NOVEL DESIGN AND ANALYSIS ON FLAT FRAME CHASSIS FOR OFF ROAD VEHICLE

Mr. Mayur M. Jain\textsuperscript{1} and Dr. K.B. Waghulde\textsuperscript{2}

\textsuperscript{1}PG Student, \textsuperscript{2}HOD Department of Mechanical Engineering, TSSM’s PVPIT, Bavdhan, Pune

Abstract- Work gives solution to replace pipe joint at the bottom of roll cage body in the area where stability and weight loading exist. Tubular structure at the bottom surface is replaced with flat frame structure having some spaces for attachments for assembly. Overall this work is with roll cage structure design and development with the validation of flat joint. Flat frame structure with new design is verified with engineering formulation and CAE validation. Project gives optimized idea and structural development insight about typical roll cages used in off road vehicles. The benefits from it will be easiness in mounting and stability for the worst case of vehicle assembly and running conditions. Mostly dismantling items on roll cage have become very easy if we used this kind of flat body frame at least at bottom of cage.

Keywords- CAE, off road vehicle, Flat Frame, Roll Cage etc.

I. INTRODUCTION

A roll cage is a specially engineered frame built in (or sometimes around, in which case it is known as an exo cage) the passenger compartment of a vehicle to protect its occupants from injury in an accident, particularly in the event of a roll-Over also for mounting the other components of vehicle on this frame.

Automobile chassis is a skeleton on which various mechanical elements like engine, tires, axle assemblies, brakes, steering etc. are bolted. At the time of manufacturing, the body of a vehicle is molded according to the shape and size of chassis. Automobile chassis is usually made of light sheet metal or composite plastics. It provides strength needed for supporting vehicular components and loads acting on it. Chassis ensures low levels of noise and vibrations throughout the run of an automobile. Chassis is considered as a framework to support the body, engine and other parts which make up the vehicle. Chassis lends the whole vehicle support and rigidity. Chassis usually includes a pair of longitudinally extending channels and multiple transverse cross members that intersect the channels. The transverse members have a reduced cross section in order to allow for a longitudinally extending storage space.

There are many different roll cage designs depending on the application, hence different organizations have differing specifications and regulations. They also help to stiffen the chassis, which is desirable in applications.

Project work is to Design the flat frame assembly with easy attachments of cage fitment and avoiding welding joints with base frame.

II. LITERATURE SURVEY

Madhu Ps et al \cite{1} in this research work modification of chassis frame based on results and modal analysis of structure is achieved. First modelling of structure done by PRO-E software and static analysis is done by using following software Hypermesh, Radios, and Hyper view. Results show von Mises stress below yield strength of the material, which proves the design and deflection is about 5.648mm. Modification of design is done out to reduce deflection of structure. Deflection of the new
modified structure is 3.706mm. Therefore frame deflection has been reduced from 5.921mm to 3.706mm by modification. Finally the natural frequency and vibration modes of modified structure are obtained by modal analysis.

**Denish S. Mevawala** et.al [2] In this paper states that: roll cage is to provide a 3-dimensional protected space around its secondary objectives of roll cage are to provide reliable mounting locations for parts low in cost and light in weight. These objectives were met by choosing a roll cage material that has good strength and also weighs less giving us an advantage in weight reduction. The cad modeling of the roll cage chassis is done by using pro-e software. With analysis is done by some FEA softwares. We began the task of designing by conducting extensive research of ATV roll cage through finite element analysis.

**Alexander Mausolf** et.al [3] The objective of this paper is the optimization of the Chevrolet Silverado 1500 frame for the NVH load cases, using FEA methods. The prescribed content covers the complete process that starts with the baseline analysis, which at first has to be verified with the real test results and continues with the setup for each optimization. During the investigation it is at several steps obvious that the bare use of FEA methods for a successful weight saving is not the best way. Only the combination of FEA based optimization with the intelligent use of lightweight materials and today's design possibilities can lead to a perfectly optimized structure.

