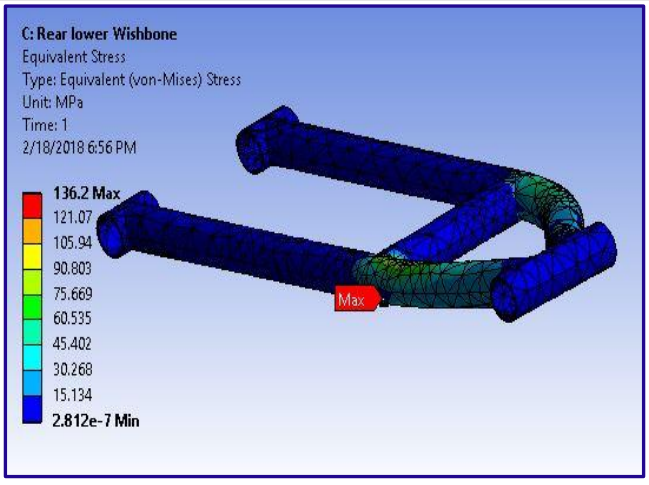
Lower Rear H-Arm

Boundary Condition



F = 900 N by approximating weight distribution on one of the rear wheels. It would jointly act at wishbone mounting and fox mounting points, But keeping those points fixed and applying force on wheels would also generate the same effect.

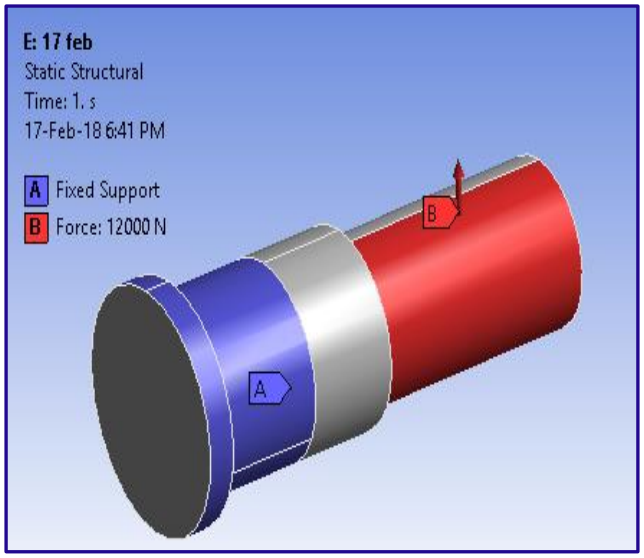
Results



Maximum Stress	136.2 MPa
Material Selected	AISI 4130
Yield Strength	560 MPa
Factor of Safety	4.11

