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Design and Fatigue Analysis of Upright on FSAE Vehicle

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Abstract: *Formula cars have to go through lot of mechanical stress for which components of the system needs to designed and optimized properly. Suspension in a car plays a important role to maintain car stability at higher speeds and even during cornering. which are all assembled to form a functional system. Design of knuckle was done in SolidWorks and analysis was done in Ansys. Weight reduction on part is significant as to increase vehicles performance, increase fuel efficiency which is done through many topological improvements.*

KEYWORDS: FSAE, upright, suspension, Hexa core mesh, ANSYS, SOLIDWORKS, Total deformation, Equivalent Stress.

1. Model:

The Rear knuckle is modelled using SolidWorks. Taking reference of the team's older designs, a newer design was needed which had to not only be structurally strong but also lightweight. Using good engineering techniques, we created the knuckle suitable for the car's suspension geometry and the parts used in wheel assembly.

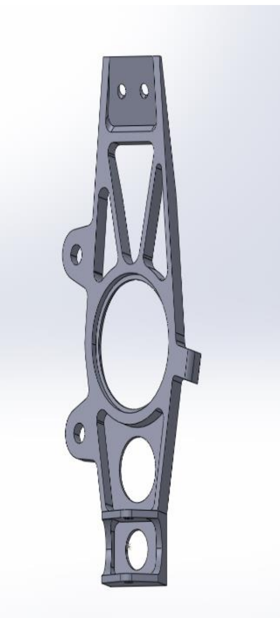

Figure 1- Front upright

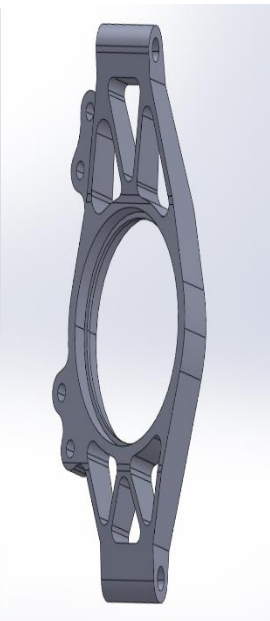

Figure 2- Rear Upright

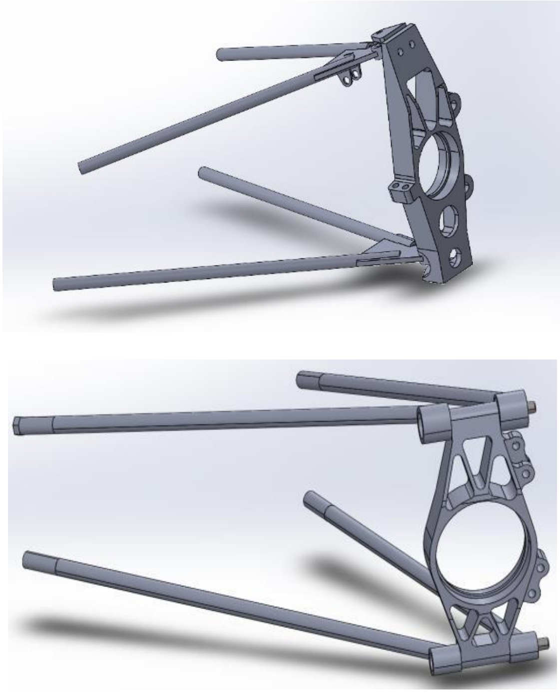

Figure 3- Assembly in SolidWorks

2. Material:

Before taking the parts through the initial stress and deflection calculations, the material needed to be considered. Only aluminium alloys were considered due to the low weight, ease of manufacturability, and low cost. Through research, 7075-T6 aluminium, a strong aircraft grade aluminium was preferred, although the material needed for the knuckle would be greatly out of the project budget. Other alloys were researched, and 6061-T6 proved to be just as light, while retaining an acceptable strength, with a significantly lower cost. Therefore aluminium 6061-T6 was selected for manufacturing the knuckle.

