INTERACTION OF CHILD RESTRAINT SYSTEMS AND SIDE AIRBAGS

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INTRODUCTION

ABOUT 80% of all newly-registered passenger cars in Germany are equipped with side airbag systems. But the interaction of child restraint systems (CRS) and those airbags is still widely unknown, as most studies on side airbags focused mainly on out-of-position situations of unrestrained children [1, 2]. In this research project the interaction of child restraint systems and side airbags was investigated to find out whether there is an injury risk for properly restrained children due to the inflating side airbag. The project was a co-operation of BASt, TUB, ADAC and GDV.

METHOD

First of all type, design and mounting position of side airbag systems in current passenger cars, available in Germany, were analysed. This information was combined with several seating positions of child dummies in the most common child restraint systems. Based on this analysis the five obviously most critical geometrical configurations of side airbags, child restraints and child dummies were chosen for static deployment tests (Table 1). In all configurations the dummy was placed on the front passenger seat, which was in the rearmost position, and the thorax was slightly leaning towards the door. But it was not an out-of-position seating position. The combination of a group II booster without backrest and a three year old child dummy with a weight of 15 kg is a worst case scenario. It can often be found in cabs.

The load limits for child dummies, proposed by "The Airbag Out-of-Position Injury Technical Working Group" [2] were used to evaluate the measured dummy loads. This working group used the Hybrid III child dummies for their test procedures. So these dummies were also used in this study.

Table 1 Test matrix for the static deployment tests

Vehicle	Type of Side Airbag	Child Restraint System	Child Dummy
A	seat-mounted side airbag	booster seat without backrest	Hybrid III, three year old (3YO)
B	seat-mounted head-thorax-bag	booster seat without backrest	Hybrid III, six year old (6YO)
C	door-mounted side airbag	booster seat without backrest	Hybrid III, 6YO
D	seat-mounted head-thorax-bag	booster seat with backrest	Hybrid III, 3YO
E	seat-mounted head-thorax-bag	forward facing ISOFix seat shell with shield	Hybrid III, 3YO

In a first step every configuration was investigated in static deployment tests. The exact seating position of the child dummy in the vehicle can have a significant influence on the dummy loads. Therefore three tests for every configuration were carried out.

The side airbag of vehicle A induced the highest loads to the dummy and vehicle D's airbag belongs to those cars with the lowest airbag-related injury risk in the tested sample. Therefore both vehicles were chosen for the full-scale tests according to regulation ECE-R95 but with the barrier hitting the vehicle on the passenger side. Two pairs of these vehicles were tested with and without side airbag, respectively. The vehicles' sensors were responsible for firing the side airbags in the crash tests.

In the four tests the booster seat without backrest and the three year old child dummy were used as a worst case scenario on the front passenger seat. A static deployment test with vehicle D, the booster seat without backrest and the three year old child dummy was carried out to have comparable results.

RESULTS - STATIC DEPLOPYMENT TESTS

None of the tested side airbags caused high loads to the child dummies in the static deployment test series. All measurements were clearly below the limits. Only the side airbag of vehicle A produced higher neck loads compared to the other four vehicles.
It was detected, that the volume of the side airbag is not necessarily responsible for high loads on the dummy. All tested head-thorax-bags had a good deployment behaviour. The impulse on the dummy

was low and no relative movement between head and thorax was detected. Vehicle E was tested with an ISOFix CRS, which is fixed laterally. Nevertheless, the side airbag did not damage the CRS.
The shape of the bag and its deployment behaviour seem to have a greater influence on the kinematics of the dummy. Vehicle A's side airbag has a more cylindrical shape and it is deploying also towards the dummy. Therefore the lateral moment about the X axis ("lateral moment", [2]) and the rotational moment about the Z axis, in the following called "twist moment" [2], measured on the upper neck, are much higher than in the other vehicles. The door-mounted side airbag of vehicle C deployed also towards the dummy. But the straps in the bag limit the lateral thickness of the airbag. During the deployment of the side airbag there was no significant contact with the dummy.

RESULTS - FULL-SCALE CRASH TESTS

Vehicle A had a moderate lateral intrusion of the doors. The side airbag reduced the loads to the head and chest clearly (Table 2), but there was no clear benefit for the neck due to the airbag. The different measurements were too close together, as to prefer the vehicle with airbag or without, respectively. In both cases most tolerance limits were not exceeded. Only the twist moment of the neck was above the limit. The cylindrical shape of the airbag induced a heavy rotation of the neck.

The lateral dynamic intrusion of vehicle D was approximately 30% higher than in vehicle A. Due to the collapsing structure it was almost impossible for the side airbag to reduce the loads to the child dummy. There was only a little positive influence of the side airbag on the dummy loads on a few body regions. Whereas the load to the head and the chest were still below the tolerance limits, the limits to the neck were exceeded. But the side airbag again induced a rotation around the vertical axis of the head combined with an increased twist moment of the neck.

Table 2 Results of the full-scale crash tests

Injury Criteria	Limit (3YO)	A (with airbag)	A (without airbag)	D (with airbag)	D (without airbag)
Head					
HIC_{15ms} [-]	570	224	1,013	341	346
a_{3ms} [g]	-	52.1	90.1	63.0	69.2
Upper Neck					
N_{ij} [-]	1	0.55	0.50	1.05	1.04
Tension [N]	1,130	690	625	1,678	2,074
Compression [N]	1,380	471	547	352	301
Lateral Moment [Nm]	30	8.1	14.7	11.5	45.4
Twist Moment [Nm]	17	20.1	12.0	18.3	9.0
Thorax					
Deflection [mm]	36	12	24	13	10
Deflection rate [m/s]	8.0	2.7	5.0	2.8	2.9
a_{3ms} [g]	-	56.1	81.3	87.5	96.2

CONCLUSION

In the static deployment tests and the full-scale crash test by deployment of the side airbag, a risk for the restrained children was not found. In conclusion, the test series indicated that a side airbag can help to reduce the loads to a properly restrained child. Only in some special configurations, such as booster seat and small children, the side airbag can induce a rotation around the vertical axis of the neck connected with an increased twist moment. The higher load on a specific body part must be compared to the obvious benefit of the side airbag to the head and thorax. The negative influence of side airbags to children can be avoided by a appropriate shape and deployment behaviour of side airbags. The airbag must be more plain than cylindrical and the deployment towards the occupant must be avoided. It was also obvious, that a side airbag can not substitute a rugged passenger compartment.

REFERENCES

[1] International Organisation for Standardisation (ISO), Technical Report 14933, Draft, 1999

[2] The Side Airbag Out-of-Position Injury Technical Working Group: Recommended Procedures for Evaluating Occupant Injury Risk from Deploying Side Airbags, Insurance Institute for Highway Safety (IIHS), 2000