iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 7 Issue: I Month of publication: January 2019

DOI: http://doi.org/10.22214/ijraset.2019.1042

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887
Volume 7 Issue I, Jan 2019- Available at www.ijraset.com

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

Mayur D. Mahajan[1], Dr. E. R. Deore[2]
[1]PG Student, [2]Professor, Dept. of Mechanical Engineering, S.S.V.P.S's B.S. Deore College of Engineering Dhule (M.S.), India

Abstract: Death due to Accidents are greater than natural disaster and terror attack in India. One of the most injurious cases is the crash between car and heavy vehicle. Every year lacks of passengers are killed due to road accidents in which 8% are due to heavy vehicles. Road accident causes loss of life and also property. Accidents can not be avoided completely but the impact force is decreased by application of High energy safety impact guard. High Energy Safety impact guard is protecting device used to reduce collision impact at rear end of heavy vehicle when accident occurs. Another aim of this project is to increase the striking area of collision so that the underride crashes of car should be avoided, which is done by using two outer members of safety guard. The of crushing element inside the safety guard cylinder act as a force destroying device. Presence of crushing element results into reduction of impact force at the collision area. This paper proposes analysis of new design of High Energy Safety guard mounted on the rear end of a heavy vehicle to protect under running of smaller vehicles like car.
Keywords: Impact, Crushing Element, High Energy Safety Guard, Crushing, Underride.

I. INTRODUCTION

When a road accident between a car and a heavy vehicle happens, all the protection features for the occupants built into the car, such as seatbelts and airbags, have a reduced effectiveness. This because of the very big differences in geometry and stiffness between the two vehicles. The very large height of the truck, especially when the heavy vehicle is not equipped with a Safety Guard, it can allow the underride or also called underrun of the car.

Many people get injured during underride accidents. Because of high Collision impact between car and Heavy vehicle chassis, passenger present in car will cause death or seriously injured. To avoid such accidents safety guard has to be installed on the heavy good vehicle which would prevent the passenger of the small vehicle from getting fatal injuries. Without installation of the safety guard, entire energy will be on the frontal car structure which would not be able take such impact. The entire vehicle has gone underneath the truck and the car structure has got crushed due to the sudden impact load. Figure shows damage to small passenger vehicle during a rear underride accident.

Fig. 1: Underride Crash of Car

According to ministry of road transport and highways transport research the increase in rate of accident from year 2013 to year 2017 is shown in the table.

Table 1: Number of Accident and Number of Persons Affected from 2013 to 2017

Year	Number of Accidents		Number of Persons affected		Accident Severity
	Total	Fatal	Killed	Injured	No. of persons killed per 100 accidents
2013	4,86,476	1,22,589	1,37,572	4,94,893	28.3
2014	4,89,400	1,25,828	1,39,671	4,93,474	28.5
2015	5,01,423	1,31,726	1,46,133	5,00,279	29.1
2016	4,80,652	1,36,071	1,50,785	4,94,624	31.4
2017	4,64,910	1,34,796	1,47,913	4,70,975	31.8

In 2017, 53 accidents and 17 deaths occurred per hour. According to the publication, the most efficient age group 18-45 accounted for a share of 69% of all road traffic accident deaths in India which will reflect on developement of the nation. Problem of under ride crashes can solve by attaching High Energy safety impact guard at rear end of Heavy Vehicle. Presence of crushing element results into reduction of impact force at the collision area during crushing action.

II. LITERATURE SURVEY

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

A. Rear-End Collisions

A vehicle usually an automobile or a truck crashes into the vehicle in front of it. Factors responsible for rear-end collisions includes loss of attention or distraction of driver, work fatigue or continuous hours of driving, Insufficient front lighting of passenger vehicle also in rainy season presence of water on road surface results into reduced friction between vehicle and road responsible for rear end collision.

Condition of roadways on which vehicles travel is also important reasons behind the cause of accident, poorer condition of roadways leads to increased severity of accident. One of major roadways which carry most of road traffic in India is National Highways which is described as below:

According to NHAI, India’s total road network is of 56 lakh Km, which is second largest road network in the world.

Out of total 56 lacks km road network National Highways constitute only 2% but National Highway carries majority of road traffic which is about 40%.

Number of vehicles has been growing almost at an average pace of 10% per annum over the last five years. Increase in number of total Registered vehicle in India from 1951- 2016 is as shown in figure:

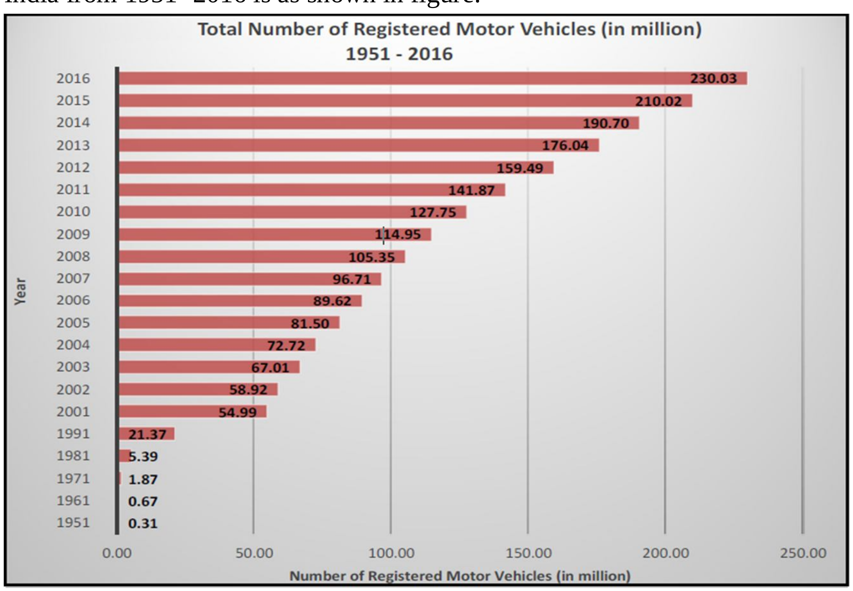

Figure.2 : Total number of vehicle population (in millions)

Recent Scenario of growth of population in India indicates that there is rapid increase in population over the last few decades. To fulfill the need of transportation of this increased population, number of vehicle goes on increasing. As explained earlier the reasons responsible for accidents and increased number of vehicles leads to increased in number of accidents. Therefore, to reduce number of accidents an underrun protecting device i.e. High Energy safety Impact guard is needed because of that we can save lives and prevent loss of property.
Percentage of persons killed in total casualties in Road accidents during 2012-2017 is as shown in Table

Table 2: Percentage of Persons Killed in Total Casualties in Road Accidents during 2012-2017

Year	2013	2014	2015	2016	2017
All India	28.3	28.5	29.1	31.4	31.8

B. Ground Clearance

One of major reason behind the underrun crash is ground clearance of Heavy duty vehicle. The ground clearance provided in Heavy Duty vehicles is larger compare to small passenger vehicle. Because of that when collision between car and heavy vehicle happens the rear side of heavy vehicle cuts the upper part of passenger vehicle. i.e. underride of car happens which results into death or severe injury to passengers which present in car.

C. Position of Rear Impact Guard

Consider the case in which, Passenger vehicle like car is travelling at a certain speed and ahead of car a loaded heavy duty vehicle is running. Obviously since heavy vehicle is loaded it will travel at lower speed than that of passenger vehicle. In case if any obtrusion comes in front of heavy duty vehicle it will apply sudden brakes, due to that speed of heavy vehicle reduces immediately in fraction of seconds. Due to this driver of passenger vehicle could not get control over vehicle and car will undergo into beneath of heavy vehicle due to undercutting of upper part of passenger vehicle as shown in figure.

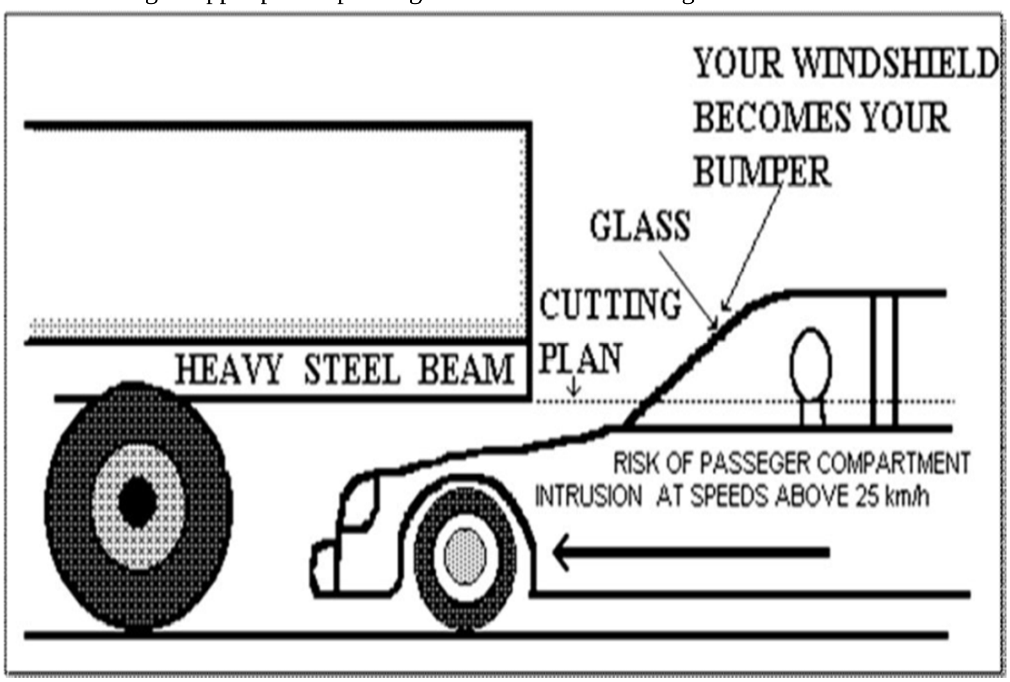

Fig.3: Position of Vehicle when crash is going to happen

To overcome the problem of underride crash, hollow bar is attached at the rear end of heavy duty vehicle which will act like solid body i.e. it does not have shock absorbing capability. At the time of collision the impact force by car is such a large that this bar is not able to absorb the shock and get damaged and allows under running of vehicle.
Due to this problem High Energy safety Impact guard is attached to the rear end of Heavy duty Vehicle so that the underside crash should be avoided. Further new research and design modifications will be done and implemented.

