Crashing Analysis of Rear under Run Protection Device (RUPD)

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Abstract: This paper deals with studying, modeling & analysis of a Rear under Run Protection (RUPD) system under crashing status. The main objective is to ensure the safety of the car and the occupants by designing the RUPD. The choices of material and the structural design are the two major factors for impact energy absorption during a crash. It is important to know the material & mechanical properties and failure conditions during the impact. This study focused on study about RUPD and also the various factors influencing rear under run protection device. This study is a complete work of a major project wherein the RUPD will be subjected to explicit dynamic testing with variable load distributions at different location on RUPD. Under-running of passenger vehicles is one of the important parameters to be considered during design, optimization & development of heavy commercial vehicle chassis. In INDIA, the legal requirements of a RUPD are fixed in regulation IS 14812-2005 which are derived from ECE R 58, which provides strict requirements in terms of device design and its behavior under loading that the device needs to fulfill for the approval of commercial vehicles.

1. Introduction

Many people get injured during underride accidents. Underride occurs when a small passenger vehicle goes under the heavy commercial vehicle either from the front or rear or side. During such accidents the passenger compartment of the small vehicle strikes the chassis of the heavy vehicle causing severe injuries to passenger in the smaller vehicle. Underride accident are of three different types namely front, rear and side underrun accidents.

To avoid such accidents an underrun device has to be installed on the heavy good vehicle which would prevent the passenger of the small vehicle from getting fatal injuries. In this paper we are going to increase the absorption bearing capacity of the impact load of crashing vehicle and thereof of the RUPD (Rear Under-Run Protection Device).

Without the installation of the RUPD the entire energy will be on the frontal car structure which would not be able take such impact. Figure shows damage to small passenger vehicle during a rear underride accident. The entire vehicle has gone underneath the truck and the car structure has got crushed due to the sudden impact load.

Figure 1: Accidental Image

2. Literature Review

The heavy commercial vehicles are equipped with under-run protection devices (UPD) to enhance safety of occupants in small vehicles in the event of under-run. These UPD are popularly classified as RUPD (rear under-run protection devices), SUPD (side under-run protection devices), and FUPD (front under-run protection devices). do not revise any of the current designations.

- Gholap Umesh .S, Prof. Shinde.V.B formulated head on collision contribute significant amount of serious accidents which causes driver fatalities. The car safety performances can work effectively by providing FUPD to the heavy trucks. The trucks with UPD can reduce the car driver fatalities by 40 % In India, for Front Under-run Protection Device, IS 14812:2005 regulation is required in for the trucks to meet the safety requirement to protect under running of the passenger car.[6]

- Mr. George Joseph's objective of the study, one under ride protection device for a rear under ride accident was designed and its performance compared. A quasi static test was performed on guard to test the strength and energy absorption capacity by

withstanding the applied loads. All the constrained and boundary condition used for the study worked well. Nearly six designs were studied and run simulation to study the effectiveness of each guard and results were plotted.[14].

• Kaustubh Joshi Head on collision contribute significant amount of serious accidents which causes driver fatalities. The car safety performances can work effectively by providing UPD to the heavy trucks. The trucks with UPD can reduce the car driver fatalities by 40 % In India, for Rear Under-run Protection Device, IS 14812:2005 regulation is required in for the trucks to meet the safety requirement to protect under running of the passenger car. In above said design, the maximum displacement of RUPD bar is limited to 50mm and the plastic strain is limited.[10]

• Satish Gombi, Mahendra .S.B, Amithkumar H: focused on energy absorption analysis of a Rear under Run Protection Device (RUPD) under crash scenario. The aim of the study is to replace Steel RUPD with RUPD made of composite material to reduce weight of the vehicle. In this study carbon fibre reinforced plastic composites were selected due to their high specific strength and specific stiffness which make them a preferred candidate in the material selection for modern lightweight structures in automotive engineering which can contribute to the improvement of mileage in addition to safety of the occupants.[13]

3. LEGAL REQUIREMENTS OF IS 14812 – 2005

RUPDs to be implemented are regulated by ECE's R58. An Indian regulation IS 14812 – 2005 is derived from ECE R58 standard, and its requirements are follows.

1. The device shall offer adequate resistance to forces applied parallel to the longitudinal axis of the vehicle, and be connected; when in the service position with the chassis side members or whatever replaces them. This requirement shall be satisfied if it is shown that both during and after the application, the horizontal distance between the rear of the device and the rear extremity of the vehicle does not exceed 400 mm at any of the points P1, P2 and P3.

In measuring this distance, any part of the vehicle which is more than 3 m above the ground when the vehicle is un-laden shall be excluded.

