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Reinforcement Design and Crash Analysis of Medium Duty Trucks for Rollover Crash Accidents

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***Abstract:*-- Safety of the driver and other occupants of the medium duty trucks during the event of the crash is a vital consideration for Cab body in white design. According to the data released by NHTSA, there were 37,461 people killed in crashes in 2016 which is a 5.6% Increase as compared to the previous year [6]. In the past, most of the dynamic analysis were done by testing or contracted out. Now with the use of Computer simulation the dynamic analysis can be simulated to reflect real world testing.**

Virtual simulation in the computer provides opportunities to reduce development time and also reduces number of physical prototypes consumed for verification of the design and its validation for safety regulations. Among rear, front impact and rollover accidents, rollover accidents results in severe casualty for occupants.

As per Regulation ECE-R29.03, the cab body of the medium duty truck shall be so designed and attached to the vehicle in such a way that in the event of crash it exhibits a sufficient survival space and eliminate the risk of injury for the occupants to the greatest possible extent. In this project, simulations are performed to verify various safety aspects to ensure crash worthiness using the nonlinear explicit finite element program ANSA and LS-DYNA[11] to the baseline model of the truck for rollover 180 case (which constitutes both side impact and roof crush) as per ECE-R29.03 and the intrusions are recorded. It is found that the Baseline Cab is failed for crash and there is a need for strengthening the cab by adding few reinforcements at different locations [5].

Now various Reinforcement concepts are developed and added to the Cab at the rear wall and roof and simulations were performed in the form of iterations and the results are obtained. These results are correlated with the Baseline crash results. Finally, it is found that the crash results have improved.

Key Words- Reinforcements; Rollover; Body in White; Baseline; Simulation

I. INTRODUCTION

In recent times, the safety of the occupants has become more and more important for truck design. The legal requirement for the safety of the occupants is mentioned in ECE R-29 regulation and these are already in force in Europe [3]. Equivalent regulation in India is Automotive Industry Standard AIS-029.

As specified in the regulation ECE R29-03[8], there are three tests; Test A: Frontal impact; Test B: A-pillar strength test; Test C: Rollover 180 test. Among all the three Rollover 1800 is the most critical one as it includes both side impact and roof crush, hence in this study Rollover 1800 case is studied.

II. TEST REQUIREMENTS OF ECE-R29-03: ROLLOVER 1800/ROOF STRENGTH TEST

Rollover 1800/Roof strength test is shown in figure 1. the test depicts the whole process of 180° rollover accidents, it includes two parts, Test A:Side Impact, dynamic pre-loading to test the strength of the roof longitudinal beam and the upper of A-pillar when 90° rollover occurs, the impact energy of the rectangular impactor shall be 17.6 KJ; Test B: Roof quasi-static load to test the roof strength when truck rolls over up to 180°, a static loaded corresponding to the maximum mass authorised for the front axle or axles of the vehicle, subject to a maximum of 100KN[2].

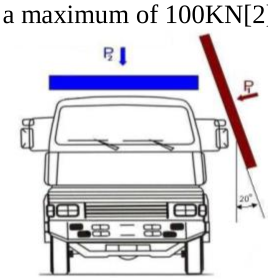

Figure 1: Roof strength or Rollover 1800 crash test [1]

III. NUMERICAL SIMULATION OF BASELINE CAB FOR ROLLOVER 180O TESTS

Here the medium duty truck cab model is chosen for simulation which has FAW (Front Axle Weight) 75KN, hence the design the done considering the FAW.

1. Description of FE Model[9][10][3]

1a: Components used in Cab Model:

FE model used for simulation consist of major parts like welded cab assembly structure, steering column, steering wheel, cover of steering column and wheel, instrument panel

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mounting structure and brackets, chassis frame, front and rear suspensions of cabin etc.

1b: Meshing Details and Boundary Conditions:

The model is meshed in ANSA which is a preprocessing tool; the global size used for meshing is 8mm (average). The sheet metal parts were meshed by shell elements (Quad elements) and solid elements (Tetrahedral elements). The complete shell model of the Cab BiW (Body in White) will be obtained by following mid surface extraction procedure. Manual meshing is done to maintain a smooth mesh flow shown in Figure 2 by controlling the number of Tria elements, as these elements are rigid and will not deform at any load conditions. Spot welds were modeled using spot elements (Hexa) using different cards in ANSA.