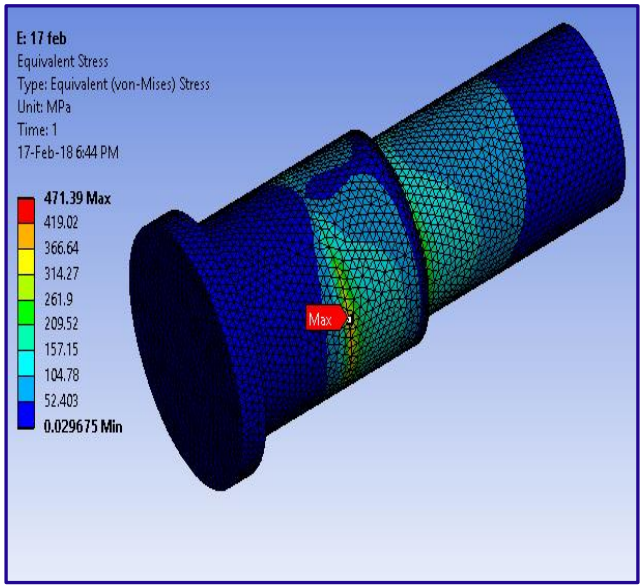
Front Wheel Axle

Boundary Condition



12000 N force on axle determined by ADAMS MBD Analysis.

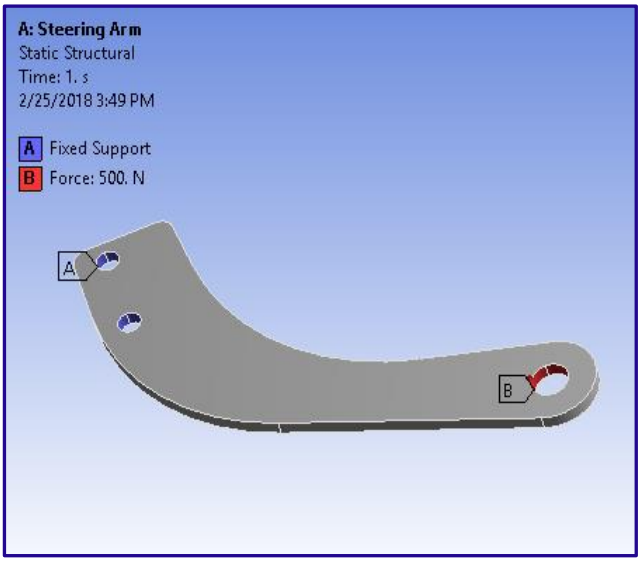
Results



Maximum Stress	229.25 MPa
Material Selected	Al 7075
Yield Strength	560 MPa
Factor of Safety	2.44

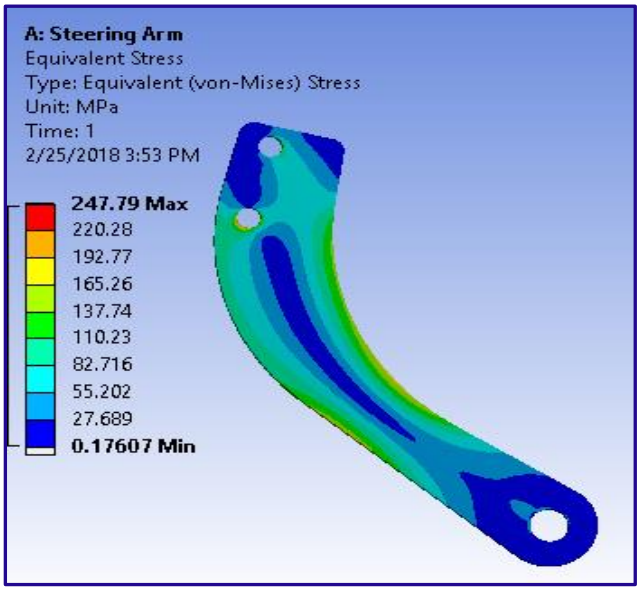
Steering Arm

Boundary Condition



Steering Force approximated as 500 N. Fastening points on knuckle fixed.

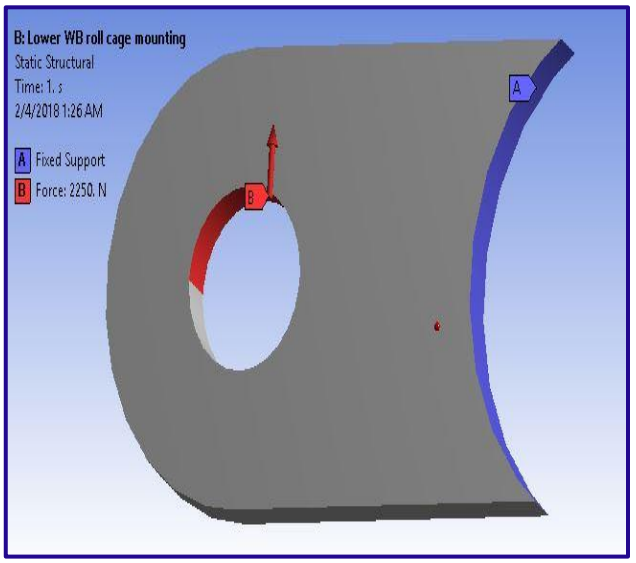
Results



Maximum Stress	247.79 MPa
Material Selected	Mild Steel
Yield Strength	370 MPa
Factor of Safety	1.49

