Child safety system Takata 14-neo, award for contemporary design by Museum of Modern Art, New York, USA, 2005

Integrated Approach for Seat Development of Child Restraint Systems

Children require a special protection in road traffic. But passenger cars usually accommodate a maximum human occupant height range of 150 to 200 cm. This 50 cm difference in height is leading to technical solutions such as seat height and fore/aft adjustments as well as mechanisms for adapting seat belt geometry, which do not apply however to the group of the children. Takata presents an integrated approach to develop children seats – correctly termed child restraint systems – optimally.

1 Introduction

The child passenger as part of a mobile society deserves special attention when addressing passive passenger vehicle safety [1]. Passenger vehicles usually accommodate a maximum human occupant height range of 150 to 200 cm. This 50 cm difference in height is leading to technical solutions such as seat height and fore/aft adjustments as well as mechanisms for adapting seat belt geometry. A child's body from 0 to12 years old, however, measures between 50 and 150 cm. This growth in height is considerable and demands significant enhancements in passenger vehicle seating and seat belt geometry adaptability. These enhancements are available as integrated child seat systems in some vehicles, although these systems generally presume a minimum height of 80 cm.

Additional distinctive features in a child's body make compatibility between child and passenger safety even more difficult. For example, a child's head is disproportionately heavy compared with an adult's. Whereas an adult's head weighs about 7 % of total body weight, the head of a one-year-old child takes up 25 %. In addition, up to the age of twelve, a child's spinal column is composed of cartilaginous connections between each vertebral element and arch. This leads to reduced stability in the backbone and reduced protection of the spinal cord. In the absence of defined neck musculature and tendons, the cervical vertebrae are especially at risk should any crash forces be applied [2].

Along with this cervical vertebrae sensitivity, the abdominal region (area of the trunk between thorax and basin) should be viewed separate from adult safety considerations for two reasons. First, the form of a child's pelvic ilium bone is not yet fully developed and is still soft because pelvic ossification has not yet occurred. In adults, however, conventional passenger vehicle seat belts utilise the crest shape of the ilium, since it forms a natural guide, thus protecting the pelvic area well in the event of an accident. This missing guide and the soft bones in children's bodies often lead to severe internal abdominal injuries. Second, since the costal arch in children remains undeveloped until four years old, risk of injury to the upper abdominal area is increased by using conventional three-point seat belts. This means that, for the most part, the ribs do not protect the liver, which can be easily injured in an accident.

Along with the purely physiological characteristics of a child's body, a child's behaviour in a passenger vehicle cannot be ignored. Tests have shown that approximately 75 – 90 % of all children sleep when riding in passenger vehicles [3]. The associated muscle relaxation often leads to the torso bending sideways and at the same time either rolling out of the asymmetrical three-point seat belt or the seat belt cuts across the throat. Both shoulder belt positions should be avoided as they can cause severe injuries.

To sum up, it shall be established that typical passenger vehicle interiors as well as their occupant safety systems are only partially capable of protecting children in a crash. For this reason, in 1993, lawmakers in Germany established the "Straßenverkehrsordnung §21 Abs. 1a StVO" (Road Traffic Act, paragraph 21 section 1a) in 1993, which enforces the use of additional, officially approved equipment to protect children up to their twelfth birthday or to a height of 150 cm. These safety devices are colloquially called child seats, but should be correctly termed child safety systems (CSS) or child restraint systems (CRS).

Author

Dr.-Ing. Reiner Nett is Manager of the European Child Seat department at Takata-Petri AG in Aschaffenburg (Germany).

