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Designing and Analysis of Roll Cage of an ATV

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Abstract
Automotive chassis is an important part of an automobile. The chassis serves as a frame work for supporting the body and different parts of the automobile. Also, it should be rigid enough to withstand the shock, twist, vibration and other stresses. Along with strength, an important consideration in chassis design is to have adequate bending stiffness for better handling characteristics. So, strength and stiffness are two important criteria for the design of the chassis. This report is the work performed towards the static structural analysis of the All-Terrain Vehicle chassis. Structural systems like the chassis can be easily analyzed using the finite element techniques. So a proper finite element model of the chassis is to be developed. The chassis is modeled in Solid Works. FEA is done on the modeled chassis using the Solid Works Simulation.
Keywords: FEA, Tubular frame, Stress analysis, Finite element method, All Terrain Vehicle chassis, structural analysis

I. INTRODUCTION

Automobile chassis usually refers to the lower body of the vehicle including the tires, engine, frame, driveline and suspension. Out of these, the frame provides necessary support to the vehicle components placed on it. Also the frame should be strong enough to withstand shock, twist, vibrations and other stresses.

The chassis Frame consists of beams welded together. Stress analysis using Finite Element Method (FEM) can be used to locate the critical point which has the highest stress. This critical point is one of the factors that may cause the fatigue failure. The magnitude of the stress can be used to predict the life span of the roll cage. The accuracy of prediction life of roll cage is depending on the result of its stress analysis.

II. DESIGN OF THE ROLL CAGE

The roll cage is designed with a two box assembly one is the driver's cabin and the other one is the engine cabin. The steering system and brake system is integrated to the driver's cabin. It is done in order to get the minimum wheel base without compromising the cabin space. Several beam elements are attached to make the roll cage using the elements in solid works. The roll cage is designed so as to carry a driver of 120kg, a fire extinguisher of 2kg, an engine of 23kg and a gear box differential arrangement of 16.5kg. The beams used are pipes with thickness of 1.8cm. Pipe of circular crossection is used it is selected due to its availability in the market and its ability to withstand various forces.

III. Basic specifications of the roll cage

Total length of the roll cage : 2100mm
Maximum height of the roll cage: 1456.52mm
Wheel Base of the roll cage : 1400mm
Max Width of the roll cage : 700mm
Total weight of roll cage : 213.053kg
Outer diameter of the pipe : 33.4mm
Inner diameter of the pipe : 15.4mm
Total length of pipe used : 43.256mm
The material used is AISI 4130.

IV. Calculation of forces

The vertical forces acting on the front and rear of the roll cage is calculated.

Maximum vertical force acting on one of the wheels at the rear $= 4.5 * R$ **(1)**

$= 4.5 * 118.625$

$=533.8125\text{kg}$

Maximum vertical force acting on the one side of the rear portion of the roll cage $= \frac{P}{sin\theta}$ **(2)**

$= \frac{533.8125}{\sin(54.2151)}$

$= 6850.3832\text{N}$

Maximum vertical force acting on one of the wheels at the front $= 4.5 * R$

$= 4.5 * 63.875$

$= 287.4375\text{kg}$

Maximum vertical force acting on the one side of the front portion of the roll cage $= \frac{P}{sin\theta}$

