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Structural Analysis and Prototyping of Truck Under-run Protection Device

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Abstract: In the present research work we are focusing on side under-run protection devices protect road users such as pedestrians and cyclists from slipping sideways under the wheels of trucks and trailers, and can also improve the aerodynamic performance of heavy vehicles. The basic objective is to improve the safety of the car and the occupants by designing the Rear Under-run Protection Device (RUPD) and car bumper. The choice of material and the structural design are major factors for impact energy absorption during a crash. This study concentrates on component functions, geometry, behavior of material and other parameters that influence the compatibility of the car bumper and rear under run protection device. The analysis was carried out using Finite Elements software SOLIDWORKS. This analysis is a partial work of a major project wherein the RUPD will be subjected to static testing with variable load distributions at different locations on RUPD. After the analysis, the pattern of the part is obtained using Rapid prototyping machine. This can be used for Machining/ casting of the original part. Rapid Prototyping (RPT) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer aided design (CAD) data.

Keywords: Solidworks; RUPD; under-run; finite element analysis; Rapid prototyping; Von Mises Stress.

I. INTRODUCTION

The collisions can be classified in many ways such as crashes oncoming vehicle's lane, under icy, snowy, or wet conditions; crashes into heavy vehicles generally occurred in daylight, on workdays, in winter etc. Primary evaluation is according to head and chest injuries. The injuries are categorized based on critical, death head injuries and multiple fatal injuries. Investigators also looked at data concerning suicide and driving with alcohol for a proper statistical representation. They also observed that the risk of frontal collisions may be reduced by a mid-barrier, front energy absorbing structure for trucks and buses and driving conditions. The accidental event, when a passenger car or a light load-carrying vehicle crashes and is wedged under the rear part of the vehicle chassis, is called rear under run. The rear under run protection device (RUPD) prevents the vehicles from being wedged under the chassis during accidental crashes and with that significantly increases the safety of occupants. The regulation also calls for a practical RUPD testing on the testing machine, where the RUPD is subjected to prescribed loads at some particular points. If the measured deformations fall into the allowable range, the RUPD can be declared to comply with the regulation. The practical testing is required for all standard mounted RUPD. Point load applications on mechanical member are as shown below

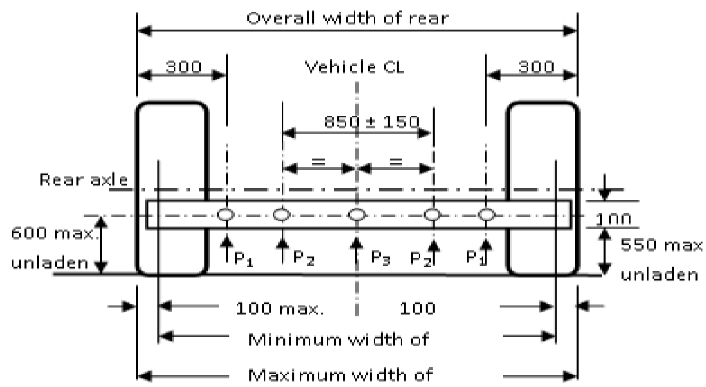

Chart 1: Point load application on mechanical member

II. COLLISION STATISTICS

There has been a significant amount of statistics and surveys conducted over the years recording the occurrence of passenger vehicle to heavy vehicle collisions. These findings illustrate the injuries, their severity and the amount of fatalities. In Canada, a study conducted between 2001 and 2005 investigated these types of collisions. In total, there was a yearly average of 2500 road accident fatalities. These included all collisions involving passenger cars, vans, light trucks, heavy vehicles and pedestrians. During the same time period, there was a yearly average of 148,828 injuries. Of the 2500 fatalities, 12.4% of them involved tractor-trailers, 6.3% involved straight trucks and 18.3% were with heavy trucks. The other 63.0% was caused by other types of vehicles. Of the 148,828 injuries, 2.7% were caused by tractor-trailers, 3.1% by straight trucks and 5.7% by heavy vehicles [1] [2].

