DESIGN AND ANALYSIS OF IMPACTOR BARRIER FOR FRONT CRASH TEST

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ABSTRACT: This paper attempts to deal with designing an impact barrier capable of carrying out the impact test as per regulations. Significant steps in frontal protection, such as the cab's dynamic testing are known as Front Impact Test. A frontal result is the most common type of crash, resulting in fatalities. The impactor should be capable of handling varying impact energies. Moreover, it should have a quick-release mechanism. It should have a provision for handling using a crane during non-testing or maintenance period. The impactor should be able to handle minimum impact energy of 30 KJ. It would then be possible to determine the amount of force absorbed by the component (cab) by knowing the component's displacement or deformation. The principal goal of this work is to develop an impactor.

***Keywords*: Front Crash test, Impact test**

1. INTRODUCTION

In India, Frontal Impact (Head On) Collisions are the foremost cause of road accidents. According to the Ministry of Road Transport and Highways, 35% of reported accidents between 2007 to 2017 are due to head-on collisions. Despite the many safety improvements, there is increasing fear regarding a more significant risk of injury to the driver and occupants during collision among diverse sizes and mass vehicles. The difference in size and mass of two vehicles colliding, mainly when the struck vehicle is minor and lighter, is a constant threat for occupant injury. Currently, India has police accident investigations only one machinery of collecting accident data The leading cause of Frontal Impact Collisions is the cause being lack of dividers to separate vehicles running in a reverse direction and people who do not follow traffic rules and speed limits. Thus a significant concern for manufacturers is Cabin safety. Head-on collisions demands for improving the safety of cabins. .Therefore, there is a vital need to realize road safety issues and improve immediate measures to mitigate accidents and injuries on Indian roads. A Front Pillar Impact Test is a type of frontal impact test in which the impactor collides against the test vehicle cabin's front windscreen pillars. The institutes manufacturing this kind of testing equipment are of high capital investment, and hence cheaper and simpler alternatives are adopted by these institutions. The testing laboratories and institutes should have the authority to certify the component undergoing tests in their institute; moreover, their certification needs to be of an authority to be accepted widely. This authority being seldom available, there are hardly any private institutions willing to take up this kind of project work.Crash tests is a way to ensure safety by means of destruction, in the automotive industry, impact tests between cars are performed to analyze the damaged caused by the impact forces at certain velocities. These programs focus on improving the crashworthiness of motor passenger vehicles, and reduce the number of injuries. In Europe there is the New Car Assessment Program (NCAP), based on the program introduced in 1979 by the NHTSA (National Highway Traffic Safety Administration) in USA. Protection of occupant is prime role of any automotive company; there has been growing concern about the harm that some vehicle designs may inflict on occupants of other vehicles with which they may collide. A comparison of HCV and passenger car crashes in previously performed studies that HCVs inflict higher harm than passenger vehicles for a number of reasons including their greater weight, stiffer structure and higher ride height. The Front Pillar Impact Test Rig being a dynamic crash testing machine involves forces of extensive magnitudes generated. The corresponding high stresses develop in the components of the test rig. Designing such kind of a complex machine involves rather complex calculations and is a massive process. With other alternatives like static testing and numerical method tools like CAE, which has simulation and analysis software like ANSYS and Hyper Works, not much work has developed such kind of test rigs. Furthermore, the institutes manufacturing this kind of testing equipment are subjected to high capital investment, and hence cheaper, these institutions adopt accessible alternatives. The testing laboratories and institutes should have an authority to certify the component undergoing test in their institute; moreover, their certification needs to be of authority to be acceptable widely. This authority being seldom available, there are hardly any private institutions willing to take up this kind of project work. National Automotive Sampling System results revealed that Fair collisions account led to 79% of all brain injuries. Belted residents were at fewer risks than unbelted. Unbelted aged residents were at 10.5 and 8 times higher risks. Adopted occupant protection strategies appear to be lacking to reduce the risk of life-threatening brain injuries significantly. More effort to improve resident and injury-specific process for the limitation of brain injuries is needed. Various studies show that the steering wheel also plays an essential role during accidents; mostly, they affect the chest area. From different analyses, it is found that the bar impact shape provides lower chest criteria responses compared to the hub. Inertial and viscous effects of the upper body affect the reactions. Generally, females sustained a greater risk of distal lower limb injuries as relative to males. The driver's raised mass was also observed to have a concrete connection with the damage. Close to passenger cars, vans exhibited a protective effect against sustaining lower limb injury, whereas no association was shown for light trucks or SUVs. It is observed from the various studies that even steady improvement in vehicle crash test performance, below-knee lower extremity injuries remain the most common injury in real-world frontal crashes. On expressways, 66.0% of accidents occurred due to the negligence of the driver, 20.4% due to drowsiness, and 9.7% because of a truck breakdown. Most accidents (85.4%) occurred when a truck driver was going on a straight road based on driving situations. Light is also one of the critical factors in a crash. According to one study, 11,030 (26.6%) occurred during rural daylight conditions, 4429 (10.7%) occurred during the dark rural situation. 20,122 (48.5%) occurred during urban daylight condition, 2081 (5.0%) occurred during the dark urban situation.

