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# **Dynamic full assembly certification test procedure (inverse test setup) in conjunction with functional test**

**7th Meeting of the GRSP Flex PLI Technical Evaluation Group  
Bergisch Gladbach, December 8th, 2008**

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## **Pendulum certification test proposal**

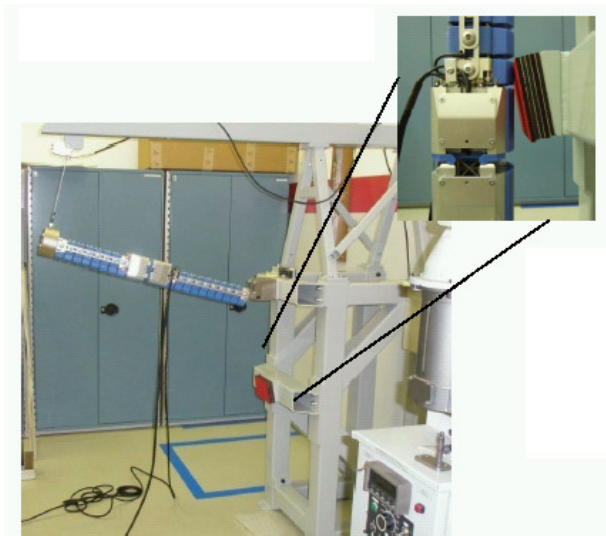
Inverse certification test proposal

Relevance in vehicle tests

Summary

Next steps

- The full calibration test procedures for the Flex-GTR (TEG-056) include a dynamic certification test
- The legform impactor is suspended upside down without flesh and skin over a pin joint from a fixed test rig with support arm and release magnet
- The femur section is loaded with an additional mass
- The impactor is lifted up to a (tbd) height and then released
- A stopper with several layers of neoprene and rubber sheets, mounted at a defined pitch and yaw angle on a cross beam, is hit by the knee joint of the released impactor



Pendulum certification test proposal [Source: FTSS]

