Experimental Study on Transportation Safety of Package in Side Collision of Heavy Duty Truck

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1. Objective

The accidents in road transportation of package may be collision ,fall and fire. It is necessary to examine all cases very carefully because collision might be caused by other vehicle. Collisions are classified into head-on collision , rear-end collision , side collision. A lot of experiments and analyses are reported on head-on collision , so the behavior of vehicle and package may be predicted without difficulty.Rear-end collisions bring about less impact and may be applied corresponding to the head-on collisions.

About side collisions, few experiments or analyses are reported, and most of them are about passenger cars not about trucks. So it becomes important to study the transportation safety of package carried on a heavy duty truck when hit on the side by another truck similar in size.

2. Plan of experiments

2.1 Analysis of traffic accidents statistics

(1) Side collision in ordinary road

70% of the side collisions are bumping into each other when passing the intersection , and 60% of them are at right angle.

The speed of side collision shows the greatest number at 30～40km/h , and the cumulative percentage is 80～100 at 40～60km/h.

(2) Side collision in expressway

Most of the side collisions in expressway are observed at junction or at time of changing lanes.But the angle of collision is usually small and they don't give serious impact.

Rarely a car rushes across the central separation fence and attack another in the flank. In this case , supposing the speed of striking car is 80km/h and the angle of collision is 40° , the equivalent speed at right angle collision is 64km/h.

2.2 Conditions of experiment

(1) Angle of collision

It is appropriate to suppose right angle collision for the severest senario , or the maximum aggressiveness of striking car.

(2) Speed of collision

The maximum obtainable speed for 9 tons gross weight vehicle is 70km/h determined by the capacity of facilities.

(3) Position of attack

To avoid the turning motion of the struck car , it is desirable to attack the center of gravity of the struck car. And it is necessary not to attack the rear axle whose stiffness is very high.

(4) Loading of the striking car

Loading of the striking car makes conditions of the experiment very complicated , so it is desirable to leave the striking car vacant.

2.3 Plan of experiments

Three cases of experiment were planned for varions collision speed.

	elementary test	preliminary test	final test
objective	to study the behavior of vehicles at side collision	to study the behavior of package at side collision	to confirm the safety of package at side collision
gross vehicle weight	9 tons	9 tons	9 tons
collision speed	30 km/h	50 km/h	70 km/h
angle of collision	rectangular	rectangular	rectangular
posision of attack	nearest point to the center of gravity of struck car except rear axle	same as left	same as left
package on the struck car	two dummy con tainers (same dimension and weight as con- tainer and assembly for transportation)	same as left	one real con- tainer contain- ing mimic fuel and one dummy container same as the elemen- tary test

Tab.1 Plan of experiments

3. Simulation of side collision

Two types of numerical computation were performed.
One is kinematic analysis and the other is impact analysis.

3.1 Kinematic analysis

The horizontal motion of both cars was analyzed. Simulation model of a car is a rigid body having many elasto-plastic springs around it.

(1) Example of analysis at a 30km/h collision

Fig.1 shows the position of both cars after collision and skid marks. Each car was running at 30km/h speed. Numerical analysis of a case when the struck car was standing, showed a similar result about the relative position of both cars. Therefore it may be appropriate to conduct an experiment with the stuck car standing at zero speed.