To get an understanding of how many heavy vehicles are on the roads along with their configurations in Canada in comparison to the amount of light vehicles, the 2009 Canadian Vehicle Survey Summary Report is investigated [3]. The report shows that in 2009, there were 437,997 medium trucks (vehicles between 4.5 and 15 tons) and 317,219 heavy trucks (vehicles over 15 tons) on the roads. During that year, there were 19,755,954 light vehicles on the road.

In comparison to the Canadian statistics, in 2010, the United States saw 3,675 fatalities related to large truck accidents and approximately 80,000 injuries. The number of fatalities saw a

9% increase compared to 2009 which had 3,380. The statistics show that of all fatalities, 76% were occupants of the small vehicle, 10.0% were non-occupants and 14% were people inside the large trucks. Of these, 18% occurred when the car had an impact point with either the left or right side of the large truck [4]. The same report estimates that there was a yearly average between 1995 and 2005 of 28,274 injuries related to light vehicle to combination trucks collisions with 5,085 of these being occupants injured during side underride [5] [6]. The NHTSA website published a chart which shows the 2011 statistics of fatal crashes when a motor vehicle would crash into a transport by different initial points of contact. In this chart, the left side of a transport accounted for 266 of fatalities and the right side for 155. It may also be noted that in 2011, there was 3,608 reported deaths involving small car to transport collisions [6].

III. METHODOLOGY

In modern engineering analysis it is rare to find a project that does not require some type of simulation for analyzing the behavior of the model under certain specified conditions. The advantages of simulation are numerous and important. A new design concept may be modeled to determine its real world behavior under various load environments, and may therefore be refined prior to the creation of drawings and changes can be inexpensive. Once a detailed CAD model has been developed, simulations can analyze the design in detail, saving time and money by reducing the number of prototypes required. An existing product which is experiencing a field problem, or is simply being improved, can be analyzed to speed an engineering change and reduce its cost.

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 edges.

IV. MODELING OF TRUCKUNDER-RUN DEVICE

The height of the shield front is 10mm. The width of the shield front is 2500mm.Thickness is 10mm.

Properties:

Name:	Normal Steel
Model type:	Linear Elastic Isotropic
Default failure criterion:	Unknown
Yield strength:	2.20594e+008 N/m^2
Tensile strength:	3.99826e+008 N/m^2
Elastic modulus:	2.05e+011 N/m^2
Poisson's ratio:	0.28
Mass density:	7870 kg/m^3
Shear modulus:	7.9e+010 N/m^2
Thermal expansion coefficient:	1.3e-005 /Kelvin

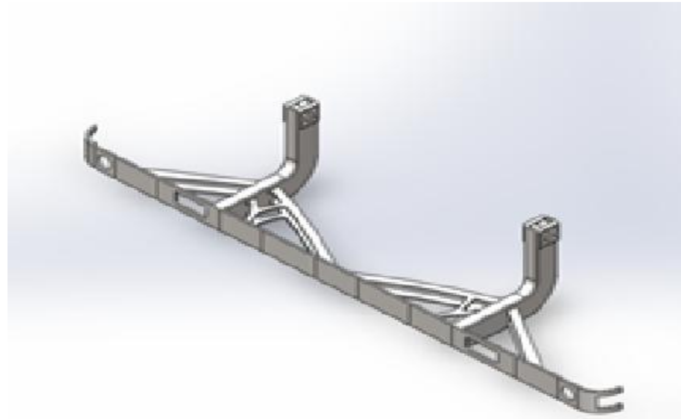

Figure 1: Final Model

V. STRUCTURAL ANALYSIS OF TRUCKUNDER-RUN DEVICE

There are three different load cases (P1, P2, and P3) which have to be tested. The load is applied as a pressure on a specified area, one load at a time. Load area size is 200mm x 100mm. Applied pressures are:

$$P1 = 12.5x10^5 Pa,\ P2 = 25x10^5 Pa,\ P3 = 12.5x10^5 Pa$$

Application of P1 Load:

