WorldSID Evaluation

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Introduction

WorldSID Evaluation

- Part of a wider programme on side impact safety
  - Benefits and costs of potential updates to UNECE Regulation 95
  - Assessment of AE-MDB test at a higher speed (60 km.hr^{-1} for barrier tests; 65 km.hr^{-1} for car-to-car tests)
  - Effect of development of vehicle structures for frontal impacts

- Two-part assessment of WorldSID
  1. Pendulum impactor tests to evaluate the RibEye implementation in the WorldSID 50M and compare with 1D/2D IR-Tracc measurements
  2. 60 km.hr^{-1} full-scale AE-MDB crash test to
     - Compare with WorldSID ES-2
     - Evaluate WorldSID in a full-scale crash test

- WorldSID 50M RibEye loaned by Transport Canada
  - Assistance from PMG Test, Boxboro Systems and Denton
- WorldSID 5F loaned by FTSS
- Sponsored by UK Department for Transport!

Thank you!

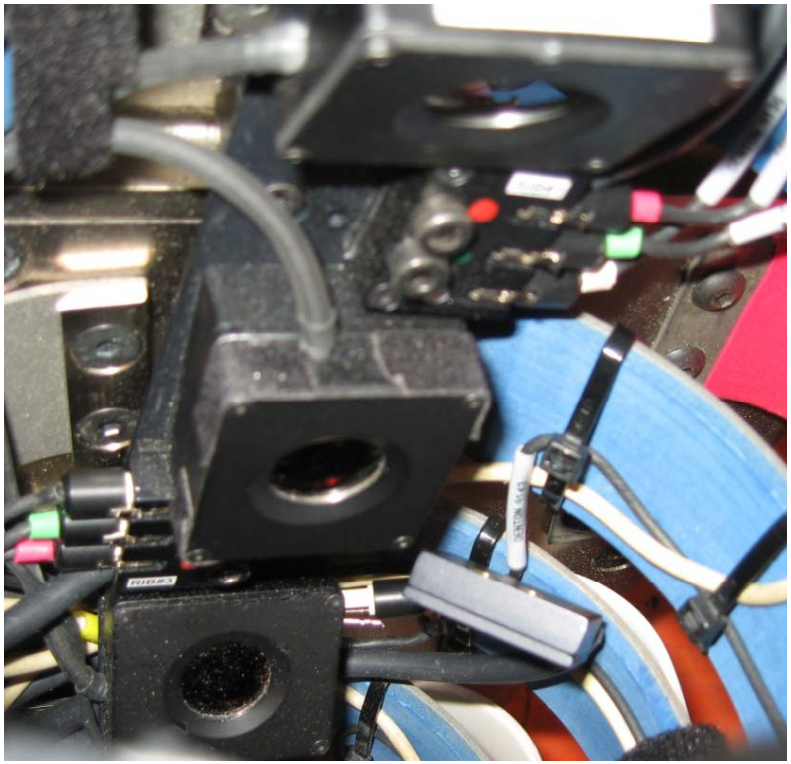
Background

Rib defection measurement options

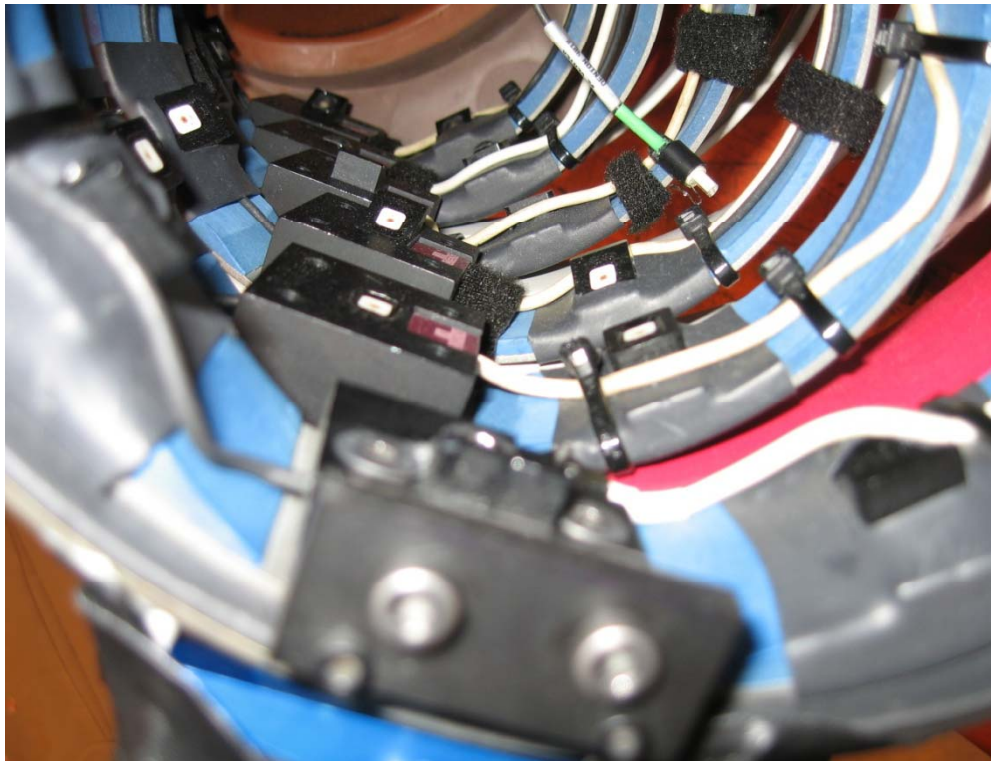
- 1D IR-Tracc
  - The original WorldSID 50M instrumentation
- 2D IR-Tracc
  - Developed for the WorldSID 5F in APROSYS EC project
- RibEye
  - Developed by Boxboro Systems
  - Integrated in WorldSID 50M by Boxboro, Denton and Transport Canada

