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# Quasi Static FE Analysis of Rear Under-Run Protection Device (RUPD)

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***Abstract***

*In the design and development of component in heavy commercial and passenger vehicle the certain part is specially design for safety. The Under-Runner is one of the most important parameters that considered during development and design of chassis of vehicle. The Rear Under-run Protection Device (RUPD) plays a crucial role in stopping under-running of vehicles from rear side of a truck. In our country, the legal requirements of a RUPD are set fixed in regulation of Indian standard (IS 14812-2005). Thus main objective of this project is to simulate a Rear Impact Test of RUPD and validate the results of the simulations obtained from the FEA software, for that quasi static analysis method is used in RUPD analysis with successive loading. An explicit finite element tool like LS-DYNA is used for the simulation purpose. The deformation of RUPD bar and stresses generated in RUPD components are calculated before the physical test. And it also predicts failure of the system. Although it strictly compliance requirements as per IS 14812-2005.This paper mainly explains the study the Energy Absorption pattern of RUPD structure during the event of rear impact and overall design safety of RUPD for Crash for the occupants. All the results that obtained from the CAE analysis are access to set in the requirements of IS 14812-2005 which mainly minimises the cost and process development time involved in the process.*

***Keywords:****Rear Under-run Protection Device (RUPD), IS 14812 -2005, Chassis design, ECE R58, Heavy commercial Vehicle Systems, LS-DYNA*

## 1. Introduction

A commercial vehicle that most commonly used in daily basis is mainly for transportation of goods or passengers. According to European Union a Heavy commercial vehicle is motorised road vehicle type of construction and equipment which is design for capable of transporting. The component that most importantly attached to commercial vehicles is RUPD. This special fitment provided on front, rear and side position in the vehicle, the main objective is to provide safety to the vehicle and the occupants. The designing of RUPD and vehicle bumper main purpose is to provide safety. As during collision, there is always risk of vehicle penetrate under (run under) the front or rear part of the truck. Thus there are great chances of fatal injuries to the occupants inside the car. The study of such various statistical data is done by Bjorsting et.al [1-7].

The under- running of the passenger vehicles is mostly commonly avoided by Under-Run Protection Device (UPD) which is a special attachment fixed to the heavy vehicle. Another function of RUPD is to minimise the opportunity of serious fatal injuries to the vehicle occupant. The main objective is to simulate a Rear Impact Test of RUPD and validate the results of the simulations obtained from the FEA softwarein successive loading condition. And study the Energy Absorption pattern of RUPD structure during the event of rear impact, withstudy of overall design safety of RUPD in under running of the passenger vehicle from the rear of the heavy commercial vehicle. The RUPD basic requirement are specified in Indian Standard IS 14812-2005 .The testing is done with 5 points successive loading with specific standard loading condition. The ram hit the RUPD to evaluate its strength. This complete data is replicated using Finite Element (FE) solvers like LS-DYNA. The load taken by the RUPD is evaluated using Von- misses stresses induced in the components and the deformation in the RUPD members. This virtual validation is important for cost saving in the tooling, repetitive testing of the vehicle and cost involved in the same.

## 2Literature Review

Bjorsting et al. [1] have studied the data of accidents occurred in northern Sweden between 1995 and 2004. In the research they have observed that 293 passenger car occupants died out in which half involved heavy vehicles. They also had seen from the data that annual number of passenger car occupant death per 100000 car-truck collision remains same as they were in 1980. The main reasons of collisions are differentiate in different ways such as crashes oncoming vehicle's lane, under icy, snowy, or wet conditions. They also observed that crashes into heavy vehicles are generally occurred in day time, on working days and in winter etc. The Primary affected zones are according to head and chest injuries. The fatal injuries are divided based on critical, head injuries and multiple fatal injuries of occupant. Researchers also observed at data related to suicide and driving with alcohol for a suitable statistical representation. At lastly they observed that the risk of frontal collisions was reduced by a mid-barrier, and frontal energy absorbing structure such as bumpers for trucks and buses and driving conditions etc.

Hirase et al. [2]carried out research study in Japan. They presented Japanese approach for car-to-truck compatibility in head-on collisions. Front Under-run Protection Devices (FUPD) was designed in manner that it meets the Economic Commission of Europe (ECE) R93 so that it removes the under-running of the vehicle in head on collision with trucks. Japan Automobile Research Institute (JARI) has studied and analysed the different accidents consequences in Japan. Researchers study was done on different aspects such as vehicles with and types of collisions, without seat belts, types of vehicles incorporated in crash. They also showed that car driver fatalities reduced by 45 percent by incorporating truck with FUPD. Finally they also suggested that off-road vehicles like tipper trucks and cement trucks are also equipped with FUPD. Because it is advantageous in head on collide for car occupant.