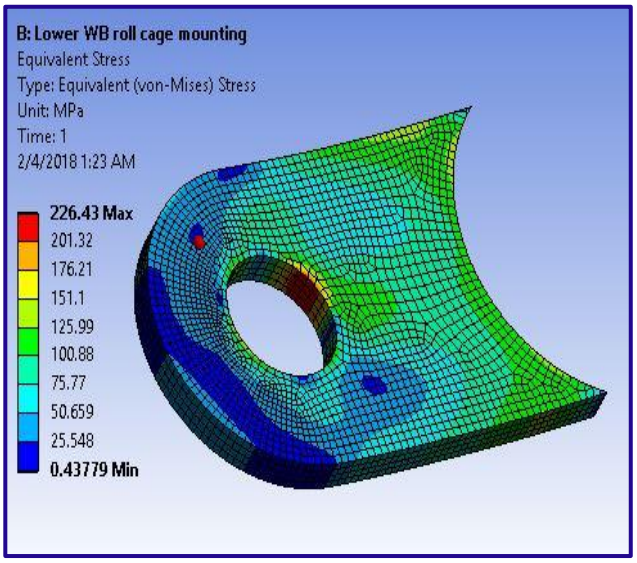
Wishbone Mountings

Boundary Condition



Forces on lower wishbone mounting points are estimated to be equal to 2250N

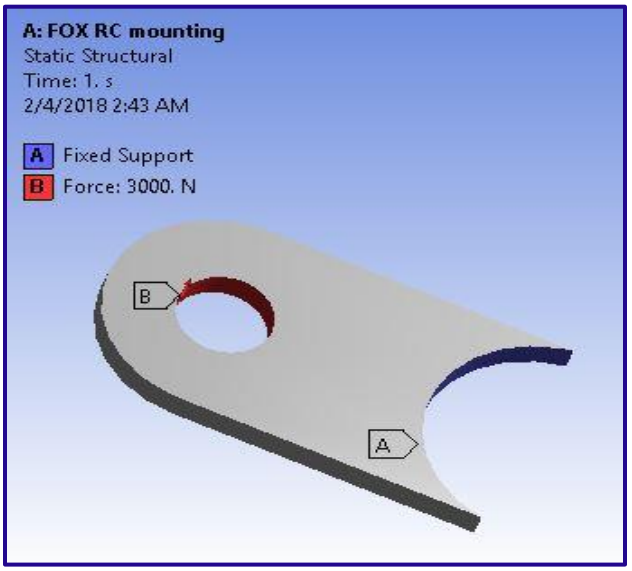
Results



Maximum Stress	226.43 MPa
Material Selected	Mild Steel
Yield Strength	370 MPa
Factor of Safety	1.63

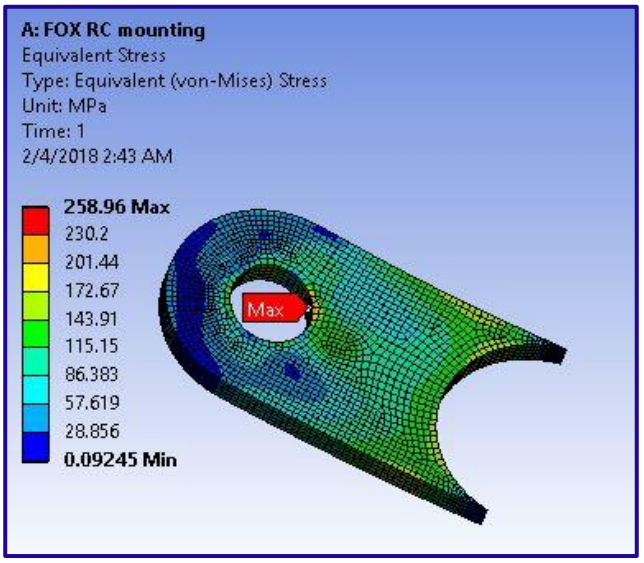
Fox Mountings

Boundary Condition



Forces on fox mounting points are estimated to be equal to 3000 N

Results



Maximum Stress	258.96 MPa
Material Selected	Mild Steel
Yield Strength	370 MPa
Factor of Safety	1.43

