APPLICATION OF REAR HEAD AIRBAG TO MITIGATE REAR IMPACT INJURIES

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ABSTRACT

In the real world, the accident ratio of rear impact is high. The injury scheme in those accident scenarios is mainly caused by whiplash. The intrusion of the rear end of the vehicle during impact combined with movement by occupants seated on rear seats plays a significant roll. This paper discusses an airbag which deploys from the roof header along the rear window. By means of numerical simulations and tests, the mitigation of biomechanical injuries of passengers seated on rear seats during rear impact was observed. Significant occupant protection was assessed under high-speed rear-impact conditions.

Keywords: Airbag, Rear impact

INTRODUCTION / ACCIDENT RESEARCH

When evaluating NASS/CDS (National Automotive Sampling System / Crashworthiness Data System) data, according to rear-impact injuries covering the years 1996 to 2005, it can be observed that in 47 % of all AIS1+ injuries, 40 described accidents in which passengers seated on rear seats sustained head injuries and 53 % concerned neck injuries. A significant increase in this injury ratio is observed when evaluating the data from NASS/CDS according to the AIS2+ injury scale for the head and neck region (5 accidents described). Injuries to the head account for 80 % of all injuries to this body region in rear impacts. Figure 1 depicts the ratio of head and neck injuries in vehicle rear impact for AIS1+ and AIS2+.

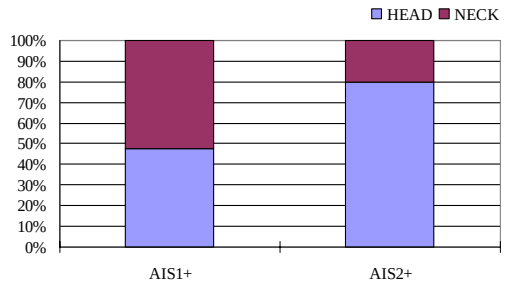

Figure 1. Injury ratio of head and neck (NASS/CDS, AIS1+: 40 cases, AIS2+: 5 cases)

The NASS/CDS data base also permits derivation and evaluation of the sources of these injuries. The sources for AIS1+ injuries are varied. During a rear-impact accident, the passenger's head can come into contact with various vehicle body parts such as the C-pillar, rear window, seat-back, rear header, head rest and roof. The distribution of these injury sources affecting AIS1+ head injuries is depicted in Figure 2. Contact is most frequent with the C-pillar (23 %), rear window (18 %) and the seat back (17 %).

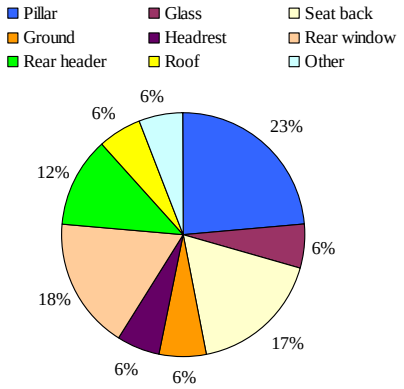

Figure 2. Injury sources for head injuries in rear-end collisions (NASS/CDS, AIS1+: 20 cases)

The injury sources causing head injuries according to the Abbreviated Injury Scale AIS2+ are limited. The accident data analysis shows three main contact points that lead to severe head injuries. Besides C-pillar and roof contact, each of which accounts for about 20 %, contact of the head with the rear header is most frequent. The ratio of the injury scenario is 40 % of all injury sources. Figure 3 depicts the breakdown of injury sources producing AIS2+ head injuries.

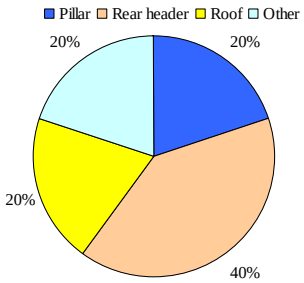

Figure 3. Injury sources for head injuries in rear-end collisions (NASS/CDS, AIS2+: 5 cases)

Rear passengers in which vehicle group are exposed to the most danger? This can also be derived from the NASS/CDS data base. The data indicates that 45 % of all head injuries occur in small cars. It suggests that the smaller the vehicle, the more likely a head injury will occur in an vehicle rear-end accident. Figure 4 illustrates that the ratio of mini cars is 25 % and those of compact cars is 20 %. The percentage attributable to intermediate cars is also 20 %.