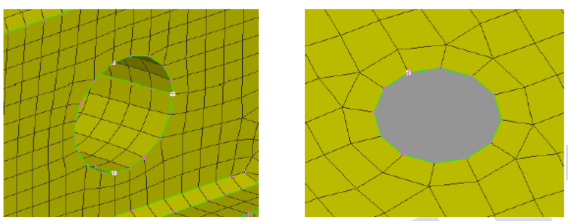

Figure 2: Smooth/ Proper Mesh Flow

The Baseline Model of the truck is constrained at three locations at the chassis using rope or chain elements in ANSA

1c: Parts Material Details:

The entire cab body consists of around 300 parts having different materials. Cold Rolled Steel is used for the parts having thickness <3mm and Hot Rolled Steel is used for the parts of thickness >3mm. The Steel used has Strength ranging from 120MPa to 350MPa.

1d: Load Conditions:

Concerning Roof Strength Test, The Impactor Load condition for Dynamic pre-loading is similar to Test A and Test B as mentioned above, the loading device for Roof Quasi-Static Load is a rigid with a mass equivalent to front axle load of the vehicle, for simulation, the rigid plate is represented by a thin plate made up from shell elements which is placed on the roof and set free in gravity.

1e: Pre/Post Processing:

The Pre-Processing uses ANSA, The entire crash process which includes both side impact and roof crush is simulated for 1.2 seconds in the solver LS-Dyna and the results are extracted using post processor MetaPost.

2. Results of Numerical Simulation of the Baseline Cab Model: Rollover 180^0/Roof Strength tests

The simulation results of the Baseline Model for Rollover 180 which includes side impact and Roof crush is shown below:

2a: Rollover 1800: Side Impact results (Test A) for Baseline Cab Model

The criterion for Side Impact passing is that the dummy should not touch the Body side of the cab during impact. Firstly the distance is measured from body side RH to dummy at Driver location before running simulation. The distance is found to be 295 mm as shown in the Figure 3below:

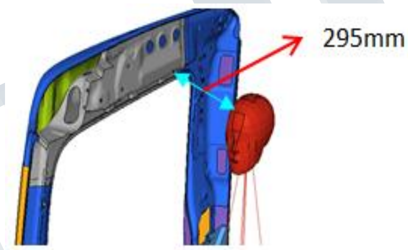

Figure 3: Distance from Driver Dummy to Body side

Then again the distances are measured after simulation, the difference between the two gives the Intrusions.

Below Figure shows the body side in contact with the dummy, there is a risk of Driver coming in contact with side. After the side impact, there is 15mm penetration at the driver side hence creating negative survival space which is clearly shown below in the sectional view:

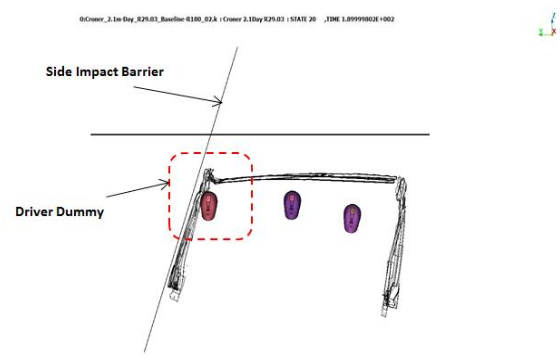

Figure 4: Side Impact showing Driver in contact with the body side (Sectional View)

2b: Rollover 1800: Roof Crush results (Test B)

The second step in Rollover 180 case is roof quasi-static load to test the Roof strength when truck rollovers up to 1800. The results for Roof crush test are shown below in the Figure 5. It can be seen that the rectangular barrier crushes the occupants and there is no survival space.

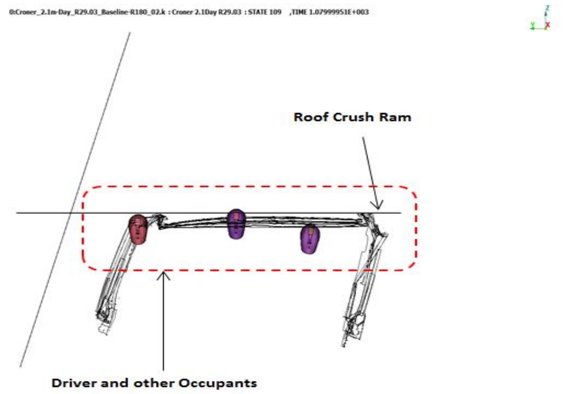

Figure 5: Roof Crush showing occupants in contact with the roof (Sectional View).

The figure 5 shown above represents the sectional front view of the cab at occupant's location. From the figure, we can see that the Intrusions are penetrating the manikin/dummy and there is no survival space which can be seen as a dotted red line.

