A NUMERICAL STUDY ON THICKNESS OF REAR UNDER-RIDE PROTECTION IN CASE PICK-UP TO SEMI-TRAILER FULL REAR IMPACT

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ABTRACT

In the global supply chain, large trucks, tractors, and semitrailers are essential as the final step in this complex network. However, they have many potential dangers because the gaps from the semi-trailer's floor to the road surface are high, so small cars easily get underride. To solve this issue, some regulations have required the installation of additional protection devices on the front, sides, and rear where these gaps exist, for example, FMVSS 223, 224 of the US, or UNECE R58 of Europe. Using LS-DYNA software and trailer and pick-up models from proven sources to set up a collision simulation, then proceed to change the thickness of the rear underride protection device to assess the effect. The collision was designed with 55.8 km/h of pick-up and a stationary trailer. The effect of change thickness on axial displacement and energy changes is presented. The study results are expected to be helpful for the structural design and safety assessment of various structures including marine vehicles and cars against collisions.

Keywords: *Rear under-ride, protection device, design, truck, semi-trailer*

I. INTRODUCTION

Using LS-DYNA is the trend of crash studies, of course including rear-end trailer collisions for the development of RUPD. In 2013, Joseph et al. [1] optimized the structure of the RUPD structure by LS-DYNA and the calculation results for the guard tube were performed, which increased the load capacity of the RUPD. In 2014, Sun et al. [2] proposed a type of barrier structure inspired by the cross-section of sheep's horns. As a result, the simulation shows significantly improved force absorption. In 2015, Gombi and Amithkumar [3] replaced the steel RUPD with a composite RUPD made up of carbon-reinforced resin composite, with the ability to absorb about 50% of kinetic energy. Although the absorption is lower than that of RUPD steel (90%) it has the advantage of being much lighter in weight (15 kg versus 75 kg). In 2019, Albahash and Ansari [4] designed a model of the rear device and compared it to the classic model. Absorption is increased to 88.32%, achieving the goal of reducing acceleration to 15.83g and getting the job done to keep the passenger compartment to a minimum. In 2021, Anh and Luu [5] simulated a collision between a passenger vehicle and 10 tons truck. Then, compared two conditions with or without rear protection devices. The above studies are almost researched on the geometric form. This article researches the effect of increasing the thickness of RUPD. A pick-up vehicle FEM will strike the end of a stationary trailer FEM at 55.8 km/h. In collision simulation, have two samples with different part thicknesses, detailed in **Table 3**. The results of the two models are compared based on displacement, acceleration, and kinetic energy. The study's findings can be applied to the design of various structures, including marine vehicles, especially for their protection parts that are subjected to collisions.

II. MATERIAL AND METHODS

To perform a collision simulation, usually go through the following steps. First, we need to build the geometric model of the vehicle. The software that supports this can be mentioned as Solidworks, Catia V5. In the second step, proceed to divide the geometric net with tools like HyperMesh. This is a job that takes a lot of time in reality to get a good model. The third step is to import the model divided into LS-DYNA and set basic parameters such as Material, Properties, boundary conditions, and control cards. Finally, practice tests for testing the Model solution. However, to save time and inherit what has been studied, the article uses two models that have been approved and published.

1. Finite element model (FEM)

Chevrolet C-1500 1992 FEM by Zaouk et al. [6] simulate the collision of a pick-up vehicle and wall according to NCAP test standards, with a velocity of 55.8 km/h. Information of model such as **Table 1.**

Table 1. Vehicle model data information

Number of parts	251
Number of nodes	66586
Number of shells	54565
Number of beams	163
Number of solids	3561
Number of elements	58313

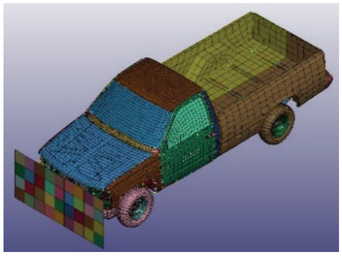


Fig. 1. Chevrolet C-1500 FE

48-ft semi-trailer FEM, built by NTRCI University Transportation Cen-ter, simulates a crash test with a barrier on a highway. Model details are described in the phase B report by Plaxico et al. [7]. This article uses a rear-end trailer instead of a wall. After the collision simulation is complete, the displacement of the RUPD will be shown. Information of model such as **Table 2**.

