NON LINEAR ANALYSIS OF ROLL OVER PROTECTION STRUCTURE

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Abstract- Roll over Protection Structure (ROPS) is a structure of vehicle and are expected to prevent overturn deaths. Rollover of a vehicle is most common due to imbalance, high speed, high center of gravity and also working on slopes and rough terrain. After Rollover vehicle may block the doors complicating the escape of passenger and may lie on its side or roof. In such conditions ROPS are expected to protect the occupant or driver. This paper depicts the importance of computer aided modeling and finite element analysis. Meshing and Non linear analysis was performed by using different software on newly designed SD190 Full ROPS as per ISO 3471.

Keywords- ROPS, SD190, Non linear analysis, Rollover

I. INTRODUCTION

Rollover protective structures are safety devices fitted to vehicles to provide protection to the driver during rollover of vehicle. In addition to provision of safety, the ROPS also acts as a base for mounting various sub-systems of the vehicle. It also helps the vehicle to strengthen under various collisions, which is desirable in racing and off-road applications. There are different ROPS designs depending on the application, hence the vehicle manufacturers have differing specifications and regulations. Heavy vehicles like tractors and loaders when working on slopes and uneven surfaces with high speed and high centre of gravity are susceptible to dynamic instability. Under these conditions, vehicle rollover, which results in many injuries and fatalities to occupants, increases. Heavy machinery is equipped with protective structure which even under rollover, provide safe zone (no obstruction by the structure) for operators. Such Rollover Protective Structures (ROPS) are expected to meet minimum performance criteria to ensure occupant safety.

The paper shows the CAD model of the structure and the meshing and Non linear analysis performed. Design of the cabin structure has been developed by using CAD tool CATIA V5.

Methodology for simulating the rollover conditions was validated and then MODAL and NON–LINEAR analysis has been carried out using ABAQUS software using beam elements, shell and Hexa elements. Nonlinear analysis has been done based on the loading standards.

II. LITERATURE SURVEY

Most of serious accidents occur when using a tractor which is not compliant with safety protection requirements, especially when the roll-over protective structure (ROPS) was not installed, or it was temporary folded in order to carry out some particular works. Even if two posts front mounted foldable ROPS can be folded down only for tractor storage or maintenance (as formally specified also in users’ manuals provided by manufacturers), and always kept upright up the rest of the time the tractor is used, an high percentage of cases of non correct use of this type of ROPSs has been encountered. Thus, a specific research work by Gattamelata D (2012) was carried out in order to design a non foldable ROPS for narrow-track wheeled tractors, which provides rollover protection all the time without making agricultural works more difficult. [6]

Roll-over protective structures (ROPS) are known to prevent tractor overturn deaths, but not enough tractors are equipped with them in the United States to reduce the rate of these deaths to levels seen in several European countries. Data from a national survey for the calendar year 2003 were used to assess the prevalence of ROPS use on Hispanic-operated farms. The overall ROPS prevalence rate on Hispanic farms was 52.2%. The age of the farm operator, the farm status as a full- or part-time operation, and the type of farm operation were also important factors. The results can be used to target ROPS promotion programs for Hispanic farmers across the United States. [5]

A rollover protective enclosures same kind of frame but totally encloses with metal and glass. Phenomena of experimental testing and performance parameters required for tractor cabin were used as per SAEJ2194 in mathematical model. Meshed model was created using Hyper Mesh and 1D mesh model was created using Hyper Beam. Methodology for simulating the rollover conditions was validated and then non–linear quasi-static analysis was carried out using Radioss
Bulk and Block on structure using beam elements and full shell mesh model. Displacement control method was used for simulating the rear and front longitudinal crushing, rear and front vertical crushing and lateral crushing. Design of the cabin structure used in the analysis was safe under rollover, pitch over and crushing loading. Obtained results show that middle post contributes significantly to the resistance of the structure to vertical crushing loads. Hence, a six posts design is better over four posts structure. [4]

Saini Amandeep Singh study will deals with edge preparation techniques employed prior to welding to strengthen the ROPS and corresponding strain energy absorption at the time of collision. The ROPS is subjected to different loading conditions like front impact, rear impact, side impact and roll-over. The experiment to be performed will be scrutinized considering different edge preparations i.e. the welding of pipes at the joints will be performed with no space groove preparation, with 2.5 mm space groove preparation and 5.0 mm space groove preparation. After performing the analysis, the strength of the weld is compared against all the considered cases. Also the strain energy absorbed in each case is investigated. Obviously the one with lesser Von-Mises stress will be a better design. From the simulation it can be concluded that, the ROPS with no space provided during groove preparation, provides better protection and safety i.e. higher weld strength. The deformation during the collision increases correspondingly with the groove gap of the edge preparation. The strain energy absorption shows an upward trend parallel to the stress value.

III. CAD MODELING

CAD modeling was done by using the tool CATIA V5. Like any modeling package CATIA has some modeling guidelines. Simple guidelines for CAD Modeling in CATIA are given below. These are company specific guidelines. The ROPS structure was prepared and Figure 4.1 shows the isometric view of the ROPS.

1. Always use positive bodies to add and remove the material. Use Boolean operations for adding and removing the bodies. Use simple sketch/curve to create features. For metal components always use shell command for uniform thickness as last feature.

2. Make sure to use different bodies for each and every attachment. Use axis systems for creating new components. Do not link up with one part to another. The model should be always parametric. The following sequence should be followed for developing specification tree. Sketch based features are used first then surface based up features, dress up features and the holes and chamfer. Transformation features are mostly avoided.

