FlexPLI as Sensing Impactor for UN-R 127: Contact Biofidelity

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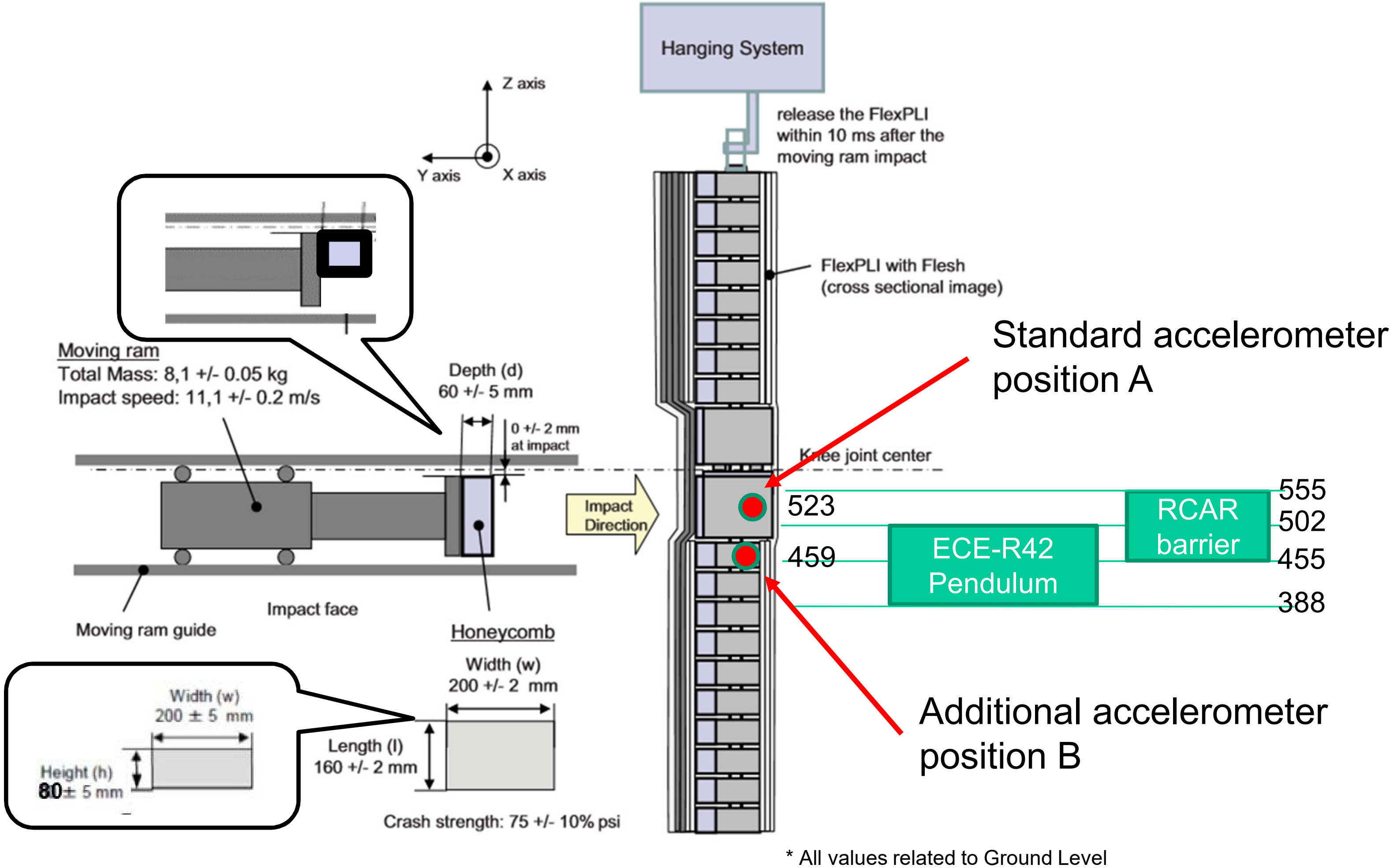
Proof of ‚contact biofidelity‘ of FlexPLI as a verification impactor for DPPS sensor systems

- Biofidelity of injury measures and kinematics was intensively considered during development of FlexPLI and is sufficiently proven.
- Regarding ‚contact biofidelity‘ the following physical properties of FlexPLI are relevant for signal in use with contact sensors. They should be within relatively narrow tolerances:

Signal relevant property of Flex-PLI	Proof of stability
Total mass	Very stable due to design & concept; see tolerance specification of impactor manufacturer
Mass distribution/inertia moments/center of gravity	
Impactor width in y direction for all load paths	
Bending stiffness around y axis	
Local stiffness / compression behavior in x direction (especially in middle load path/cross beam height)	**Double integral** of **filtered** (CFC-180) impactor acceleration signal during **inverse test** are inside of a narrow range of intrusion

Inverse test setup for proof of contact biofidelity



Justification (1)

Why inverse test?
This official dynamic inverse impactor calibration test is commonly accepted as part of GTR9/UN-R127and NCAP test protocols and directly addressing the impactor stiffness in the corresponding height.