Transmission System Components

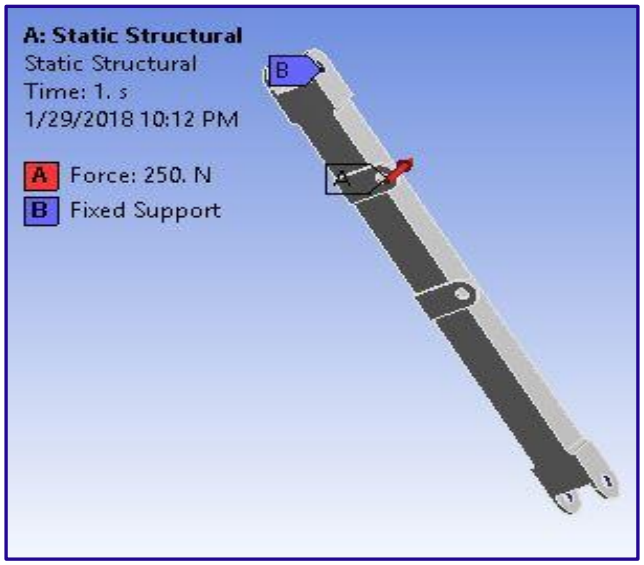
Engine Mounting

Gear Box Casing

Gear Box

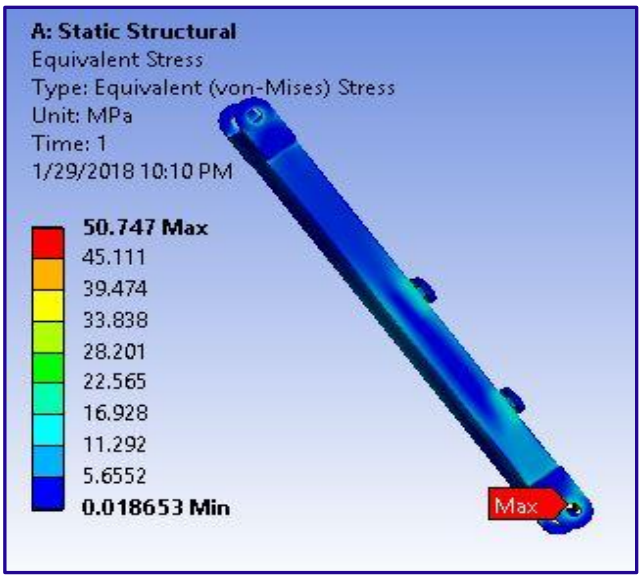
Engine Mounting

Boundary Condition

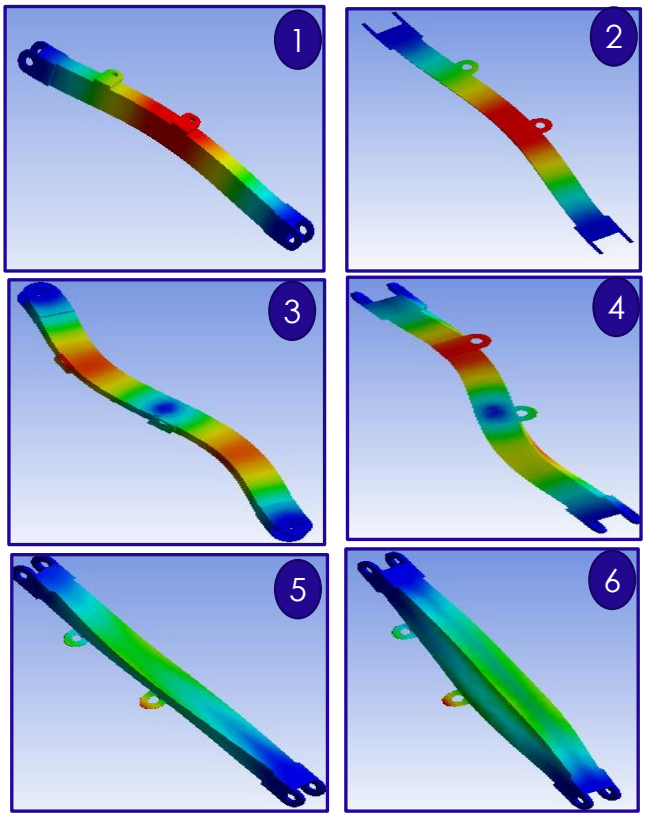


Fastening Points fixed and Force equivalent to Weight of the engine. Also, to prevent drastic failure due to resonance generated due to matching of engine frequency and Engine mounting's natural frequency, it is required to check that the modal natural frequencies of the Engine Mounting is well below the frequency of the Engine.

Results: Equivalent stresses



Result: Modal Analysis



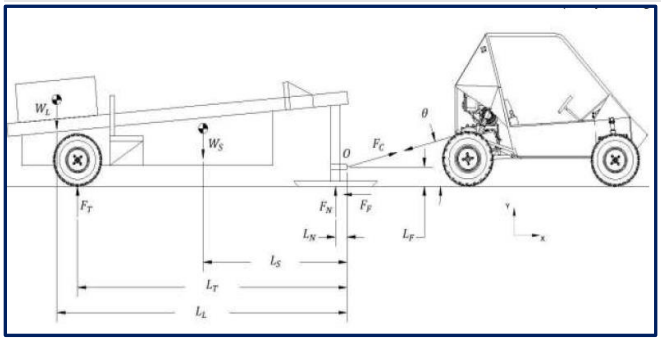
Results

Maximum Stress	50.747 MPa
Material Selected	AISI 4130
Yield Strength	560 MPa
Factor of Safety	11.03
1st Harmonic Mode	1256.4 Hz
2nd Harmonic Mode	1567.3 Hz
3rd Harmonic Mode	3266.0 Hz
4th Harmonic Mode	3693.8 Hz
5th Harmonic Mode	3930.0 Hz
6th Harmonic Mode	5378.0 Hz
Engine Frequency	0-150 Hz

Frequencies well above engine and road frequencies. Safe for the application

Boundary Condition Determination of Gears and Pinions

Calculating Required Gear ratio



- From Weight Distribution during Sledge pull event the traction required was calculated to be equal to 1391.208 N.
- Taking tire diameter under consideration, Required torque was obtained to be equal to 406.37 Nm.
- Torque delivered by the engine being 17.5 Nm, Gear Ratio of CVT being 3.9,
- Considering 78% efficiency of CVT and 95% efficiency of the Gearbox, Required Gear Ratio of Gearbox was obtained to be equal to **8**.

