TRUCK FRONT STRUCTURE PENDULUM IMPACT AS PER AIS REGULATION

Veeresh Gurav[1], Assistant Professor Mahesh Kori[*]

[1]*Post Graduate Student, Department of Mechanical Engineering, KLS GIT, Belgavi, Karnataka, India*
[*]*Assistant Professor of Mechanical Engineering, KLS GIT, Belgavi, Karnataka, India*

Abstract - In the early 2000s, between 700 and 800 truck drivers were killed in truck accidents each year. In recent years, the number of truck driver fatalities has declined largely due to an overall reduction in fatalities. However, the ratio of drivers killed to the number of fatal truck accidents has remained between 14 and 16 percent over the years.

During the frontal pendulum impact on commercial vehicles, flat front end vehicles generally exhibit strong deformation in the cabin. In most cases, the impact load acts directly on the cab structure causing severe damage to the front of the cab. This results in cabin separation, deformation and a high risk of injury to the cabin occupants. Reducing these injuries during impact means limiting unwanted movement of the cabin structure and ultimately preserving the safety of the occupants. To achieve these goals, virtual testing of the impact scenario must be performed with the help of CAE Analysis.

Key Words: Commercial Vehicles, Truck Accidents, Virtual Testing, CAE Analysis.

1.INTRODUCTION

Frontal impact shares the root cause of all Truck accidents that carry a high risk of injury and death for the driver, crew and occupants. Most of the mandatory passive safety standards for trucks are more related to passenger safety and less to driver safety.

In order to ensure the safety of the occupant, certain design measures are necessary. These design measures need to be evaluated in terms for crash and overall strength of structure. The pendulum crash test is an important device that can be used to estimate vehicle subsystems and predict how they will behave during an accident. The pendulum crash test offers flexibility and control in vehicle design.

The AIS-031 standard specifies the pendulum test on a body section according to which a pendulum of steel or plywood with evenly distributed mass shall be released from such a height that it strikes the defined body section at speed between 3 and 8 m/s.

1.1 OBJECTIVE

The objective of this project is to limit the undesirable displacement of cabin structure and ultimately maintain occupant safety with the help of an explicit dynamic solver.

1.2 SCOPE OF WORK

1) FE modelling and simulation as per the AIS-031 standard and the pendulum hit the structure at the speed between 3 and 8 m/s.
2) Assigning material properties.
3) Assigning boundary conditions.
4) Result extraction and interpretation.

2.LITERATURE SURVEY

[1].The safety analysis contained in NHTSA report is based on the University of Michigan Transportation Research Institute's (UMTRI's), Trucks Involved in Fatal Accidents (TIFA) survey file, NHTSA's General Estimates System (GES) and the Large Truck Accident Cause Study (LTCCS). TIFA and GES data from 2006 to 2010 were used in the categorical analysis, while LTCCS data were used for further clinical review of cabin behaviour in frontal and rollover crash. Results showed that the cabin strength has improved significantly because of improvements in structural analysis, design development and durability analysis.

[2].Sumit Sharma and Sandeep Sharma, Sanjay Tiwari, Umashanker Gupta (2015) these people are from volvo group. They conducted a frontal impact test on Heavy Commercial vehicle(HCV) as per FE simulation of AIS 029 .They used FE model with appropriate non-linear material properties were used to simulate the test scenario and then simulation results were compared with the test results. They found reasonable correlation was found in test and CAE results in terms of structural deformation and survival space. It was found that the front cabin suspensions sustained tensile load while rear cabin suspensions experienced compressive loading during frontal pendulum impact. More than 70% of the energy was absorbed by the front and the chassis frame. The validated AVC model will be used to

evaluate different types of possible impact directions and energy levels.

[3].Pooja Dwivedi and Adwait Kulkarni, Sujit Chalipat and Mahesh Pardeshi (2011) these people conducted frontal impact test on heavy commercial vehicle to improve the survival space by using the various protection devices. Their case study shows the benefits of having specific protection devices to meet the regulatory requirement. Their study shows that such protection devices can be implemented as add on components with minimal design changes. CAE based evaluations have helped to explore number of design concepts and arrive at effective solutions faster thereby reducing the development time while ensuring optimized weight and cost. By their study protection devices have been validated through CAE simulations with the intent to serve their specific purposes.