Weather condition is one of the significant factors affecting crash severity levels. Interestingly, fatal crashes are less likely to happen on a snowy or rainy day when drivers are more cautious than usual. Validation of such a hypothesis can result in a warning sign on good weather to remind drivers to a driver under speed limits or apply speed enforcement under good weather. Fog affects drivers' visualization and makes large trucks hard to control.

Thus, under these conditions, the probability of multiple-fatality crashes is predicted to increase. An icy road surface is a definite factor of hits

Adverse weather and unlighted conditions increased the odds of downgrade truck crashes, truck-related impacts on downgrades that most drivers were male (92%). Young drivers represented only 3% of truck-related crashes, while middle-aged drivers accounted for 90% of such impacts. The outcomes also revealed that 86% of drivers in truck-involved crashes followed the speed limit, while 60% of such clashes occurred in clear weather conditions. The outcomes showed that 87% of truck clashes happened during weekdays. The report also suggested that 89% of truck-related clashes happened at places with speed limits above 50 miles an hour. The odds of a truck crash on a dry road were approximately 54% higher than other road conditions. It is due to the higher amount of travel on weekdays.

According to Federal Motor Carrier Safety Administration, Run-off-road (ROR) (also known as roadway departure) crashes occur due to a vehicle crossing an edge line or a centerline of a roadway/and leaving the designated lane. These types of collisions roughly composed 54% of all traffic casualties in the U.S. In the present study, ROR collisions requiring large trucks are of special interest for two reasons. First, large trucks play a vital role in the economy. Second, ROR crashes are a nationwide problem that needs to be wholly examined; in 2010, they constituted 57% of all fatal crashes and 16% of nonfatal crashes Run-off-road (ROR).

FMCSA has defined three categories based on the inspection value

- inspection values of 75 or greater have higher risk carriers
- inspection values between 50 and 74 have medium risk carriers
- inspection values less than 50 have low-risk carriers

Low inspection values generally indicate better-performing companies; A truck with a company inspection value between 30 and 70 or greater than 90 is significantly more prone to multiple-fatality crashes.

Even though there are cheaper and less complicated alternatives available, their accuracy can hardly match dynamic tests' accuracy. The maximum accuracy of analysis using numerical methods is 90%, and that too simple an analysis problem. The accuracy goes on dipping vastly as the complexity of the problem increases. Furthermore, the quality of results depends highly on the correctness and fineness of the meshing and appropriateness of specifying the boundary conditions. Dynamic analysis is one of the most detailed analyses; its accuracy is hardly sufficient to rely upon without further validation. In the case of static testing, the test pieces are flashed to static loads. Although such testing accuracy can be relatively high, it hardly predicts the behavior and failure characteristics of components under dynamic conditions. The size and mass of two vehicles crashing, mainly when the struck vehicles are heavy are consistent risk factors for occupant injury. Heavy Commercial Vehicles differ from cars in two key areas:-

1. They have greater mass and stiffness, resulting in higher intrusion when striking other vehicles.

2. The geometry of HCVs places the bumper above the frames of smaller vehicles, resulting in more intrusion.

As a result, the safety designs ten or fifteen years ago are not adequate in today's incompatible vehicle collisions. New technology must be developed and implemented. Mass is a point about survivability in collisions. Researchers are finding suitable vehicle geometry and energy-absorbing interfaces to be critical factors in developing that is crash compatible with the disparity of the vehicle fleet. Crash test results impacted on the front show that the impact energy absorbed largely depends on the **vehicle's crumple zone**.