2 Safety

The primary role of a CRS is to protect in case of an accident. A CRS is evaluated for its performance in frontal, side, rollover and rear impact situations and offers so-

Figure 1: Auto-lock belt guidance Takata 312-neo – belt guidance, which is easy for the user to recognize, and automatic belt threading

Figure 2: Display of the baby size (maximum 82 cm) in the „Bugaboo car seat developed by Takata"

lutions such as the 5-point belt system, Isofix, seat belt clamps and pre-tension assemblies, energy-absorbing crash elements and special synthetic materials, which can also absorb higher energy impacts. The goal of these technical measures is to allow the child and CRS to share in crash deceleration, keeping a protective, rigid shell around the child and holding the child within this shell. The kinematics of a child's body and the seat are finely tuned in order to subject the child's body to as little loads as possible [4].

Due to legislation and consumer protection organizations, the passive safety in CRS is constantly improving, and is currently at an all-time high. As a result, the number of children dying while occupying passenger vehicles has been steadily decreasing since 2000. In Europe, the risk of a child being fatally injured is one-fifth that of the average risk to all passengers [5]. Further optimization is possible and desired, but when considering the following topics, it should be conducted with due caution.

3 Operability

The user has to carry out three tasks correctly in order to utilize the passive safety performance of a good CRS:
- Secure the CRS in the vehicle
- Adjust the size of the CRS
- Secure the child in the CRS.

Often these tasks are difficult to accomplish, so that the rate of CRS misuse is very high. This misuse can lead to severe injuries because of a crash [6].

When securing the CRS in the vehicle, the user is confronted with CRS that are usually used with the vehicle's three-point seat belt. Good CRS are designed so that the belt-guiding elements are conspicuous, intuitive, safe and easy to use. **Figure 1** shows a new, patented by Takata belt guidance system at the Child safety system Takata 312-neo, which is easy for the user to recognize and access from all angles, and which allows for almost automatic belt threading. In addition, the mechanism closes by spring pre-tensioning so that the seat belt cannot slip out of the belt guidance under any circumstances.

All adjustment mechanisms used for adapting the size of the CRS to the child's physical dimensions should be easy to identify, accessible and intuitively usable in their implementation. Multiple separate adjustment options should be avoided. **Figure 2** shows a display centrally located on the CRS with a scale to help adjust its size correctly, and shows the corresponding child height. This gives the user one adjustment option and provides immediate help in managing it. The baby seat for infants up to about 15 months features a single operation which shows a size display for adjusting not only the correct shoulder belt height on the five-point belt but also the shape of the back rest. In another product version for children three to twelve years old, the size display helps the user adapt the correct position of the shoulder belt guide, the height of the head support, and the width of the backrest in just one operation, Figure 4.

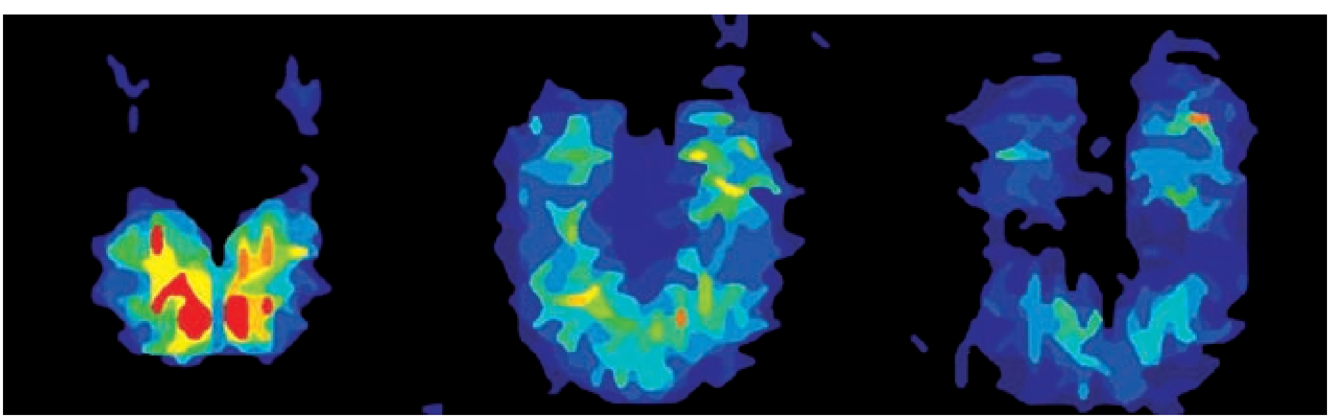

Figure 3: Seat pressure distribution of a six-year-old child (from left: in a car seat, in a CRS with padded cover, in a Takata CRS with comfort foam cover)