Density	2700 kg/m^3
Tensile strength ultimate	310 MPa
Tensile strength yield	275 MPa
Modulus of Elasticity	70 GPa
Poisson Ratio	0.33

3. Manufacturing

Figure 4 - Front Upright Assembly

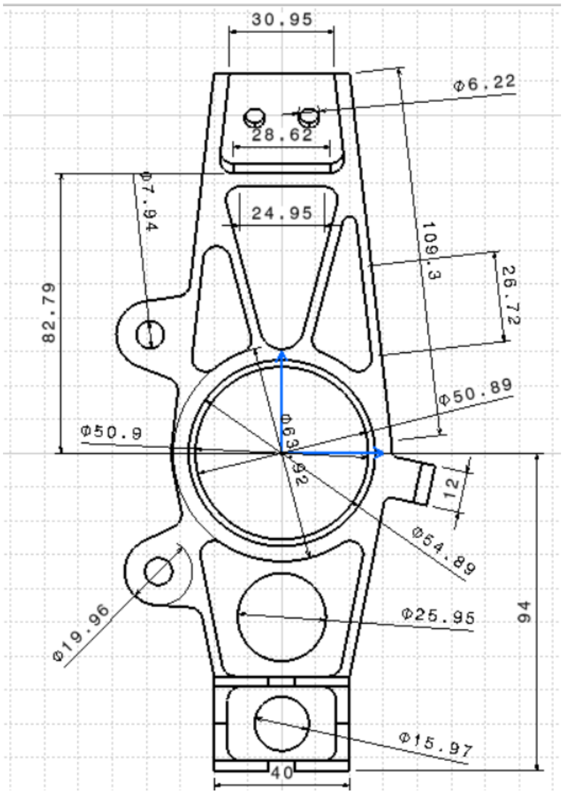

Figure 5 - Front Upright Draft

Figure 6 - Rear Upright Assembly

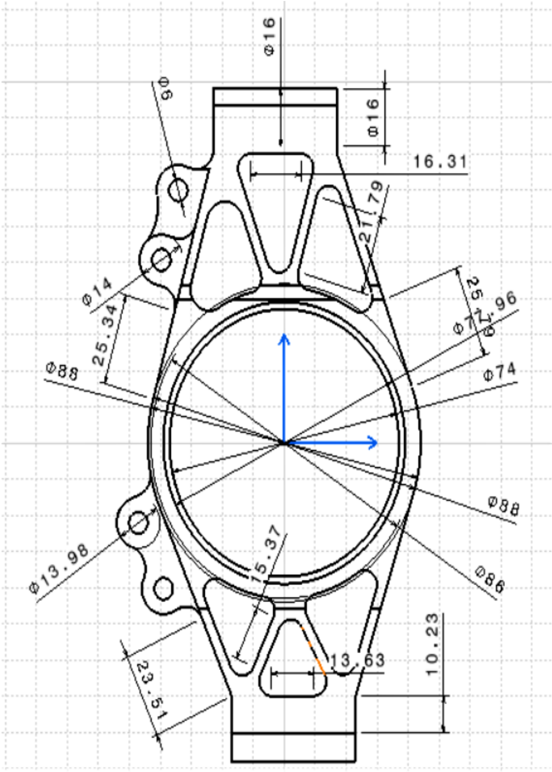

Figure 7 - Rear Upright Draft

4. Points:

	X axis (mm)	Y axis (mm)	Z axis (mm)
Front Upper ball joint	187.10	542.65	293.03
Front Lower ball joint	180.00	563.90	120.00
Rear Upper ball joint	1777.03	540.43	125.00
Rear Lower ball joint	1782.96	519.56	295.00

