INJURY MECHANISM AND EVALUATING METHODS FOR SMALL OVERLAP AND OBLIQUE FRONTAL CRASHES

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ABSTRACT

According to a National Highway Traffic Safety Administration (NHTSA) study, small overlap and oblique frontal crashes account for 25% of fatal accidents in the United States. This is a large proportion, and comprises the accident mode with the highest fatality rate. The fact that occupants collide with the cabin is a factor in this. The purpose of the present research is to recreate the injuries that occur to occupants in actual accidents involving small overlap and oblique frontal crashes, and to formulate a method for evaluating them. By enhancing vehicle body performance and occupant restraint performance, the goal is to reduce fatalities and injuries. In order to verify the circumstances of injury during small overlap and oblique frontal crashes, crash simulations were performed by numerical computation. A human body model was also placed in the driver's seat to verify the occupant movement and extent of injury. The oblique mode that the NHTSA is slated to adopt was first verified using numerical simulation, but collision on the occupant's chest could not be confirmed. For the present research, therefore, verification of the angle and speed parameters was carried out so that occupant movement could be recreated in a way that conformed to actual accident circumstances. The result of simulation was that occupant movement with respect to the vehicle together with vehicle body deformation showed the occurrence of collision with the occupant's chest when the evaluation vehicle (a passenger car) was impacted by an OMDB with an overlap (LAP) of 25%, at an angle of 30°, and at a speed of 110 km/h. The collision occurred in the same place, with injury to the same areas, and with the same degree of injury as shown under actual accident circumstances in a small overlap and oblique frontal crash. In light of these results, it was confirmed that injuries would be reduced by increasing the body strength of the evaluation vehicle to reduce deformation and by installing air bags on doors where oblique loading affected occupant movement. Numerical simulation of the above modes was performed using a passenger car that received the highest evaluation from the Insurance Institute for Highway Safety (IIHS). While vehicle body deformation was evaluated at the GOOD level even in oblique mode (in-house data), vehicle body deformation increased and occupant chest collision occurred that resulted in AIS4+ level injuries. This method of evaluation was confirmed to offer possibilities for evaluation of small overlap and oblique frontal crashes that conforms to actual accidents, and for evaluation that may further reduce fatalities and injuries. The effectiveness with respect to these injuries of measures taken through restraint devices and the vehicle body by means of numerical simulation using a human body model was verified. The results confirmed that combining vehicle body and restraint device measures had the effect of reducing injuries.

INTRODUCTION

Attention in the United States is being focused on small overlap and oblique frontal crashes because these types of crashes often result in fatal accidents even though the vehicle has the most up-to-date body technology and safety equipment. According to an NHTSA study, small overlap and oblique frontal crashes account for 25% of fatal accidents in the United States, which is a large proportion, making this the accident mode with the highest fatality rate [1]. According to Rudd et al. [2] it has been reported that in small overlap and oblique frontal crashes, 45% of AIS3+ injuries to occupants in the driver's seat are to the chest and 38% to the head. It is clear that causal factors in those injuries to the head are collision with the A-pillar, and to the chest, collision with the door, resulting in the large proportions of these injuries. One distinctive feature in the case of the chest, in particular, is that the ribs on the non-belted side collide with the door, causing fracture injuries. It is reported more chest injuries with the door as a factor in small overlap crashes than in co-linear crashes, and they consider these to be the result of the occupant's lateral motion and deformation of the vehicle body. Iraeus et al. [3] defined the crash mode accompanied with lateral movement as an oblique mode. They studied the mechanism of chest injury during oblique crashes using a human body model, and indicated that fractures occured when the load input from the seatbelt caused the body to bend in a longitudinal direction so that the rib cage bulgeds outward on the side, and the lateral motion of the body caused that side to crash into the door trim, resulting in fracture. There are also the findings in Lindquist et al. [4] and Brumbelow et al. [5] that the sites of fractures that occur in small overlap crashes in real-world accidents extend throughout the entire left side (ribs 1 to 12), with a particularly large number in ribs 1 to 10, which attach to the sternum.

In order to achieve further advances in vehicle body safety performance with regard to small overlap and oblique frontal crash accident patterns, and to reduce the distinctive injuries in such types of accidents, the Insurance Institute for Highway safety (IIHS) initiated a new evaluation in 2012 for the purpose of reducing injuries from small overlap and oblique frontal crashes. The SOT (Small Overlap Test) evaluation tests of the IIHS involve crashing a vehicle into a rigid barrier with 150-mm curvature on the corners at a speed of 64 km/h and the front end offset 25%. The NHTSA is considering revision of the New Car Assessment Program (NCAP) with a test method(Oblique test) using an Oblique Moving Deformable Barrier (OMDB) with attached aluminum honeycomb that collides with the test vehicle at a speed of 90 km/h and at an angle of 15° with a 35% offset in a small overlap crash for evaluation.

The present research sought a reduction in fatalities and injuries by focusing attention on the chest, in particular, as the location of injuries in small overlap and oblique frontal crashes, and devised an evaluation method that could enable reduction of those injuries. A numerical simulation was first implemented using a passenger car in the oblique test that is currently scheduled to be adopted for the NCAP. This approach used an adult male human body finite element (FE) model to verify the occurrence of the occupant’s chest collision with interior car body, and it sought test configurations that would recreate the injuries sustained in actual small overlap and oblique frontal crash accidents. It also used an OMDB FE model to verify configurations that make it possible to evaluate the vehicle. Directions to be taken in measures addressing this issue of injuries to the chest were examined in terms of both vehicle body and restraint device measures necessary for reducing future fatalities and injuries.

