PROJECT REPORT

ME3060 Machine Design Practice

TOPIC: DESIGN AND ANALYSIS OF CAR AXLE

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INTRODUCTION

An axle is a rod or shaft that rotates the wheels and supports the weight of a vehicle. It is a very important part of a vehicle as it supports the whole body and helps in the motion of the automobile. The number of axles that a vehicle needs depends upon the number of wheels the vehicle has. Usually, for cars, there are 2 axles, one for the front pair of wheels and one for the rear pair. For Lorries with 6 wheels, there are 3 axles.

TYPE OF AXLE

Several factors determine what type of axle a vehicle needs. Mostly it depends on the dimensions of the vehicle and the amount of load the vehicle will be carrying.

Generally there are three types of axles:

- **Rear Axle:** This axle is responsible for delivering power to the driving wheels. It comes in two halves, known as half shafts, which are connected by the differential. In most cases, rear axles are live, meaning they rotate with the vehicle's wheels.
- **Front Axle:** Located in the front of the vehicle, this axle is responsible for assisting with steering and processing shocks from the uneven surface of the road. They have four main parts, which are the beam, the swivel pin, the track rod, and the stub axle.
- **Stub Axle:** Stub axles are attached to the vehicle's front wheels, with kingpins connecting these axles to the front axle.

This Project focuses majorly on the design and analysis of the front axle.

FRONT AXLE

The front shaft beam is one in all the main elements of the auto mechanical system. It houses the steering assembly as well. The weight of the axle is pretty significant as compared to weight of the total vehicle. Hence correct style of the front shaft beam is extraordinarily crucial.

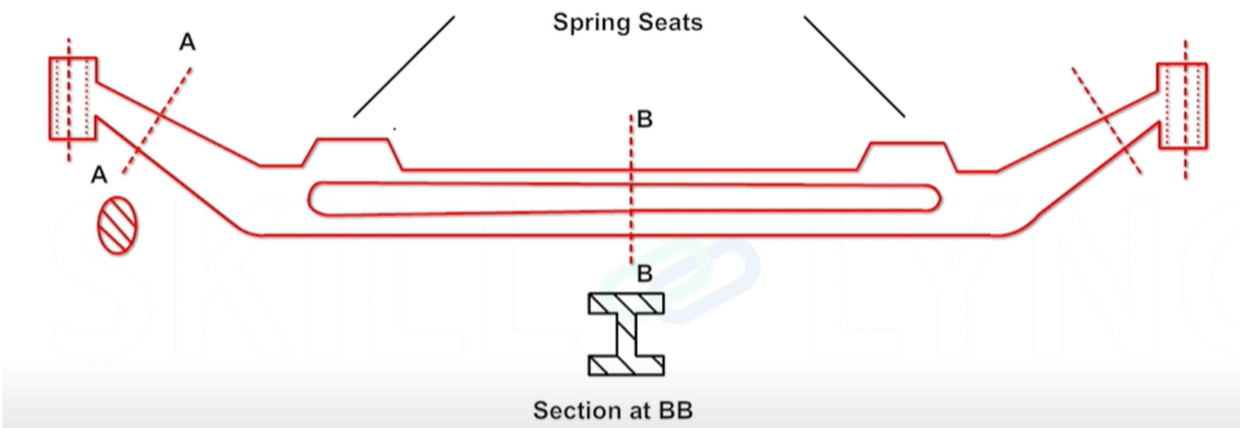


Fig: Axle beam

It balances the front part of the vehicle and also provides much needed suspension to the front part. Basically there are 2 types of Front axles: Live and Dead. Live axles provide power to the wheels from the engine, whereas the Dead axles do not. Live front axles are found in Front wheel drive vehicles and Four wheel drive vehicles (4x4). The wheels are attached to the front axles through the stub axles.

The front shaft is meant to transmit the burden of the car from the springs to the front wheels, turning right or left as needed. To prevent interference because of front engine location, and for providing larger stability and safety at high speeds by **lowering the centre of gravity of the road vehicles, the entire centre portion of the axle is dropped**. The shaft beam in use is of I or H-section and is factory made from alloy cast steel for rigidity and strength. For live front axle different swivelling mechanism is used to that of dead front axle. To connect the wheel hub axles with axle shafts, constant velocity joints are used for the vehicles fitted with the front live axles.

Front axles are subjected to both bending and shear stresses. In the static condition, the axle may be considered as a beam supported vertically upward at the ends i.e. at the centre of the wheels and loaded vertically downward at the centres of the spring pads. The vertical bending moment thus caused is zero at the point of support and rises linearly to a maximum at the point of loading and then remains constant.
Thus the maximum bending moment = Wl
where, W = The load on one wheel, N
l = The distance between the centre of wheel and the spring pad

Under dynamic conditions, the vertical bending moment is increased due to road roughness.But its estimate is difficult and hence is generally accounted for through a factor of safety. The front axle also experiences a horizontal bending moment because of resistance to motion and this is of a nature similar to the vertical one but of very small magnitude and hence can be neglected except in those situations when it is comparatively large.

