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EXPERIMENTAL AND ANALYTICAL INVESTIGATION OF ROLLOVER PROTECTION STRUCTURE FOR AGRICULTURAL WHEELED TRACTOR

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ABSTRACT

These research work describes the roll over nature of the tractor in cases of off balance due to misalignment of centre of gravity. It also ensures the increased percentage of occupant safety as compared to pre-existing components or design architects Roll over protection structure (ROPS) is a frame or cab which protects the seat belted operator in the event of roll over.. This paper depicts the experimental and analytical investigation of two-post foldable ROPS of agricultural tractor. The experimental testing of ROPS is carried out as per IS:11821(Part2):1994 and 2009/75/EC static load standard. The analytical investigation is done by using different computer aided design, finite element analysis.

KEYWORDS: ROPS, 2009/75/EC, IS:11821 (Part-2), Non-linear Analysis, Tractor Rollover.

INTRODUCTION

On event of trolley or trailer carrying vehicles like tractor, possess high ratio of unbalanced center of gravity, especially this tractors off balance in circumstances of steep, slopy region, valley roads or uneven distribution of grounds (e.g. sugarcane carrier tractors of the rural area). In this circumstances the tractor off balances loosing centre of gravity, resulting roll over situation. For such a situation a protective device or frame has to be designed and implemented so as to protect the occupant operating the tractor. A safety frame known as a Roll over protective structure (ROPS) has emerged as the most suitable method for affording the protection for operators of such vehicles during rollover. Roll over protection structure (ROPS) is a frame or cab which protects the seat belted operator in the event of roll over. ROPS protects the zone of protection of operator and absorbs the kinetic energy of the vehicle after roll over. From observations it is sought out that, the material handling equipment like Rubber-tired, self-propelled scrapers, Rubber-tired front end loaders, Wheel-type agricultural and industrial, Tractors, Crawler tractors, Crawler-type loaders, Motor graders shall be equipped with ROPS as per OSHA (Occupational Safety and Health safety for Agriculture) regulation..

The ROPS is considered as a safety component which protects the operator. There are various regulations which assesses the quality and design of ROPS depending upon in which region it is going to be used. The criterions of standards specifies the energy absorption and load bearing capability. The physical roll over conditions are simulated in the standards. As per standards in ‘Rear longitudinal loading’ the ROPS should absorb the strain energy of at least 1.4 times the reference mass of the tractor, in ‘Transverse loading’ ROPS should absorb the strain energy of at least 1.75 times the reference mass of the tractor& Crush or vertical loading the ROPS should withstand the load of 20 times the reference mass.

This paper presents the experimental and analytical investigation of ROPS as per standards. The analytical investigation is done with the help of Computer aided design, finite element analysis. The analysis of the ROPS was compared with testing results, concluding that design is safe for the occupant in roll over conditions.

The specific potential benefits of this research include the following:

1. This project depicts the importance of Finite Element Analysis techniques for probabilistic design of ROPS design evaluation.
2. It explains steps involved in FE Analysis of the ROPS as per 2009/75/EC and correlated with tests performed.
3. It gives the direction to the designer for selection of material.

METHODOLOGY

As per standards mentioned the experiment was carried out. For study the Rear longitudinal loading case is considered where the energy criterion is 1.4 times the reference mass. As the more than 50% mass of the tractor is on the rear wheel the load is applied from rear to front direction on upper frame at one sixth width. During loading the strain energy absorbed by the ROPS is determined by recording the force and deflection simultaneously. Then the correlation between the experimental and finite element analysis results is found. The finite element analysis of ROPS is nonlinear in nature due to material, geometric and contact non-linearity. Since the loading is concerned with the energy absorption capacity, hence to account this consideration analyses are performed in displacement control mode instead of force control mode.

EXPERIMENTAL INVETIGATION

Under the rear longitudinal loading the force is applied on upper frame at one sixth width. During loading the failure is observed at hinge location at 22 kN of corresponding 89 mm of deflection. The experimental set up and failure is shown in below figures 1.

Figure 1: Experimental Set up

CAD Modelling

Since the accuracy of result depends upon the CAD geometry and quality of meshing. The CAD modelling of two post foldable ROPS was done by using CATIA V5 software. CATIA has advanced features for solid modelling. The isometric view of ROPS is shown below in figure 2.

Figure 2: CAD model of two post foldable ROPS.

