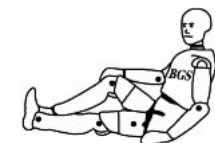


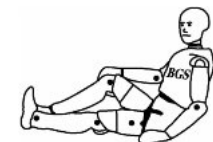
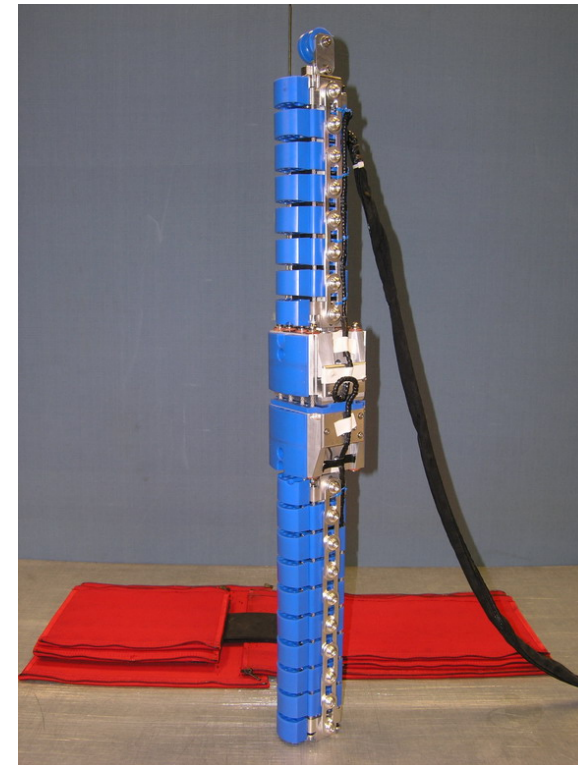
Report on Tests with the Flexible Pedestrian Legform Impactors Flex GT α and Flex GT

July 2nd , 2007
Bergisch Gladbach
Germany

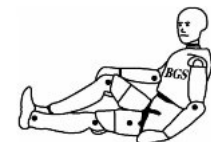
Dipl.-Ing. Dirk-Uwe Gehring
BGS Böhme & Gehring GmbH



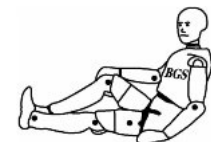
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 - Impact height
 - Differences GT α – GT
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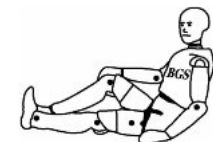
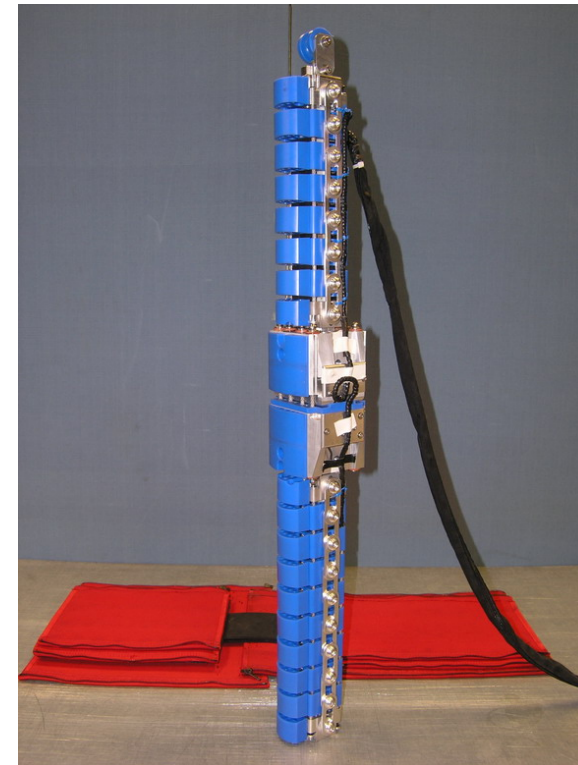
- Test series with Flex PLI version „G“ in 2005 :
 - Device not usable as a test tool
 - Measurement ranges (esp. knee elongations) insufficient
 - Design not robust enough to be used in 40 km/h impact tests
- Development of new version in 2006:
 - Name: „GT“, first prototype named „GT α “ produced in spring 2006
 - Total mass 12,4 kg (Flex G 13,9 kg)
 - Femur and tibia segments made from MC-nylon instead of steel
 - Impact faces of femur and tibia in line with knee impact face
 - Different masses and centers of gravity in femur and tibia
 - Mass concentration in massive knee area



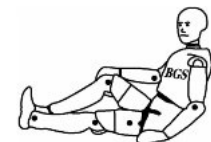
- Development of new version in 2006 (cont'd):
 - Increased knee bending capability
 - Increased knee stiffness
 - Slightly smaller femur and tibia stiffness
 - Biofidelity may be reduced
 - Improved injury assessment (according to JARI)
- BAST test series started December 2006:
 - Flex GT α (α =prototype) was sent to BAST in December 2006
 - First tests showed usability with 40 km/h
 - BAST test program based on 2005 Flex G test plan
- ACEA TF-P felt a need for additional tests with vehicles and test rigs and initiated a test program with BAST



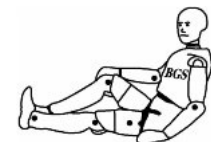
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- Impact height: Vertical distance between ground level and lowest part of the legform impactor
- 2004/90/EC (2003/102/EC): 0 mm
- TRL feasibility study: + 25 mm
- 2006/368/EC (2005/66/EC): + 25 mm
- Draft GTR current status: + 25 mm
- Flex PLI testing until Feb 2006: + 25 mm
- Results from JARI simulation analysis in 2006/2007, disclosed in February 2007, presented at 4th Flex TEG meeting April 2nd, 2007, to be proposed to GRSP for possible implementation in GTR: + 75 mm
- Flex PLI testing from March 2007: + 75 mm (+ 25 mm)

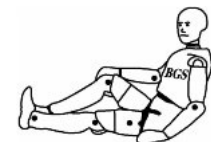


- Differences/changes presented at 4th Flex TEG meeting, April 2nd, 2007
- Flex GT α modified at BASt April 3rd to 4th, 2007
- Former Flex GT α is now Flex GT, ser. no. 5
- Three major changes:
 - Support roller
 - Outer flesh
 - Bone cores



Support Roller Flex GT α

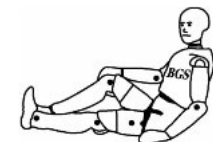
- No guiding during acceleration phase
- Impactor rotation about z-axis possible
- Likely to be damaged during test



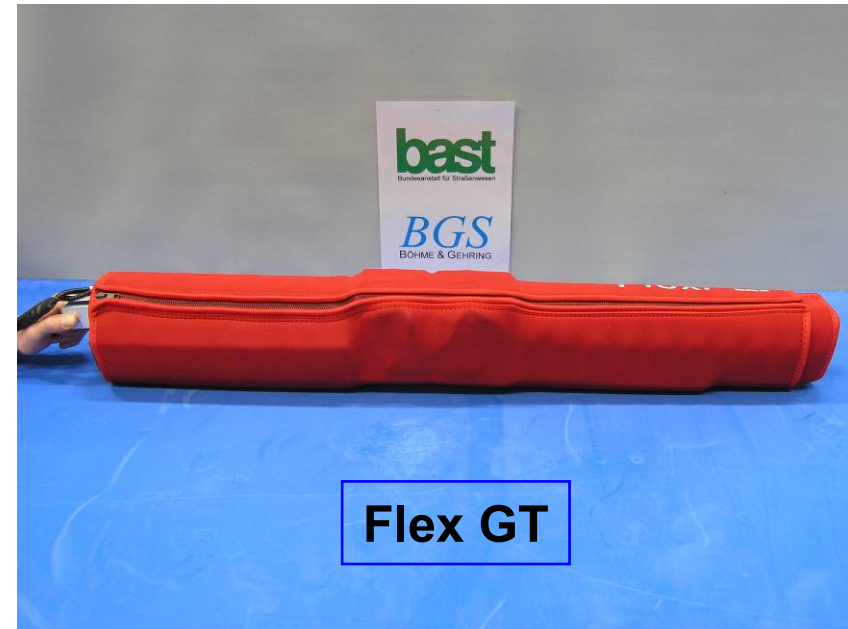
Support Roller Flex GT

BGS

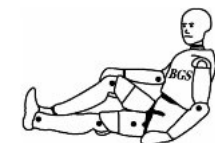
- Guided support
- No impactor rotation around vertical axis possible during acceleration phase
- Strong bracket
- Protected roller



Outer Flesh

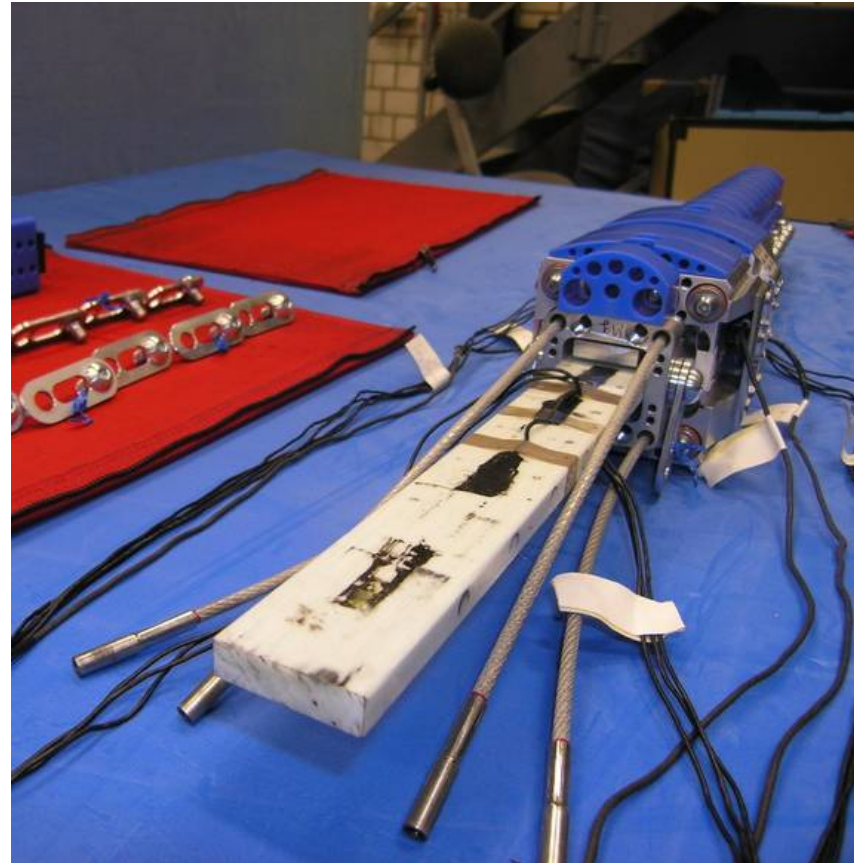


Change from two pieces to a continuous, one-piece outer flesh

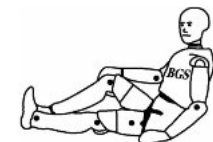


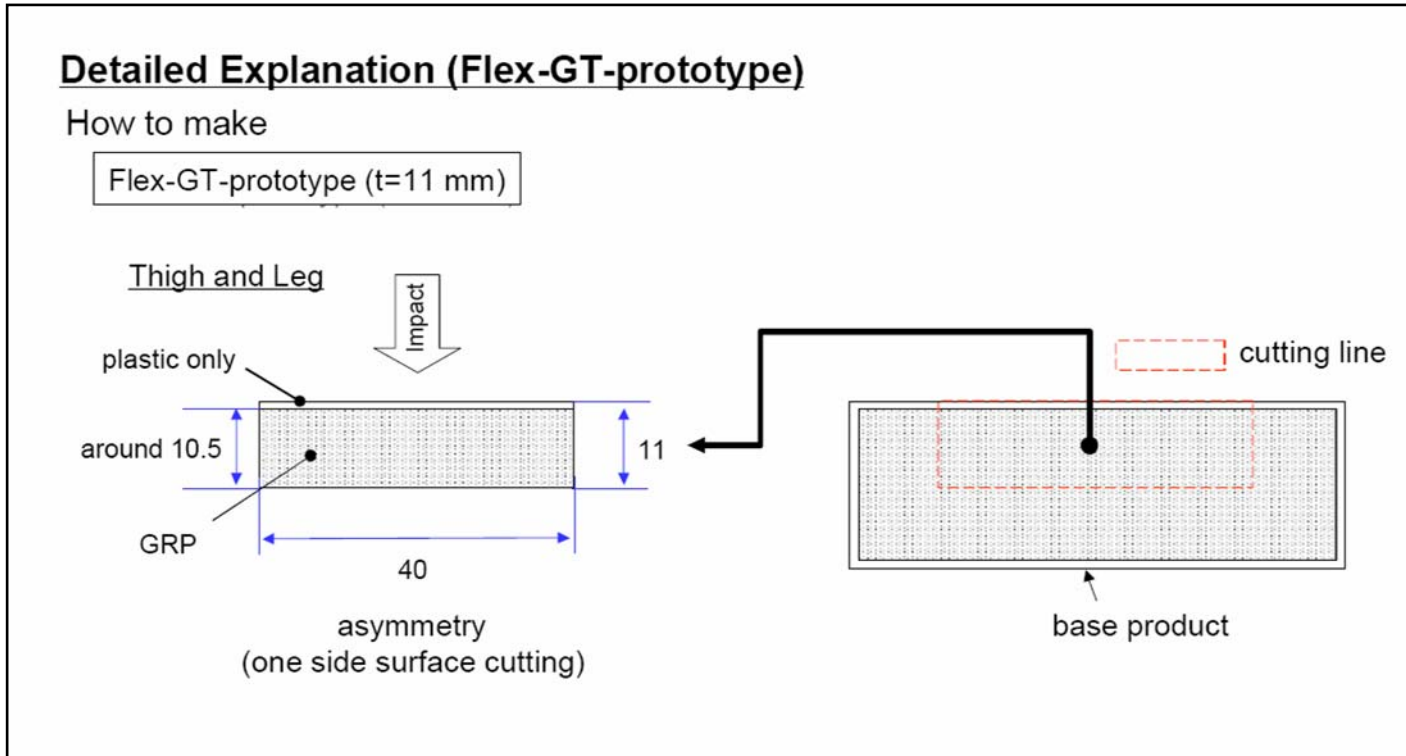
Bone Cores

- Improvement of production
- Reduction of thickness (- 0.5 mm)
- “Bending characteristic comparable”
- Additional parts also modified to avoid any play
 - Tibia and femur segment openings
 - Bone clamping devices in knee part



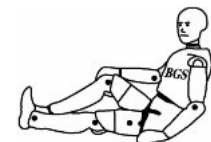
Flex GT α





(Dr. Konosu, JARI, April 20th, 2007)

GRP: Glass fiber Reinforced by Plastic

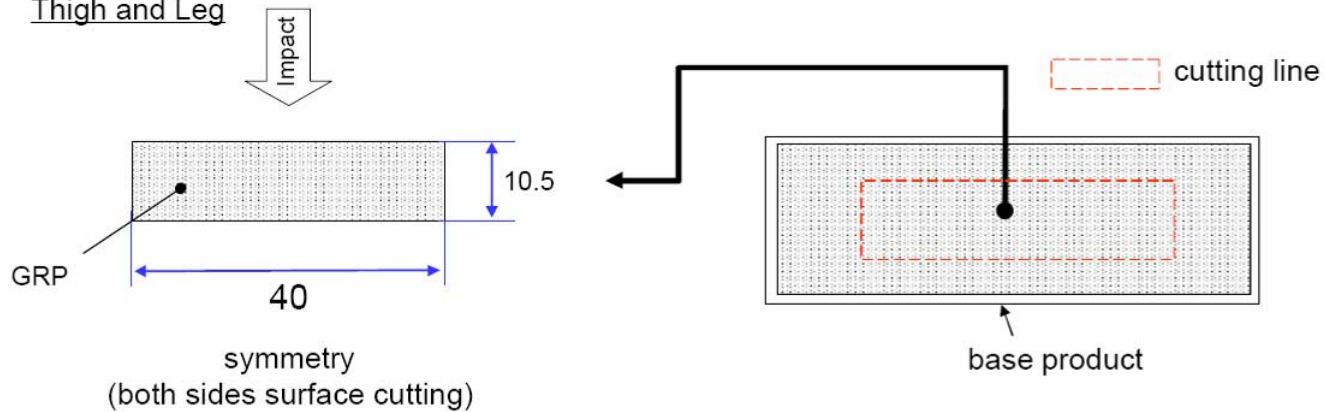


Detailed Explanation (Flex-GT)

How to make

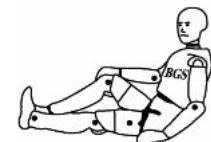
Flex-GT (t=10.5 mm)

Thigh and Leg



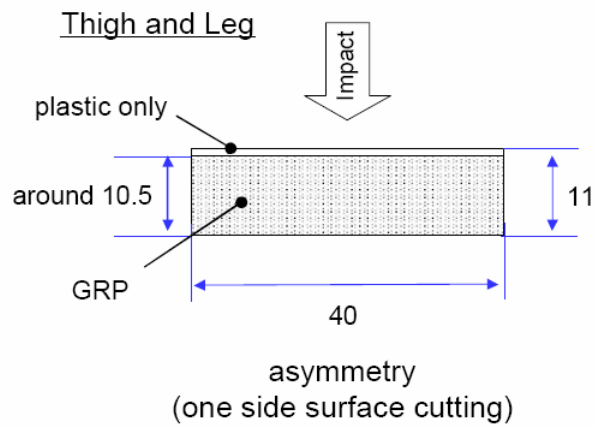
(Dr. Konosu, JARI, April 20th, 2007)

GRP: Glass fiber Reinforced by Plastic

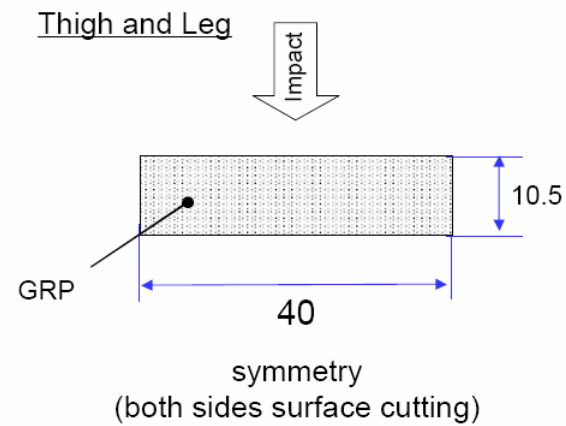


Flex-GT (Bone core, Thickness)

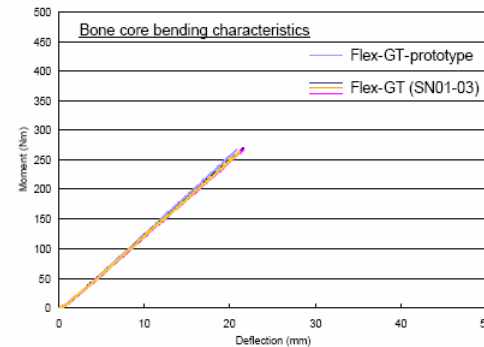
Flex-GT-prototype (t=11 mm)



Flex-GT (t=10.5 mm)

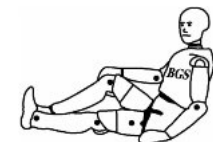


Bending characteristic is comparable

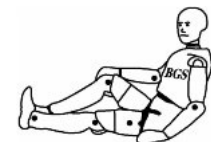


GRP: Glass fiber Reinforced by Plastic

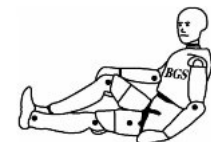
(Dr. Konosu, JARI, April 20th, 2007)



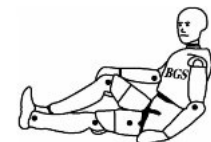
- Flex GT α was sent to BASt in December 2006 without a sensitivity list
- BASt and BGS asked JARI for a sensitivity list
- A sensitivity list was provided in December 2006 without further information on the derivation of the values
- Tests were performed using this list
- In April 2007 an error was detected during the discussions about the change of the bone core thickness
- The error occurred during the estimation of the sensitivities in December 2006, which was necessary because no certification was performed before sending the Flex GT α to Germany.