[4].Johann Gwehenberger, Klaus Langwieder, Guido Bromann, Dieter Zipfel they studied on real world crash analysis by observing the real-world accidents which were happened because of heavy commercial vehicles across their country Germany. Data they collected shows that single truck and truck/truck accidents are most dangerous kinds of accidents for truck occupants. Typical injury patterns for truck occupants are presented, which are generally different from other road users involved in an accident. One of the main reasons for this difference is that truck drivers often don't wear seat belts. The other main reason is the intrusions in the lower part of the cockpit which lead to injuries to the lower limbs, while the abdominal injuries are caused by the steering wheel. They also show that a broad spectrum of passive safety methods could reduce personal injuries. Therefore, a benefit study will be carried out for different measures, such as the use of seat belts, additional restraint systems or improvements in cab stiffness. A theoretical study of car intrusions will be carried out with reference to delta v in order to define the requirements of future passive safety systems.

[5].This research work report is distributed by the U.S. Department of Transportation, National Highway Traffic Safety Administration, in the interest of information exchange in the year 2014 .This research project did not investigate forces or accelerations experienced by truck cabs or occupants; however the research clearly identifies crash scenarios and injury mechanisms that can be tied to potential countermeasures including cab strengthening. Rollover and frontal impact in a collision event have been identified as the types of collisions associated with the most severe driver injuries. Rollover and frontal impact collisions 95 accounted for 72.7% of all truck and tractor driver fatalities. Rollover events with strapped drivers account for 37% of all injured truck drivers, while non-belted drivers account for 50%. Focusing on the risk associated with rollover, one in nine seatbelt drivers dies or suffers disabling injuries, while one in three unbelt drivers dies or suffers disabling injuries. Seat belts have been shown to be particularly effective in reducing fatalities and disabling injuries in the event of a rollover by three times.

3.METHODOLOGY

The analysis is carried out using LS-DYNA as solver and Hypermesh as Pre-processor for deck setup. The post-processing results can be visualized in LS-Pre-post. The modelling and analysis will be done according to commercial vehicles safety regulations as under.

SAE J2420: COE frontal strength evaluation for dynamic loading of heavy trucks.

ECE R29: Protection of occupant sitting inside the cab of commercial vehicles.

AIS 031: Indian standard for occupant protection against pendulum impact.

The tests to be carried out on commercial vehicle serves two purposes:

1) To study the analysis of injuries and deaths of truck drivers in truck accidents related to cab collision resistance.
2) Reduce the number of truck occupant fatalities and the severity of injuries.

The virtual set-up for these kinds of tests is done with Hypermesh pre-processor including mesh, boundary conditions, connections, contacts and material behaviour.

The analysis will be performed using LS-DYNA explicit solver where the physics of applied properties or boundary conditions is executed with the help of numerical methods ultimately providing the respective output. This output will be post-processed with LS-PrePost. Results and required output parameters can be visualized by correlating the values of stress, strain, deformation, accelerations, velocity after impact, etc.

4.PENDULUM IMPACT TEST ON TRUCK

During the frontal pendulum impact on commercial vehicles, flat front-end vehicles usually show severe cabin deformations. In most cases the impact load directly acts on the cabin structure causing severe damage of front part of cabin. This results in cabin separation, deformation and high risk of injury to cabin occupants.

To reduce these injuries during pendulum impact is to limit the undesirable displacement of cabin structure and ultimately maintain occupant safety. In order to achieve these goals, the virtual testing of the impact scenario needs to be executed with the help of an explicit dynamic solver.

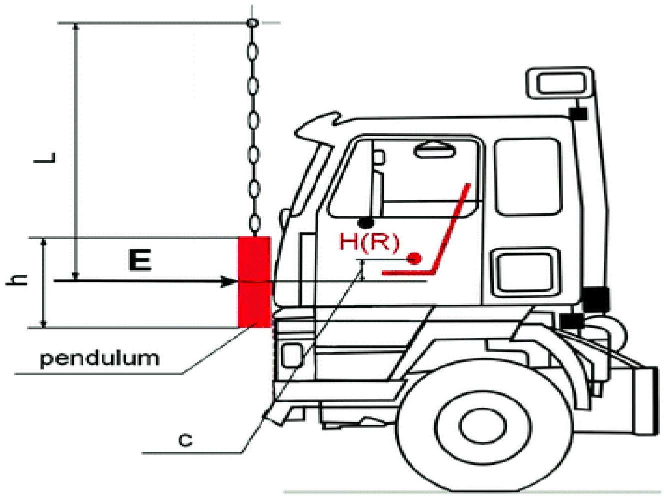

Fig 1: - Pendulum impact test on truck

5. BRIEF DESCRIPTION ON AIS-031 REGULATION

The Government of India has found the need for a permanent agency to expedite the publication of standards and the construction of testing facilities while working on the standards, because the development of safety essential parts can only be done after the standard has been published and the test facilities have been commissioned. The Ministry of Surface Transport (MOST) formed a Standing Committee on Automotive Industry Standards (AISC) to this end, as per Order No. RT-11028/11/97-MVL dated September 15, 1997. The AISC-prepared specifications will be reviewed by the CMVR's Permanent Technical Committee (CTSC). The Automotive Research Association of India (ARAI), Pune, which serves as the AIS committee's secretariat, has published this standard after it was approved. ARAI will post this document on its website to help disseminate this information more effectively.

