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Design and Optimization of Tractor Roll Over Protective Structure

[1] Mr. Sachin R. Shende, [2] Prof. V.P.Kshirsagar,[3] Mr. Ganesh R. Shelke
[1] Research Scholar, [2]Assistant Professor, [3] Research Scholar
[1] Dept. of Mechanical Engineering
[1] Wainganga College of Engineering & Management, Nagpur, India

Abstract - **The aim of this study is to describes the roll over Protective Structure of the tractor in cases of unbalance due to misalignment of Centre of gravity. It also ensures the increased percentage of occupant safety as compared to pre-existing design of Roll over protection structure (ROPS) is a frame or cab which protects operator in the event of roll over. This paper depicts the experimental and analytical investigation of Four-post ROPS of tractor. The experimental testing of ROPS is carried out as per ISO 3471: 1994 static load standard. The analytical investigation is done by using different computer aided desi gn, finite element analysis.. In order to accurately determine the stress , a nonlinear finite element analysis was carried out taking into account plastic deformations, residual stresses developed before and after design modification And these result comparing with the help of graphical representations.**

Index Terms - **ROPS; finite element analysis; residual stresses; four-post ROPS.**

I. INTRODUCTION

Tractor rollovers account for 50% of tractor related fatalities in the United States. Distracted operators, speed, and rough or uneven ground are leading causes of tractor rollover. Rollover protective structures (ROPS) became available for tractors in the mid 1960’s and were not available for all new tractors until the mid-70's. However, they were not standard equipment on new tractors until 1985. Many tractors built before that time is still in use and they contribute to the tractor fatality rate because they are not ROPS and seat belt equipped. Use of ROPS and seatbelt are 99.9% effective in preventing deaths due to tractor overturns.

All mobile machinery is at the risk of rolling over, depending on the machine characteristics, working environment and terrain. So the need to protect the operator from the risk of being injured or causing death due to a roll over has been of prime importance in the design and development of all machinery. Although the development of standards has been outpaced by the evolution of the machines, countries world over have set standards addressing the safety of the operators which these machines need to conform

For tractors that are not equipped with a ROPS, check with the manufacturer or dealer for the Discuss safe driving practices for farm tractors and machinery. Focus on the following safety precautions in preventing rollovers. availability of ROPS retrofit kits. If they are available, the tractor should be retrofitted. Install and use seat belts on tractors with ROPS. Seatbelts ensure that the operator stays within the “zone of protection” offered by the ROPS during a tractor mishap. Seatbelts should not be used on tractors without ROPS. Rollover protective structures do not prevent rollovers, but 99.9% effective in preventing death or serious injury. Distracted operators, speed, slopes, and uneven ground are leading causes of tractor rollover.

Roll-over protective structures (ROPS) are safety devices which provide a safe environment for the tractor operator during an accidental rollover. The ROPS must pass either a dynamic or static testing sequence or both in accordance with SAE J2194. These tests examine the performance of ROPS to withstand a sequence of loadings and to see if the clearance zone around the operator station remains intact in the event of an overturn. In order to shorten the time and reduce the cost of new product development, non-linear finite element (FE) analysis is practiced routinely in ROPS design and development. By correlating the simulation with the results obtained from testing a prototype validates the CAE model and its assumptions.

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II. EXPERIMENT

Material

In this study, Fatalities can be prevented or minimized due to vehicle turnover by the presence of ROPS. ROPS are one of the best machines to study on as they find application in a spectrum of industries. The current prevailing Roll-Over Protective Structure of tractor or other vehicles in the industry are made of structural steel. The average mechanical properties of structural steel are given in Tables 1. Materials of this type are widely used in automotive industry to fabricated the roll over protective structure of tractor.

Table 1 Mechanical properties of ROPS

Material	Density (Kg/m^3)	Yield strength (Mpa)	Ultimate strength (Mpa)	Young’s modulus (Mpa)	Poissons Ratio
structural steel	7850	20	460	2E+05	0.3

Experimental Procedure

The following procedure for Roll-Over Protective Structure (ROPS) are as :

1. CAD Modeling of Roll-Over Protective Structure (ROPS) in Creo-Parametric 2.0 (Pro-Engineer) Software.
2. Meshing Of Roll-Over Protective Structure (ROPS) in which we calculate the nodes and elements with the help of ANSYS Software.
3. Applying the Boundary Condition i.e, fixed support and tensile Forces.