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III. METHODOLOGY

The main objectives of this High energy safety impact guard is to avoid underride crashes and to reduce the impact force between passenger car and heavy duty vehicle so that life of passengers can be saved and also damages of vehicles can be prevented. With respect to our objective the proposed design of safety impact guard is as shown in figure:

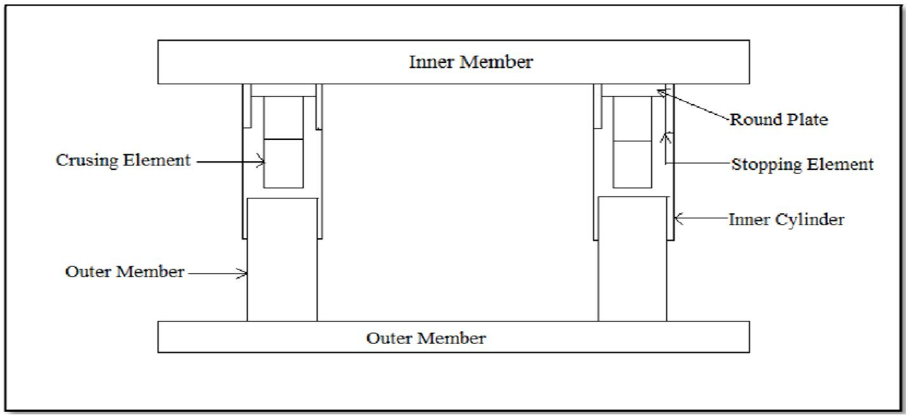

Fig. 4 Proposed Design of safety impact guard

Safety impact guard constitutes an important parts which are described as follows:

A. Inner Member

This member is attached to the chassis of heavy duty vehicle at rear side using I section member, so that the clearance in between safety impact guard and ground is reduced therefore, underride crash is eliminated. As force is absorbed by the crushing element which is present in inner cylinder therefore effect of impact force on inner member as well as on chassis of heavy vehicle is reduced. Therefore, inner member act like a rigid body and net impact force experienced by heavy duty vehicle is negligible.

B. Inner Cylinder

This cylinder is attached on the inner member. This device consist of round plate, stopping element, crushing element,. The diameter of inner cylinder should be greater than the outer cylinder, so the outer cylinder slide in inner cylinder when impact force applied on it.

C. Crushing Element

When impact force is applied on outer member of safety impact guard, the crushing element present in inner member get crushed. Crushing element is hollow in nature. The total impact force get destroyed during to crushing action of crushing element. For reduction of impact force the destruction of crushing element plays an important role. In various situations as amount of impact force varies, number of crushing element can be vary.

D. Round Plate

Round plate is inserted in inner cylinder and act as back support for inner member. Strength of inner member is increases due to round plate also it not allows the motion of outer member to go beyond inner member

E. Connecting plate

Connecting plate is used to connect the two inner members of safety guard in parallely.

F. Stopping Element

Stopping element is added in inner cylinder to restrict the motion of outer cylinder up to certain limit. When impact force acts on the outer member then it pushes outer cylinder into inner cylinder and allows sliding motion between inner and outer cylinder. This impact force very large therefore it is necessary to restrict this motion otherwise it will damage the inner member therefore stopping element is added.

G. Outer Member

The outer member is the element on which the impact force act when passenger vehicle strikes at rear end of heavy vehicle.

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H. Outer Cylinder

This cylinder is attached on the outer member. The impact force is transmitted through the outer member to outer cylinder to the crushing element. The diameter of outer cylinder is less than the inner cylinder so that it can slide. For this project to design such type of safety impact guard two vehicle models are considered as follows:

Heavy Duty Vehicle: TATA LPS 3516 EX
Passenger Vehicle: Huyndai *i10*

From the specification and dimension of above considered vehicles we can design some member of safety impact guard.

IV. DESIGN, MODELLING ANALYSIS OF SAFETY IMPACT GUARD

A. Design of Safety Impact Guard

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

Impact Force = Kinetic Energy/ Impact Distance …………….(1)

Consider the impact distance for maximum case, for this project impact distance is consider as 0.5m.

Kinetic Energy of a passenger vehicle is calculated as follows:

Kinetic Energy = ½ mv^2 ……………………………………….(2)

Where m = mass of passenger vehicle i.e car; v = velocity of passenger vehicle

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

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

$K.E = ½ * 1040*(22.23)^2 = 256.969*10^3$ J

Therefore equation (1) becomes:

$\therefore$ Impact Force $=256.969*10^3/0.5$
=513.939 KN

Total force acting on both the members is 513.939KN. Therefore, force acting on single member is half of it i.e. 256.969KN. Impact Force 256.969KN have to sustain by safety impact guard. By using impact force we have to design the safety impact guard to sustain this much of force in reverse manner.