John and Rechnitzer [3] had carried out research in the benefit of energy absorbing structure for front of the heavy trucks. They showed that there is significant weight difference between passenger car and heavy commercial trucks. Due to this reason there was a great risk of injuries to passenger car occupants in case of car collision with heavy commercial trucks. They also explains that it was not possible to remove the weight difference between the car and heavy commercial trucks, but is possible to made changes in the truck in such a way that effects of impact in between the heavy commercial trucks and car is minimised. This paper also estimates the effects of changing the front of the heavy commercial truck to incorporate the energy absorbing structure with stiffness characteristics same as to front of cars. They also finally explains the equation of motion that was used to show the truck with front energy absorbing device increase deceleration distance by 40 percent and reduce average deceleration by factor 1.4. And the passenger car injuries minimised by 33 percent with a real time example.

Joshi et al. carried out analysis of Finite Element Analysis of Rear Under-Run Protection Device (RUPD) for Impact Loading. They proposed that Under-running of passenger vehicles is the key parameters to be considered in development and design and of Heavy vehicle chassis. They studied that the Rear Under-run Protection Device (RUPD) carries an important role in avoiding under-running of vehicles from rear side of a truck. In the paper they proposed that to reduce number of iterations during the development process, the computational simulation method is used in RUPD analysis for impact loading. And explicit finite element tool like LS-DYNA was used for the simulation. At finally they concluded that the deformation of RUPD bar is less than 50 mm and plastic strains in RUPD limited to 15 percent which meet the compliance requirements of IS 14812-2005standard. And the Under-running protection fixed to the heavy trucks significantly

### *3.Legal Requirement of IS-14812-2005*

RUPD standards are regulated by ECE R58 and in Indian regulation IS 14812- 2005 is derived from ECE R58 standard, and the requirements of Indian standard are as follows [6]

1. The UPD primarily offer sufficient amount of resistance forces which is applied parallel to the longitudinal axis of the vehicle, and it is fixed when in the service position with the chassis side, rear of front position. This requirement of standard is fulfilled in during and after the application the minimum horizontal distance in rear of the UPD device at the points P1, P2 and P3 and the rear end of the vehicle does not exceeds 400 mm. In measurement of this distance above the ground at any part of the vehicle does not exceed more than 3 m, when the vehicle kept without loading. The Point P which is located 300+25 mm at outer end of the wheels on the rear axle from the longitudinal planes.

Whereas the point P2 are geometrically symmetrical at a distance of 100 to 800 mm from point P2 to the median longitudinal plane of the vehicle. And this point is located on the line joining point P1. The height above the ground of points P1, and P2 (see Figure 1) within the lines that fixed the device horizontally are defined by the vehicle manufacturer When the vehicle is unloaded the height does not exceed 600 mm. The straight line joining points P2 along with centre point P3.

2. A forces along horizontal direction are applied of 12.5 percent of the maximum permissible standard weight of the vehicle which not crosses 25 kN limit. These load condition applied successively to both points P3, and to point P.

3. A horizontal force of 50 percent of the maximum permissible standard weight of the vehicle which not exceeding 100 kNare allowed. And these load applied successively to both points P2.

4. The forces mentioned above are applied independently, whereas the forces are applied may be specified by the manufacturer.

5. Thusa practical testing is also carried out to verify exactly the above mentioned requirements. And the standard requirements are satisfied.

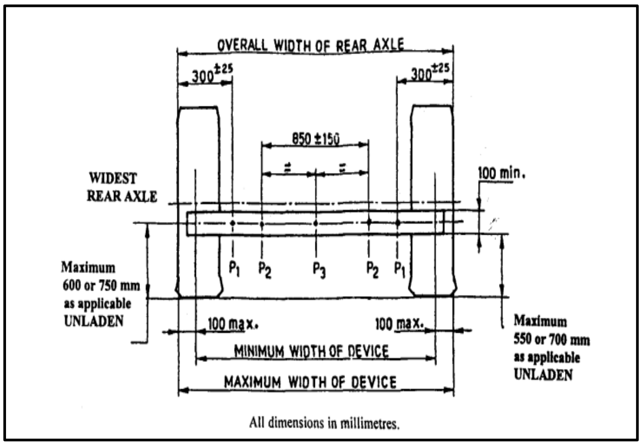
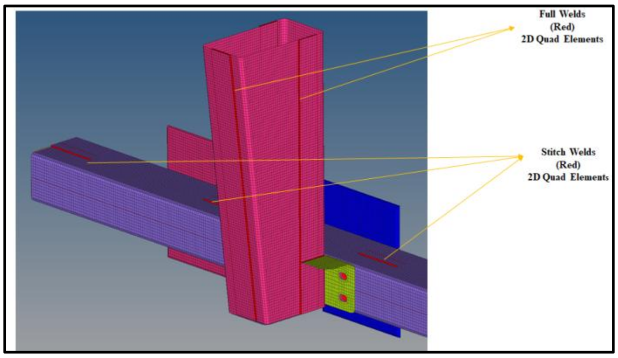