4 Comfort

CRS are often mistakenly considered as purely passive safety equipment for passenger vehicles. These generally established evaluations often neglect daily seat comfort, which is a prerequisite for the child to always and consistently be transported in a CRS, and for him to remain seated in the CRS even on longer journeys.

Figure 3 shows test results using pressure sensitive measuring film to determine localized pressure distribution from a child's bottom. The sequence of images (from left to right) shows the pressure distribution of a six-year-old's bottom on a passenger vehicle seat, on a CRS with simple, thin padding (t = 5 – 10 mm), and on a CRS with comfort foam (t = 20 – 25 mm). The passenger vehicle seat is too deep, does not allow the child's thigh to rest on it, so that pressure is concentrated in the area of the buttocks and is therefore excessive. Simply adapting a shortened CRS geometry with padded covering provides noticeably more uniform distribution at a low level. Optimised cushioning by the Takata comfort foam (foam thickness and rigidity) distributes and reduces the pressure level even further and provides a significant increase in comfort.

The seating environment of a CRS can be designed using universal structures. The covering materials should be open-pored, so that heat and body moisture from the child's body can be wicked away. The selected lining material for the cover should ensure sufficient air volume behind the body. Thin padding, which can be completely compressed by the seated child, does not have the ability to wick away body moisture. In the ideal scenario, open-pored covering materials in sufficient thickness and stiffness should be used throughout, as well as an open shell design, which allows the saturated air to dissipate.

5 Style and Additional Uses

The child's altered position in society is leading to an increasing number of products that are lifestyle oriented. Today's CRSs should not be regarded as merely functional, but also designed customer-

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Vieweg Verlag | GWV Fachverlage GmbH
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Managing Directors Dr. Ralf Birkelbach, Albrecht Schirmacher
Senior Advertising Thomas Werner
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Senior Sales Gabriel Göttlinger

EDITORS-IN-CHARGE

Dr.-Ing. E. h. Richard van Basshuysen
Wolfgang Siebenpfeiffer

EDITORIAL STAFF

Editor-in-Chief
Johannes Winterhagen (win)
Phone +49 611 7878-342 · Fax +49 611 7878-462
E-Mail: johannes.winterhagen@vieweg.de

Vice-Editor-in-Chief
Dipl.-Ing. Michael Reichenbach (rei)
Phone +49 611 7878-341 · Fax +49 611 7878-462
E-Mail: michael.reichenbach@vieweg.de

Chief-on-Duty
Kirsten Beckmann M. A. (kb)
Phone +49 611 7878-343 · Fax +49 611 7878-462
E-Mail: kirsten.beckmann@vieweg.de

Sections

Body, Safety
Dipl.-Ing. Ulrich Knorra (kno)
Phone +49 611 7878-314 · Fax +49 611 7878-462
E-Mail: ulrich.knorra@vieweg.de

Chassis
Roland Schedel (rs)
Phone +49 6128 85 37 58 · Fax +49 6128 85 37 59
E-Mail: r.schedel@text-com.de

Electrics, Electronics
Markus Schöttle (schoe)
Tel. +49 611 7878-257 · Fax +49 611 7878-462
E-Mail: markus.schoettle@vieweg.de

Engine
Dipl.-Ing. (FH) Moritz-York von Hohenthal (mvh)
Phone +49 611 7878-278 · Fax +49 611 7878-462
E-Mail: moritz.von.hohenthal@vieweg.de