1.1 Crumple Zone

The crumple zone is an essential feature in automobiles; it absorbs impact energy during a traffic collision by controlled deformation. Crumple zones' primary purpose is to absorb the energy from the impact. It is situated in the front part of the vehicle and is used to absorb a head-on collision. According to a British study, vehicle impact damage mainly occurs: 65% were front impacts, 25% rear impacts, 5% left side, and 5% right side. Crumple zones work by absorbing impact energy and prevents the deformation of the passenger cabin. Thus protects the car occupants against injury. This is attained by strengthening and increasing the rigidity of the inner part of the car's body, making the passenger cabin into a 'protective cell' by using more reinforcing beams and higher strength steels.

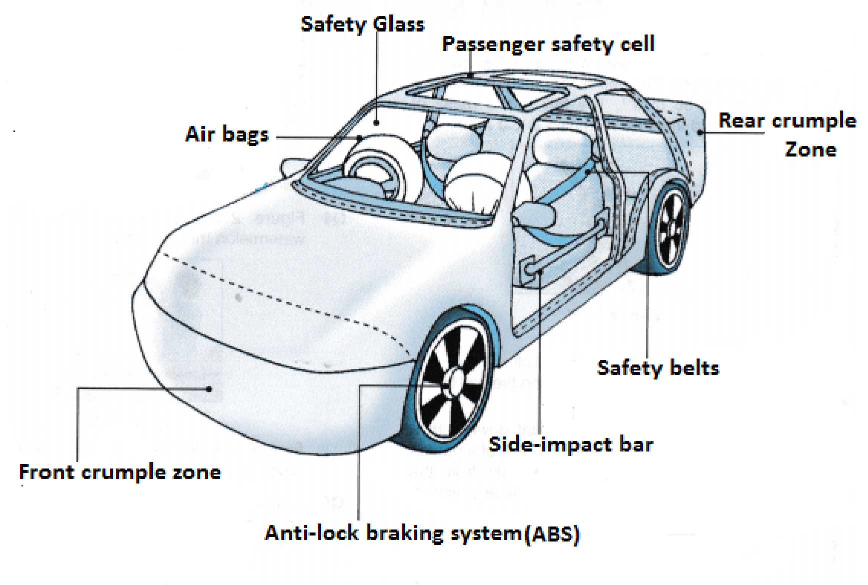


Fig. 1.1: Crumple Zone

(Source:https://www.aplustopper.com/aware-need-safety-features-in-vehicles)

Impact energy, which reaches the 'safety cell,' is spread over more expansive areas and reduces impact energy and deformation. When a vehicle consisting of passengers and luggage traveling at speed, they have momentum, which means that they will continue to move forward with that direction and speed (Newton's first law of motion). In the sudden deceleration of a vehicle due to impact, vehicle contents will continue to move in forwards at their previous speed due to inertia, with force equal to several times their average weight due to gravity. Hence crumple zones are provided to slow down the colliding effect and to absorb its energy.

1.2 Statistical Data Of Front Impact Collisions (India)

According to the Records of the World Health Organization, India has one of the highest numbers of traffic accidents globally. Henceforth, there is an urgent need to understand road safety issues and develop immediate measures to reduce accidents and injuries on Indian roads. Data sets are applied not only to understand the real-world accidents and injury but also to change safety strategies pointed towards improving vehicle safety and road infrastructure. Presently India only has one mechanism to collect road accident data, which are police accident investigations.