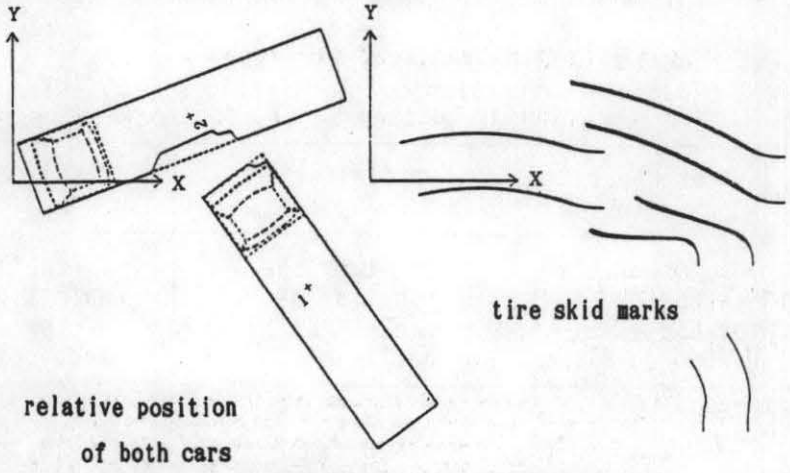

Fig.1 a 30/30 km/h side collision

(2) Example of analysis at a 70km/h collision

Fig.2 also shows the position of both cars after collision and skid marks. In the actual experiment, the struck car rolled, but this is not included in the simulation modeling.

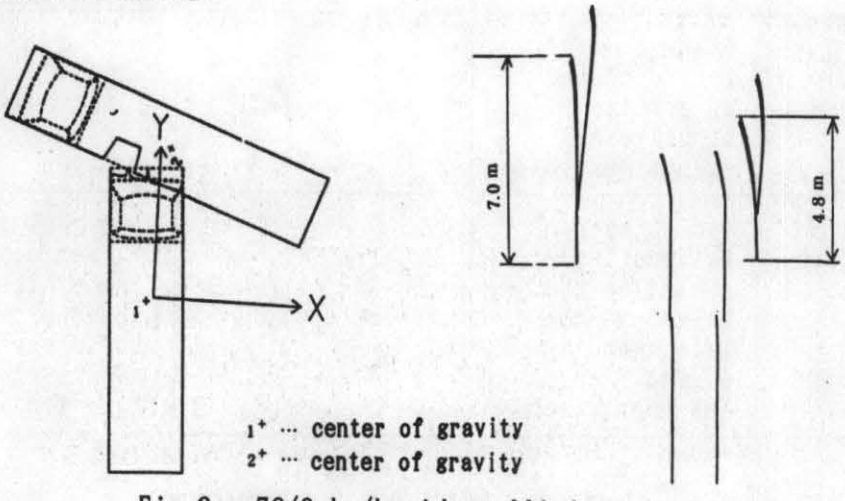

Fig.2 a 70/0 km/h side collision

3.2 Impact analysis

The analysis was performed with DYNA 3D code. Fig.3 shows finite elements of both cars and package.

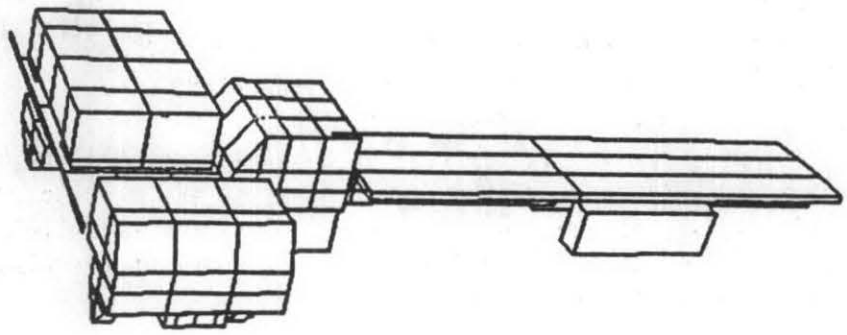

Fig.3 Finite elements of the model

Fig.4 shows the deformation of both cars at 200 msec after a 70 km/h collision.

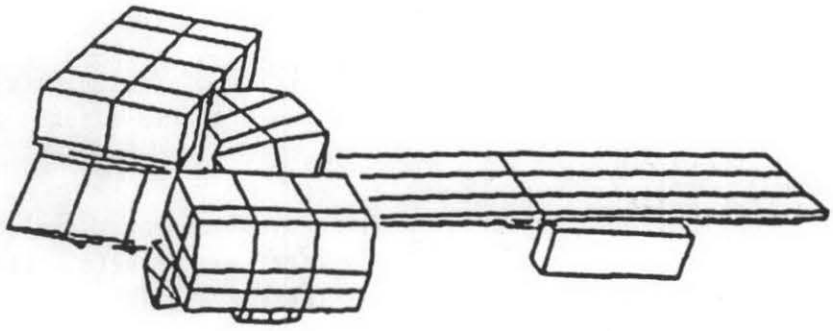

Fig.4 Deformation at 200 msec after a 70 km/h collision

The picture of actual experiment (Fig.5) shows good coincidence to the numerical analysis (Fig.4).