Heavy Duty Techniques
Ruben Danisch (rd)
Phone +49 611 7878-393 · Fax +49 611 7878-462
E-Mail: ruben.danisch@vieweg.de

Online
Caterina Schröder (cs)
Phone +49 611 7878-190 · Fax +49 611 7878-462
E-Mail: caterina.schroeder@vieweg.de

Service, Event Calendar
Martina Schraad
Phone +49 212 64 232 64
E-Mail: martina.schraad@vieweg.de

Transmission, Research
Dipl.-Ing. Michael Reichenbach (rei)
Phone +49 611 7878-341 · Fax +49 611 7878-462
E-Mail: michael.reichenbach@vieweg.de

English Language Consultant
Paul Willin (pw)

Permanent Contributors
Christian Bartsch (cb), Prof. Dr.-Ing. Peter Boy (bo), Prof. Dr.-Ing. Stefan Breuer (sb), Jens Büchling (jb), Jörg Christoffel (jc), Prof. Dr.-Ing. Manfred Feiler (fe), Jürgen Grandel (gl), Erich Hoepke (ho), Prof. Dr.-Ing. Fred Schäfer (fs), Bettina Seehawer (bs)

Address
Postfach 15 46, 65173 Wiesbaden, Germany
E-Mail: redaktion@atzonline.de

MARKETING | OFFPRINTS

Product Management Automedia
Sabrina Brokopp
Phone +49 611 7878-192 · Fax +49 611 7878-407
E-Mail: sabrina.brokopp@vieweg.de

Offprints
Martin Leopold
Phone +49 228 6907-87 · Fax +49 228-6907-88
E-Mail: leopold@medien-kontor.de

ADVERTISING | GWV MEDIA

Ad Manager
Nicole Kraus
Phone +49 611 7878-323 · Fax +49 611 7878-140
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E-Mail: heinrich.reuss@gwv-media.de

Display Ad Manager
Susanne Bretschneider
Phone +49 611 7878-153 · Fax +49 611 7878-443
E-Mail: susanne.bretschneider@gwv-media.de

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SUBSCRIPTIONS

VVA-Zeitschriftenservice, Abt. D6 F6, ATZ
P. O. Box 77 77, 33310 Gütersloh, Germany
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PRODUCTION | LAYOUT

Kerstin Gollarz
Phone +49 611 7878-173 · Fax +49 611 7878-464
E-Mail: kerstin.gollarz@gwv-fachverlage.de

Figure 4: Takata 312-neo – life-style oriented, but also safe

Figure 5: Multifunctional stroller frame with baby seat resting on to top, „Bugaboo car seat developed by Takata"

friendly as an aesthetic object in shape, colour, texture and feel. The goal is to make the CRS seem child-friendly, modern, fashionable and match the vehicle interior. Rounded outer edges, uniform surfaces and smooth covers are fundamental design elements, **Figure 4**.

As a part of a society that is becoming increasingly mobile, the mobility of children in relation to CRS needs to be addressed. New types of baby seats are compatible with strollers and together form what is called a Traveller System, **Figure 5**. A CRS product for children three to twelve years old is made in the appropriate size and is foldable, so that it can be tucked into a backpack and carried neatly and securely outside of the vehicle, **Figure 6**.

6 Conclusion

Single, predominant observations about CRS passive safety according to standardised crash tests often lead to products on the market that only meet limited everyday demands. The consequence is that because CRSs often lack comfort and user-friendliness, they are used improperly or not at all. Both factors increase the risk child encounters in a passenger vehicle.

All aspects regarding passive safety, user and seating comfort therefore have to be considered in terms of a complete, balanced package, and be designed with style, quality and cost in mind to be marketable. The innovative CRS product solutions shown here as examples point up the feasibility of this claim and show that there is considerable room for improvement in the details when addressing the subject of child safety in the passenger vehicle.

Figure 6: Foldable Takata 312-neo for neat and secure carriage

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