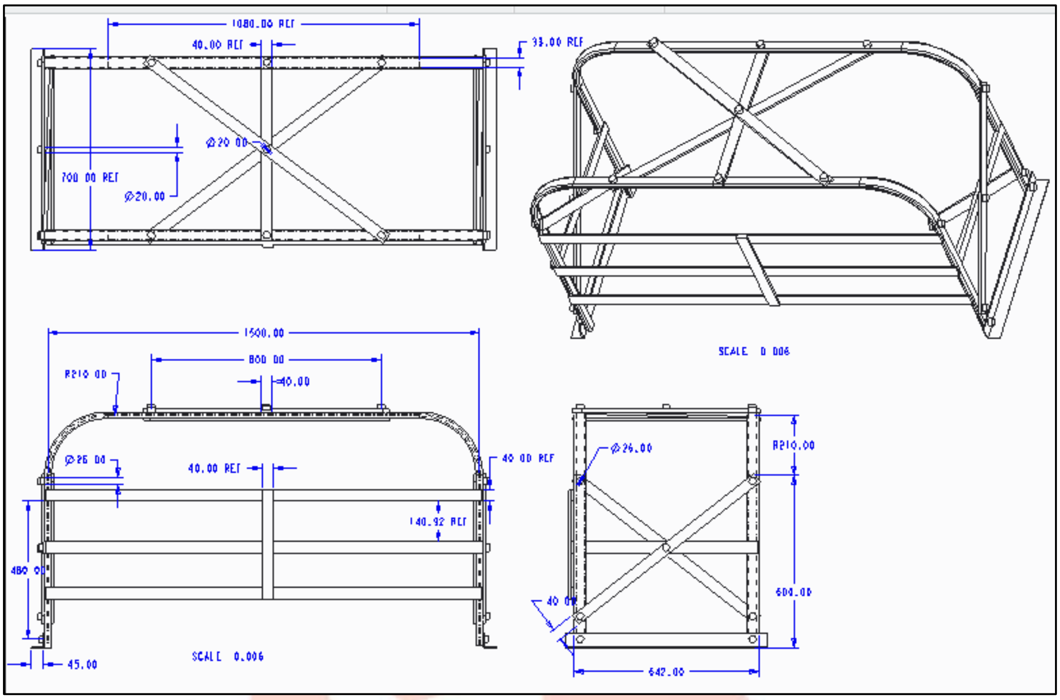


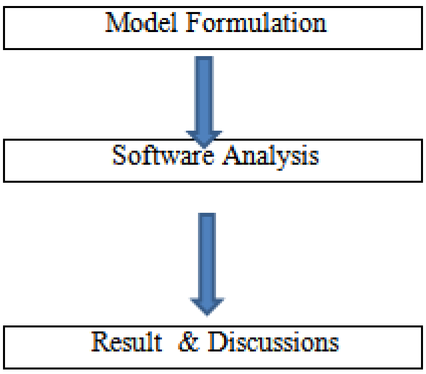
Fig. 1 Configuration of Roll-Over Protective Structure (ROPS) (unit : mm)

III. FINITE ELEMENT ANALYSIS

In order to optimize the Roll-Over Protective Structure (ROPS) models, the stress states developed in the structure should be determined accurately. For this purpose, a commercial FEA software, ANSYS (version 15), was used. Residual stresses developed during the formation of Roll-Over Protective Structure (ROPS). However, the residual stresses arising from non-uniform plastic deformations during loading were determined throughout the nonlinear stress analysis

Many different types of mechanical systems are usually uses different methods for calculations of stresses. Finite element analysis using analytical method for such system is quite difficult, but it can be make convenient by changing general machine system such as an airplane engine, transmission system, a diesel engine drive or a boat etc, to an equivalent disc and shaft system. So for same purpose simplified method has been integrated and developed which are given in this project and that can be surely used to solve for stresses of system.

