

# Design, Modelling & Analysis of Safety Impact Guard for Heavy Duty Vehicle

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**Abstract**— *The problem of accident is a very acute in highway transportation. Traffic accident leads to loss of life and property. We cannot avoid accidents completely but impact of accident we can reduce by applying safety measures, safety instrument. Safety impact guard is one of the safety instruments which can reduce collision impact at rear end collision when accident occurs. Also provide safety against under ride crashes which is cause due to passenger vehicle collides with the truck or trailer. Proposed design of safety impact guard includes crushing element as force destroying material. Because of that when rear end collision is occurs the force or energy or impact is destroyed due to crushing action. Another aim of this project is to reduce the height of safety impact guard from ground so that the truck under ride crashes should be avoided. So that we can save the life and prevent the loss of property. The objective of this entire project would be of possible design of rear impact guard which provides safety against rear end collision.*

**Keywords**— *Impact, Crushing Element, Safety Guard, Crushing, Crashes.*

## I. INTRODUCTION

The problem of accident is a very acute in highway transportation due to complex flow pattern of vehicular traffic, presence of mixed traffic along with pedestrians. At present many safety measures are present which can reduced accidents. The Statistical analysis of accident is carried out periodically at critical locations or road stretches which will help to arrive at suitable measures to effectively decrease accident rates. According to ministry of road transport and highways transport research the increase in rate of accident from year 2005 to year 2009 is shown in the table. In 2009, 14 accidents occurred per hour.

TABLE I  
Number of Accidents and Number of Persons Involved: 2001 to 2009

Year	No. of Accidents		No. of persons affected		Accident severity
	Total	Fatal	Killed	Injured	(No. of persons killed per 100 accidents)
2005	4,39,255	83,491	94,968	4,65,282	22
2006	4,60,920	93,917	1,05,749	4,96,481	23
2007	4,79,216	1,01,161	1,14,444	5,13,340	24
2008	4,84,704	1,06,591	1,19,860	5,23,193	25
2009	4,86,384	1,10,993	1,25,660	5,15,458	25.8

As we cannot avoid accidents completely therefore many research is going on to reduce the impact of collision when accident occurs [4]. This study work consist design of such safety instrument which can reduce the impact or force when rear end collision occurs known as safety impact guard. When a passenger vehicle collides with a large truck or trailer rig, this mismatch is further aggravated when the passenger vehicle continues beneath the rear or side of the trailer truck. These are called truck under ride crashes and often decapitate the upper half of the passenger vehicle and its occupants.



Fig. 1: Under ride Crashes

Trailer, trucks or heavy loaded vehicles are slow in speed due to their load but passenger cars or vehicles speed much greater than the trailer, truck or heavy loaded vehicles. As high speed passenger vehicle collides to heavy loaded vehicle at the rear end the collision force or impact is greater. This force or impact can injure the passenger and also cause damage to vehicles property. This both problems can solve by attaching rear impact guard at the rear end of the trailer [6].

Problem of under ride crashes can solve by attaching safety impact guard and lowering the height of guard from ground. Also, force or impact of collision can reduce by action of crushing of crushing element used in rear impact guard.

## II. LITERATURE SURVEY

Before going to direct design consideration about rear impact guard we will see some other chapters which are related directly or indirectly to working of rear impact guard

### A. Causes of Accidents:

The various causes of road accidents are:

1) *Road Users*: Excessive speed and rash driving, violation of traffic rules, failure to perceive traffic situation or sign or signal in adequate time, carelessness, fatigue, alcohol, sleep etc.

2) *Vehicle*: Defects such as failure of brakes, steering system, tyre burst, lighting system.

3) Environmental factors: unfavourable weather conditions like mist, snow, smoke and heavy rainfall which restrict normal visibility and makes driving unsafe [4].

### B. Road Traffic Collisions:

Road traffic collisions generally fall into one of four common types:

1) Lane departure crashes, which occur when a driver leaves the lane they are in and collide with another vehicle or a roadside object. These include head on collisions and run-off-road collisions.

2) Collisions at junctions include rear-end collision and angle or side impacts.