Study name	Static 5
Analysis type	Static
Mesh type	Solid Mesh
Thermal Effect:	On
Thermal option	Include temperature loads
Zero strain temperature	298 Kelvin
Include fluid pressure effects from SolidWorks Flow Simulation	Off
Solver type	FFE Plus
Soft Spring:	Off
Inertial Relief:	Off
Incompatible bonding options	Automatic
Large displacement	Off
Compute free body forces	On
Friction	Off
Use Adaptive Method	Off
Mesh type	Solid Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points	4 Points
Element Size	26.4763 mm
Tolerance	1.32382 mm
Mesh Quality	High

Table 1: Applications of P1 load

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STUDY RESULTS

Name	Type	Min	Max
Stress1	VON: von Mises Stress	2.36011 N/m^2 Node: 14969	1.67424e+008 N/m^2 Node: 21502

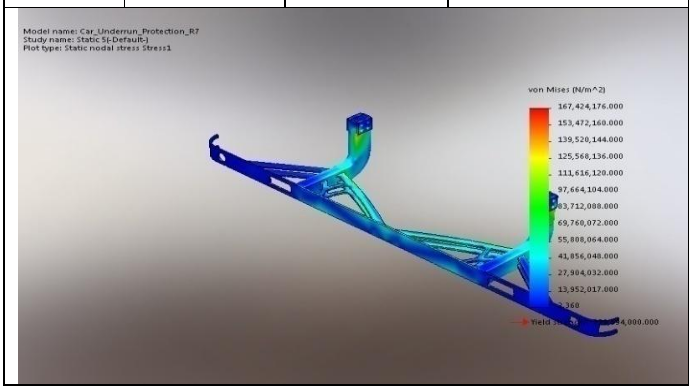

Figure 2: Stress 1 of P1 load

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0 mm Node: 29	1.74788 mm Node: 1038

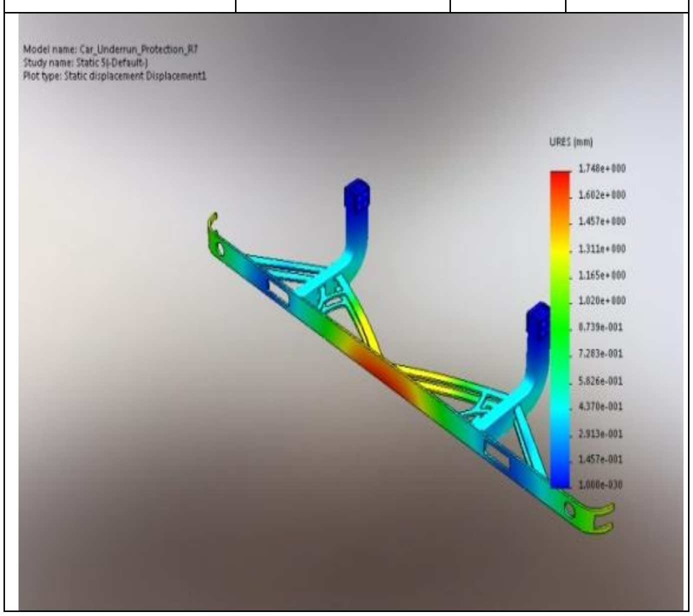

Figure 3: Displacement 1of P1 load

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	8.41736e-012 Element: 7209	0.000561163 Element: 6880