**Indu Gadagottu** et.al [4] states that the composite structure provides great versatility as a wide range of core and facing material combinations can be selected. The following criteria should be considered in the routine selection of core, facing, and adhesive. Static analysis calculates the effects of steady loading conditions on a structure. Modelling is done through by using solid works in existing model, after that modified model and later honey comb model is designed later on completion of modelling. Analysis will be done using Ansys 14.5

From the literature review it is seen that most of the studies on chassis frame designs had focused on Tubing pattern not considering flat frame structure considering maximum stress and deflection as a failure criterion. Therefore this study is conducted to design the chassis base structure as a flat frame by making flat joints.

### III. PROBLEM DEFINATION

**A. Problem Statement:**

Material loading vehicle have multiple mountings and accessories on bottom frame and these attachments are joined by welded joints which involves extra machining and lot of tedious work. These mounting must be easy to attach and dismantling must be feasible in this application so that fastening platform can be provided in chassis frame. For that we are planning to change pipe structure into flat flanges frame with its strength validation.

**B. Objectives:**

1. To design a flat frame chassis for the bottom of roll cage using cad Software and its strength validation by FEA and experimental method.
2. To improve the static behaviour of chassis frame by changing the geometrical dimension and structural properties.
3. To develop a new flat frame chassis.

### IV. METHODOLOGY

a) **Material Selection:**

Material selection is the basic stage before stepping towards manufacturing of the drawing analysis and production part. A vehicle frame is the strong skeleton upon which the car is constructed. So, as structural steel has good formability, good corrosion resistance. So we decided to carry out
experimentation as well as analysis work on structural steel. Among all S355JR and S235 have good formability and weldability characteristics so they were selected.

**Table 1. Mechanical properties of S355 JR**

| Sr.No | Properties                  | Values   |
|-------|-----------------------------|----------|
| 1     | Density                     | 7850 kg/m³ |
| 2     | Yield Strength              | 355 MPa  |
| 3     | Tensile Strength            | 476-630 Mpa |
| 4     | Min Impact Energy at (20°C) | 27J      |
| 5     | Elongation                  | 18-20 (%) |
| 6     | Young’s Modulus             | 190-210 Gpa |

**Table 2. Mechanical properties of S235**

| Sr.No | Properties                  | Values   |
|-------|-----------------------------|----------|
| 1     | Density                     | 7750-8300 kg/m³ |
| 2     | Yield Strength              | 195-235 MPa |
| 3     | Tensile Strength            | 360-510 Mpa |
| 4     | Min Impact Energy at (20°C) | 25J      |
| 5     | Elongation                  | 20-24 (%) |
| 6     | Young’s Modulus             | 190-210 Gpa |

b) Primary Design:

Creo-2 has been used for 3d modelling of frame parts and assembly in CAD. Ansys workbench is using for CAE results and modal analysis. Three stage assembly of frame is drawn by taking three frames components to assemble. All the components are taken into dimensioning of frame layout are provided by supplier inputs.

Working of base plate as a platform for holding whole assembly. This base plate will play
important role to execute scrapping application as all the boundary conditions.

![Image](image1.png)  ![Image](image2.png)

**Figure 1. Layout of Frame Assembly**  **Figure 2. Complete Assembly**

c) Analytical Treatment:

Bending of frame components or plate bending, refers to the deflection of a plate perpendicular to the plane of the plate under the action of external forces and moments. The amount of deflection and stresses can be obtained by solving the differential equations of an appropriate plate theory. The stresses in the plate can be calculated from these deflections by making use of sfd, bmd diagrams. The stresses values, failure theories can be used to decide whether a plate will fail under a provided load. So fbd, sfd, bmd for all 3 parts have been drawn to calculate max stress and max deflection.