3) Collisions involving pedestrians and cyclists [4]

Although other types of collision do occur. Rollovers are not very common, but lead to greater rates of severe injury and death. Vehicle rollovers are divided into two categories: tripped and untripped. Tripped rollovers are caused by forces from an external object, such as a curb or a collision with another vehicle. Untripped crashes are the result of steering input, speed, and friction with the ground. Due to this the vehicle starts to turn over. Some of these are secondary events that occur after a collision with a run-off-road crash or a collision with another vehicle.

### C. Rear-End Collisions:

A rear-end collision often called simply rear-end or in the UK a shunt is a traffic accident wherein a vehicle usually an automobile or a truck crashes into the vehicle in front of it. Common factors that contribute to rear-end collisions include by driver inattention or distraction, tailgating, panic stops, and reduced traction due to weather or worn pavement. It may also be a rail accident wherein a train runs into the rear of a preceding train. Typical scenarios for rear-ends are a sudden deceleration by the first car for example, to avoid someone crossing the street so that the following car does not have the time to brake and collides with the first. Alternatively the following car may accelerate more rapidly than the leading for example, leaving an intersection resulting in a collision.

According to NHAI, Indian road network of 33 lakh Km. Is second largest in the world.

1) About 65% of freight and 80% passenger traffic is carried by the roads.

2) National Highways constitute only about 1.7% of the road network but carry about 40% of the total road traffic.

Number of vehicles has been growing at an average pace of 10.16% per annum over the last five years [2].

By statistical study of accident occurrence at a particular road or location or zone of study for a long period of time it is possible to predict with reasonable accuracy the probability of accident occurrence per day or relative safety of different classes of road user in that location.

TABLE II  
Percentage of Persons Killed to Total Casualties in Road Accidents during 2003-2007

Year	2003	2004	2005	2006	2007
All India	16.5	16.6	17.0	17.6	18.2

In short as we see Indian scenario population goes on increasing, transportation also goes on increasing, number accidents are increases because of several reasons as mentioned before. Therefore to reduce the effect of accidents i.e. to save the life we have to implement strong and efficient safety instrument. Rear impact guard is safety device or instrument because of that we can save lives and prevent loss of property.

### D. Top selling Cars and Trucks in India:

Ground clearance for top selling cars and trucks in India as follows: Ground clearance of truck or trailer:

TABLE IV  
Ground Clearance of Truck or Trailers and cars [6]

Model	Manufacturer	Ground Clearance	Model	Manufacturer	Ground Clearance
2214	Ashok Leyland	180 mm	Swift	Maruti	170 mm
2516 H	Ashok Leyland	260 mm	Wagon R	Maruti	165 mm
1613 H	Ashok Leyland	260 mm	i10	Huyndai	165 mm
DI3200 CRX	Mahindra	190 mm	i20	Huyndai	165 mm
SFC 407 EX	Tata	220 mm	Indica	Tata	165 mm

From these dimension we had seen that ground clearance of trucks, trailers or heavy loaded vehicles are greater than passenger cars. Therefore if passenger vehicles could not control their speed then they easily go under the heavy loaded vehicle.

#### E. About Rear Impact Guard

We consider the case that truck, trailer or heavy loaded vehicle travelling on road and behind that passenger vehicle is travelling. In case sudden brake is applied by heavy loaded vehicle or passenger vehicle could not stop the vehicle then the passenger vehicle crashes to front vehicle i.e. heavy loaded vehicle. But passenger vehicle speed is greater as that of trailer or truck because of that the passenger car goes under the trailer or truck position. As shown in following figure this situation can also cut the wind screen which also cut upper part of body of the passenger. Also the impact of the collision is much greater.

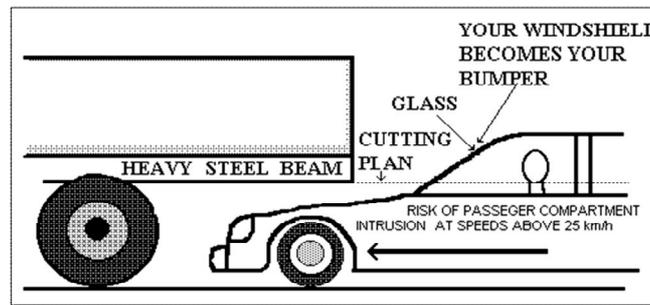


Fig.2: Position of Vehicle When Crash is Going to Happen

Initially to overcome both these problem, at the rear end of the truck bar is attached. If collision happens then the bar acts like bumper to stop the car. But only this bar is not sufficient to stop the car because small vehicle speed and impact is greater. Due to sudden force exerts on bar then the bar may be fail. Further more research and design is modified and implemented. This arrangement is as shown in following picture:



Fig.3: Crash Bars Attached to the Rear End of Vehicle

But only this bar is not sufficient to stop the car because small vehicle speed and impact is greater. Bar may fail or break due to large force. Therefore this system is insufficient. Therefore to absorb or destroy this energy we need some more arrangement. For that many research and inventions are going on till now. We will see in some cases as follows: Huddle *et al* From US gets patent for rear impact guard assembly for trailer.

### III. SCOPE OF WORK

As explained before when we consider the rear end collision, then two main problems are underride crashes and loss of life and property. To overcome these problems, rear impact guard is a solution. There are two possible designs for rear impact guard as explained follows:

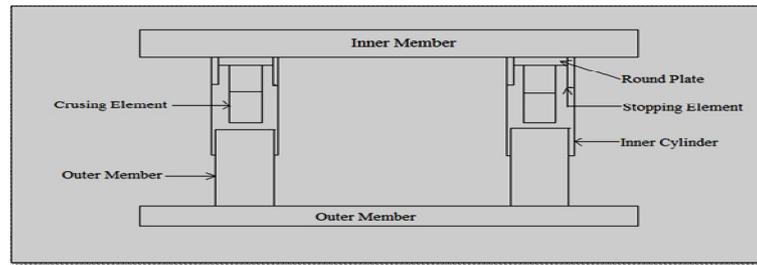


Fig.4: Proposed Design of Safety Impact Guard

Proposed design of safety impact guard should include:

**A. Inner Member:**

This member should attach to the chassis of heavy duty vehicle through the projections made by I section member. So that the height of this safety impact guard from ground level should reduce. So our first aim should be completed i.e. reduce the ground clearance of safety impact guard to avoid under ride crashes. As this member is attached to chassis of heavy duty vehicle so the effect of impact is negligible on chassis. Therefore the Inner member and chassis act as rigid member. The overall effect of impact on heavy duty vehicle is negligible.

**B. Inner Cylinder:**

This attached to the inner member. These consist of crushing element, round plate, stopping element. The diameter of inner cylinder should be more than the outer cylinder. So the outer cylinder can play sliding motion in inner cylinder when impact comes.

**C. Crushing Element:**

Crushing element is the element which crushes after impact comes from the outer element. Crushing element is hollowing. Due to crushing effect the impact force will be destroyed as well as the effect of this crushing element also destroyed. We accept the destruction of crushing element as they play an important role in destruction of impact energy. According to impact force to sustain this force number of crushing element and inner element can vary.

**D. Round Plate:**

Round plate should be placed inside the inner cylinder as back support. Due to round plate strength of inner member & inner cylinder increases also restricts the motion of outer cylinder going besides the inner member.

**E. Stopping Element:**

Stopping element is added in inner cylinder to stop the motion of outer cylinder. When impact force acts on the outer member then it pushes outer cylinder which causes sliding motion between inner and outer cylinder. This impact force is very large therefore to stop motion this stopping element is added.

**F. Outer Member:**

The outer member is the element on which the impact force acts or the passenger vehicle back to the heavy vehicle crashes on this outer member.

**G. Outer Cylinder:**

This is attached to the outer member. The impact force is transmitted through the outer cylinder to the crushing element. The diameter of this outer cylinder is less than the inner cylinder.

For this project to design such type of safety impact guard two vehicle models are chosen as follows:

Heavy Duty Vehicle: TATA LPS 3516 EX

Passenger Vehicle: Hyundai i10

From the above specification and dimension we can design some member of safety impact guard. In this project manufacturing, testing and trials are not included.

**I. Calculation of Impact Force:**

In mechanics, an impact is a high force or shock applied over a short time period when two or more bodies collide.

$$\text{Impact Force} = \text{Kinetic Energy} / \text{Impact Distance}$$

Impact distance in maximum case consider as 0.5m. For this project impact distance is consider as 0.5m.