Here we study the effects of vehicle load on a Dead front axle.

PROJECT OUTLINE

In this project the stress distribution will be evaluated on the Light duty front axle beam by using FEA. The finite element analysis is performed by using ANSYS R19.2 version.

Static analysis due to Laden Weight = 6000 kg will be carried out to calculate stresses and deflection followed by fatigue analysis to calculate life of axle.

Three different materials will be studied here as below;
1. Structural Steel
2. Aluminum Alloy
3. Grey Cast iron

Properties of the materials:

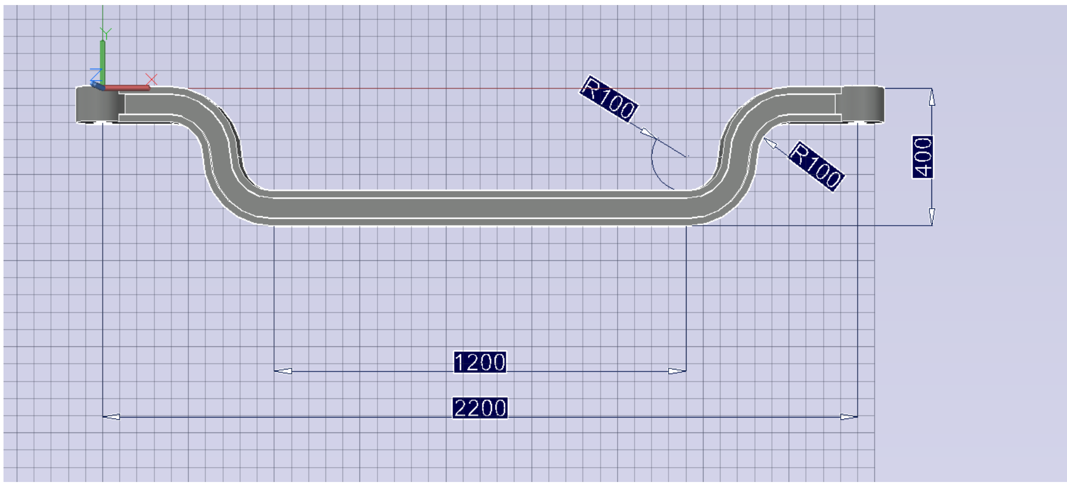
	Material Strength (MPA)		
Material	Yield Strength	Ultimate Tensile Strength	Ultimate Compressive Stress
Steel	250	250	460
CI	240	240	820
AL Alloy	280	280	310

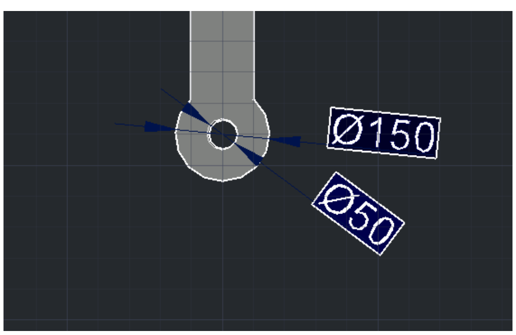
Material	Young's Modulus (GPa)	Poisons Ratio	Density (Kg/m3)
Steel	200	0.3	7850
CI	110	0.28	7200
AL Alloy	71	0.33	2700

Geometry of the Axle Used in the Simulation:

Total length of the axle: 2m

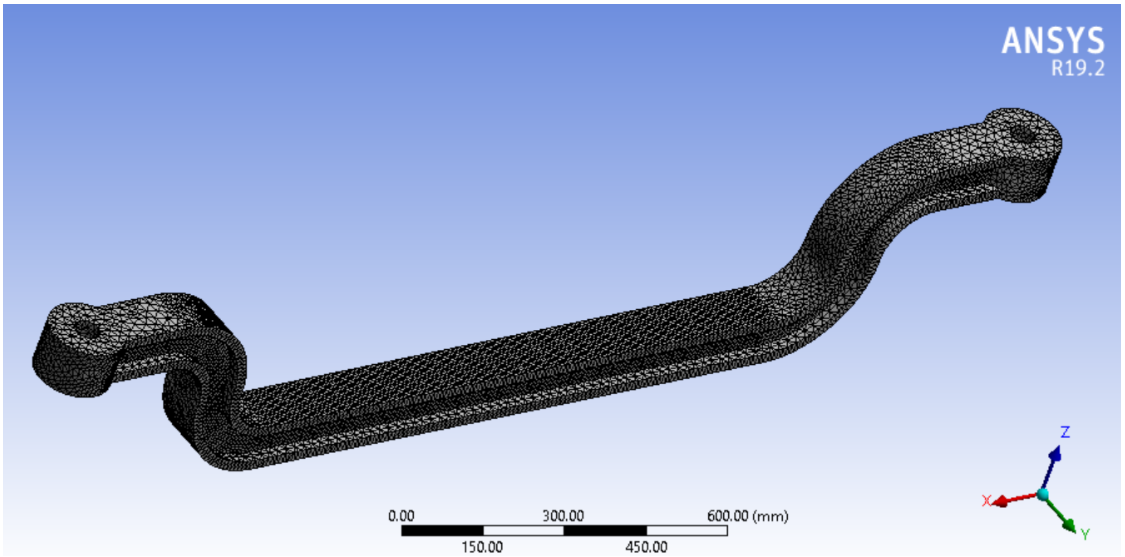
Clockwise from top: front view, Cross section of the beam(I section), top view of supporting ends.