Table 2. Trailer model data information

Number of parts	95
Number of nodes	325542
Number of shells	220062
Number of beams	32
Number of solids	12913
Number of elements	233019

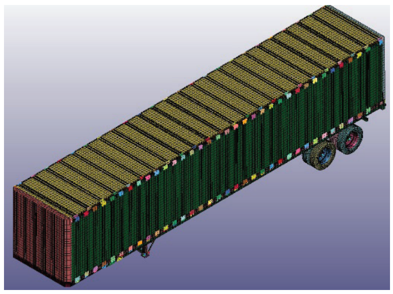


Fig. 2. 48-ft semi-trailer FEM.

2. Collision simulation

Importing two models into a crash simulation, replace the NCAP wall with rear-end trailer. The pick-up velocity is 55.8 km/h, and the trailer velocity is 0 km/h. This arti-cle has two samples with thickness parameters as **Table 3.**

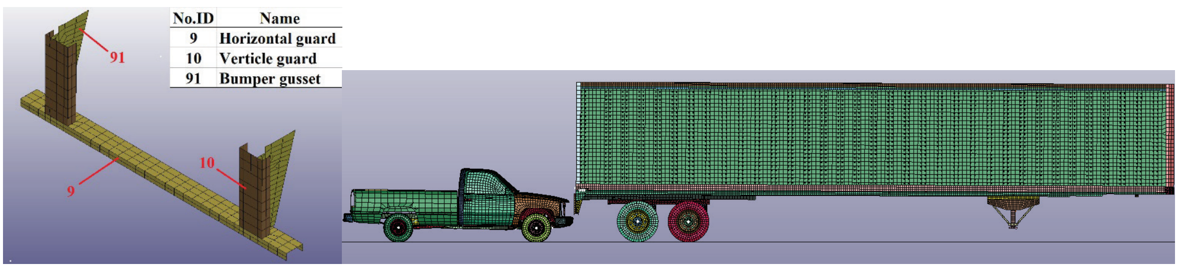


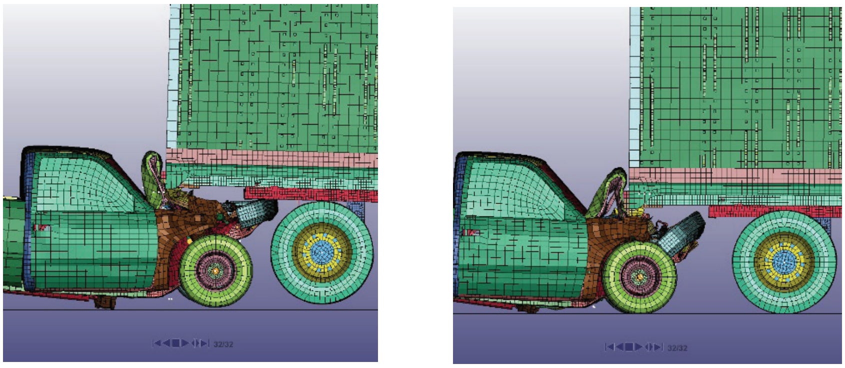
Fig. 3. The basic RUPD and vehicle position in collision simulation.

