DRIVER AIRBAG SOLUTIONS FOR NEXT GENERATION STEERING WHEELS

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ABSTRACT

The steering wheel as the central vehicle motion control device gives today's drivers a high level of trust in the controllability of their vehicles. Changing vehicle interiors as well as new occupant positions / postures related to highly automated driving are impacting the form and function of steering devices. Three technology trends are influencing future steering wheels: growing electronic content, changing steering wheel geometries and transformation capabilities and seamless designs.
Over the last decades the appearance of the steering wheel was determined by a round 360° steering wheel shape, a visible gap between driver airbag & steering wheel, and driver safety enabled by an airbag deployment centrally from the front surface. However, future steering wheels are becoming increasingly seamless with higher integration of HMI functionalities and new surface appearances like wood optic or glass applications. Such innovative designs require new driver airbag solutions.
This paper examines an alternative concept capable of revolutionizing the front panel of a steering wheel by incorporating a driver airbag inside of the steering wheel. The airbag cushion can deploy from the top side of the wheel through the rim and covers the front panel, thus helping to protect the driver in case of a crash.

STATE OF THE ART

Today's driver airbag modules are mechanically fixed in the center of the steering wheel, the cushion volume is released by a frontal opening through an airbag cover (thermo plastic material, TPE) towards the driver. Future interior designs, in-vehicle digitalization and a higher degree of automation [1], are providing new design possibilities for future steering wheels. The frontal opening of conventional driver airbags have limitations regarding design, functional enrichment and material selection in the opening area especially when those designs become seamless with a hard surface; e.g. polycarbonate or the integration of displays, figure 1.

Additionally new steering wheel shapes like yoke designs [2, 3] are offering alternative approaches for deployment of driver airbag cushion volumes. Byton's M-Byte concept [4] presented in 2018 was a round shaped steering wheel incorporating a central 8-inch display while the airbag inflates below the display screen. Driver airbag modules with a top mounted display are in opposition to the interior trend of slim steering wheel designs and a frontal deployment might lead to incompatibility with seamless designs.

Figure 1. ZF concept (seamless design incorporating a top deployed airbag)

TECHNICAL SOLUTION AND APPROACH

ZF has begun development of an alternative driver airbag solution where the driver airbag is not located in its traditional area. The airbag cushion can deploy from the top side of the wheel through the rim and covers the front panel, thus helping to protect the driver in case of a crash. [5, 6]

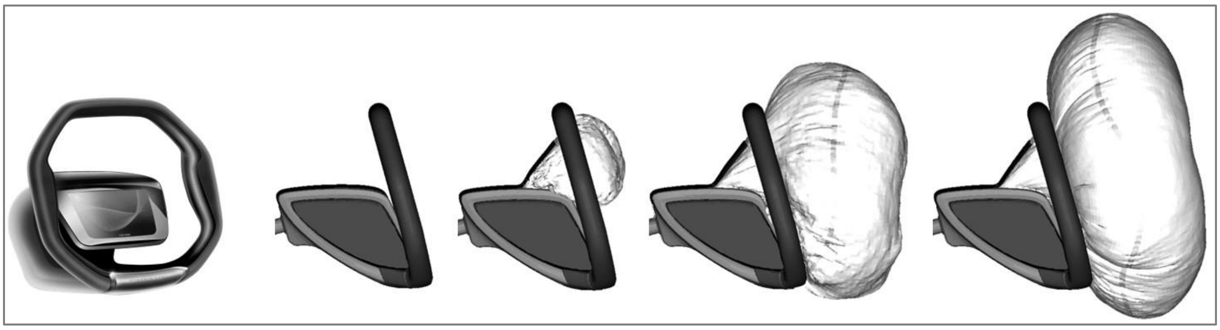
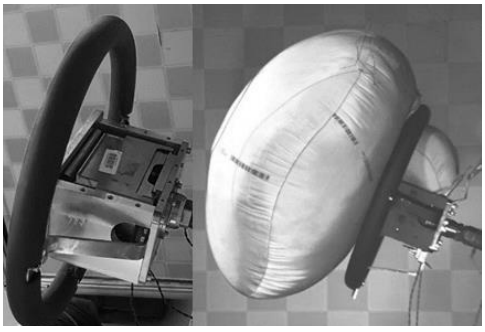


Figure 2. Safety concept for a top deployed airbag

Main challenges to deploy the airbag from the top side of such a concept are enabling stable deployment through the steering wheel rim, a rapid coverage of the rim at the 6 o´clock position and to maintain today's steering wheel and driver airbag packaging options.