Background

RibEye in WorldSID 50M



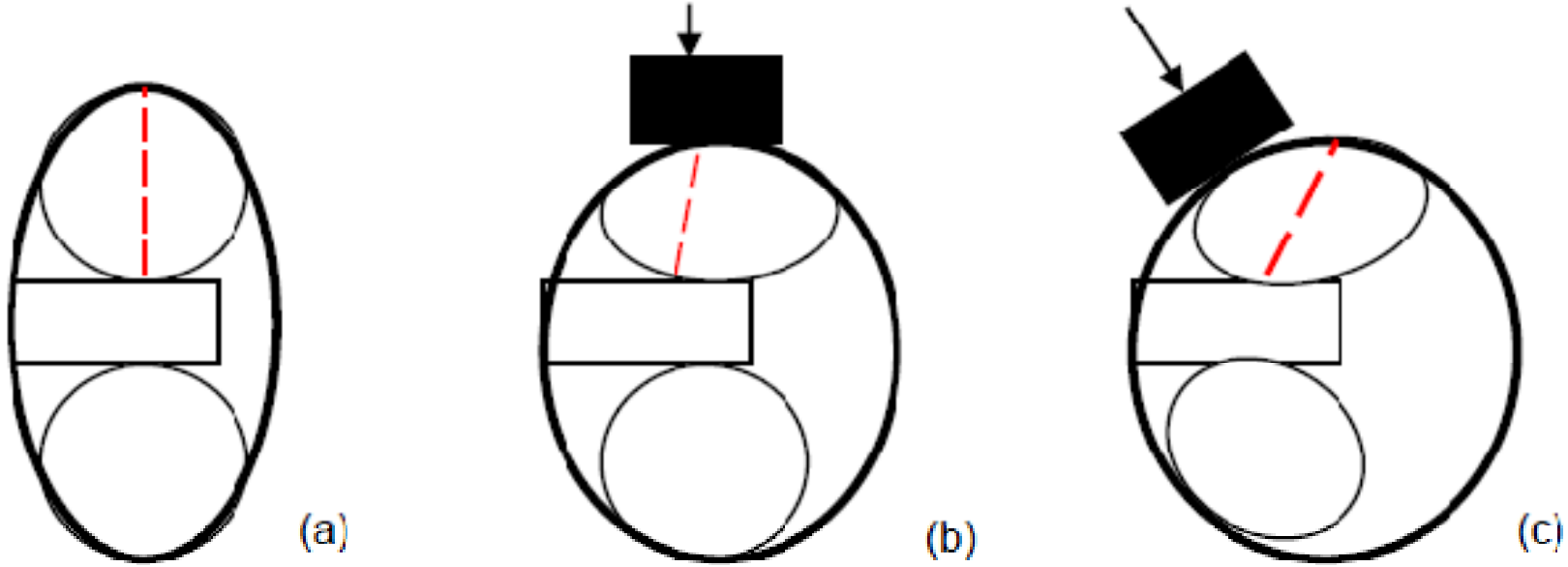
- RibEye sensor array attached to spine box