**All dimensions are in mm*

Object after Meshing:



Loading Conditions:

Given that Laden Weight = 6000 kg

Actual weight coming on axle can be calculated as:

Considering 3g condition (bump load) , Load=3 x 6000 kg = 18000 kg

Total Weight on axle is given by = 18000* 9.81 N = 176.580 kN

Weight on each spring seat = 176.58/2

= **88.29 kN (downwards)**

The analysis is performed in Ansys where in the above calculated load is applied at the places where the spring seat would be attached to the axle.

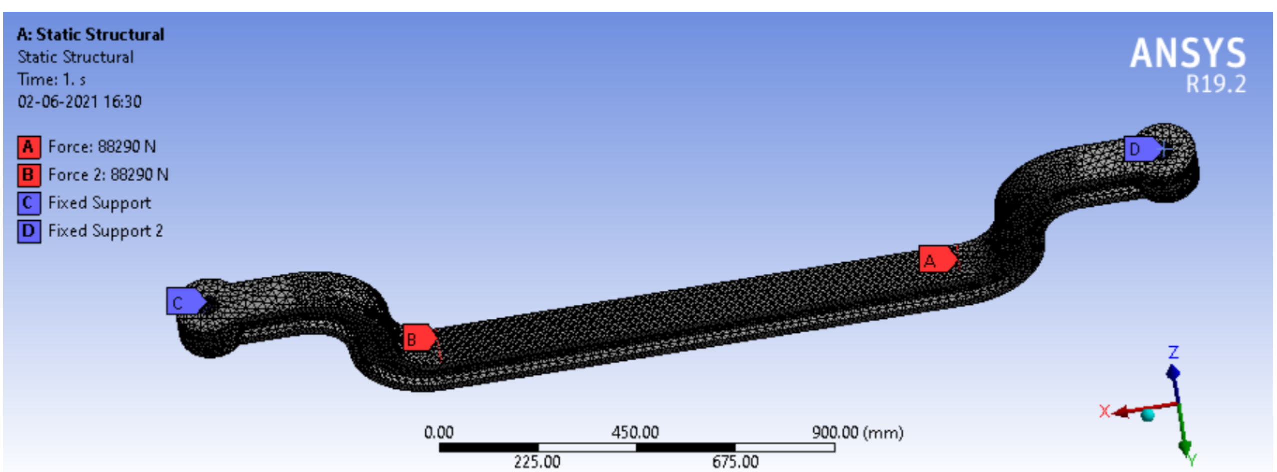