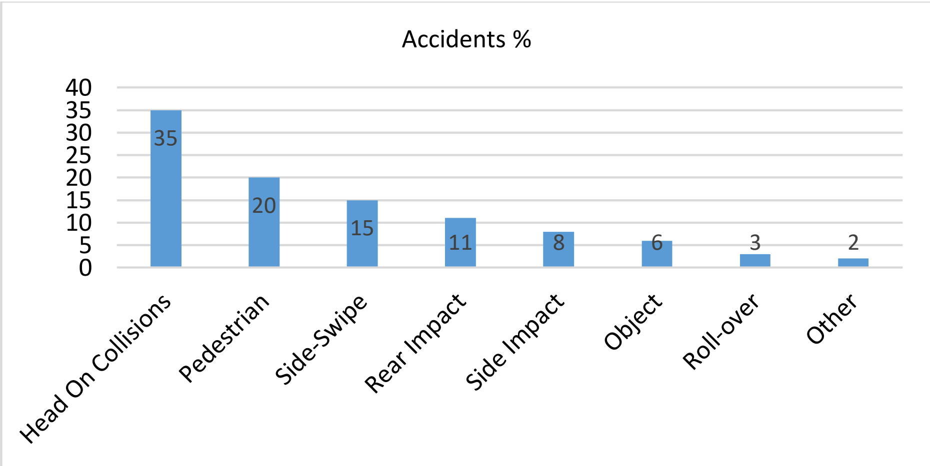


Fig. 2.2: Categorization Of Reported Accidents (2007-2017)

(Source: Ministry of road and transport)

A conclusion of lethal road traffic events at a national level and data such as type of road users (age, sex, and vehicle type), incident rates for states and cities, road type, etc. can be delivered through this report. From the chart shown above, it can be observed that the number of accidents is increasing over the last ten years. As seen from the statistics, Head-on Collisions (Frontal Impacts) were the majority of reported accidents between 2007 and 2017. Head-on collisions are more broadly reported in city areas and small roads than highways. The reason is the absence of dividers to separate vehicles moving in the opposite direction, and non-abidance of traffic rules and speed limits. Cabin safety is thus a primary concern for manufacturers. While head-on collisions call for improving cabins' safety, cases of objects crashing into windscreens have also been listed. The objects may be small debris, catching the drivers by surprise and causing them to swirl over to the other side of the road resulting in collisions or large particles entering directly into the cabin by shattering the windscreen. 167 accidents were examined on various state and national highways over nearly 151 km of roads. 71 accidents Out of 167 accidents caused fatalities. 210 casualties remained registered from these 71 fatal injuries, 80 sustained fatal injuries, and 31 suffered severe injuries. More than one-third (35%) of the fatal accidents were head-on collisions. With this increase in the number of vehicles and demand for faster transportation, the number of accidents has increased considerably over the decade.

1.3 Front Pillar Impact Test

A Frontal Impact Crash Test is a test for safe design standards and crash compatibility and uses a destructive testing method. The impact is accomplished using an impactor, which may be cylindrical, rectangular, or triangular based on applications. Each crash test is very costly, so the maximum quantity of data must be extracted from each test. This test requires the crash test dummy and high-speed data acquisition system. A Front Pillar Impact Test is a type of frontal impact test in which the impactor assembly collides against the test vehicle cabin's front windscreen pillars.

The test is principally displayed out to determine the Crumple Zone of vehicle. The crumple zone is a structure used to absorb the impact energy during a traffic collision by controlled deformation. Three activities provide the technical basis for the research:-

1. A structural survey of the energy-absorbing structure to create a database of positions and dimensions will help determine proper structural contact areas for vehicles.
2. Analysis of accidents for estimating the benefit and cost of improved compatibility.
3. A crash testing program of car-to-car and carton-barrier crash tests to validate the crash test procedures and develop appropriate performance criteria.

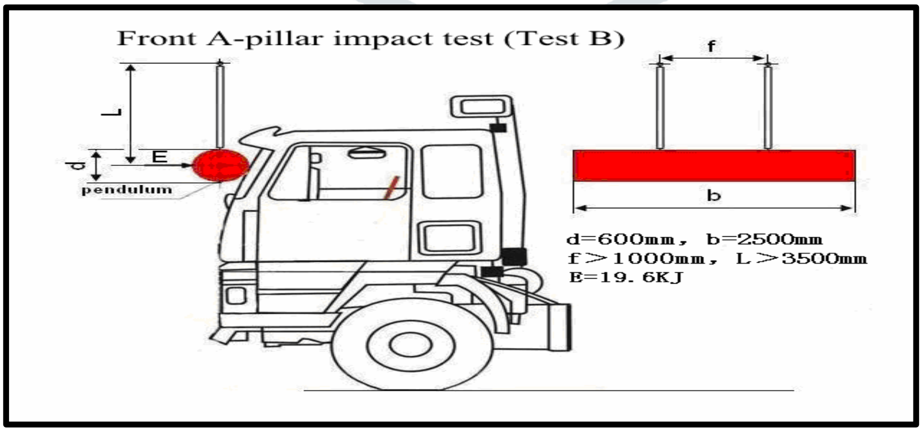


Fig. 1.3: Front Pillar Impact Test

(Source: UNECE R29.03)

The crash testing activity's objective is to accomplish full-scale crash tests and related analyses to help develop and confirm a suite of test procedures to increase car frontal impact compatibility.