Kinetic Energy of a passenger vehicle is calculated as:  $\text{Kinetic Energy} = \frac{1}{2} m V^2$

Where m = mass of passenger vehicle, V = velocity of passenger vehicle

For sustaining all impact energy we have to consider maximum impact force acting on heavy duty vehicle. For calculation of maximum impact force, consider maximum velocity of passenger vehicle travelling on Indian highway is 80 km/hr. i.e. 22.23 m/sec.

We consider the passenger vehicle mass i.e. Hyundai i10 1040 kg. Therefore the eqn. (2) becomes:

$$K.E = \frac{1}{2} * 1040 * (22.23)^2 = 256.969 * 10^3 \text{ J}$$

Therefore above equation becomes:

$$\begin{aligned} \text{Impact Force} &= 256.969 * 10^3 / 0.5 \\ &= 513.939 \text{ KN} \end{aligned}$$

Impact Force 513.939 KN we have to sustain by safety impact guard. Reversely we have to design the safety impact guard to sustain this much of force mentioned above.

We know the basic of design that:  $\text{Stress} = \text{Force}/\text{Area}$  [3, 5]

Therefore required area:  $\text{Area} = 2055.756 \text{ mm}^2$

Therefore the required compressive area of crushing element should be  $2055.756 \text{ mm}^2$ . According to above dimension crushing element drawing as follows:

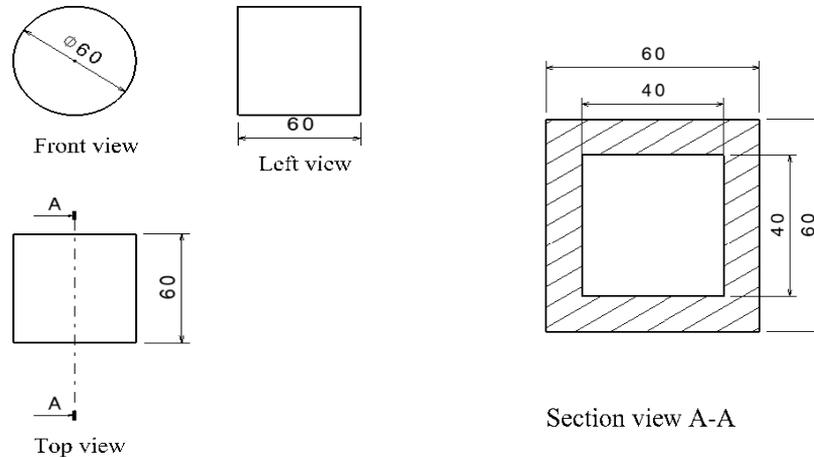


Fig. 5: Detailing of Crushing Element

#### IV. DESIGN, MODELLING ANALYSIS OF SAFETY IMPACT GUARD

The assembly of safety impact guard is done with help of assembly workbench in CATIA. All detailing and parts for this model assembly was explained before. Assembly of safety impact guard consist of:

- Inner Member, 2 Inner Cylinder, 2 Round Plate
- Outer Member, 2 Outer Cylinder

So detailing and assembly pictures shown in below:

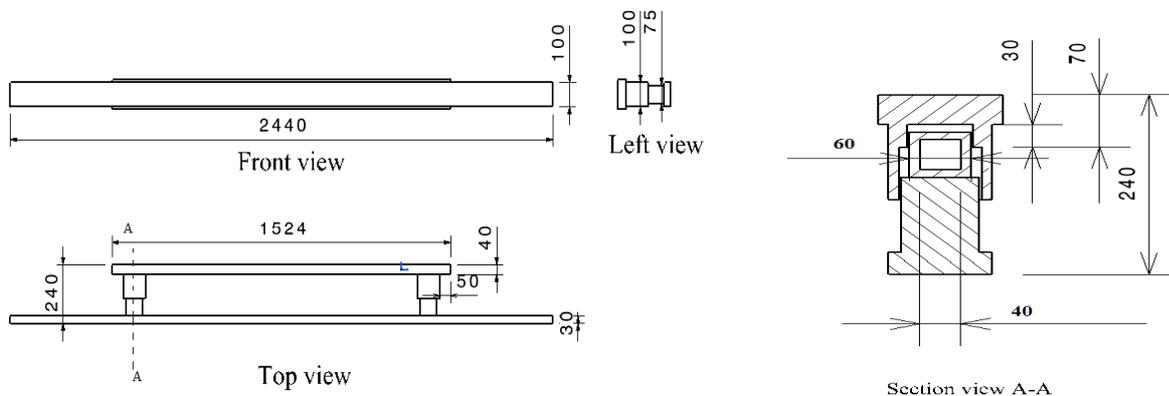


Fig. 6: Detailing of Assembly of Safety Impact Guard

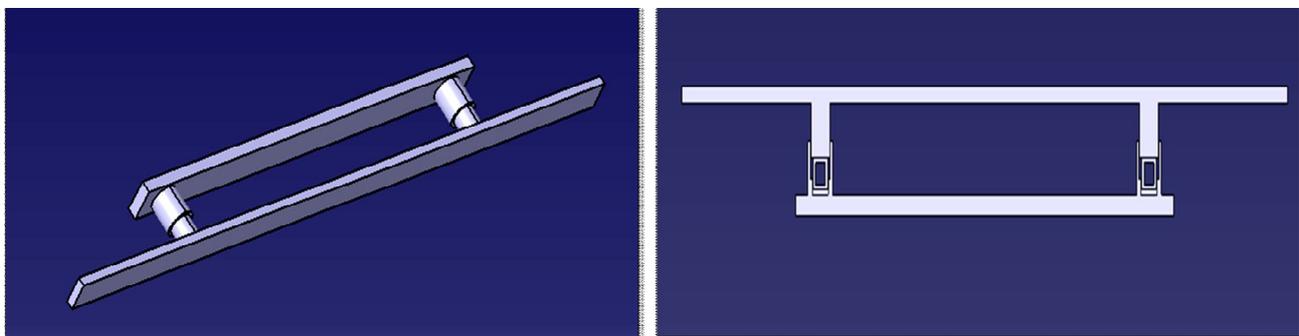


Fig. 7: Image of Modelling and section view of Assembly Safety Impact Guard

Above model is analysed using ANSYS Workbench. As impact force acts on outer member then outer member displace to some distance. But for this project analysis scope limited to the static structural analysis, displacement on surface of crushing element and outer member is added. By giving the appropriate input parameters on ANSYS Workbench software to the model i.e. fixed support, displacement, load analysis of the safety impact guard is carried out.

Above safety impact guard is analysed for 10% of force of total impact force which is 5139.39N. Result for maximum stress value is as follows:

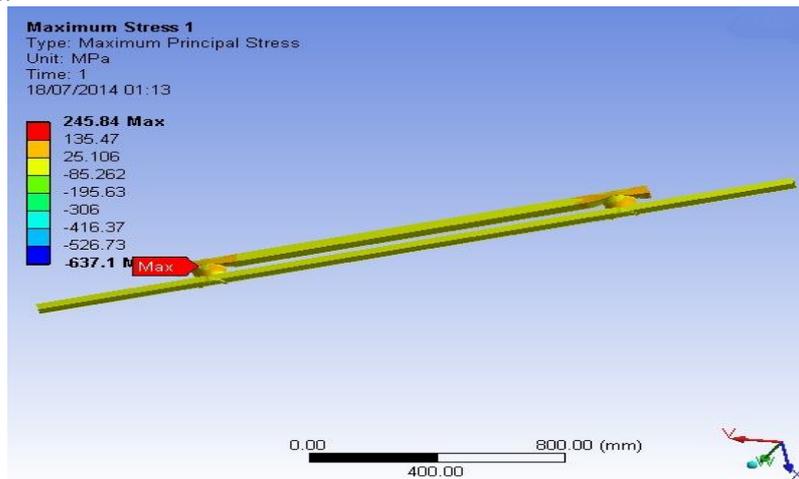


Fig. 9: Maximum Stress Acting on Safety Impact Guard

For this much of force stress acting on safety impact guard is 246MPa while permissible stress is 250MPa. Therefore this design is acceptable. In this design for 10% of load crushing element used in number two. According to that for sustaining 20% loading condition crushing element should be used in number is four according to that for sustaining 40% loading condition crushing element will be eight in number also for sustaining 80% loading condition crushing element will be 16 in number.