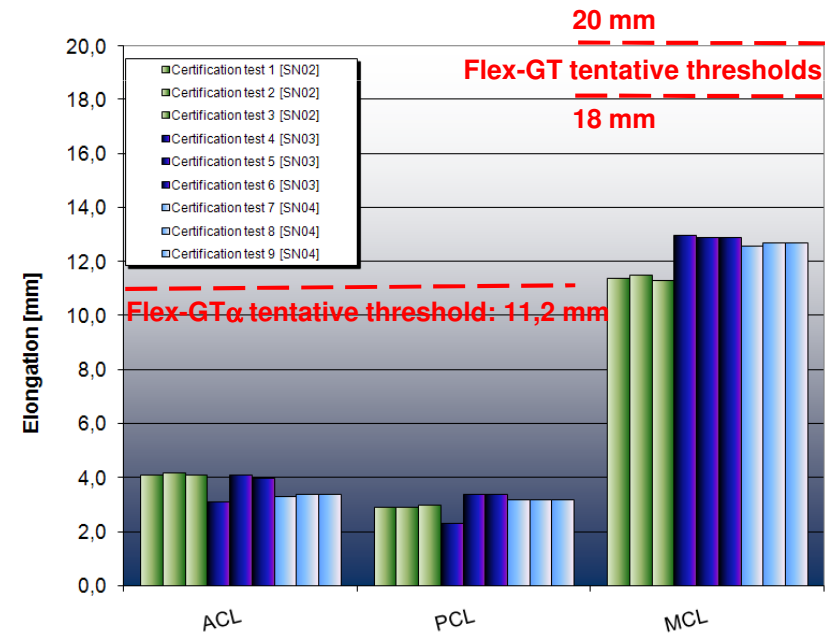
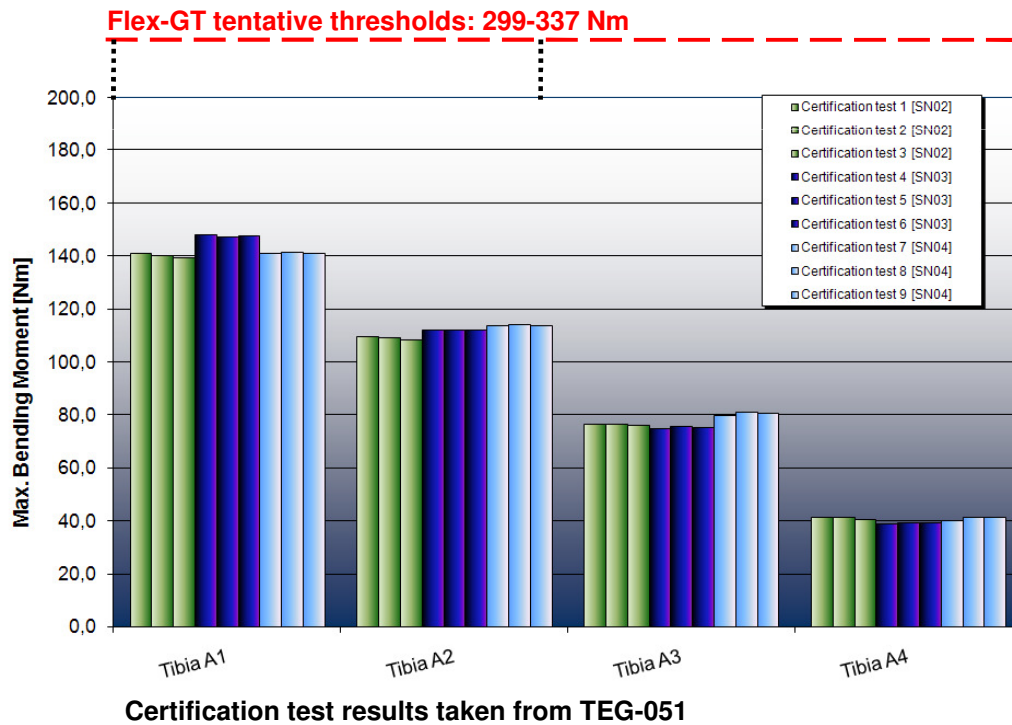
## Readings:

- string potentiometers (ACL, PCL, MCL and LCL)
- strain gauges (femur and tibia)
- tibia top accelerometer
- tibia or femur end angular rate / acceleration

# Pendulum certification test proposal



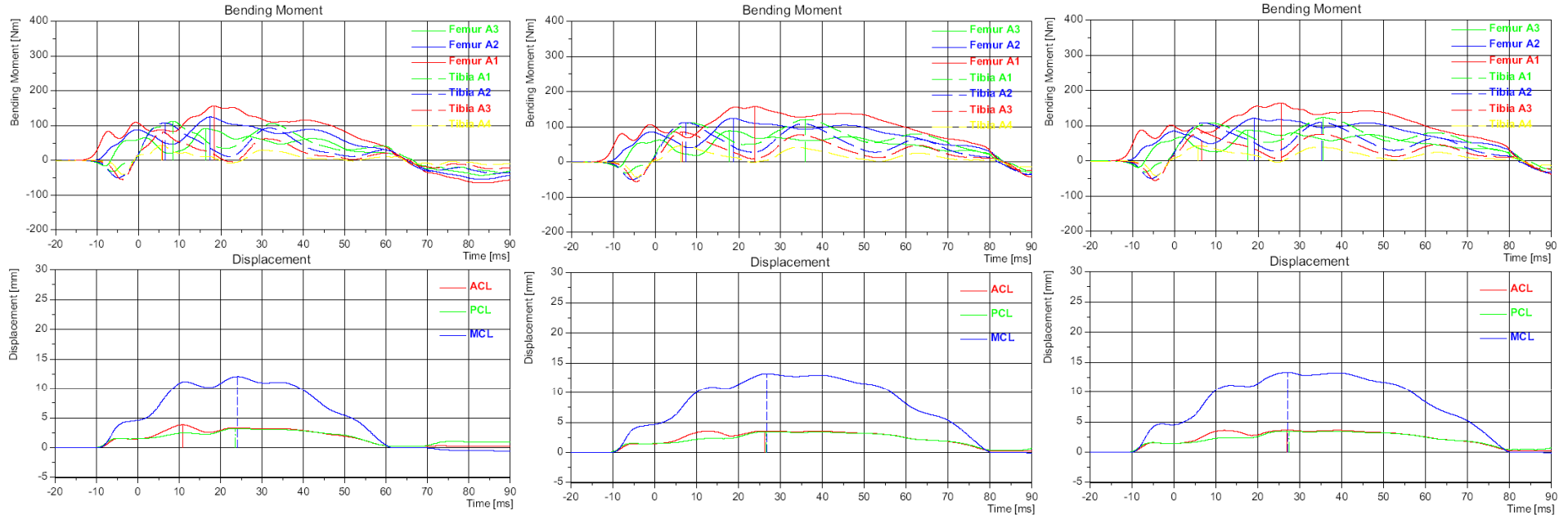
- Pendulum certification test proposal of the impactor without flesh and skin
- Pendulum test represents a good functional test of the strain gauges and string potentiometers in order to immediately recognise the general functionality
- On the other hand, the test results are far out of a critical range and don't mirror the real accident / injury scenario:



# Pendulum certification test proposal



## Comparison pendulum function test with / without additional impactor mass



### Maximum Bending Moment

CFC 180	
Femur A3	91.9 Nm at 16.4 ms
Femur A2	125.2 Nm at 17.4 ms
Femur A1	156.3 Nm at 18.3 ms
Tibia A1	112.2 Nm at 8.4 ms
Tibia A2	107.2 Nm at 6.5 ms
Tibia A3	82.1 Nm at 5.8 ms
Tibia A4	43.6 Nm at 5.7 ms

### Maximum Displacement

CFC 180	
ACL	3.8 mm at 10.8 ms
PCL	3.2 mm at 23.6 ms
MCL	12.1 mm at 24.1 ms

**0,68 kg**



### Maximum Bending Moment

CFC 180	
Femur A3	88.6 Nm at 17.7 ms
Femur A2	124.7 Nm at 18.7 ms
Femur A1	157.6 Nm at 23.9 ms
Tibia A1	120.7 Nm at 35.9 ms
Tibia A2	112.9 Nm at 7.4 ms
Tibia A3	85.2 Nm at 6.6 ms
Tibia A4	46.2 Nm at 6.2 ms

### Maximum Displacement

CFC 180	
ACL	3.6 mm at 26.3 ms
PCL	3.4 mm at 26.6 ms
MCL	13.2 mm at 26.7 ms

**+ 2 x 0,68 kg**



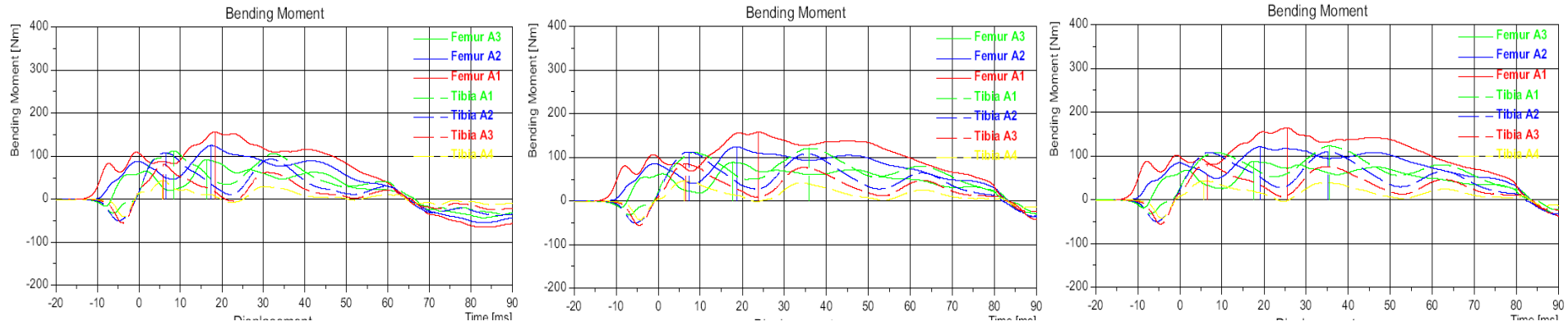
### Maximum Bending Moment

CFC 180	
Femur A3	88.5 Nm at 17.6 ms
Femur A2	121.1 Nm at 19.0 ms
Femur A1	164.3 Nm at 25.5 ms
Tibia A1	123.1 Nm at 35.5 ms
Tibia A2	109.6 Nm at 35.2 ms
Tibia A3	80.8 Nm at 6.6 ms
Tibia A4	42.7 Nm at 5.7 ms

### Maximum Displacement

CFC 180	
ACL	3.6 mm at 27.0 ms
PCL	3.4 mm at 27.4 ms
MCL	13.3 mm at 27.1 ms

# Pendulum certification test proposal

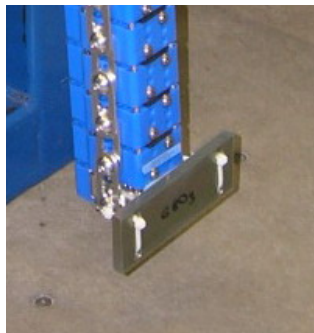


## Conclusion:

- Test results within the normal range
- 1.36 kg Additional weights and different CoG on femur and tibia not visible in test data

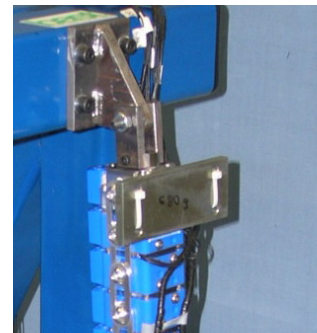
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- **Hard impact: neoprene / rubber sheets on steel beam are used as substitute for legform flesh → test represents legform impact against rigid object**
- **Influence of stopper and neoprene / rubber sheets on test results disproportionately high (independent from stopper material control)**
- **Consistency test of stopper needed (see TEG-056)**
- **Pendulum test procedure not necessarily reveal existing defects / Malfunctions**
- **No influence of additional weights and different CoG on femur and tibia on test results**
- **Pendulum test procedure does not ensure proper functionality of impactor**
- **Test after each vehicle test necessary → high effort needed**
- **However, on top of this pendulum test, a certification test that immediately reveals failures or the proper impactor functionality, is needed**

Pendulum certification test proposal

**Inverse certification test proposal**

Relevance in vehicle tests

Summary

Next steps



# Inverse certification test proposal



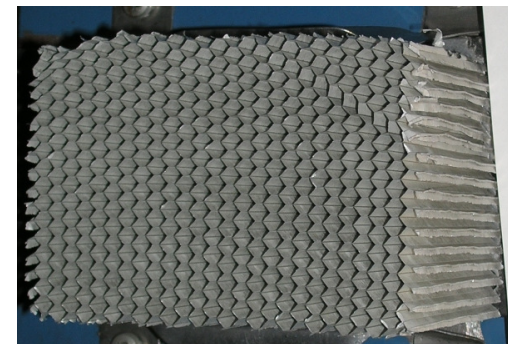
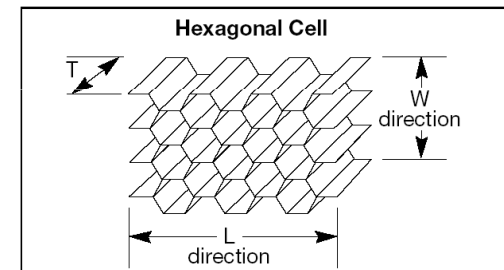
- Flex PLI is impacted by the upper edge of a linearly guided Al honeycomb impactor at a previously defined impact speed
- Impact location: upper edge of the honeycomb in line with center of knee
- Measurement items – pass/fail parameters:  
three string potentiometers (ACL, PCL, MCL), four strain gauges (tibia moments)