Fig: Boundary conditions applied

A) Static Structural Analysis for the material- Structural Steel

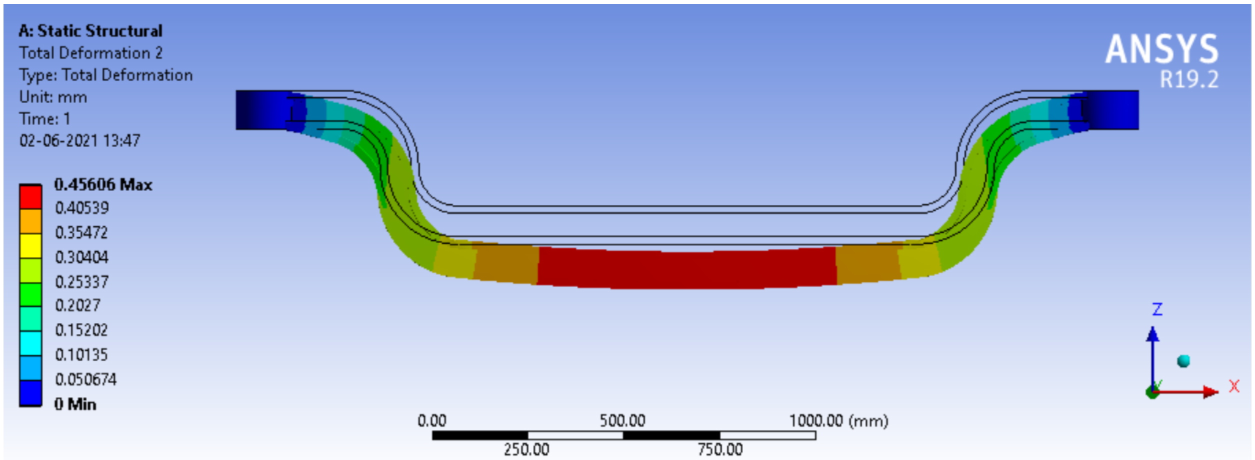


Fig: Total deformation (Structural steel)

A maximum deformation of 0.45606mm is observed at the red area

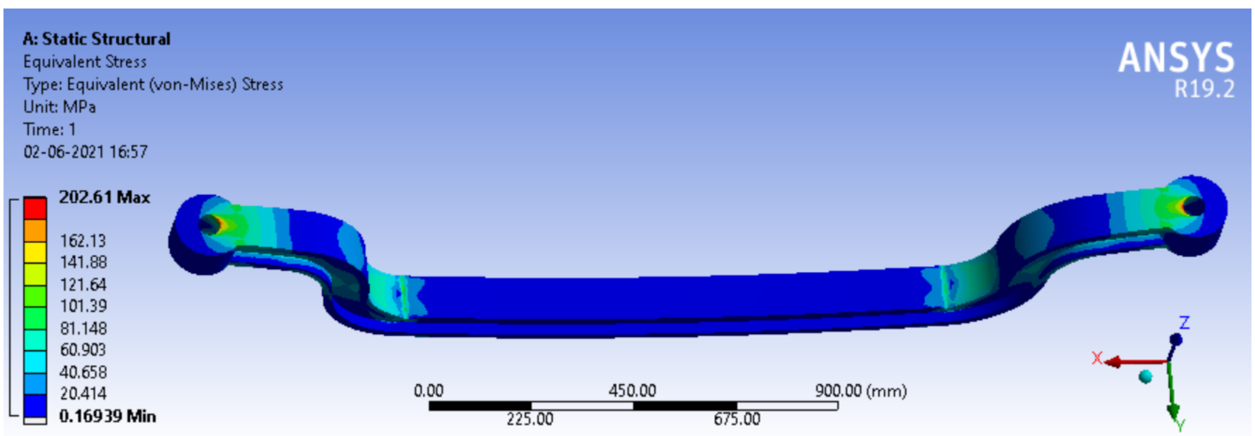


Fig: Equivalent Von-Mises Stress (Structural steel)

It can be seen that the maximum von-Mises Stress observed is 202.61 MPa at the area indicated in red.

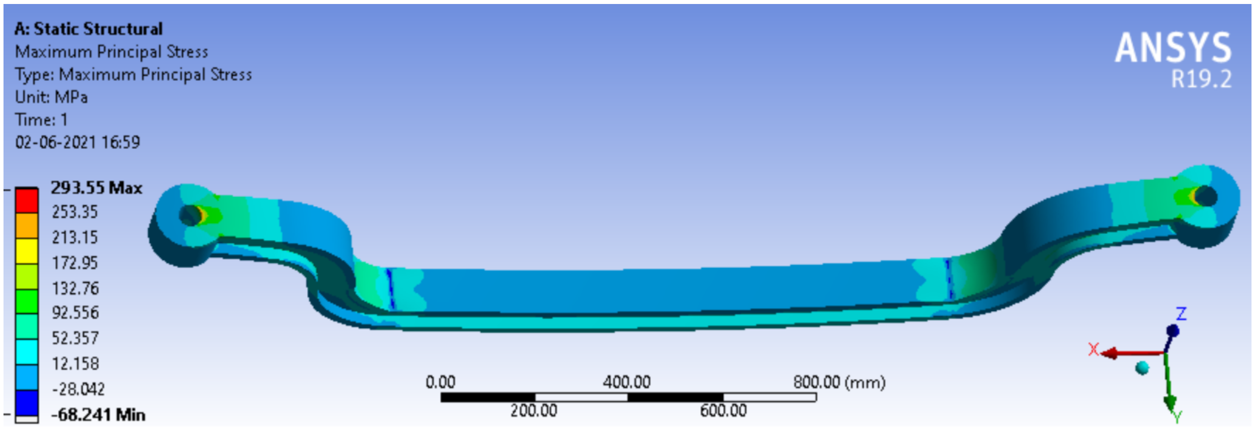


Fig: Maximum Principal Stress (Structural steel)