2c: Baseline Cab Crash results summary:

The curve below shows Force vs Displacement vs Time for Baseline Cab, it depicts both Side Impact and Roof Crush tests. The following inferences can be drawn from the curve:

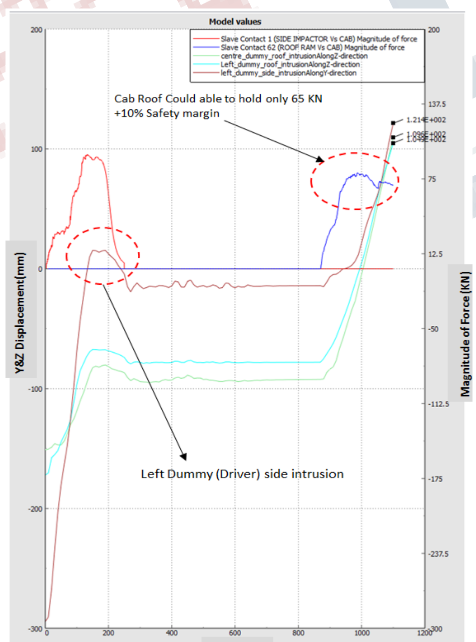

Figure 6: Force vs Displacement vs Time Curve for side impact and Roof Crush for Baseline Cab Body

Side Impact test:

From the curve above, the intrusions at the drive location can be seen, we see that there is a penetration of 15mm at the driver location which is been highlighted in dotted red line.

Roof Crush test:

From the curve above we can see that the cab could only sustain a load of 65KN with 10% safety margin and the intrusions are reaching the dummy at all the three occupant's location.

The Baseline Cab model failed the Rollover 1800 crash test which comes under the regulation ECE-R29.03, Hence there is a need for Reinforcement design for the Rear wall and Cab Roof.

IV. REINFORCEMENT DESIGN TO STRENGTHEN THE BASELINE MODEL OF THE CAB

From the above Baseline results of the cab, the parts affected during crash are identified and considered for reinforcement design. The parts affected are Rear wall and Roof; hence Reinforcements are added at the Rear wall and Roof.

3. Reinforcements added at the Rear Wall of Cab Body:

Four structural members are added in the rear wall as Reinforcements without modifying the existing rear wall as shown in the Figure 7,

Figure 7: Reinforcements in the Rear Wall

The CAD modeling is done using the software CATIA (Generative Shape Design module). The parts are designed in such a way that it will not interfere with the other existing parts. The modeled parts are spot welded to the rear wall. The material chosen for the reinforcements is Cold Rolled Steel having high strength.

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3a: Vertical member at RH Side and LH Side at the Rear wall

The below Figure 8 shows the Vertical member added to the Rearwall at Left hand side and Right hand side.

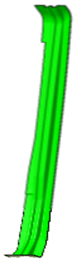

Figure 8: Vertical member at RH Side and LH Side at the Rear wall

3b: Horizontal member top:

The horizontal member which is shown below in the Figure 9 is assembled at the top of the rear wall. The material used for this is High Strength Cold Rolled Steel having Dimensions 1313x70x2.5mm

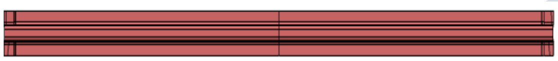

Figure 9: Horizontal member top

3c: Horizontal member bottom:

The Horizontal member which is shown in Figure 10 is modelled and assembled at the bottom side of the Rear wall. The material used for this is High Strength Cold Rolled Steel having Dimensions 1375x60x2.5mm

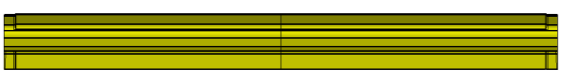

Figure 10: Horizontal member bottom

4. Reinforcements added at the Roof of Cab Body:

Four Brackets are added to the roof in order to connect Roof Cross member to the body side which is as shown in the Figure 11 below.