Parameter	Reduction 1	Reduction 2
Teeth on Pinion	18	18
Teeth on Gear	52	52
Diameter of Pinion	46	52
Diameter of Gear	130.1	147
Pinion Face Width	30	40
Gear Face Width	20	30

Force Determination : Reduction 1

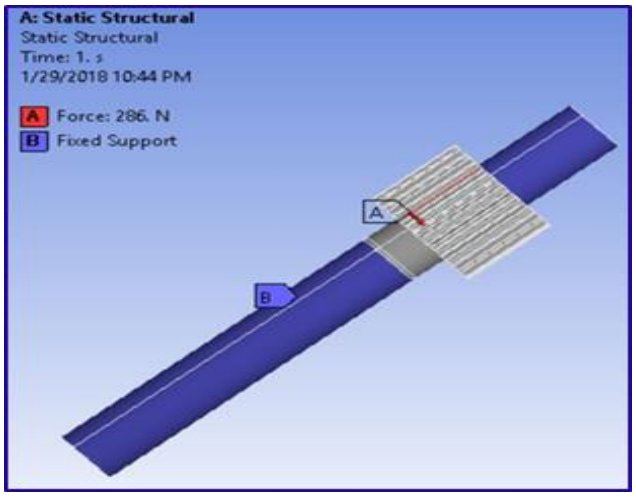
Torque Available from Engine = 20 Nm
Gear Ratio of CVT = 3.9
Radius of pinion 1= 23 mm
Force on Gear set 1 contact point
= 20*3.9*0.98*.80*1000* cos 20/23
= 2498.43 N

Force Determination : Reduction 2

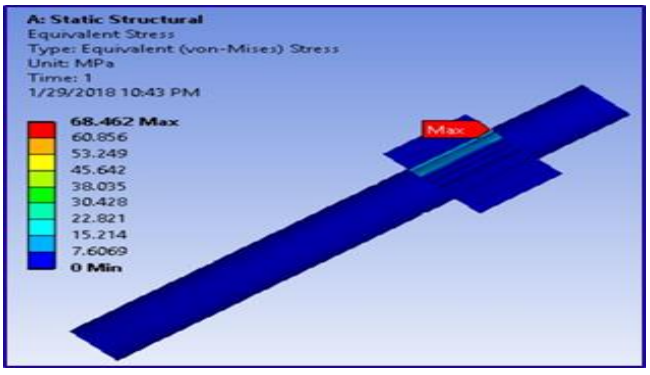
Torque Available from Engine = 20 Nm
Gear Ratio of CVT = 3.9
Radius of pinion 1= 23 mm
Gear ratio of First Gear set= 2.82
Force on Gear Set 2 contact point
= 20*3.9*0.98*0.80*2.82*cos 20*1000/26
=6232.643 N