For finding the stresses in Roll-Over Protective Structure (ROPS), we can use the ANSYS software. First upon we create the model in Creo-parametric 0.2 software. ANSYS and Creo-parametric 0.2 both are design software. In this we can find out lovarious result related with design phenomenon



Meshing

ANSYS meshing technologies provide physics preferences that help to automate the meshing process. For an initial design, a mesh can often be generated in batch with an initial solution run to locate regions of interest. Further refinement can then be made to the mesh to improve the accuracy of the solution. There are physics preferences for structural, fluid, explicit and electromagnetic simulations. By setting physics preferences, the software adapts to more logical defaults in the meshing process for better solution accuracy.

After Meshing in ANSYS Software, find out Nodes and Element ,
Nodes : 84146, Element : 42313

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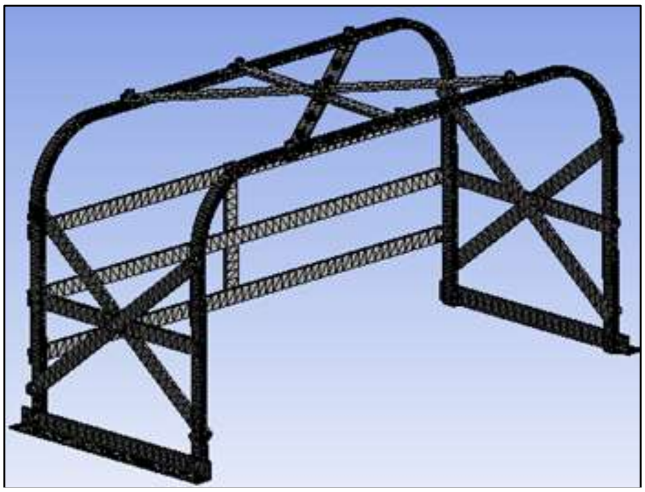


Fig.2 Meshing in the FE model

boundary conditions

The boundary conditions in the FE model of Roll-Over Protective Structure (ROPS) are shown in Fig.3,4 and 5. The loading application points for lateral, vertical and longitudinal directions are first marked on modified ROPS. These loading on the modified ROPS structure as per standards described in ISO standards.

Lateral loading

The load application points in the case of lateral loading are applied at center of the lateral supporting plate. The dimensions of the same are given in the figure 1. And lateral loading on the M-ROPS shown in 3 A] Force1 = 20000N; B] Force2 = 20000N; C] Fixed Support