Why double integral/intrusion?
A direct analysis of the acceleration during inverse test would mainly reflect the folding behavior of the aluminum honeycomb (above all in the high frequencies), which may scatter a lot. This distorting effect is strongly damped by using the double integral.
Besides, modern algorithms based on acceleration use robust criteria like intrusion velocity (simple integral) and/or the intrusion itself (double integral) to generate a fire decision. For pressure sensor systems (like pressure tube), the intrusion is even directly measured.

Why filtering the signals?
This filter class is defined in the official inverse test specification. For the analysis of the vehicle‘s sensor data current crash algorithms also work with filtered signals (corresponding at least CFC 180) due to robustness reasons.

Why measuring at impactor side (not at honeycomb side)?
The acceleration measurement has to take place at the impactor side in order to directly get the full path of travel of the impactor and to damp the effect of the scattering of the folding honeycomb (10% tolerance in crash strength!). It should be a validation test for the impactor, not for the aluminum honeycomb.

Why not replacing the scattering honeycomb by a rigid plate?

Typical vehicle frontends have a stiffness which is well comparable to the aluminum honeycomb. So both constellations show a very similar acceleration progress and impact duration. A rigid plate would deliver an unrealistic fast signal with too high acceleration peaks. The inelastic folding of the honeycomb compared to the almost total elastic intrusion of the vehicles frontend at the lower threshold speed does not matter: the different behavior has an effect on the rebound phase only which is much later than typical firing times.

Why measuring at two positions in the middle load path?

The middle load path of all vehicles that are affected by RCAR test procedure is located around **z = 505mm** above ground level in order to offer a sufficient robust support structure (cross beam) for RCAR test. Common pedestrian sensor systems on the market are typically located in the middle load path (bumper fascia or radiator grill for accelerometers) or even at the cross beam itself (pressure tube sensors)

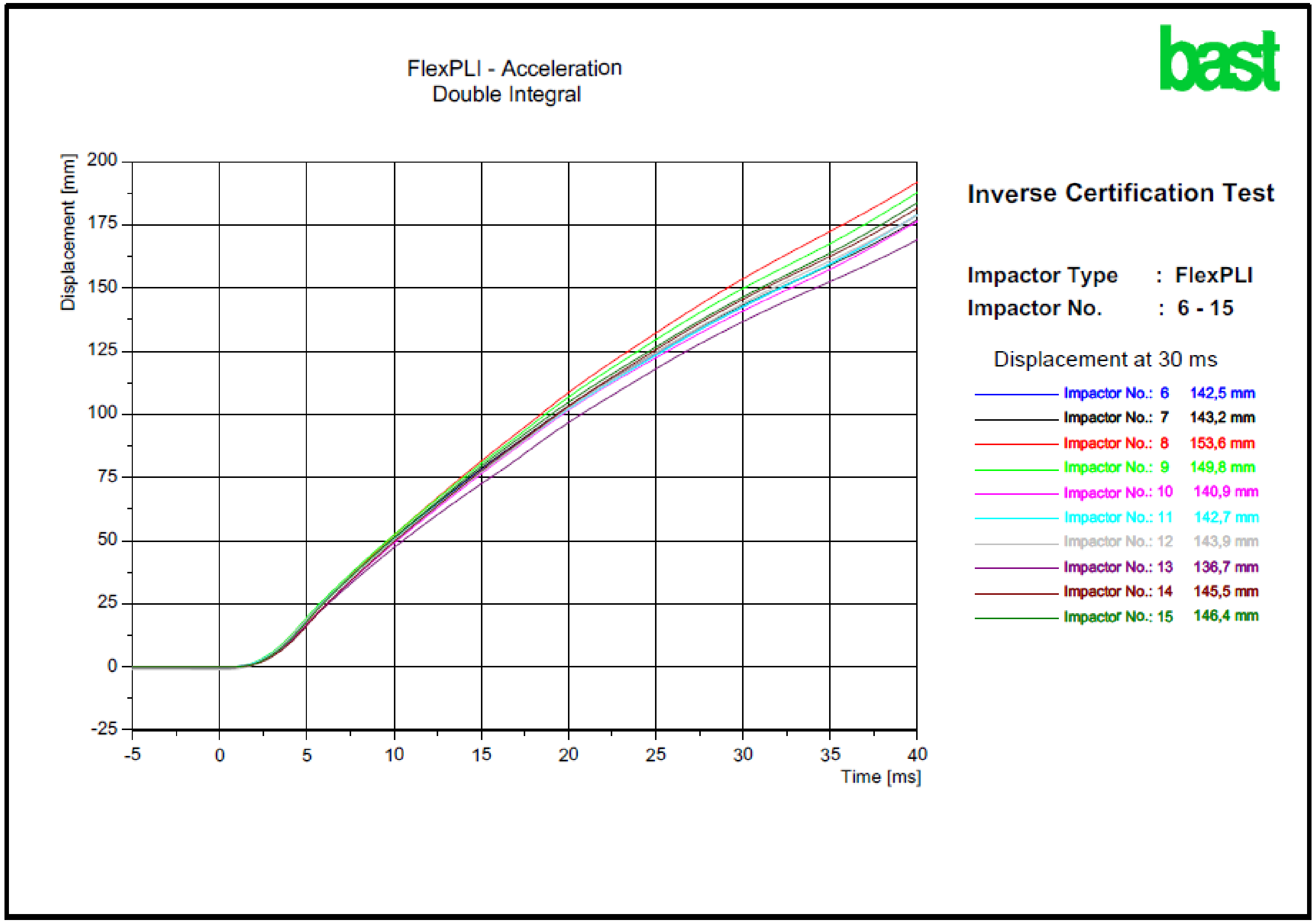
It should be sufficient to proof the repeatability of the Flex-PLI for two worst case heights of typical cross beam structures around the RCAR requirement (two separate shots with adapted height of honeycomb):