Point P, are located 300 + 25 mm from the longitudinal planes tangential to the outer edges of the wheels on the rear axle;

Point P2 which are located on the line joining point P1, are symmetrical to the median longitudinal plane of the vehicle at a distance from each other of 700 to 1000 mm inclusive, the exact position being specified by the manufacturer.

The height above the ground of points P1, and P2 shall be defined by the vehicle manufacturer within the lines that bound the device horizontally. The height shall not, however, exceed 600 mm when the vehicle is un-laden. P3 is the center point of the straight line joining point P2.

2. A horizontal force equal to 12.5 percent of the maximum technically permissible weight of the vehicle but not exceeding 25 KN shall be applied successively to both points P, and to point P3.

3. A horizontal force equal to 50 percent of the maximum technically permissible weight of the vehicle but not exceeding 100 KN shall be applied successively to both points P2.

4. The forces specified above shall be applied separately, on the same guard. The order in which the forces are applied may be specified by the manufacturer.

5. Whenever a practical test is performed to verify compliance with the above mentioned requirements, the following conditions shall be fulfilled.
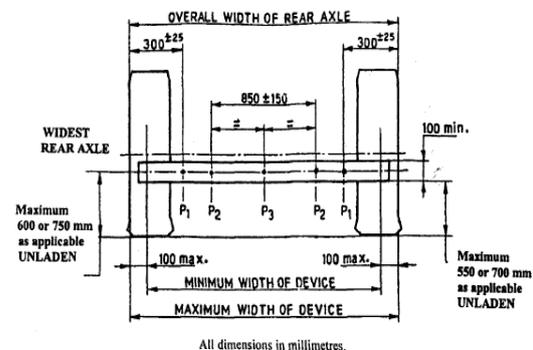
Figure 2: Indian Standard of RUPD (IS 14812-2005). [2]

4. REAR UNDER RUN PROTECTION DEVICE STUDY

RUPD is a right part located on the rear side of a heavy duty vehicle in order to prevent the passenger cars under-running from rear side of the vehicle, as seen in Figure 1. Safely designed RUPDs helps to avoid the severe crashes of passenger cars and their underride collision to the rear side of vehicle. It has been revealed that when a passenger car travels at a speed of 70 km/h and hits to a standing heavy duty truck with zero speed from the full head on, the passenger car will feel a deceleration of 38g or more which will also translate to the passengers inside.

This possible life threatening decelerative impact increase directly to 46g or more when the passenger car speed increase from 70 to 100 km/h. The maximum distance between the RUPD and the chassis of the vehicle must be not more than 450mm (side view). The RUPD must have maximum ground clearance as 550mm. It should have good load bearing capacity and must not come out of its fitment position during the time of the impact. The height of the transversal profile of the device should not be smaller than 100mm. The side edges of this profile should not be curved back and should not have any sharp edges. RUPD's have two major effects on the outcome of crashes:

∟ Firstly, under run can expose light vehicle occupants to direct contact with rigid structural parts of the vehicle before the light vehicles crashworthiness has fully come into play.

∟ Secondly components of the heavy vehicle (e.g. Rear axle) can be compromised to the degree that, the vehicle is not controllable in coming to a stop or the vehicle cannot be move after the collision. The maximum distance between the RUPD and the chassis of the vehicle must be not more than 450 mm (Side View). The RUPD must have maximum ground clearance as 550 mm. It should have good load bearing capacity and must not come out of its fitment position during the time of the impact. The height of the transversal profile of the device should not be smaller than 100 mm. The side edges of this profile should not be curved back and should not have any sharp edge.
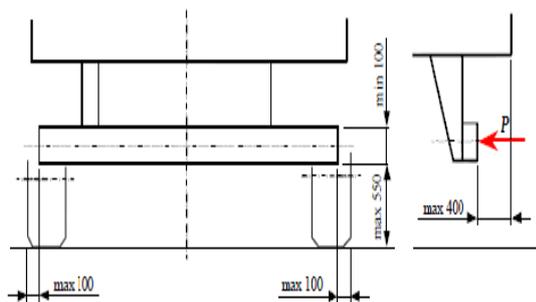
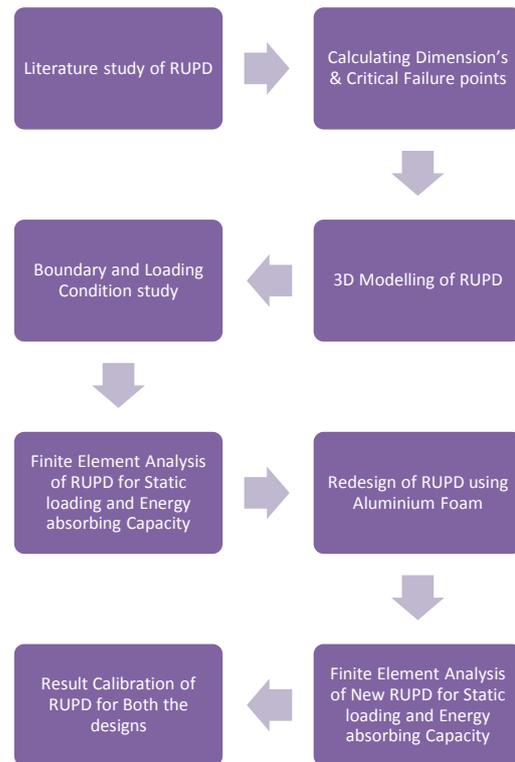Figure 4: RUPD Study.