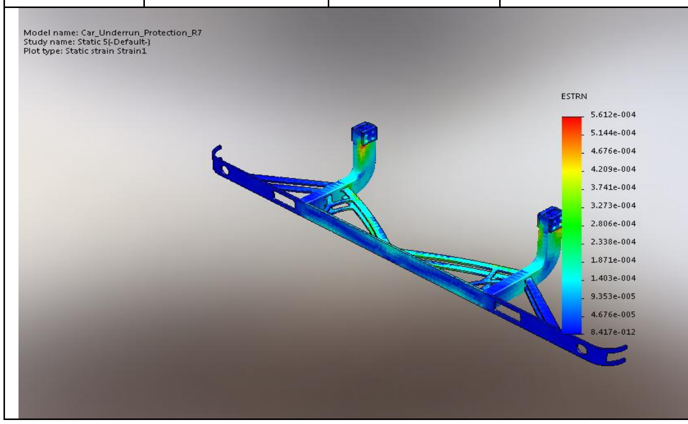

Figure 4: Strain 1of P1 load

VI. RAPID PROTOTYPING OF TRUCKUNDER-RUN PROTECTION DEVICE

The model has been scaled to 50% as the volume of machine is confined to 230LX150WX140H.After the .STL file of gear is imported into the fused deposited machine. The 3D printing has been done for 36hrs.The following prototype has been obtained .The material used is ABS material.

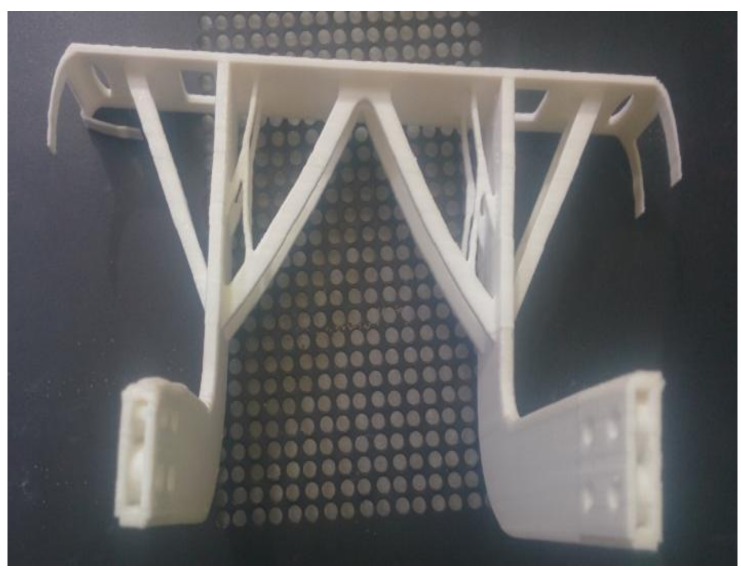

Figure 5: Prototype top view

VII. RESULTS OF EXPERIMENT

By comparing the above results the displacement for P1 load, P2 load and P3 load is 1.747mm, 2.92175mm and 5.521mm which is less than the maximum deformation of 40mm.

The stress results for P1 load, P2 load and P3 load is 16.7MPa, 48.0MPa and 34.4MPa which is less than maximum allowable stress of 355Mpa

As our Truck under run protection device is within the limits then RAPID PROTOTYPING of Truck under-run protection device has been done.

S. NO	Point of Application of Load	VON Misses Stress (MPa)	Displacement (mm)	Strain
1.	P1 LOAD	16.72	1.74788	0.0005 61163
2.	P2 LOAD	48.00	2.92175	0.0011 5903
3.	P3 LOAD	34.46	5.52131	0.0009 24848

Table 2: Results and discussions

VIII. CONCLUSION

Through study and analysis, the wireless remote meter-

Side under run protection devices protect road users such as pedestrians and cyclists from slipping sideways under the wheels of trucks and trailers, and can also improve the aerodynamic performance of heavy vehicles. The basic objective is to improve the safety of the car and the occupants by designing the RUPD and car bumper. The choice 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 mechanism during the impact.

By comparing the above results the displacement for P1 load, P2 load and P3 load is 1.747mm, 2.92175mm and 5.521mm which is less than the maximum deformation is 40mm. The stress results for P1 load, P2 load and P3 load is 16.7MPa, 48MPa and 34.4MPawhich is less than maximum allowable stress of 355Mpa.

As our Truck under-run protection device is within the limits then RAPID PROTOTYPING of Truck under-run protection device has been done. The Prototype has been used as pattern for limited volume of production

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