A) the standard measurement at knee location is appropriate for maximal height
B) A position at upper-most tibia segment corresponds well to the lowest height

Why considering the first 30ms of intrusion signal only for the corridor check?

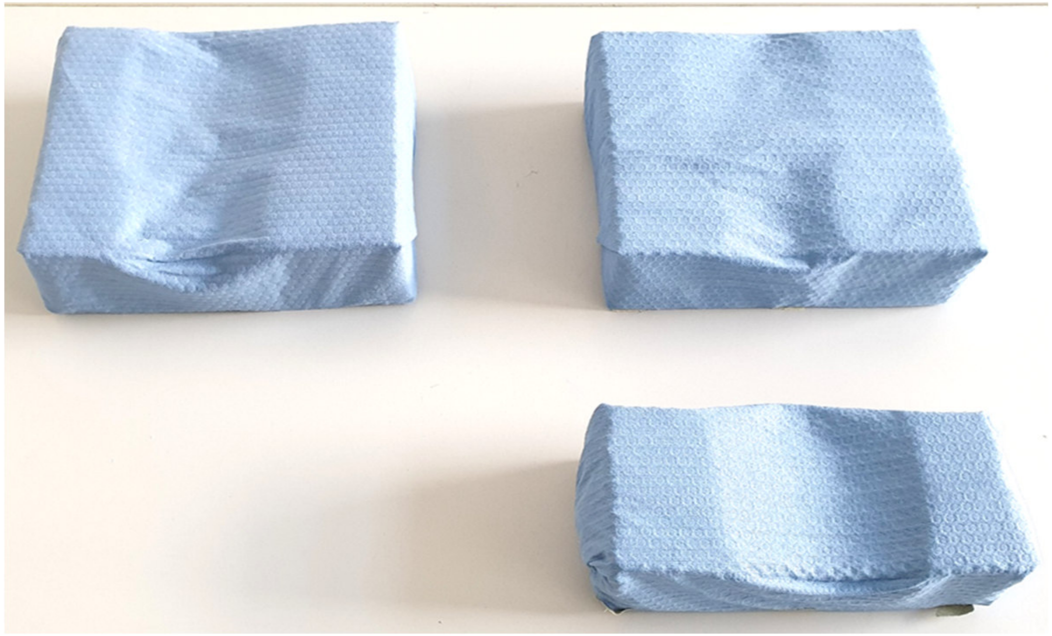
This duration of this signal analysis is sufficient to cover the timing of firing of the bonnet (typically <20ms).