3. Use non hybrid design, it makes easy to modify or replace reference elements easily. Generative shape design is used wherever it requires. The merging distance for join command should be 0.001mm. Use the reference surfaces in different geometrical sets for different bodies. Always rename the bodies and geometrical sets, it will easy to refer and continue the work for the next designer. Draft analysis is performed before releasing the component.

4. Check the clashes in assembly after designing the part. Check section cut in x, y and z directions to avoid interferences. Design a component in such a way that it should be assemble easily with minimum cost.

5. Assembly Name = Assembly Instance Name.x = Filename.

6. All Parts and Assemblies should have a Product Description (Properties Menu).

7. Broken links should be immediately reattached with File + Desk and Edit + Links or by using Replace Component.

8. Constraints are permitted between parts within a single assembly. Fix all Assembly Components that are not constrained. Parts should not be hidden in the assembly structure.

9. Make sure that angle of projection is as per the client requirement before starting the drafting. Dimensions should be fully associative on exact views. Dimensions are not permitted on Isometric Views or picture drawings. Avoid Fake dimensions. Drawings are numbered with the first nine digits of the assembly or part number with a suffix indicating the drawing sheet number -01, 02, etc. (i.e. M57P54321-01). One sheet per CAT Drawing. (No limit on the number of detail sheets per drawing). All Drawings should be created with the proper Title Block as per company templates. All views should be locked prior to filing or vaulting. View frames should be turned off prior to vaulting. Section Views should not be pasted across drawings. The section should be generated from a front view which is scaled down, moved off the drawing sheet, and hidden.

Fig 1: CAD Model generated using CATIA
IV. FE MODELING

FE modeling is converting CAD model in to small elements which will be used to solve the problem by iterative method. One should know the area of interest for the analysis. Normally, all metallic parts need to be converted in to FE entities. Ornamental parts, cloths, rubber padding, etc. may not be modeled to help reduce work. FE model has been created using HM 10.1 and following are the details of parameters considered. The complete FE model is shown in fig 4.3

i. All plates are modeled using SHELL modeling.
ii. All Beams are modeled using BEAM modeling.
iii. All welds are modeled using SHELL modeling.
iv. All beams are modeled with linear properties.
v. All Non Linear springs modeled using spring Elements.
vi. All Linear springs modeled using spring Elements.
vii. Lap welds are modeled by connecting both the plates using shell elements and throat size of weld has been used as the shell thickness for weld elements. But in case of Filled/T-joint, the plates or channel s are extended to create the weld connection.

<table>
<thead>
<tr>
<th>Quality Parameters</th>
<th>Targets</th>
<th>Absolute Values</th>
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<tr>
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<tr>
<td>Total Quads</td>
<td>Total Trias</td>
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</tr>
</tbody>
</table>

There are some points to be taken care while preparing the FE model. Free edges, duplicates are critical and should be monitored. Some rules and guidelines below will help us to check the model.

1. There should not be free edges in the model. If unintended free edge is left, it is treated as a crack in the part.
2. Duplicate elements should be avoided.
3. Shell normal should be consistent. It makes considerable difference in the results if there are any deviations as mentioned above.
4. Mesh should be refined in the area of our interest.
5. There should not be Triangular elements near weld and the bolt holes.
6. There should not be triangular elements over fillet.
7. Mesh transition should be smooth and features should be properly captured.
8. Element size should not be very small to avoid high computation cost.

V. MATERIAL DATA, ISOLATOR DATA AND ANALYSIS CRITERIA

1. Analysis Criteria
The lateral load (120834 N) and strain energy (23818 J) criteria must be attained as per ISO 3471 standard in lateral loading.

Material Properties
i. Material - 1:
   a) Linear Properties:
   Young's Modulus (E) = 205000 Mpa
   Poisson Ratio = 0.3
   b) Non-Linear Properties:
ii. Material - 2:
   a) Linear Properties:
      Young's Modulus (E) = 205000 MPa
      Poisson Ratio = 0.3
   b) Non-Linear Properties:
      True Stress - True Strain Curve

iii. Material - 3:
   a) Linear Properties:
      Young's Modulus (E) = 205000 MPa
      Poisson Ratio = 0.3
   b) Non-Linear Properties:
      True Stress - True Strain Curve

iv. Material - 4:
   a) Linear Properties:
      Young's Modulus (E) = 205000 Mpa
      Poisson Ratio = 0.3
   b) Non-Linear Properties:
      True Stress - True Strain Curve

v. Material - 5:
   a) Linear Properties:
      Young's Modulus (E) = 1000000 MPa
      Poisson Ratio = 0.3

vi. Material - 6:
   a) Linear Properties:
      Young's Modulus (E) = 1000000 MPa
      Poisson Ratio = 0.3

2. Material Plot:

3. Isolator properties:
   Each isolator has been simulated as non-linear translational (Kx, Ky, Kz) springs and linear rotational (K_θx, K_θy, K_θz) springs.
b) Non-Linear properties:

### Force -Deflection Curve

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4.2 Von-Mises Stress

The von-Mises stress results of both the designs for lateral loading are as shown in figure 8.3.

The maximum stress obtained is 830.638N/mm² for baseline design and 832.203 N/mm² for modified design in case of lateral loading.

4.3 Von-Mises Plastic Strain

The von-Mises plastic strain results of both the designs for longitudinal unloading are as shown in figure 8.4.

The maximum strain obtained is 0.02 for baseline design and 0.02 for modified design in case of lateral loading.

**CONCLUSION**

The paper gives the designer CAD modeling techniques and FE modeling techniques. Material properties are shown. Vector sum displacement, von-mises stresses and von-mises plastic strain are shown. The analysis of lateral loading is done and further analysis can be done on vertical loading and longitudinal loading. Experimental results can also be preformed to correlate the analysis. Fatigue analysis can also be perform further to know life of structure.

**REFERENCES**


