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SIMULATION OF AN OFF-ROAD VEHICLE ROLL CAGE A STATIC ANALYSIS

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Abstract:
Increased concern about the rollcage of an off-road vehicle for the SAEINDIA's BAJA has created the importance of simulation thereby predicting failure modes of the frame. The objective of SAE BAJA competition is to simulate real world engineering design projects and their related challenges. The objective is to develop not only the best performing vehicle but also the rugged and economical vehicle frame that will comply all the SAE BAJA design requirements. To achieve our goal the rollcage has been analysed into different environments and each member is assigned a specific subcomponent. It is focused to, design the vehicle frame by keeping in mind the SAE BAJA requirements, driver's comfort and safety, and to increase the performance and driveability. Here the researchers carried out the static analysis in the form of frontal collision, thereby applying loads and various boundary constraints to evaluate the deformation and the von-mises stress on different members to study the high stress concentration points. The results plotted were brilliant and acceptable.

Keypoints: failure modes, rollcage, deformation, von-mises stress.

Introduction:

A frame of a vehicle is of vital important, for the passenger and mass safety the passenger cabin must of great strength to resist crimple. The front and the rear can be failed during the various testing but the passenger cabin must be safe to withstand load. It could be achieved either by using the material of high strength or of better cross section against the applied load. The SAE BAJA vehicle development manual restricts us about the vehicle weight, shape and size, and dimensions [1]. Material is also a limitation, increment in dimension raising overall weight, thereby lowering the fuel efficiency, so in order to overcome all this, circular cross-section is employed for the roll cage development. And circular section is always a perfect one to resist the twisting and the rolling effects. Circular section is preferred for torsional rigidity [2].

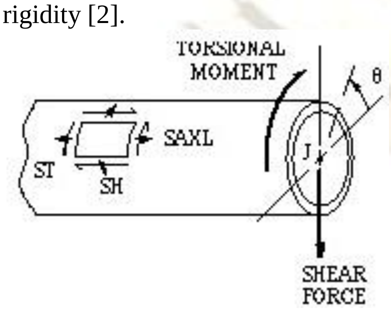

Fig 1. Section of the pipe used.

Rollcage Modelling in ANSYS:

This rollcage is developed in Ansys APDL Multiphysics Menu by plotting the keypoints, lines and arcs. The element type [3] selected for it is PIPE 16 is a uniaxial element with tension-compression, torsion, and bending capabilities. The element has six degrees of freedom at two nodes: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes. The real constants involved in the pre-processing of PIPE 16 element are its outer diameter and thickness value. The material used for the rollcage is AISI 1020 with Young's Modulus 210 GPa; yield strength is 294.8 MPa and Poisson's ratio 0.29. The density of material 8000 kg/m^3 with hardness 111 HB at ambient conditions (25°C) [4].

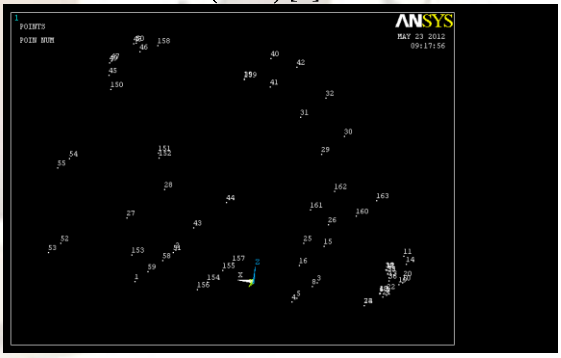

Fig 2. Modelling of keypoints with numbering

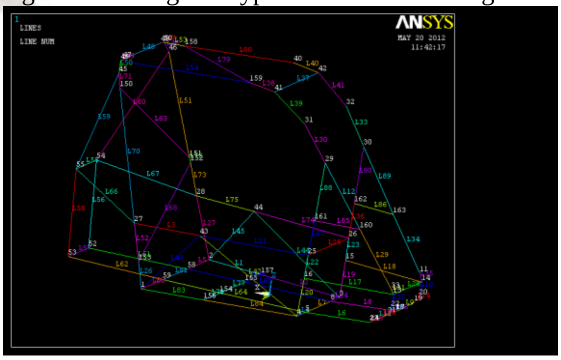

Fig 3. Modelling of lines with numbering.