FE Modelling

The approach of finite modelling is to divide the body into finite number of elements, solving the problem for each elements and combining the solution for whole body. The FE model of ROPS is created by using Altair Hypermesh 15 by importing the CAD model. The mid- surfaces were extracted from the CAD model. The complete ROPS assembly comprised of shell elements, beam and rigid elements. The mesh model contains 12067 shell elements with 12518 number of nodes. To ensure computational convergence and to keep computational time reasonably low, minimum element length used is 8 mm. The features like fillet, small holes having dimensions less than 8 mm were deleted because of less structural significance. The FE model is shown below in figure 3.

Figure 3: FE model of two post foldable ROPS

Boundary Conditions

In order to simulate experimental model accurately where the base of ROPS is fixed to the tractor chassis, in FE model the base is constrained at each translational degree of freedom. Loading was achieved by motion of rigid plunger over the zone same as that in experimental test.

Material Properties

The material properties of ROPS main frame is calculated by uniaxial tension test. The tensile test was conducted on the sample derived from the existing design and on the basis of this results gained ,it was further utilised to analytical and experimental evaluation.. The material properties are converted to true stress and true strain suitable for non-linear analysis. Figure shows the engineering stress-strain curve of materials.

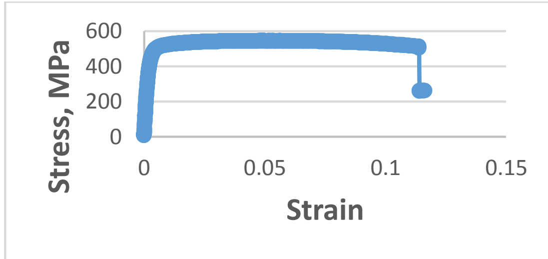


Figure 5- Engineering stress-strain curve of material.

FEA Results

The analysis of ROPS under Rear Longitudinal loading in Von-Mises stress distribution, effective plastic strain for ROPS frame and hinge are shown in below figures6 &7. The load deflection of plunger is also shown in below figure8.

The Von-Mises stress distribution of ROPS under the rear longitudinal loading shows that the significant yielding at lower portion of ROPS left pillar and at hinge point of pillars. The yielding can also be verified by the effective plastic strain distribution.

The load deflection profile for ROPS under applied rear longitudinal loading compares well that obtained from the corresponding experimental loading indicates the developed numerical model is stiffer.