The vehicle cab must be designed and secured to the vehicle in such a way as to eliminate as much as possible the risk of injury to the occupants in the event of an accident. This norm establishes the minimum survival space requirements for occupants of a category N commercial vehicle's cabin. This standard is part of the Truck Body Code.

During the preparation of this AIS, considerable support has been obtained from ECE R 29 (Rev 01, amendment 1 of the 02 series of amendments: date of entry into force: 27 February 1999) Uniform provisions relating to the approval of the vehicle type regarding the protection of the occupants of the cabin of a commercial vehicle.

5.1 SCOPE

The Survival space specifications for protecting the occupants of a commercial vehicle's cabin are defined in this automotive industry norm.

5.2 APPLICATION FOR APPROVAL

1) The application for approval of a vehicle type with regard to the protection of the occupants of the cabin of a commercial vehicle must be submitted by the vehicle manufacturer / truck body builder to the testing body.
2) Must be accompanied by vehicle floor plans, showing the position of the cab in the vehicle and how it is fixed, and sufficiently detailed plans relating to the cab structure, all these plans are presented by the Vehicle. Truck builder / bodybuilder.
3) Drawings of the vehicle and parts of its interior arrangement which affect the strength of the cabin or the survival space.
4) The orientation of the unladen vehicle's centre of gravity in longitudinal, transverse, and vertical directions.
5) A complete vehicle or complete cabin representative of the type to be approved will be sent to the inspection body responsible for carrying out the type approval test, unless the type approval is made by calculation, in which case the calculation will be sent. to the test agency.

5.3 PENDULUM TEST ON BODY SECTION

1) ENERGY LEVEL AND DIRECTION OF IMPACT

1) The energy that will be transmitted to a certain section of the body will be the sum of the energies declared by the manufacturer that will be assigned to each of the transverse ring included in that particular section of the body.

2) The pendulum must apply the appropriate proportion of the prescribed energy to the body section so that at the moment of impact the direction of movement of the pendulum forms an angle of 25 ° (+ 0 °; - 5 °) to the axis central longitudinal. vertical plane of the body section. The exact angle within this range can be specified by the vehicle manufacturer.

2) TEST CONDITIONS

1) Sufficient testing must be performed for the testing agency performing the test to meet the requirements specified in this AIS standard.
2) For the purpose of the test, the body sections will have sections of the normal structure interposed between the pillars with respect to the floor, under the frame, the sides and the ceiling. Once installed, items such as roof racks, air vents, etc. will also be included.
3) All doors and windows that open from the body section must be closed and locked, but not locked. Windows and glazed partitions can be glazed or non-glazed at the discretion of the applicant.
4) Where appropriate, the seats may also be inserted, at the choice of the manufacturer, in their normal positions with respect to the body structure. The normal fixings and joints between all elements and accessories will be incorporated. The backrests, if adjustable, will be in their most upright position and the seat height, if adjustable, will be the highest position.
5) The side of the body section to be impacted is at the discretion of the manufacturer. When more than one section of the body needs to be tested, both should be hit from the same side.
6) High-speed photography, deformable models, or other appropriate means will be used to determine that the requirement specified in Section 6.1 of this AIS Standard has been met. The templates will be fixed in a substantially non-deformable part of the structure.
7) The section of the body to be tested must be firmly and firmly fixed to the mounting frame by means of the cross brackets or the parts that replace them in such a way that during the impact no significant energy is absorbed in the support frame and its accessories.
8) The pendulum will be released from a height hitting the body section at a speed between 3 and 8 m / s.