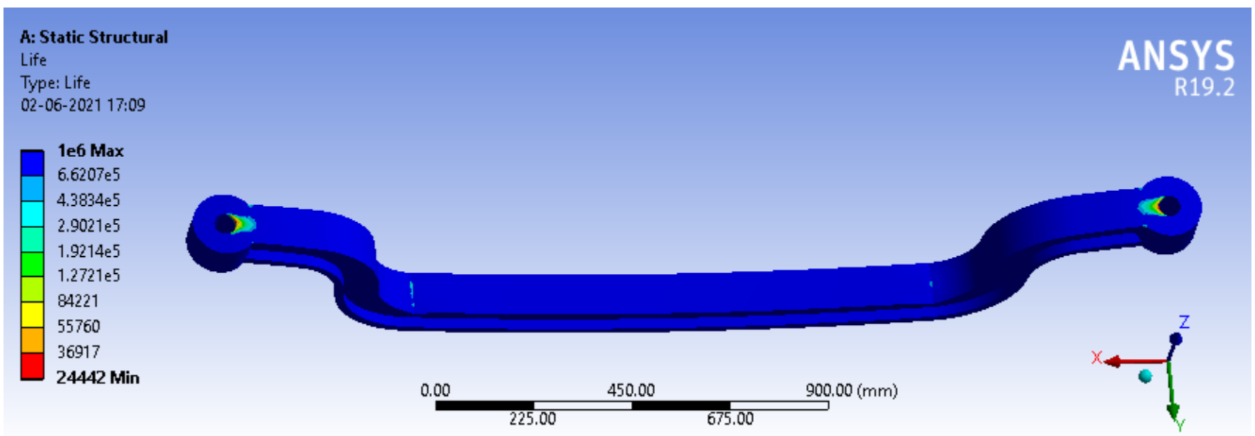


Fig: Fatigue Life of Structural Steel Axle

B) Static Structural Analysis for the material- Aluminium Alloy

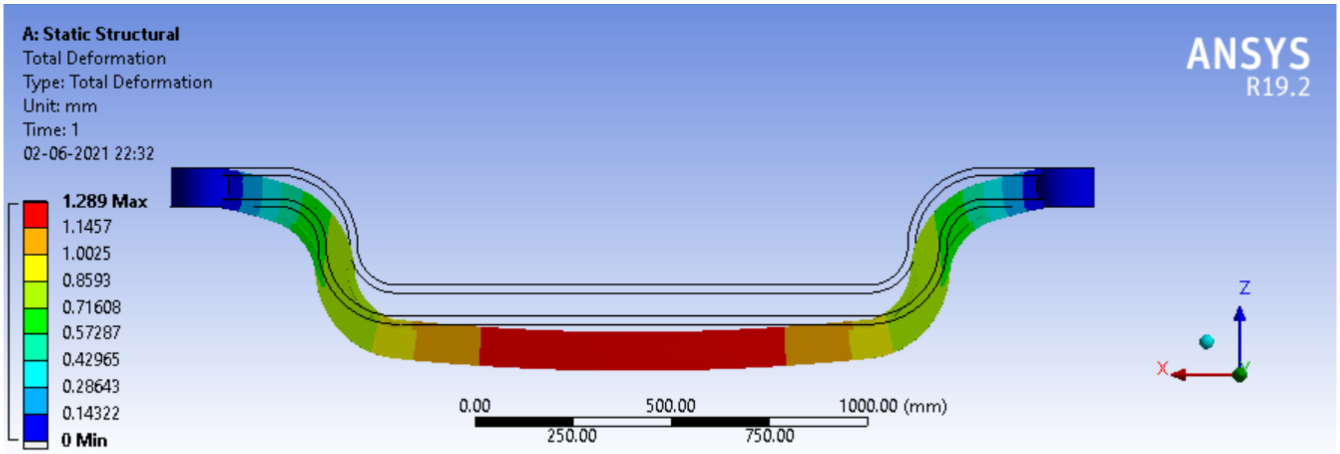


Fig: Total deformation (Aluminium Alloy)