$= \frac{2874.4375}{\sin(61.4498)}$

$= 3272.3607\text{N}$

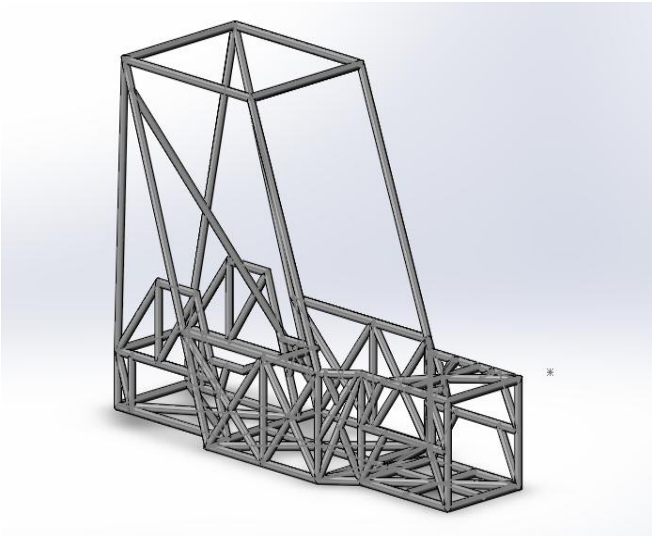

Fig 1. CAD model of Roll cage

V. Loading and Boundary condition

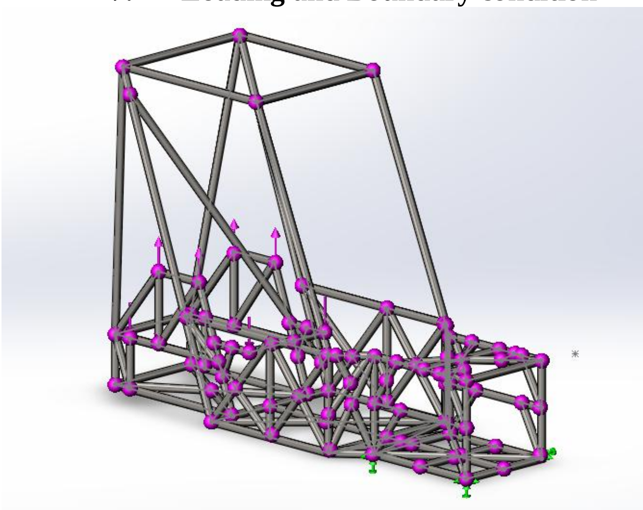

Fig 2 . Roll cage after loading

A vertical load of 10100 N is applied on either side of the rear portion of the roll cage. Along with this the weight of the driver is also added to the seat supporting member which is 1000 on each of the two joint. These forces are applied by arresting the motion of the four joints in x, y, and z directions.

Here Static structural analysis is done on the frame using SolidWorks simulation. A numerical method for approximating the displacements and resulting stresses in a model by breaking the geometry into a set of 'finite elements' and solving the appropriate partial differential equations based on specified boundary condition assumptions.

Take the universal equation of motion:

$$\frac{[M]d^2x}{dt^2} + \frac{[C]dx}{dt} + [K]x = F[t] \quad \textbf{(3)}$$

Where M is the inertia matrix, C is the damping matrix, K is the stiffness matrix.

In static analysis the loads are applied slowly and they are constant. That is the inertia matrix and the damping matrix will be equal to zero.There for F= [K]x. Also we assume a linear relationship between applied loads and induced responses. In this we assume that we do not reach yield point of materials and that deflections are small such that stress stiffening /softening do not occur.

For carrying out the FE Analysis of roll cage as per standard procedure first it requires to create merge part for assembly to achieve the connectivity and loading and constraining is required to be applied. Then idealization of parts is done on structure. This will lead to faster analysis since the connected structure will not be physical but it will be a sketch with all the mechanical properties .

VI. Meshing of Roll Cage

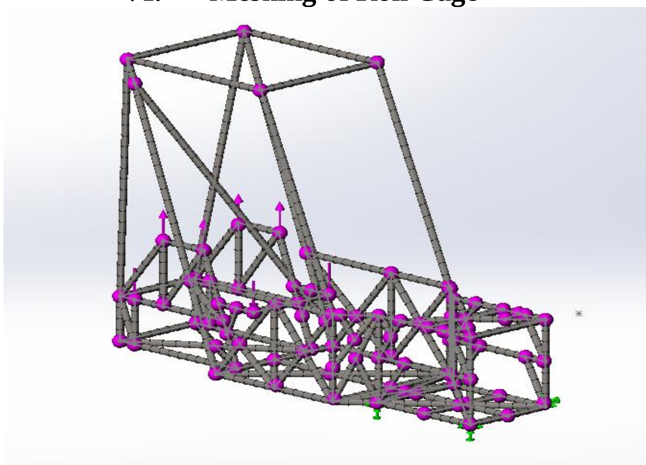

Fig 3. Roll cage after meshing

The All-Terrain vehicle Roll Cage has 1125 elements and 1099 nodes. Each node has three degree of freedom. Tetrahedral volume mesh elements are used.

VII. RESULTS

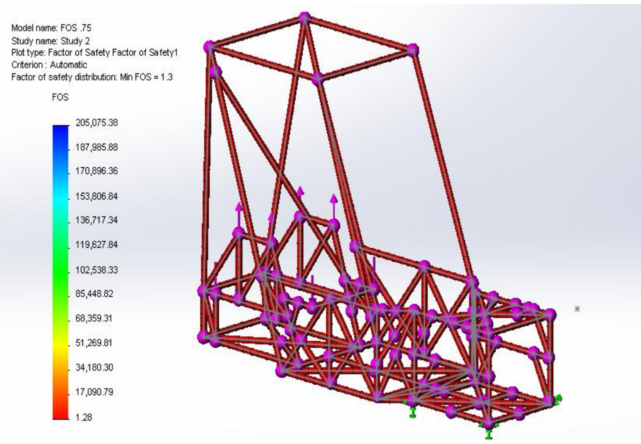

Fig 4. Factor of safety for various parts

The minimum factor of safety for the above simulation was obtained as 1.28.

VIII. CONCLUSION

The minimum factor of safety obtained for the above analysis done with calculated force is 1.28. This makes this chassis usable as a roll cage for the All-Terrain vehicle.

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