METHODS AND RESULTS

Reproducibility of chest injury by Oblique test

Crash simulations were conducted by numerical simulation using an explicit FE code. LS-DYNA(v971 6.1.2) to verify the actual injuries sustaied in small overlap and oblique frontal crashes. A human body model was setted on the driver's seat (DR) to verify the occupant movement and extent of injury. The human body model used for this was an adult male model developed by Ito et al.[6]. Current human body models only allow for whole body movement and fracture prediction, and cannot be used for direct evaluation of more serious (life-threatening) injuries to internal organs. Evaluation was therefore performed according to the number of fractured ribs predicted by the numerical simulation from the relationship between the rib fractures throughout the chest of the L side which is characteristic of the chest injury indicated by the abobe-mentioned past study. The simulation was first conducted through a configuration of the oblique test protocol scheduled to be adopted by the NHTSA[7]. The vehicle used for verification was a 2011 model year small passenger car. The vehicle model had a driver air bag and a 3-point seat belt as a restraint device. Figure1 shows the configuration

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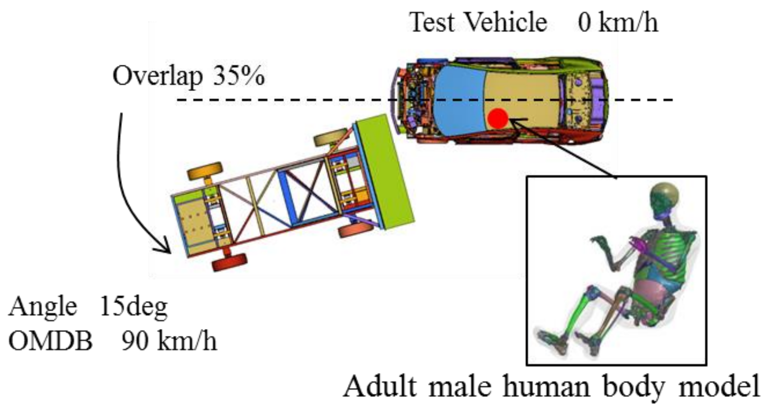


Figure1. Test configuration of Oblique

Figure 2 shows the results from confirmation of the vehicle body deformation, the movement of the human body model, and the number of bones fractured. A distinctive feature of chest injuries in actual small overlap and oblique frontal crash accidents was fractures on the non-belted side (left side) caused by collision with the door trim. However, collision with the door trim did not occur in the vehicle used for verification. The result showed three fractures concentrated in the lower part of the ribcage at #10, #11, and #12 ribs on theleft side. The injuries sustained here differed from the chest injuries that occurred in actual small overlap and oblique frontal crash accidents, where fractures occurred a particularly large number in ribs 1 to 10.

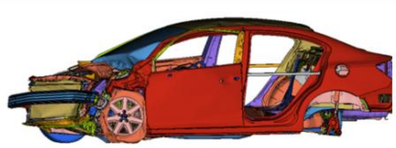
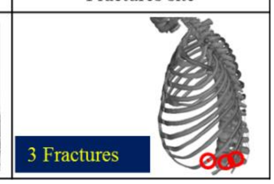
Vehicle body	Passenger	
Vehicle deformation at maximum displacement	Maximum excursion	Fractures site
	 Non Contact	 3 Fractures

Figure2. CAE Result of vehicle deformation and passenger injury

In the results obtained by Saunders et al.[8] confirming the reproducibility of Vehicle to Vehicle(VtV) and OMDBtV, configurations that provide high reproducibility of the toepan were selected for the configuration of the oblique mode that is currently scheduled to be adopted. These are configurations that place an emphasis on evaluation of tibia injuries, which are numerous in small overlap and oblique frontal crashes. According to Saunders et al. [8], the interaction of longitudinal members of own vehicle and opponent vehicle also influences the A-pillar displacement and accompanying chest injuries. In the case of modes in which there is no engagement of longitudinal members with the opponent vehicle, they indicate a high degree of reproducibility in the A-pillar. In order to reproduce actual accidents resulting in chest injury, deformation of the vehicle body (particularly the A-pillar) needs to be made to more closely resemble what happens in actual accidents. With a view to reproduction of chest injury, therefore, which is the purpose of this verification, the overlap was changed from 35% to 25% so that this would not be a mode that is no engagement between longitudinal members. Other elements of the configuration are the same as shown above. Figure 3 shows the appearance of the vehicle body during the crash.

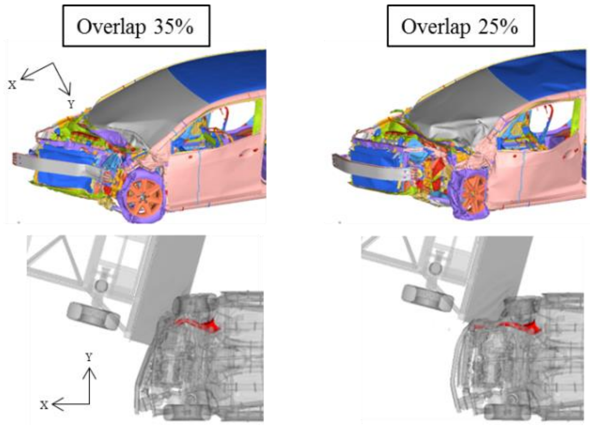


Figure3.Comparison of vehicle body deformation betweem overlap 35% and 25%

The result of numerical simulation with the overlap changed to 25% resuled in a mode in which engagement with the outer side of the longitudinal members did not occur, and there was increased deformation of the upper portion of the A-pillar. Although the increased deformation of the A-pillar also tended to increase the deformation of the door, this did not occur to the extent that the occupant would collide with the door trim. Occupant collision with the door trim did not occur, and no change was seen in the number of fractures or fracture sites. Figure 4 shows the occupant movement and fracture sites.