Table 3. Thickness parts of two sample

Sample	Part name	Part No. in FEM	Thickness (mm)
A (Basic)	Horizontal guard	9	4.8
	Vertical guard	10	4.8
	Bumper gusset	91	5.96
B	Horizontal guard	9	6
	Vertical guard	10	6
	Bumper gusset	91	9

III. RESULTS AND DISCUSSION

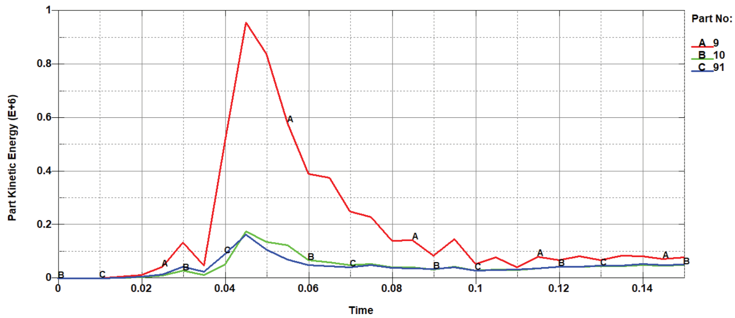
After running two simulations with two different thicknesses, two 3dplot results were obtained for comparison. When the simulation starts at T (Time) = 0, the pick-up vehicle moves at 55.8 km/h. The software simulates the rear-end trailer collision in 0.15s.



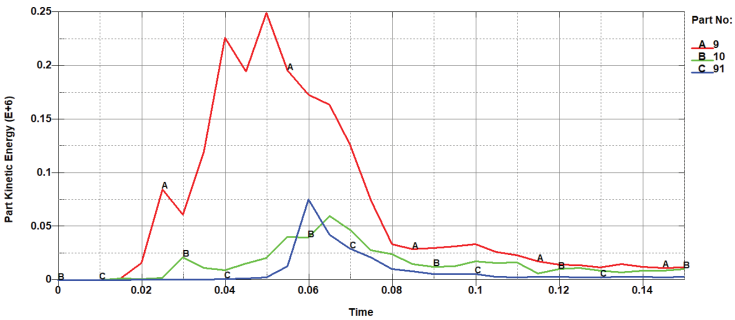
Sample A Sample B

Fig. 4. Result of simulation at T = 0.15s.

1. Kinetic energy



a) Kinetic energy of sample A

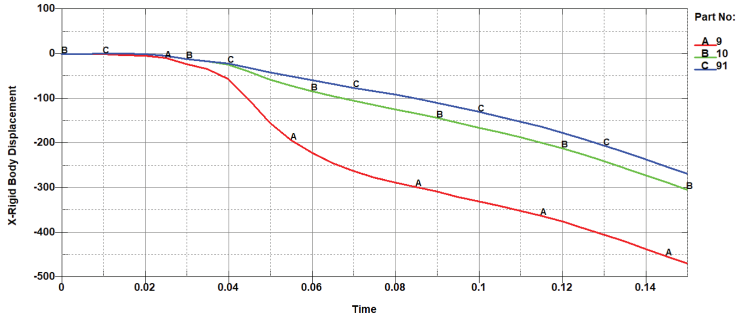


b) Kinetic energy of sample B

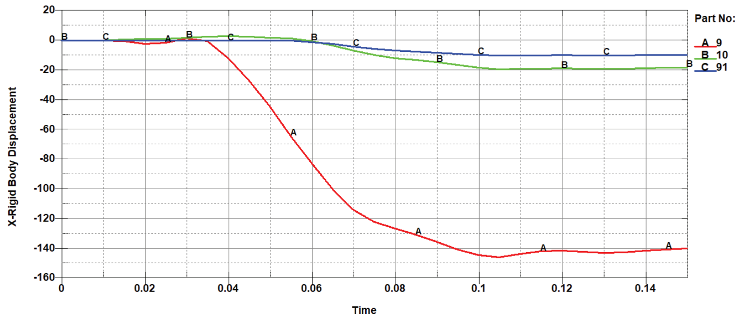
Fig. 5. Kinetic energy impact on RUPD sample.