The aim was to investigate and validate an adaptive test device design that represents a wide range of current known steering wheel geometries. This steering wheel device is a modular design, so different sizes / positions of the rim and the dimensions of the housing can easily be adjusted, figure 3.

Figure 3. Test device

As a sample reference a serial driver airbag was selected as a baseline for the study using a dual stage inflator with the same propellant and a bag size of 700mm diameter. For validation the following tests have been considered: Static deployment, head impact, body block, linear impactor, out of position and sled tests.

RESULTS

To evaluate robustness static deployment test were employed at full temperature ranges from -35°C to +85°C and at low temperature the main challenges are ensuring a fast deployment through the steering wheel rim, the 6 o´clock rim coverage and the bag filling times. At high temperature the focus is on integrity requirements, a slow initial unfolding that can lead to high pressure in the first chamber and leading to potential integrity issues. At all temperatures the 6 o’clock rim coverage and the filling time are in the same range as the reference module (table 1).

Table 1.
Static deployment test results

	Top deployed Driver Airbag		Conventional Driver Airbag (Reference)	
Temperature	6:00 coverage	Filling time	6:00 coverage	Filling time
-35°C	20 ms	44 ms	16 ms	34 ms
+23°C	18 ms	32 ms	14 ms	28 ms
+85°C	17 ms	29 ms	13 ms	22 ms

Conformity of head impact and body block test according to ECE R12 [7] as a legal requirement is mandatory. For head impact the criteria of head acceleration has a 3ms limit (80g) and a max limit (120g) that must be fulfilled and for body block the upper limit is 111 daN. For both test cases two impact positions were tested at the 3 and 6 o´clock positions. Both test load cases are not critical, see figure 4 and table 2.

Table 2.
Head impact and body block

Head impact		Body block	
Impact position	a_3ms_max / a_max	Impact position	Max. force
3 o´clock spoke	25.2g / 37.1g	3 o´clock spoke	6.6kN
6 o´clock spoke	16.8g / 42.1g	6 o´clock spoke	6.9kN

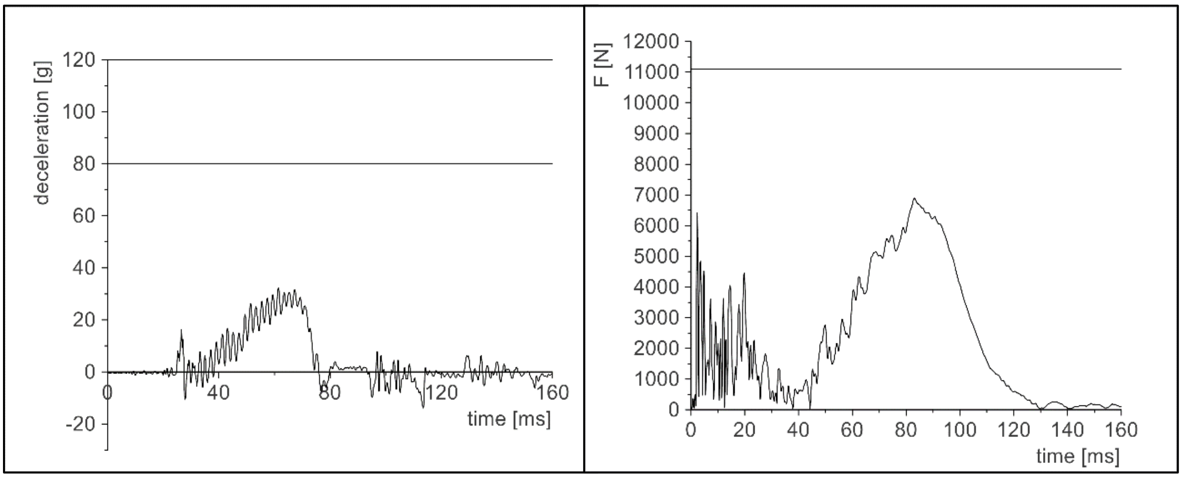


Figure 4. Head impact and body block test results

To evaluate the restraint performance of the airbag module a comparison with the reference driver airbag on a linear impactor device was used, and two setups were considered. Configuration 1 is representing a scenario of late dummy contact to the cushion with low energy and configuration 2 is representing an early contact with high energy.