Table 1 – Ball Joint Hard Points

5. Calculations:

- Track Width front-1240mm and rear=1200mm
- CG height=240mm Weight of vehicle-254Kg
- Static weight distribution 45: 55(Front: Rear)
- Weight on front axle = 0.45*254= 114.3kg
- Weight on rear axle = 0.55*254= 139.7kg
- Weight on each tire (Front) = 57.15kg.
- Weight on each tire (Rear) = 69.85kg
- Distance between center of brake caliper mount and center of spindle= **Fc** is the force acting on the caliper mounts while braking

F1 is the force acting on the UBJ while braking

F2 is the force acting on LBJ while braking

F3 is the force acting on the UBJ while cornering

F4 is the force acting on LBJ while cornering

5.1) Front upright

A) **For Braking**

Longitudinal weight transfer

= (Brake 'Gs Weight of vehicle Height of c.g)

/Wheelbase

= (1+254*240)/1600 = 38.1 kg

Weight on the front axle while braking

= 114.3-38.1 kg

= 76.2 kg

Weight on each tire (Front) = 38.1 kg

Load on each tire (Front) = 38.1*9.81 = 373.761 N

Frictional Force = 0.7 *373.761 = 261.6327 N

Braking Torque = Frictional Force Radius of tire

= 348.8436*0.254 = 66.454 N-m

Fc Braking = Torque / r

= 66.454/0.075348

= 881.97 N

F1 = 282.5 N (towards right)

F2 = 605.039 N (towards left)

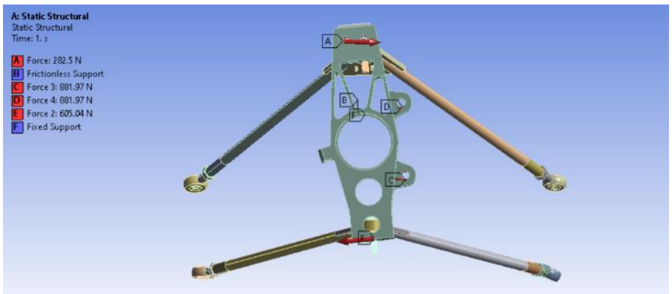

Figure 8 - Braking Forces

B) **For Cornering**

Longitudinal weight transfer=

(Longitudinal acceleration* Weight of vehicle *Height of cg)/ Wheelbase

= (1+254*240)/1600

= 38.1 kg

Weight on the front axle = 114.3-38.1 kg = 76.2 kg

Weight on each tire = 76.2 /2 = 38.1 kg

Lateral weight transfer on front axle=

(Lateral acceleration*Weight on front axle *Height of c.g)/Trackwidth

= (1.33*76.2*240)/1200

= 20.2692kg

Weight on outer tire in lateral acceleration

= 38.1+20.2692= 58.3692kg

= 572.01816 N

F3=942.48 (in the outward direction as seen from the side view of the vehicle)

F4=2018.6 N (in the inward direction as seen from the side view of the vehicle)

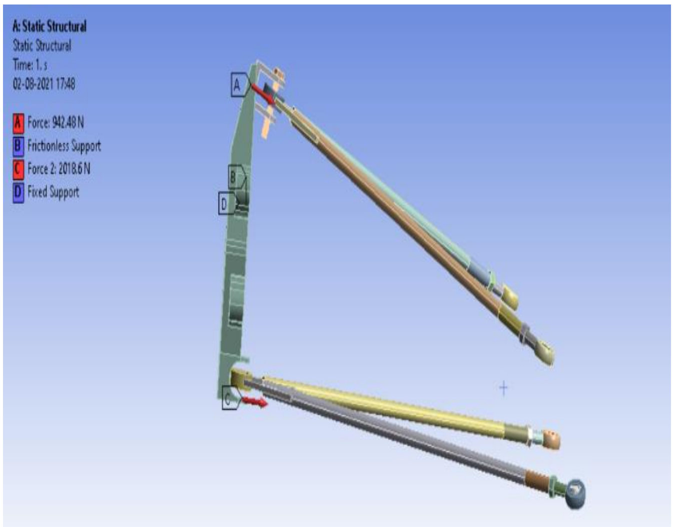

Figure 9 - Cornering Forces

5.2) Rear upright

A) **For Braking**

Longitudinal weight transfer

= (Brake 'Gs Weight of vehicle Height of c.g)