Meshing, Constraints and Boundary Conditions:

The meshing has always been the key of the finite element model and for the exact solution of any object; it should be properly meshed with relevant element shape and size. Generally for the solid bodies the hexahedron mesh is preferred, so as we did. We introduced the element division in each line for the sufficient meshing, i.e., number of divisions 5.

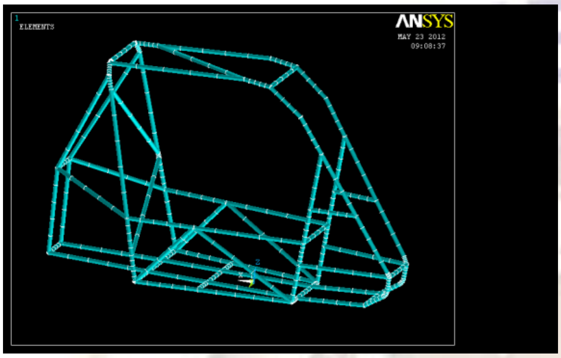

Fig 4. Meshed model with element shape.

As the rollcage was developed by plotting keypoints, lines and splines, so every member of the rollcage is considered to be properly constrained at every joint. For boundary conditions of the rollcage, it is to be fixed from the rear side or we can say that the joints of rear members will bear zero degree of freedom, and the front member will come across the applied load. The load will be distributed among the number of joints framed by front members in the opposite direction to the frame, i.e. in X axis.

Analytical calculation for frontal Impact:

The vehicle is designed for maximum speed of 15.278 mps (55 kmph). The total weight of the vehicle including the driver is estimated to be 290 kgs. For a perfectly inelastic collision the impact force [5] can be estimated by—

$$Wnet = \frac{1}{2}mv^2(final) - \frac{1}{2}mv^2(initial)$$

$$Wnet = force * displacement$$

This equation states that change in kinetic energy is equal to the net work done and the work needed to stop the vehicle is equal to the force times the distance.

$$f * d = -\frac{1}{2}mv^2$$

It is considered for the static analysis that the vehicle comes to net 0.1 sec after the impact.

For 15.278 mps speed the travel of the vehicle after the impact is 1.5278 m.

Therefore, impact force, f

$$f = \frac{1}{2} * 290 * (15.278)^2 * \frac{1}{1.5278}$$

Force, $f = 22153.1\ N$

For the perfect behaviour of the rollcage to analysed, the gravity effect has to be considered. So, we also applied the gravity of 9.81m/s^2.

Hence, applied force is 22000 N across the frame & gravity 9.81m/s^2 in Ansys APDL Multiphysics.

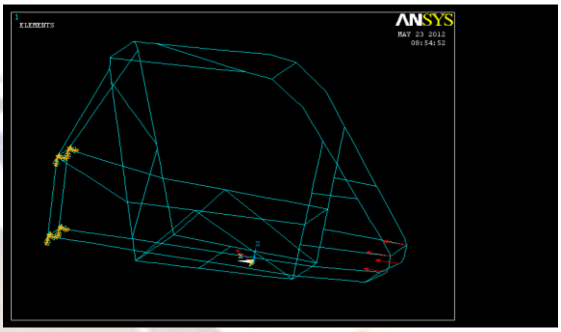

Fig 5. Applied load and displacement.

Results:

The digest of the problem is represented here in the form of deformed shape and the von mises stress plotted.