We know the basic equation of stress which is: Stress = Force/Area

$\therefore$ Compressive area = 2055.756 mm^2

Therefore the required compressive area of crushing element which is going to crush should be 2055.756 mm^2. According to area dimension of crushing element are designed as follows:

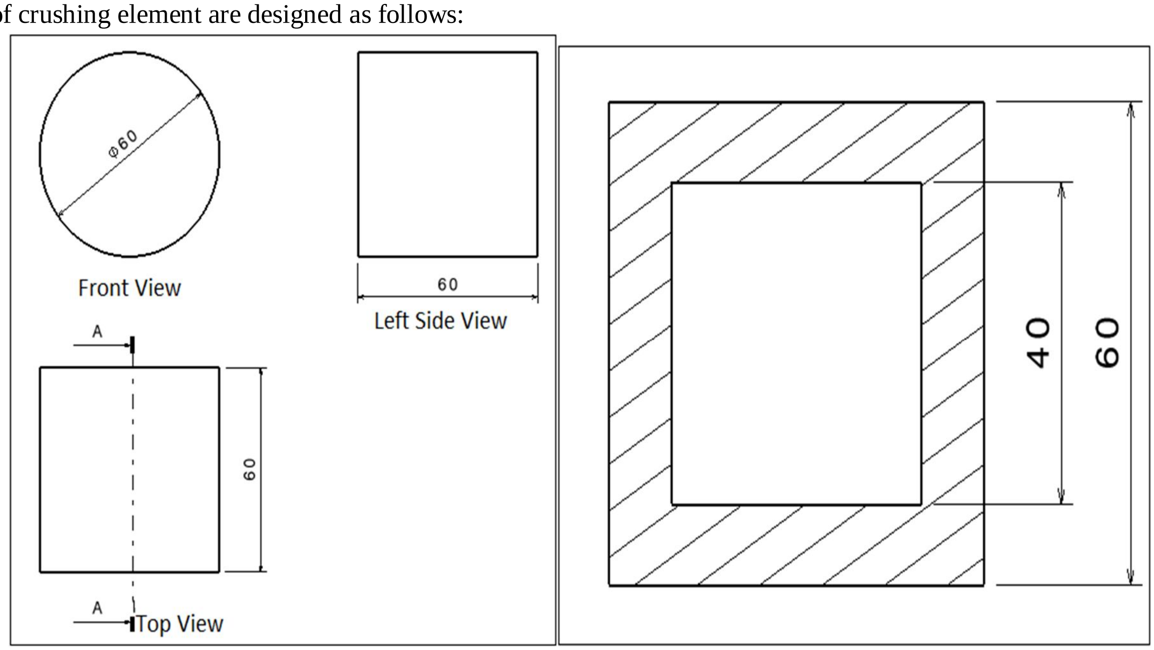

Fig.5: Detailing of crushing Element

B. Design of Plate Thickness

The Outer member will act like a overhang beam which is to be acted by uniformly distributed load.

Total force acting on both the members is 513.939KN, Therefore force acting on single member is half of it i.e. 256.969KN.

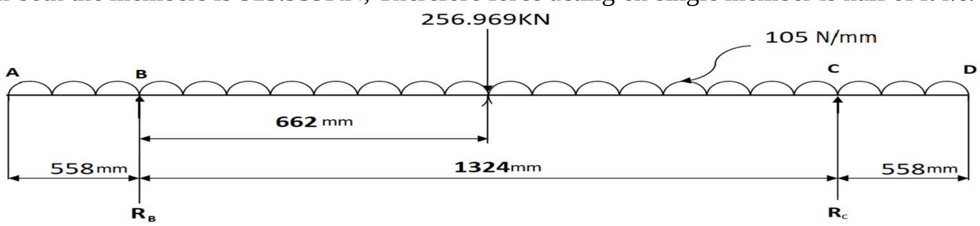

Fig. 6: Loading Diagram of outer member

To Find out Support Reactions R_B and R_C;

$\sum F_y = 0$

$\therefore R_B + R_C = 256.969$ ………………………(3)

To Find out R_B ;

Take $\sum$Moment at point B = 0

$\therefore 256.969 \times 662 - R_C \times 1324 = 0$

$\therefore R_C = 128.484$ KN, Put this value of R_B in Equation (3), we get;

$R_B + 128.484 = 256.969$

$\therefore R_B = 128.484$ KN

1) Shear Force Calculations

Shear Force at A = 0

Shear Force at B_L = -105 x 558 = -58590 = -58.59 KN

Shear Force at $B_{R\,=}$ 58590+128484= 69.894 x 10^3 = 69.894 KN

Shear Force at C_L = 69894 – (105 x 1324)= -69.126 x 10^3 = -69.126 KN

Shear Force at C_R = -69126 + 128484 = 59.358 x 10^3 = 59.358 KN

Shear Force at D = 0

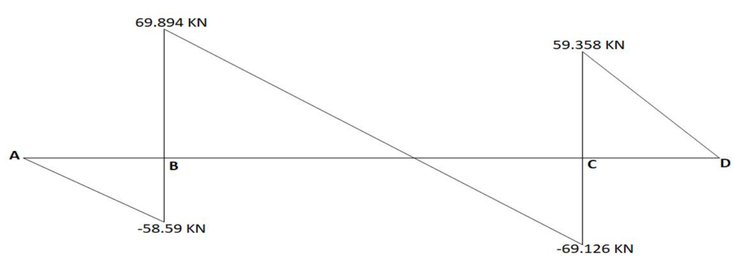

Fig. 7: Shear Force Diagram of outer member

2) Bending Moment Calculations

$M_A = 0$

$M_B = -105 \times 558 \times \frac{558}{2} = -16.346 \times 10^3$ KNmm

$M_C = (-105 \times 1882 \times \frac{1882}{2}) + (128484 \times 1324) = -15.838 \times 10^3$ KNmm