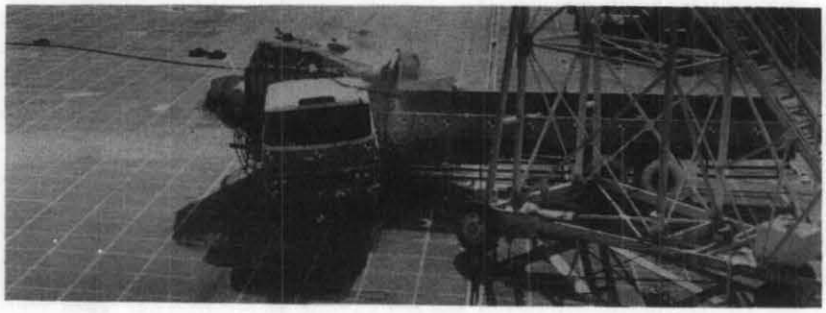

Fig.5 Deformation observed in experiment

4. Experiment of a 70km/h collision

4.1 method of experiment

(1) Outline

The striking car with 9.2 tons gross weight was towed by wire rope driven by an electric motor , bumped in the flank the struck car with 16.5 tons gross weight carrying package at 67.6km/h.

(2) package

Fig.6 shows the layout of the package carried on the struck car. The container is RCC1-A type and containes one mimic fuel assembly and one dummy weight equivalent to fuel assembly. Dummy container is equivalent to the container with two fuel assemblies in it.

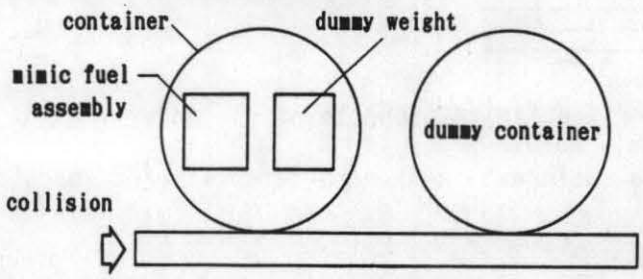

Fig.6 Layout of the package

(3) Electronic measurement

The speed of collision, the impact load,the tension of fastening wire rope for package and the accelerration at various points were measured electronically.

(4) Optical measurement

Slow motion pictures were taken to analyze displacement , velocity and rolling angle of vehicle and package. Many target marks were attached to vehicles and package for the convenience of image analysis.

4.2 Results of the experiment

The struck car rolled over , but the package remained tightly fastened to the loading platform by wire rope , impact limiter and metal fittings.

(1) Damage to the struck car

Fig.7 shows the deformation of the chassis frame of the struck car. The longitudinal wooden piece supporting platform was broken at 4 points, and 4 of the tie bolts were broken.

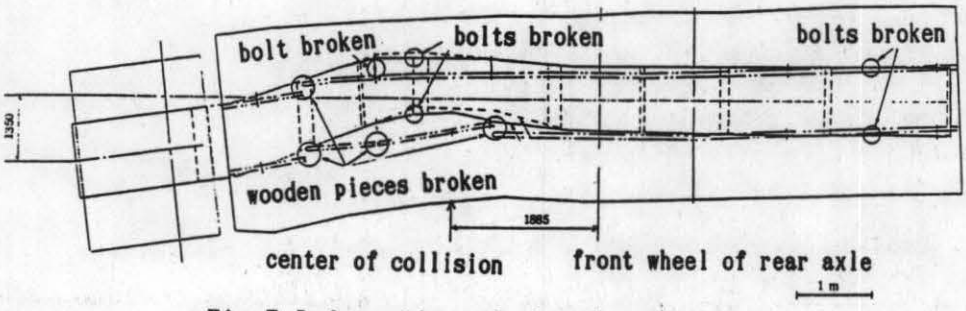

Fig.7 Deformation of the chassis frame

(2) Damage to package

Fig.8 shows the detail of the damage to the package. The container was dented in two places and one of the 38 quarter-turn bolts was broken and three of them were loosened. Inside of the container, several deformation or marks of contact were obsered.