3) DESCRIPTION OF THE PENDULUM

1) The swing-bob will be made of steel and its mass will be evenly distributed; its mass will be 1500 + 250 kg. Its flat and rectangular striking surface will be 2500 mm wide and 800 mm high. Its edges must be rounded with a radius of curvature of not less than 1.5 mm.
2) The swing-bob set must be of rigid construction. The swing-bob will be suspended freely from two beams rigidly fixed to it and spaced no less than 1000 mm. The beam will have an "I" section with a core height of not less than 100 mm or a section that has at least an equivalent moment of inertia. The beams must have a minimum length of 3500 mm from the suspension axis to the geometric center of the plumb line.The swing-bob will be positioned so that it is upright.
3) Its striking face is in contact with the front of the vehicle.
4) its center of gravity is 50 + 5 / - 0 mm below the R point of the driver's seat with the vehicle unladen.
5) its center of gravity lies in the median longitudinal plane of the vehicle.
6) The pendulum height calculations (length of the chord) to obtain the desired kinetic energy.

6. PROCEDURE FOLLOWED

1) Software tools used LS Pre-Post, Hypermesh, LS Dyna.
2) The first step is to design a model.
3) The modal is designed in pre-processor tool as per the customer requirements.
4) Then the rectangular pendulum is designed as per the customer requirements.
5) After designing the save modal is imported to hypermesh tool for meshing.
6) Meshing is done in hypermesh as per the meshing criteria.
7) Then the same meshed finite element model is imported in LS-Prepost. The main inputs to the model and to the test are given here.
8) The structure contains too many parts. In part ID part data is given to every part of the structure.
9) The rectangular pendulum is hanged with the help of two ropes.
10) Boundary conditions SPC-NODE must be given to the top end of the ropes.
11) The materials must be added to the each and every part of the truck structure.
12) After material assignment the contacts are given to the surfaces of the structure by defining them.
13) The joints and the spot welds between the parts are defined.
14) A human dummy model is designed as per the regulation AIS 031 and it is also converted to FE model after meshing in hypermesh.
15) Then the dummy model is placed in the driver seat.
16) The contacts are given to the surfaces which are going to affect during test.
17) We have to define the contact between the ropes and the Rectangular pendulum.

18) The velocity is defined for each element of the rectangular pendulum.
19) After giving all inputs to the structure.
20) The structure is saved in .k file format.
21) Then the same .k file is opened in LS-Dyna Solver.
22) After adding job to LS-Dyna we have to start termination in LS-Dyna Solver.
23) It will take some hours to solve the job.
24) After solving some files are generated in the file folder.
25) These files contain Binary and ASCII files.
26) Binary files contain image files some of these are d3 plots, d3 dumps and runrsf files.
27) ASCII files contains result graph.