$M_D = 0$

3) Location of Maximum Bending Moment

Let assume at a section x-x from point A; Bending Moment is Maximum

$M_{x\text{-}x\,=} -[105^* \, x^*\frac{x}{2}] + 128484^*(x-558)$

Solving this equation; we get x = 1586mm from point A

4) Maximum Bending Moment

$= -105^*1586 * \frac{1586}{2} + 12848^*(1586-558)$

B.M. $_{max} = 23.262^*10^3$ KNmm

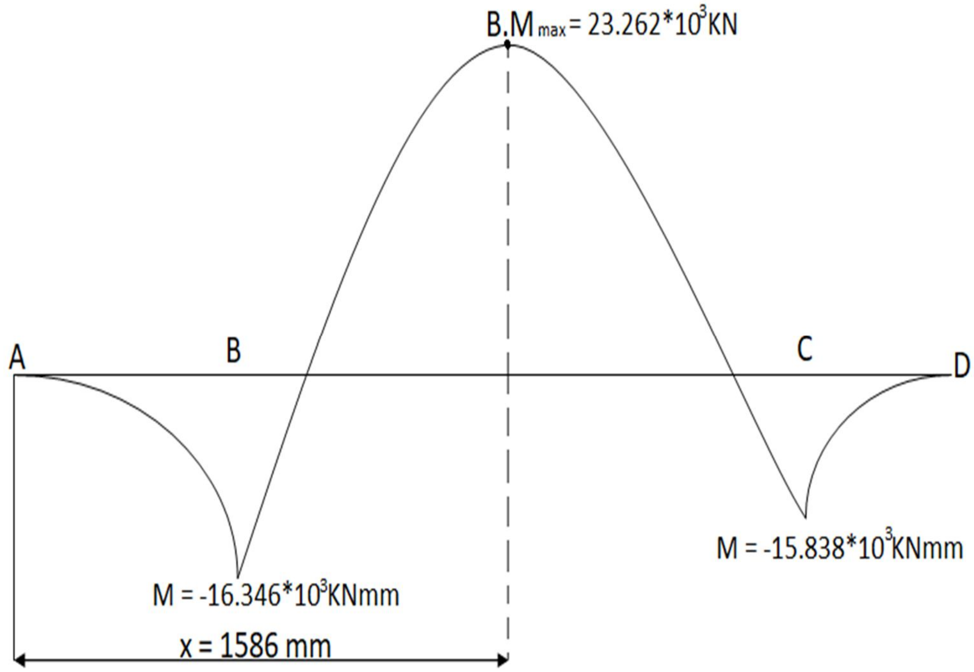

Fig.8: Bending Moment Diagram of outer member

5) Moment of Inertia of Plate

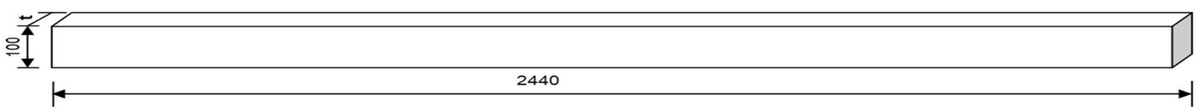

Fig. 9: Dimensions of outer member Plate

Equation for Moment of Inertia of plate is

$$I = \frac{bd^3}{12}$$

$$= \frac{2440t^3}{12}$$

$$\therefore I = 203.33\ t^3\ mm^4$$

Position of neutral axis from base

$$y = \frac{100}{2}$$

$$\therefore y = 50\ mm$$

Therefore, using Maximum Bending Moment and allowable stress we can calculate the thickness of plate :

$$\sigma = \frac{Mx * y}{I}$$

$$250 = \frac{23.262*10^6*50}{203.33t^3}$$

$$t^3 = \frac{23.622*10^6*50}{250*203.33}$$

$$t^3 = 28.33mm$$

$$\therefore t \approx 30\ mm$$

Therefore, thickness of outer member is selected as 30 mm and for inner member to increase its strength and rigidity thickness selected is 40mm.