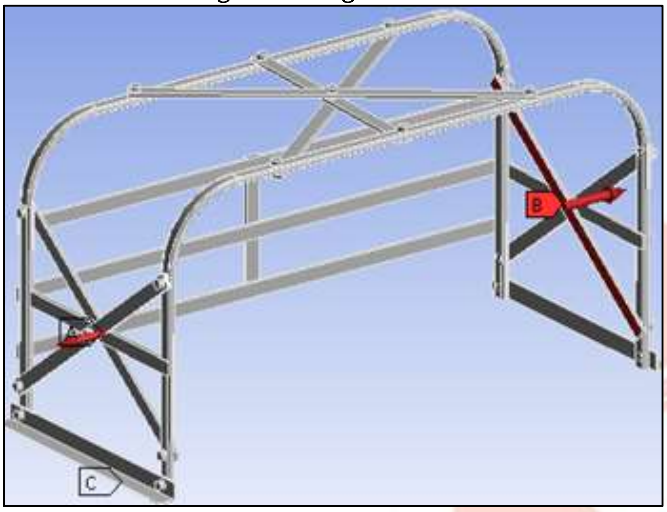


Fig. 3 Lateral loading of Modified ROPS

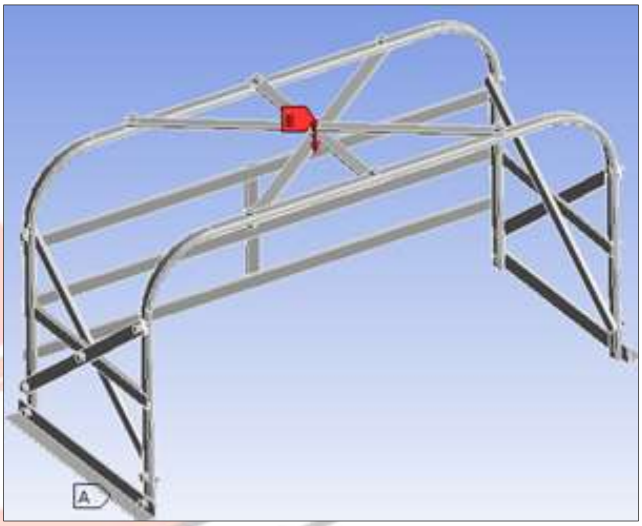


Fig. 4 Vertical loading of Modified ROPS

Vertical loading

After removal of lateral load, the vertical load is applied. The load application points in the case of vertical loading must be at the center of the modified ROPS structure. The dimensions of the same are given in the figure 1 and vertical loading on the M-ROPS shown in 4. A] Fixed Support; B] Force = 20000N

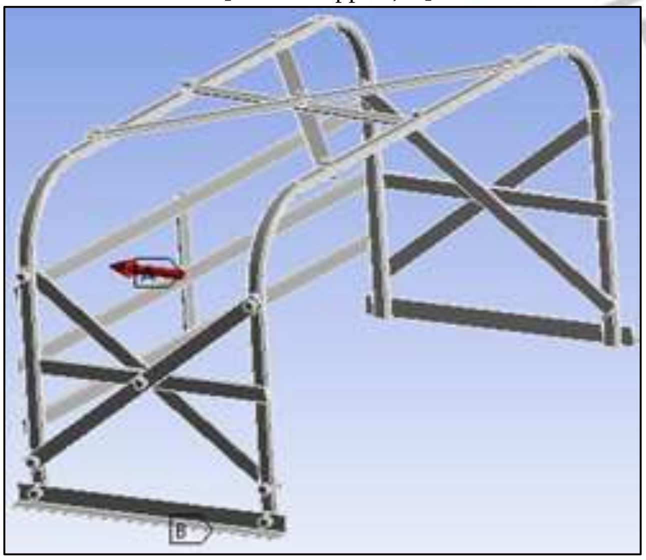


Fig. 5 longitudinal loading of Modified ROPS

Longitudinal loading

After removal of vertical load, the longitudinal load is applied. The load Application point in the case of longitudinal loading must be at the center of the width of the modified ROPS structure. The load application point needs to be parallel to the longitudinal center line of the structure These rule the design of the load application device and the dimensions of the same are given in the figure 1 and longitudinal loading on the C-ROPS shown in 5. A] Force = 20000N; B] Fixed Support

Simulation Results comparisons of current ROPS With modified ROPS :