Table 3.
Linear impactor configuration

	Configuration 1	Configuration 2
Mass	33 kg	37 kg
Velocity	5.3 m/s	7 m/s
Trigger distance	450 mm	400 mm
Kinetic energy	463 J	907 J

When comparing to the reference the performance is similar for both configurations, the deceleration peak for the top deployed airbag is slightly higher compared to the reference driver airbag, however by increasing the venting size the performance can be adjusted.

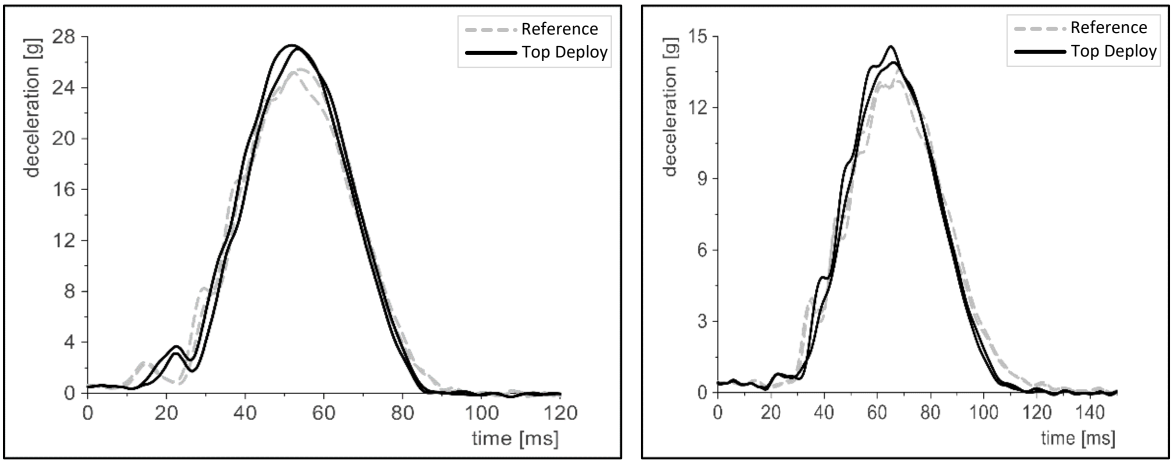


Figure 5. Linear impactor (configuration 1 and 2)