- RibEye LEDs attached to inner rib

Rib deflection measurement: 1D IR-Tracc

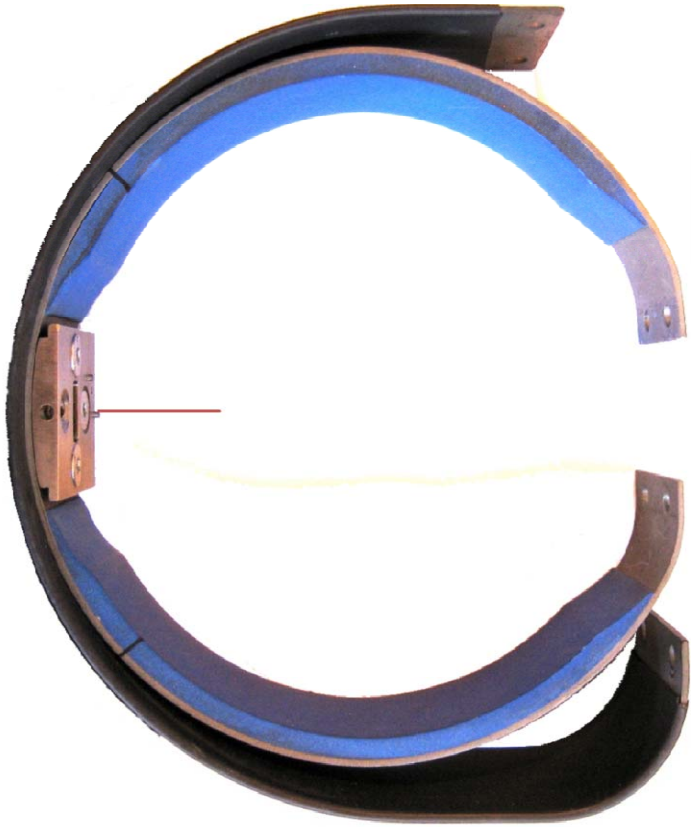
Change of length of IR-Tracc

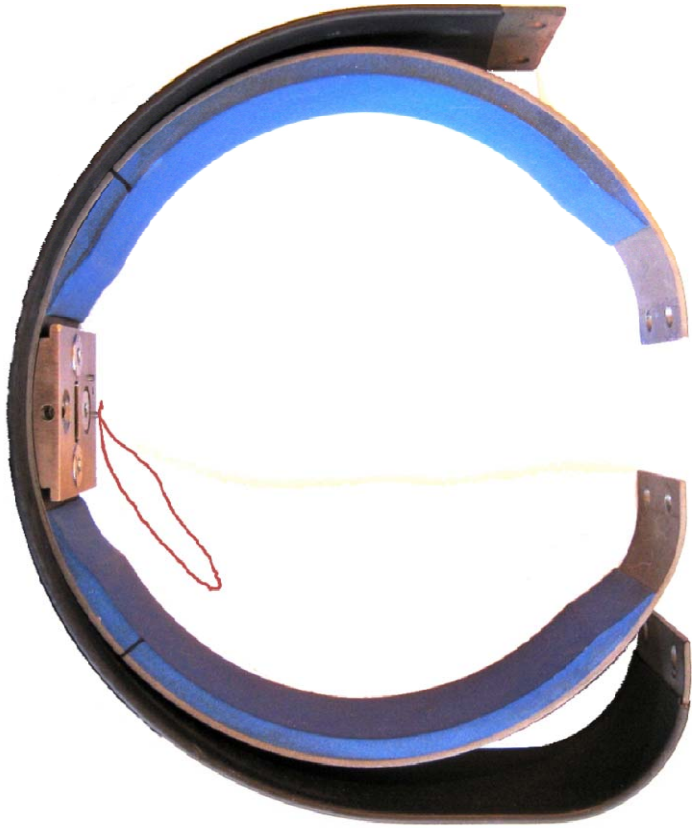


Hynd *et al.*, 2004 - IMechE Vehicle Safety

Rib deflection measurement: 2D IR-Tracc

1D IR-Tracc + lateral and resultant compression at one location

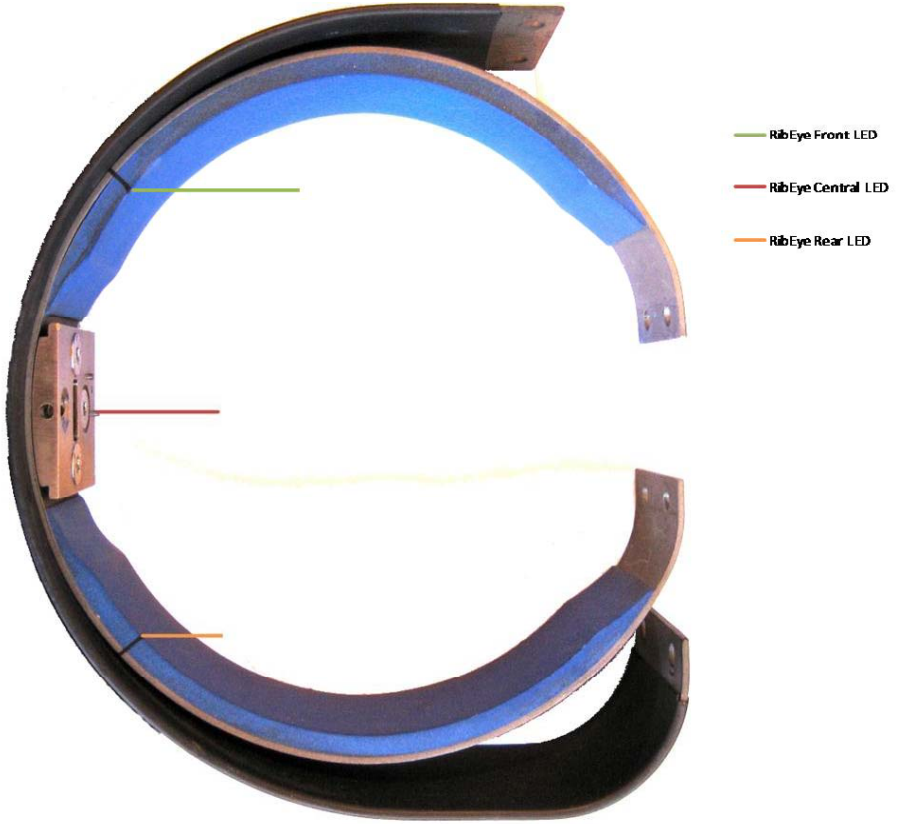


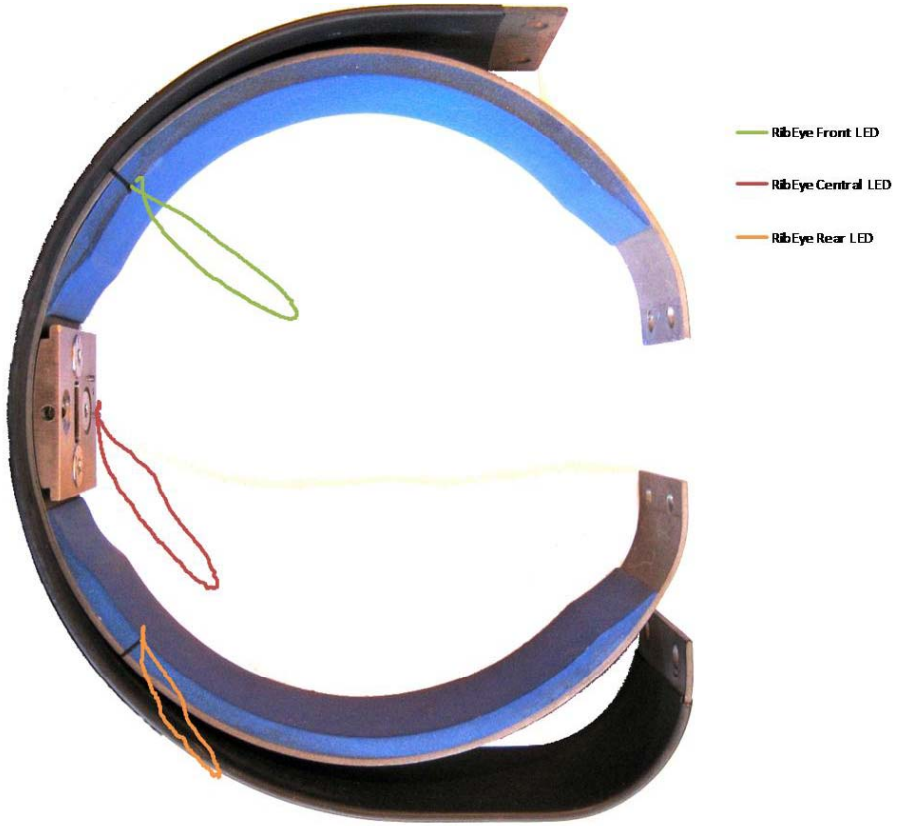


Rib deflection measurement: RibEye