**Fig. 1**Position of Rear Under-run Protection Device and the resistance points P1, P2 and P3. [6]

## 4.FINITE ELEMENT ANALYSIS OF RUPD

A RUPD assembly shown in Figure [2], the main components of RUPD is the main plate and a cross plate which are fully welded together to form vertical box section. Then this Vertical box section is bolted to the rectangular bar through brackets. The bar section also consist of Stitch Welds .The other end of this structure is connected with bolts to the chassis member.



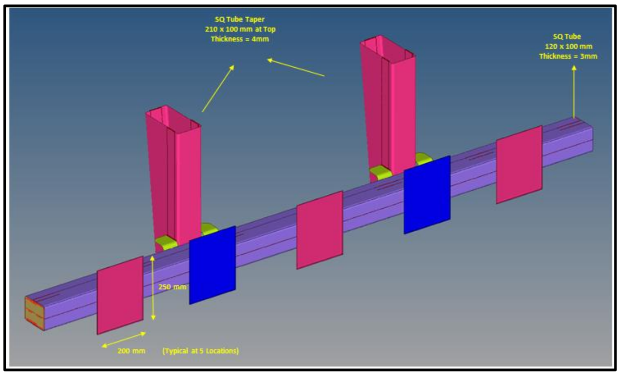




**Fig 2** Modelling of RUPD Structure

### *4.1 FE Modelling of RUPD*

All the parts of RUPD are with large surface are as compared to the thickness hence they are meshed with 2D shell elements meshing. The meshing is done in HyperMesh. The total number of 101456 nodes and 98844 elements are present in the meshing of RUPD members

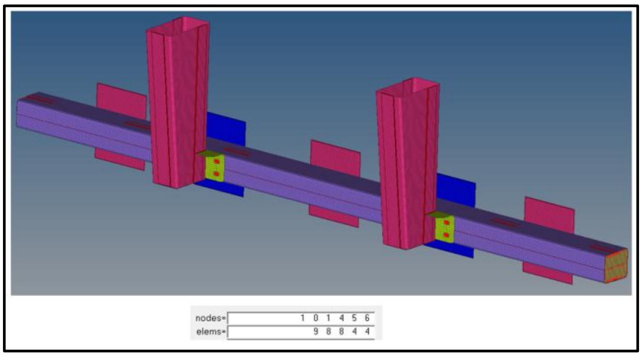



**Fig.3** Meshing of RUPD Structure

## 5. Boundary and Loading Conditions

The boundary conditions are applied such that it remains same as the physical test and it will not add any numerical error in the analysis. The loads are applied as per standard IS14812 – 2005.

### *5.1 Boundary Conditions*

The nodes of member are fixed and remain constrained in all 6 degree of freedom (Blue coloured). The ram loading as shown is categorised in successive load points from 1 to 5 respectively (see Figure 4). The rear end is opposite to the ram direction along with constrained nodes.

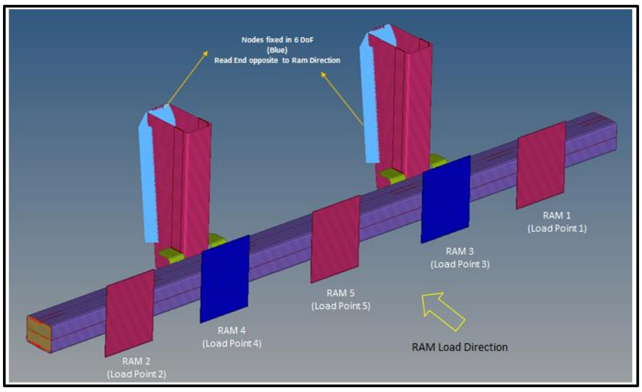



**Fig.4** Boundary Conditions used for RUPD Analysis**.**

### *5.2 Loading Conditions*

The Figure [5] shows the loading of the RUPD. The loading is done in successive manner. Firstly the standard ram with total load 30kN taken for testing. Then at location P1, P2 and P3 12.5 percent load are considered. Whereas at point P3 and P4 50 percent load are taken for loading for time duration of 0.2 seconds as per standard. It is also ensured that all the loading is quasi-static as mentioned in the regulation. A figure [6] below shows the quasi static loading curve. Also the positions of the entire ram are as per regulation.