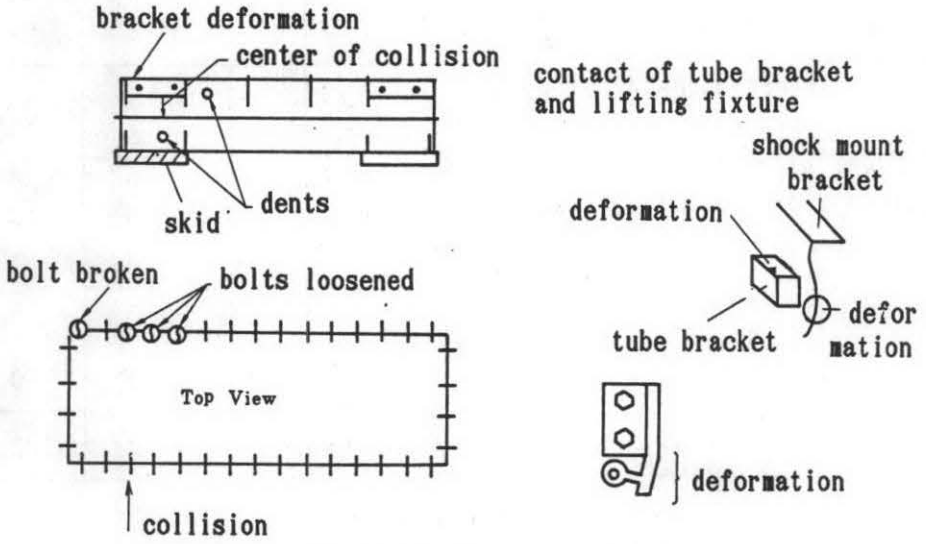

Fig.8 Detail of the damage to the package

Four brackets used for fastening the package remained undamaged, but one of transverse wooden pieces to which the brackets were fixed was broken.

The 17×17 elements type mimic fuel assembly was covered with cardboards, and no marks of oppression was found on it. After the removal of cardboards, the mimic fuel assembly looked completely intact.

(3) Impact load and acceleration

The maximum tensile load of 3.6 tons of wire rope was observed at the moment of collision, adding 2.1 tons to the initial tensile load of 1.5tons.

The maximum lateral acceleration of the container was 21.8G, observed at the moment of collision at the center of front end. The acceleration observed at the moment of roll was generally 1/2～1/5 of the maximum value.

Fig.9 shows the fluctuation of acceleration vs time.

The maximum observed acceleration was as follows.

35.5G at the front shock mount at the moment of collision
20.0G at the nozzle of mimic fuel assembly at the moment of collision
20.7G at the rear shock mount at the moment of roll

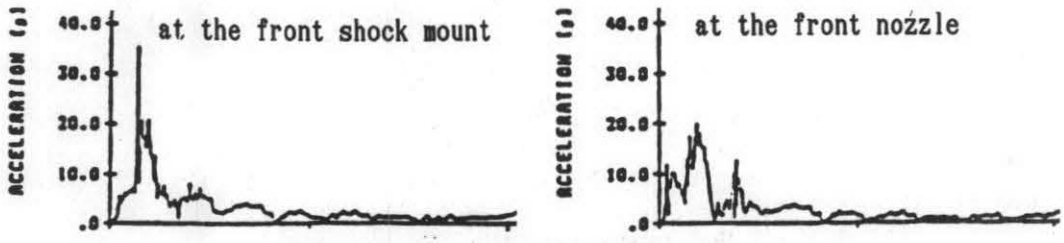

Fig.9 Time trend of acceleration

4.3 Examination of the result of experiment

(1) Mode of energy absorption

Tab. 2 shows the mode and percentage of energy absorption for three experiments.