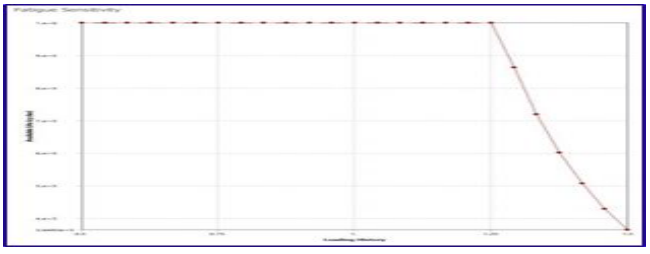
Pinion 1

Boundary Condition



Results

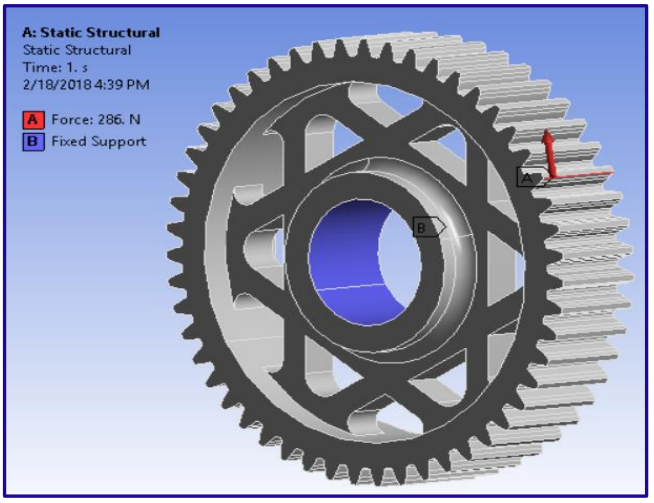




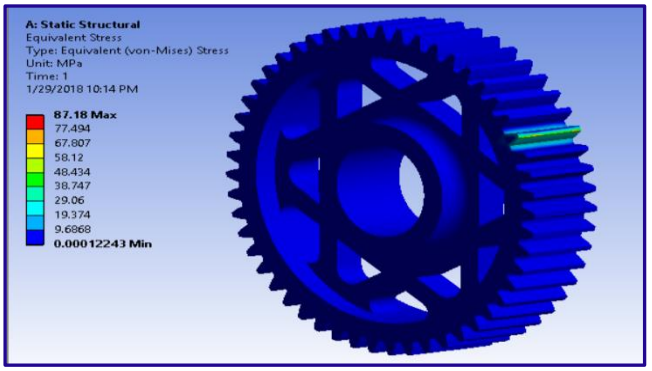
Maximum Stress	68.462 MPa
Material Selected	EN 24
Yield Strength	650 MPa
Factor of Safety	9.49
Fatigue life (cycles)	Infinite

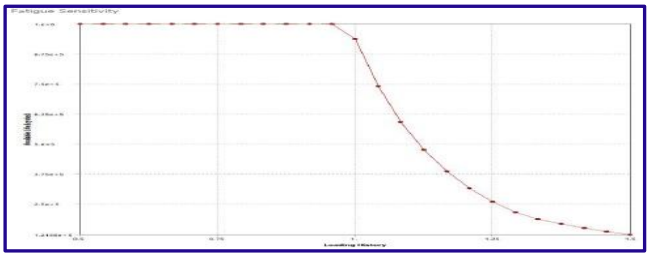
Gear 1

Boundary Condition



Results

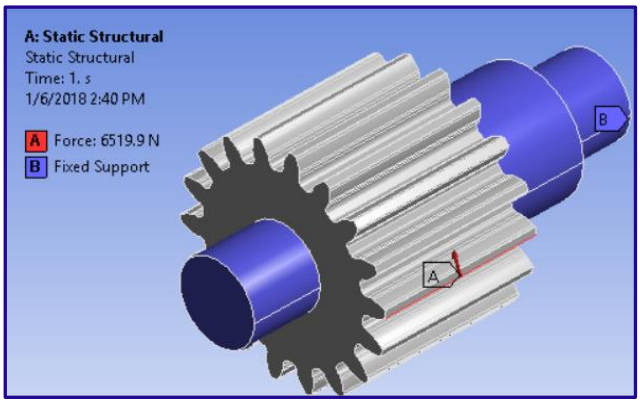




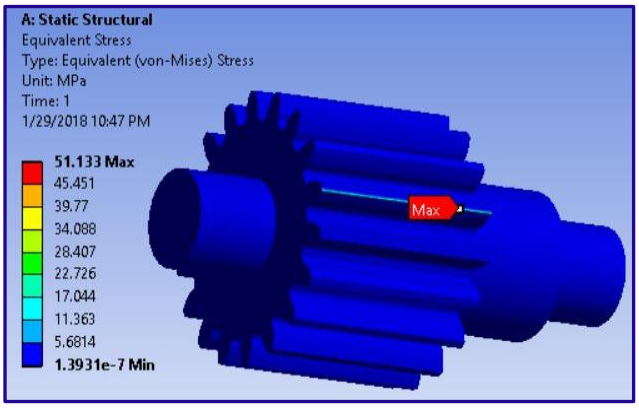
Maximum Stress	87.18 MPa
Material Selected	EN 24
Yield Strength	650 MPa
Factor of Safety	7.46
Fatigue life (cycles)	9.25e5