Figure 11: Roof Bracket

The roof bracket is modeled and assembled to the cab considering the packaging space available at the Roof. The bracket designed should not interfere with the other existing parts of the Cab body in white. Roof Brackets are added in order to increase the load bearing capacity of the Roof which is not there in the Baseline Cabin. The material used for this is High Strength Cold Rolled Steel having Dimensions 120x60x2x0.9mm

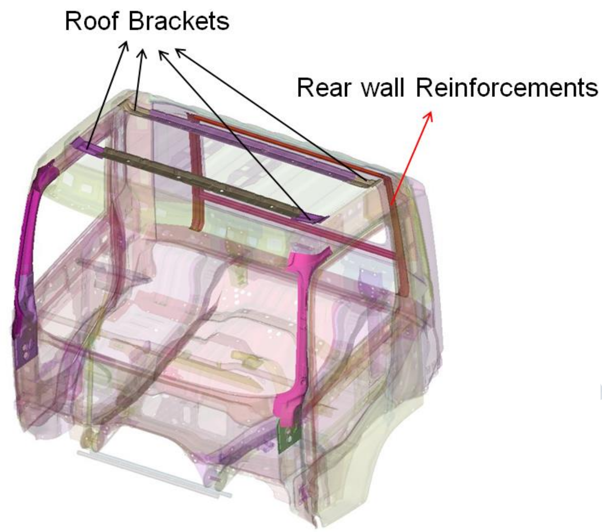

Figure 12: Cab Body with Reinforcements

The above Figure 12 shows the cab body in white with Reinforcements. The total weight of the Added Reinforcements is ~8 Kg.

V. CRASH RESULTS OF THE CAB BODY WITH REINFORCEMENTS FOR ROLLOVER 1800/ROOF STRENGTH TESTS

Here the medium duty truck cab model with added Reinforcements is chosen for simulation which has FAW (Front Axle Weight) 75KN, hence the design the done considering the FAW.

5. Results of Numerical Simulation of the Modified/Improved Cab Model: Rollover 1800/Roof Strength tests

The cab BiW with added Reinforcements is considered for CAE simulation in the form iterations. The test condition chosen is Rollover 180 (Side impact and Roof Crush); the model is preprocessed using ANSA analysis tool. After the preprocessing, the data is fed into LS DYNA [11] solver and the results are extracted using postprocessor MetaPost. Along with the Reinforcements some other existing parts are also

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modified by changing the material and the thicknesses. The final results after 5 iterations is shown below

5a: Rollover 180^0: Side Impact results (Test A) for modified cab model

Below Figure 13 shows the improved results for Side Impact, The Driver Dummy is not touching the body side and there is a survival space of ~18mm.

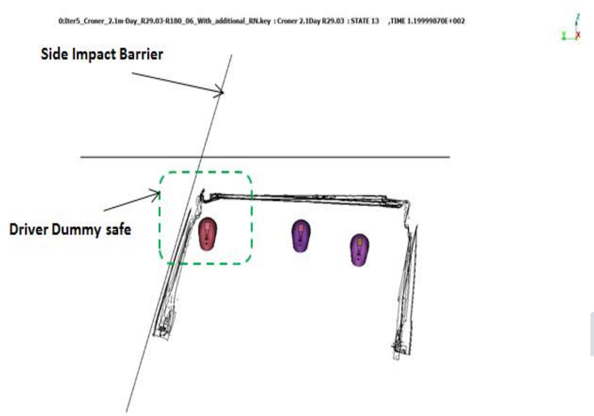

Figure 13: Side Impact showing dummy not touching the body side (Sectional View)

5b: Rollover 1800: Roof Cush results (Test B) for modified cab model:

The second step in Rollover 180 case is roof quasi-static load to test the Roof strength when truck rollovers up to 1800. The results for Roof crush test for Modified Cab Model is shown below in the Figure 14. It can be seen that Cab could able to hold ~95KN with 15 mm survival space.

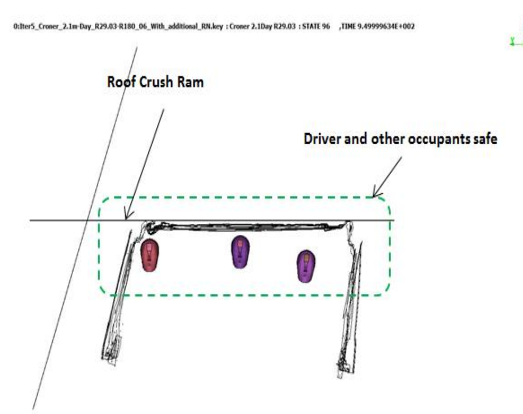

Figure 14: Roof Crush showing occupants safe (Sectional View).