/Wheelbase

= (1+254*240)/1600 = 38.1 kg

Weight on the rear axle while braking

= 139.7-38.1 kg

= 101.6 kg

Weight on each tire (Rear) = 50.8 kg

Load on each tire (Rear) = 50.8*9.81 = 498.348 N

Frictional Force = 0.7 *498.348 = 348.8436 N

Braking Torque = Frictional Force Radius of tire

= 348.8436*0.254

= 88.6063 N-m

Fc Braking = Torque / r

= 88.6063/0.075348

= 1175.961 N

F1= 334.124 N (towards right)

F2= 682.967 N (towards left)

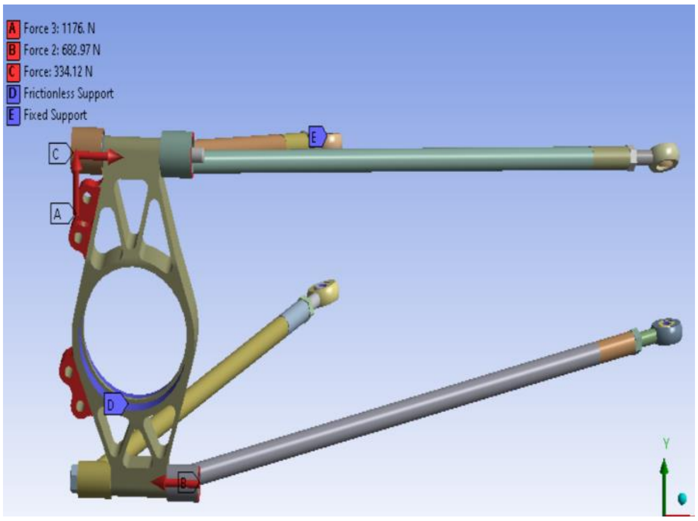

Figure 10 - Braking forces

B) **For Cornering**

Longitudinal weight transfer=

(Longitudinal acceleration* Weight of vehicle *Height of cg)/ Wheelbase

= (1+254*240)/1600 = 38.1 kg

Weight on the rear axle = 139.7-38.1=101.6 kg

Weight on each tire = 101.6/2=50.8 kg

Lateral weight transfer on rear axle=

(Lateral acceleration*Weight on rear axle *Height of c.g)/Trackwidth

= (1.33*101.6*240)/1200

= 27.0256 kg

Weight on outer tire in lateral acceleration

= 50.8+27.0256 = 77.8256 kg

= 763.469139 N

F3 = 931 N (in the outward direction as seen from the side view of the vehicle)

F4 = 2217 N (in the inward direction as seen from the side view of the vehicle)