7. MODEL AND MESHED MODEL OF THE TRUCK

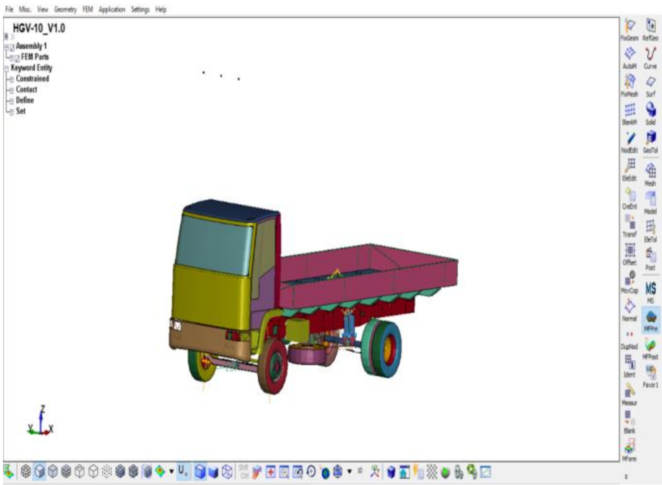

Fig 2: - Isometric View of the Truck Model

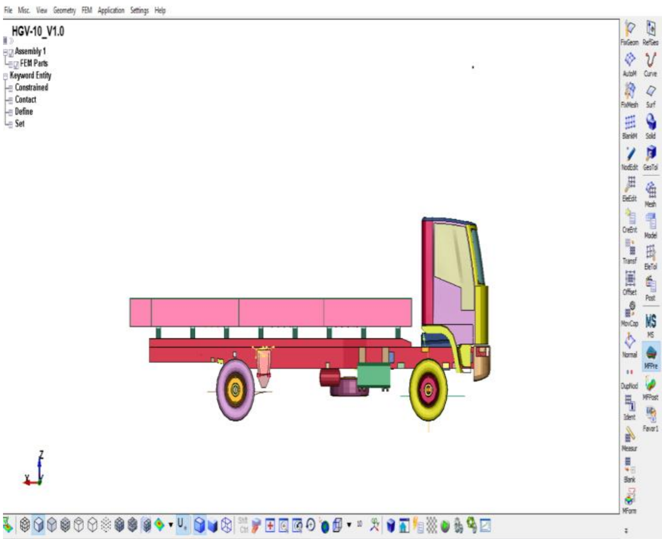

Fig 3: - Right View of the Truck Model

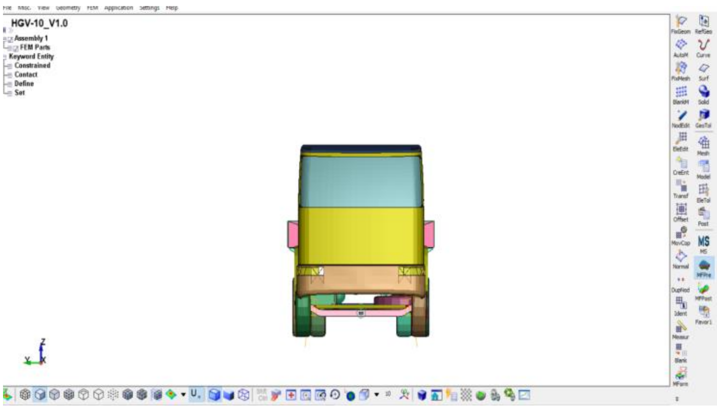

Fig 4: - Front View of the Truck Model

As we seen the figures of the truck model in three different views that is Isometric, Right, Front view.

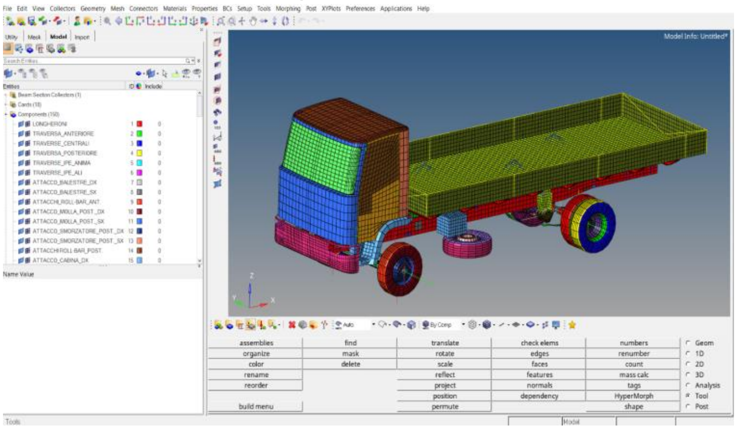

Fig 5: - Meshed View of the Truck Model

Some of the important details of FE model are

1) Total Vehicle Mass = 9.8 tons.
2) Number of Elements = 47324.
3) Number of Nodes = 49853.

Here are some check points we have to check at the time of meshing

1) Check Free Edges.
2) Duplicate Elements.
3) Quality Criteria.
4) Mesh Flow according to the flow line.
5) Check Normal.
6) Proper Geometry Capture with appropriate elements.
7) Bumps on planar sections.
8) Thickness.
9) Avoid opposite tri, maintain proper mesh flow, avoid rotating quad elements.