The kinetic energy of the two samples in **Fig. 5** shows that the energy absorption of sample B is better. Therefore, the kinetic energy impacted on sample B by collision is also lower. That makes the x-axis displacement of sample B also lower, as shown in **Fig. 6.**

2. X-axis displacement



a) X-axis displacement of sample A



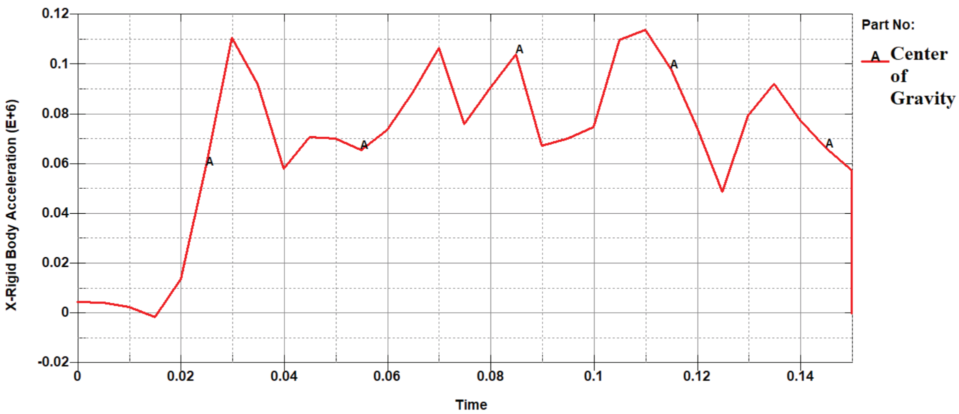
b) X-axis displacement of sample B

Fig. 6. X-axis displacement of RUPD sample

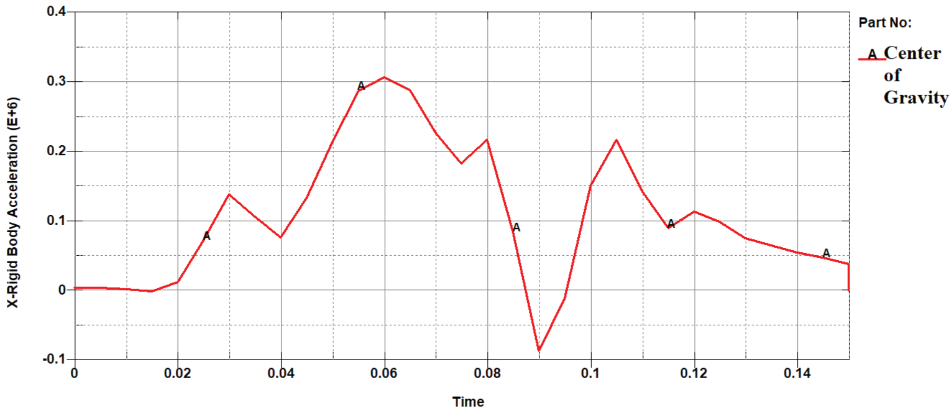
Fig. 6 shows that increasing the thickness of the RUPD increases the stiffness and reduces the displacement in the direction of external forces.

3. X-axis acceleration

The article chooses the center of gravity (C.G) to get data. **Fig. 7** shows that the higher stiffness for RUPD, the larger the collision acceleration and the larger the amplitude. That is, the occupants in the pick-up vehicle will be more affected by vibrations.



a) X-axis acceleration of pick-up C.G point with sample A



b) X-axis acceleration of pick-up C.G point with sample B

Fig. 7. X-axis acceleration of pick-up C.G point

IV. CONCLUSION

The simulation results show that increasing the thickness of the RUPD helps to in-crease the stiffness. It reduces the displacement of the RUPD and thus reduces the possibility of the cabin being underride. However, when two objects with great rigid collide, the rebound impulse is also greater and impacts the passenger. Therefore, it is necessary to combine the solution of shock absorption in a collision. Using shock absorbers is one solution. The findings of this study are expected to be helpful for the design and safety assessment of engineering structures including marine vehicles and cars against collisions.

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