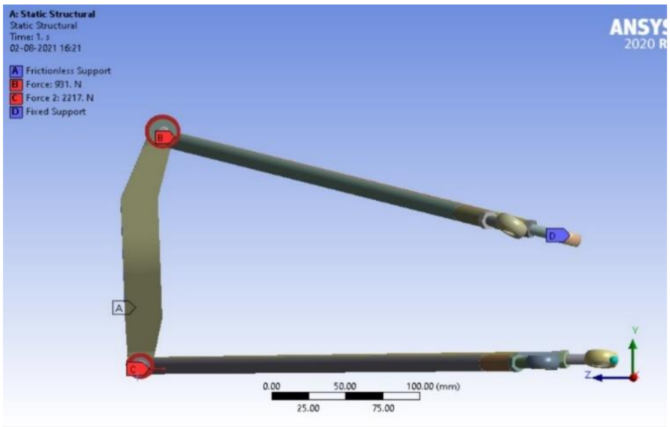

Figure 11 - Cornering forces

6. Analysis:

6.1) Front Upright

A)Mesh

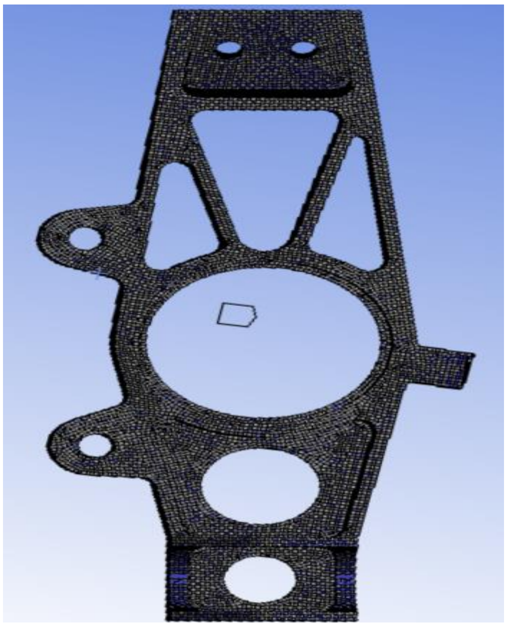

Figure 12 - Hex Dominant

A1) Case – 1 for Braking

A1.1) Total Deformation

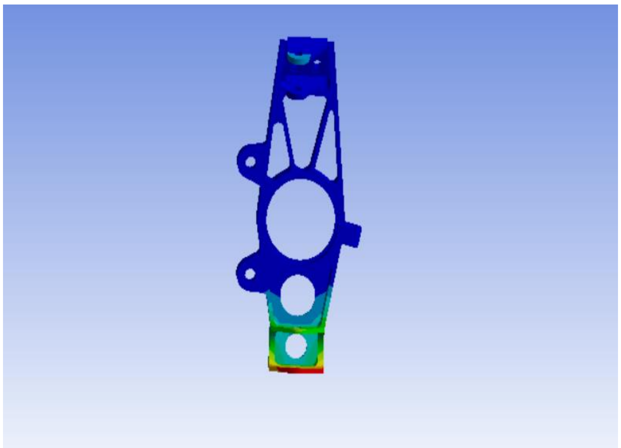

Figure 13 – Total Deformation

	With only Hex Meshing
Nos of node	1228633
Nos of elements	841814
Minimum Deformation	0. mm
Maximum Deformation	6.8239e-002 mm
Average Deformation	6.468e-003 mm

1) Minimum Deformation occurs on upper C-mount.

2) Maximum Deformation occurs on lower C-mount.

A1.2) Equivalent Stress – Von Mises

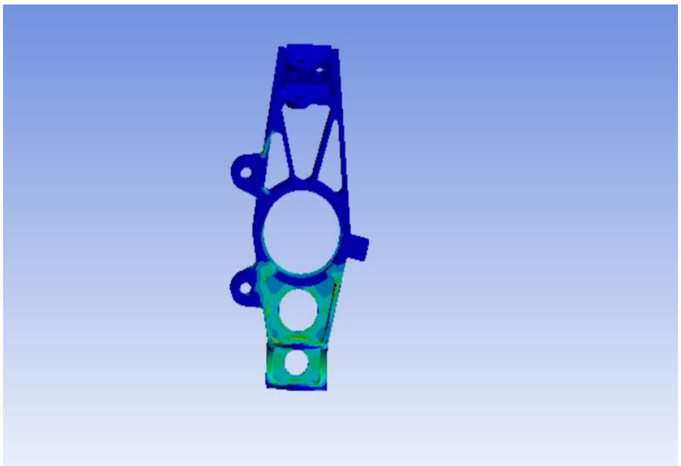

Figure 14 – Equivalent Stress (Von mises)

	With only Hex Meshing
Nos of node	1228633
Nos of elements	841814
MinimumStress	1.4564e-004 MPa
MaximumStress	72.011 MPa
Average Stress	5.506 MPa

1) Minimum Stress occurs on upper C-mount.
2) Maximum Stress occurs on bottom C-mount.