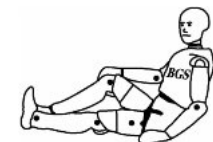
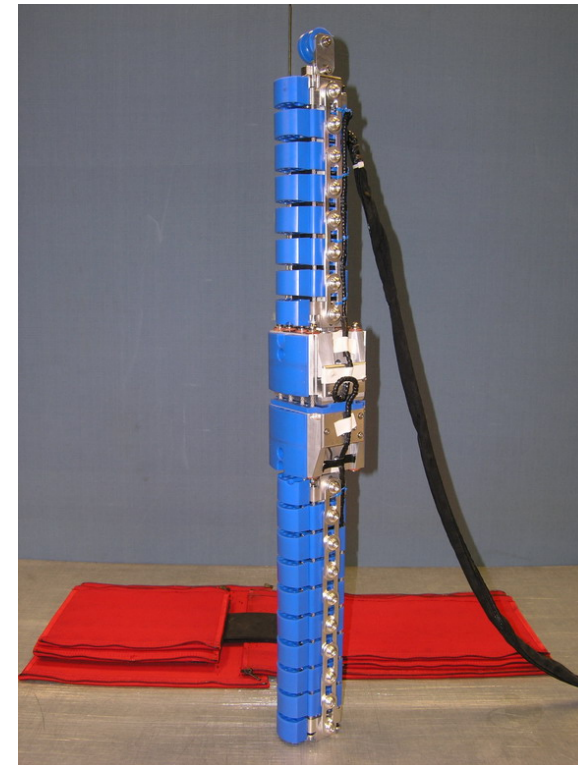
- The estimation was carried out as follows:
 - A bone core of 11 mm thickness (GRP only) was used to determine the sensitivities
 - Knowing that Flex GT α has only 10,5 mm of GRP, a factor of approx. **1,138** had to be used to calculate the sensitivities
 - Mistakenly, a factor of approx. **1,38** was used for the calculations.
 - These calculated values were sent to BAST/BGS in December 2006 without information on their derivation
- Thus, the presented results of the tests carried out until March 2007 were circa 15 - 20% too low
- In April 2007 a recalibration of the bone cores of Flex GT α was performed at JARI and a new sensitivity list was provided.



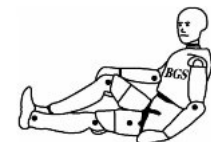
- **All test results and graphics presented in this report and its annexes are already re-calculated with the new, correct sensitivities.**



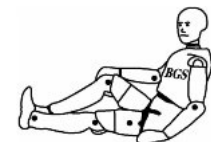
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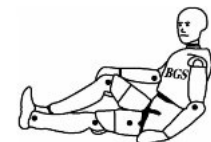
- Mercedes Benz A-Class:
 - Flex GT α : 7 tests, 6 impact positions, 2 modifications, impact height 75 mm
- Volkswagen Golf:
 - Flex GT α : 7 tests, 3 impact positions, impact height 75 mm
- Jaguar XK:
 - Flex GT α : 16 tests, 4 impact positions, impact height 75 mm and 25 mm, additional sensors for PUB-analysis
- Audi Q7:
 - 3 tests, 1 impact position, 3 different impactors: EEVC WG 17 legform, EEVC WG 17 upper legform, Flex GT (75 mm)



- Test rig:
 - Flex GT α : 15 tests, 5 impact heights, 3 tests per height
- Inverse tests:
 - Flex GT α : 5 tests, same configuration
- Comparison Tests Flex GT - GT α
 - Mercedes Benz A-Class:
Flex GT: 2 tests, 2 impact positions, impact height 25 mm
 - Volkswagen Golf:
Flex GT: 2 tests, 2 impact positions, impact height 75 mm

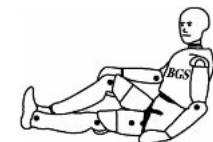


- Overall test parameters
 - Impact velocity: 11,1 m/s (40 km/h) \pm 0,2 m/s
 - Impact accuracy: \pm 10 mm in y and z-direction
 - Rotations: \pm 5° around x-, y- and z-axis
 - Ballistic flight curve of the Flex PLI
 - In each test all these parameters were met.



Tests with A-Class (1)

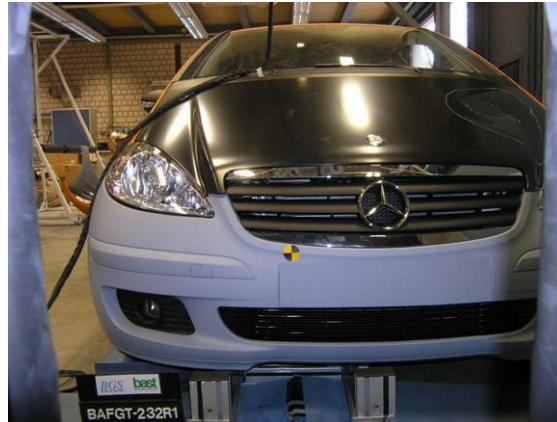
Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGT-650L1	75	650	
BAFGT-440R1	75	-440	
BAFGT-232R1	75	-232	L2a (Euro NCAP test point)
BAFGT-530-L1	75	530	L3b (Euro NCAP test point)
BAFGTA-232R2	75	-232	L2a, without bumper foam
BAFGTA-440L2	75	440	Without bumper foam
BAFGT-0M1	75	0	



Tests with A-Class (2)



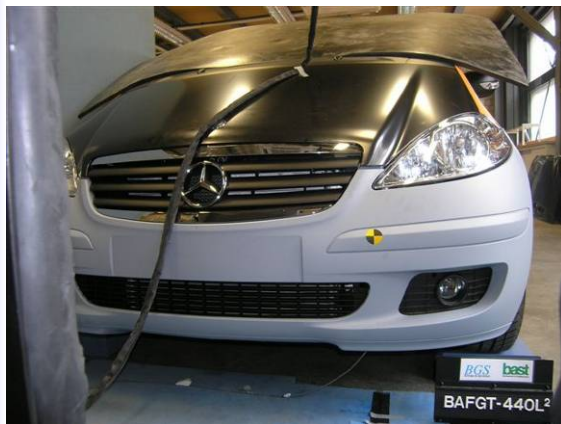
Y= -440 mm



Y= -232 mm



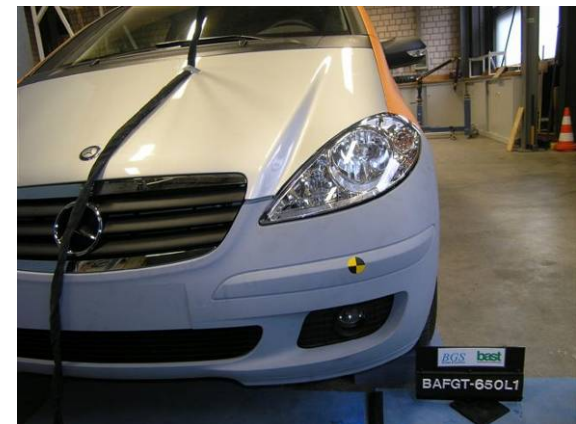
Y= 0 mm



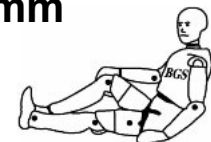
Y= 440 mm



Y= 530 mm

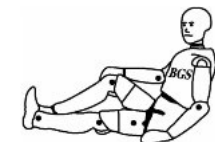


Y= 650 mm



Tests with Golf (1)

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTG357R	75	-357	L1b (Euro NCAP test point)
BAFGTG357R-2	75	-357	L1b
BAFGTG357R-3	75	-357	L1b
BAFGTG51L	75	51	L2b (Euro NCAP test point)
BAFGTG51L-2	75	51	L2b
BAFGTG51L-3	75	51	L2b
BAFGTG357L	75	357	Symmetric position to L1b



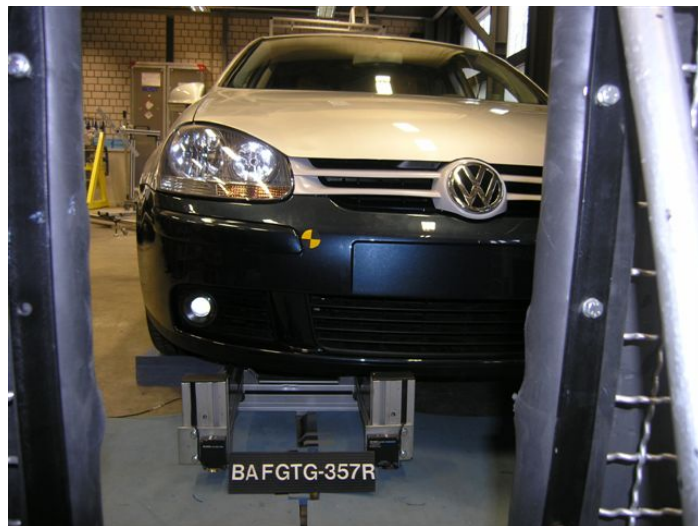
Tests with Golf (2)



Y= 51 mm

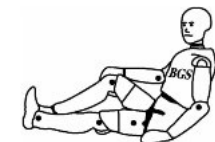
Y= -357 mm

Y= 357 mm



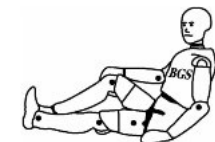
Tests with XK (1)

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTX-420-1	75	420	In all tests, the output of the PUB sensor and of two additional accelerometers at the inner face of the bumper cover were measured.
BAFGTX-0-1	75	0	
BAFGTX-220-1	75	-220	
BAFGTX-420-2	25	420	
BAFGTX-0-2	25	0	
BAFGTX-220-2	25	-220	
BAFGTX-420-3	25	-420	



Tests with XK (2)

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTX-420-4	25	420	see previous page
BAFGTX-0-3	25	0	
BAFGTX-220-3	25	-220	
BAFGTX-420-5	25	-420	
BAFGTX-420-6	25	420	Error in impact height, test not charged
BAFGTX-420-7	75	420	
BAFGTX-0-4	75	0	
BAFGTX-220-4	75	-220	
BAFGTX-420-8	75	-420	
BAFGTX-420-9	75	-420	



Tests with XK (3)

BGS

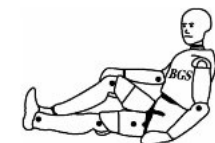


Y= -420 mm

Y= -220 mm

Y= 0 mm

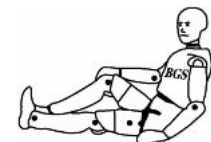
Y= 420 mm



Tests with Q7 (1)

- For these tests, the vehicle was lifted up to achieve a Lower Bumper Reference Line of 501 mm

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BALQ298L	0	298	WG 17 legform
BAUQ298R	--	-298	WG 17 upper legform
BAFGTQ298L	75 mm	298	Flex GT

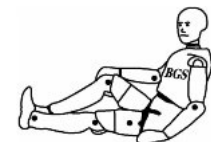


Tests with Q7 (2)

BGS

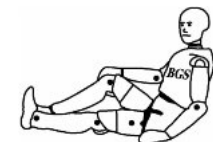


Y= 298 mm



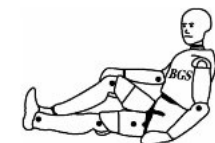
Tests with Test Rig (1)

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTG50-1	50		Impactor knee higher than
BAFGTG50-2	50		foam edge
BAFGTG50-3	50		
BAFGTG25-1	25		
BAFGTG25-2	25		
BAFGTG25-3	25		
BAFGTG0-1	0		Impactor knee in line with
BAFGTG0-2	0		foam edge
BAFGTG0-3	0		

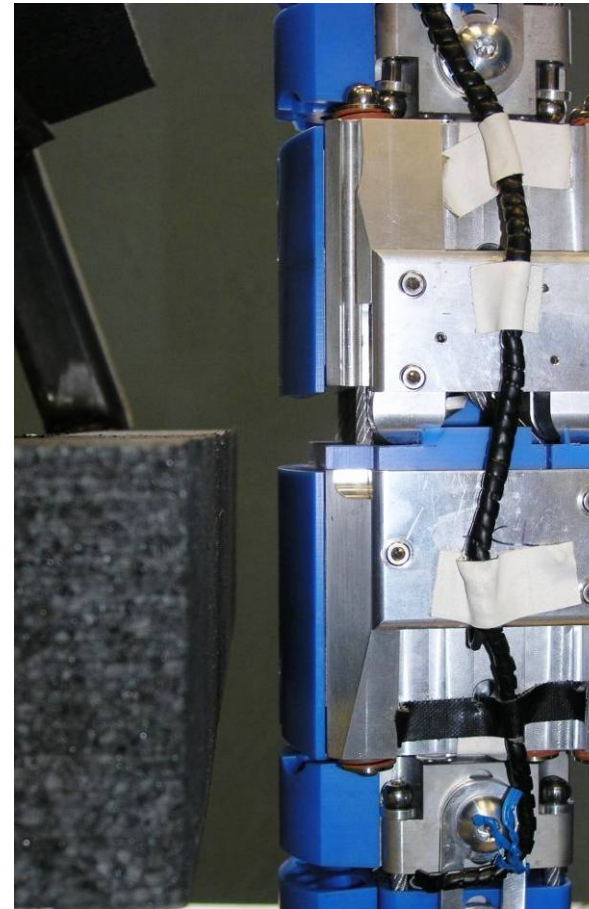
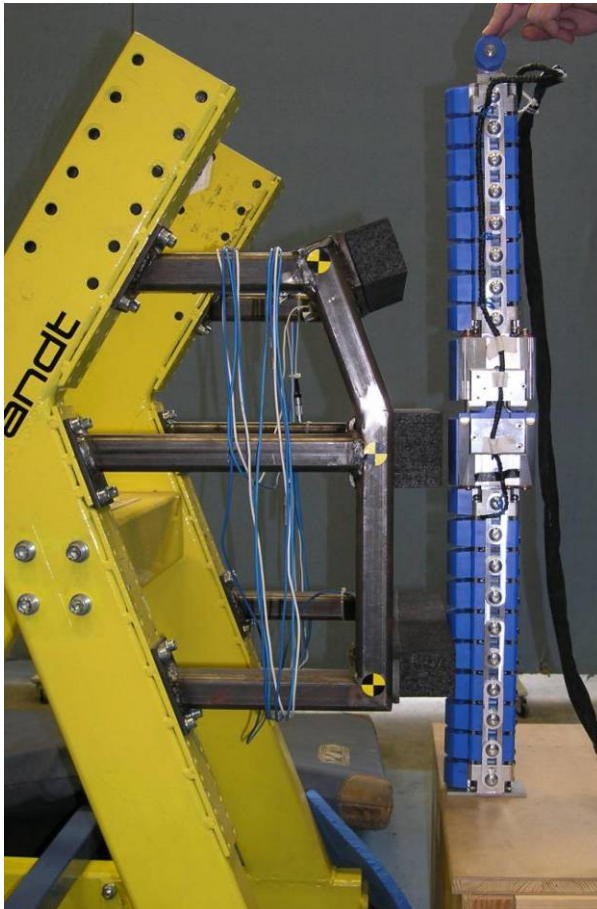


Tests with Test Rig (2)

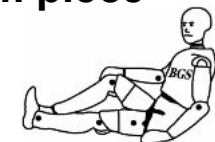
Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTG-25-1	-25		Impactor knee lower than
BAFGTG-25-2	-25		foam edge
BAFGTG-25-3	-25		
BAFGTG-50-1	-50		
BAFGTG-50-2	-50		
BAFGTG-50-3	-50		



Tests with Test Rig (3)

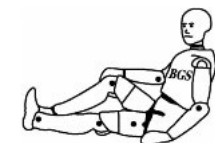


Impact height 0 mm: Centre of knee in line with upper edge of second foam piece

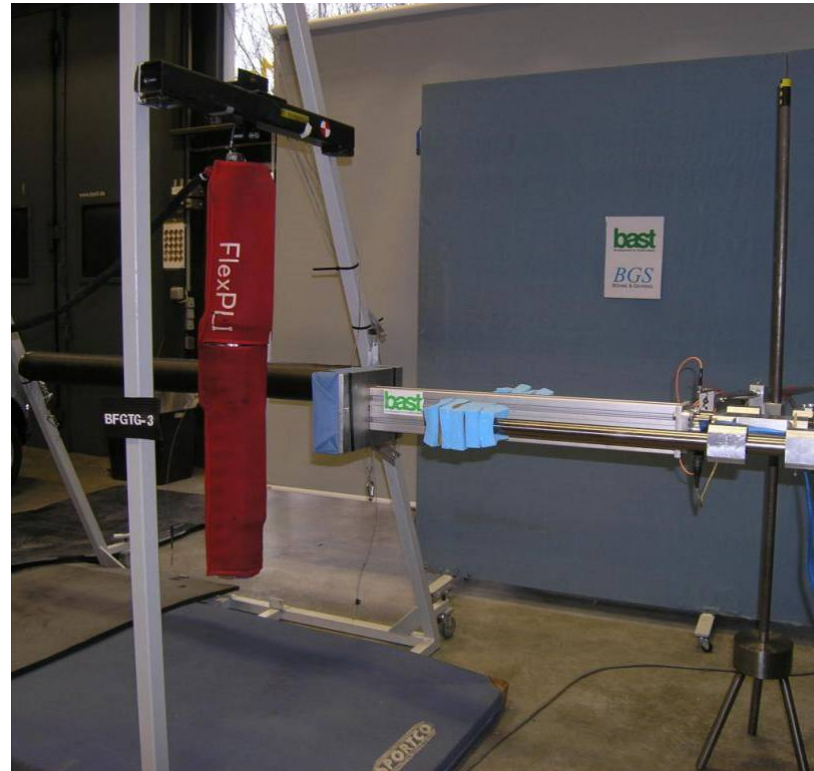


Inverse Tests (1)

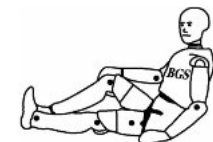
Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BAFGTI-1	0		Impactor knee in line with
BAFGTI-2	0		upper honeycomb edge
BAFGTI-3	0		
BAFGTI-4	0		
BAFGTI-5	0		



Inverse Tests (2)

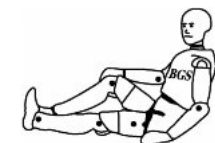


Impact height: Upper edge of aluminium honeycomb in line with centre of knee

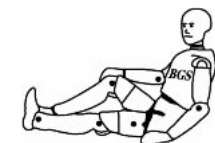
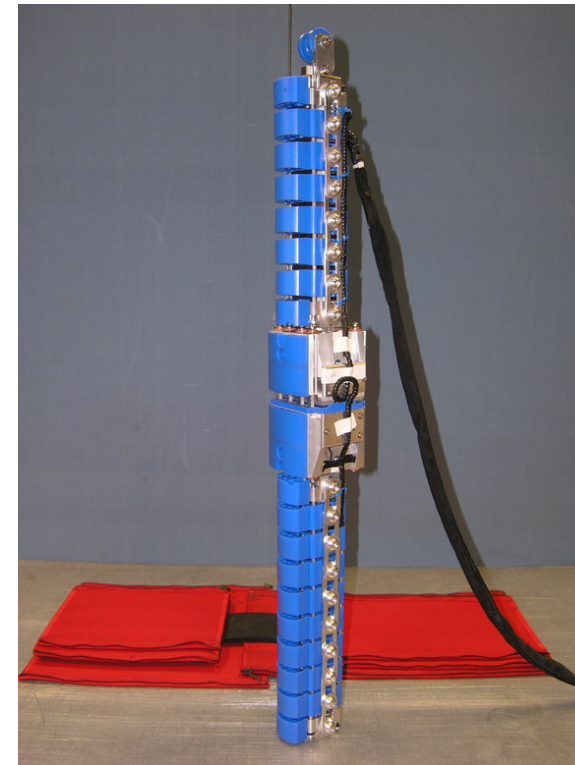


Comparison Tests Flex GT - GT α

Test No.	Impact height [mm]	Impact position (Y-value) [mm]	Remarks
BFGTA1-N	25	-232	A-Class L2a
BFGTA2-N	25	530	A-Class L3b
BFGTG1-N	75	-357	Golf L1b
BFGTG2-N	75	51	Golf L2b