8. MODEL AND MESHED MODEL OF THE TRUCK WITH PENDULUM

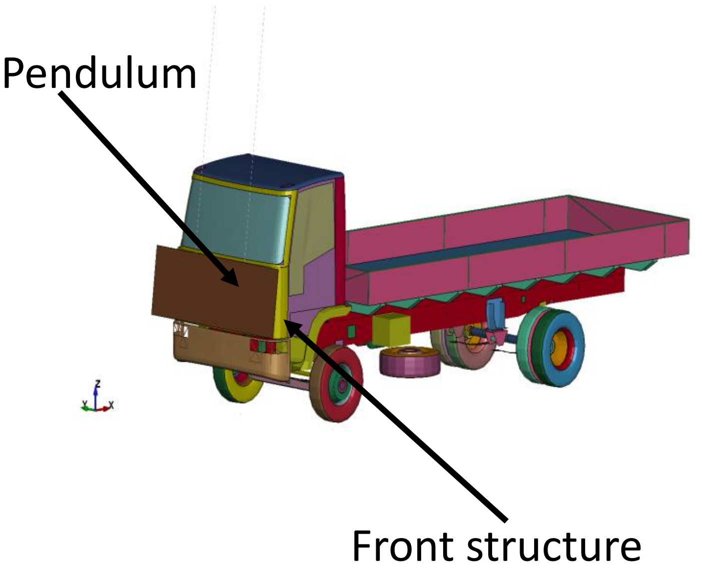

Fig 6: - Isometric View of the Truck Model with Pendulum

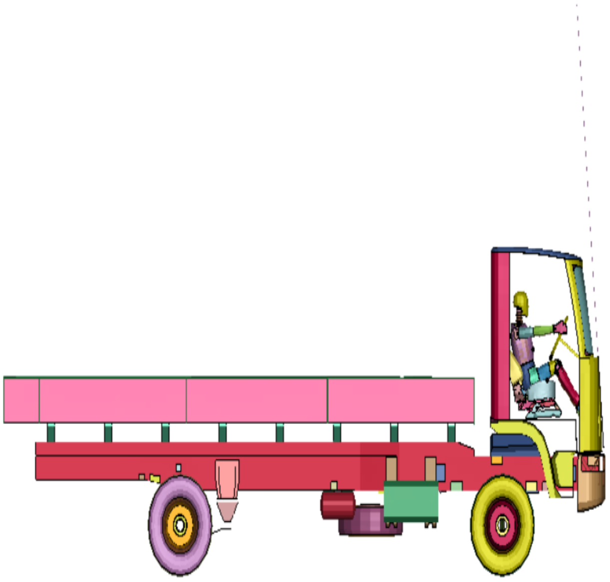

Fig 7: - Right View of the Truck Model with Pendulum and Dummy

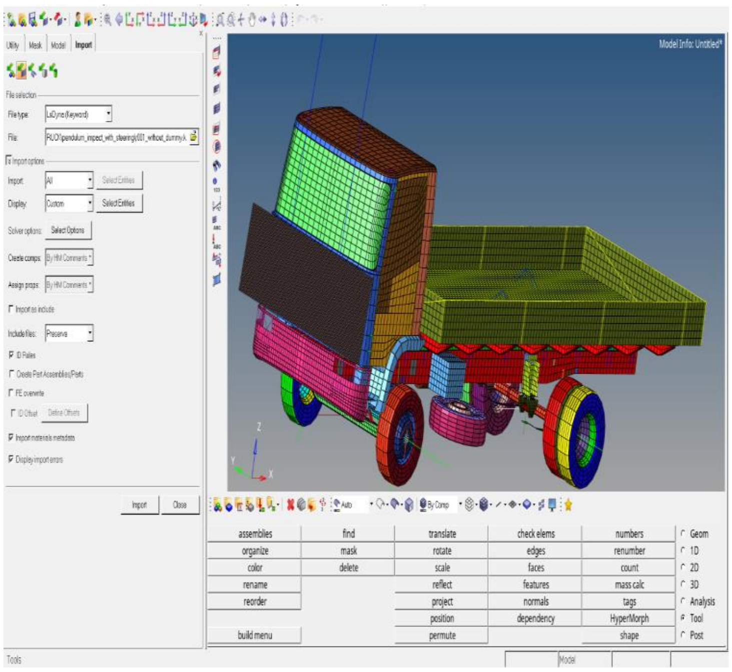

Fig 8: - Meshed View of the Truck Model and Pendulum

MATERIAL & PROPERTIES

A material & Properties assigned to Rectangular Pendulum:

TABLE-1

Density	7.5E-06 T/mm³
Young's Modulus	210 GPa
Poisson's Ratio	0.3
Material	MATL20
Card Image	Sect Shll
ELFORM	16
Thickness	0.1 mm

9. RESULT ANS DISCUSSION

The test problem is solved by tool LS Dyna and the inputs to the structure are given by LS Pre-Post. The inputs are given as per AIS-031 regulation. After solving this problem in LS Dyna, we obtain some results which are shown below.

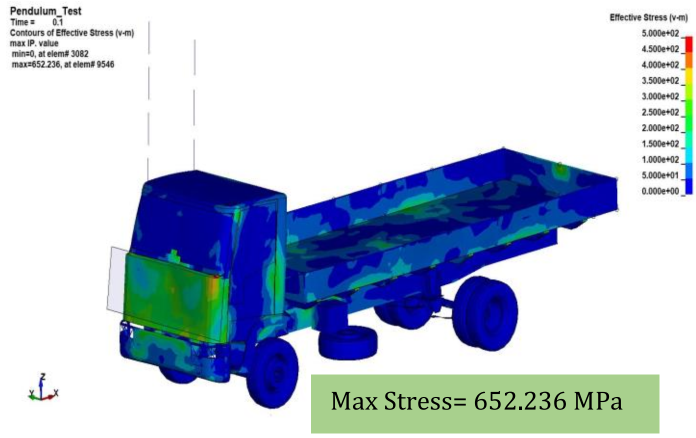

Fig 9: - Stress Plot

When the rectangular pendulum is impacted on the truck front structure the stresses are generated on the truck. The stresses are distributed on the structure unevenly. The maximum stress generated on the on the structure is 652.236 MPa on the element number 9546 and maximum stress 0 MPa is generated on the element number 3082.

