Crashing Analysis of Rear under Run Protection Device (RUPD)

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Abstract – This paper concentrates on studying, modelling & analysis of a Rear under Run Protection (RUPD) system under crashing status. The prime objective is to improve the safety of the car and the occupants by designing the RUPD. The selection 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 concentrates on study about RUPD and also the various factors influencing rear under run protection device. This study is a partial 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 behaviour under loading that the device needs to fulfil for the approval of commercial vehicles.

Index Terms – RUPD (rear under-run protection device), UPD (under run protection device), SUPD (side under-run protection devices), FUPD (front under-run protection devices), LS-dayna, Solidworks.

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 passengers in small vehicles. These UPD are mostly classified as RUPD (rear under-run protection devices), SUPD (side under-run protection devices), and FUPD (front under-run protection devices). In this regard some of the following papers has been reviewed as follows:

- Prakash Kumar Sen, Shailendra Kumar Bohidar and team formulated head on collision contribute 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. [4]

- 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. [3]

Kaustubh Joshi also enhances on the fact of using Rear Under-run Protection Device and following IS 14812:2005 regulation for the trucks to meet the stated safety requirement to protect under running of the passenger car. In his design of RUPD, the maximum displacement of RUPD bar is limited to 50mm and the plastic strain is limited. [2]

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.

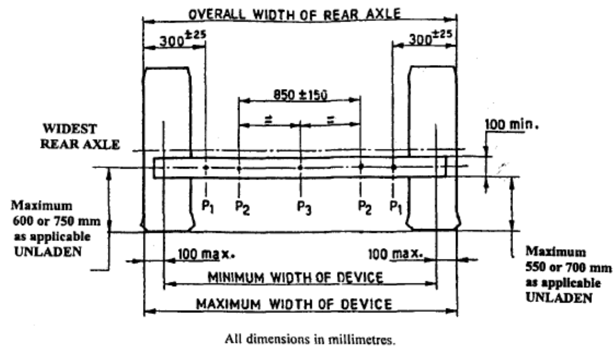

Figure 2: Indian Standard of RUPD (IS 14812-2005). [2]

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.

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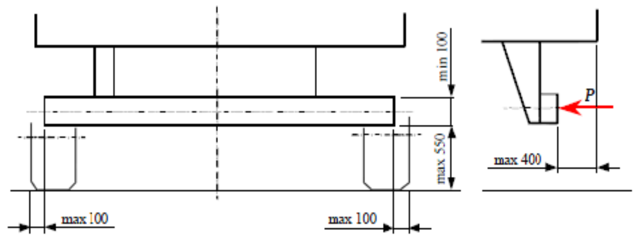

Figure 3: RUPD Study. [4]