**Frame 1**

![Image](image3.png)

**Figure 3. FBD**

![Image](image4.png)

**Figure 4. Shear Force Diagram**
From the BMD maximum bending moment occurs at center and is 125625 N-mm. According to bending equation, bending stress is given by

$$\sigma_b = \frac{M_b y}{I}$$

Hence,

$$\sigma_b = 58.88 \text{ N/mm}^2$$

Maximum deflection occurs at center and is given by,

$$\delta_{\text{max}} = \frac{W L^3}{192 E I}$$

$$\delta_{\text{max}} = 0.26884 \text{mm}$$

**Frame 2**

From the BMD of frame 2, maximum bending moment occurs at center and is $M_b = 56644 \text{ N-mm}$. According to bending equation, bending stress is given by

$$\sigma_b = \frac{M_b y}{I}$$

Hence,

$$\sigma_b = 20.42 \text{ N/mm}^2$$

Maximum deflection occurs at center and is given by,

$$\delta_{\text{max}} = \frac{w L^4}{384 E I}$$

$$\delta_{\text{max}} = 0.02211 \text{mm}$$

**Frame 3**

From the BMD of frame 3, maximum bending moment occurs at center and is $M_b = 225000 \text{ N-mm}$. According to bending equation, bending stress is given by

$$\sigma_b = \frac{M_b y}{I}$$

$$\sigma_b = 105.47 \text{ N/mm}^2$$

Maximum deflection occurs at center and is given by,

$$\delta_{\text{max}} = \frac{W L^3}{192 E I}$$

$$\delta_{\text{max}} = 0.054930 \text{mm}$$
d) CAE Validation:
The cad model designed in CREO is imported in ANSYS workbench and is used for the Stress and Deformation analysis. Meshing is done in Ansys itself. Specific boundary conditions were given and particular loads were applied as per inputs for testing purpose.

**FEA Analysis on Frame 1:**

**Figure 6. Max Stress**

**Figure 7. Max Deformation**

**FEA Analysis for Frame 2:**

**Figure 8. Max Stress**

**Figure 9. Max Deformation**

**FEA Analysis for Frame 3:**

**Figure 10. Max Stress**

**Figure 11. Max Deformation**

e) Experimental Method:
Analytical methodology is an approximate method for the part analysis. So the Numerical result has to be compared with either FEA results or with experimental results to ensure validity as per working requirement and the safety of the component.
Figure 12. Experimental Setup
This is the Semi-Automated Strain Gauge Output Analogue on which Experimental testing is carried out. Strain gauges are fixed on testing specimen by soldering operation. After loading machine gives strain developed into the specimen. By using stress strain relation stress occurring in a component is calculated. Pneumatic or Hydraulic bar are used for loading.

Figure 13. Components Loaded For Experimental Validation

V. RESULTS AND DISCUSSION

Percent deviation in stress obtained by using FEA and experimental analysis is within the acceptable limits. Thus numerical as well as experimental result shows that flat frame chassis designed with flat joints and suitable material has reduced the stress concentration compared to existing chassis structures around.

Table 3. Results

| Parameter       | Engineering | CAE  | Testing |
|-----------------|-------------|------|---------|
| Frame 1         |             |      |         |
| Bending Stress  Mpa | 58.8        | 52.78| 69      |
| Deformation mm  | 0.26        | 0.18 | 0.24    |
| Frame 2         |             |      |         |
| Bending stress Mpa | 20.42       | 18.95| 17.96   |
| Deformation mm  | 0.022       | 0.016| 0.017   |
| Frame 3         |             |      |         |
| Bending stress Mpa | 105.47      | 107.5| 104     |
| Deformation mm  | 0.055       | 0.08 | 0.064   |
VI. CONCLUSION

Structural arrangement with flat frame chassis is feasible solution towards saving cost and manufacturing difficulties. Conventional way of tube structure is more complicated and non-necessity for heavy chassis frames so we have avoided importing heavy conventional chassis structure. Though both systems are weldment structured our solution is very fine and light as it is removable assembly from vehicle integration assembly.

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