Vertical Loading

Total Deformation Max.= 4.5536 mm

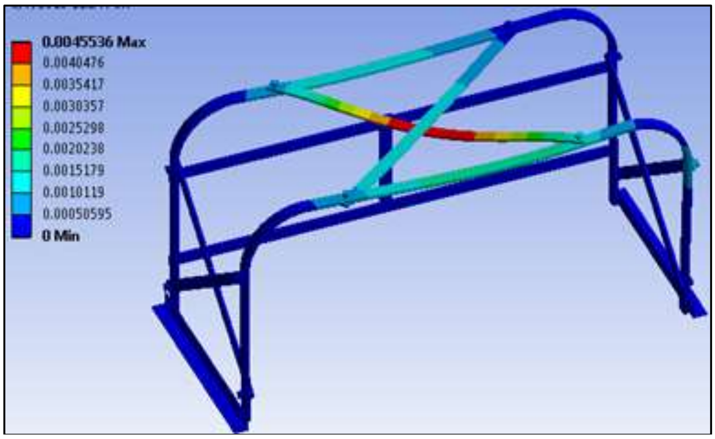


Fig.6 Total Deformation during vertical loading on C-ROPS

Total Deformation Max.= 3.0189 mm

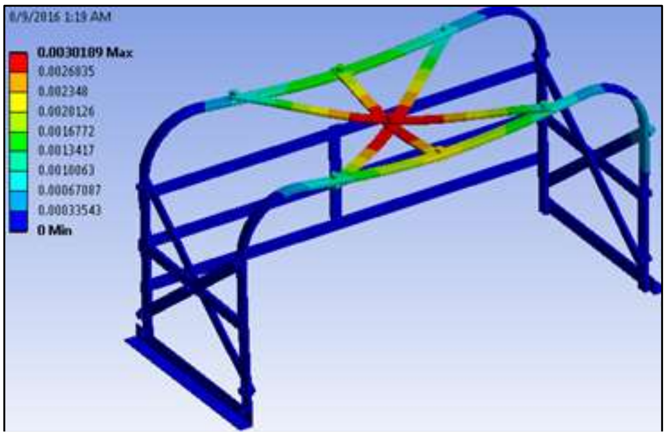


Fig. 7 Total Deformation during vertical loading on M-ROPS

von-Mises Stress Max.= 2.7063 Mpa

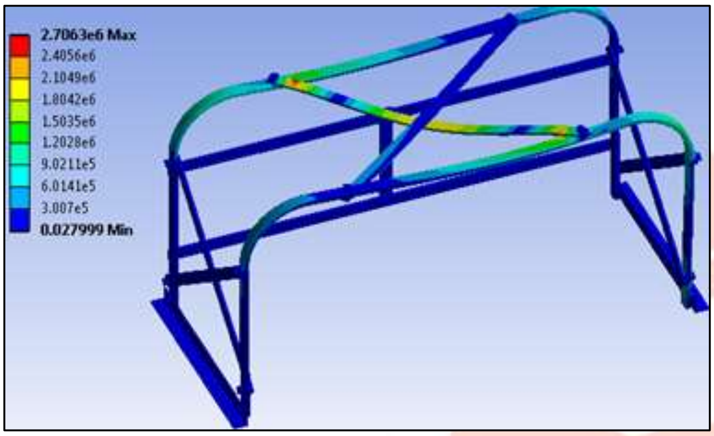


Fig. 8 von-Mises Stress during vertical loading on C-ROPS

von-Mises Stress Max.= 2.7063 Mpa

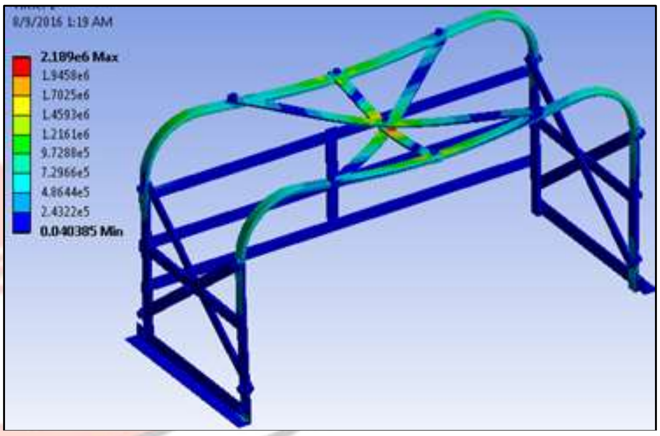


Fig. 9 von-Mises Stress during vertical loading on M-ROPS

Maximum Principal Stress Max.= 2.6847 Mp

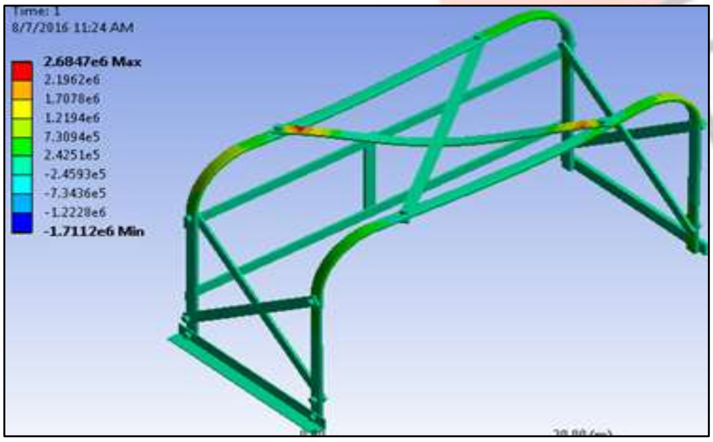


Fig. 10 Maximum Principal Stress during vertical loading on C-ROPS

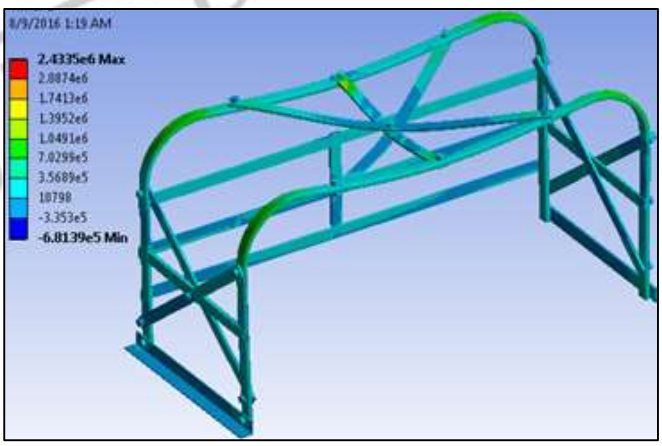


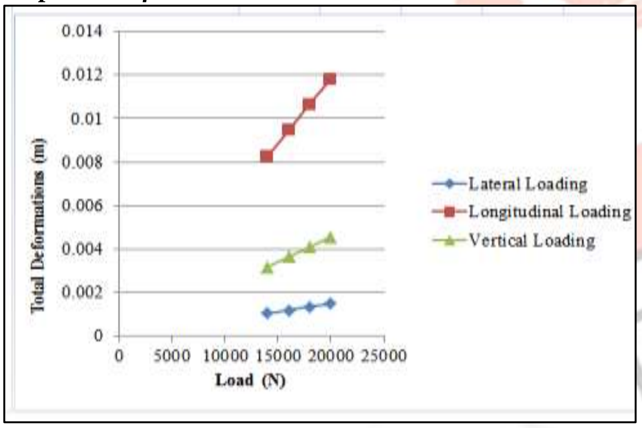
Fig. 11 Maximum Principal Stress during vertical loading on M-ROPS

Similarly result are found in C-ROPS and M-ROPS for lateral, longitudinal and vertical loading therefore all results are shows in tabulated form in current ROPS and modified ROPS as shown in table 2