1.4 Finite Element Analysis Method

The finite element method is consisting of three major phases: -

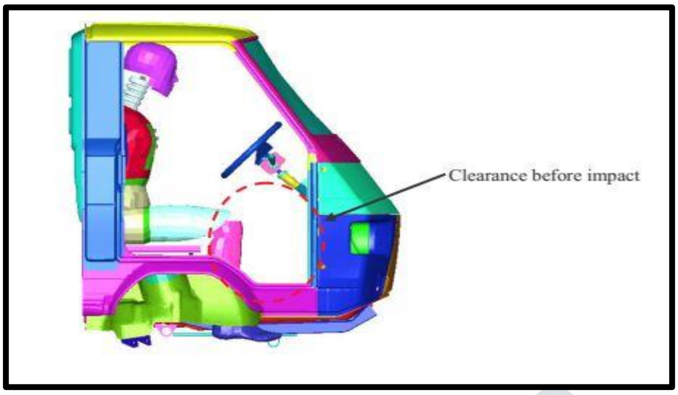
1. Pre-processing, in which a finite element mesh is generated by an expert to divide the substance geometry into sub-domains for mathematical analysis, and material properties and boundary conditions are applied.

1. The solution, in the program, is obtained by administering matrix equations from the design and solves for the primary measures
2. Post-processing, in which the expert does the solution's validity, examines the values of primary measures (such as displacements and stresses) and derives and examines additional measures (such as specialized stresses and error indicators).

FEM is considered the most influential vehicle crash analysis appropriate for creating and simulating a 3-D car model.

1.4.1 Lumped Parameter Modeling

The theory of lumped parameters has its roots related to the experience of spring stiffness. This method is an analytical way of solving a vehicle crash. It uses kinematics and dynamic equation. For example, suppose a mass-spring and damper model to describe a car colliding with a dangerous obstacle. This method is worthy of representing a real crash and compared to FEM; it makes it the right candidate for calculating car crash data. The models can represent the front panel with mechanical unit equations for better approximation, such as mass, suspension, etc. This modeling method's disadvantage is the estimation of the spring and damper parameters, which are typically found based on the real crash for a particular case. It can be utilized for rough calculation for the case where the real data is collected.



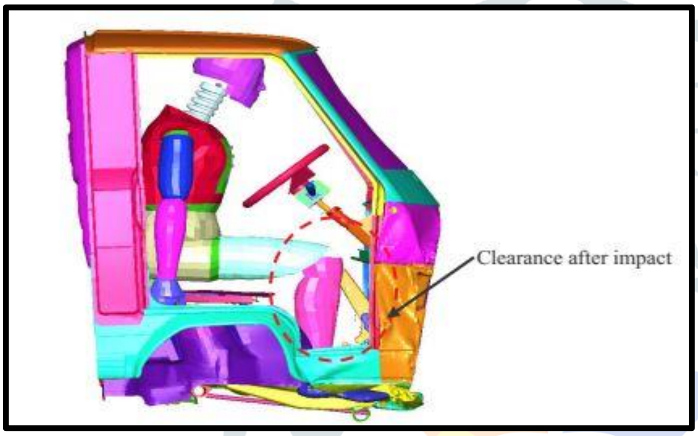


Fig. 1.4: Lumped Parameter Modelling

1.5 Testing Regulations

According to the R29 regulations laid out by the United Nations Economic Commission for Europe (UNECE), the impactor was outlined. The regulations do present below: -

1. The impactor shall be stiff, and its minimum not be less than 1,000 kg. It should have a cylindrical diameter d of 600 ± 50 mm and a length b minimum of 2,500 mm. Its boundaries shall be round to a radius of curvature of a minimum of 1.5 mm.
2. Assembly shall be of rigid construction. It shall be freely suspended by two beams firmly attached to it and spaced minimum f= 1,000 mm apart. The beams shall have minimum L = 3,500 mm long.
3. Its core of gravitation is the middle between the lower and the upper windscreen frame.