5c: Modified/Improved Cab Crash results summary:

The curve below shows Force vs Displacement vs Time for Modified/Improved Cab body, it depicts both Side Impact and Roof Crush tests. The following inferences can be drawn from the curve:

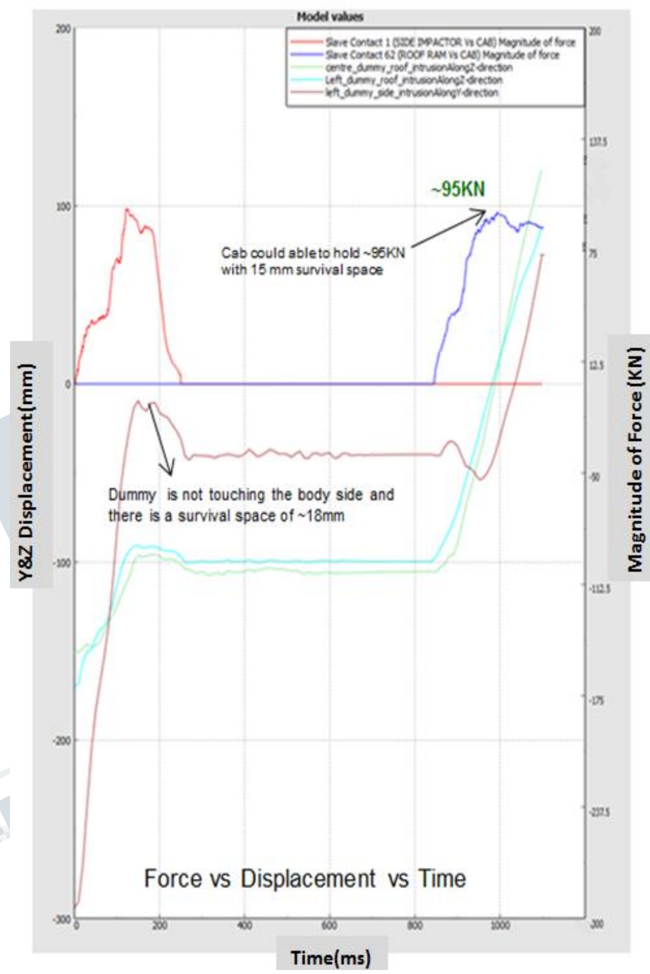

Figure 15: Force vs Displacement vs Time Curve for side impact and Roof Crush for the Modified/Improved Cab Body.

Side Impact test:

From the curve above, we can see that the dummy at the Driver location is not touching the body side and there is Survival space of ~18 mm.

Roof Crush test:

From the curve above we can see that the cab could able to sustain a load of 95KN with ~15 mm survival space which is well above the FAW (Front Axle Weight) 75KN

The Modified/Improved cab has passed the Rollover 1800 crash test which comes under the regulation ECE-R29.03 [8].

VI. CONCLUSIONS

The Cabin used is Cab-over Engine type. In general, the truck cab is softer than passenger car during simulation process it will crumple hence it should be made strong enough to sustain higher loads during crash. In order to make dummy to have enough survival space and save more passengers, the Roof and Rear wall need be welded with some longitudinal and transverse members to support it in order to improve severe crushing deformation.

From the above results we can say that the cab can pass the crash tests by addition of Reinforcements in the weaker regions.

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REFERENCES

[1] Dengfeng Wang, Liya Liu et al. (2011), Simulation for Structure Optimization Design on Truck Rollover Test, IEEE, 978-1-4244-9439-2/11.

[2] Pooja Dwivedi, Adwait Kulkarni et al. (2011), Protection Devices to Improve Frontal Pendulum Impact Performance of Heavy Commercial Vehicles, SAE International, 2011-26-0099.

[3] Sujit Mungale and Leo S, (2013), Evaluation of Truck Driver Safety in Various Crash Scenarios, SAE International, 2013-26-0029.

[4] Vehicle Safety 2016- European Commission.

[5] Article: Crash Summary- North Dakota Department of Transportation (NDDOT) 2016

[6] Article: 2016 Fatal Motor Vehicle Crashes: Overview, NHTSA

[7] Article: Global Automotive Safety Regulations in Nutshell 2015, Altair, by Nithin Kumar Lokhande Director, Technical Wissen Baum Engg. Solutions LLP

[8] Article: Crash Regulations ECER29.03 (http://www.unece.org/fileadmin/DAM/trans/main/wp29/wp29regs/R029r2e.pdf)

[9] Jay Tudor, David Tao et al. (1999), Effect of Polyurethane Structural Foam on Vehicle Stiffness, SAE, 1999-01-1785

[10] Dengfeng Wang, Liya Liu et al. (2011), Simulation Analysis of New Safety Impact Regulation on Cab of Commercial Vehicle, IEEE, 978-1-4244-9439-2/11.

[11] Livermore Software Technology Corporation, LS-DYNA KEYWORD USER'S MANUAL, America, 2006.