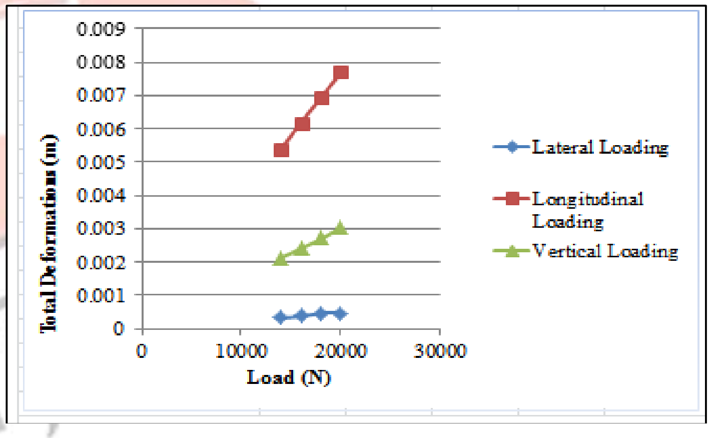
Table 2 - Results of C-ROPS and M-ROPS

Types of Loading	Load (N)	Current ROPS Results			Modified ROPS Results		
		Total Deformations (m)	Von-mises stress (MPa)	Maximum Principle stress (MPa)	Total Deformations (m)	Von-mises stress (MPa)	Maximum Principle stress (MPa)
Lateral Loading	14000	0.001043	2.2968	2.1987	0.00032828	1.7511	1.7298
	16000	0.001192	2.6249	2.5128	0.00037518	2.0013	1.9724
	18000	0.001341	2.953	2.8269	0.00046897	2.2514	2.2189
	20000	0.00149	3.2811	3.1409	0.00046897	2.5016	2.4655
Longitudinal Loading	14000	0.0082673	4.655	4.7513	0.0054001	3.077	3.5133
	16000	0.0094484	5.32	5.4301	0.0061716	3.5166	4.0132
	18000	0.010629	5.985	6.1088	0.006943	3.9561	4.5171
	20000	0.01181	6.65	6.7876	0.0077144	4.3957	5.019
Vertical Loading	14000	0.0031875	1.8944	1.8793	0.0021132	1.5323	1.7034
	16000	0.0036429	2.1651	2.1477	0.0024151	1.7512	1.9468
	18000	0.0040982	2.4357	2.4162	0.002717	1.9701	2.1901
	20000	0.0045536	2.7063	2.6847	0.0030189	2.189	2.4335