4. The length is equally distributed over the vehicle's width, overlapping the full width of both A-pillar

5. The direction of impact will be horizontal and shall parallel to the median longitudinal plane of the vehicle. The impact energy which will produce during this collision shall be 30 kJ

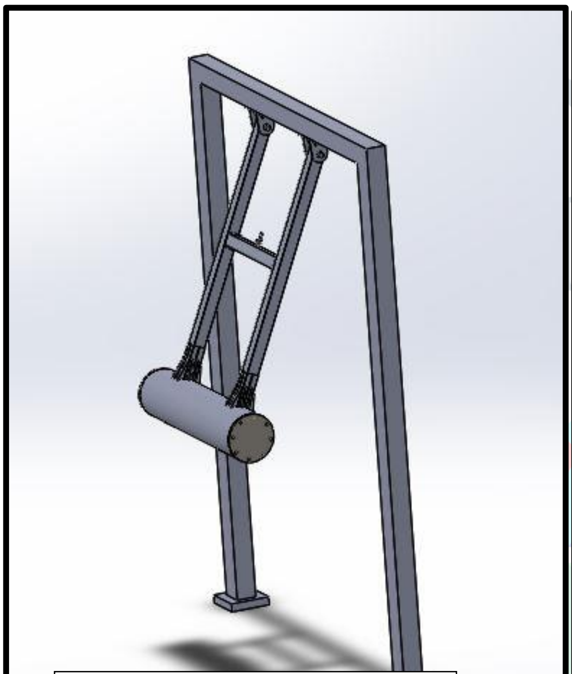


Fig. 1.5: Isometric view

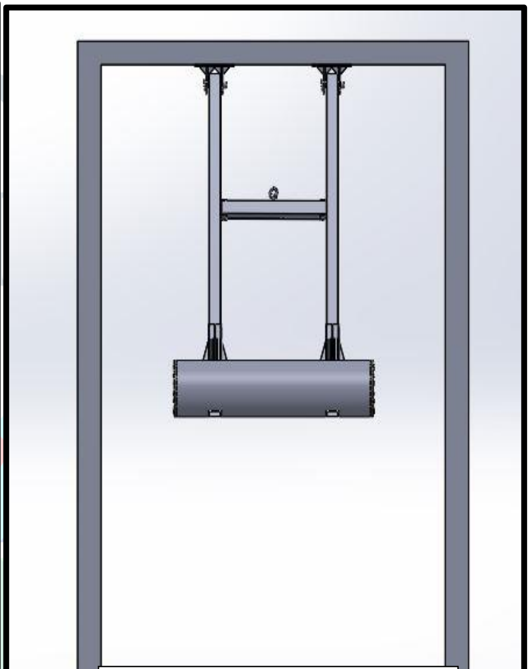


Fig. 1.6: Front View

Fig. 2.9 : Isometric View

Fig. 2.10: Front View

2. UNCERTAINTY REPORT

Measurement Uncertainty may be a non-negative parameter characterizing the diffusion of the values endorsed to a measured quantity. All dimensions are subject to uncertainty and a dimension result's press release of the associated uncertainty. By international agreement, this uncertainty features a probabilistic basis and reflects incomplete knowledge of the number value.

Reading No.	Length (b)	Outer Diameter (d)	Inner Diameter (d_i)	Arms Centre Distance (f)	Pivot to Bob Center (L)	Weight (m)
1.	2504	601	559	1500	3500	1038
2.	2503	601	559	1500	3501	1038
3.	2504	601	560	1500	3500	1038
4.	2504	600	560	1500	3501	*
5.	2504	600	560	1500	*	*
6.	2503	601	560	1500	*	*
7.	2504	601	560	1500	*	*
8.	2504	601	559	1501	*	*
9.	2503	600	560	1501	*	*
Average	**2503.667**	**600.667**	**559.667**	**1500.222**	**3500.5**	**1038**
Standard Uncertainty	**0.5**	**0.5**	**0.5**	**0.45**	**0.25**	**0**

Table 2.1: Uncertainty Report

3.DYNAMIC ANALYSIS

The worst-case scenario is that the impactor is entirely rigid and does not absorb any force. The reinforcements providing the required thickness to the impactor would be excluded. If the impacting mass sustains this maximum reaction, the design is validated. Following are the details of the analysis:-