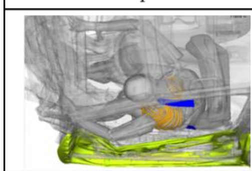
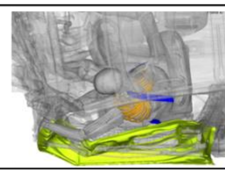
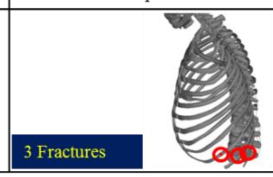
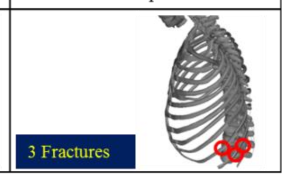
Passenger movement		Fractures site	
Overlap 35%	Overlap 25%	Overlap 35%	Overlap25%
			

Figure 4. Comparison of passenger movement and fracture sites betweem overlap 35% and 25%

Reproduction of accident situation

Among the causal factors in the collision of occupant and door trim are the amount of intrusion by the vehicle body and the occupant movement that accompanies vehicle body movement (lateral slide). These are considered to be important parameters. The capability of this mode to reproduce actual accidents was verified by taking three points as tuning parameters. These three points were that overlap was such that it would not depend on longitudinal members, that the angle was such that occupant movement that becomes an impact with the door trim was reproduced, and that the level of kinetic energy (speed) was such as to result in a collision. In order to calculate the configuration for an OMDB, VtV computer simulation was first used to verify that this mode would reproduce the injuries sustained in actual accidents. A 2 ton class SUV was used as a vehicle with a weight ratio to the passenger car of 1:1.6. Figure 5 shows a graph of the estimated number of accidents according to the own vehicle/opponent vehicle weight ratio, as obtained from NASS-CDS accident data (1320 cases from 2000 to 2013). Based on this graph, the ratio of 1:1.6 is positioned to include more or less the entire range of accidents that occur(99%). Next, for the purpose of configuring the speed, Fig. 6 shows the barrier equivalent velocity (BEV) on the horizontal axis and the estimated number of actual accidents on the vertical axis on the left. The average AIS value in the speed range of those accidents is shown on the vertical axis on the right. It is apparent from Fig. 6 that the average extent of injury increases abruptly in the 60-70 km/h speed range, rising to around 4 or less on the Maximum Abbreviated Injury Scale (MAIS). Since an injury rated as AIS4+ is severe, efforts were directed to this region in order to reduce fatalities and injuries. When a BEV of 60-70 km/h is expressed as ΔV, it is the equivalent of approximately 80 km/h.

According to the NHTSA accident study results, this covers 80% of the range of speeds that involve fatal accidents.[1].

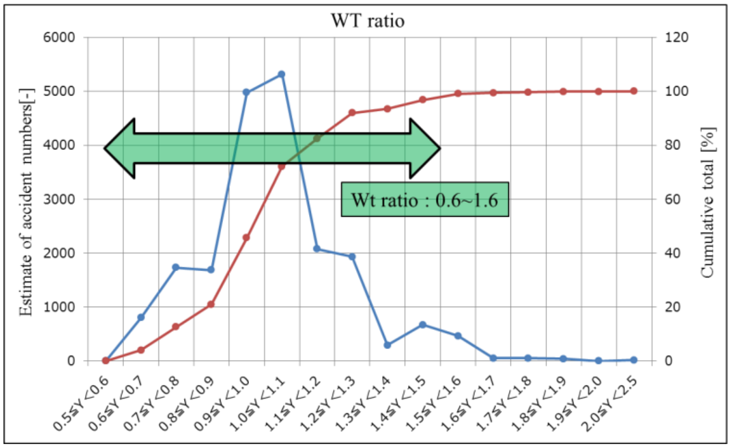


Figure5.The number of accidents by Wt ratio(Opponent vehicle/Own vehicle) in US

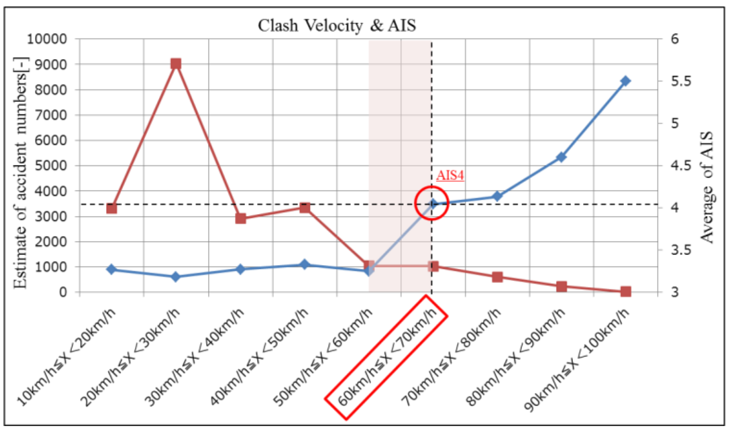


Figure6.The number of accidents and AIS average by BEV

Since the angle results in occupant movement in the direction of the door, the angle was changed from the 15° chosen for the oblique test to 30° with the aim of having the occupant move into a region where the occupant cannot be protected by the driver (DR) air bag that is intended for a conventional frontal crash. The overlap was set to 25% so as to avoid interference by longitudinal members. Figure 7 shows the configuration.

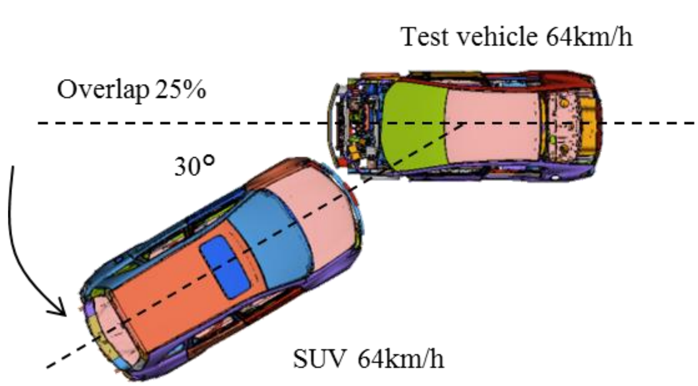
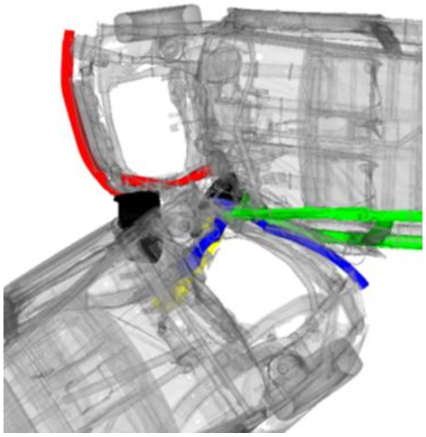