Comparison of the C-ROPS and M-ROPS

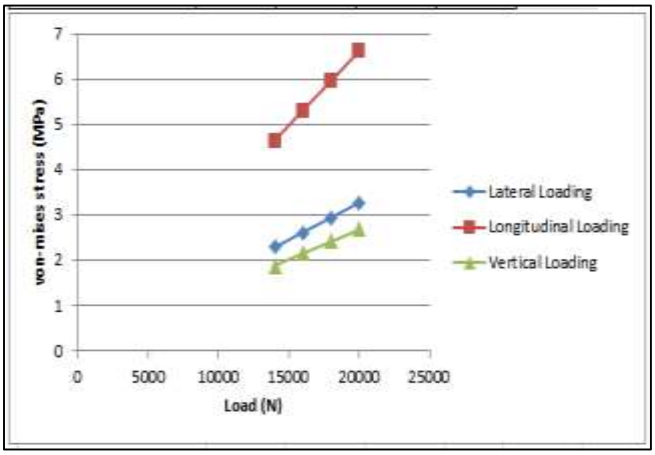


Fig, 12 Load (N) VS Total Deformation (m) of C-ROPS

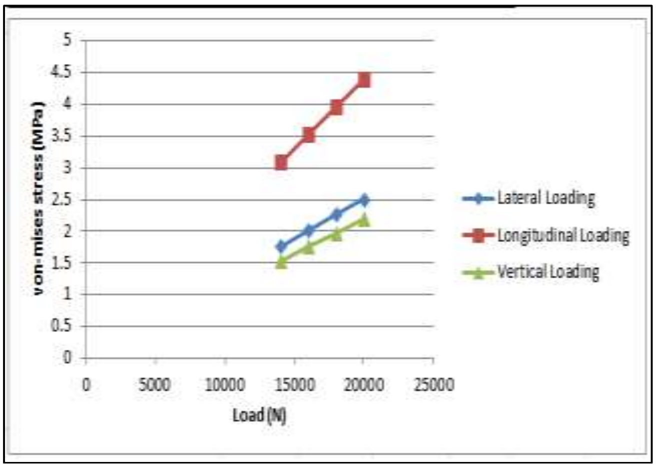


Fig, 13 Load (N) VS Total Deformation (m) of M-ROPS

Above graph shows the variation in Total deformation (m) with load (N). It was found that there is a direct relationship between the Total deformation (m) with load (N). For Current design, the total deformation is attained at longitudional load range with a deformation of 0.008m to 0.012. and it can be reduced, For Modified design, the total deformation is attained at longitudional load range with a deformation of 0.005m to 0.008. Similarly, For the Current design, the total deformation is attained at lateral and vertical load range can be reduced for modified design at respective loadings. The results summary is shown in figure 12 and 13.