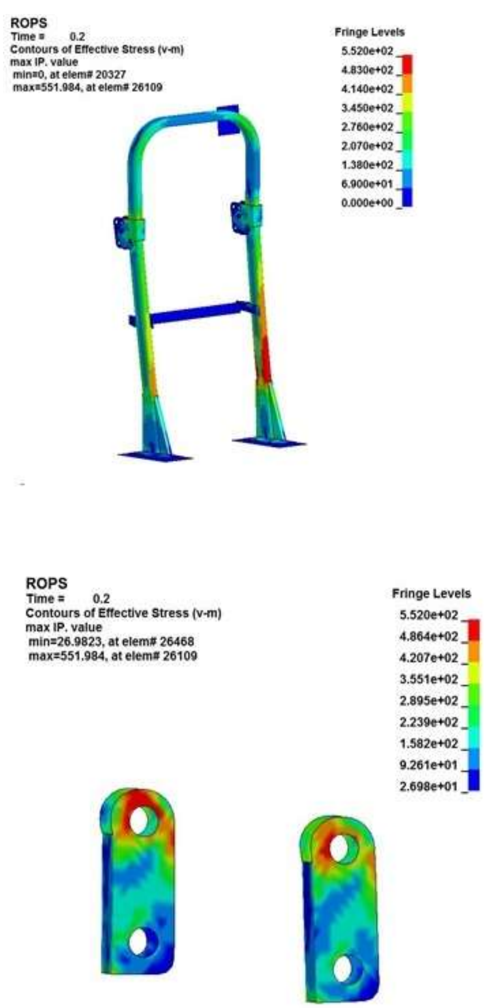


Figure 6: Von- Mises stress distribution of ROPS

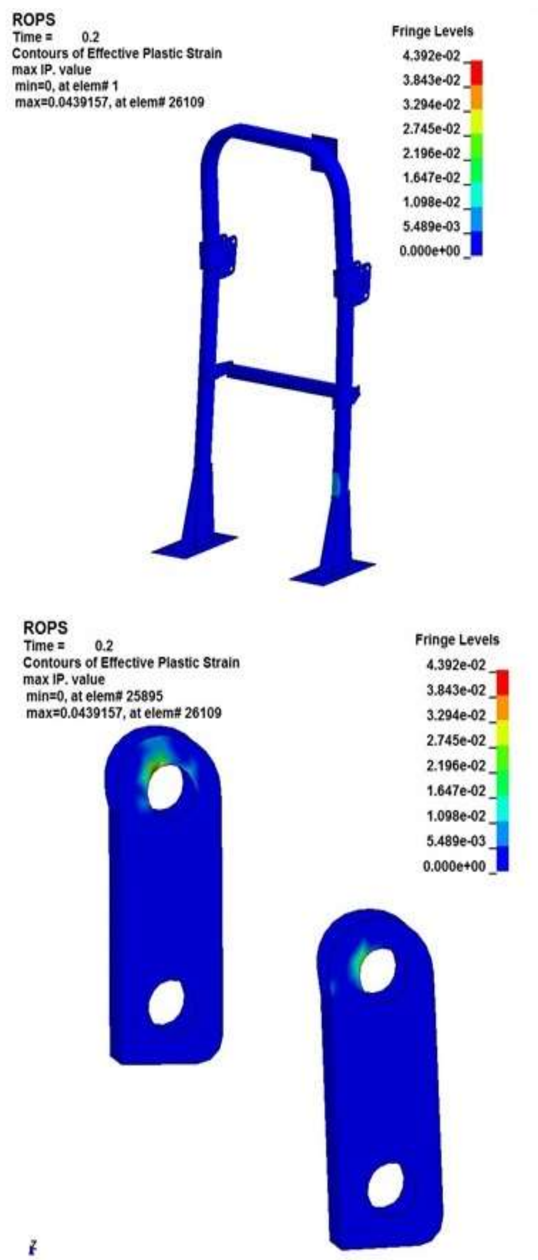
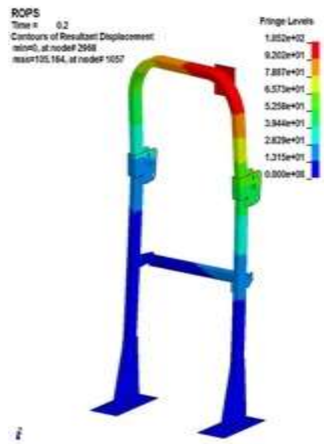


Figure 7: Effective Plastic strain distribution of ROPS



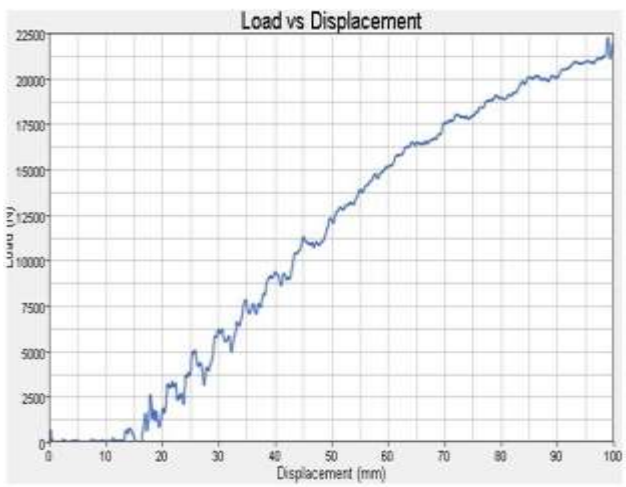


Figure8: Displacement of ROPS

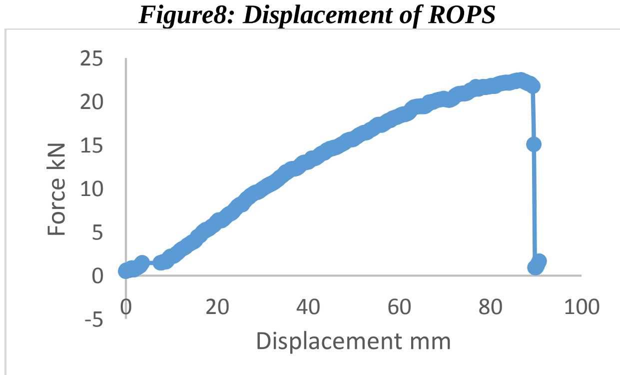


Figure9: Experimental Result of ROPS force vs displacement

Modified Design

The major modification had been made in the ROPS assembly to absorb the required strain energy. Since the ROPS could not absorb the strain energy as the failure observed at hinge of ROPS pillar. The hinge provided for folding the ROPS in rearward direction was sheared off by the pin. The material of hinge was the prominent factor to enhance the performance of the ROPS. Previously it was low carbon material, hence the material of high tensile strength selected as per IS:2062:2011 Hot rolled medium and high tensile structural steel.