Figure7. Test configuration of VtV

Figure 8 shows the appearance of vehicle body deformation obtained through computer simulation. No engagement between longitudinal members occurred, and the bumper beam of the large vehicle (SUV) therefore collided directly with the A-pillar portion of the test vehicle. Increasing deformation of the A-pillar was accompanied with increasing deformation of the door, so that the door intruded into the occupant compartment space. Figure 9 shows the similar category of vehicle body deformation obtained from NASS-CDS as an example of a small overlap and oblique frontal crash compared with CAE result. Energy could not be absorbed by longitudinal members, and the progressive interference of the opponent vehicle with the A-pillar portion increased the load on the occupant compartment so that the upper portion of the A-pillar became deformed. It is apparent that the deformation mode obtained by computer simulation closely resembles the mode of deformation that occurs in actual accidents.



Figre 8. No engagement of the longitudinal structure

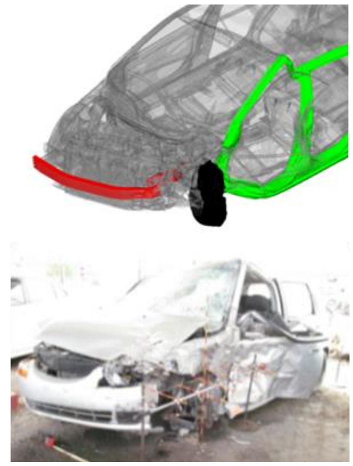


Figure9.Comparison of CAE result and example of small overlap actual accident

Next, in the interest of evaluating chest injury in small overlap and oblique frontal crashes, the deformation shown in VtV was reproduced using OMDB and the capability of reproducing the injury sustained by the occupant's chest in actual accidents was confirmed. In order to have the same vehicle body deformation mode, the overlap and angle were fixed and the speed parameter was tuned to conduct verification. Displacement equal to VtV was defined as the target, and X-Y deformation was confirmed using "toepan_center," " toepan_L," and "A-pillar" as judgment criteria. In order to confirm whether the injuries sustained in small overlap and oblique frontal crashes were successfully reproduced, the occupant contact location and number of fractures were confirmed. The speed of the vehicle crashed into was fixed at 0 km/h and confirmation was conducted in three levels with the OMDB crashed into the vehicle at 10-km/h increments from 90 km/h to 110 km/h. The point at which the computer simulation results were equal to or better than VtV for the OMDBtV at every deformation measurement point was when the OMDB was crashed at a speed of 110 km/h. Figure 10 shows the deformation and occupant movement that the OMDB was crashed at a speed of 110 km/h. Unlike VtV, the mode of large vehicle bumper beam directly impacting the A-pillar could not be reproduced with the OMDB. In the course of proceeding until A-pillar deformation was equal, therefore, the displacement in other regions tended to be greater than in VtV. Occupant movement was the aim of the 30° angle, and the direction was into an area not protected by the front air bag and in the direction of the door, where it coincided with the direction of intrusion by the door so that the chest came in contact with the door trim. This collision resulted in fractures of the ribs, and the result was that the contact sites and number of fractures were the same as the results given for actual accidents. This successfully indicated the possibility that evaluation of chest injury in small overlap and oblique frontal crashes using OMDB could yield the same phenomena as injuries sustained in actual accidents when the OMDB was crashed into the test vehicle at a speed of 110 km/h, an overlap of 25%, and an angle of 30° in the Small Overlap & Oblique (SOO) configuration.

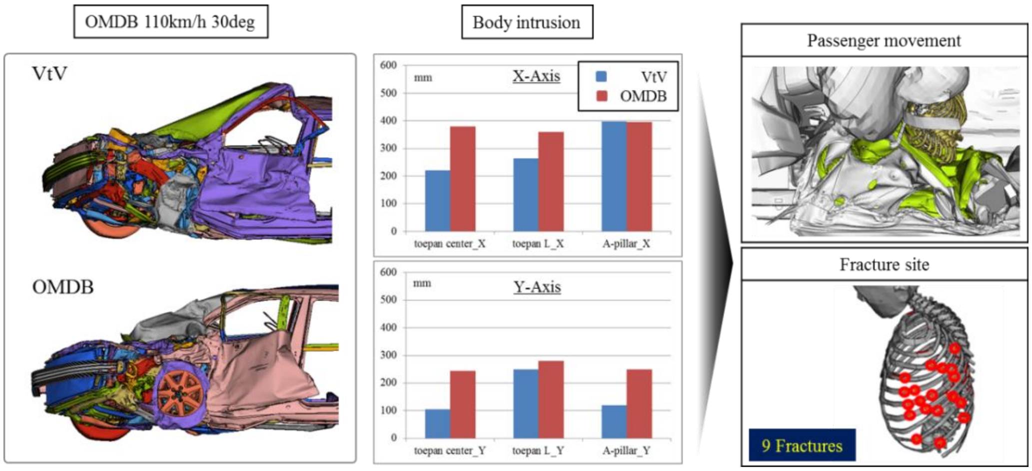


Figure10. VtV and OMDBtV Comparison

Comparison of Oblique test and SOO mode

A comparison of SOO mode and oblique mode was made using the vehicle that was tested for the present research. Figure 11 shows the various mode configurations.