A2) Case 2 – For Cornering

A2.1) Total Deformation

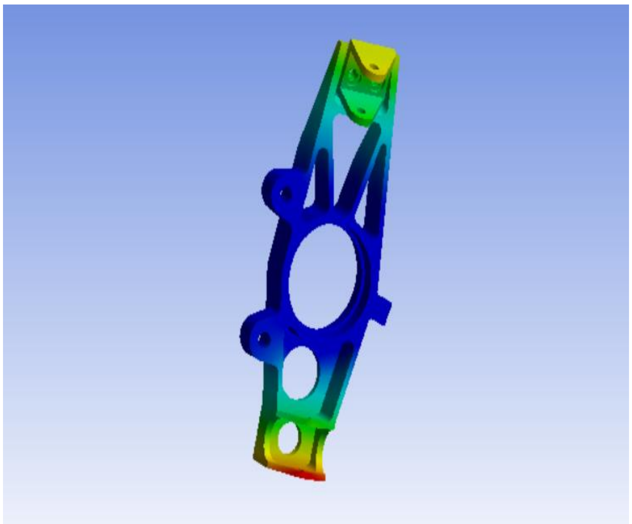

Figure 15 – Total Deformation

	With only Hex Meshing
Nos of node	1228633
Nos of elements	841814
Minimum Deformation	0
Maximum Deformation	0.12699 mm
Average Deformation	2.7615e-002 mm

1) Minimum Deformation occurs on the top C-mount.
2) Maximum Deformation occurs on the lower C-mount.

A2.2) Equivalent Stress Von-Mises

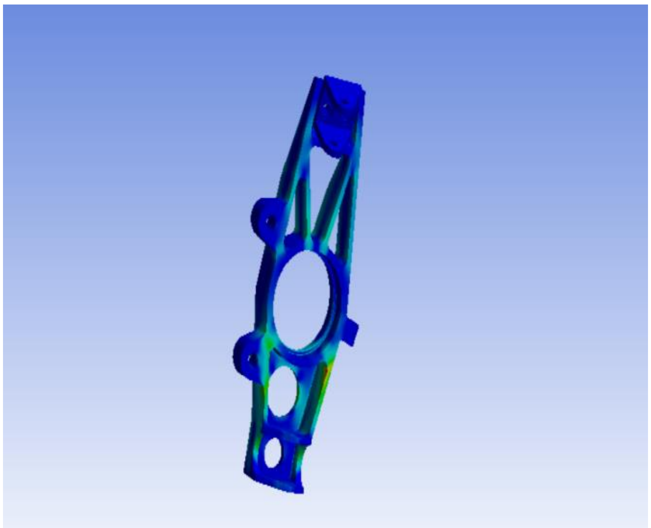

Figure 16 – Equivalent Stress (Von mises)

	With only Hex Meshing
Nos of node	1228633
Nos of elements	841814
Minimum Stress	7.3768e-004 MPa
Maximum Stress	196.84 MPa
Average Stress	16.039 MPa

1) Minimum Stress occurs on upper bolt connecting the upright to wishbone.
2) Maximum Stress occurs on the sides of upright.