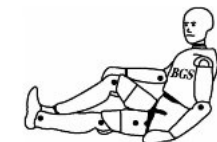
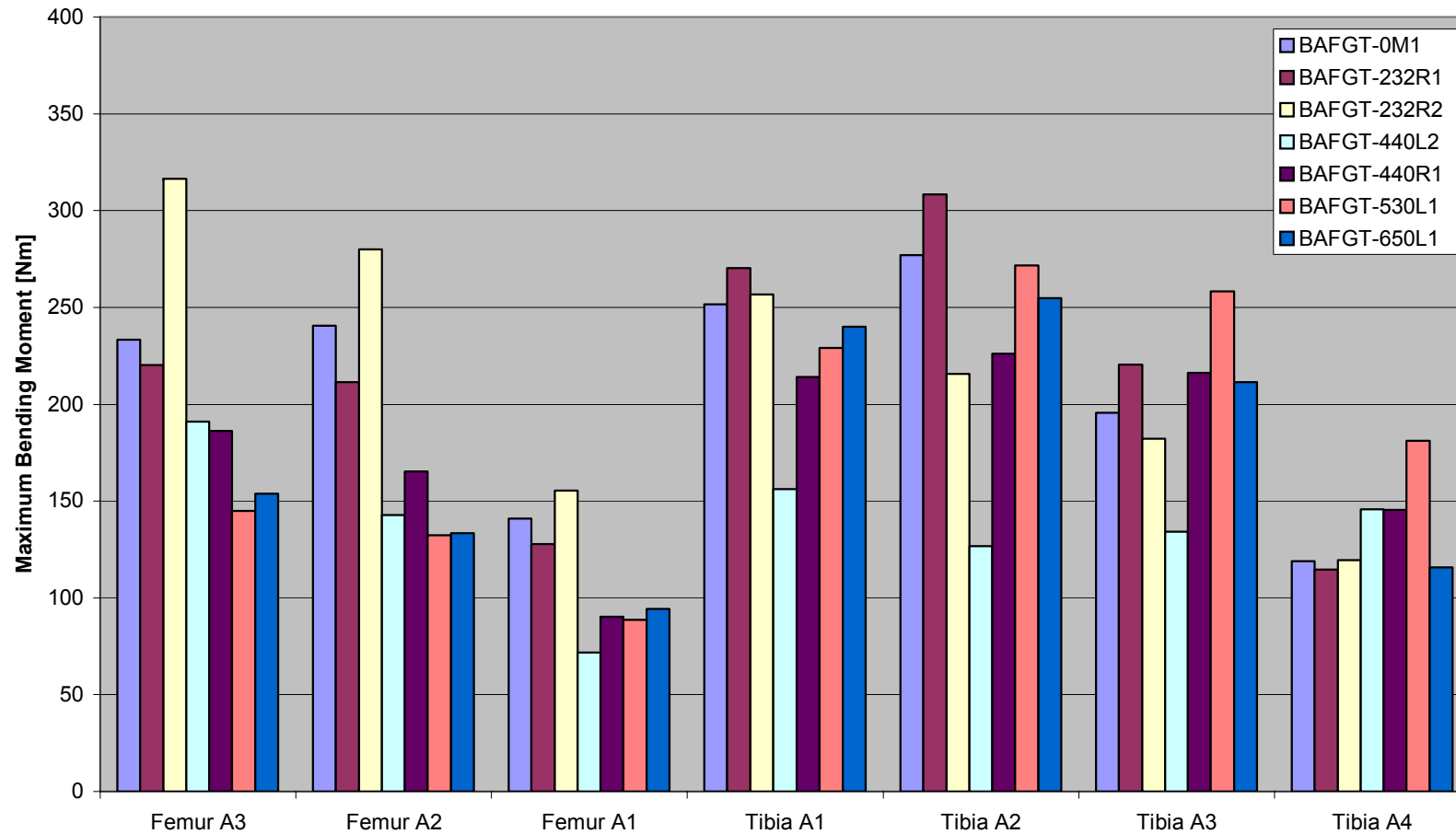


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 - Handling and usage of the impactor
- Conclusions



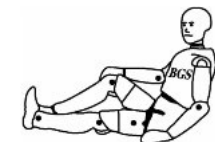
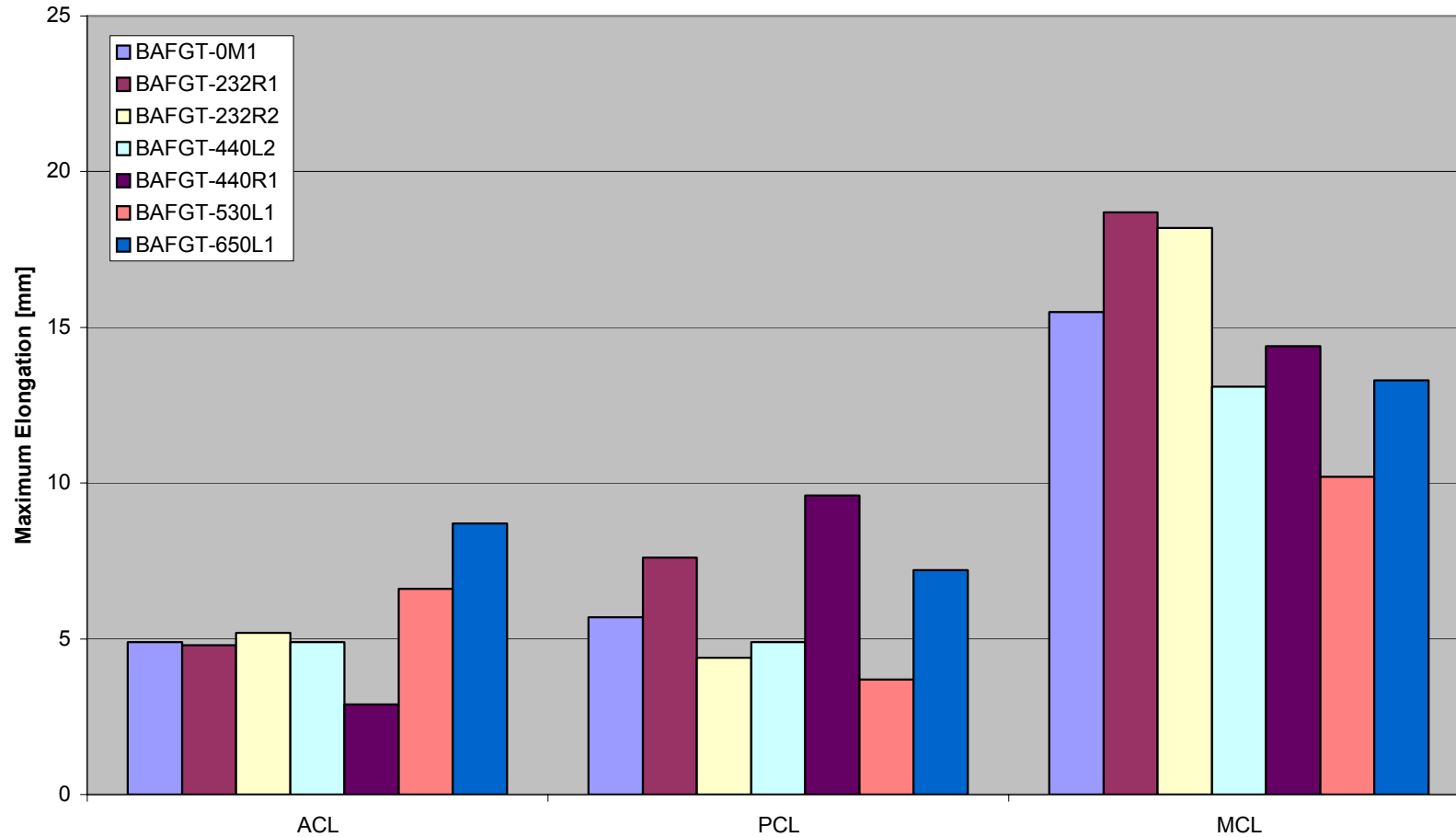
Test Results A-Class

Mercedes Benz A-Class Bending Moments



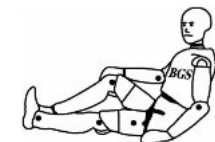
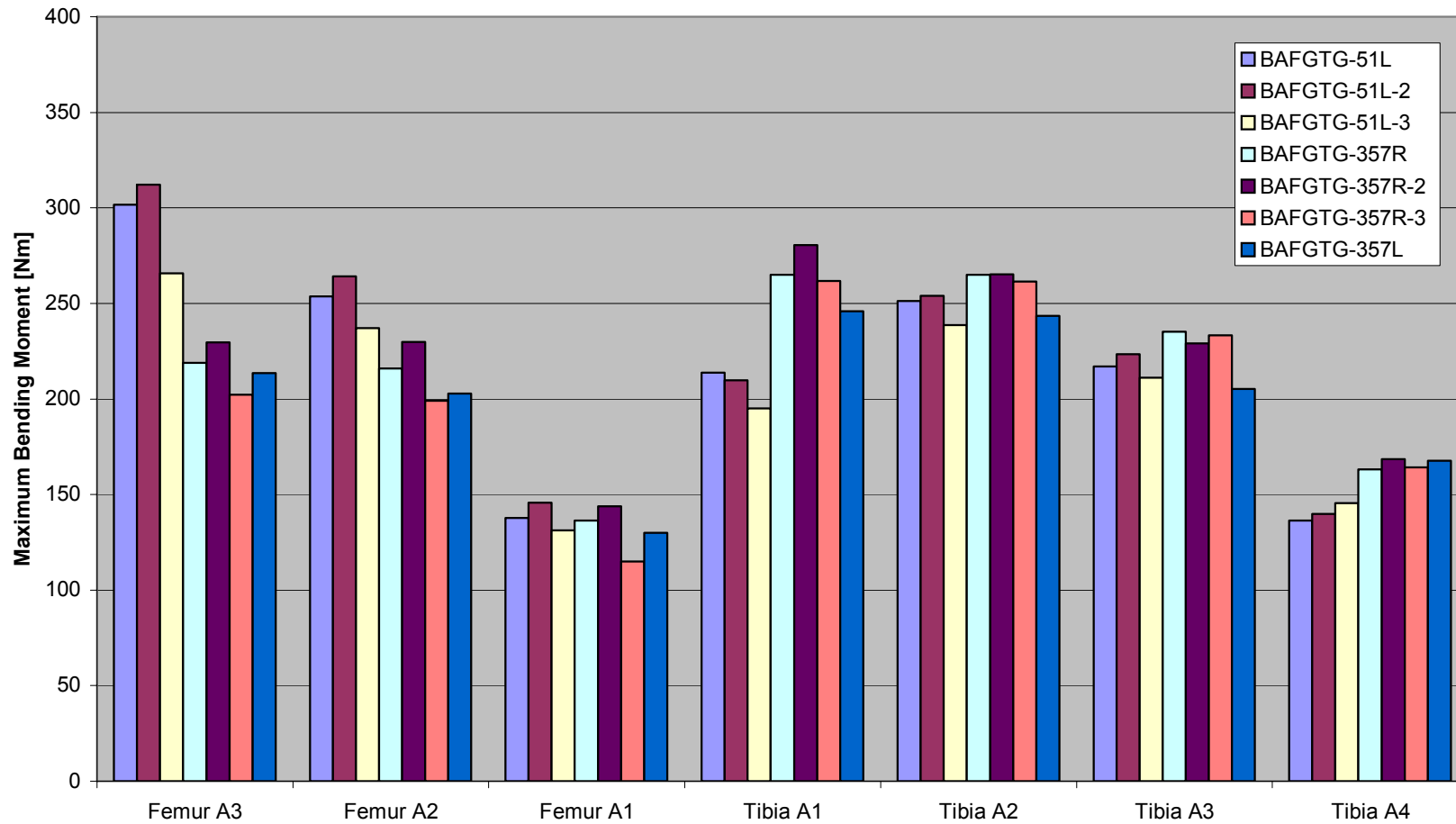
Test Results A-Class

Mercedes-Benz A-Class Elongations



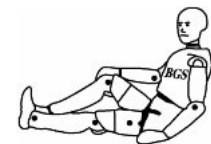
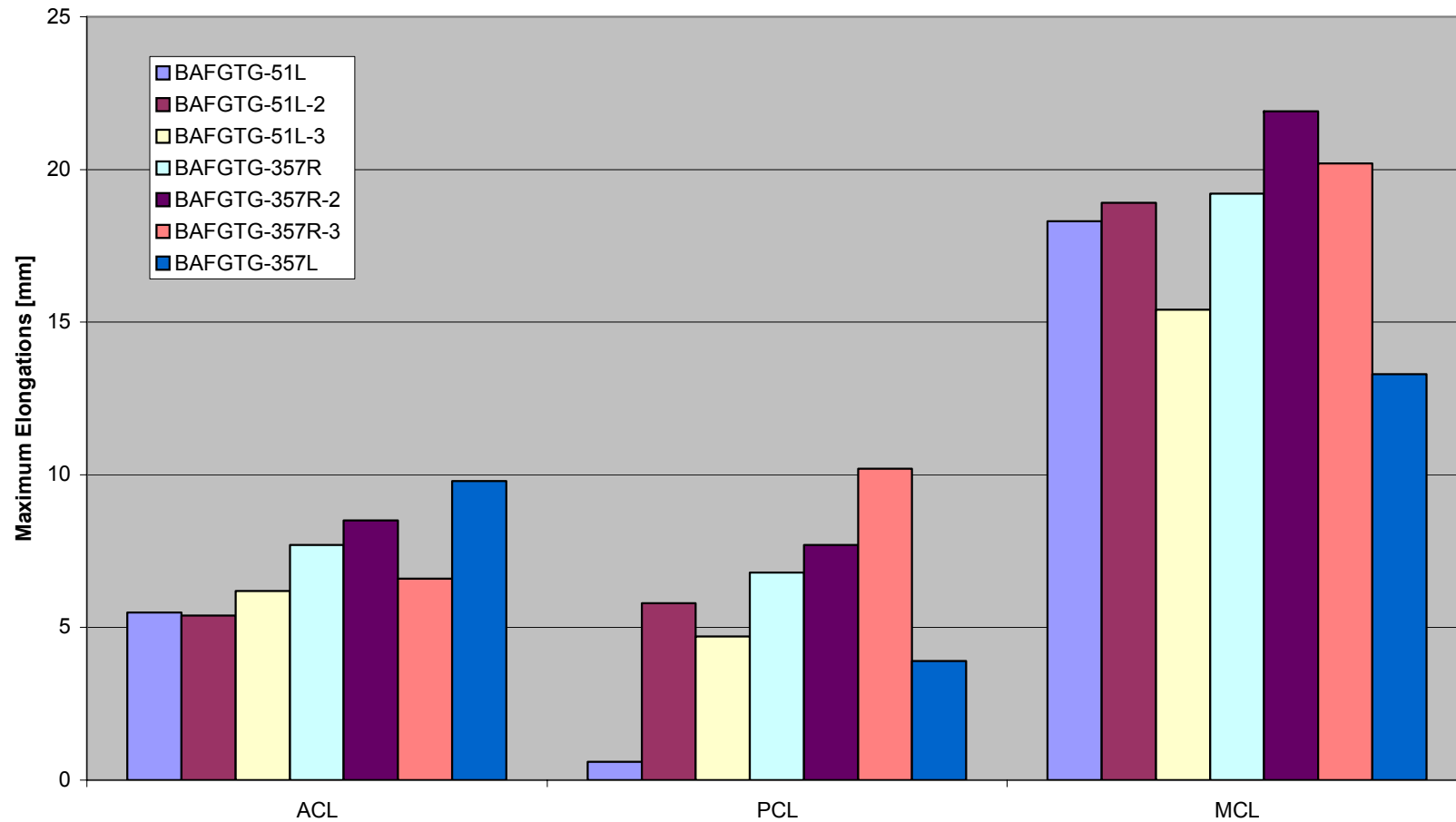
Test Results Golf

Volkswagen Golf Bending Moments



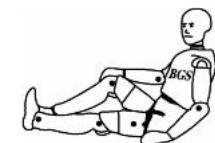
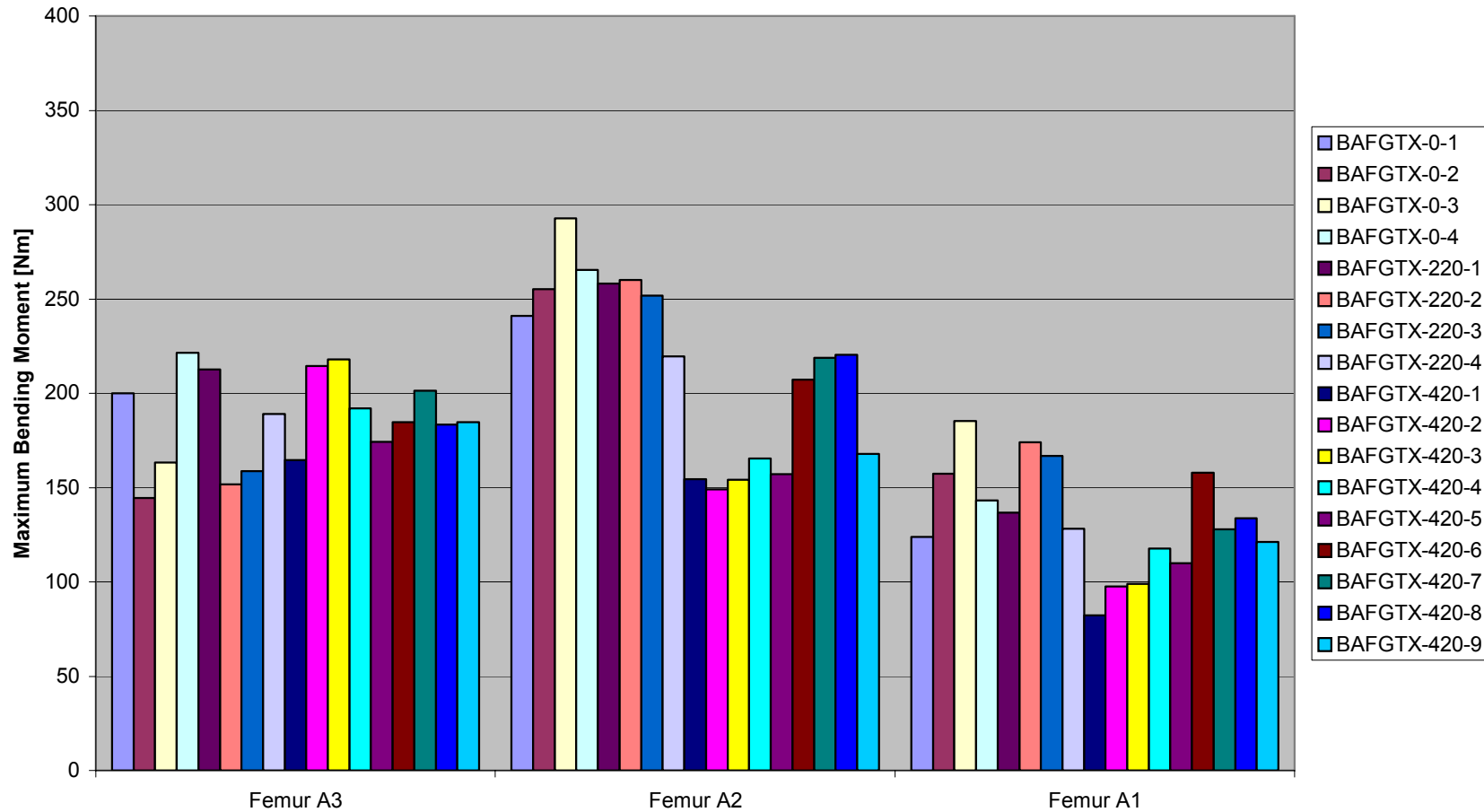
Test Results Golf

Volkswagen Golf Elongations



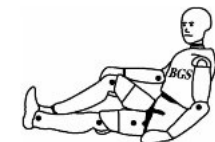
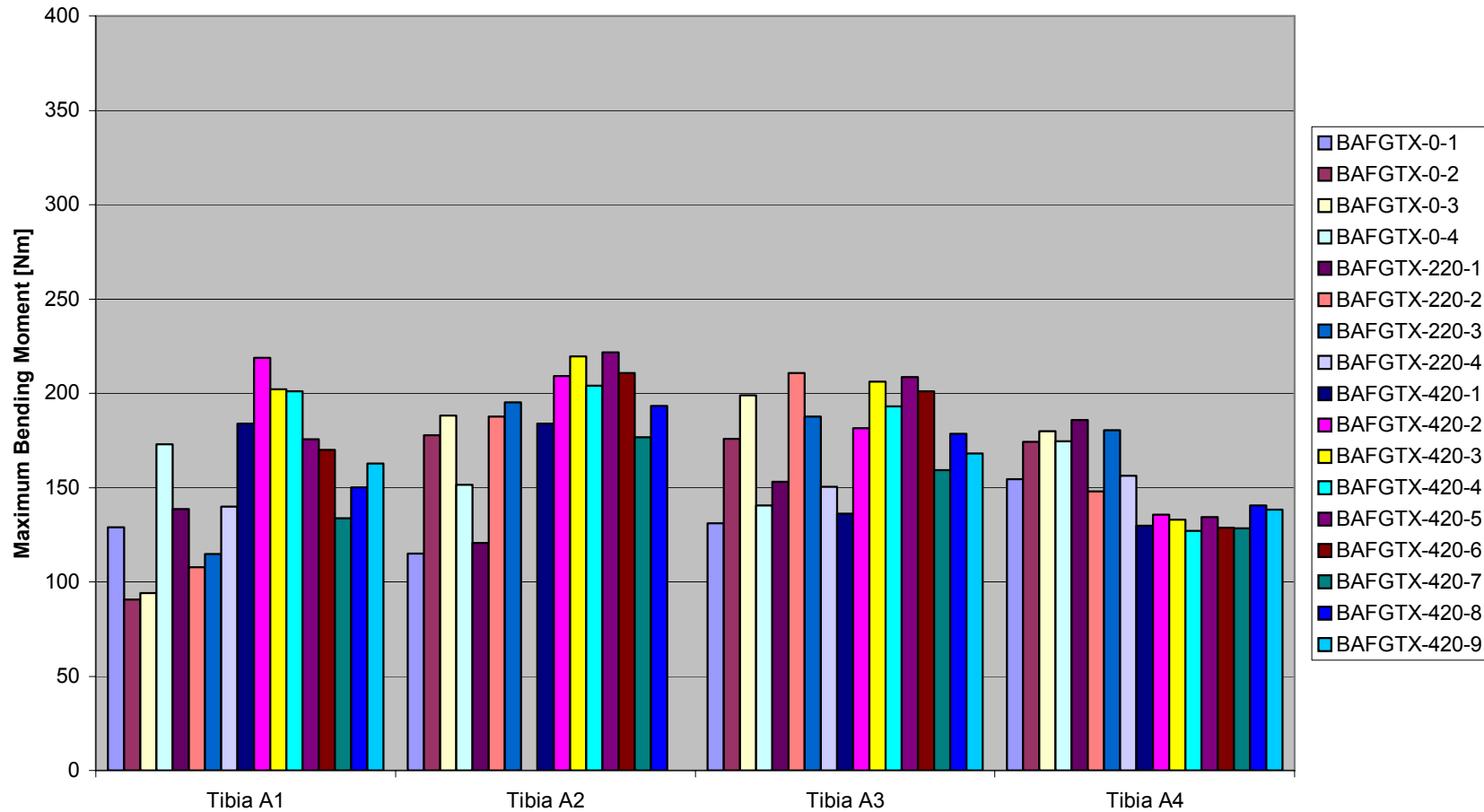
Test Results XK