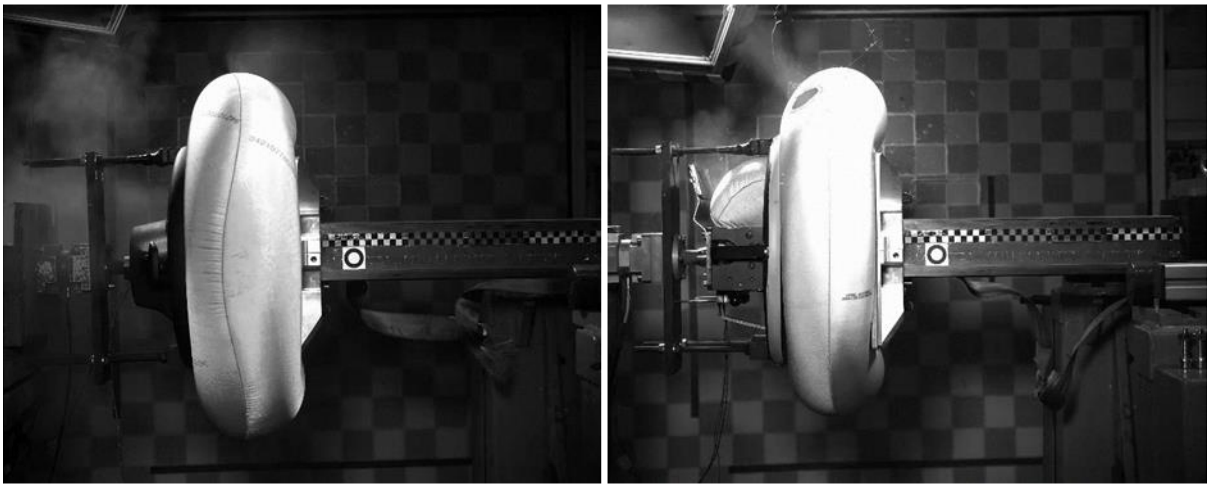


Figure 6. Linear impactor, conventional vs. top deployed airbag

The fulfillment of OoP requirements [8] are crucial for driver airbag modules. In today's standard driver airbag systems high neck forces and torsions can be reduced by guiding a bag deployment through and behind the rim. For a top deployed airbag this effect can't be used because the cushion remains under the chin and deploys between occupant and steering wheel in the 6 o´clock direction and pushes the occupant backwards, figure 7. An appropriate bag design is required to reduce the NIJ criteria (neck injury) due to its neck forces and momentum.

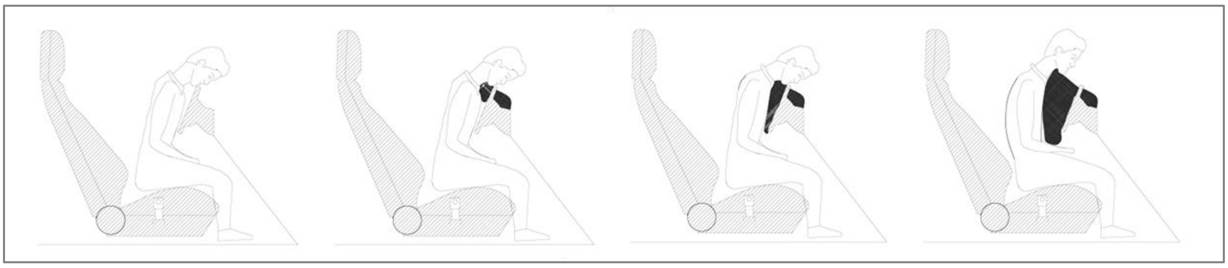


Figure 7. OoP - Chin on rim

The Out of Position results for dummy position 1 (DP1, chin on rim) and dummy position 2 (DP2, chin on module) are listed in table 4.

Table 4.
OoP Results (Alternative test device)

DP1 NIJ	DP1 FZ	DP2 NIJ	DP2 FZ
52.7%	52.8%	73.1%	35.2%
49.0%	37.6%	77.3%	32.6%

Preliminary tests to evaluate the restraint system performance were considered with a hybrid III 5% dummy and a second one with a THOR 50% dummy.
The Euro NCAP [9] full-frontal sled test with hybrid III 5% dummy showed a fast and straight bag positioning in the small area between lower rim section and chest, a de-folding towards the driver was not observed, figure 8.

Figure 8. Hybrid III 5% dummy

The sled test with a THOR 50% dummy was performed according to Euro NCAP MPDB setup [10]. Compared to a conventional driver airbag the top deployed airbag is showing an equal restraint performance, see table 5.