X, Y and Z axis displacement of three LEDs

↳ 2D IR-Tracc + Z-axis displacement + 3 locations per rib

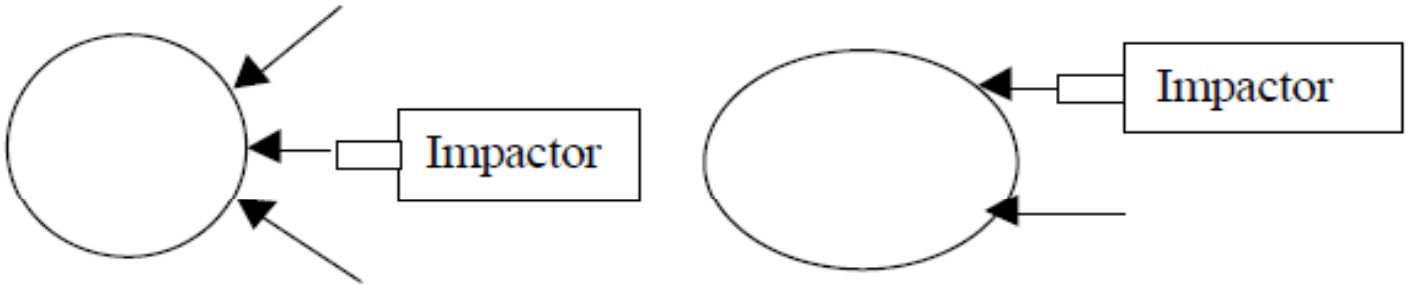




Pendulum Impactor Tests

Pendulum Impactor Testing

- Objectives
  - Assess the new RibEye Multi-Point Deflection Measurement System ('RibEye')
  - Compare the output from the RibEye with equivalent measurements from a 1D or 2D IR-Tracc sensor
- Methodology
- Testing had two regimes
  - Oblique
  - Offset
- In two different postures
  - Suspended upright