5. METHODOLOGY

Figure 5: Methodology

6. FINITE ELEMENT ANALYSIS (Original Design)

6.1 FE Model (Original Design):
Considering the Indian standards of RUPD general requirements (IS 14812:2005), RUPD for heavy truck is designed and created its 3D model in SolidWorks 2015.
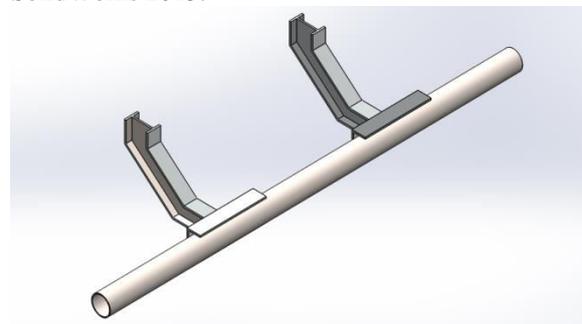
Figure 6.1: CAD model of an RUPD (Original)

6.2 Impact Loading:

To attain safe working conditions of RUPD maximum impact loading conditions will be considered during analysis for original model.

Table 1: Impact Loading Condition

Point	Impact loading condition
P1, P3	A horizontal force equal to 12.5 percent of the maximum technically permissible weight of the vehicle but not exceeding 25 kN shall be applied successively to both points P1 and P3
P2	A horizontal force equal to 50 percent of the maximum technically permissible weight of the vehicle but not exceeding 100 kN shall be applied successively to both points P2

6.3 Material Selection:

Plain carbon steel AISI 1020 has been selected for the RUPD being cheaper material and easily for manufacturing.

Table 2: Material Properties

AISI 1020 steel properties	
Yield strength	350 MPa
Ultimate strength	420 MPa
Poisson's ratio	0.29
Young's modulus	205 GPa
Shear modulus	80 GPa
Density	7.87 g/cm3

6.4 Boundary Conditions:

The Original RUPD has been made with the boundary condition as keeping vertical supports fixed since the RUPD will be fixed in the chassis section of the automobile truck.

6.5. Static Analysis

The Static analysis on the original has been performed using ANSYS software.
• Fixed support of RUPD to the vehicle chassis
• Static load at point p1 and p3 of 25kN

At Pt. P1, for the force of 25KN the stresses induced in the original model of RUPD is shown in the following figure.
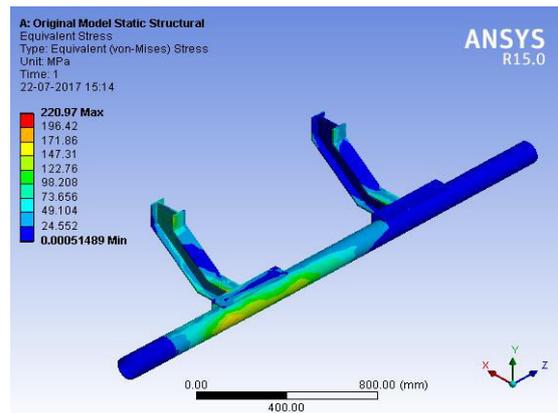

Figure 6.5.1: Static Analysis for Pt. P1(Original Design)

Also for Pt. P3, for the force of 25KN the stresses induced in the original model of RUPD is shown in the following figure.
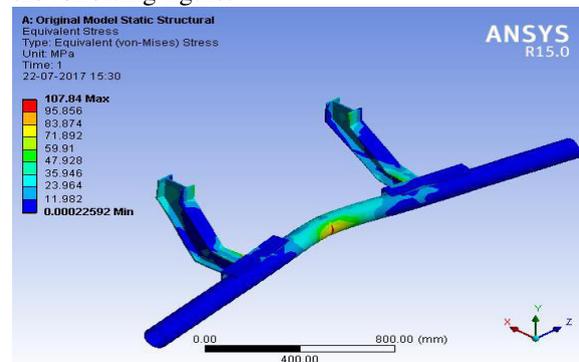