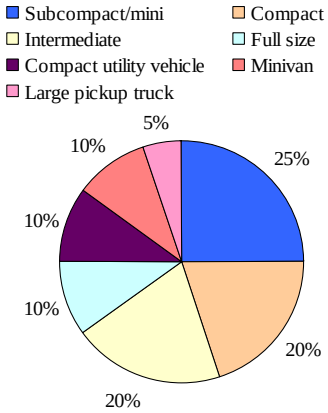

Figure 4. Ratio of car classes relating to head injuries (NASS/CDS, AIS1+: 20 cases)

The impact velocities delta v (km/h) of rear impact in real-life accidents can also be derived from the NASS/CDS data base. When evaluating the impact scenarios, it is remarkable that the impact velocity affecting this head injury of AIS1+ level is between 16 and 35 km/h. Rear-end collision velocities higher than 40 km/h cause injuries to the rear passengers of AIS2+. Figure 5 illustrates the various rear-impact velocities for AIS1 and ASI2+.

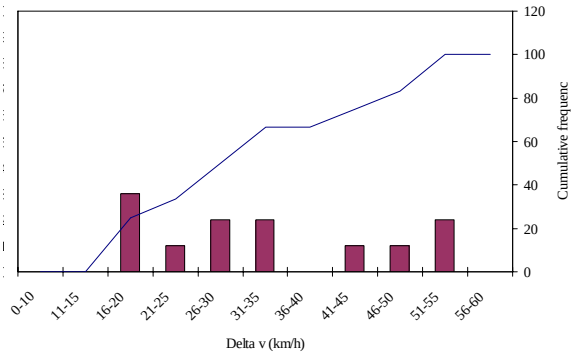

Figure 5. Rear-impact velocities relating to the injury scale (NASS/CDS)

When evaluating the same accident data based on rear occupant weights, no significant difference can be observed. The following Figure 6 presents the occupant weights sustaining head injuries AIS1+.

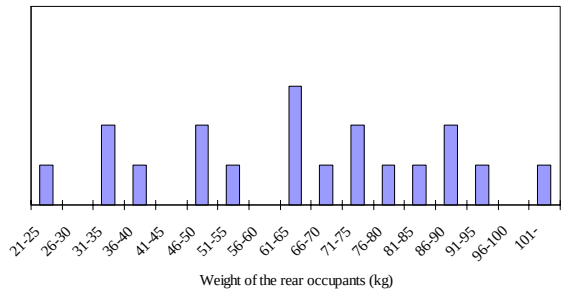

Figure 6. Weight of rear passengers in rear-end collisions (NASS/CDS)

Accident research has shown that occupants seated in rear seats can sustain severe head injuries in rear-impact accidents. The risk of passengers being injured in small vehicles is significant. Independent of weight respective to height, the occupants have hardly any contact to vehicle body parts such as the rear header, C-pillar and roof.

OCCUPANT PROTECTION CONCEPT IN HIGH-SPEED REAR IMPACT

Based on rear-impact research, a procedure has been designed to evaluate the risk of head and neck injuries in rear-end collisions. In this low-speed rear-impact test procedure, the equivalent of a stationary vehicle being struck by a vehicle of the same weight at a velocity of 32 km/h is applied. A BioRID 2 dummy is placed on the front seat measuring the loads during the rear-impact crash. Application of this test procedure will evaluate introduction of safety features mostly integrated into the seat back or head rest of frontal seats. These technical solutions are introduced to enhance the protection of front seat occupants in low-speed rear-impact crashes.

Front-seated vehicle occupants can be protected by headrest systems, which lower the gap between the head and the headrest. By means of crash-absorbing seat structures and a rocker system which uses the occupant's seat intrusion to displace the headrest or pyrotechnical actuators, the kinematics of the occupant head can be optimised. The protection concepts introduced are mainly designed for protecting front-seated passengers.