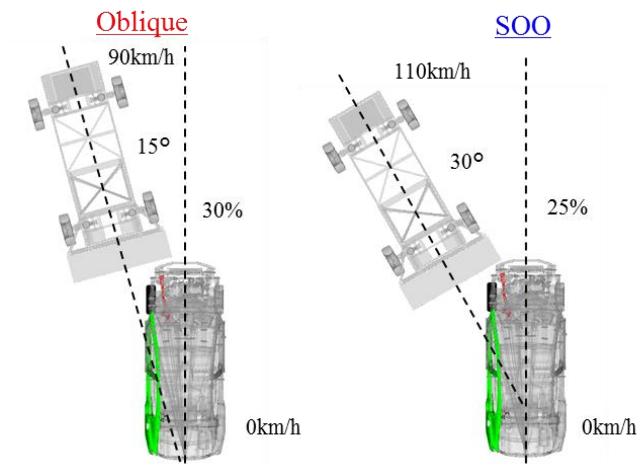


Figure11. Test configurations of Oblique test and NEW vehicle test

The comparison was made in terms of the evaluation vehicle ΔV, which indicates the severity to the occupant. Figure 12 shows ΔV of SOO mode and oblique mode. In oblique mode, the evaluation vehicle ΔV was 64 km/h, while in the SOO mode indicated in the present research, the ΔV was 78 km/h, which places the occupant in a severe situation. However, it was confirmed that ΔV corresponding to 80 km/h was achieved, which was the target, given that the purpose of the present research was to reduce fatalities and injuries. Comparison was then made of deformation in each area of the vehicle body. The comparison was made using the STRUCTURE index defined by IIHS as a reference index for the purpose of the comparison. Figure 13 shows the results of deformation at the measurement points where IIHS evaluation is performed[9].

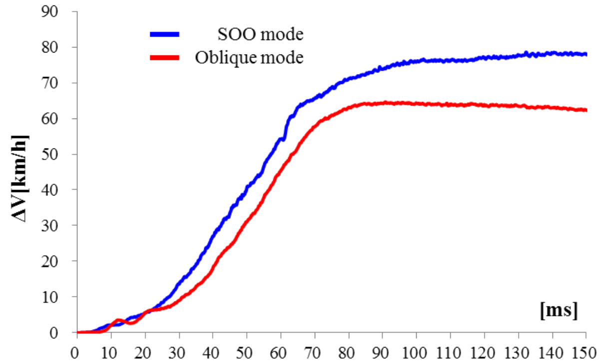


Figure12. ΔV of SOO mode and oblique mode

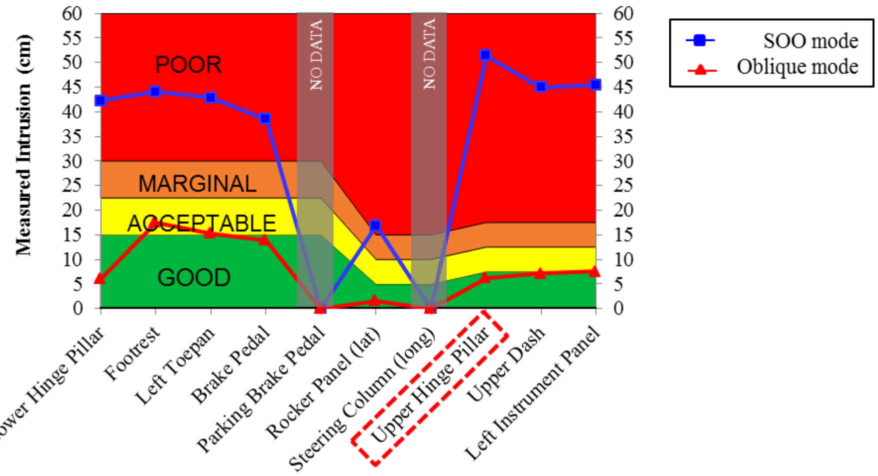


Figure13.Occupant compartment intrusion (IIHS evaluation)

Deformation tended to increase significantly in SOO mode in all regions. Deformation of the A-pillar was particularly conspicuous, and there was an increase of 45 cm in the upper portion of the A-pillar relative to the oblique mode. The contribution of the angle, speed, and overlap parameters was confirmed assuming that the deformation of 45cm was 100%. It was found that changing the angle from 15° to 30° produced 24% of the total increase, changing the speed from 90 km/h to 110 km/h produced 57% of it, and changing the overlap from 35% to 25% produced 19% of the increase in deformation. The increase in deformation due to speed was the result of the increase in input energy. In the case of overlap, energy absorption by longitudinal members did not take place, and the resulting increase in load on the occupant compartment caused the increase in deformation. The causal factors in the increased deformation due to the angle were examined in terms of the appearance of intrusion shown in Fig. 14.

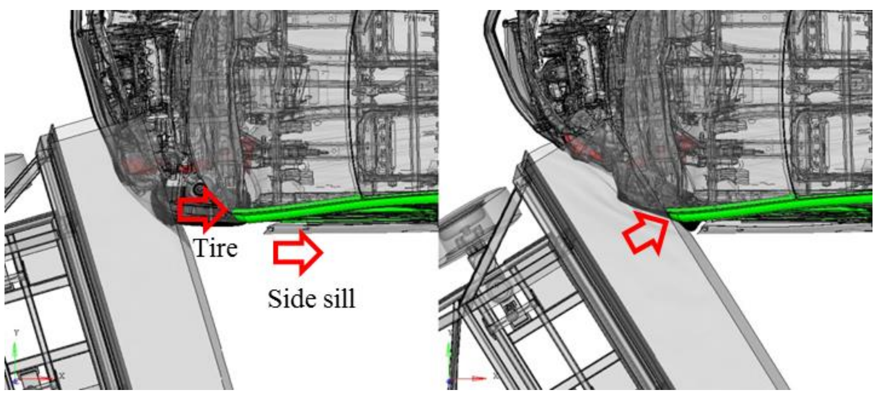


Figure14. Comparison of Oblique test(left) and SOO test(right)