Jaguar XK Femur Bending Moments



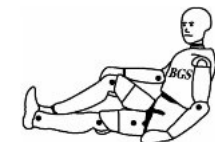
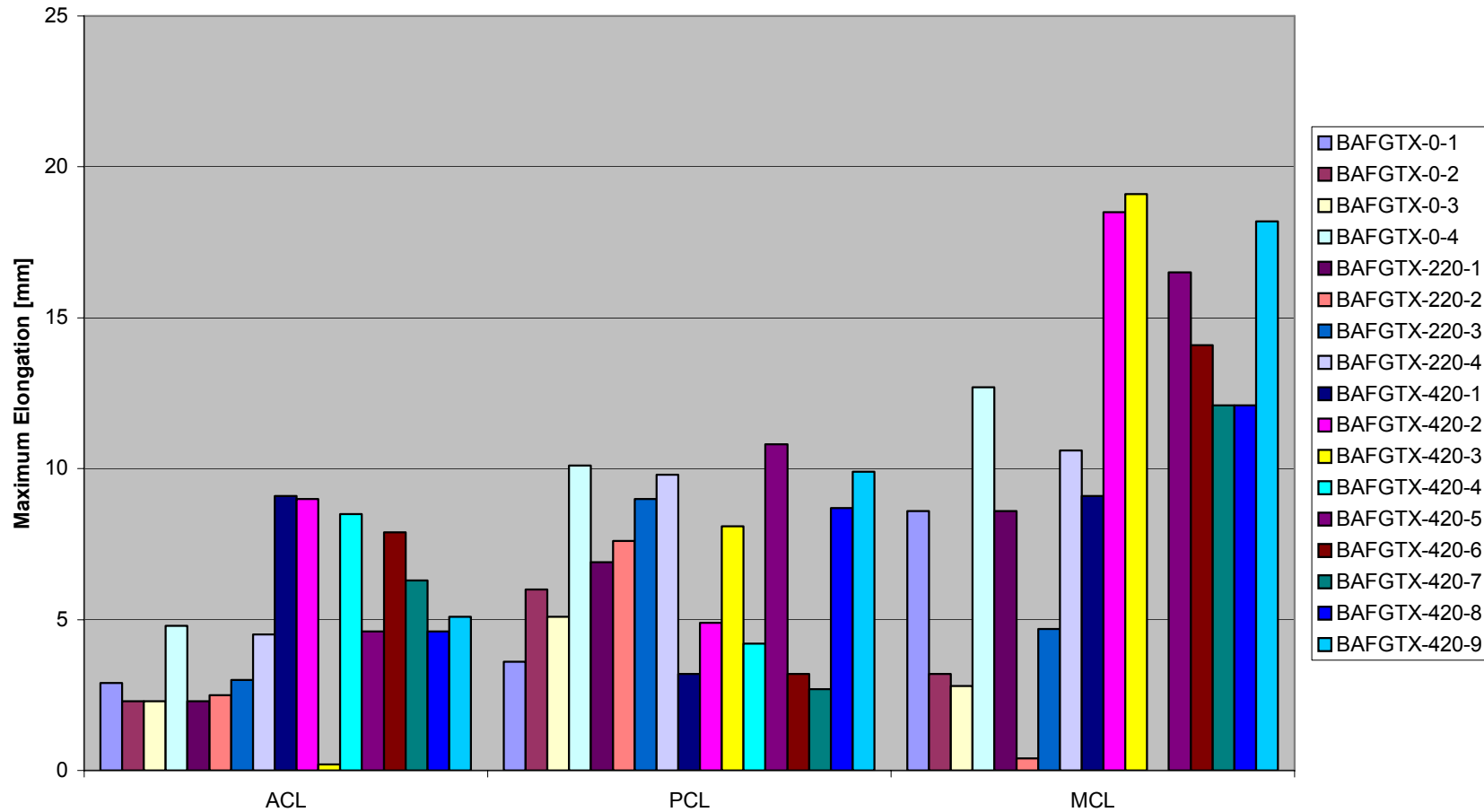
Test Results XK

Jaguar XK Tibia Bending Moments



Test Results XK

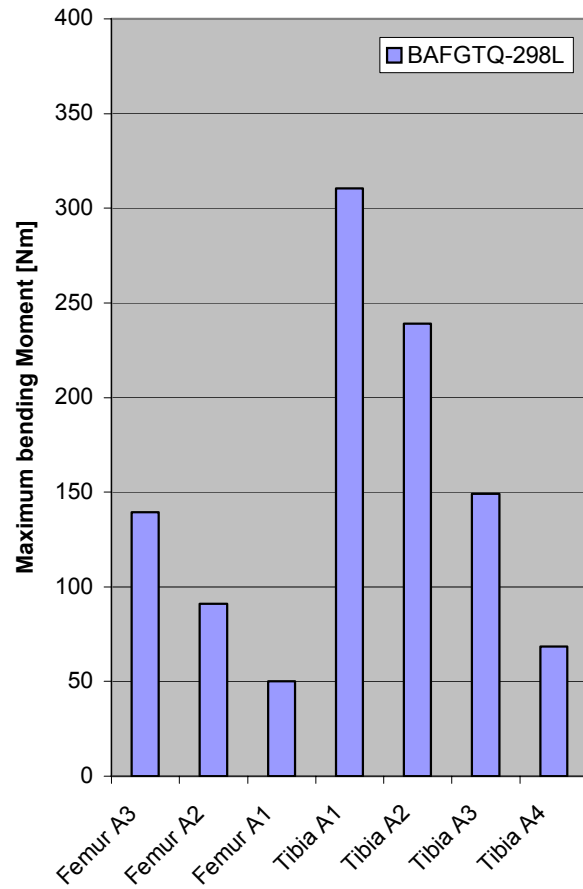
Jaguar XK Elongations



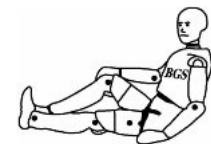
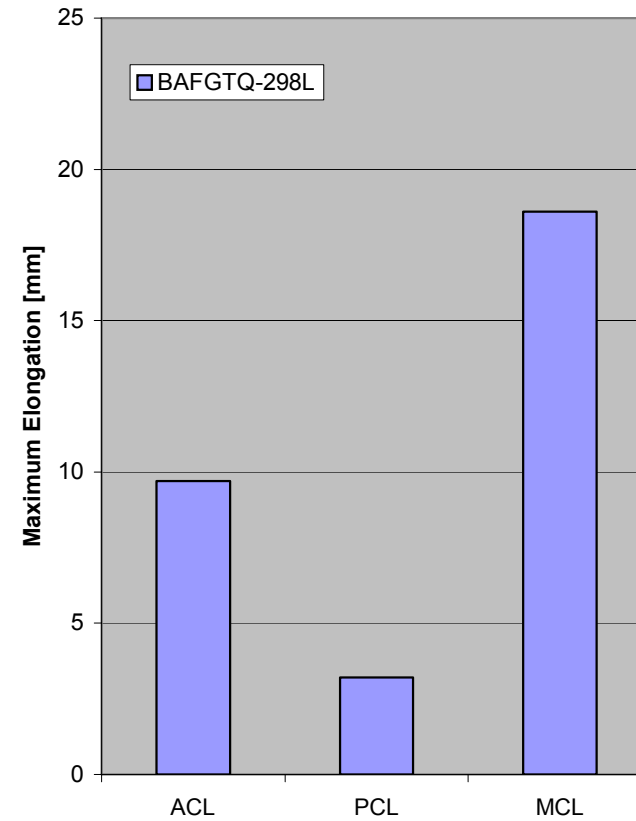
Test Results Q7 (Flex GT)

LBRL=501 mm

Audi Q7 Bending Moments

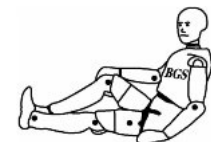


Audi Q7 Elongations



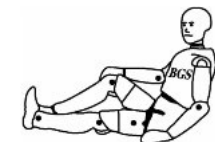
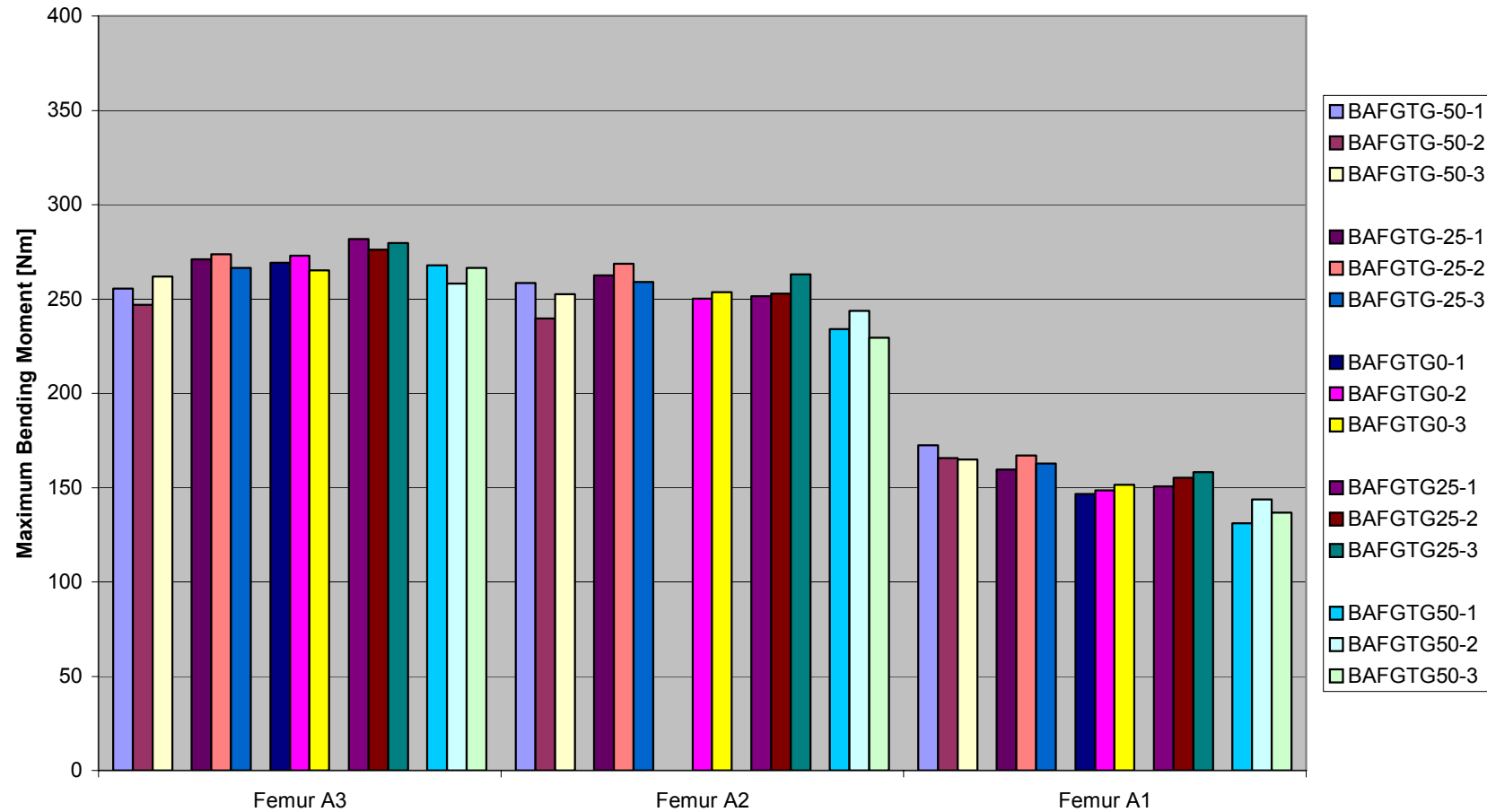
LBRL=501 mm

- WG 17 Legform Impactor
 - Max. Acceleration: -85,9 g
 - Max. Bending angle: 17,9°
 - Max. Shear Displacement: 2,7 mm
- WG 17 Upper Legform Impactor
 - Max Bending Moment: 347,9 Nm
 - Max. Sum of Forces: 6,23 kN



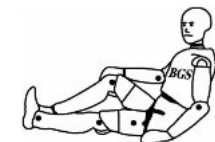
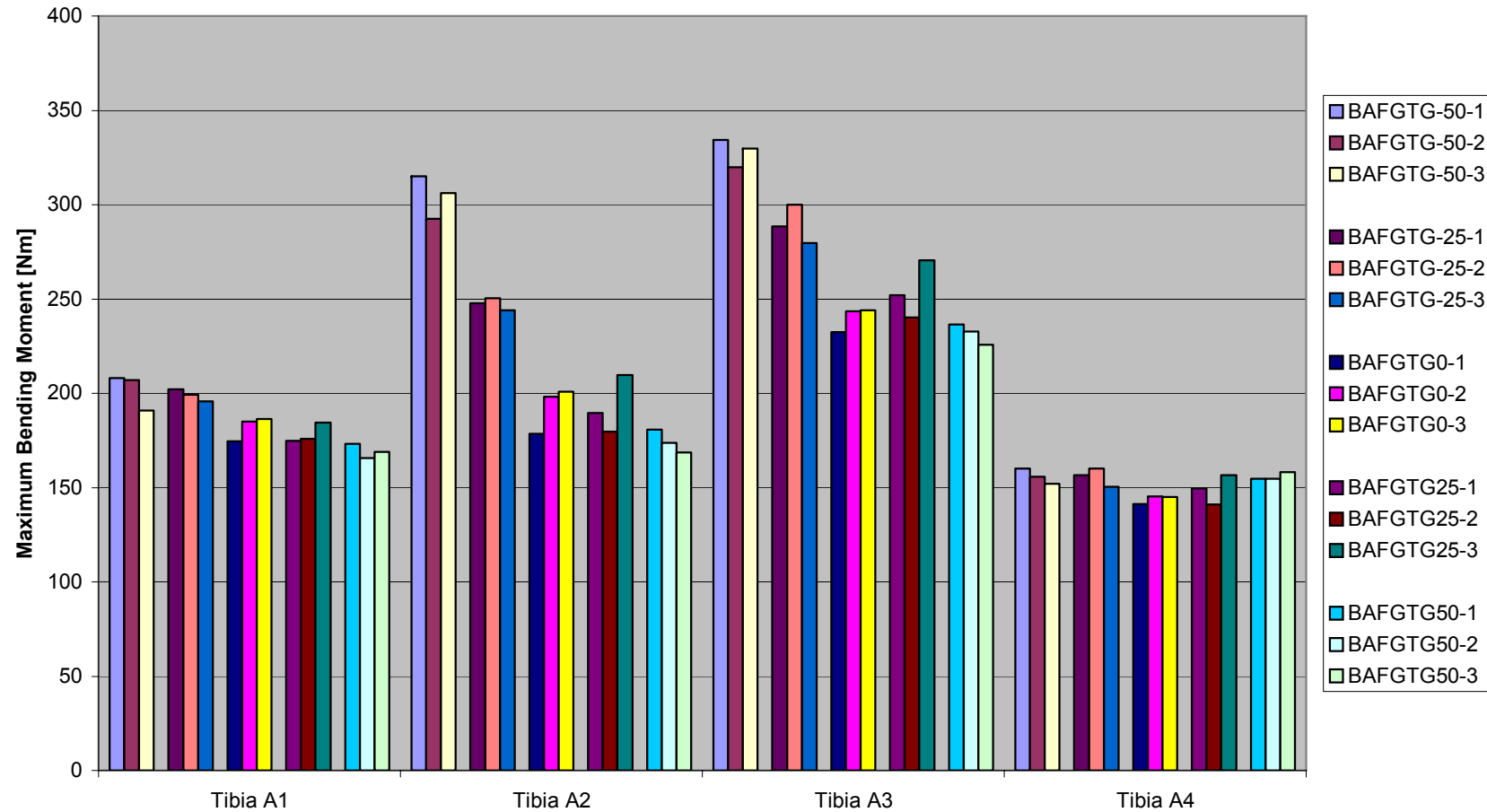
Test Results Test Rig

Test Rig Femur Bending Moments



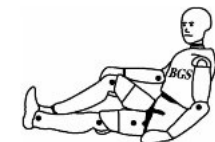
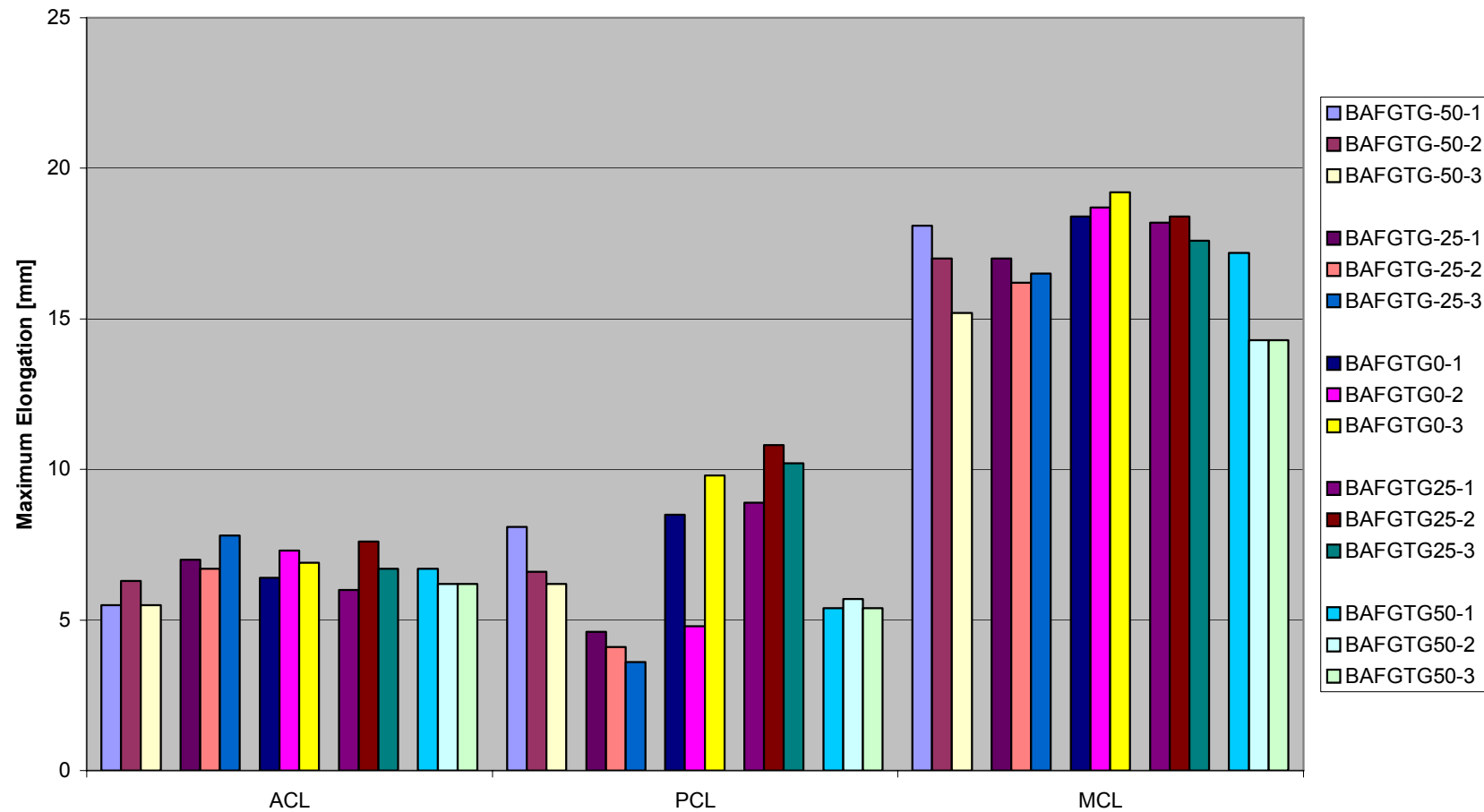
Test Results Test Rig