Software	ANSYS
Solver	Explicit Dynamic
Meshing	Adaptive, Fine
Constraint 1	Anti-intrusion Plate
Constraint 2	Impact Mass (Velocity =10 m/s)
Impact Time	0.01 sec

Table 3.1 : Analysis Parameters

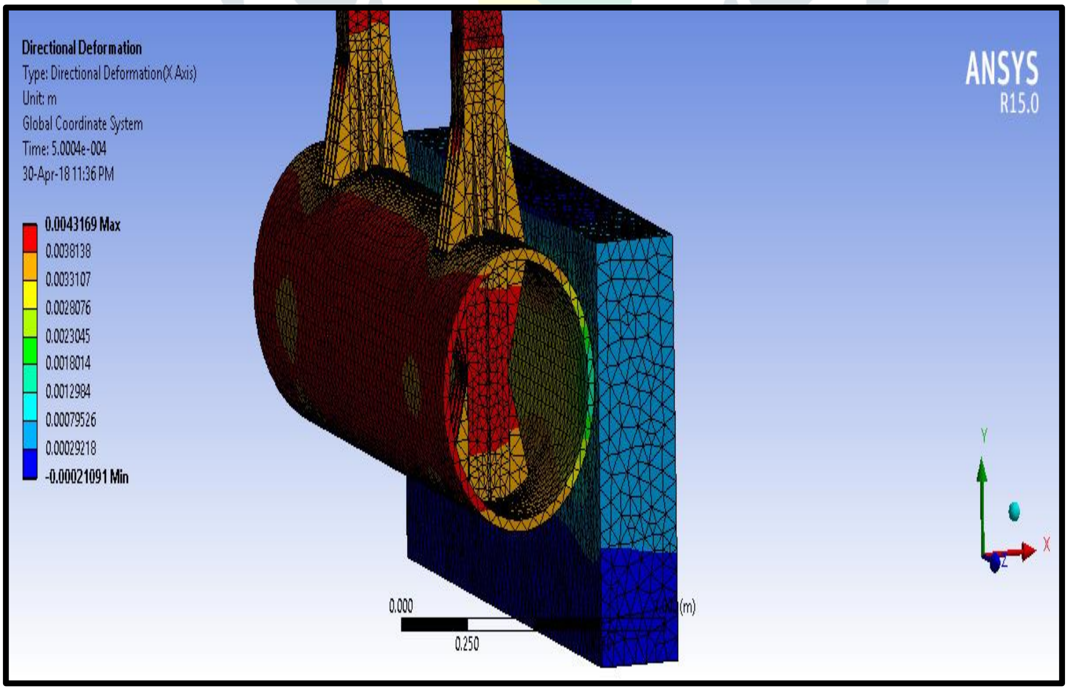


Fig. 3.1: Directional Deformation

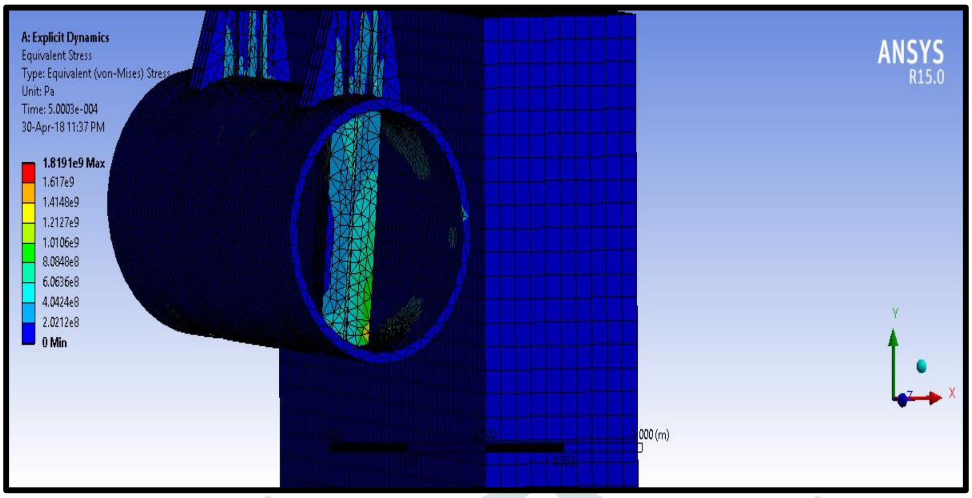


Fig. 3.2: Equivalent Stress

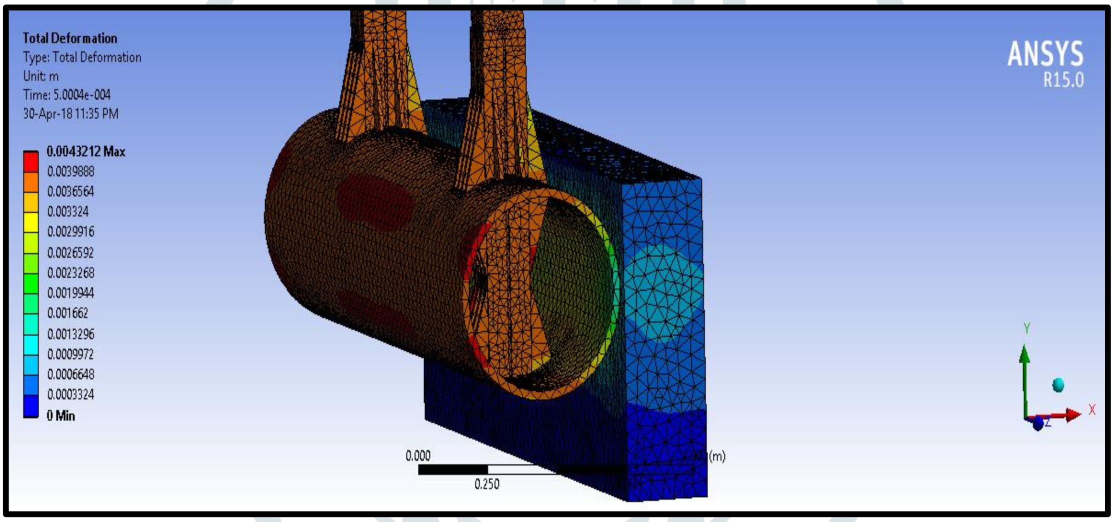


Fig. 3.3: Total Deformation

The analysis yields the following results:-

Maximum Stress Induced	**202.12 MPa**
Maximum Deformation	**4 mm**

It can be seen from the above results that the maximum stress is within permissible limits and deformation is within elastic limits as the plastic strain is zero. Hence the design is safe

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4 Final Component Selections

Item	Material	Dimensions (mm)
M.S Square Pipe	IS 4923 YST 310	150 x 150 x 5
L Section	IS 2062 E350 A	75x75x5 Length : 1000mm
Channel Section	IS 808	175×75×6×10.2
Cylinder	API 5L Grade B X60	OD- 610 Length -2500
End Plate	IS 2062 E350 A	OD-600
End Plate Ring	IS 2062 E350 A	OD-549 , ID-469
Re-enforcement Ribs	IS 2062 E350 A	FRONT Thickness : 16 mm Length : 250mm SIDE Thickness : 16mm Length : 250mm INNER Thickness : 16mm Length : 250mm
Electromagnetic Plate	IS 2062 E350 A	700×350×10

Table 4.1: Final Component Selection

5 CONCLUSION

The central purpose of the project was to design and validate the vertical impact drop test rig. The components were decided according to the regulations' functionality and keeping in mind the initial cost and the final cost of assembly. The test rig was composed using standard-sized cylinders and box sections. The maximum deflection of the test rig was **4mm**, while the test rig was constrained to a maximum stress of **202.12 MPa** in the worst-case condition, and hence was termed safe by the issuing authorities. Components like electromagnetic quick-release mechanism, overhead crane, or the erecting of supporting structure were not considered in the estimated cost, since they were already available at the site. The design was certified to be safe, stable, and valid by the Safety Officer of PSL, and the estimate, too, was well within the budget. Thus it can be considered that the project undertaken by the team was a successful one.

6 FUTURE SCOPE :-

The Impact Test Rig will be used for the frontal impact testing of Heavy Commercial Vehicles, thereby achieving vehicles' passive safety and ensuring increased occupant safety. The testing method can be further modified to provide an environment close to the actual accident zone. It will prevent multiple tests and yield accurate results without any complications. The impact angle and height can be modified so that varying impact energies can be applied.

Testing results can help design better crumple zones and rigid cells of the vehicle, thereby reducing the damage and injury in case of a head-on impact.

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