C. Modelling and Assembly of Safety Impact Guard

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

- 2 Inner Member, 4 Inner Cylinder, 4 Round Plate, 4 Crushing Element, 2 Connecting Plate
- 2Outer Member, 4 Outer Cylinder

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The detailing and assembly of High Energy safety impact guard is as shown in below:

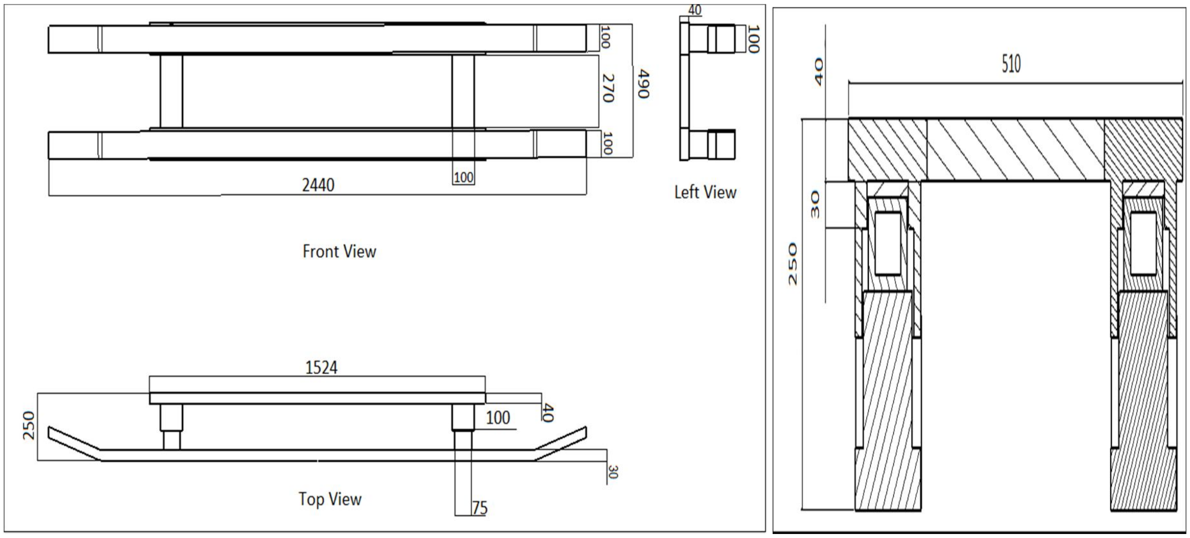

Fig.10: Detailing of assembly of safety impact guard

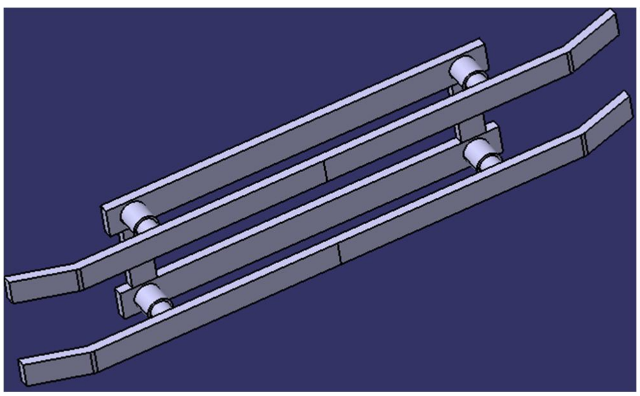
Fig.11: Modelling of assembly of safety impact guard

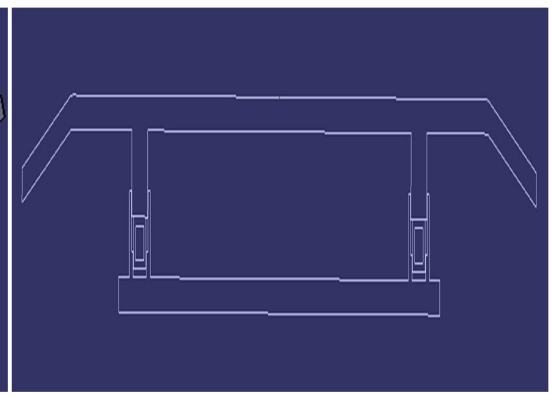
Fig12: Section View of Catia model of Safety Guard

Above CATIA model is analyzed using ANSYS Workbench, for this project scope of analysis is limited to static structural. Displacement to the crushing element and outer member these boundary conditions are applied. when impact force acts on outer member then outer member displace to some distance inside of inner member due to crushing action. By giving the appropriate input parameters on ANSYS Workbench software to the CATIA model i.e. fixed support, displacement to outer member, load application analysis of the safety impact guard is carried out.
Above safety impact guard is analysed for 20% of force of total impact force which is 51393.9N Results for maximum stress value is as follows:

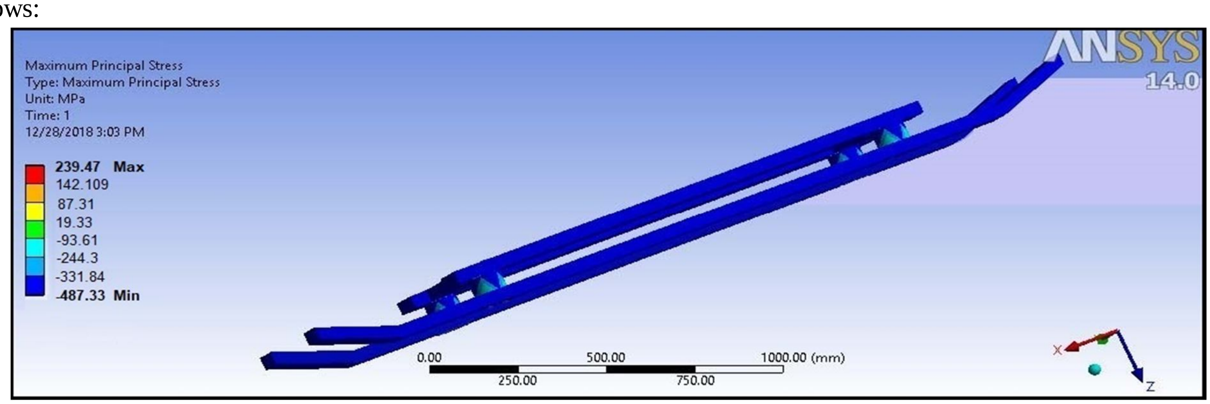

Fig.13: Maximum stresses induced in Safety Impact guard for 20% of loading

For this much of force stress acting on safety impact guard is 239MPa while permissible stress is 250MPa. Therefore this design is acceptable. In this design for 20% of load number of crushing element used in four. According to that for sustaining 80% loading condition crushing element should be used in number is sixteen. For sustaining 80% of load design of safety impact guard has to be change. Design changes are made as shown in next figure.

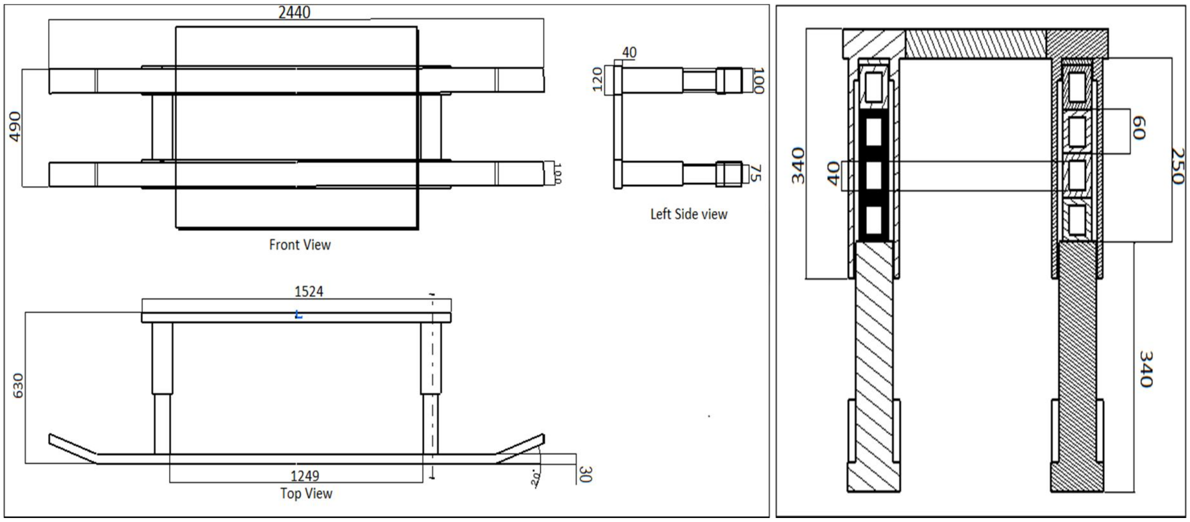

Fig.14: Detailing of assembly of safety impact guard designed for sustaining 80% of loading

For 80% loading same analysis procedure is carried out and the result for maximum stress induced is explained below:

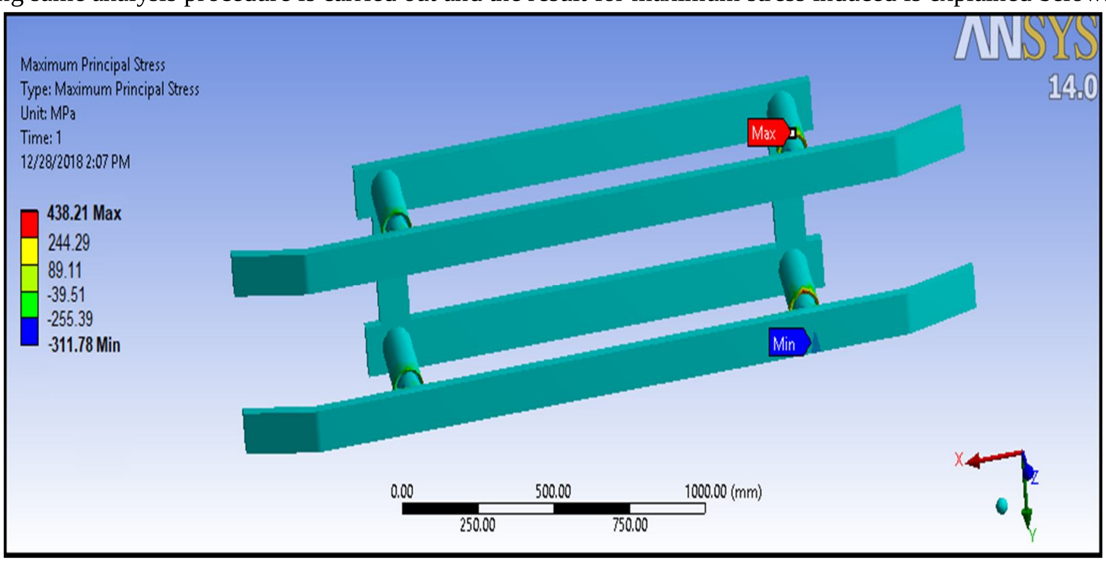

Fig.15: Maximum stresses induced in Safety Impact guard for 80% of loading

Maximum stress appearing is 438MPa in some region. This minor fault and modification will be corrected in future. It is observed that stress in other part of safety guard is lies in between 89-244 MPa. Therefore this trial is successful. Our aim to conduct the trial is to sustain impact force and increasing striking area so that underride crash is prevented is satisfied. Therefore, this design of safety impact guard is accepted concept wise.

V. CONCLUSION

High Energy Safety Impact Guard is one of the safety instruments which can reduce collision impact at rear end collision when accident occurs. Safety guard provides protection against under ride crashes by increasing striking area by using two outer members of safety guard. With respect to our objective design, modelling and analysis of High Energy safety impact guard is done. By implementing this safety impact guard life of passenger present in passenger cars can be saved and also passenger is saved from getting serious injuries, and vital parts of passenger vehicle i.e. engines etc. will be prevented from damage.

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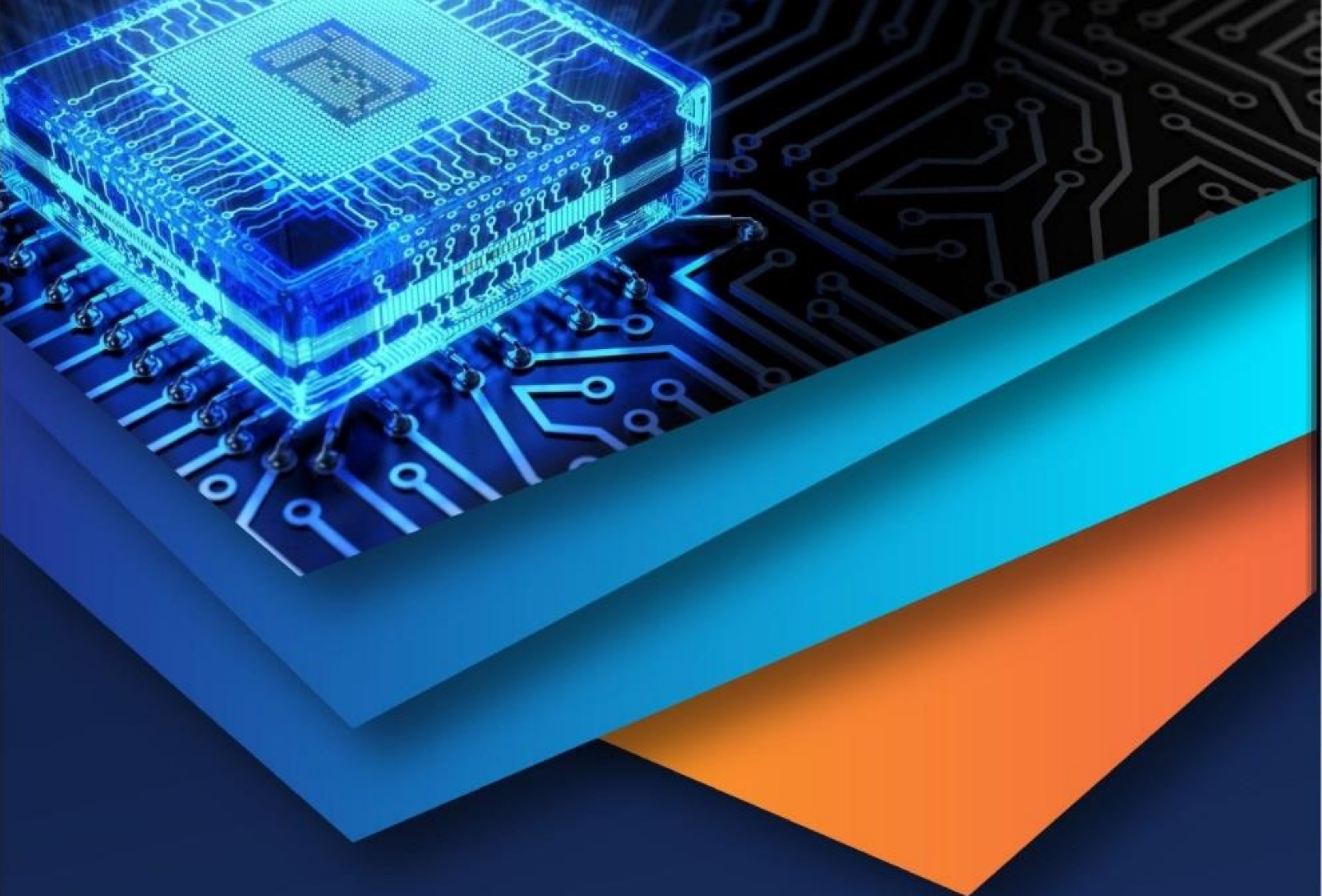

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