Test Rig Tibia Bending Moments



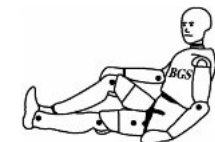
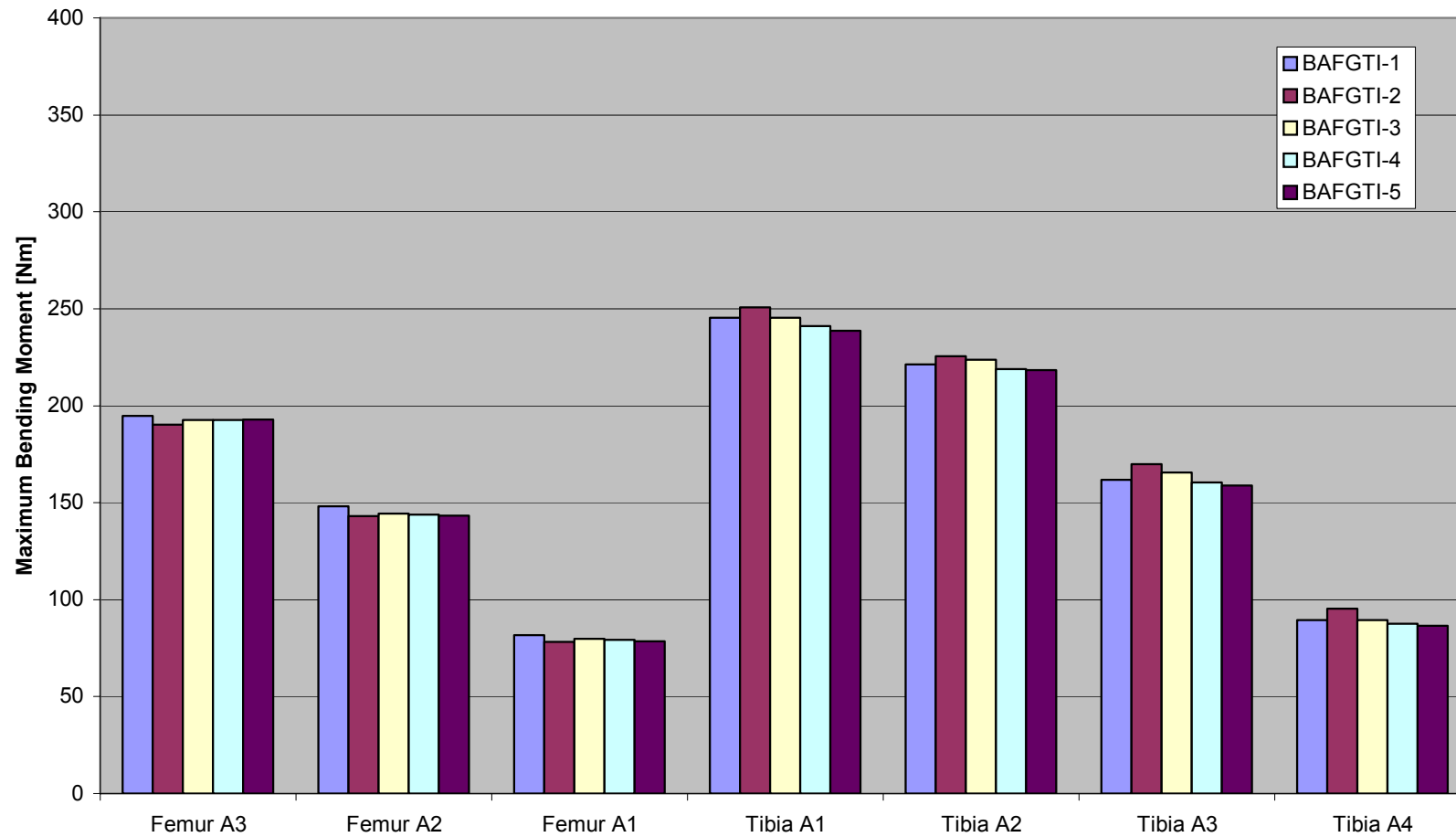
Test Results Test Rig

Test Rig Elongations



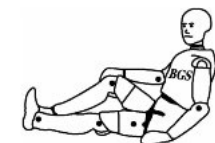
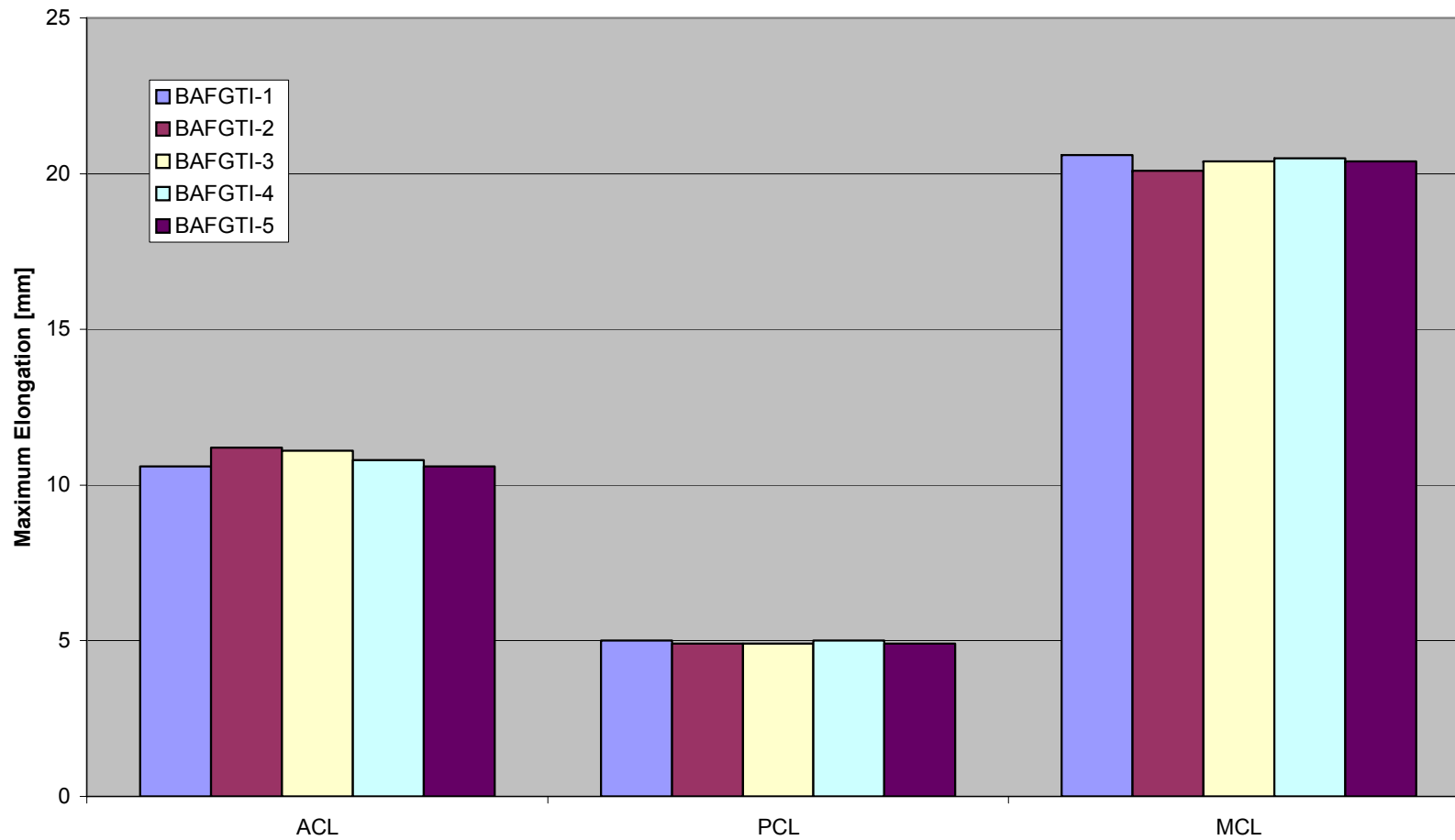
Test Results Inverse Tests

Inverse Tests Bending Moments

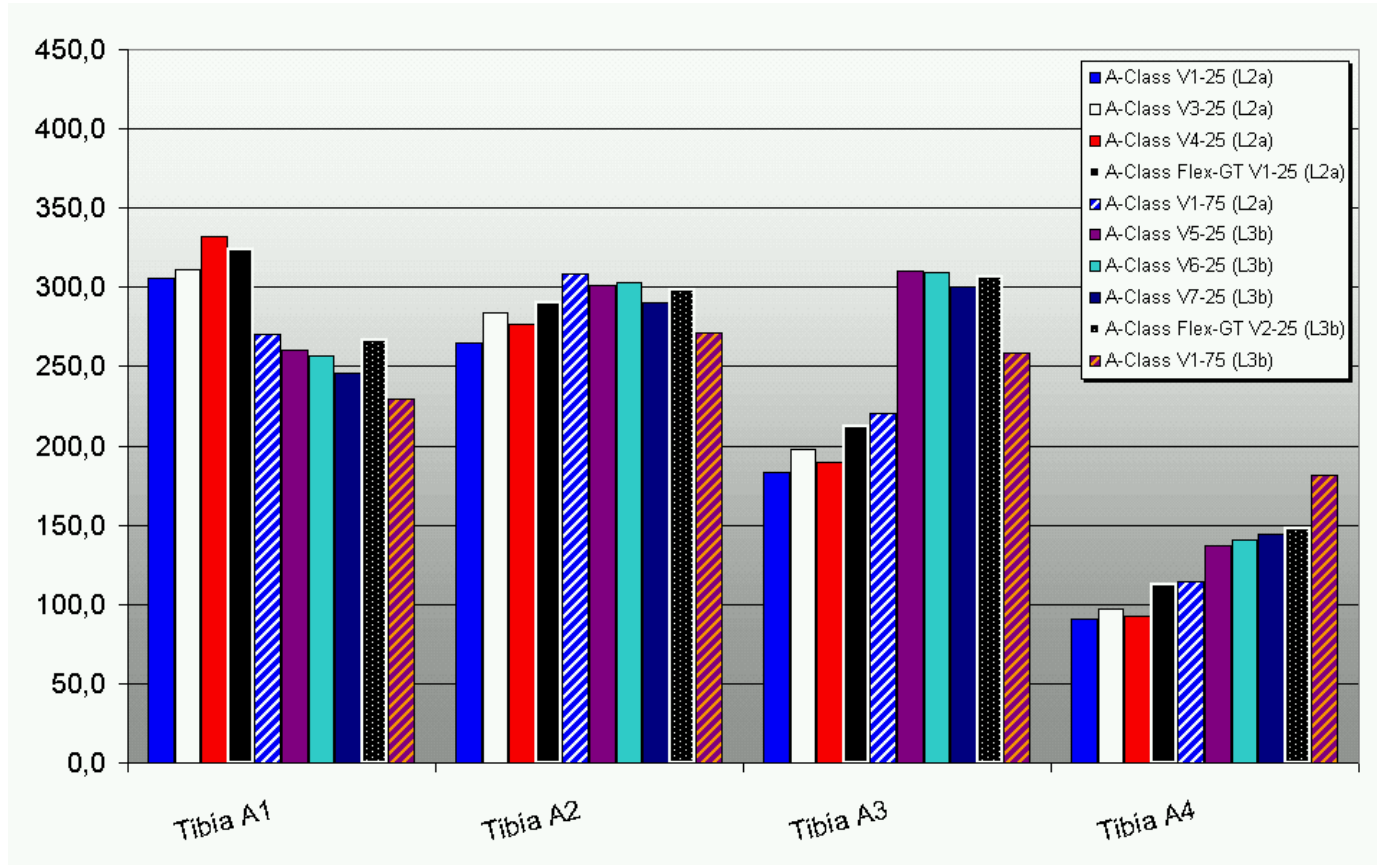


Test Results Inverse Tests

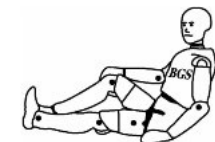
Inverse Tests Elongations



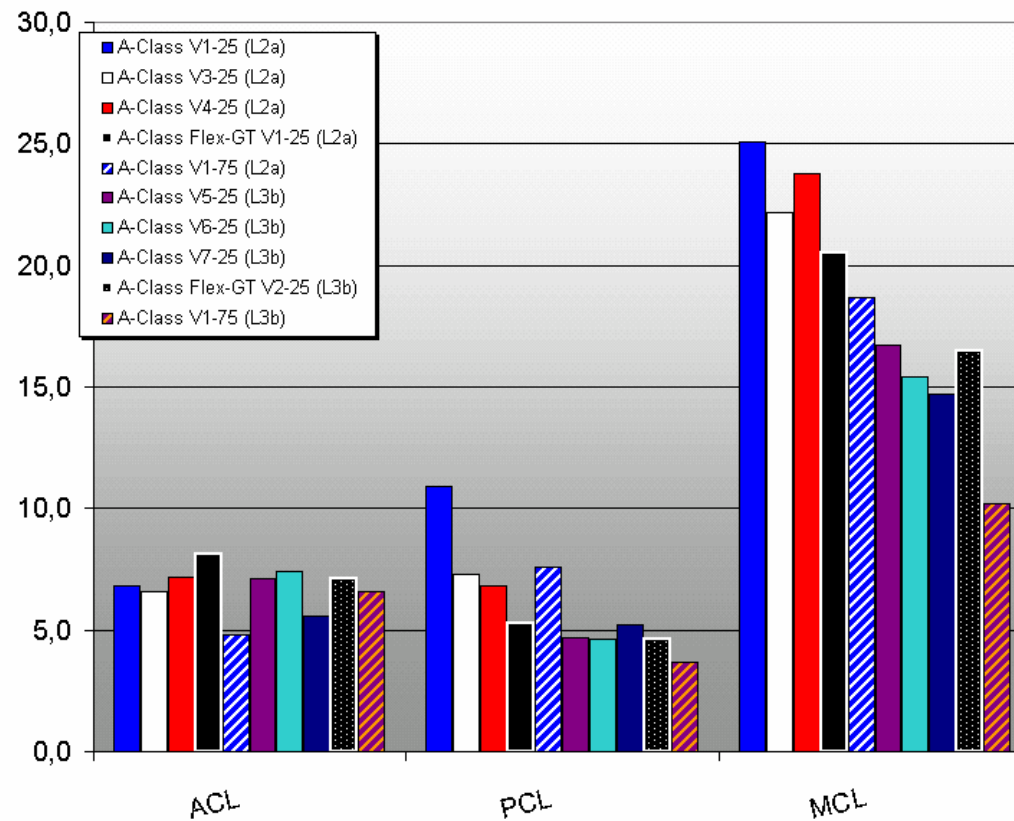
A-Class Tibia Bending Moments



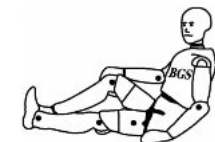
Graphic provided by O. Zander, BAST, including tests of the BAST-only test program



A-Class Elongations

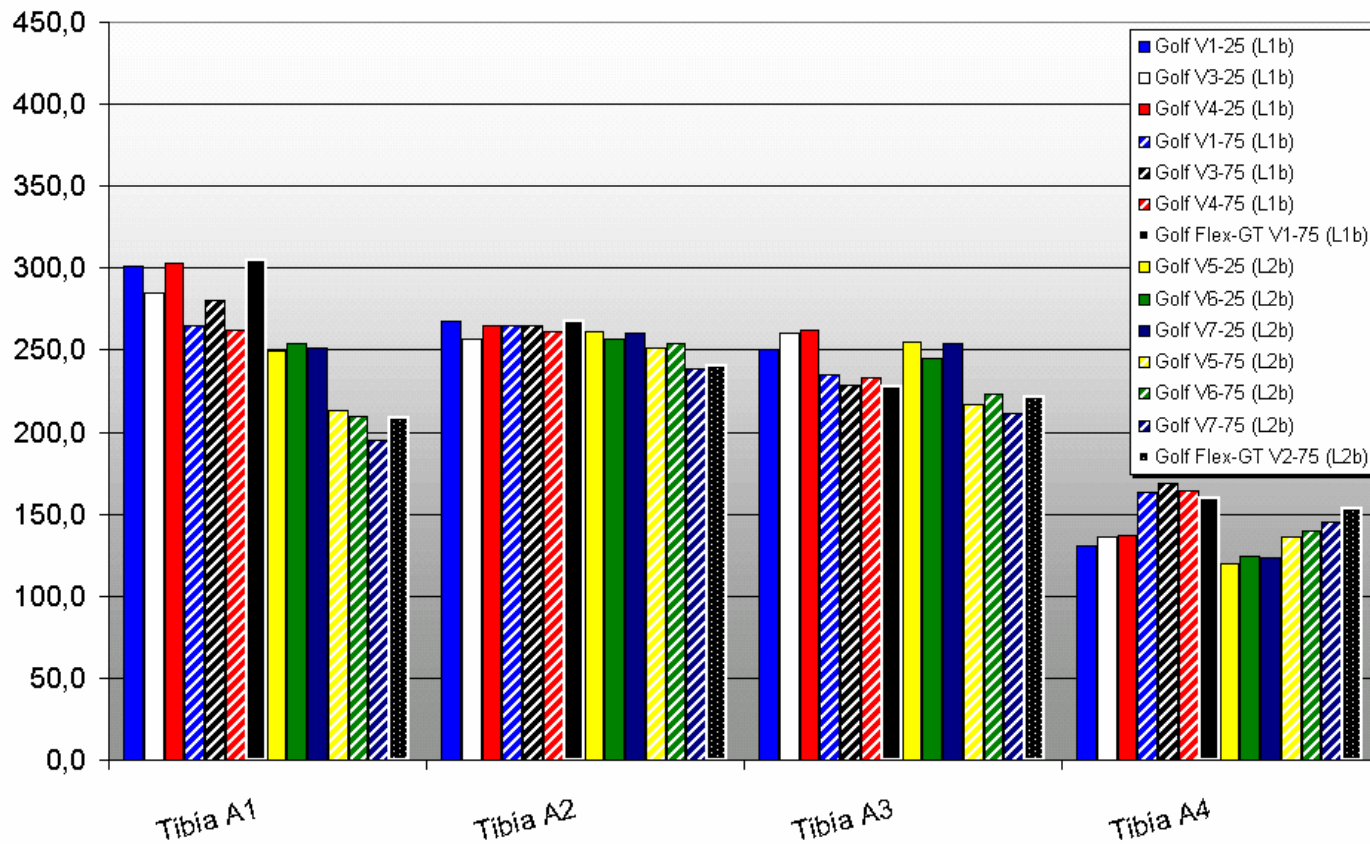


Graphic provided by O. Zander, BAST, including tests of the BAST-only test program

