A new vehicle bound system to secure elder children and small adults on back seats

Toni Weber[1] , Kai-Uwe Schmitt[1,2] , Markus H. Muser[1], Christoph Kerkeling[3]

Abstract A vehicle bound restraint system was developed to secure elder children as well as small adults seated on the back seat. The overall aim was to design a restraint system that is not obviously perceived as a ("child") restraint system, but shows at least a similar protective potential as a standard booster seat. To assess the new restraint system's performance a frontal crash test was conducted, comparing a P6 dummy seated on the new restraint system and a P6 seated on a standard booster seat. In addition, computational simulations were performed and the comfort of the new restraint system was rated by volunteers.
Results showed that for both systems the biomechanical tolerance criteria as specified in FMVSS 213 [1] and ECE R44 [2] were fulfilled. No submarining and no significant contact with the vehicle interior was observed. Values measured for the new restraint system were similar or better than those for the standard booster seat. Computational simulations indicated an advantage of the new restraint system compared to the standard back seat, such that the system seems also of benefit for small adults. Comfort was rated good, i.e. the child volunteers preferred the new restraint system in comparison to the standard booster seat. Therefore an increased acceptance among elder children might be expected.

Keywords child restraint system, seat comfort element, elder children, small adults

I. INTRODUCTION

Today several countries require the use of suitable child restraint systems. While most regulations focus on younger children, several approaches also require children up to 12 years of age and/or 150 cm body height to be secured in a suitable child restraint system (CRS). The benefit of CRS has been shown in various studies and a lack of CRS usage by elder children was clearly identified (e.g. [3], [4]). Consequently children use less CRS the older they become, which might be a reason why the amount of injured and fatally injured children increases with age [5]. Also, consumer organisations such as EuroNCAP currently intend to strengthen the consideration of these passengers in their test programmes [6].

Today there are various child restraint systems for back seats available, e.g. the 2-stage integrated booster cushion [7], and different suggestions concerning restraint system and back seat safety improvement have been made e.g. a raised base of the restraint to make the angle of the seatbelt lap webbing more vertical [8, 9] or a pretensioner positioned at the lap belt, seat ramps and/or redefining the anchor points of the seat belt [10]. However, currently available restraint systems still show disadvantages such as specific (height-)stages aimed at specific occupant/age groups, storage problems (standard booster seat) or a relatively high misuse rate [11, 12]. It is expected that the injury rate in children will decrease, if (some of) those disadvantages are eliminated.

In this research project a novel approach for a vehicle bound restraint system for the back seats of a passenger car (aimed at "Group II-III" occupants) was developed. Its key feature is a mechanism to lift a part of the seat cushion. Using the system, the child passenger sits in a higher position which improves the belt geometry in the pelvis and shoulder region without changing the belt system itself. Consequently, the system offers a safety level comparable to other child restraint systems (e.g. booster seats) and has the advantage that the system may be regarded as a comfort element rather than a child restraint system.

II. METHODS

A concept for a vehicle bound restraint system on the back seat was created. This system is particularly designed for elder children and meant to be used instead of a booster seat. The vehicle-based belt system is the critical component in that respect such that the belt has to be guided in order to load the pelvis and upper leg and not the abdomen. Furthermore the upper part of the belt has to ensure a good and comfortable fit in the shoulder/neck region. The system developed incorporates a mechanism which makes it adjustable in height,

[1] AGU Zürich, [2] Institute for Biomedical Engineering, University and ETH Zürich, [3] Honda R&D Europe (Deutschland) GmbH

while the belt system remains unchanged. To assess its performance, a recent vehicle (Acura RL) was equipped with a model of the new restraint system offering a seating height comparable to a booster seat. The comfort issue which is regarded of high relevance was assessed by three child and two small adult volunteers, who were asked to sit on the new restraint system, attach and detach the seat belt and finally to answer a questionnaire and comment on the new system.