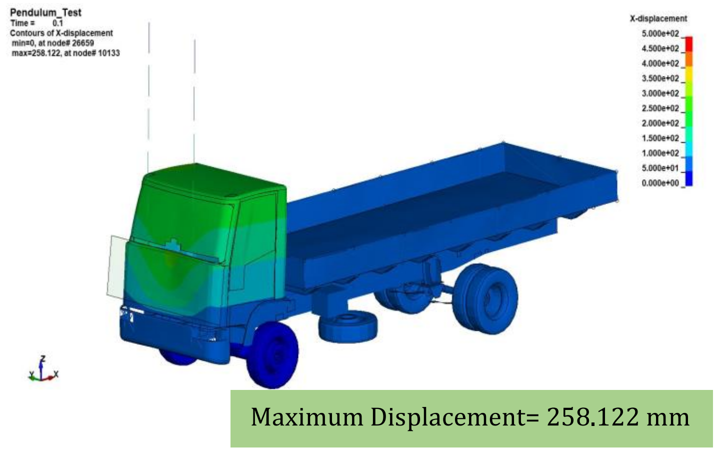

Fig 10: - Displacement Plot

When the impact happens on the front structure of the truck by rectangular pendulum. The elements in the structure got displaced due to the impact. The displacement is varied by the element to element. The maximum displacement in the structure is 258.122 mm at node number 10133 and the minimum displacement is at node number 26659 is 0 mm.

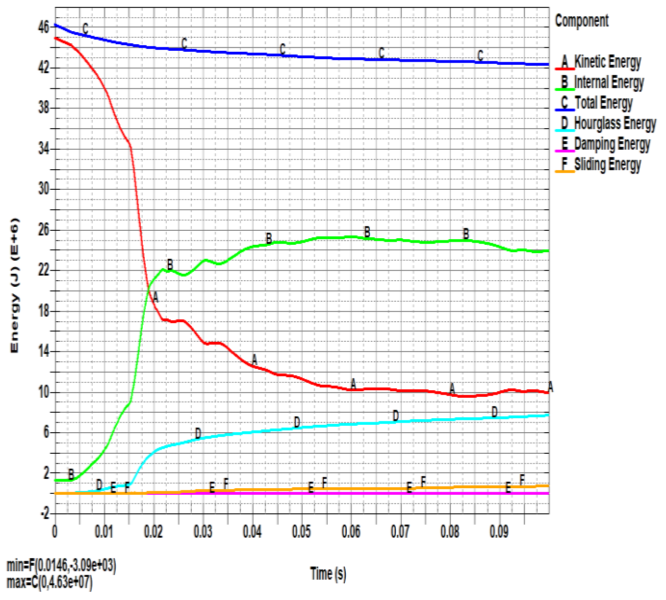

Fig 11: - Energy Plot

When the truck front structure got impact by the rectangular pendulum. Some energies are absorbed by the structure. These are kinetic Energy, Internal Energy, Total Energy, Hourglass Energy, Damping Energy, Sliding Energy.

As in the regulation AIS-031 the energy absorbed by the structure must be around 45 KJ. Here in the experiment result we got 45 KJ on impacting then Kinetic Energy decreases gradually with respect to time.

The internal energy absorbed by the structure on impacting is around 1 KJ and then it increases gradually with time at some point it reaches its maximum limit then it will be constant level.

Among all the energies the total energy absorbed by the structure is more than other energies. On impacting 46 KJ is absorbed by the structure it does not vary too much after some time it reaches constant level.

As per the regulation the hourglass energy absorbed by the structure must be 5 % of the kinetic energy absorbed. Here in the results, we got the same results. Zero hourglass energy is absorbed on impacting then as time increases the hourglass energy also increases with respect to time. This energy also reaches a constant limit at certain point.