According to that design of safety impact guard has to be change. Design changes detailing is given in next figure.

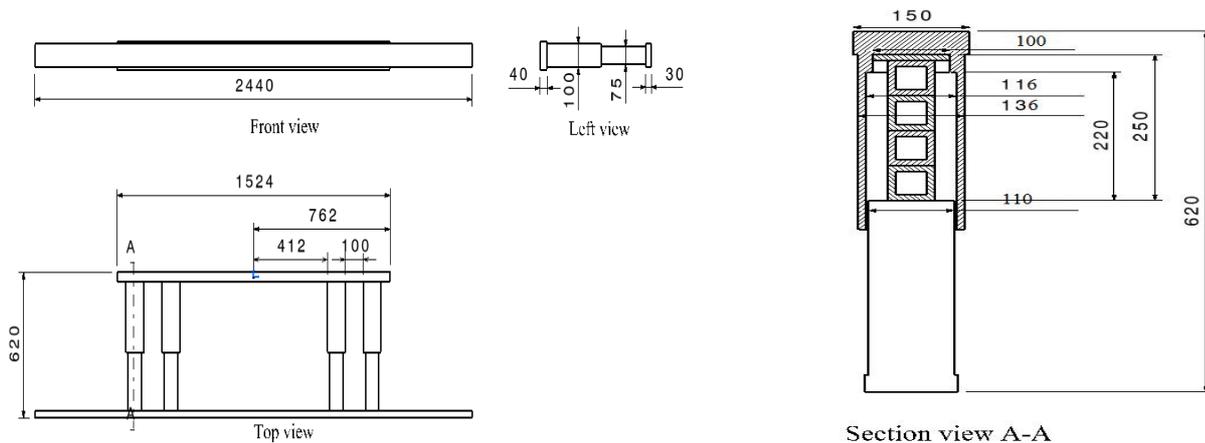


Fig. 10: Detailing of New Safety Impact Guard

For above design same analysis procedure is carried out. The result for maximum stress is explained below:

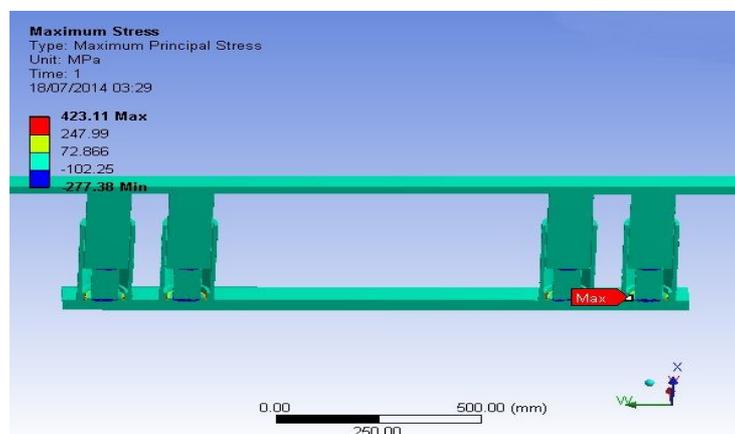


Fig. 11: Image of Maximum Stress Induced



From above image we can say that by increasing inner diameter of inner cylinder, stress appeared in surface of inner member is less in magnitude. At the inner member maximum stress is 423.11MPa in some region. This minor fault or modification will be corrected in future. It is observed that stress in other part of safety guard is lies in between 72-247 MPa. Therefore this trial is successful. Therefore for this project to satisfy aim i.e. to sustain impact force this design of safety impact guard is accepted concept wise.

#### V. CONCLUSION

Safety Impact Guard is one of the safety instruments which can reduce collision impact at rear end collision when accident occurs. Also provide safety against under ride crashes which is cause due to passenger vehicle collides with the truck or trailer. According to that design, modelling & analysis is done. By implementing this safety impact guard passenger life present in passenger cars can be safe. Also vital parts of passenger vehicle i.e. engines etc. will be safe. For resistance of impact force there is no need to add any safety instrument on passenger vehicle as this safety impact guard attached to the heavy duty vehicle.

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