Experimental Testing

One frontal crash test was performed at the Dynamic Test Centre (DTC AG) in Vauffelin (Switzerland). The test was conducted on the basis of FMVSS 213 and ECE R44, i.e. a frontal crash into a non-deformable barrier, 100% overlap, delta-v (change of velocity) of 48km/h (30mph). The test conditions were modified such that a full scale crash test was performed instead of a sled test as required in the regulations of FMVSS 213. The vehicle was equipped with two instrumented P6 dummies seated on the outboard positions of the back seat. The first dummy was placed on a standard booster seat (model: babidéal "Lucky", Group II-III (15-36 kg)) as a reference and the second dummy was seated on the new restraint system. Dummy instrumentation included accelerometers on the head, thorax and pelvis. Various film targets were positioned for video analysis. In addition, the acceleration of the vehicle and the belt forces on the rear seats (shoulder and lap) were measured. Four high-speed cameras were used to record the test.

Computational Modelling

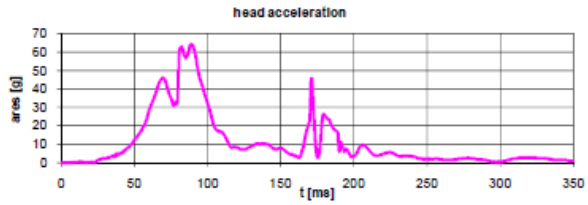
Computational simulations with Madymo® software using a multi body model approach were performed as a part of the design process. The simulations allowed considering a variety of parameters and assessing their influence on the performance of the new restraint system, in particular to ascertain the performance when used by small adults. Analysed parameters included three different occupant/dummy sizes (P6, P10 and Hybrid III 5%ile female), various sitting heights and crash pulses and changes to the seat belt system such as additional pretensioners.

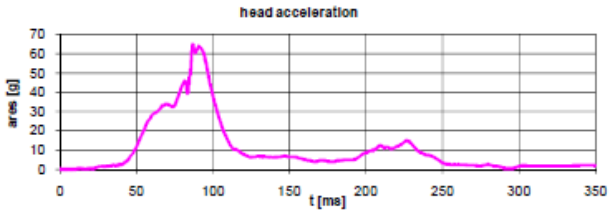
III. RESULTS

The values determined in the crash test showed similar characteristics for both systems. A pelvis displacement of 163mm (in forward direction) was measured by video analysis for the dummy seated on the new restraint system; during impact both dummies touched the seat backs of the front seats with their feet. No other contact with the vehicle interior was detected. Both systems resulted in a stable belt position, i.e. the belt did not slide into the abdomen and no submarining was observed. They also showed no visible damage or remaining deformation after the crash.

As can be seen in Table 1 the head acceleration values were in the same order of magnitude for both systems. HIC values were clearly lower for the new restraint system. Based on the values measured by video analysis, the head of the dummy seated in the new restraint system rotated more in the forward direction during the impact than the dummy seated on the standard booster seat. The dummy seated on the new restraint system exhibited a lower acceleration of the thorax as presented in Table 2. It has to be noted that the 3ms criterion of the standard booster seat slightly exceeded the limit of 55g given in ECE R44. For the new restraint system, the values did not reach the biomechanical limits at any time. Also injury severity was estimated and, especially at thorax, was lower for the P6 on the new restraint system. In terms of pelvis acceleration the diagrams in Table 3 indicate that the P6 on the standard booster seat was subjected to a rather sharp peak resulting in a higher peak value but a smaller 3ms value. In Table 4 it can be seen that the lap belt force is lower for the P6 on the standard booster seat while shoulder belt force is lower for the P6 on the new restraint system.

P6 seated on standard booster seat P6 seated on new restraint system

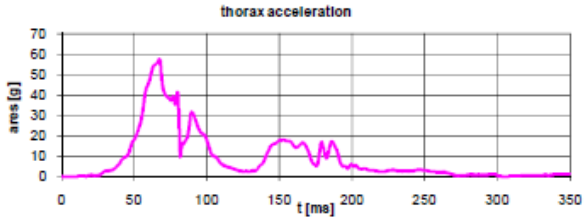


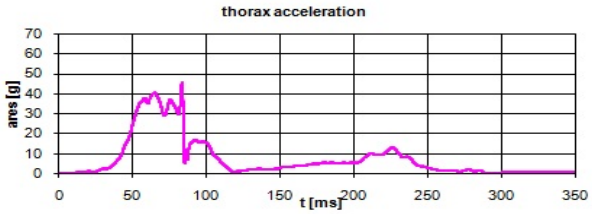


Peak (resultant acceleration) [g]:	64.4	Peak (resultant acceleration) [g]:	65.0
3ms max (resultant acceleration) [g]:	61.9	3ms max (resultant acceleration) [g]:	62.2
HIC36:	563	HIC36:	494
Rotation angle in forward direction [°]:	80	Rotation angle in forward direction [°]:	93