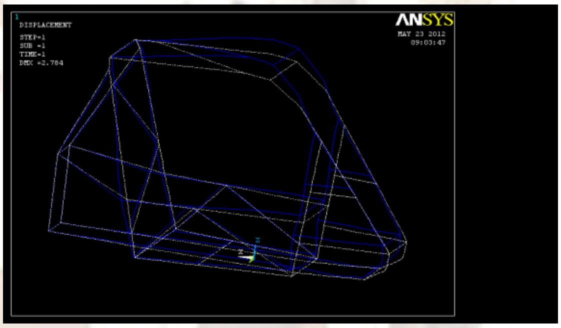

Fig 6. Deformed shape of the rollcage.

The value recorded for the deformend shape is 2.784 mm which is quite acceptable and with in the permissible limits and the nodal displacements also figures the same result with colur contours highlighting the maximum deformed members. The driver cabin members are shown with skyblue colours which reflects that safety of driver cabin even when such a high load is introduced.

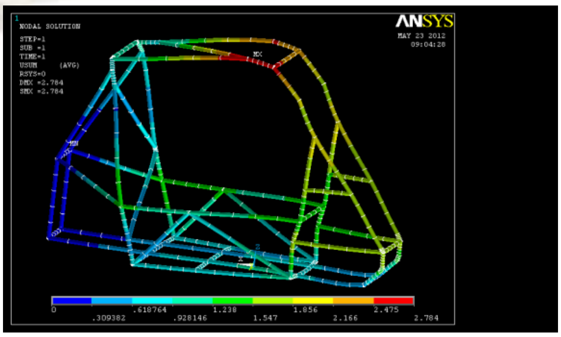

Fig 7. Nodal displacement diagram of the rollcage.

The von mises stress diagram represents the stress in individual member during the applied load. The significant value for the stress is 191.299 MPa, which is within the permissible limits of the material, depicted in figure 8.

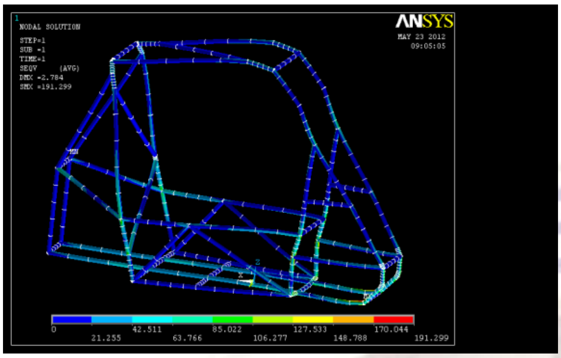

Fig 8. Von mises stress diagram.

The total mechanical strain intensity evolved in this case is 0.001175 mm shown in figure 9.

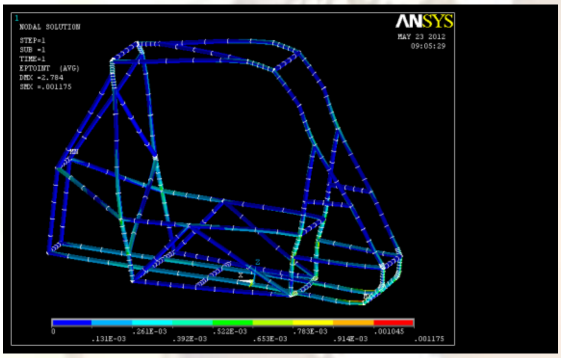

Fig 9. Total mechanical strain intensity diagram for rollcage.

Conclusion:

This project helps us to understand the vital components of designing. As mentioned above the yield strength of the material which we are using is 294.8 MPa. The maximum value of stress generated while frontal impact on rollcage is 191.299 MPa which is well within the limits. And therefore, the factor of safety of our rollcage is 1.54. Safety is of utmost concern in every respect; for the driver, crew & environment. Considerable factor of safety (FOS) or design factors is applied to the rollcage design to minimize the risk of failure & possible resulting injury. This FOS value implies the safe value of applied loads and deformations.

References:

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