Acceleration results (position A) taken from calibration data base (impact speed 40 km/h)



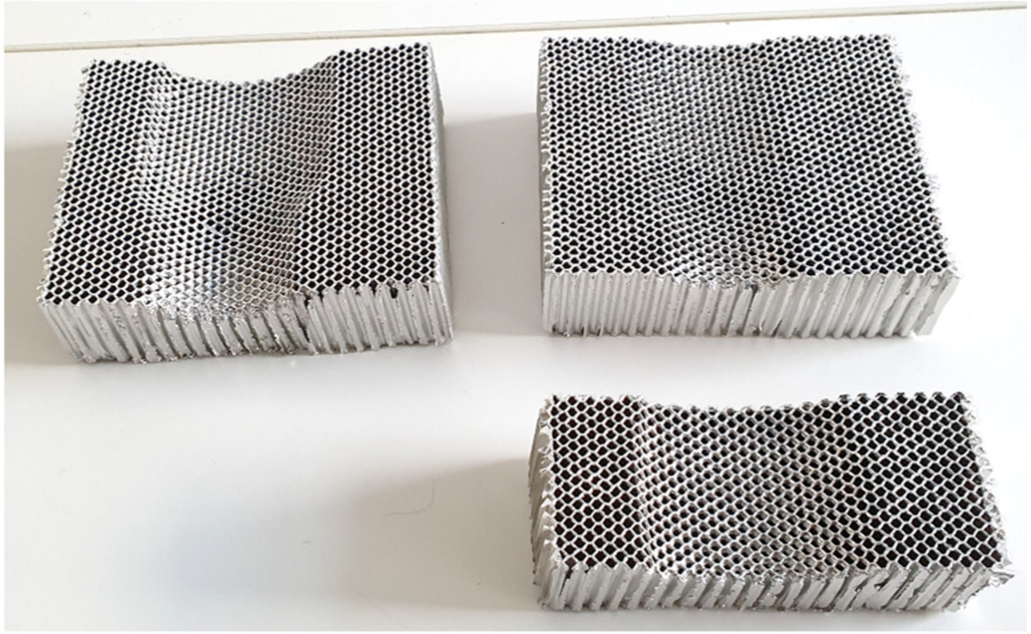
Initial tests with accelerator position A at 25 kph (BASt contribution to the IWG): Honeycomb deformation

40 kph **25 kph**



25 kph

40 kph **25 kph**



25 kph

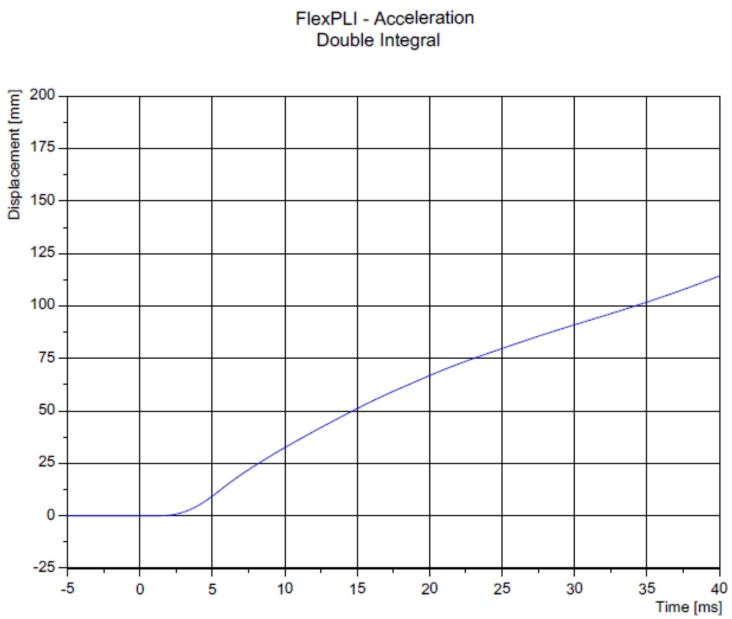
Initial tests with accelerator position A at 25 kph (BASt contribution to the IWG): Honeycomb deformation