  - Reclined on the dummy's certification bench



Results

Offset tests – suspended (multiple ribs contacted)

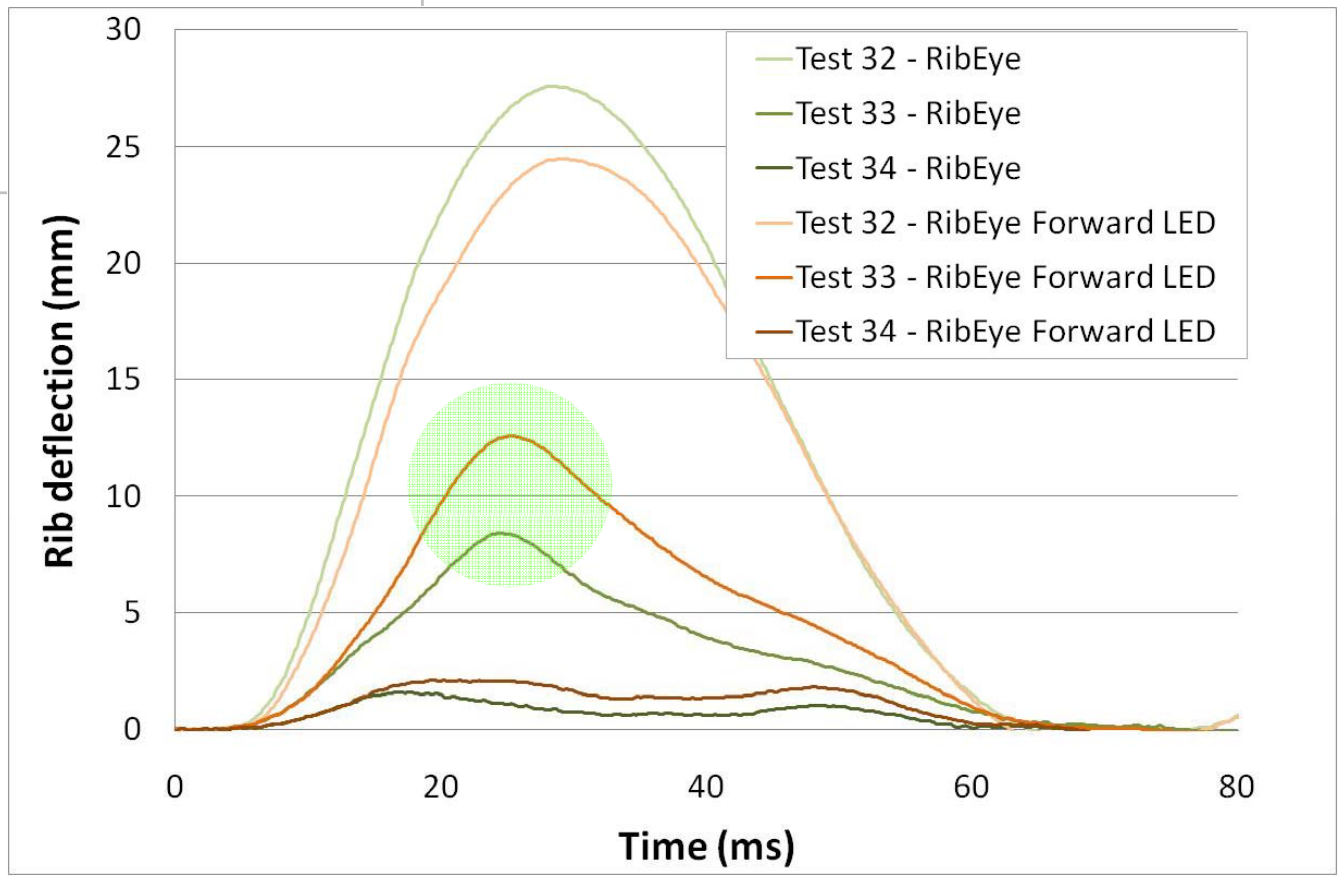
Impact offset	1D IR-Tracc	2D IR-Tracc lateral displacement	2D IR-Tracc resultant displacement	RibEye middle LED resultant	RibEye front LED resultant
-75	23.0	26.7	37.5	37.5	36.1
-50†	27.8	30.4	39.4	39.5	34.1
-25	28.4	29.2	31.8	31.8	27.8
0	24.3	24.4	24.8	24.8	25.2
25	22.3	22.4	23.0	23.1	23.0
50†	18.3	18.7	20.7	21.0	23.9