5. METHODOLOGY

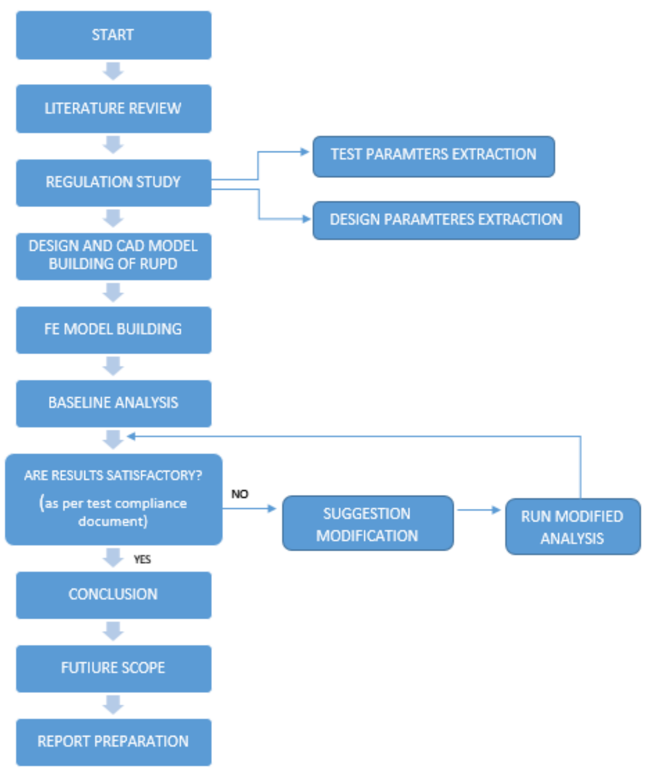

Figure 4: Methodology

6. FINITE ELEMENT ANALYSIS

6.1 FE Model: -

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

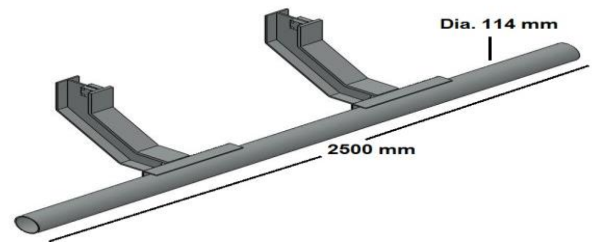

Figure 5: CAD model of an RUPD

6.2 Impact Loading: -

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

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

6.4 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

6.3 Boundary Conditions: -

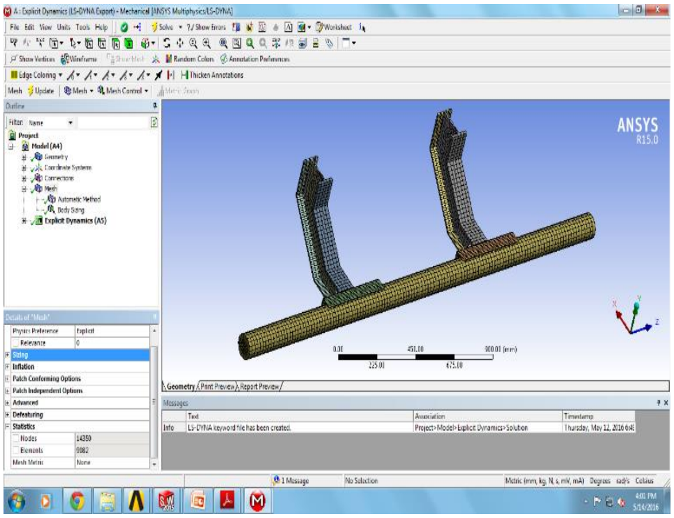

Figure 6: CAD model with boundary conditions.

The RUPD shown in the Figure 6 has been made providing boundary condition as keeping vertical supports fixed.

7. RESULTS AND DISCUSSIONS

7.1 Explicit Dynamic Analysis: -

The Explicit dynamic analysis 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 10KN was applied along center line (2500mm) of the cylindrical shaft for the time period of 0.05 seconds

7.2Induced Stresses: -

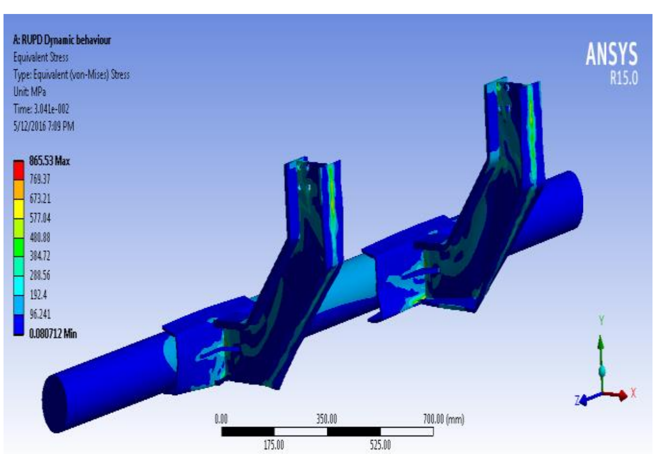

Figure 7: Induced stresses visualization

7.3Total Deformation: -

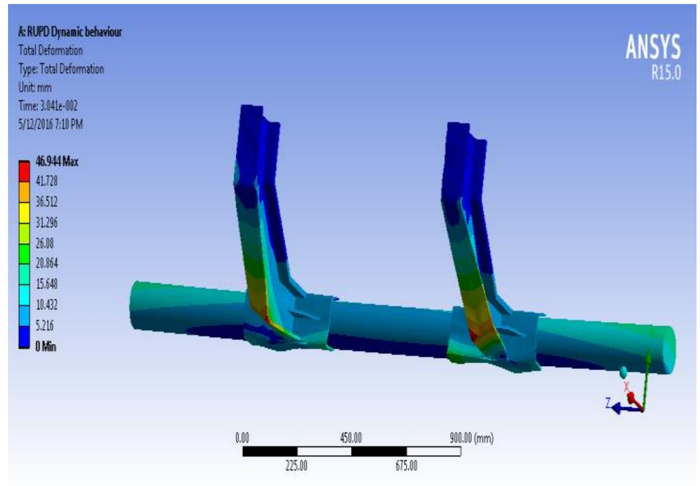

Figure 8: Total Deformation visualization

Table 3: Ansys Results

ANSYS results	
Induced stress	865.5 MPa
Total deformation	46.9 mm

8. CONCLUSION

This study proves 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. The explicit dynamic analysis performed shows induced stress and total deformation under permissible limit.

9. 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 cases 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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