A maximum deformation of 1.289 mm is observed at the red area

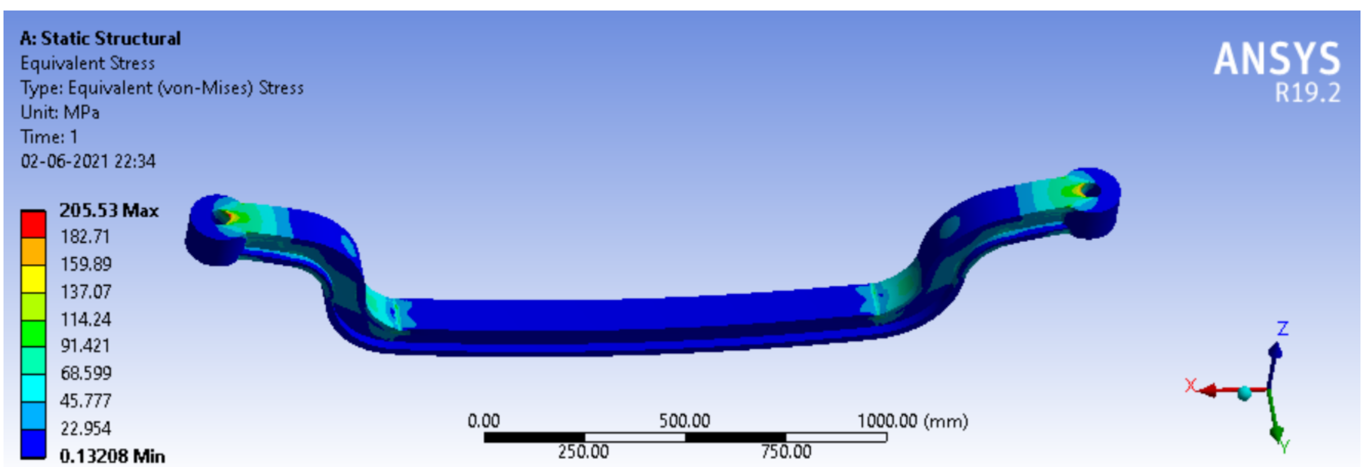


Fig: Equivalent Von-Mises Stress (Aluminium Alloy)

It can be seen that the maximum von-Mises Stress observed is 205.53 MPa at the area indicated in red.

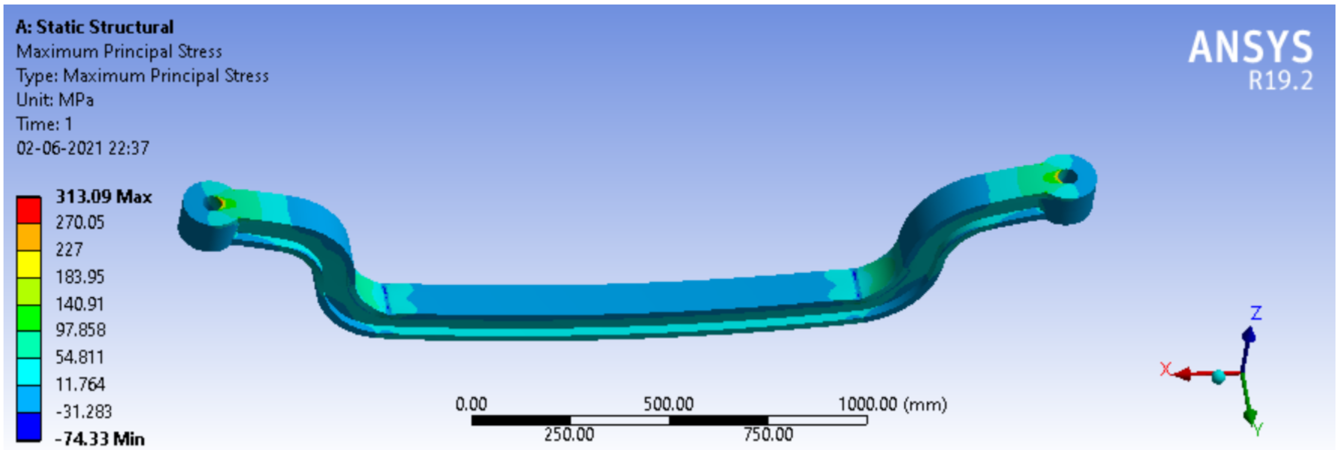


Fig: Maximum Principal Stress (Aluminium Alloy)