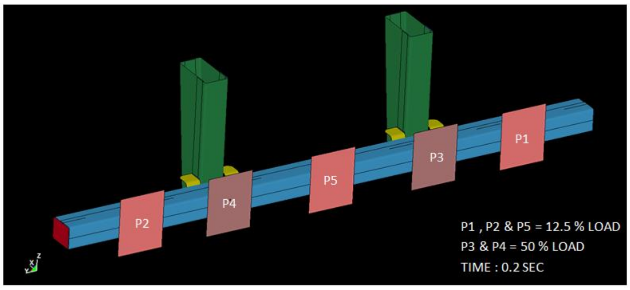



**Fig.5**Loading of the RUPD with all the 5 loading points

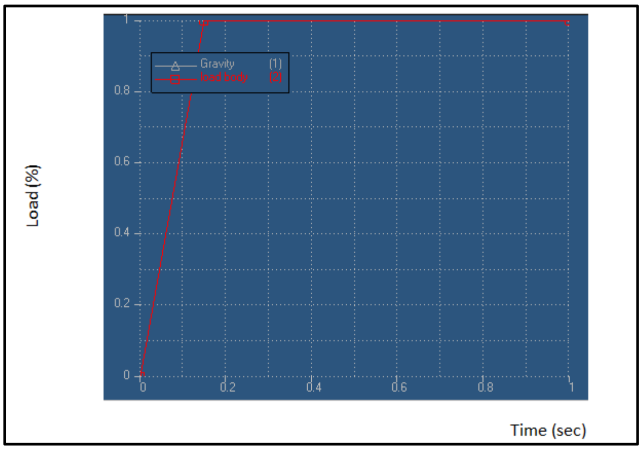



**Fig. 6** Quasi static load curve

*5.3 Acceptable Criterion for FE Analysis*

1. The maximum displacement of RUPD bar should be less than 400mm after the application of all the quasi static successive loading testing.
2. The RUPD should remain attached to chassisin rear collision and offer effective protection against under running of vehicles with passenger which covered under the standard.

## 6.RESULT AND DISCUSSION

The energy balance is method to evaluate the correctness of the numerical analysis. The typical energy balance of RUPD system is shown in Figure 7. All the energies are shown in the plot. The internal energy has started from the zero magnitude and increased to maximum. This increase in the internal energy is due to deformations in the system. The energy in terms of the applied force is stored in the RUPD in terms of plastic deformation. The kinetic energy in the system is very negligible which shows that there are no real velocities in the system. It also ensured that the FE analysis is quasi-static. The peaks shown at some locations are due to sudden interaction of the successive load with the RUPD bar. The hourglass energy, damping energy and sliding energy is very negligible. The total energy is the addition of all the other energies like kinetic energy, internal energy, sliding energy, damping energy and hourglass energy etc. Thus overall energy balance is appropriate hence it the FE analysis results are acceptable.

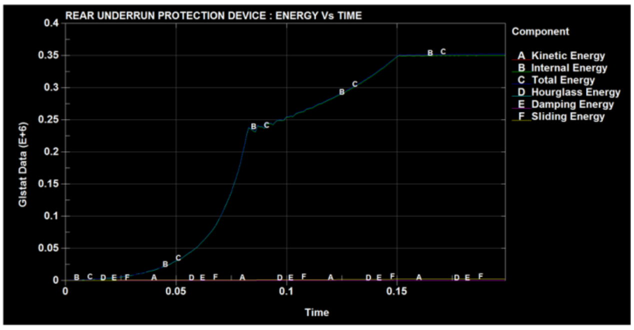



**Fig .7**Energy Balance in FE Analysis of Design component

Another aspect for result evaluation is displacement in the members and the induced von- misses stress. All the load applies is quasi static and in successive manner. This also confirmed that RUPD is loaded as per regulation. The displacement and von-misses stresses are observed for all the loads points at P1, P2, P3, P4 and P5. The displacement is one of the major parameter on the basis of which RUPD could be evaluated. The maximum displacement in the RUPD bar member and the mounting plates is less than 10 mm (see Figure 9) which is very much less than limiting value.