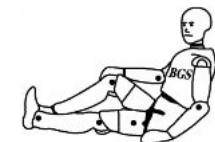


Test Results Flex GT - GT α Comparison

Golf Tibia Bending Moments

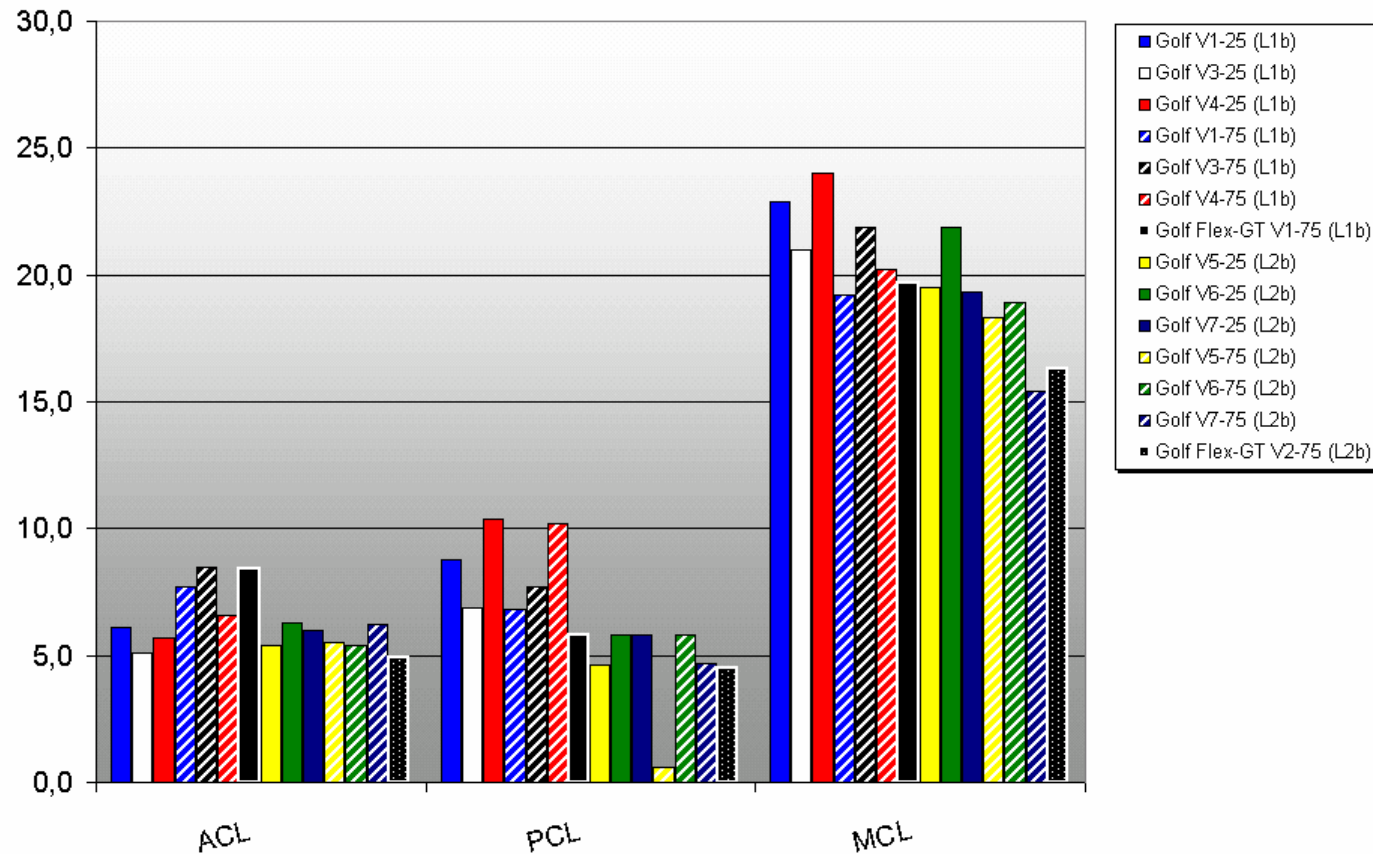


Graphic provided by O. Zander, BAST, including tests of the BAST-only test program

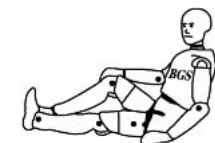


Test Results Flex GT - GT α Comparison

Golf Elongations

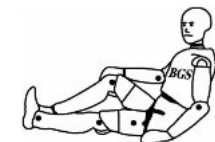
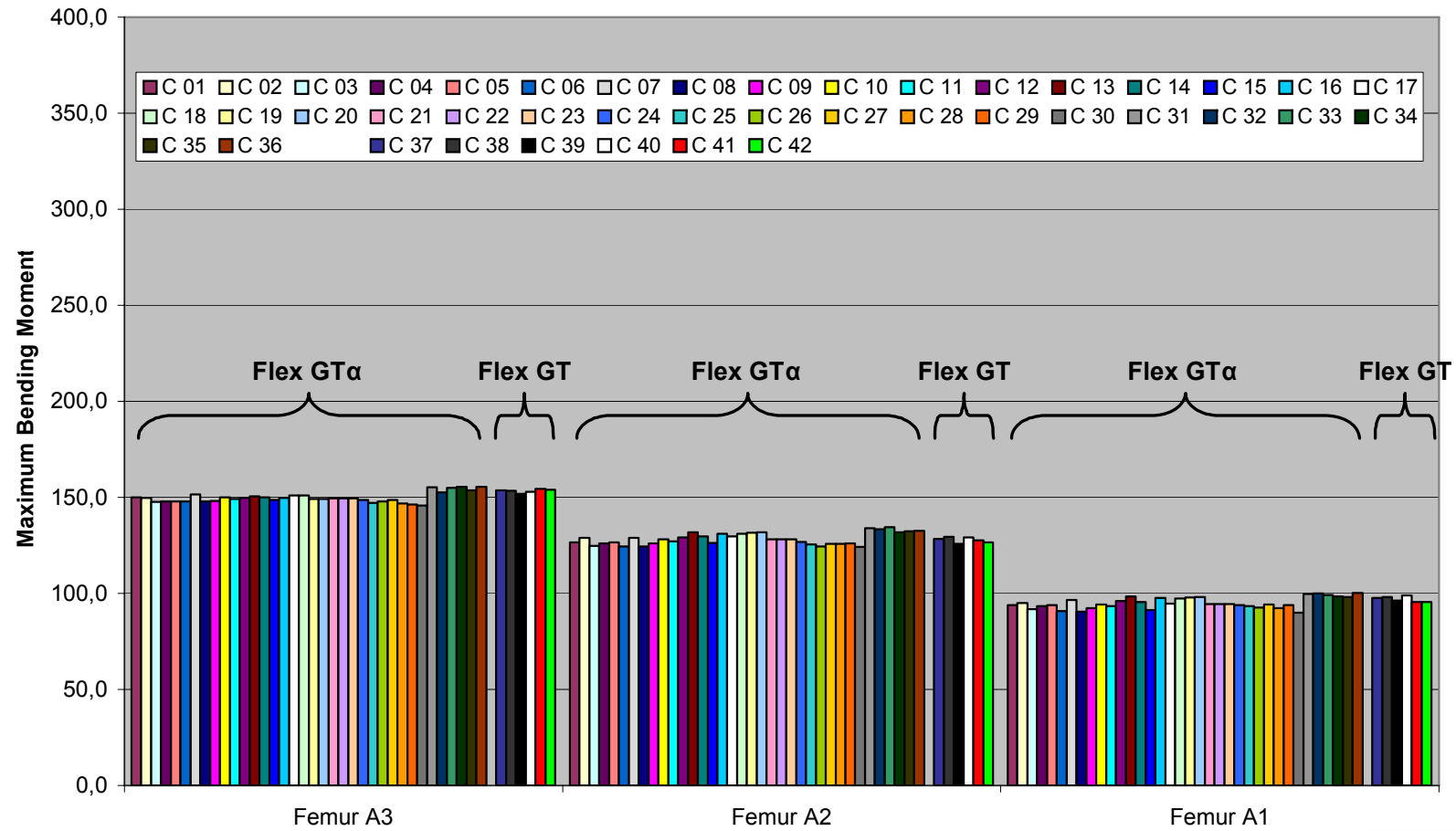


Graphic provided by O. Zander, BAST, including tests of the BAST-only test program



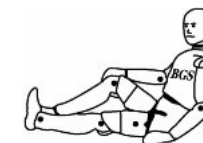
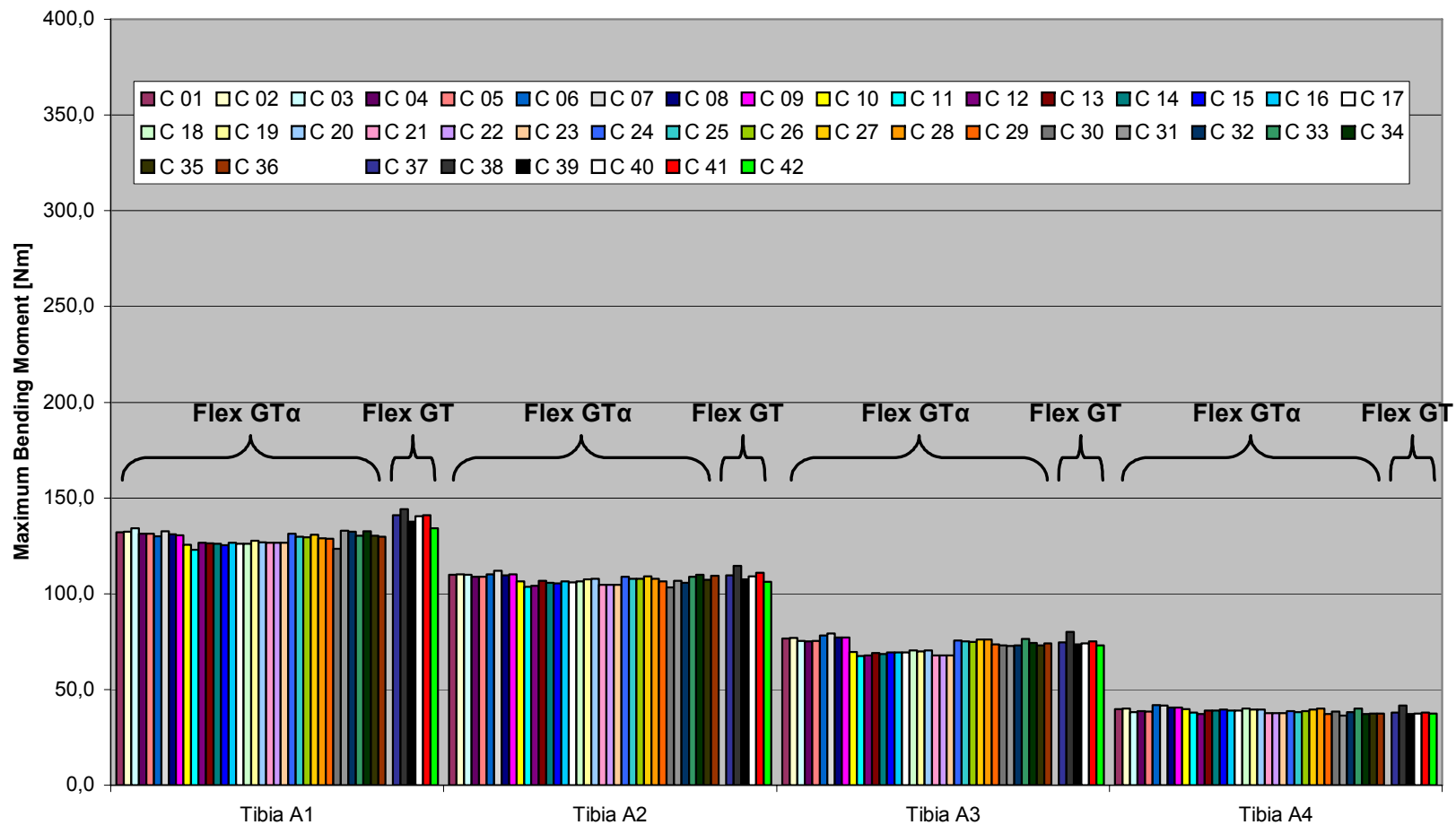
Certification Results

Certifications: Femur Bending Moments



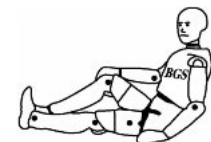
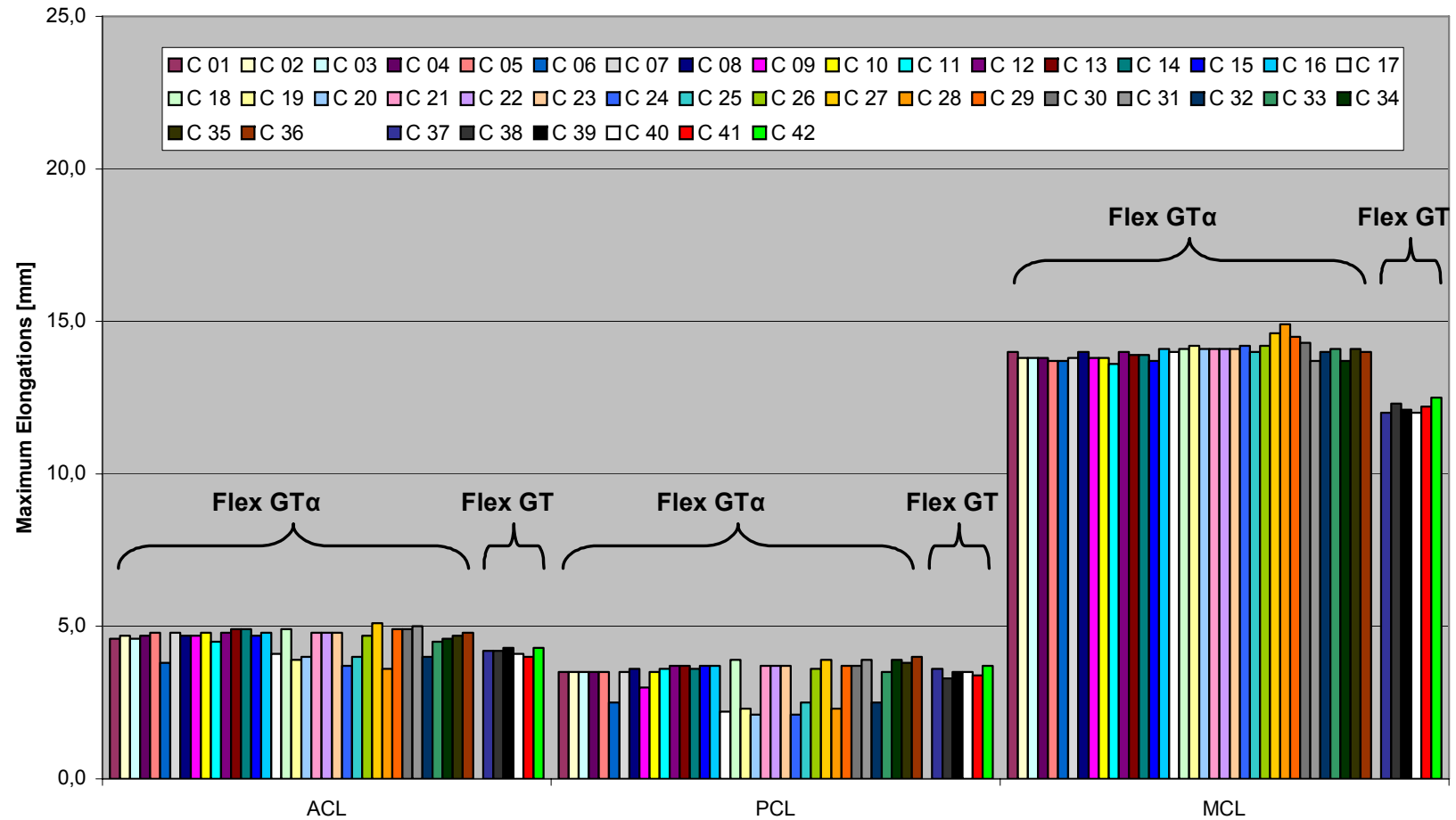
Certification Results

Certifications: Tibia Bending Moments

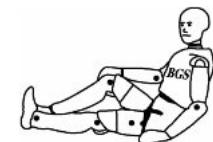


Certification Results

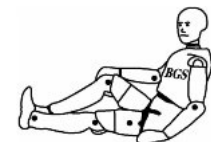
Certifications: Elongations



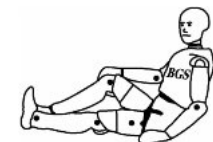
- Test preparation
- Test execution
- Inspection after test
- Certification
- Time between tests
- Particularities
 - Wiring
 - Defects
- Proposals



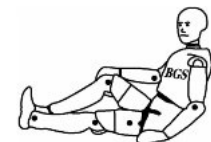
- Installation of the legform support onto the accelerator
- Height adjustment of the guiding system to achieve the required impact height
- Installation of the certification rig next to the impact test stand (in order to avoid disconnecting and connecting the sensor cables between impact test and certification)
- Connection of the impactor instrumentation to the data acquisition system and its preparation:
10 – 17 channels (10 standard, 7 redundant)
(EEVC WG 17 legform impactor: 3 channels; max. no. of channels required for current pedestrian protection tests: 5.)
- Certification test



- Settings are similar to tests with the EEVC WG 17 legform
 - 40 km/h, ballistic flight, no rotations
 - Different impact height (25 mm / 75 mm)
- Special care of the 17 cables is required
 - Likely to be damaged when the impactor falls on them
 - Influence of the flight behaviour due to the cable mass
- Roller guiding of Flex GT α allowed rotation around z-axis during acceleration
 - Possible reason for scatter in ACL and PCL results
 - Flex GT with modified roller bracket to avoid this rotation



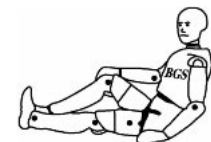
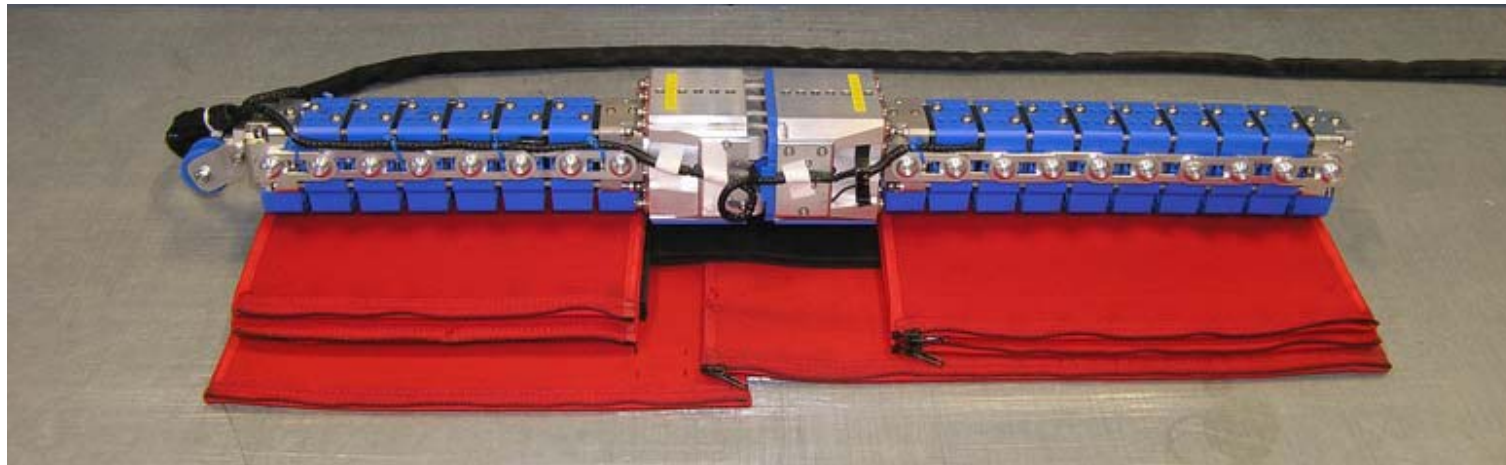
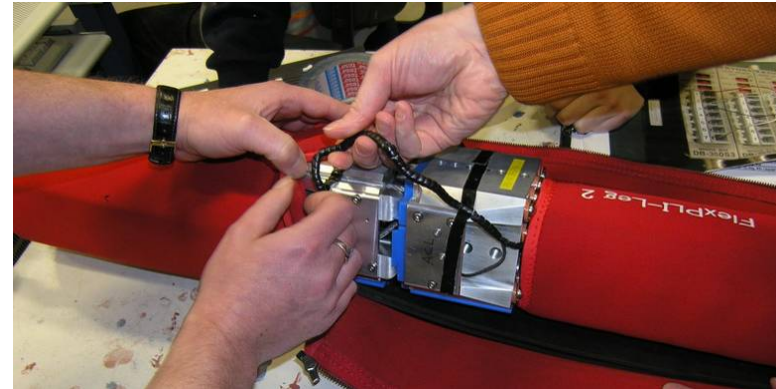
- Edged shape of the legform's impact surface seems to increase rotation around z-axis during impact
 - Possible reason for scatter in ACL and PCL results
- Impact accuracy detection by paint spot is difficult with Flex GT α
 - Due to movement of the two outer skin pieces
 - Flex GT with one-piece outer skin shows only little skin movement
- Behaviour after impact
 - Higher flight curves and greater rotations around y-axis, compared with the EEVC legform, were observed in some cases.