Figure 6.5.2: Static Analysis for Pt. P3 (Original Design)

6.6 Explicit Dynamic Analysis

The Explicit Dynamic analysis on the original has been performed using ANSYS software.
• The trial run of explicit dynamic analysis has been carried out to check the stresses induced and behavior of the assembly
• The force of 25KN was applied along center line (2500mm) of the cylindrical shaft for the time period of 0.05 seconds

At Pt.1, the explicit dynamic analysis for original RUPD design is been shown in following figure.
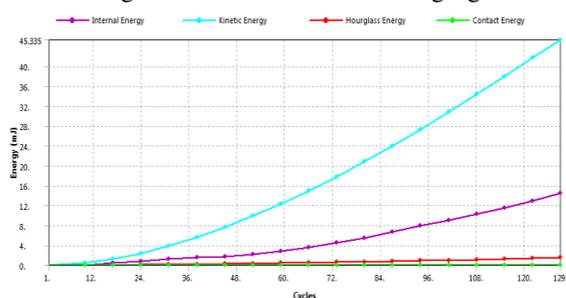

Figure 6.6.1: Explicit Dynamic Analysis at Pt.1

At Pt.3, the explicit dynamic analysis for original RUPD design is been shown in following figure.
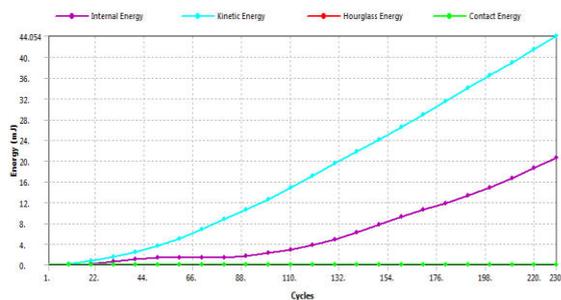

Figure 6.6.2: Explicit Dynamic Analysis at Pt.3

6.7 Result

The above shown analysis for the original design model for RUPD shows the result as follows

|	At Pt. P1	At Pt. P3
Stress (Mpa)	220.97	107.84
Internal Energy (mj)	15	20

From the above result it is been clearly shown that at Pt. P3, RUPD buckled and failed to sustain the given conditions.

So, there is a need to redesign the model for the same given conditions in order to sustain the required conditions of IS 14812-2005.

7. FINITE ELEMENT ANALYSIS (REDESIGNED MODEL)

The redesigned model of RUPD has been made keeping all the conditions and requirements of the RUPD of IS 14812-2005 same.

7.1 FE Model (Redesigned)
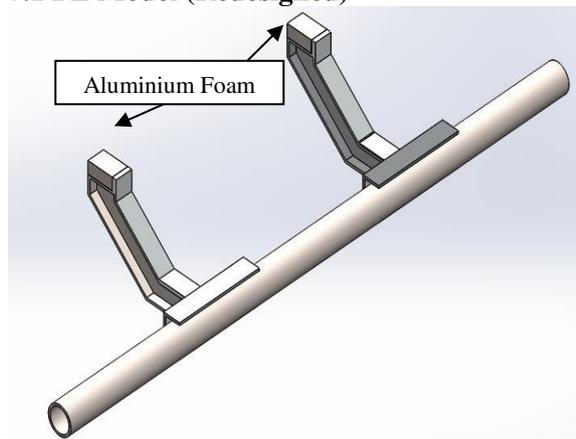
The original model of RUPD has been modified by adding aluminum foam to the vertical member of the RUPD.

7.2 Impact Loading

The impact loading for the redesigned model of RUPD is considered to be the same.

7.3 Material Selection

Aluminum foam being selected at the vertical support of the RUPD has the following properties.

Table 2: Material Properties

Aluminum Foam properties	
Tensile strength	1.24 MPa
Compressive strength	2.53 MPa
Modulus of Elasticity(Tensile)	101.84 MPa
Modulus of Elasticity (Compressive)	103.08 MPa
Shear modulus	199.95 MPa
Density	0.27 g/cm3

7.4 Boundary Condition

Boundary condition is to be kept vertically fixed for vehicle chassis of vertical members of RUPD.