All measurements in mm
† Mean of two tests

Results

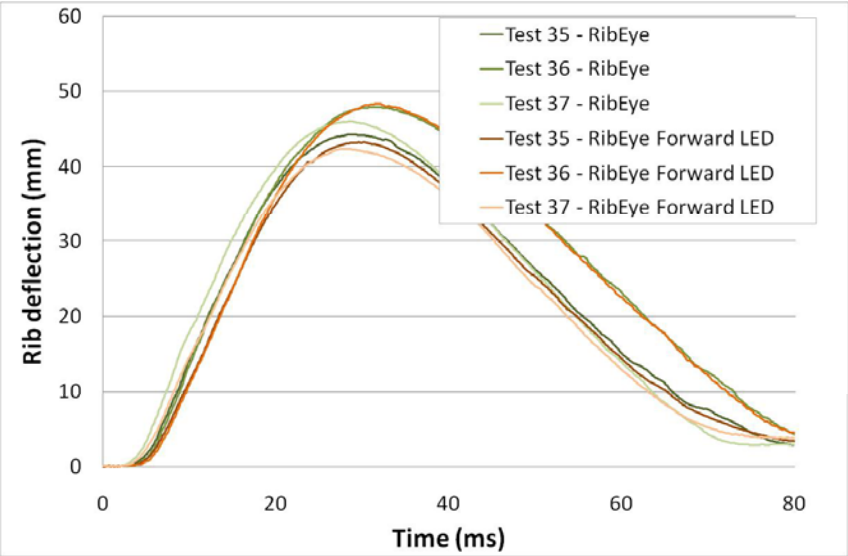
Offset tests on certification bench

- In the forward of lateral tests, the peak lateral displacement measurement from the forward LED position was greater than from the middle LED position
- Test 32 = lateral
- Test 33 = + 50 mm
- Test 34 = +75 mm

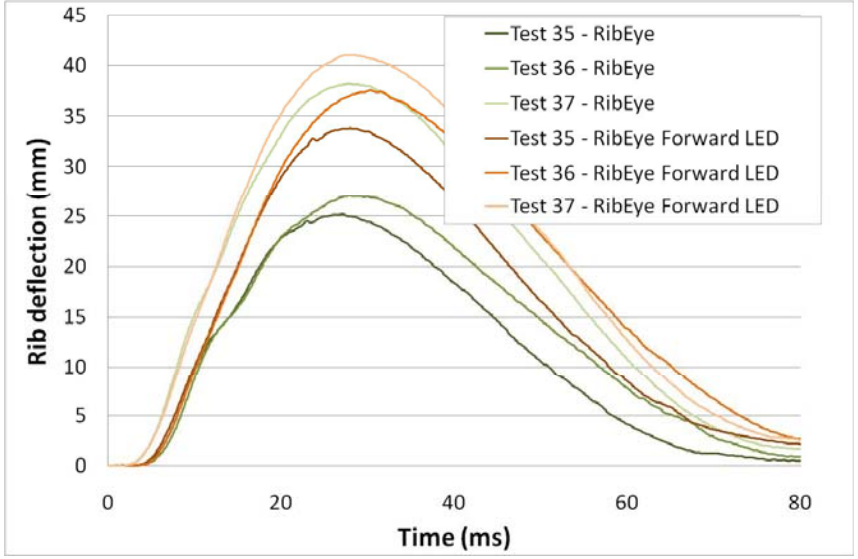


Results

Oblique tests on certification bench



- In the +30 and +20 degree conditions, with the dummy on the certification bench, the middle LED position gave approximately equal or greater resultant deflection measurements than the forward of lateral LED