Inspection after test

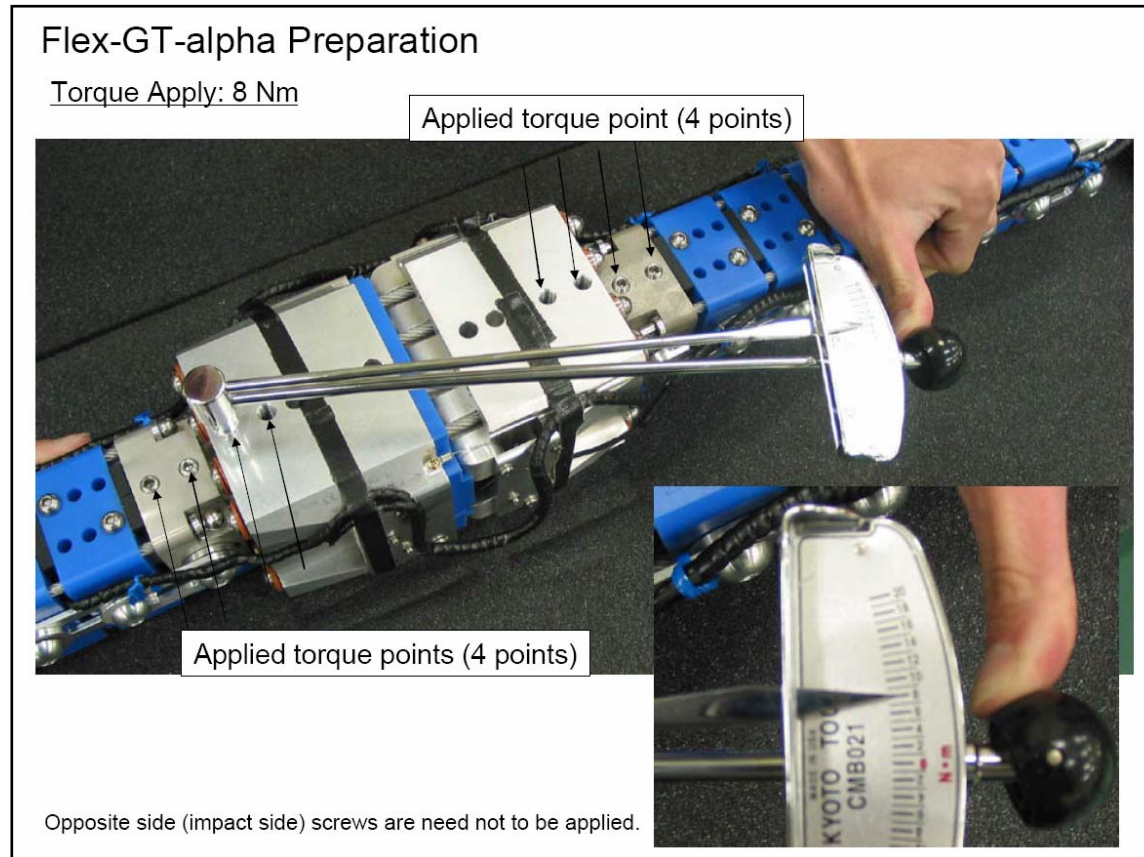
- Visual inspection of the impactor components and the cabling

Impactor shown on photographs is Flex GT α

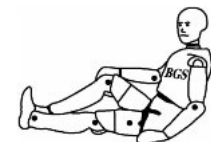


Inspection after test

- Verification of the torque of 8 screws

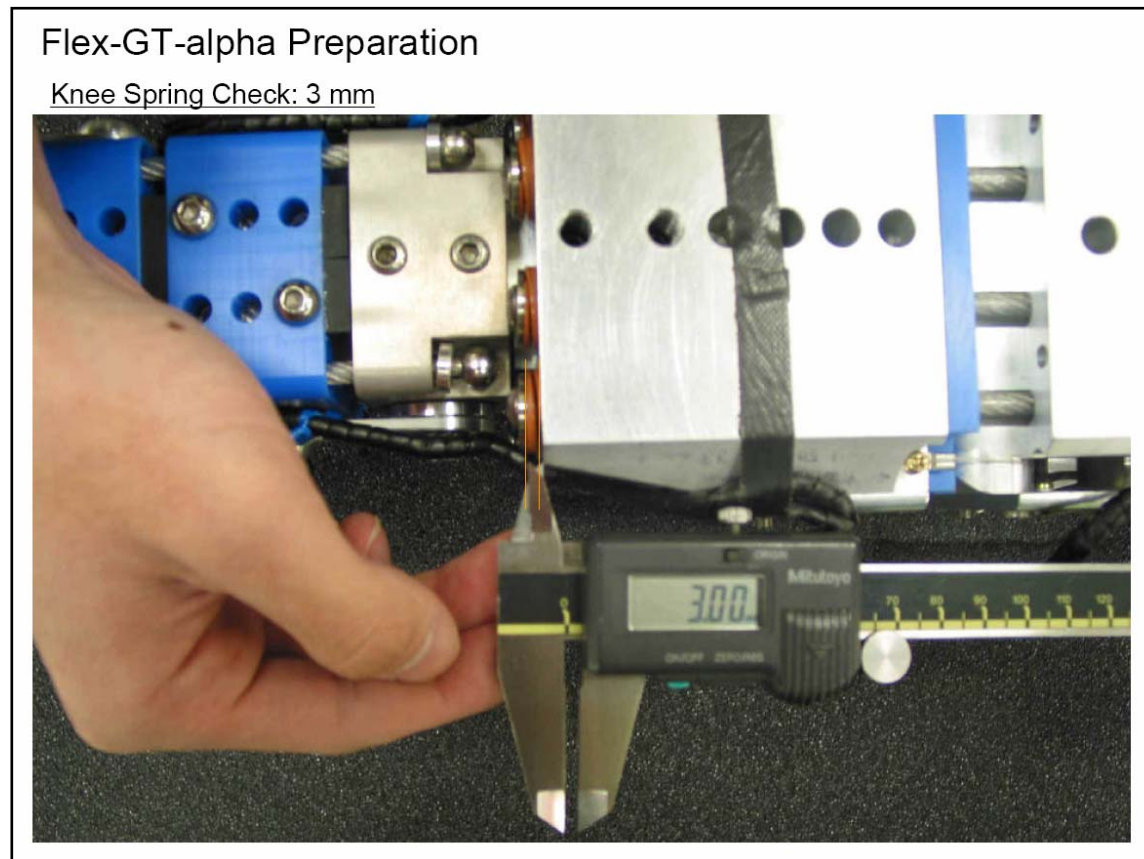


(Flex GT α Handling Manual, Konosu, 2006)

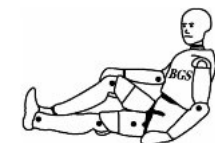


Inspection after test

- Check of the length of the 20 knee spring ends



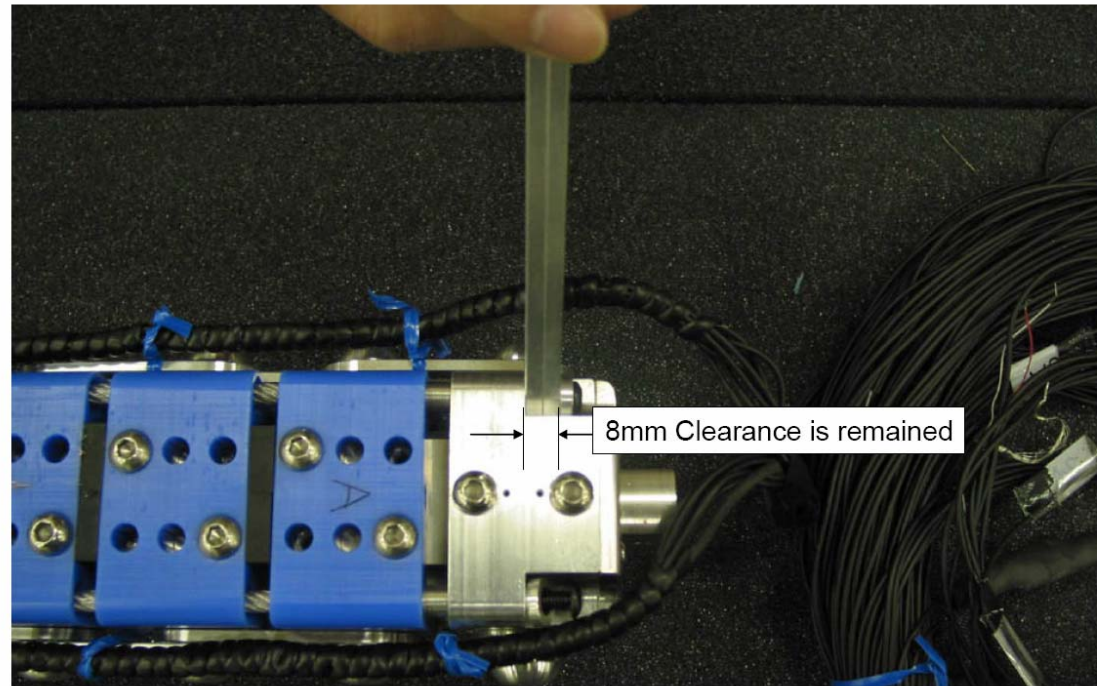
(Flex GT α Handling Manual, Konosu, 2006)



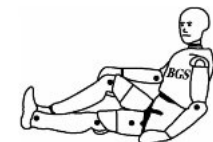
- Check of the length of the 4 upper leg bending stopper cable ends

Flex-GT-alpha Preparation

Bending Stopper Cable Clearance Check (Thigh): 8 mm



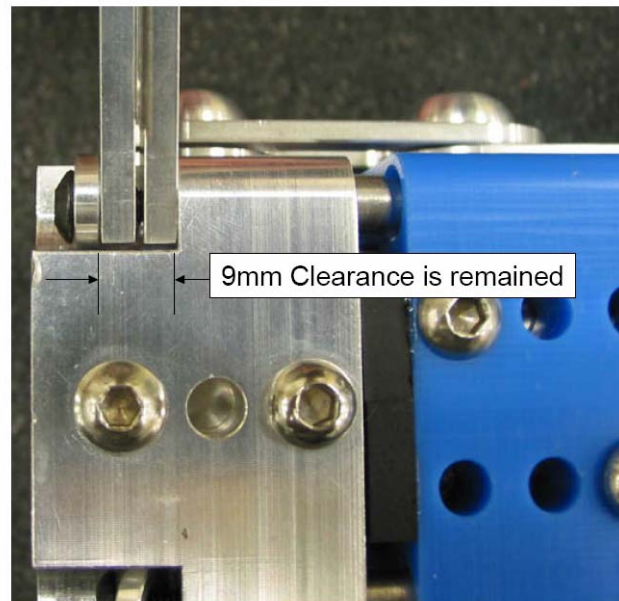
(Flex GT α Handling Manual, Konosu, 2006)



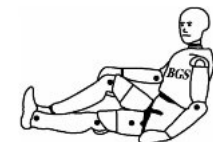
- Check of the length of the 4 lower leg bending stopper cable ends

Flex-GT-alpha Preparation

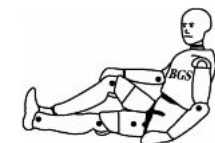
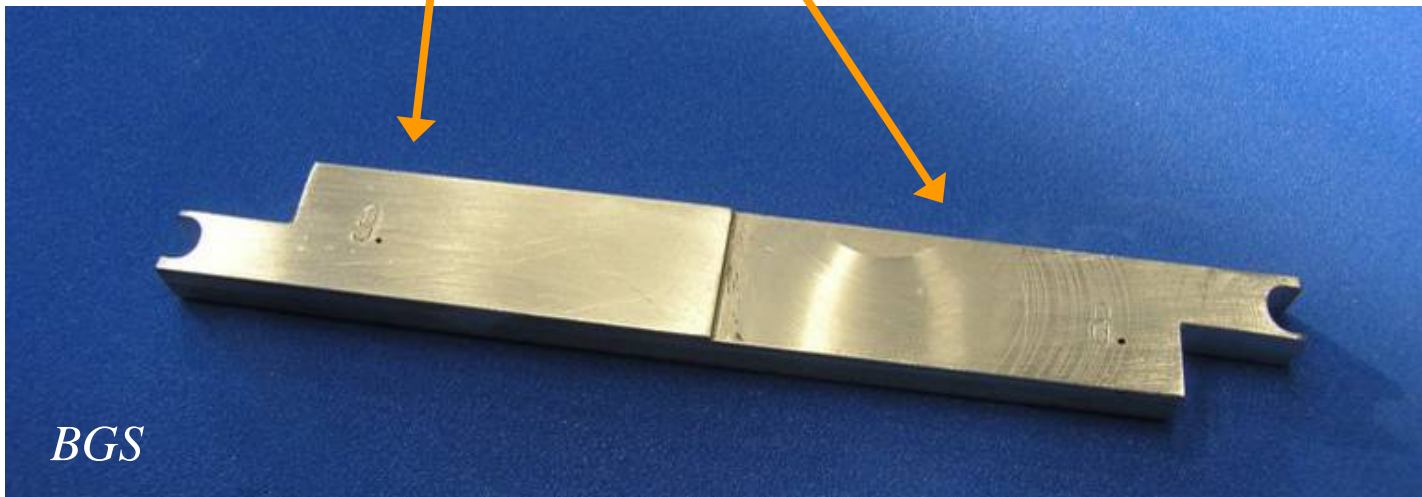
Bending Stopper Cable Clearance Check (Leg): 9 mm



(Flex GT α Handling Manual, Konosu, 2006)

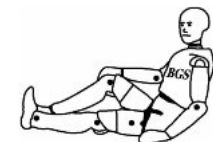
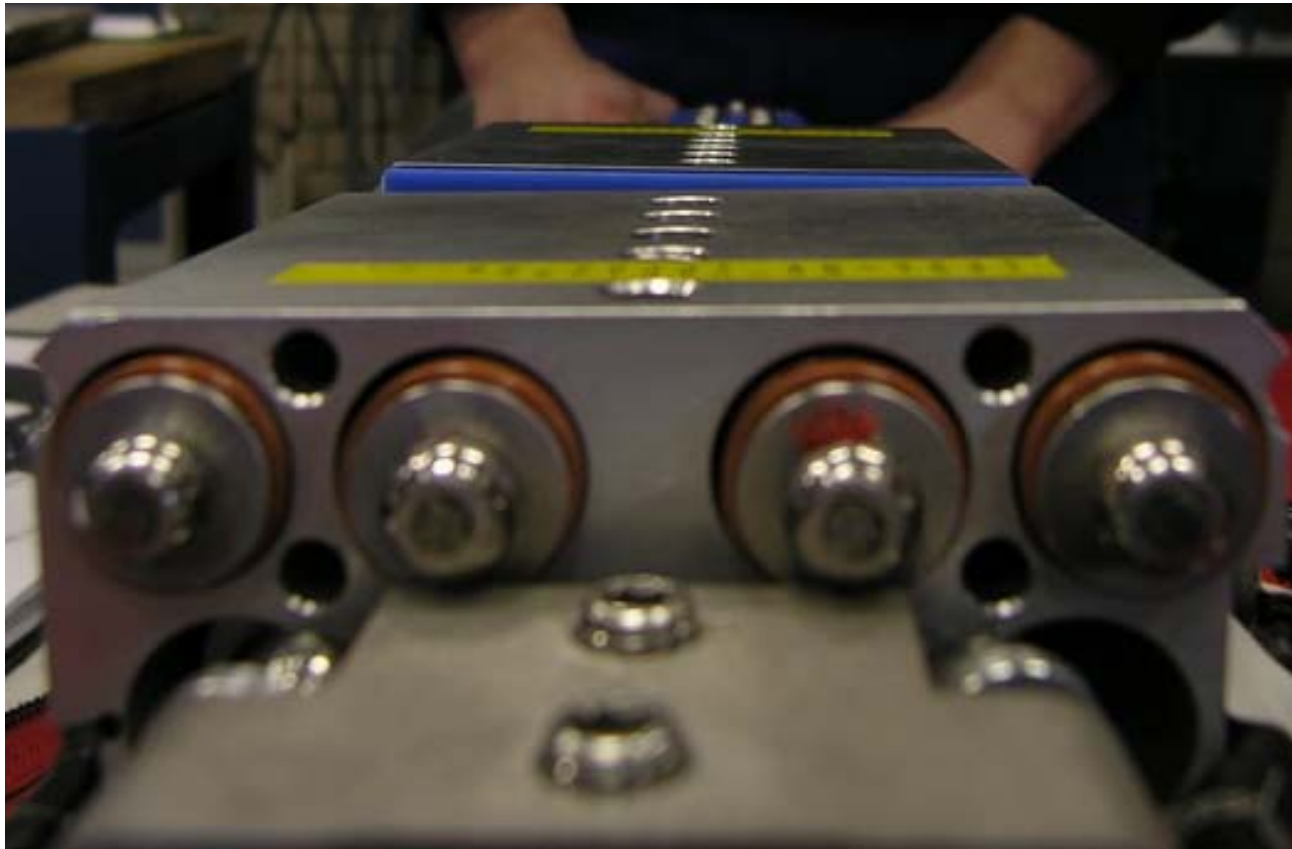


- New tool for cable clearance checks:
 - Thicknesses: 9 mm and 8 mm

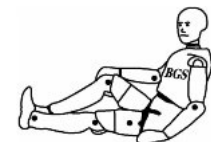
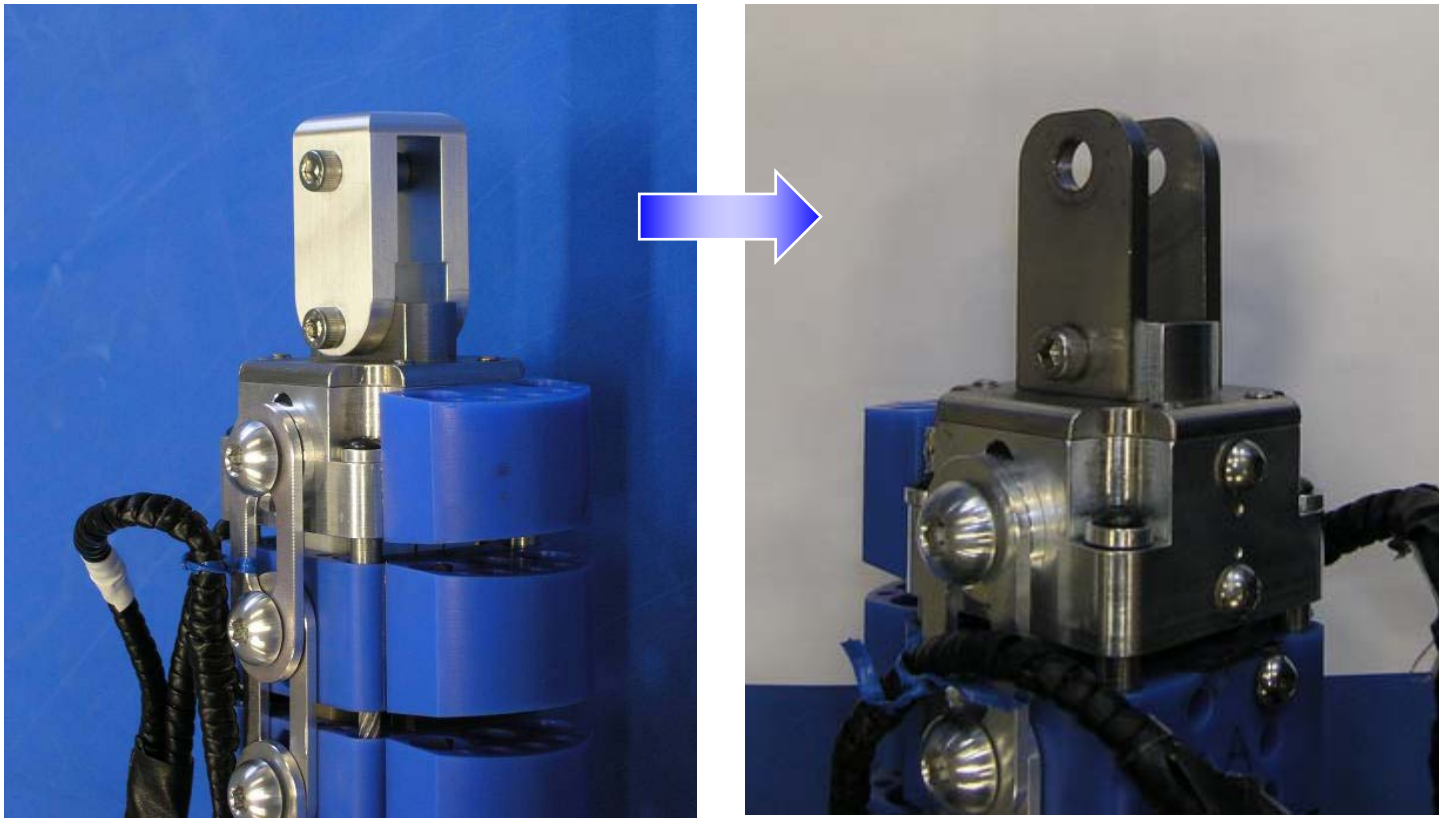