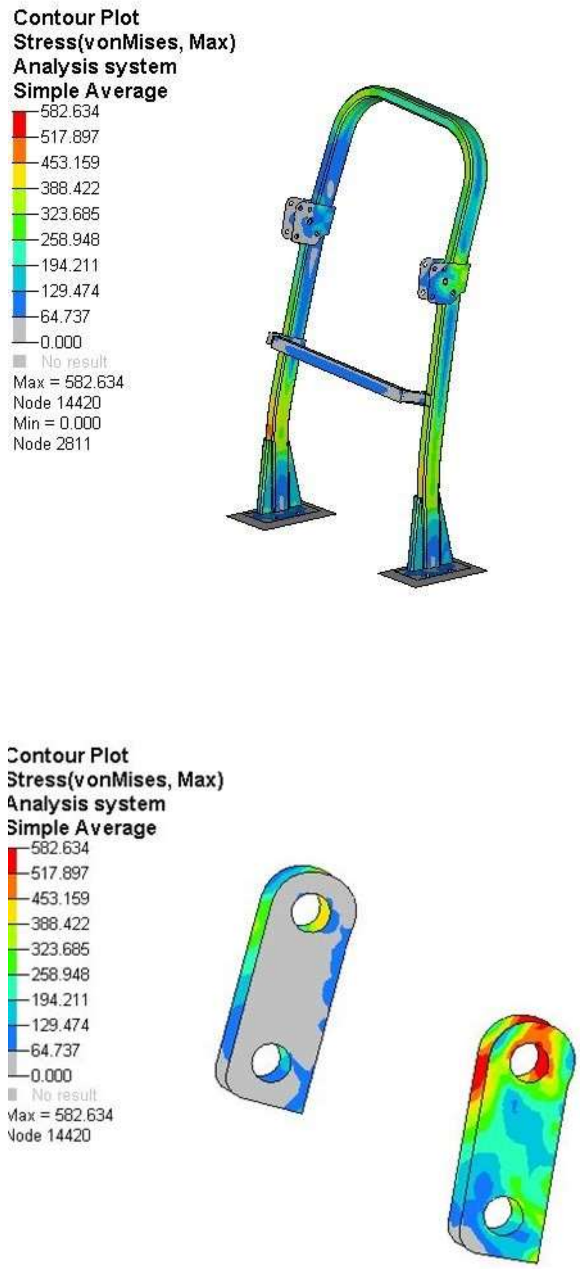
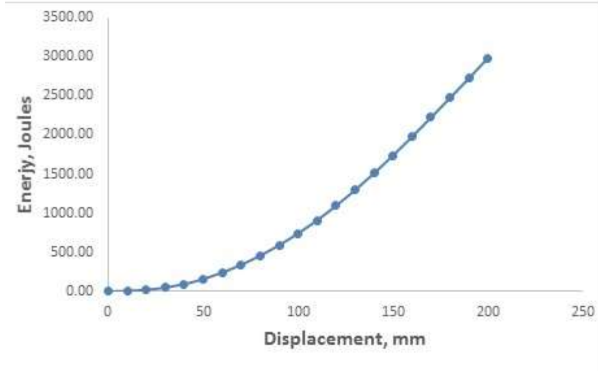


Figure 10: Von-Mises Stress Distribution of ROPS with modified design



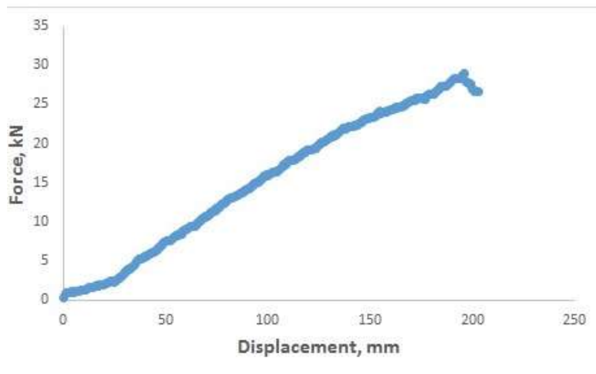


Figure 11: Experimental results of ROPS with modified design

CONCLUSIONS

It was observed that modification of the existing design and proper selection of material sustained more energy absorbing capacity at the hinges, where it was failed in number of attempts previously. The newly designed material seems to withstand the roll over condition making it more safety aspect for the occupant, and hence can be utilized in the existing design making it more reliable in terms of safety standards.

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