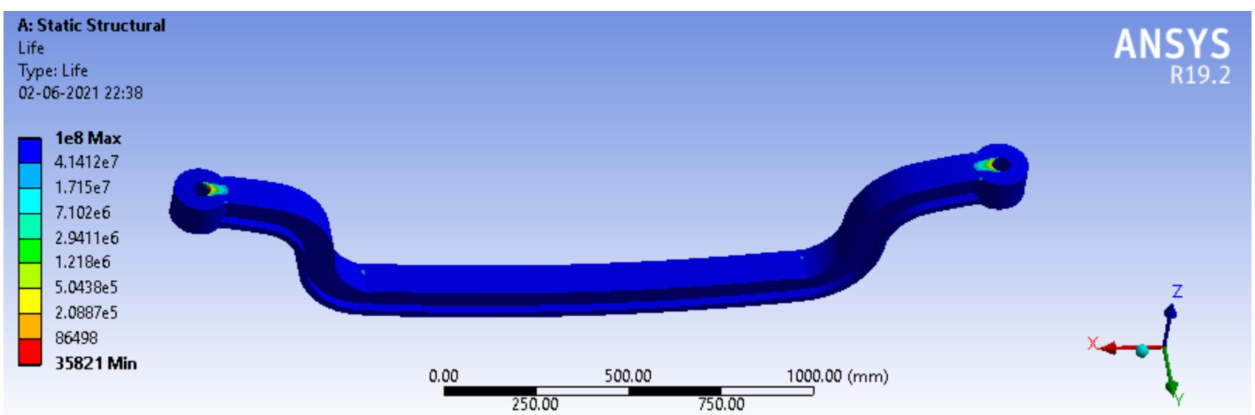


Fig: Fatigue Life of Aluminium Alloy Axle

C) Static Structural Analysis for the material- Gray Cast Iron

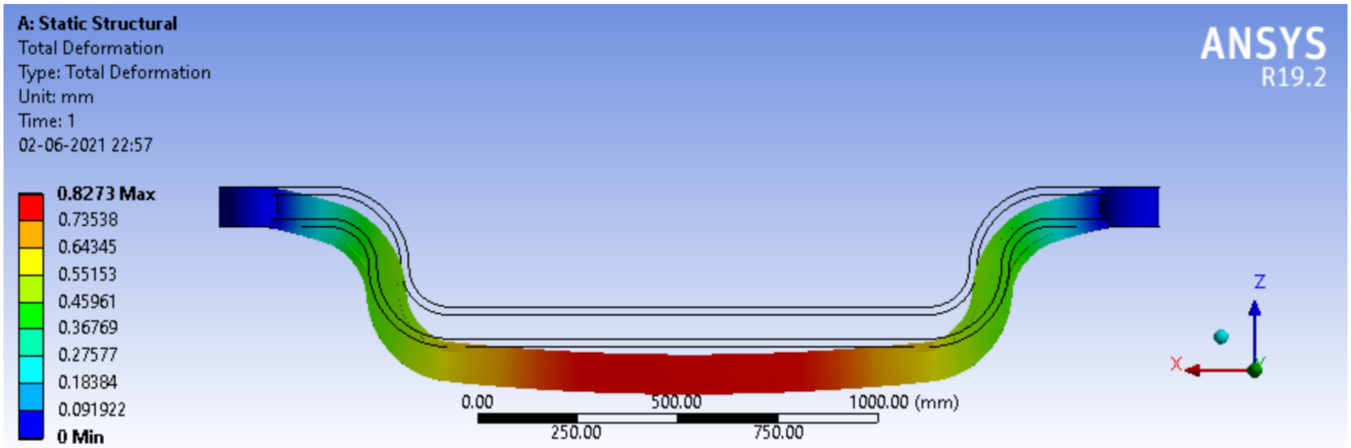


Fig: Total deformation (Gray Cast Iron)

A maximum deformation of 0.8273 mm is observed at the red area

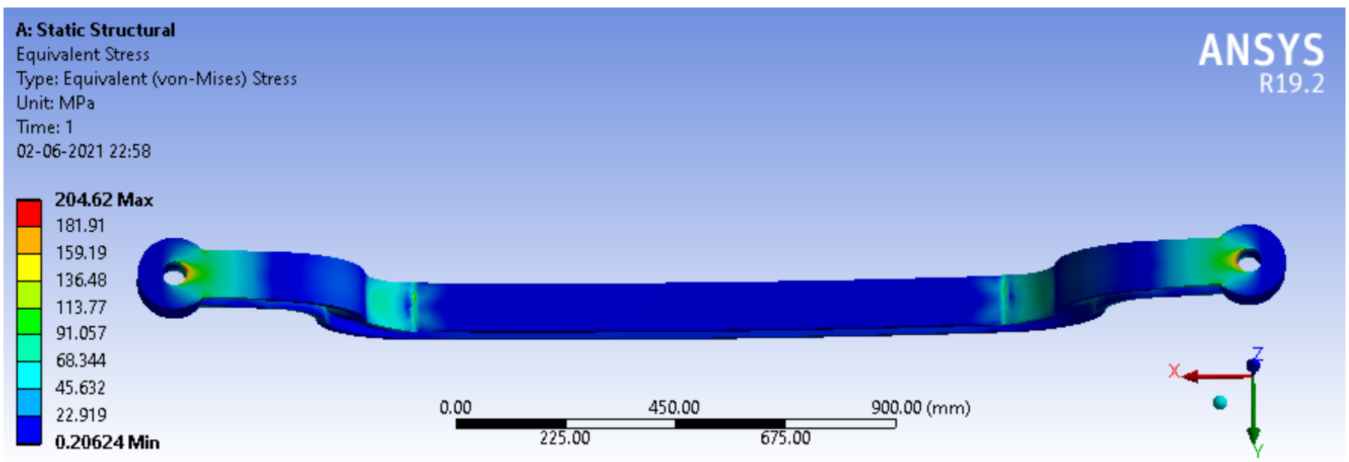


Fig: Equivalent Von-Mises Stress (Gray Cast Iron)

It can be seen that the maximum von-Mises Stress observed is 204.62 MPa at the area indicated in red.