40 kph
Honeycomb
height: 160 mm

25 kph
Honeycomb
height: 160 mm

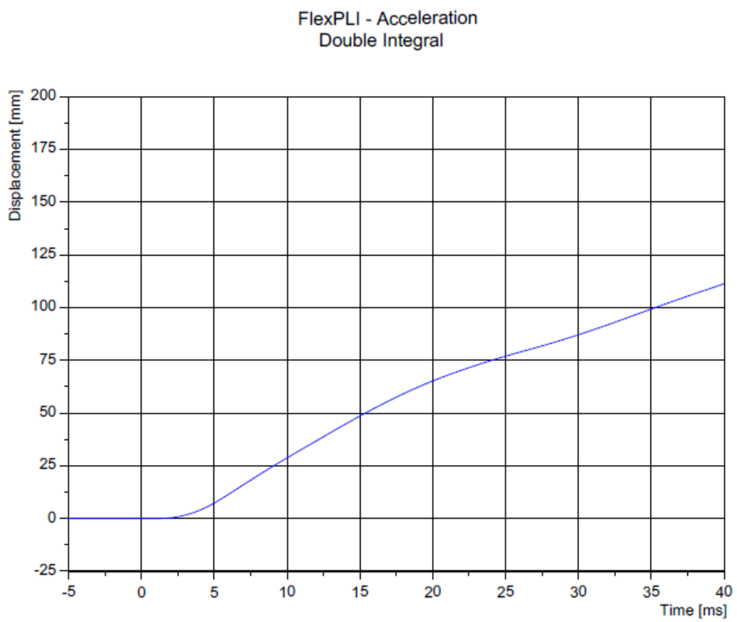
25 kph
Honeycomb
height: 80 mm

Initial tests with accelerator position A at 25 kph (BASt contribution to the IWG): Honeycomb deformation – whole vs. half honeycomb



Inverse Certification Test

Impactor Type : FlexPLI
Whole Honeycomb



Inverse Certification Test

Impactor Type : FlexPLI
Half Honeycomb

Summary and conclusions

Subsequent to a general agreement on the use of the FlexPLI as sensing impactor during the last meeting of the IWG DPPS, an initial study on the contact biofidelity of the FlexPLI was carried out.

A first analysis of the intrusion during inverse tests at different speeds indicate a good contact biofidelity and repeatability.

Further tests will be performed at speeds typical for the lower deployment threshold of DPPS (25 km/h) with two different test setups covering the height dimensions of the RCAR requirements that need to be fulfilled by a high number of vehicles.

As outlined in IWG-DPPS-6-04, alongside the introduction of the FlexPLI as sensing impactor, a general wording for DPPS working as intended as well as a wording for the need of a number of pedestrian statures being detected by DPPS must be included within the text of GTR9 and UN-R 127.

Thank you

Backup

Scatter in femur BM and accel. were higher than in tibia (and MCL); might be due to the test setup (linear impact at mid knee)

Highest scatter in acceleration

Very high range in acceleration

Highest deviation from mean value (and median) in acceleration

	Femur Up [Nm]	Femur Mi [Nm]	Femur Lo [Nm]	ACC [g]	MCL [mm]	Tibia Up [Nm]	Tibia MiUp [Nm]	Tibia MiLo [Nm]	Tibia Lo [Nm]
MV	73,2	134,6	189,1	248,2	18,6	254,8	232,9	175,3	96,3
Median	72,8	132,9	190	248,4	18,3	254	232,9	175,4	95,8
Range	13,2	30,5	35,5	65,7	3	22,5	19,6	6,6	10,5
Min	66,6	120,5	174,7	212,1	17,2	244,3	222,9	172	94
Max	79,8	151	210,2	277,8	20,2	266,8	242,5	178,6	104,5
SD	4,3	8,7	9,9	17,1	1,0	6,2	4,9	2,0	2,5
CV [%]	**5,9**	**6,6**	**5,2**	**6,9**	**5,2**	**2,4**	**2,1**	**1,1**	**2,6**
Max. Deviation from MV [%]	9,0	12,2	11,1	14,6	8,9	4,7	4,3	1,9	8,6
Max. Deviation from Median [%]	9,6	13,6	10,6	14,6	10,4	5,0	4,3	1,9	9,1

Summary and next steps

For the time being, the FlexPLI appears to be the best available pedestrian surrogate to be used as sensing impactor, provided that

- a general wording for DPPS working as intended

> “If the vehicle is equipped with a Deployable Pedestrian Protection System as defined in paragraph 2.19 of the Regulation, the test provisions laid down for type approval can, due to the complexity of testing those systems, only represent spot checks. Nevertheless it is due care of the car manufacturer that any active devices of passive pedestrian safety will ensure the necessary protection (e.g. for a variation of speeds and pedestrian statures) in order to act as intended in the event of a collision with a pedestrian.”

- a wording for the need of a number of pedestrian statures being detected by DPPS:

> “Considering the unavailability of impactors validated for the detection of pedestrians, the Flex PLI shall be used for the sensing verification of the system for the time being.
>
> Nevertheless it is due care of the car manufacturer that the system will act as intended in the event of a collision for a variation of pedestrian statures”

being included within the text of GTR9 and UN-R 127.