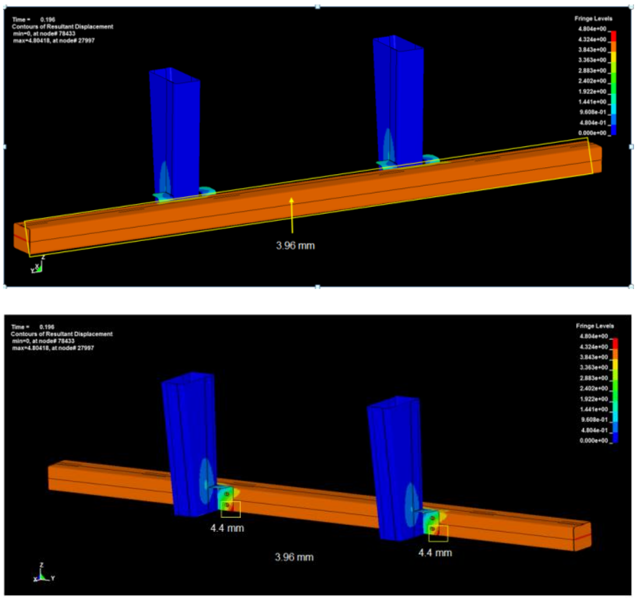



**Fig .8** Displacement in RUPD bar after successive Loading

The Von- Misses stresses are another criterion on the basis of which the failure of RUPD could be determined. The Von- Misses stresses are observed in all the members and they are compared against Yield strength of the material. The material of RUPD members are ST 52 Steel and the maximum yield strength of material is 355 Mpa. The induced Von-Misses stresses are in proportional limit of maximum yield stress of material which avoids the tearing of the parts.

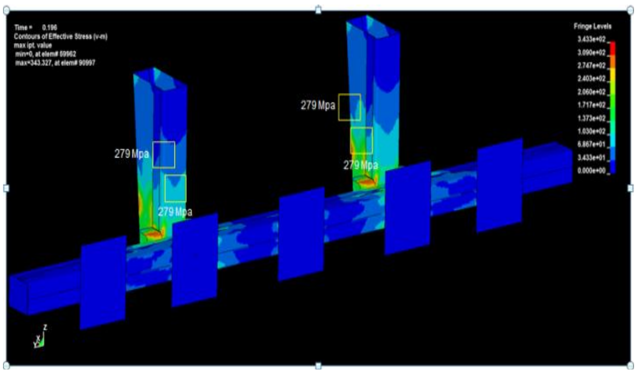



**Fig. 9** Von-Misses stresses Main Plate and Cross Plate after successive Loading.

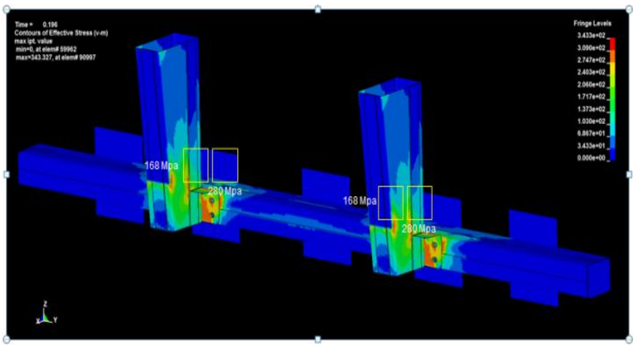



**Fig .10**Von-Misses stresses in bolted brackets after successive Loading.

The above design meets the requirements as per IS 14812 – 2005, but it is also possible to improve the design in the FE model and analyse it till meets the requirements. This way FE Analysis is a very efficient tool to for design improvements. It could also save a cost and time required in repetitive manufacturing and physical testing.

## 7. CONCLUSION

1. In Indian commercial vehicles, The IS 14812:2005 regulation is required for designing the Rear Under-run Protection Device of trucks satisfy the safety requirement to protect under running of the passenger car.
2. In above said design, the maximum displacement of RUPD bar is limited to 10mm and the Von-Misses stress are in proportional limit as it meet the requirements as per IS 14812:2005. But this needs to be certify, with physical testing in future
3. Further the virtual simulation is tool which probably used to avoid or minimised the physical testing of mechanical systems and components. Overall effect of this is cost saving and same is done with RUPD analysis.

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