For rear-seated passengers, an airbag concept covering the area of rear header, roof and C-pillar could be the key to the technical solution. The technology is similar to curtain airbag technology for vehicle side protection. The airbag covers both the rear header and window area to provide space for absorbing the energy of the occupant's head during impact. The principle layout of this airbag technology is illustrated in Figure 7.

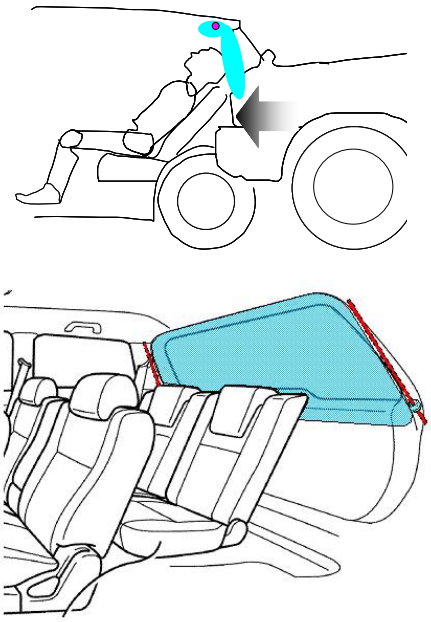

Figure 7. Principle layout of back seat head airbag concept for rear-end collisions

A gas inflator and a folded airbag are placed in the roof of the car. In the case of a rear impact, the hybrid gas inflator with a 220 kPa tank pressure characteristic starts to inflate the gas into the 20-litre silicon-coated rear row airbag. The upper part of the airbag deploys to cover the rear header of the car and the lower part turns into a rear deployment portion which is presented below in Figure 8.

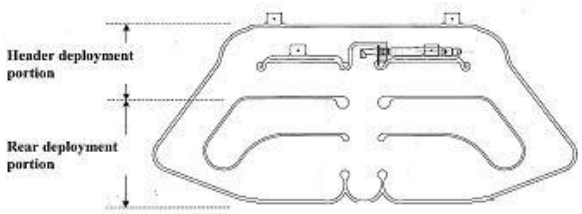

Figure 8. Rear row head airbag design

Based on this initial design, the airbag concept has been set up as a prototype. Deployment tests were performed to check the proper deployment behaviour in a real vehicle environment. The following Figure 9 depicts a video sequence of the rear row head airbag deploying in a compact car.

Figure 9. Video sequence of a static deployment test with the rear row head airbag concept

In addition to static deployment tests, impactor tests were performed to generate deceleration data for validating the numerical simulation airbag model.

INVESTIGATION OF THE PROTECTION CONCEPT BY NUMERICAL SIMULATION

On the basis of a mass production vehicle, a numerical simulation mock-up was set up. The rear end geometry of the mock-up corresponds to a compact class vehicle. Hybrid III dummies sized AF05 and AM50 were used in the simulations. A detailed seat model was introduced representing dummy-seat interactions. The dummies were not belted. According to the results of the evaluated NASS/CDS data, a rear-impact crash pulse was used in the simulation representing a 50 km/h rear-impact to a compact car.

Evaluation of protection performance - The validated rear row head airbag model was incorporated into the vehicle simulation mock-up. The two different scenarios AM50 and AF05 were simulated with the validated airbag concept. Figures 10 and 11 depict the simulation mock-up modelled using Madymo simulation software [1].

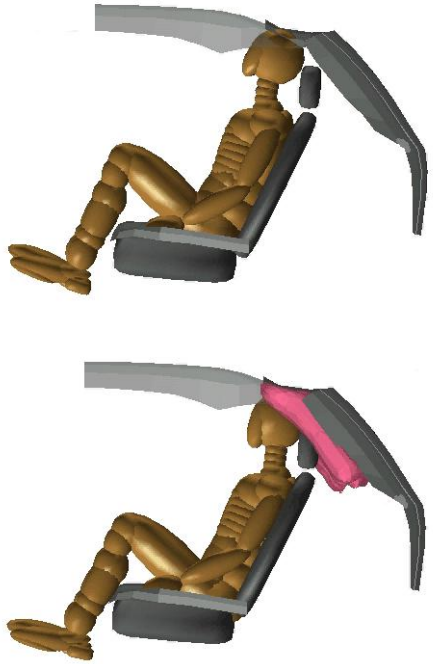

Figure 10. Video sequence of rear impact where v = 50 km/h, an AM50 dummy (top) and with rear row head airbag (bottom)