- The lateral displacement measured at the forward of lateral position was greater than that measured at the middle position in each of these tests

Conclusions

Evaluation of RibEye implementation in WorldSID-50M

- Implementation
  - RibEye system was well integrated into the WorldSID and, in general, worked well
- 1D IR-Tracc underestimates rib deflection cf. 2D IR-Tracc or RibEye
  - Slight underestimate in purely lateral impacts
  - Up to 75% underestimate of the resultant (30 degree rearward of lateral test)
- RibEye
  - Lateral LED measurements same as 2D IR-Tracc in these tests (small Z-axis motion)
  - Forward LED position often provided a larger lateral (y-axis) displacement measurement than the middle LED position
  - Forward LED position provided a larger resultant displacement measurement than the middle LED position in large offset and very oblique impacts
  - Rearward LED position rarely gave maximum displacement value in these tests
    - But may do so with more severe, concentrated loading

Conclusions

Evaluation of RibEye implementation in WorldSID-50M

- The benefit of the RibEye three-point measurement will depend on the injury criteria that is used (lateral displacement, resultant displacement, …)
  - THIS HAS NOT BEEN DECIDED
- Robustness
  - Some dummy-to-laptop communication problems during testing
  - In-dummy connector to distribution box may need to be improved
  - And/or may be a software issue

Full-scale Car Crash Test

Full-scale 60 km/h AE-MDB test

Background

- In AE-MDB test at increased test speed of 60km/h, ES-2 dummies did not register particularly high injury risks
  - High T12 load and moment indicated possible unloading of thorax

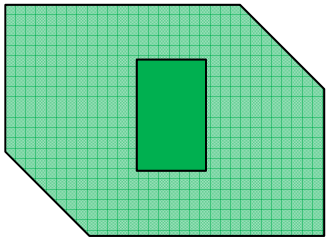
Objectives

- Compare assessment of VW Golf in AE-MDB side impact test at 60 km/h using ES-2 and WorldSID dummies
  - WorldSID 50M driver and 5F rear seat passenger cf. ES-2 in both positions
- Compare outputs of different rib deflection measurement systems in WorldSID dummies
  - 1D IR-TRACC
  - 2D IR-TRACC
  - RibEye

Driver dummy seating positions

	ES-2	WorldSID 50M
H-point manikin	X: 201* Z: 240*	X: 186* Z: 227*
H-point	X: 205* Z: 221*	X: 206–20=186* Z: 226*
Head to roof	74	119
Nose to windscreen	375	407
Nose to steering wheel	420	448
Thorax to steering wheel	322	355
Head to door	224	265
Shoulder to door	179	115
Elbow to door	94	115
Pelvis to door	168	143
Ribs to door	Top: 185 Middle: 188 Lower: 195	Top: 185 Middle: 165 Lower: n/a

*Relative to LH front door striker upper bolt



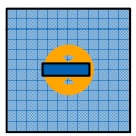
= Allowable shoulder positions (based on H-point tolerance and torso angle tolerance of ±5°

= Difference between ES-2 and WorldSID shoulder positions estimated from head measurements)

= R-point

= Allowable H-points (R-point ± 25 mm)

= Difference between ES-2 and WorldSID H-points



Dummy kinematics comparison

Driver

- ES-2 dummy shoulder moves forward and rotates away from the door in the early stages of the impact
- WorldSID 50M shoulder does not rotate as ES-2 and is directly loaded by door at waist rail level
- WorldSID pelvis movement indicates heavy pelvic loading, however pubic symphysis force of 1.6kN significantly lower than ES-2 (4.2kN)

Dummy kinematics comparison

Rear passenger

- WorldSID 5F rear passenger - head curtain airbag did not protect head; head hit door after it slid off airbag