6.2) Rear Upright

A) Mesh

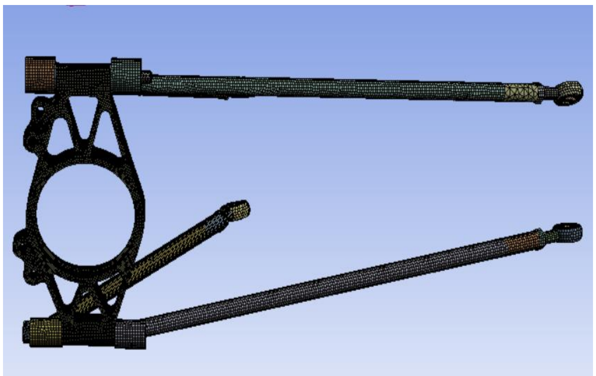

Figure 17 - Hex Core Sweep

A1) Case – 1 For Braking

A1.1) Total Deformation

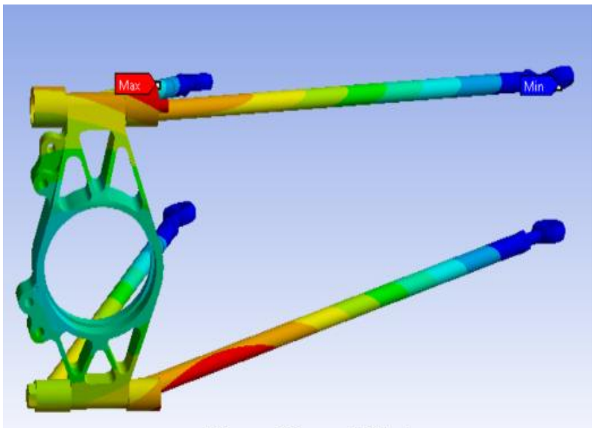

Figure 18 – Total Deformation

	With only Hex Meshing
Nos of node	1361559
Nos of elements	846366
Minimum Deformation	0mm
Maximum Deformation	0.20562 mm
Average Deformation	0.10335 mm

1) Minimum Deformation occurs on 12mm Billet.

2) Maximum Deformation occurs on the top rear left wishbone.

A1.2) Equivalent Stress – Von Mises

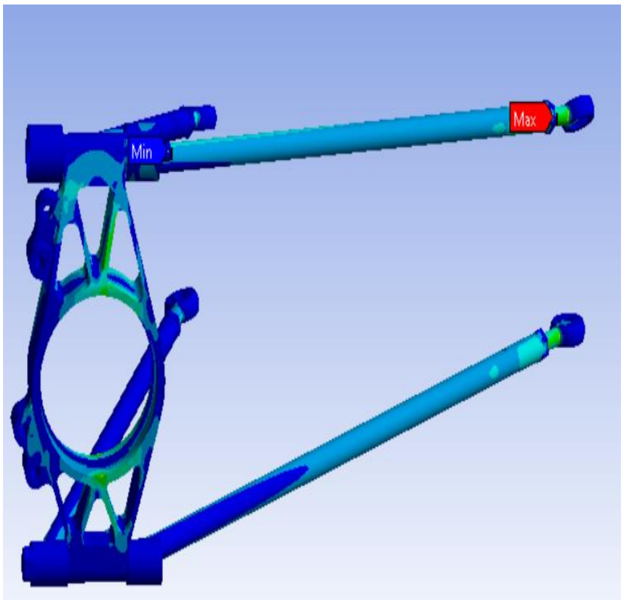

Figure 19 – Equivalent Stress (Von mises)

	With only Hex Meshing
Nos of node	1361559
Nos of elements	846366
MinimumStress	2.3034e-005 MPa
MaximumStress	78.69 MPa
Average Stress	8.409MPa

1) Minimum Stress occurs on upper bolt connecting the knuckle to wishbone.