Table 1: Acceleration values, HIC and rotation angle measured at head/neck during crash test

P6 seated on standard booster seat | P6 seated on new restraint system

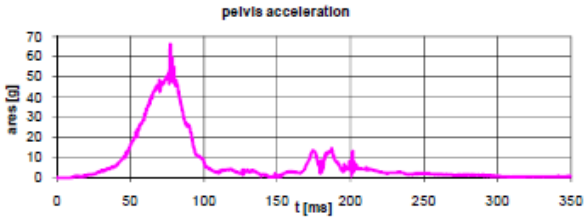


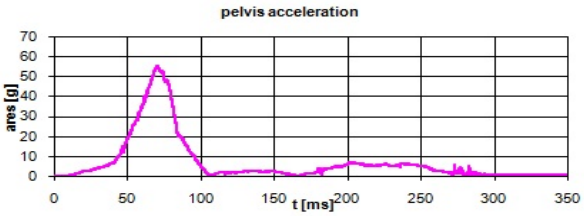


Peak (resultant acceleration) [g]:	57.7	Peak (resultant acceleration) [g]:	45.6
3ms max (resultant acceleration) [g]:	55.2	3ms max (resultant acceleration) [g]:	39.5

Table 2: Acceleration values measured at thorax during crash test

P6 seated on standard booster seat | P6 seated on new restraint system

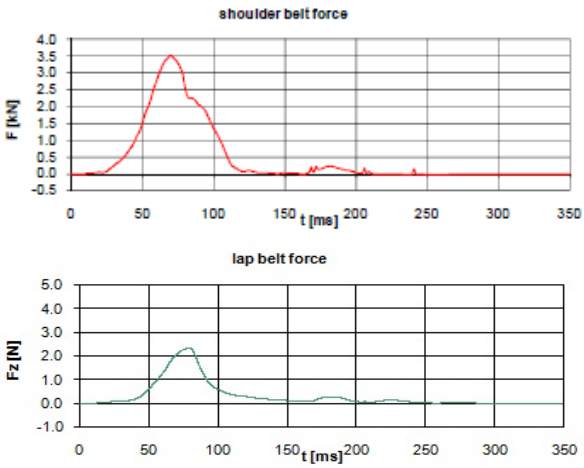


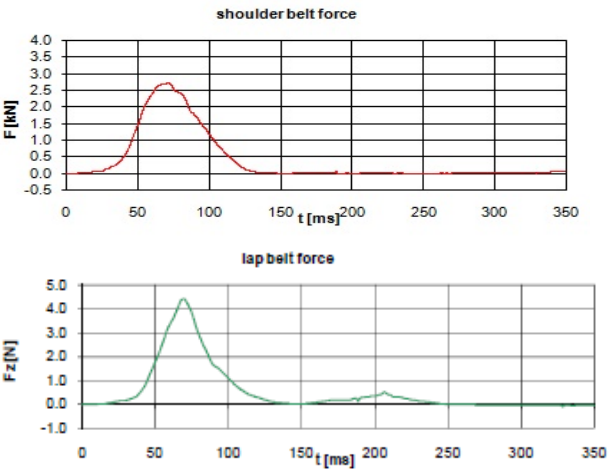


Peak (resultant acceleration) [g]:	66.2	Peak (resultant acceleration) [g]:	55.1
3ms max (resultant acceleration) [g]:	47.8	3ms max (resultant acceleration) [g]:	53.1

Table 3: Acceleration values measured at pelvis during crash test

P6 seated on standard booster seat | P6 seated on new restraint system





Belt force (shoulder / lap) [kN]:	3.5 / 2.4	Belt force (shoulder / lap) [kN]:	2.7 / 4.4

Table 4: Comparison of seat belt performance

Computational simulations using a P6 dummy resulted in a similar dummy motion compared to the crash test. Using a multi body model of a small adult (Hybrid III 5%ile female) a similar protection potential was found in comparison to the P6. However, further investigations in terms of additional crash tests and simulations are necessary.