Comparison of ES-2 and WorldSID outputs

	Parameter	ES-2 driver	ES-2 passenger	WorldSID 50M driver	WorldSID 5F passenger
Head	HIC_{36}	163.47	188.22	137.7	201.3
	Peak resultant accel (g)	42.38	48.00	42.14	49.55
	3ms exceedence (g)	40.12	45.92	40.67	46.79
Shoulder	Force Y (kN)	0.65	1.87	3.21	
	Deflection (mm)	-	-	> 50***	
Thorax	Top rib deflection (mm)	29.36	28.07	18.39*	25
	Middle rib deflection (mm)	21.01	23.11	22.31*	13.20**
	Bottom rib deflection (mm)	25.06	26.12	27.64*	18.85**
	Top rib V*C (m/s)	0.45	0.22	0.22*	0.40**
	Middle rib V*C (m/s)	0.22	0.20	0.27*	0.14**
	Bottom rib V*C (m/s)	0.25	0.29	0.27*	0.31**
Abdomen	Abdomen Force summation (kN)	1.26	1.91	-	-
	Abdomen Rib 1 deflection (mm)	-	-	32.01*	23.93**
	Abdomen Rib 2 deflection (mm)	-	-	35.44*	35.59**
	Abdomen Rib 1 V*C (m/s)	-	-	0.47*	0.49**
	Abdomen Rib 2 V*C (m/s)	-	-	0.51*	1.00**
	T12 acceleration Y (g)	63.75	64.50	54.41	101.32
Pelvis	Pubic symphysis force (kN)	4.28	3.41	0.99	1.07
	Pelvis accel Y (g)	74.32	64.28	80.22	74.35

+25 mm vertical motion

*Based on equivalent 1D IR-TRACC measurement
**Based on calculated lateral component from 2D IR-TRACC
***Value taken prior to channel failures.

Injury risk comparison

Injury risk comparison		ES-2 driver	ES-2 passenger	WS50M driver	WS5F passenger
Shoulder	Deflection	-	-	>2% AIS2+	-
	Force	-	-	92% AIS2+	-
Thorax	Top Rib deflection	12% AIS3+	10% AIS3+	<1% AIS3+*	21% AIS3+**
	Top Rib V*C	26% AIS3+	10% AIS3+	[4% AIS3+*]	-
	Mid Rib deflection	4% AIS3+	5% AIS3+	<1% AIS3+*	7% AIS3+**
	Mid Rib V*C	10% AIS3+	9% AIS3+	[6% AIS3+*]	-
	Bot Rib deflection	6% AIS3+	7% AIS3+	<1% AIS3+*	13% AIS3+**
	Bot Rib V*C	11% AIS3+	13% AIS3+	[6% AIS3+*]	-
Abdomen	Force	15% AIS3+	16% AIS3+	-	-
	Abdomen Rib 1 deflection	-	-	<1% AIS3+*	7% AIS3+**
	Abdomen Rib 1 V*C	-	-	[<2% AIS3+*]	-
	Abdomen Rib 2 deflection	-	-	<1% AIS3+*	14% AIS3+**
	Abdomen Rib 2 V*C	-	-	[<2% AIS3+*]	-
	T12 Acceleration	46% AIS3+	47% AIS3+	<2% AIS3+	-
Pelvis	Force	20% AIS2+	13% AIS2+	<1% AIS2+	<2% AIS2+
	Acceleration	24% AIS2+	21% AIS2+	19% AIS2+	[~35% AIS2+]

*Based on equivalent 1D IR-TRACC measurement
**Based on calculated lateral component from 2D IR-TRACC

Conclusions

AE-MDB Test

Dummy kinematics

- WorldSID 50M and ES-2 driver exhibited different behaviour, in particular for the shoulder interaction
- WorldSID 5F head not protected by head curtain airbag due to low head position, head contacted door at base of window

Injury criteria and risks (50M driver)

- Significantly higher shoulder load for WorldSID-50M
  - Different alignment with car and design of shoulder
  - Probably reduced loading to thorax ribs
- Significantly lower pubic symphysis loading for WorldSID-50M
  - Similar accelerations so may have been loaded via rear of pelvis
- Calculated injury risk for WorldSID-50M generally lower than for ES-2 but high risk of AIS2+ shoulder injury for WorldSID
  - Notes: WorldSID 50M injury risk curves only available for 1D IR-Tracc measurements; Shoulder injury risk function not available for ES-2

Other

- Potential issue identified with shoulder and 'RibEye' system
  - Shoulder rib deflected out of range of 'RibEye'

Overview

Overview of Findings

WorldSID RibEye and full-scale tests

- RibEye well integrated and easy to use
- RibEye gives more complete picture of rib displacement than 1D or 2D IR-Traccs
  - Middle and front LED positions most useful in these tests
  - 1D IR-Tracc underestimated rib displacement by up to 75%
- WorldSID 50M injury risk functions only available for 1D IR-Tracc
  - New injury risk functions required for 50M 2D IR-Tracc / RibEye rib compression measurements
- Shoulder interaction with car very different for ES-2 and WorldSID
  - Different alignment with door waist rail due to different geometries and seating procedures – but within Regulation 95 tolerances
  - WorldSID shoulder seemed to off-load the thorax ribs
    - This interaction should be investigated further
- RibEye shoulder LEDs moved out of range in the full-scale test