In oblique mode, the angle is shallower than in SOO mode so that the load is distributed through the tire to the side sill. It is apparent that in the NEW mode, however, the tire is turned over on its side so that the load is not transmitted to the side sill, and instead the honeycomb portion of the OMDB impacts directly against an A-pillar portion. When the angle is deeper, the distribution of load toward the rear of the vehicle body is reduced, and the extent to which a load path is not formed is the extent of increase in deformation. Figure 15 shows vehicle body acceleration in the Y direction when numerical simulation of the oblique mode is performed with the speed fixed at 110 km/h and the angle set variously to 7°, 15°, and 30°. In light of the timing of the OMDB honeycomb contact with the A-pillar portion, there is an increase of acceleration in the Y-axis direction and the vehicle body movement shifts in the Y direction. This increase in acceleration is accompanied by occupant movement in the direction of the door, which is a movement counter to the vehicle. These results show that setting the angle at 30° causes acceleration in the Y direction to increase suddenly. This is further indication of the need for a crash angle that can cause the tire to turn over on its side and induce direct impact against the A-pillar. Since collision by the occupant with the door trim occurs at this angle, 30° appears to be appropriate.

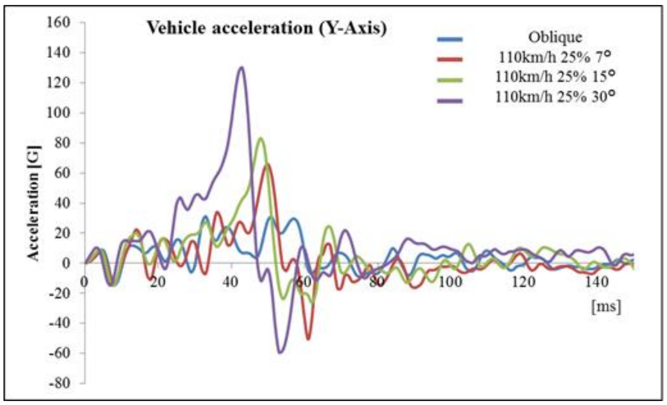


Figure15.Comparison of vehicle acceleration(Y) according to crash angle

Evaluation of SOO mode for SOT GOOD model

Up to this point, verification has been conducted using an 11M small passenger car. Research was continued using a midsize passenger car, which received a GOOD evaluation in the SOT implemented by IIHS in 2018, to confirm how the small overlap and oblique frontal crash is positioned with regard to chest injury. Although it is according to in-house data, the vehicle body in this model yielded vehicle body deformation at a level that was GOOD in terms of the SOT index even in oblique mode.Computer simulation was carried out with the configuration of 25% overlap, 30° angle, and 110 km/h speed that has been verified up to this point. Figures 16 and 17 show comparisons of the deformation and the appearance of the deformation produced with that configuration. By comparison with the SOT and oblique test configurations, the SOO configuration showed an overall tendency toward increased deformation. This was especially conspicuous in the A-pillar portion where there was a tendency to increase to the level rated POOR in the IIHS index. The reason for this was the same as in the verification performed using the 11M small passenger car, which is that the tire was turned over on its side and the OMDB honeycomb impacted directly against the A-pillar. It was found from these results that in the SOT that is presently adopted as well as in the oblique mode that is scheduled to be adopted, there is a possibility that vehicle body performance is inadequate with respect to chest injury even in a vehicle body that has the highest ranking of self-protection performance. In other words, the possibility that chest injury caused by contact of the chest with the door trim may not be comprehensively avoidable became clear. In order to pursue reduction of chest injuries and reduction of fatalities and injuries, it would be necessary to implement evaluation in SOO mode that reproduces actual accident circumstances and proceed to devise countermeasures.

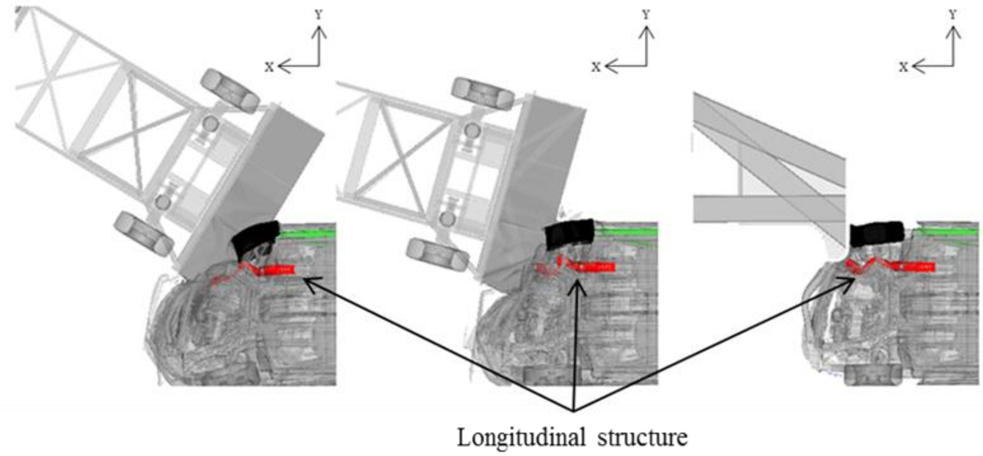


Figure16.Deformation of longitudinal structure (left:SOO,Center:Oblique,Right:SOT)