Finally comfort was rated. The seating area was large enough for all children, although it was slightly too long for the smallest (5 yo), i.e. he was not able to bend his legs. Sitting height was good for all three children and there was no comfort loss with regard to the seat back. They were able to attach and detach the seat belt by themselves without any problems. The three children preferred the new restraint system compared to the normal back seat or the normal booster seat. Both small adult volunteers rated the new restraint system similarly.

IV. Discussion & Conclusion

In this study it was shown that a vehicle bound restraint system that can be used by elder children as well as small adults, can be designed such that it performs comparable to (or better than) a standard booster seat. All values recorded for the new restraint system were below the biomechanical threshold values defined in ECE R44 and FMVSS 213 and the belt geometry was improved in the pelvis region without modification of the belt system itself. An increased seating height is not only regarded as a benefit for the lap belt geometry, but also leads to more comfortable shoulder belt guidance and allows smaller passengers a better view out of the window, which is considered advantageous with regard to comfort. Another advantage of the new system is its appearance; it is perceived as a “comfort element” rather than a “child restraint system”. Therefore an increased acceptance among elder children may be expected. In addition the system seems of benefit for small adults as well. There is also an advantage in view of changes that might be introduced in the New Car Assessment Programmes giving the safety of elder children/back seat occupants a higher weight [6].

The major limitation of this study with regard to the results is that just one full-scale crash test was performed. The interpretation is therefore limited and cannot be generalised, a proof of concept has however been achieved. Although the small amount of volunteers is not sufficient to provide a firm result with regard to the assessment of seating comfort, it provides a positive trend related to the acceptance of the new system. Further investigations on the optimisation of the system performance and on comfort issues are therefore recommended.

V. Acknowledgement

The project was funded by Honda R&D Europe (Deutschland) GmbH within the Initiation Grant Europe program. Michele Casanova provided the computational simulations for this study which were performed as a part of his Master Thesis.

VI. References

[1] FMVSS 213, 49CFR571.213 (10-1-08 Edition), US Code of Federal Regulations (CFR), pages 856-899
[2] ECE R44, r044r2e (Revision 2, 4-2-08), United Nations Economic Commission for Europe (UNECE)
[3] Jakobsson L, Isaksson-Hellman I, Lundell B, Safety for the growing child – experiences from Swedish accident data, Proceedings of the ESV Conference, 2005
[4] Singh S, McCray L, Brewer J, The effort of restraint use and crash mode on injury severity risk for children, Proceedings of the ESV Conference, 2007
[5] European Child Safety Alliance, *http://www.childsafetyeurope.org/publications/info/factsheets/childhood-road-safety.pdf* (07-06-2010)
[6] Brown J, Morgan R M, Scullion P, Nix L, Assessing head and neck injury in rear seated children aged 7-12 years in frontal crashes, Neuroscience Research Australia and University of New South Wales, Barker St, Randwick, NSW 2031, Australia, 2010
[7] Jakobsson L, Wiberg H, Isakosson-Hellman I, Gustafsson J, Rear safety for the growing child – a new 2-stage integrated booster cushion, Proceedings of the ESV Conference, 2007
[8] Griffiths M, Brown J, Paine M, A safe ride height line for child car occupants, Proceedings of the ESV Conference, 2009a
[9] Griffiths M, Brown J, Kelly P, Safer child restraints for children 6 to 10 years, Proceedings of the ESV Conference, 2009b

[10]Johannsen H, Schipper M, Schindler V, Is it possible to optimise the rear seats for children (6 YO and above) and adults? 8th International Conference Protection of Children in Cars, Munich, 2010
[11]Salvisberg U, Bischof K (Swiss Council for Accident Prevention) Benutzungsquote von Kinderrückhaltesystemen, Bern, 2004
[12]Fastenmeier W, Lehnig U, BASt-Bericht M 178, MVU, Institut für Angewandte Psychologie, München, 2006