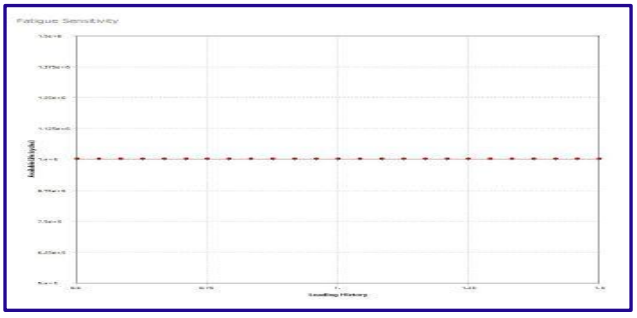
Pinion 2

Boundary Condition



Results

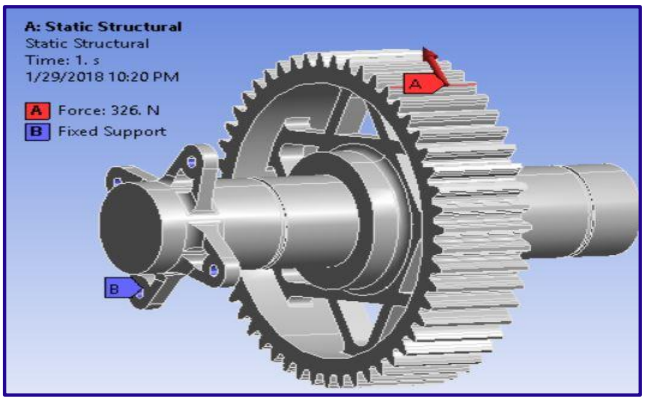




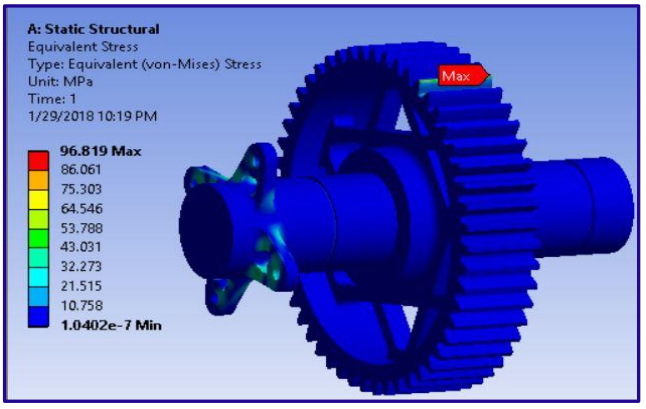
Maximum Stress	51.13 MPa
Material Selected	EN 24
Yield Strength	650 MPa
Factor of Safety	12.7
Fatigue life (cycles)	Infinite

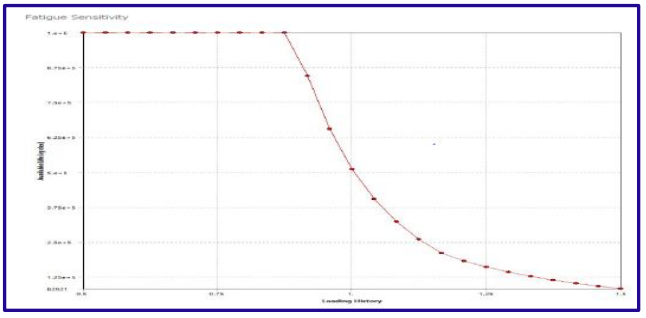
Gear 2

Boundary Condition



Results

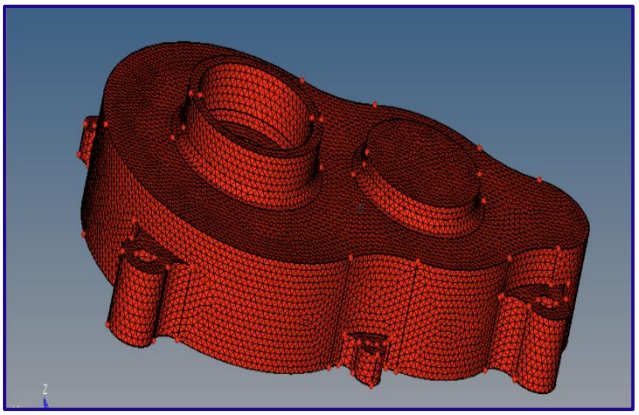




Maximum Stress	96.819 MPa
Material Selected	EN 24
Yield Strength	650 MPa
Factor of Safety	6.713
Fatigue life (cycles)	5.12e5