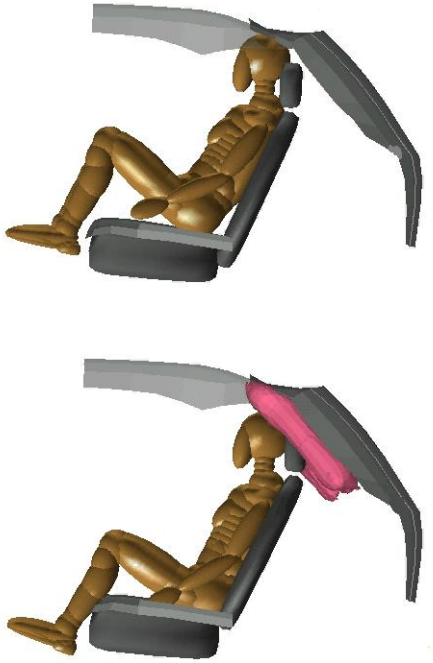

Figure 11. Video sequence of rear impact where v = 50 km/h, an AF05 dummy (top) and with rear row head airbag (bottom)

When evaluating the results derived from the 50 km/h rear-impact crash simulation, the contact between the dummy head and rear header was observed. In this case, the biomechanical loads AM50 and AF05 in the head and neck area are well above acceptable limits. The impact of the collision causes the dummy seated on rear seats to slip slightly upwards. At about 25 ms, the head hits the rear header. The hard contact ends up in a load peak. The rear airbag concept prevents the occupant's head from making such hard contact with the car. Head acceleration and neck forces are thereby reduced. The following Figures 12 to 15 show the results of the simulation.

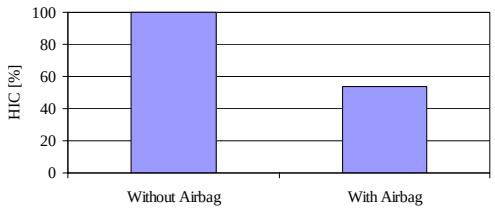

Figure 12. Comparison of HIC_{15} results with and without airbag for AM50 dummy

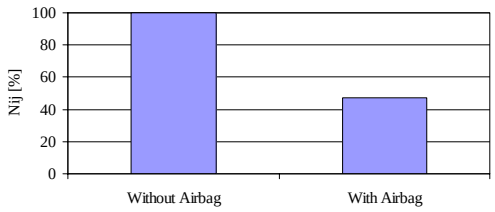

Figure 13. Comparison of Nij results with and without airbag for AM50 dummy

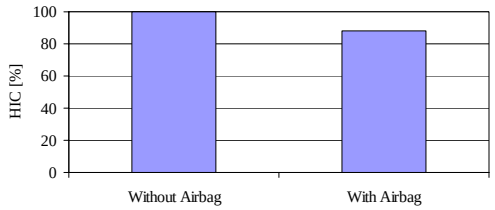

Figure 14. Comparison of HIC_{15} results with and without airbag for AF05 dummy

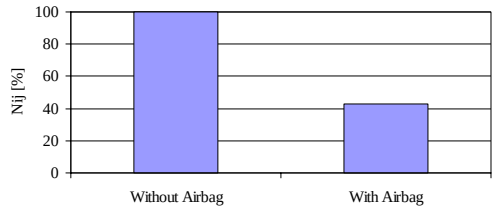

Figure 15. Comparison of Nij results with and without airbag for AF05 dummy

CONCLUSIONS

The numerical simulation discussed in this paper illustrate the importance of protecting rear row-seated occupants from hard contact with the vehicle rear header, in order to avoid significant loads on the head and the neck.

This computer-simulated investigation into rear-impact protection demonstrated that an airbag concept covering a vehicle's rear header area is very effective in preventing the rear passenger's head from sustaining severe injuries during high velocity rear impact.

REFERENCE

[1] Madymo 6.2.2 Reference / Theory Manual. TNO Madymo BV. Delft, The Netherlands. August 2006