Observed speed of collision (km/h)		30.2	49.8	67.6
Kinetic energy of striking car(ton·m)		32.5	91.4	165.2
Mode and percentage of energy absorption	Skid of struck car	35.9	44.0	30.8
	Frame deformation of struck car	14.7	11.6	10.8
	Roll of struck car	9.8	3.6	2.5
	Cab deformation of struck car	13.2	7.9	5.2
	Unaccounted for	26.4	32.9	50.7
Total		100.0	100.0	100.0

Tab. 2

(2) Deformation of the frame of struck car

Fig.10 shows the result of simulation and experiment for various collision speed.

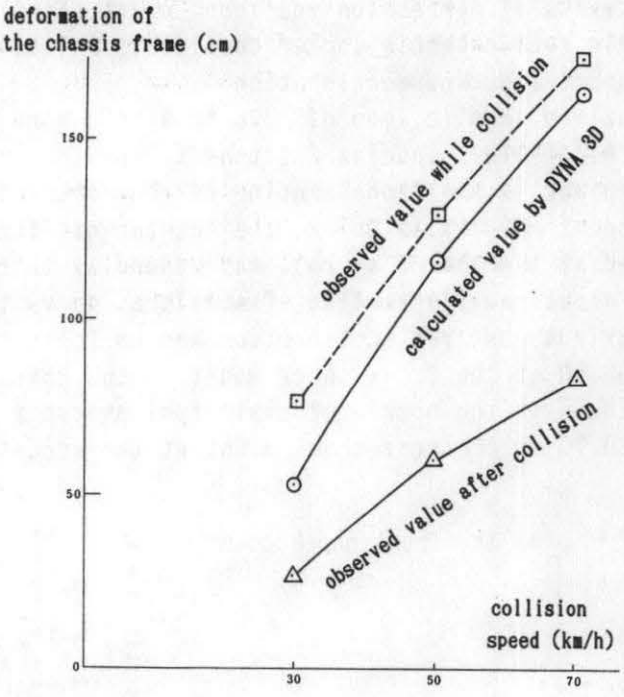

Fig.10 Maximum dynamic deformation of chassis frame vs collision speed

The maximum value of dynamic deformation obtained from film image analysis , showed good coincidence to that of simulation by DYNA 3D code.

(3) Tensile load of wire rope

Fig.11 shows the maximum observed tensile load for various collision speed.Tensile load of the front row shows linearity to the collision speed.

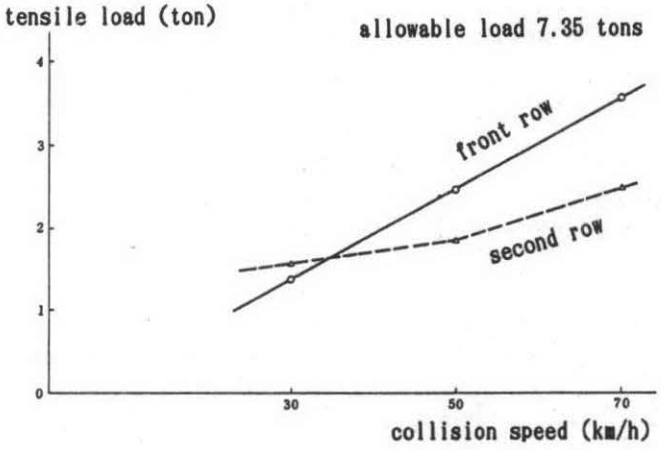

Fig.11 Tensile load of wire rope vs collision speed

5. Conclusion

(1) The impact to package by 9.2 tons gross vehicle weight,67.6km/h collision was much slighter than that of 9 m free drop test. The container was slightly damaged and the mimic fuel assembly looked undamaged.

(2) By the experimental result of three different collision speeds and the numerical simulation , the technique for predicting the behavior of the package for various collision speed was established.

Acknowledgement

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