Gearbox Housing

Meshing

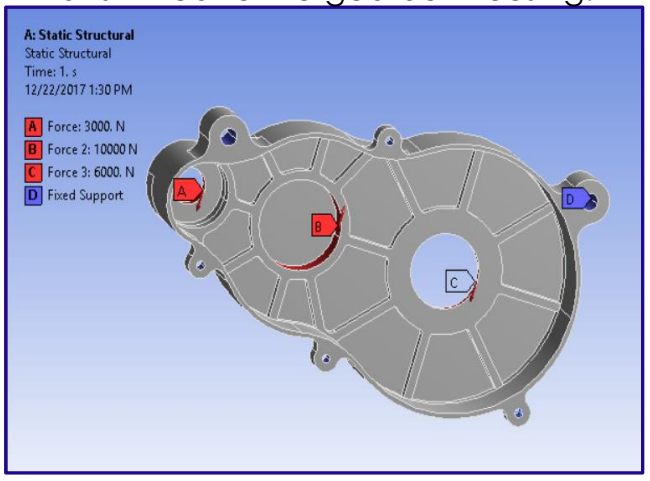


Quality factor	Value
Aspect Ratio(Max)	1.92
Jacobian (Min)	1
Skewness (Max)	38.21
Tria-angle(Min/Max)	21.72/112.5

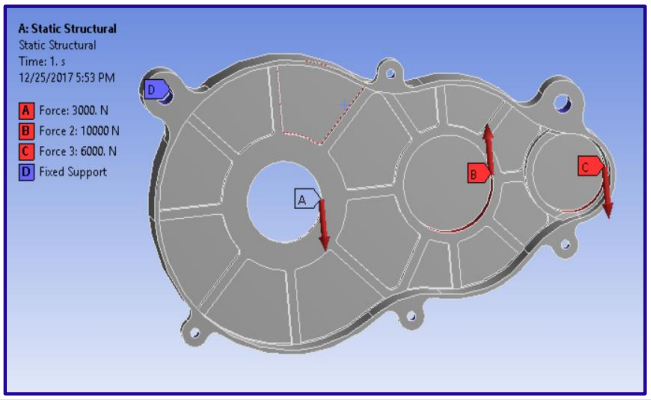
Quality factor	Value
Aspect Ratio(Max)	2.21
Tet-collapse(Min)	0.41
Jacobian (Min)	1

Boundary Conditions

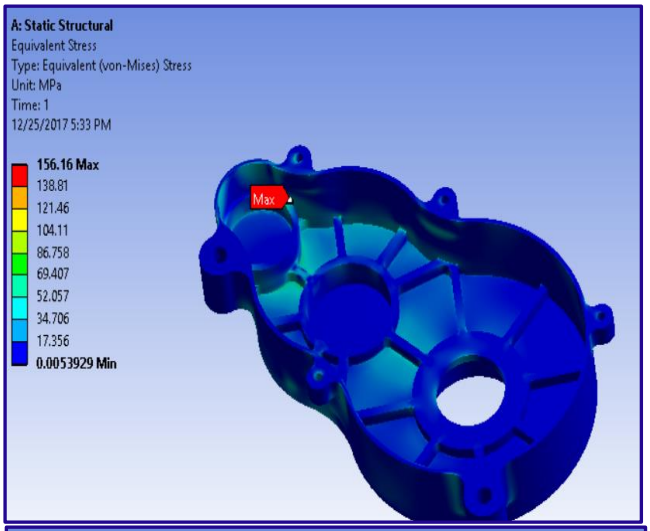
Counter Torques for the gears acting on gear shafts are ultimately transmitted to the gearbox housing.

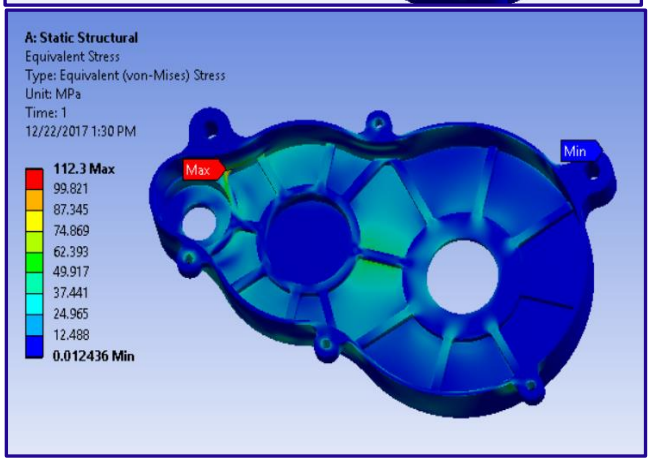


Equivalent forces to that gears are applied on the faces of Gearbox housing.



Results





Maximum Stress	156.16 MPa
Material Selected	Al 6061
Yield Strength	276 MPa
Factor of Safety	1.77