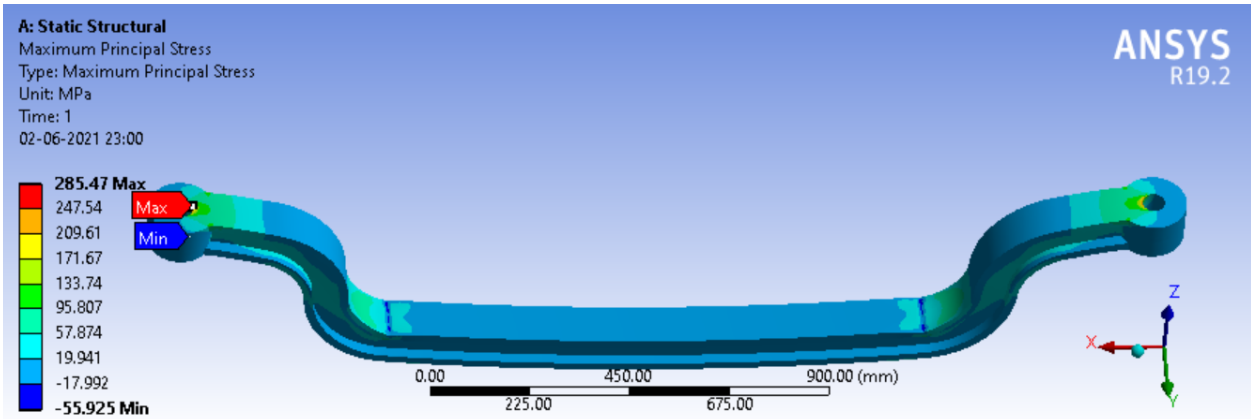


Fig: Maximum Principal Stress (Gray Cast Iron)

FACTOR OF SAFETY

Here, from the simulations, we see that critical points are at the point of support. The stress is tensile in nature at that point.

It is known that the maximum load(bump load) the front axle of the truck can bear is 18000 kg. Therefore maximum stresses associated with this load can be considered for Factor of Safety analysis

A) Structural Steel

$(\sigma_{ult})_{tensile} = 240\ MPa$

We can consider Von Mises' failure criterion for better results. From the simulation part, at critical point, Von Mises stress is found to be

$\sigma_v = 202.61\ MPa$

From here, we can find the Factor of safety for the designed front axle as:

$\sigma_{ult}/\sigma_v = FOS = 240/202.61$

$FOS \simeq 1.184$

B) Aluminium Alloy

$(\sigma_{ult})_{tensile} = 280\ MPa$

We can consider Von Mises' failure criterion for better results. From the simulation part, at critical point, Von Mises stress is found to be

$\sigma_v = 205.53\ MPa$

From here, we can find the Factor of safety for the designed front axle as:

$\sigma_{ult}/\sigma_v = FOS = 280/205.53$

$FOS \simeq 1.362$

C) Gray Cast Iron

$(\sigma_{ult})_{tensile} = 250\ MPa$

We can consider Von Mises' failure criterion for better results. From the simulation part, at critical point, Von Mises stress is found to be

$\sigma_v = 204.62\ MPa$

From here, we can find the Factor of safety for the designed front axle as:

$\sigma_{ult}/\sigma_v = FOS = 250/204.62$

$FOS \simeq 1.221$

RESULTS

	FoS	Life (cycles)	Deformation (maximum)(mm)
Structural Steel	1.184	24442	0.45606
Aluminium Alloy	1.362	35821	1.289
Gray Cast Iron	1.221	28863	0.8273

The following values were obtained for different materials after simulation.

- Here, Aluminium Alloy has the maximum FoS. But its maximum deformation is found to be higher than the rest.
- Structural steel has the minimum deformation, but it's life is the lowest.
- So, we get Gray cast iron as a material having appreciable values in all of these parameters.

Hence, we can conclude that Gray Cast iron is the best material to be used for the purpose of the front axle of a truck.

- FoS of the axle can be increased by increasing the cross sectional area of the beam.

INFERENCES

1. It was observed that more precise values of Maximum Principal and Von-Mises stresses were obtained when mesh refinement was done near the critical points.
2. We have estimated and taken Bump loading(3g) condition on the front axle which makes the load applied on the axle much more than just the static weight of the vehicle and gives a more practical loading condition.

REFERENCES

1. *https://www.caranddriver.com/research/a31547001/types-of-axle/*
2. *https://www.researchgate.net/publication/336081152_DESIGN_AND_OPTIMIZATION_OF_FRONT_AXLE_OF_HEAVY_TRUCK*
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