Flex-GT inverse testing

- **Test parameters:**
  - **Impact speed = 40 km/h**
  - **Mass of honeycomb impactor = 8,1 kg**
  - **Impact height: upper honeycomb edge in line with center of knee**
- **Test frequency: after every 20 tests or each year**
- **Aluminium honeycomb specifications:**

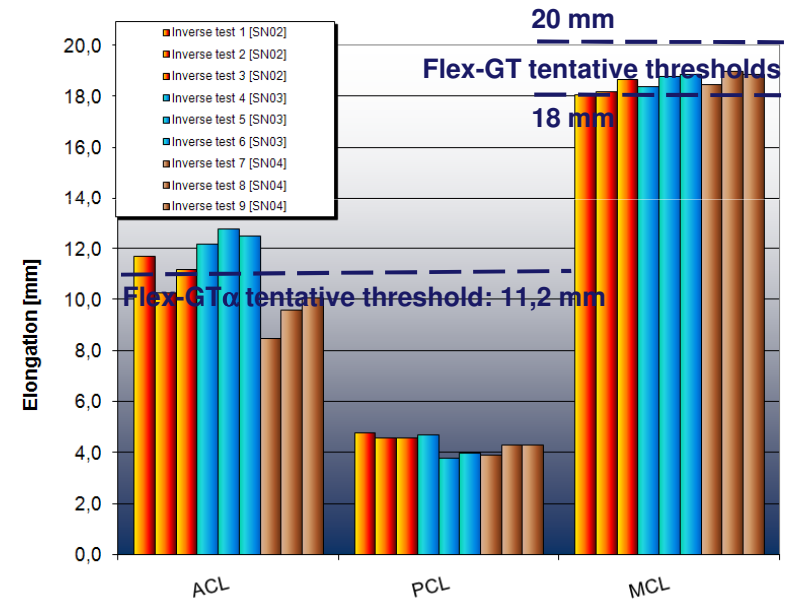
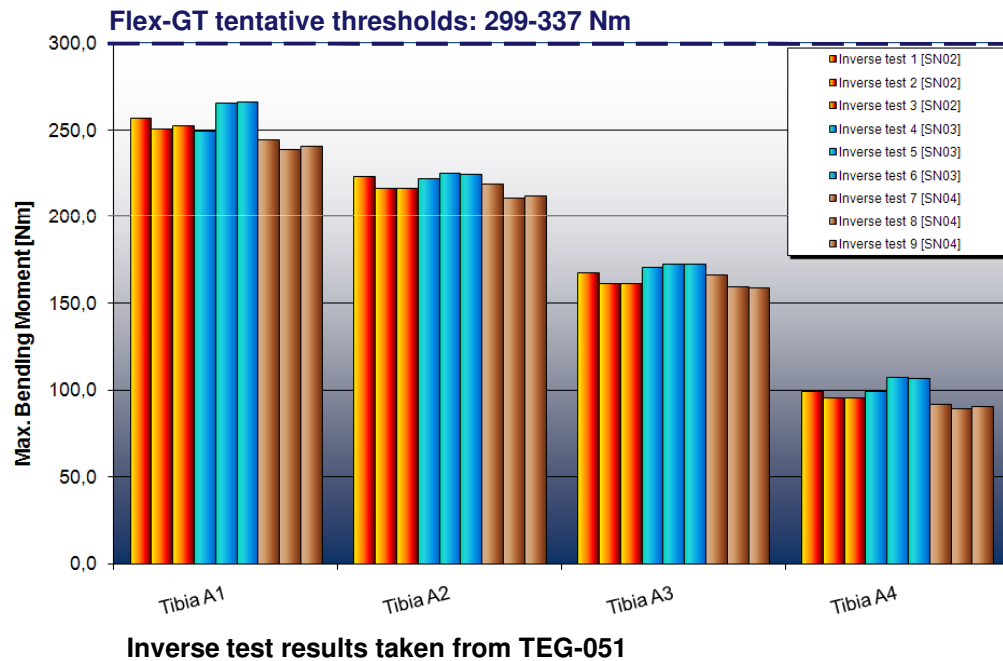
Specification	Data
Cell size	3/16
Alloy	5052
Foil gauge	.001
Density	3.1
Crush strength	75 PSI
Dimensions	250 * 160 * 60 mm