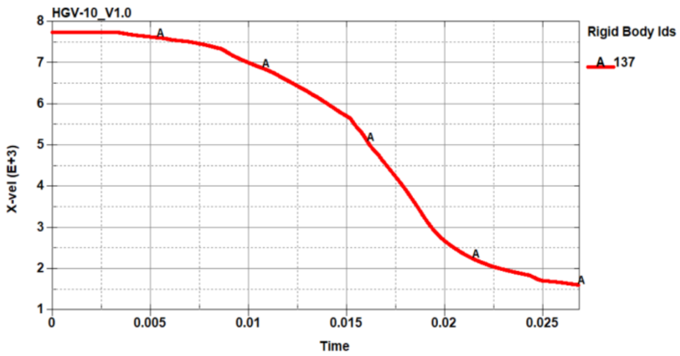

Fig 12: - Velocity Plot

During impact test the rectangular pendulum comes in contact with frontal structure of truck at the velocity 7.74 m/sec. It collides with structure at the same velocity. After impacting some energies are absorbed by the structure and the velocity of the pendulum decreases with time.

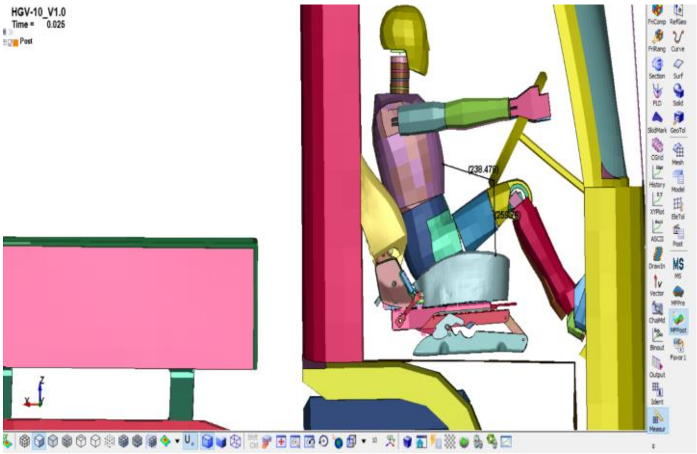

Fig 13: - Safe Distance After Impact

When impact happens between rectangular pendulum and frontal structure of truck. The parts of the truck which are attached to the frontal structure are going for displacement.

A dummy human body which is placed in the driver seat is also affected by the impact.

After impact test the distance between the steering and the dummy is 238.47 mm, distance between steering and driver seat is 259.76 mm. By these results finally we can conclude that after all impact test the driver in the seat is safe from the impact test.

10. CONCLUSIONS

The simulation of Heavy Commercial Vehicle (HCV) by Frontal Pendulum Test on cabin was performed successfully. The modelling and analysis is done according to Indian Standard for occupant protection against pendulum impact test named AIS 031. The material properties and dimensions of the rectangular pendulum are given as per the regulation.

When the pendulum impacted on the frontal structure of the truck the energies must be absorb by the truck structure. Some of those are Kinetic Energy, Internal Energy, Total Energy, Hourglass Energy, Damping Energy, Sliding Energy.

As per the regulation AIS 031 the Kinetic Energy absorbed by the structure must be 45 KJ. In this analysis test we got the same results as per the regulation. Total Energy absorbed by the structure is 46 KJ on impact and Internal Energy on impact is 1 KJ when impact happens between structure and pendulum. This indicates that the occupant in the cabin is safe by the impact as per the energy is absorbed by the structure. After this impact test the distance between displaced steering and human dummy is measured 238.47 mm and the distance between displaced steering and driver seat is 259.78 mm. so the driver in the cabin is safe from impact.

11. REFERENCES

[1] "Traffic Safety Facts," National Highway Traffic Safety Administration, February 2017.
[2] S. Sharma, S. Tiwari, and U. Gupta, "Finite Element Simulation and Validation of Fully Suspended Heavy Duty Commercial Vehicle (HCV) as per AIS029 Pendulum Impact Test," SAE International, SAE Technical Paper 2015-01-2873.
[3] Pooja Dwidevi, Adwait Kulkarni, Sujit Chalipat and Mahesh Pardeshi, "Protection Devices to Improve Frontal Pendulum Impact Performance of Heavy Commercial Vehicles," SAE International, SAE Technical Paper 2011-26-0099.
[4] J. Woodrooffe, and D. Blower, "Heavy truck crashworthiness: injury mechanisms and countermeasures to improve occupant safety.," National Highway Traffic Safety Administration.(NHTSA), May 2015.
[5] M.Esfahanian, S. Ziaeni-Rad R. Mirzaamiri, "Crash Test Simulation and Structure Improvement of IKCO 2624 Truck According to ECE R29 regulation," International Journal of Automotive Engineering, pp. 180-192, 2012.
[6] Clarence R. Hitchings and Jerry G. Wallingford, "A Discussion On Using A Pendulum as a Method for Impact Testing Vehicle Sub-systems," SAE Standard, SAE 01- 0687, March 2002.