Table 5.
Euro NCAP MPBD

Sled Test Front Impact
Type of Test: Euro_NCAP_MPDB
Regulation: Euro NCAP 2020

Criterion			Driver SP 1 (T3)			
Head & Neck		(4P)			4.000	*
Head	Hard contact?		no			
	HIC 15		335.54			
	Acceleration a_R		62.65	g		
	3ms cumulative		57.64	g		
	Modifiers					
	BrIC (monitoring)		0.88			
	UBrIC (monitoring)		0.44			
	DAMAGE (monitoring)		0.57			
	HAIC (monitoring)		69.47	rad/s		
	CIBIC (monitoring)		0.56			
Neck	Shear Force Fx (abs)		0.67	kN	4.000	*
	Tensile Force Fz+		0.70	kN	4.000	*
	Extension My-		-16.55	Nm	4.000	*
Chest & Abdomen		(4P)			3.114	
Chest	Deflection Upper Left		31.71	mm	4.000	*
	Deflection Upper Right		40.54	mm	3.114	*
	Deflection Lower Left		19.93	mm	4.000	*
	Deflection Lower Right		24.30	mm	4.000	*
	Diagonal belt upper force[1)]		4.10	kN	-0.000	✓
	Modifiers					
Abdomen	DeflectionLeft		-39.62	mm	4.000	*
	DeflectionRight		-45.51	mm	4.000	*
Knee, Femur & Pelvis		(4P)			4.000	*
Left	Acetabulum Force		0.60	kN	4.000	*
	Femur Compression Fz-		-0.65	kN	4.000	*
	Knee Slider Displacement		-0.20	mm	4.000	*
	Knee & Femur Modifiers					
Right	Acetabulum Force		0.45	kN	4.000	*
	Femur Compression Fz-		-2.22	kN	4.000	*
	Knee Slider Displacement		-0.52	mm	4.000	*
	Knee & Femur Modifiers					
Ilium Fx-	Submarining		378.72	N/ms	-0.000	✓
	Abdomen & Pelvis Modifiers					
Lower Leg & Foot		(4P)			3.733	
Left	Compression upper Fz-		-1.33	kN	4.000	*
	Compression lower Fz-		-1.86	kN	4.000	*
	Tibia Index upper		0.32		4.000	*
	Tibia Index lower		0.24		4.000	*
Right	Compression upper Fz-		-1.49	kN	4.000	*
	Compression lower Fz-		-2.04	kN	3.973	*
	Tibia Index upper		0.46		3.733	*
	Tibia Index lower		0.19		4.000	*
	Modifiers					
Foot & Ankle						
	Brake rearward displacement		0	mm	4.000	*
	Clutch rearward displacement		0	mm	4.000	*
	Accel. rearward displacement		0	mm	4.000	*
	Modifiers					
Total Assessment[2)]		(16P)	92.8	%	14.847	

Notes:
1) based on polynomial cal.
2) listed modifiers are included only

Points
* 4.000
* 2.670 - 3.999
* 1.330 - 2.669
* 0.001 - 1.329
* 0.000

SP 1 (T3)

CONCLUSION

Deploying a cushion volume from the top side of a driver airbag module and through the steering wheel rim is an innovative approach and enables new possibilities for future steering wheel designs. Even when the applied tests have been conducted in a specific device it can be shown that upcoming customer demands can be fulfilled, specific styling investigations and near-series toolings must be considered in order to bring higher confidence to the solution. Furthermore, a top deployed airbag must be tested with new steering wheel rim geometries e.g. Yoke shapes. Instead of deploying the airbag from the top side investigations from the bottom are notable. As future interior styling aims to provide comfort seating positions, dual contour bag solutions which have not yet been considered must be investigated.

REFERENCES

[1] SAE, J3016, "Levels of Driving Automation," https://www.sae.org/binaries/content/assets/cm/content/blog/sae-j3016-visual-chart_5.3.21.pdf, accessed Dec. 2022.

[2] Tesla, "Model S - Interior of the Future – Yoke Steering," https://www.tesla.com/models, accessed Dec. 2022.

[3] CNET, "Lexus' New Steering Yoke Is Weird but Kinda Wonderful," https://www.cnet.com/roadshow/news/lexus-rz-steering-yoke, accessed Dec. 2022.

[4] CNET, "Byton electric concept car: All the details you need to know," https://www.cnet.com/roadshow/news/byton-electric-concept-car-all-the-details, accessed Dec. 2022.

[5] Safetywissen, "Bereit für autonomes Fahren: ZF entwickelt neues Lenkrad-Konzept mit fortschrittlichen HMI-Lösungen," https://www.safetywissen.com/object/A11/N01.p377367168uptx3ve3u35614jlrd5s63652211614/safetywissen, accessed Dec. 2022.

[6] Schledorn M., Balbas A., "Alternative approaches to steering devices of the future", Airbag Conference Mannheim, 2018

[7] ECE R12 / Regulation No. 12 Regelung Nr. 12 der Wirtschaftskommission der Vereinten Nationen für Europa (UN/ECE), "Einheitliche Bedingungen für die Genehmigung der Kraftfahrzeuge hinsichtlich des Schutzes des Fahrzeugführers vor der Lenkanlage bei einem Aufprall"

[8] 49 CFR Part 571.208 (FMVSS 208), 49 CFR 571.208 - Standard No. 208, Occupant crash protection

[9] European New Car Assessment Programme, (Euro NCAP), Full Width Frontal Impact Testing Protocol, 2019

[10] European New Car Assessment Programme, (Euro NCAP), MPDB Frontal Impact Testing Protocol, 2019