2) Maximum Stress occurs on 12mm billet

A2) Case 2 – For Cornering

A2.1) Total Deformation

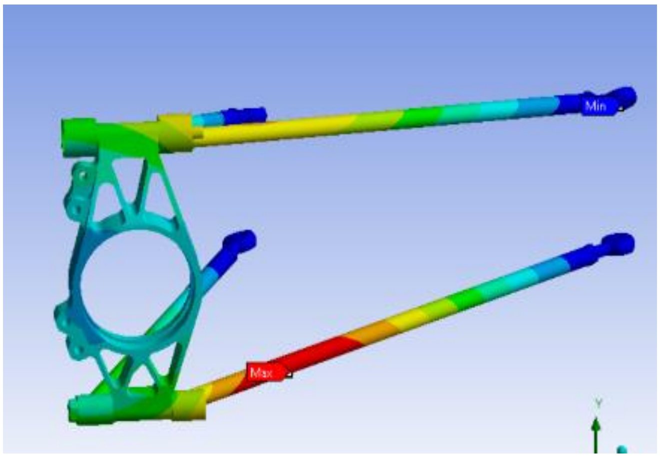

Figure 20 - Total Deformation

	With only Hex Meshing
Nos of node	1361559
Nos of elements	846366
Minimum Deformation	0mm
Maximum Deformation	0.22881 mm
Average Deformation	8.5608e-002 mm

1) Minimum Deformation occurs on 12mm Billet.

2) Maximum Deformation occurs on the top rear left wishbone.

A2.2) Equivalent Stress Von-Mises

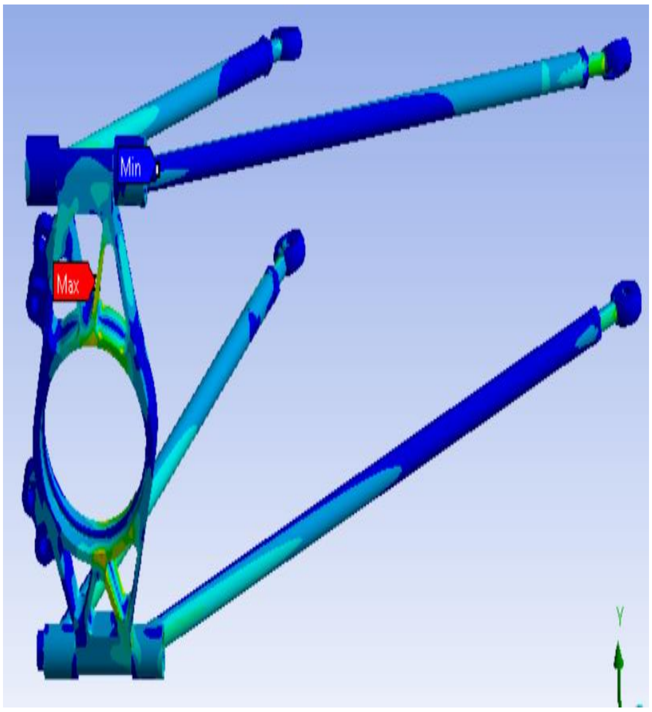

Figure 21 - Equivalent Stress (Von Mises)

	With only Hex Meshing
Nos of node	1361559
Nos of elements	846366
Minimum Stress	2.8939e-006 MPa
Maximum Stress	55.857 MPa
Average Stress	7.7553 MPa

1) Minimum Stress occurs on bolt connecting knuckle to wishbone.

2) Maximum Stress occurs on Knuckle

7) Limitations:

1. There were a few limitations while using Ansys, as there were limited material options available using the free version, Aluminium Alloy material had to be used instead of 'Aluminium 6061-T6'.

2. A better result interpretation would have been obtained if the sub system parts like the brake callipers, wheel hub, bearings, rim and tyres were used but due to the material selection problem, they weren't added to the model.

CONCLUSION

Lighter weight of the upright can be achieved by proper calculations, less complex design and proper analysis. The mesh type in analysis plays a vital role in determining exact deformation and stress acting on part so Hex core mesh type is used. Hex core mesh produces even and linear mesh over the part body thus producing accurate results. Material is selected based on cost and properties as AL-6061 T6 produces almost same results when compared to AL-7075 T6 thus, AL-6061 T6 is selected.

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