# Inverse certification test proposal



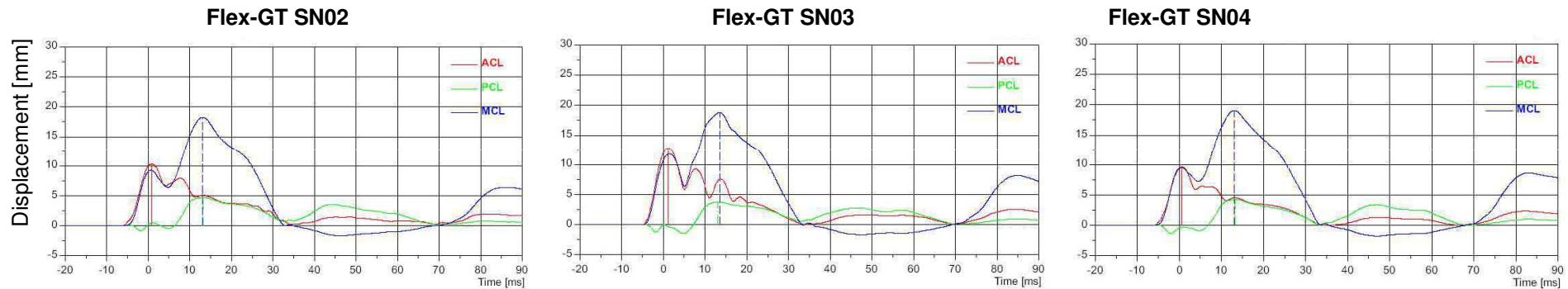
- Certification of the fully assembled impactor with flesh and skin
- Certification test checks the impactor functionality and sensor responses under real impact conditions
- Test results are within a more critical range and mirror the real accident / injury scenario as well as the vehicle impact tests:



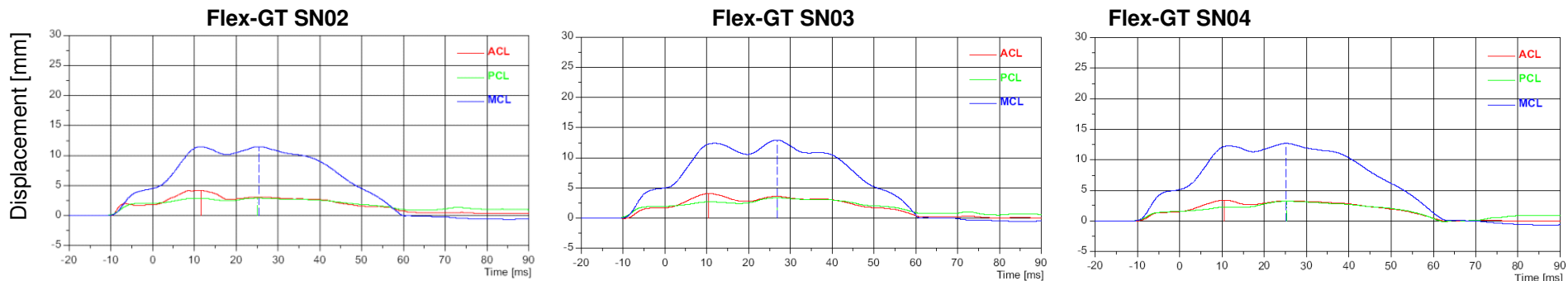
# Inverse certification test proposal



- No consistency test of stopper needed
- No fixation of legform end
- No impactor modification (e.g. additional mass)
- „Soft“ impact due to deformable honeycomb material
- Certification after every 20 tests or each year → lower effort needed
- Inverse certification test reveals existing defects / malfunctions better than previous procedure:



Inverse certification test results - Traces taken from TEG-051



Current certification test results



Pendulum certification test proposal

Inverse certification test proposal

**Relevance in vehicle tests**

Summary

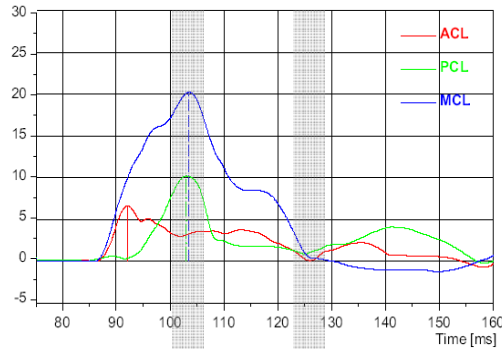
Next steps



# Relevance in vehicle tests

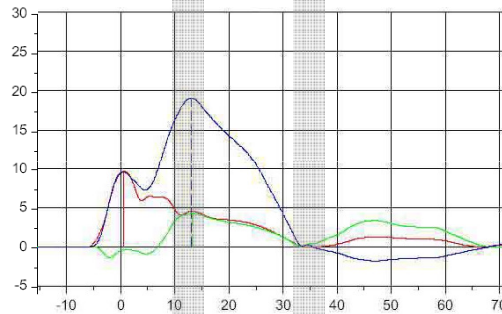


ACL, PCL, MCL



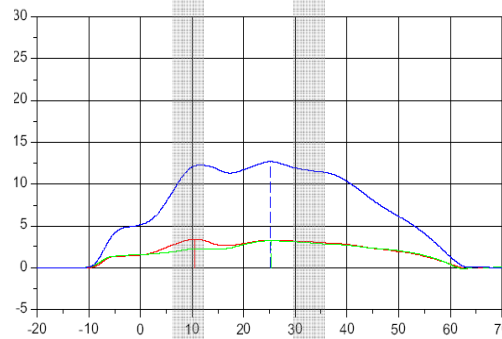
## Car impact

High impactor rotation during impact, high influence of impactor mass and CoG.



## Inverse free flight certification

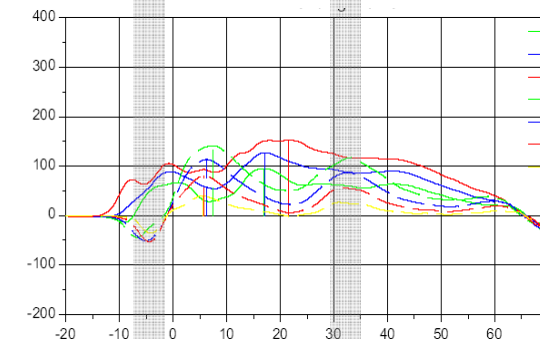
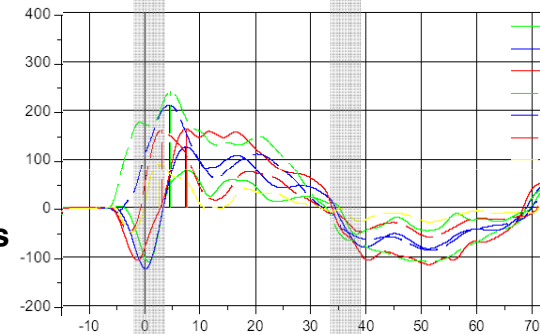
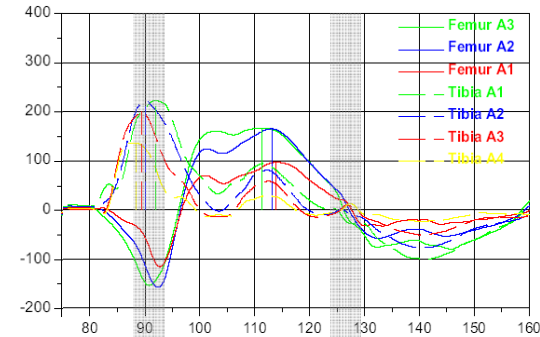
Timing, **kinematics** and values within relevant range and mirror the real car test scenario. High influence of different impactor mass and CoG. Impactor rotation is taken into account.