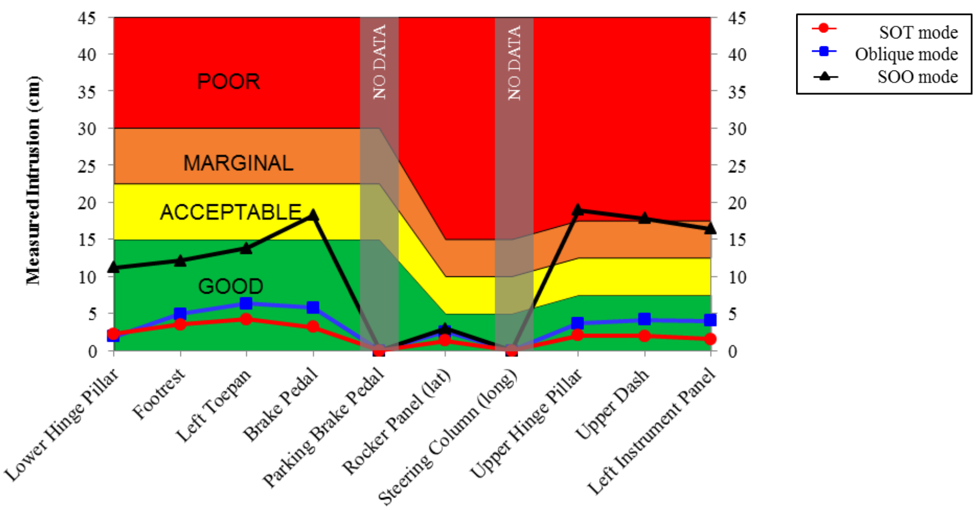


Figure17.Comparison of occupant compartment intrusion

Reduction of chest injury in small overlap and oblique frontal crashes

Body strengthening In investigating approaches to countermeasures, verification was first implemented for countermeasures on the vehicle body side intended to reduce vehicle body deformation. Taking the 11M small passenger car as a baseline, the thickness was changed at five places on members that contribute significantly to vehicle body deformation. For all five parts, the thickness was increased in increments of one rank (RNK) of 0.2 mm each. The OMDB was then crashed into the 11M small passenger car in SOO configuration and computer simulation was performed. Figure 18 shows the vehicle body strengthening areas and a plot of the maximum displacement of the A-pillar portion. As noted above, the 18 M midsize passenger car has the newest vehicle body performance and is positioned at the IIHS GOOD level. The deformation to this 18M midsize passenger car is plotted on the right of the figure. The deformation that occurred at strengthening to the fourth rank (4RANK) showed the same extent of intrusion into the vehicle body as in the 18M midsize passenger car. When further strengthening was applied to raise this to the seventh rank (7RANK) above the BASE, confirmation of occupant movement and occurrence or otherwise of fractures showed that contact with the door was still occurring and fracture injuries were found. Figure 19 shows the fracture status of the respective occupants. The movement of the respective occupants in the Y direction counter to the vehicle movement is shown in Fig. 18. Although doing such strengthening is not a realistic possibility in terms of the marketability of the vehicle body, even if the rigidity of the vehicle body were to be increased to the point of making it so rigid that the vehicle framework did not undergo any deformation at all, then the vehicle body would rotate by an amount that is in inverse proportion to the decrease in intrusion. It was confirmed that the movement of the occupant in the Y direction would therefore increase, and contact with the door could not be avoided. Although the number of fractures decreased, this resulted in a total of six fractures in ribs 5 to 11, with the lateral load input causing the fractures being concentrated in the ribs on the left side and to the rear from the very left. These fractures are reason for concern about injury to internal organs. It was confirmed, therefore, that there is a limit to countermeasures consisting of increased strengthening of the vehicle body against small overlap and oblique frontal crashes.

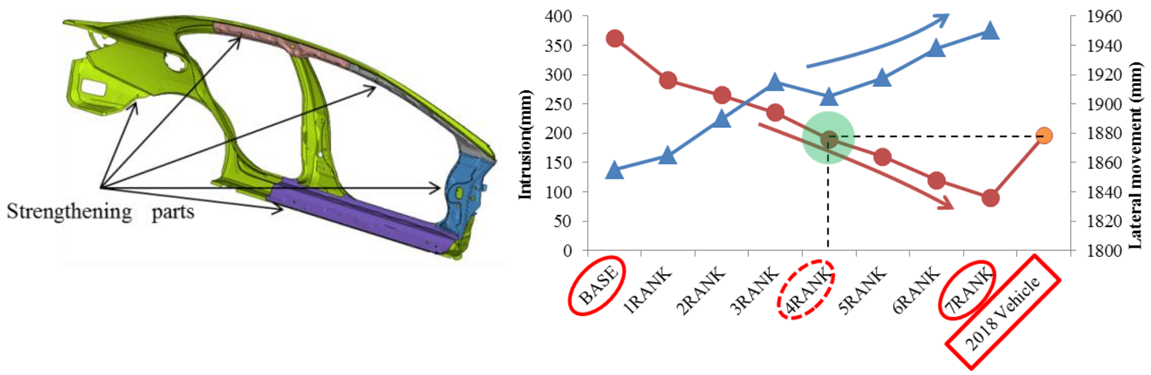


Figure18. Occupant compartment intrusion and occupant movement to lateral direction by body strengthening(left:strengthened parts)