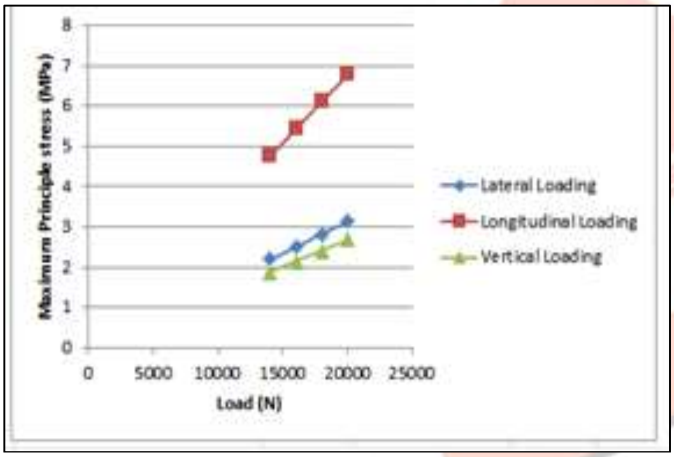


Fig, 14 Load (N) VS Von-Mises Stress (MPa) of C-ROPS

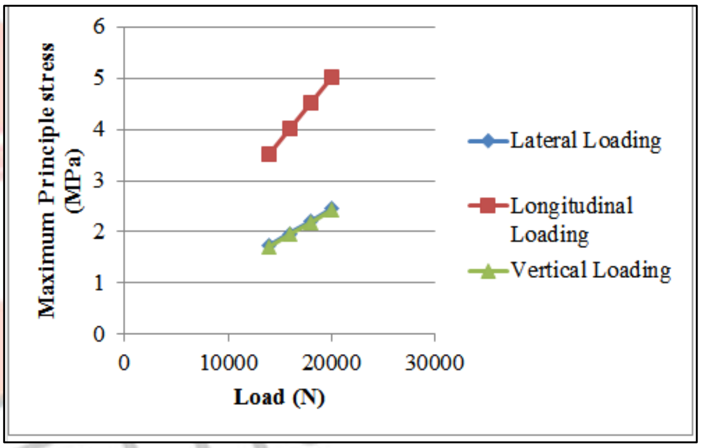


Fig, 15 Load (N) VS Von-Mises Stress (MPa) of M-ROPS

Above graph shows the variation in von-mises stress (MPa) with load (N). It was found that there is a direct relationship between the von-mises stress (MPa) with load (N). For Current design, the von-mises stress is attained at longitudional load range with a von-mises stress of 4.66 Mpa to 6.65Mpa. and it can be reduced, For Modified design, von-mises stress is attained at longitudional load range with a von-mises stress of 3.00Mpa to 4.5 Mpa. Similarly, For the Current design, the von-mises stress is attained at lateral and vertical load range can be reduced for modified design at respective loadings. The results summary is shown in figure 14 and 15.



Fig, 16 Load (N) VS Maximum Principal Stress (MPa) of C-ROPS



Fig, 17 Load (N) VS Maximum Principal Stress (MPa) of M-ROPS

Above graph shows the variation in maximum principal stress (MPa) with load (N). It was found that there is a direct relationship between the maximum principal stress (MPa) with load (N). As the load increases the maximum principal stress is also increases. For Current design, the maximum principal stress is attained at longitudional load range with a maximum principal stress of 5.00 Mpa to 7.00Mpa. and it can be reduced, For Modified design, maximum principal stress is attained at longitudional load range with a maximum principal stress of 4.00Mpa to 5.00 Mpa. Similarly, For the Current design, the maximum principal stress is attained at lateral and vertical load range can be reduced for modified design at respective loadings. The results summary is shown in figure 16and 17.

IV RESULTS AND DISCUSSIONS

Based on the information available in Literature and results listed above we come to a conclusion that Rollover accidents in Heavy commercial vehicle are violent and cause greater damage and injury as compared to other type of accidents. Roll over analysis is still fairly unexplored topic and needs lot of further research. During roll over the structure of driver cabin need to sustain as much load as possible to protect the driver.

FEA analysis can be done effectively to evaluate the strength of the ROPS. The results obtained from current design i.e. deformation and stresses are reduced the results obtained in modified design.

Cost reduction is the key to the success of any industry and if it supplemented with the weight reduction, it gives further advantage of additional mileage (fuel efficiency) to the vehicle. This CAE driven design methodology not only reduces the product development cycle but also can provide verified and optimized design concepts to the design group before releasing final design.

The Analysis and results of both designs are compared. The loads are applied according to analysis performed in all loading cases and stresses are compared.

V CONCLUSION

The effects of the loading and geometric configuration on ROPS structure can be directly incorporated in the structural stress method. Tensile tests are done for the roll over protective structure. It was observed that the von-Mises Stress and maximum principal stress is maximum for current design of ROPS and minimum for minimum for modified design So it is found that we come to a conclusion that Rollover accidents in Heavy commercial vehicle are violent and cause greater damage and injury as compared to other type of accidents. Roll over analysis is still fairly unexplored topic and needs lot of further research. During roll over the structure of driver cabin need to sustain as much load as possible to protect the driver.

The current design has been assessed with 3 design modifications including removing one central supporting plate on rear , lateral and vertical side of structure

The modified design has shown a slight marginal improvement (2 to 3 %) in the max displacement under the load achieved for similar loading conditions.

The results indicate all these 3 design modifications can be incorporated and needs to be incorporated together as a package.

VI ACKNOWLEDGMENT

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