7.5 Static Analysis

Static analysis on the redesigned model of RUPD has been performed keeping the same considerations as original model.
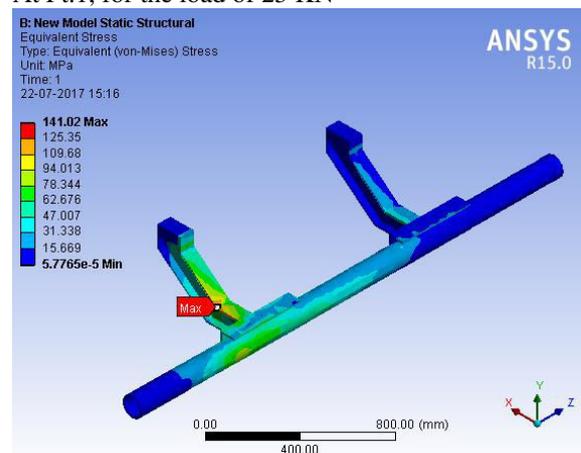
At Pt.1, for the load of 25 KN

Figure 7.5.1: Static Analysis at Pt.1
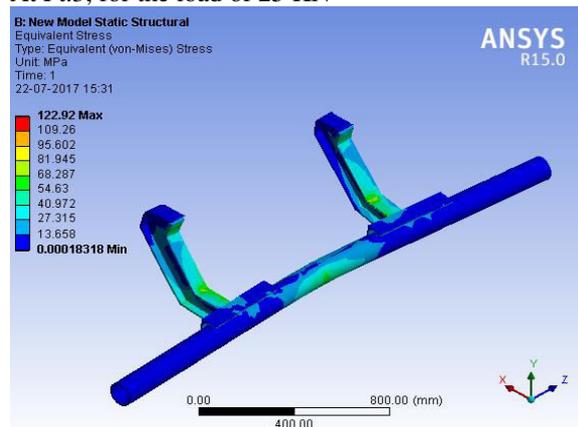
At Pt.3, for the load of 25 KN

Figure 7.5.2: Static Analysis at Pt.3

7.6 Explicit Dynamic Analysis

The Explicit Dynamic Analysis for the redesigned model has been performed keeping the same considerations as original model.

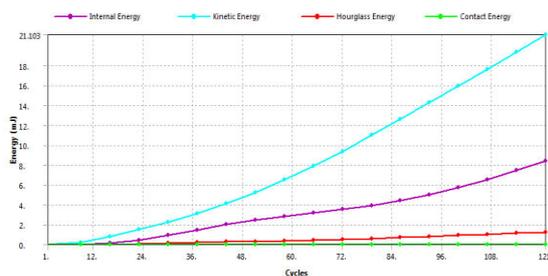At Pt.1, the explicit dynamic analysis has been performed and shown below.

Figure 7.6.1: Explicit Dynamic Analysis at Pt.1

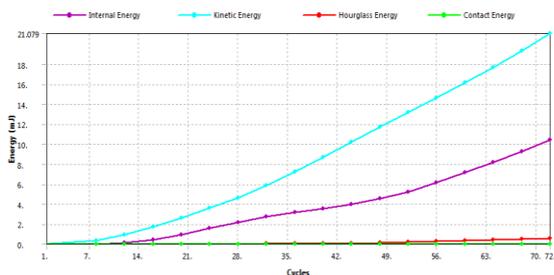At Pt.3, the explicit dynamic analysis has been performed and shown below.

Figure 7.6.2; Explicit Dynamic Analysis at Pt.3

8. Result

The redesigned model of RUPD has shown the following result and shown below in table.

Table: Result

	At Pt.1	At Pt.3
Stress (Mpa)	141.02	122.92
Internal Energy (mj)	8	10

9. Conclusion

From the above results for both original and redesigned model of RUPD it can be concluded that the redesigned model of RUPD has satisfied the requirements and considerations of RUPD. The induced stresses and internal energy generated in RUPD in under permissible Limit.

Unlike Original RUPD model, redesigned RUPD has shown the restrained property of consuming the impact loading during accidents and can sustain the induced stresses as per the IS 14812-2205 requirements.

This helps to prove the importance of installation of RUPD for commercial vehicles. RUPD can save 40% of road accidents in India. Also, the Indian regulation IS 14812 – 2005, proves to be significant and must be standardized in commercial vehicle.

11. FUTURE SCOPE

9.1. Like explicit dynamic trial analysis, the behavior of the RUPD under given standard impact loading conditions can be checked.
9.2. Energy absorption/transmission in each case can be studied.
9.3. Design modifications to improve performance if possible.
9.4.   Material changes can prove to be important.

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