maxima  
(car impact)

zero crossing  
(car impact)

Bending moment



maxima  
(car impact)

zero crossing  
(car impact)

## Pendulum function test

Only small rotation from one impactor part during impact, no significant influence of wrong mass and CoG, long time frame with different impact events and loading cases in comparison with a free flight impact. Quick and easy function check

Pendulum certification test proposal

Inverse certification test proposal

Relevance in vehicle tests

**Summary**

Next steps



# Summary (I)



Criteria	Pendulum test proposal		Inverse certification test proposal	
Impactor assembly	w/o neoprene and rubber sheets	-	full assembly with neoprene and rubber sheets	+
Setup	upside down; fixation of tibia end	-	no fixation of legform end; in line with real car test	+
Significance	good functional test of strain gauges and string potentiometers	o	complete impactor functionality verification under real impact conditions	+
Purpose	functional test, but: inappropriateness of test setup principle for certification has been already proven by EEVC WG 10	-	test with loads and responses of impactor similar to real car test	+
Failure recognition	immediate recognition of general functionality, but: no information on proper measurement in real car test	o	immediate recognition of failure and proper functionality; no re-test necessary	+
Impactor condition	additional tibia mass needed	-	standard, no modification	+
Test results	not in the critical / injury relevant range	-	within a more relevant range reflecting the real injury scenario	+
Additional tests	consistency test of stopper needed	-	no additional test needed	+
Efforts for single certification test	comparatively low	+	comparatively high, but to be performed approx. every 20 tests only	o

# Summary (II)



Criteria	Pendulum test proposal		Inverse certification test proposal	
Frequency	after each test	o	after 20 tests / each year	+
Impact	„hard“ - legform impact against rigid object (neoprene / rubber sheets on steel beam are used as substitute for legform flesh)	-	„soft“ due to honeycomb material, like impact against pedestrian-friendly, deformable vehicle front	+
Impact kinematics	kinematics completely different due to pendulum test type and additional mass	-	kinematics like in free flight	+
Influence of flesh simulation on test results	too high weighting of stopper and neoprene / rubber sheets – hard impact material used	-	balanced weighting - deformable impact material used	+
Defects	not necessarily revealed	-	revealed better because test conditions are reflecting better the real impact scenario	+
Others	measuring channels to assess the impactor functionality are partly not used for injury assessment	o	all relevant measuring channels are used	+
<b>Conclusion</b>	<b>Good functionality check to be performed between vehicle tests on the test lab's discretion</b>		<b>Good certification method with realistic test parameters to ensure proper functionality and reproducibility</b>	

Pendulum certification test proposal

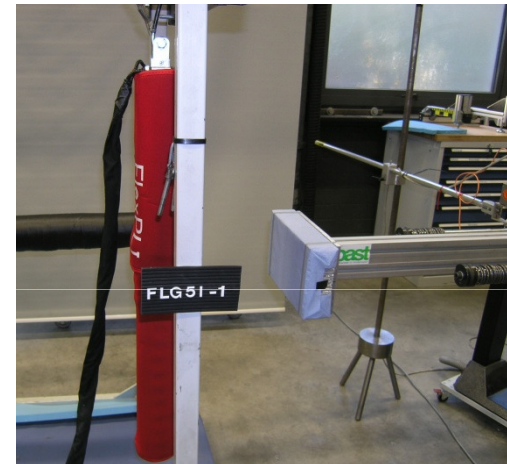
Inverse certification test proposal

Relevance in vehicle tests

Summary

**Next steps**

- **Inverse certification test results should mirror the critical values w.r.t. the Flex PLI injury criteria**
- **Verification / re-definition of aluminium honeycomb specifications**
- **Verification / re-definition of test parameters**
- **Development of a certification test protocol (including specs, corridors etc.)**
- **Round robin evaluation tests with Flex-GTR (repeatability, reproducibility, applicability)**
- **Pendulum test in addition before / after each test**



Thank you!

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