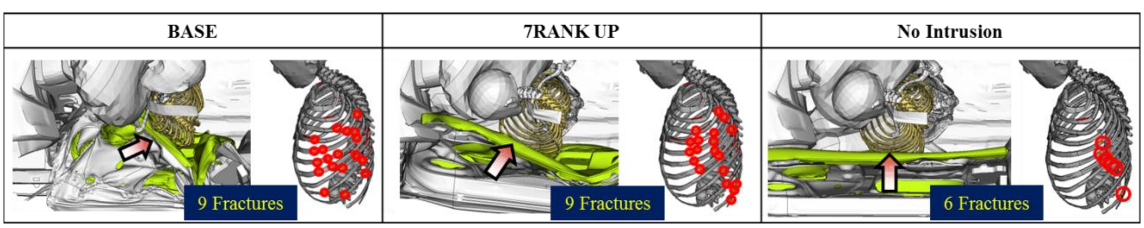


Figure19.Effect of body strengthening on occupant

Restraint device Verification of the possibility of countermeasures using restraint devices was carried out next. The area that the chest comes in contact with in small overlap and oblique frontal crashes is a blind spot in the area protected by conventional driver (DR) air bag and side air bag. Conceivable methods for addressing this are enlarging the side air bag and enlarging the curtain air bag. The purpose here, however, was to confirm effectiveness against fractures of the ribs. For the present research, therefore, a simple check was made to confirm the magnitude of the effect from installing a side air bag in the door front (FR) portion. Figure 20 shows a conceptual image of the installation and air bag deployment. Figure 21 shows the chest fractures of the computer simulation results. Where nine fractures occurred when there were no air bag in place, adding the air bag resulted in eight fractures, not significantly reducing the number of fractures. However, a check of the way the chest deflection when the fractures occurred showed that in the BASE configuration, the chest crashing against the hard structure of the door caused a load to be applied from the outside toward the internal organs locally so that the ribs were bent in toward the inside of the body. Adding the air bag changed the direction in which the ribs were bent to the opposite direction, away from the internal organs. In the former, there is a high possibility that the fracture end damages the internal organs.

This showed the possibility that the use of the air bag may mitigate the load input locally as well as the extent of injury. The effect of not taking countermeasures on the vehicle body side was confirmed as part of the present research, but for the future, it will be necessary to reduce the number of fractures by adding restraint devices that have been optimized for the characteristics of the air bag, thereby securing a survivable space by combining this approach with vehicle body countermeasures.

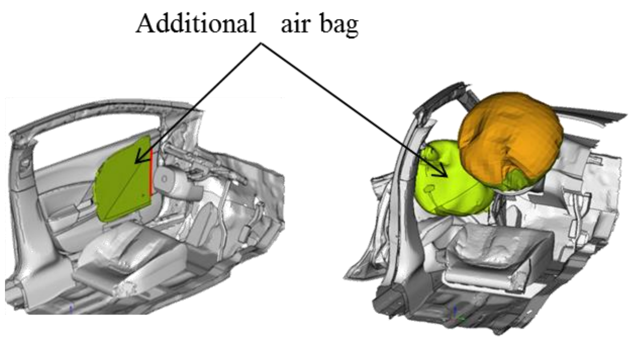


Figure20. Energy absorbing parts for oblique

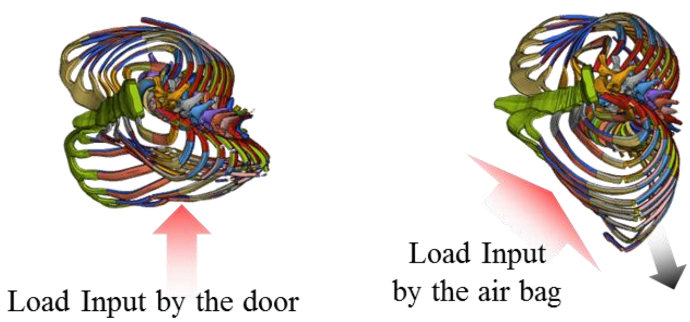


Figure21. Effect of restraint device on occupant(Left:BASE,Right:With air bag)

DISCCUSSION

Taking the view that, for the purpose of reducing fatalities and injuries, it would be necessary to establish evaluation methods that conform to actual accident circumstances, the present research focused on chest injuries during small overlap and oblique frontal crashes and sought modes that would recreate those injuries. With a view to achieving evaluation, configurations using the OMDB were calculated. The modes described above are quite severe when viewed from the perspective of ΔV in existing evaluation test configurations. However, the reason for this is that the present research has the purpose of concentrating attention on chest injuries in order to reduce further fatalities and injuries. According to the computer simulation, performing verification with severe configurations (weight, speed, angle) that systematically include actual accidents has made it possible to identify mechanisms of chest injury in actual small overlap and oblique frontal crash accidents.

The examination of countermeasures against chest injuries in small overlap and oblique frontal crashes has clarified directions for future countermeasures. There are limits to the reduction in injuries that can be achieved by strengthening the vehicle body, and it will be necessary for countermeasures that go beyond the conventional front and side restraint devices to include combinations with airbags for use in oblique crashes. This indicated the possibility that measures against chest injury may be inadequate even if vehicle body performance supports SOT, including the oblique mode that is currently scheduled to be adopted. Further advances are called for in vehicle body and restraint devices. For that purpose, however, achieving widespread adoption of restraint devices in the necessary areas will be a challenge as long as there is no evaluation of modes involving collision with the chest. The present research has not gone beyond verification using two passenger cars, which are small and midsize vehicles, and this does not suffice for proposing a complete evaluation method. For the future, it will be necessary to establish an evaluation method with the chest injury perspective. The research that will be needed for that purpose extends beyond the verification of test modes in the present research that conform to actual accident circumstances by the use of a human body model. It will be necessary to conduct future examination of the possibility of using the THOR anthropomorphic test devices (ATD) for appropriate measurement and evaluation of the characteristic displacement in the Y direction that is found in small overlap and oblique frontal crashes.

CONCLUSION

The present research used computer simulation to identify configurations that reproduce chest injuries from actual small overlap and oblique frontal crash accident circumstances.

・Overlap (LAP) 25%: This mode does not depend on energy absorption by longitudinal members.

・Angle 30°: This angle enables reproduction of occupant movement.

・Speed 110 km/h: The crash energy at this speed results in collision between the occupant and the cabin.

It was confirmed that by tuning the above three points, it was possible to reproduce the collision between chest and door trim that is a distinctive characteristic of chest injury under actual accident circumstances. These injuries were also subjected to numerical simulation using a human body model, and by this means the effectiveness of countermeasures utilizing the vehicle body and restraint devices was confirmed. This indicated that countermeasures that only strengthen the vehicle body have their limits, so that a combination with countermeasures utilizing restraint devices is needed.

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