Inspection after test

- Check for distortion

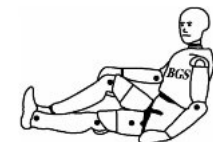
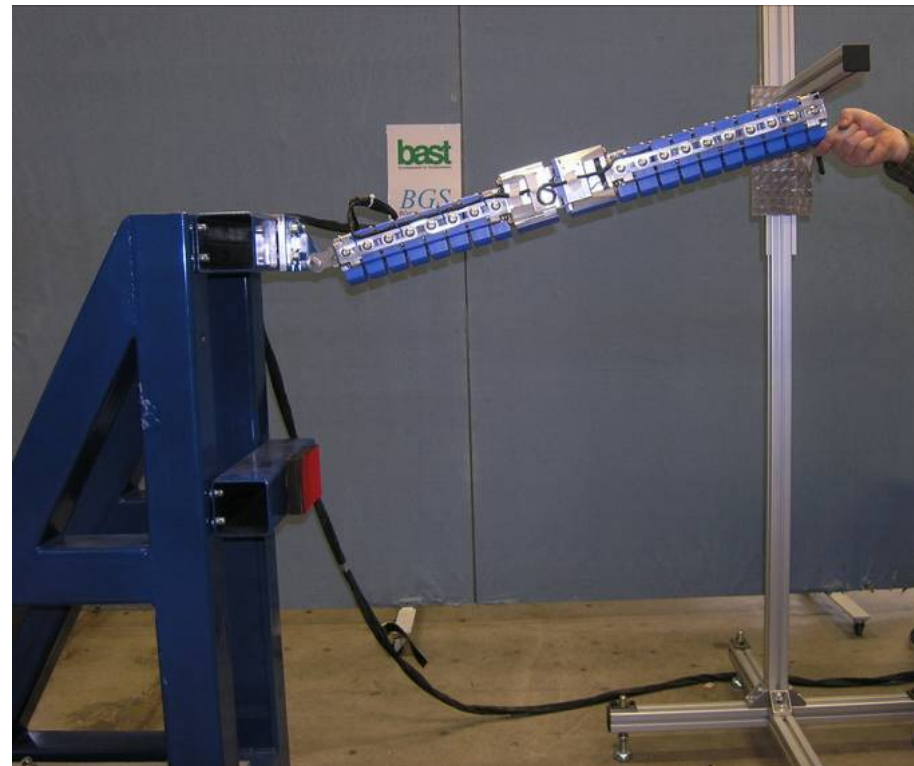


- Change from roller bracket to mounting bars

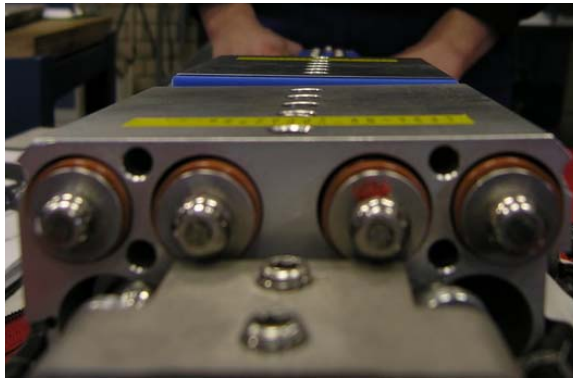


Certification

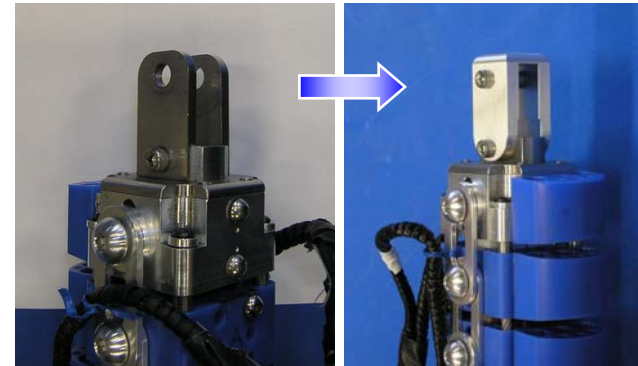
- Mount to the certification rig, zero the offsets, lift up the impactor to +15° and release



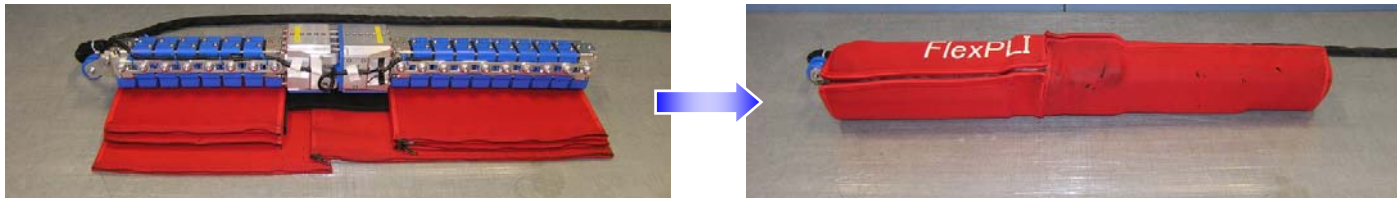
- Check again for distortion



- Mount the roller bracket again

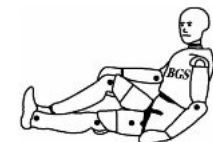


- Wrap the legform

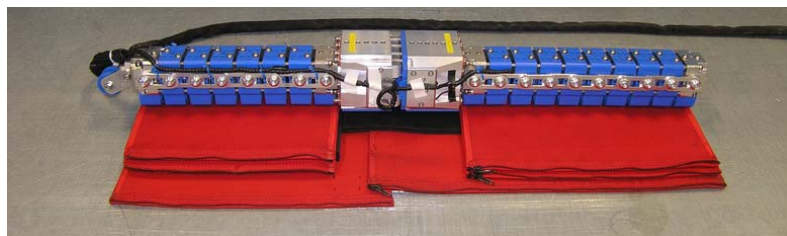
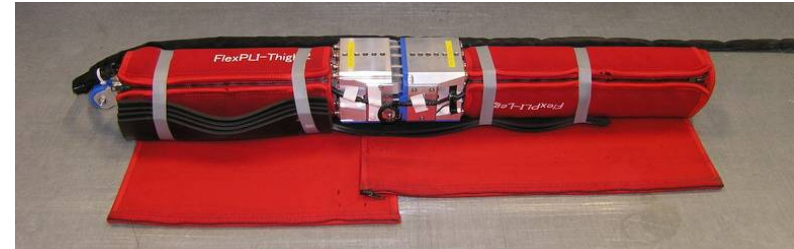
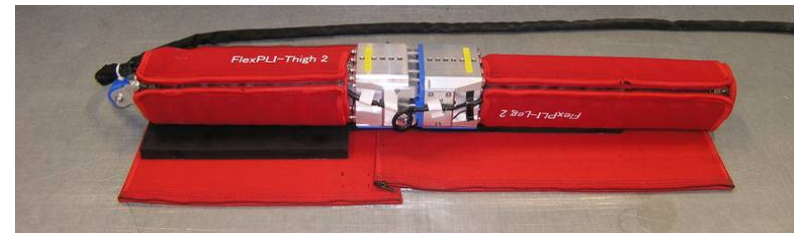
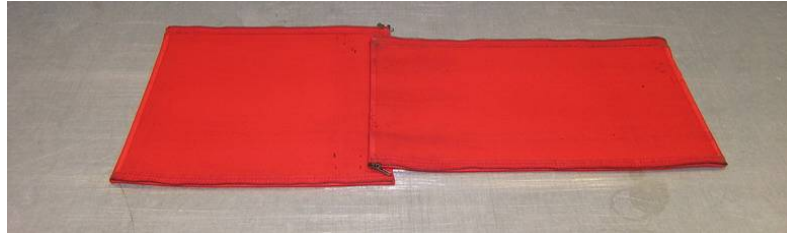


(Impactor shown is Flex GT α , Flex GT has one-piece outer skin)

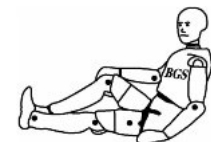
- Ready for new test



Mounting the skins



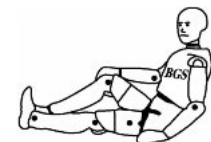
Impactor shown is Flex GT α , Flex GT has one-piece outer skin



Time between tests

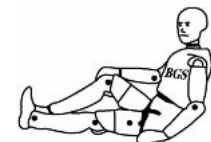
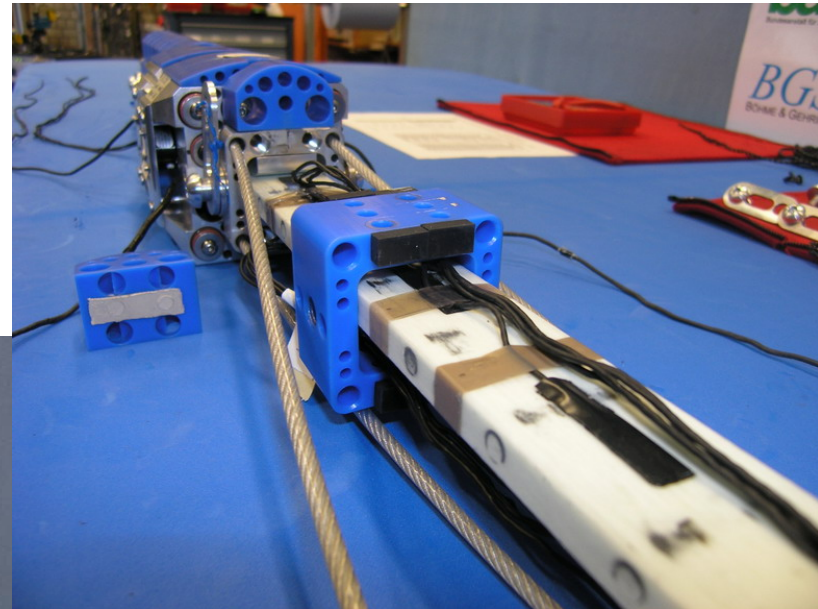
- Required work between impact tests:
 - Inspection
 - Certification
 - Minor assembly/disassembly work
- Required time between impact tests:

30 to 45 Minutes



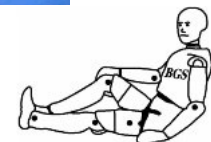
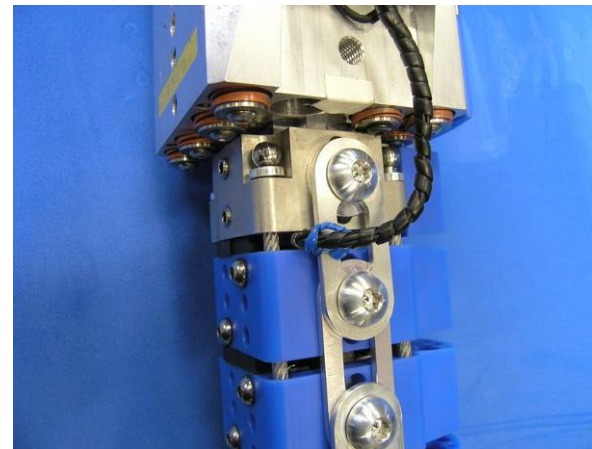
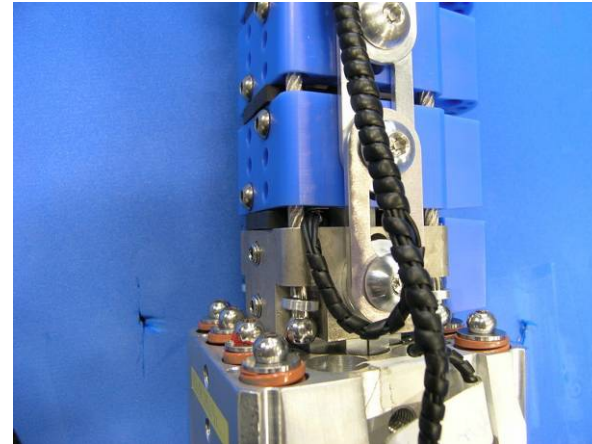
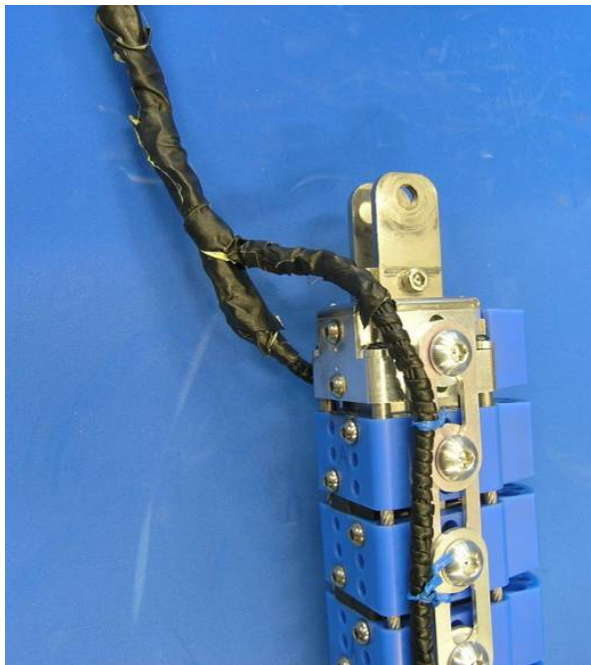
Particularities: Wiring

- In case of multiple cable damage the impactor has to be dismantled



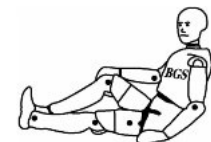
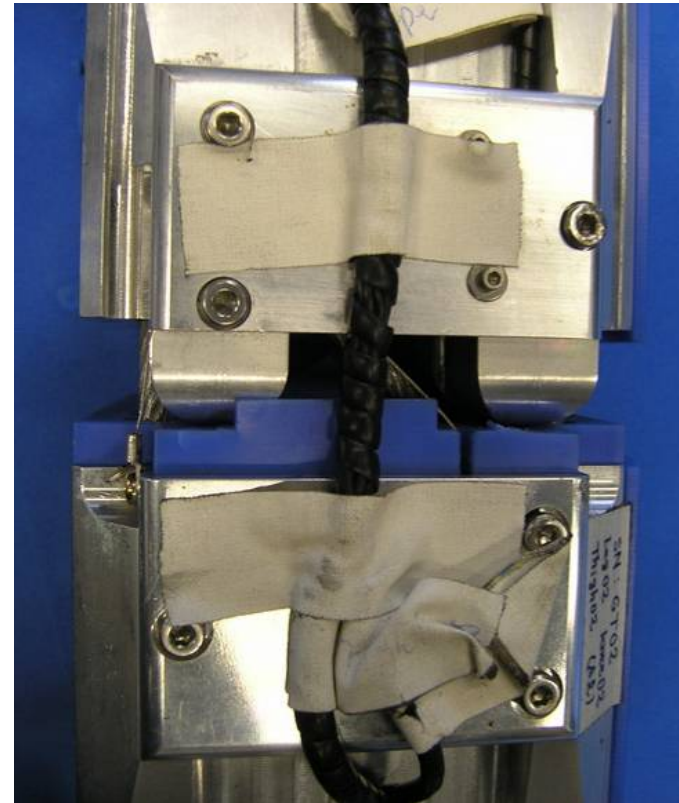
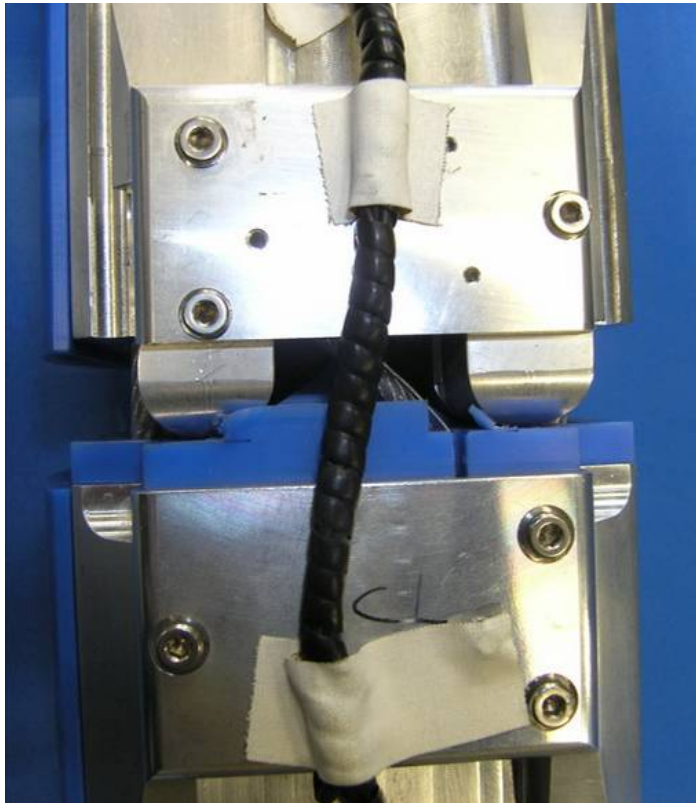
Particularities: Wiring

- Cable guiding with sharp angles and around sharp edges
- Cables likely to be damaged near the impactor



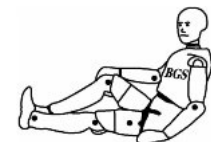
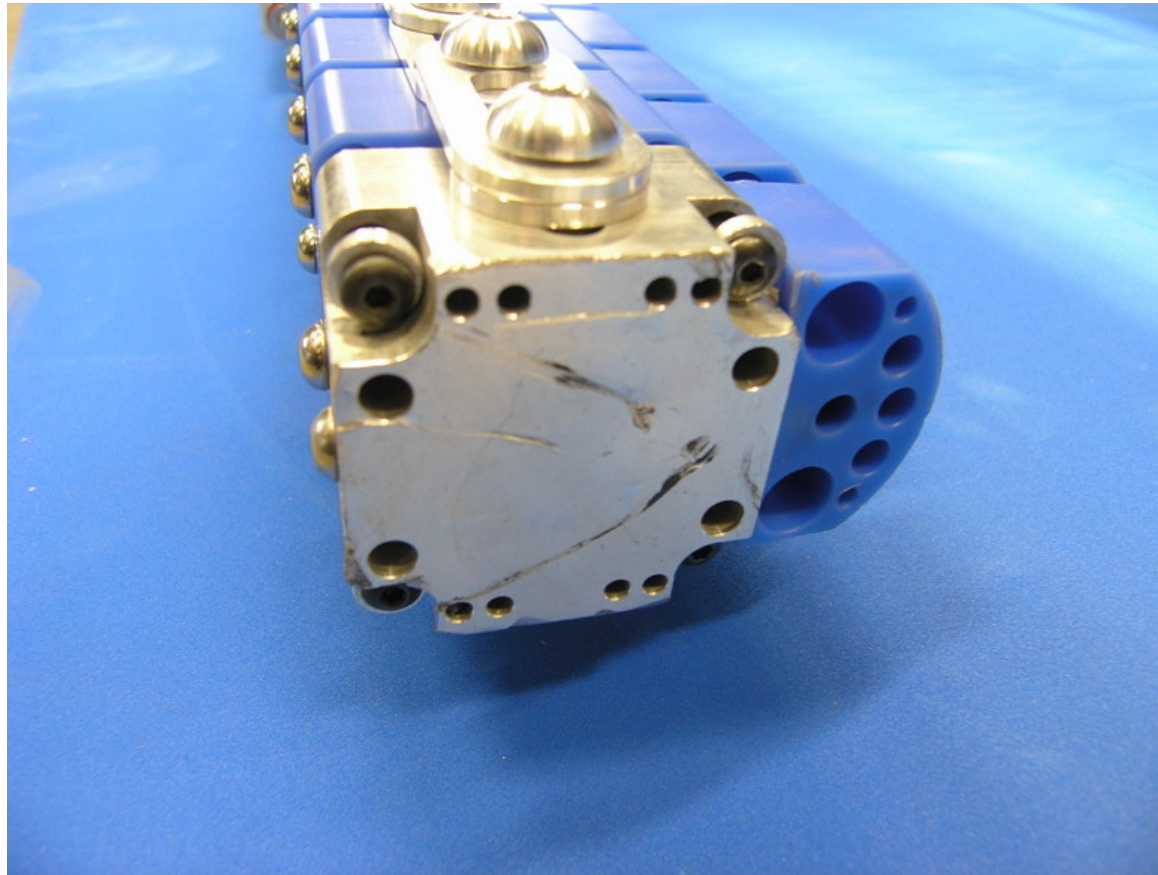
Particularities: Defects

- Broken guidings at tibia surface plate



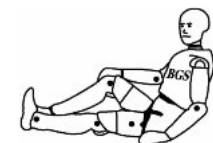
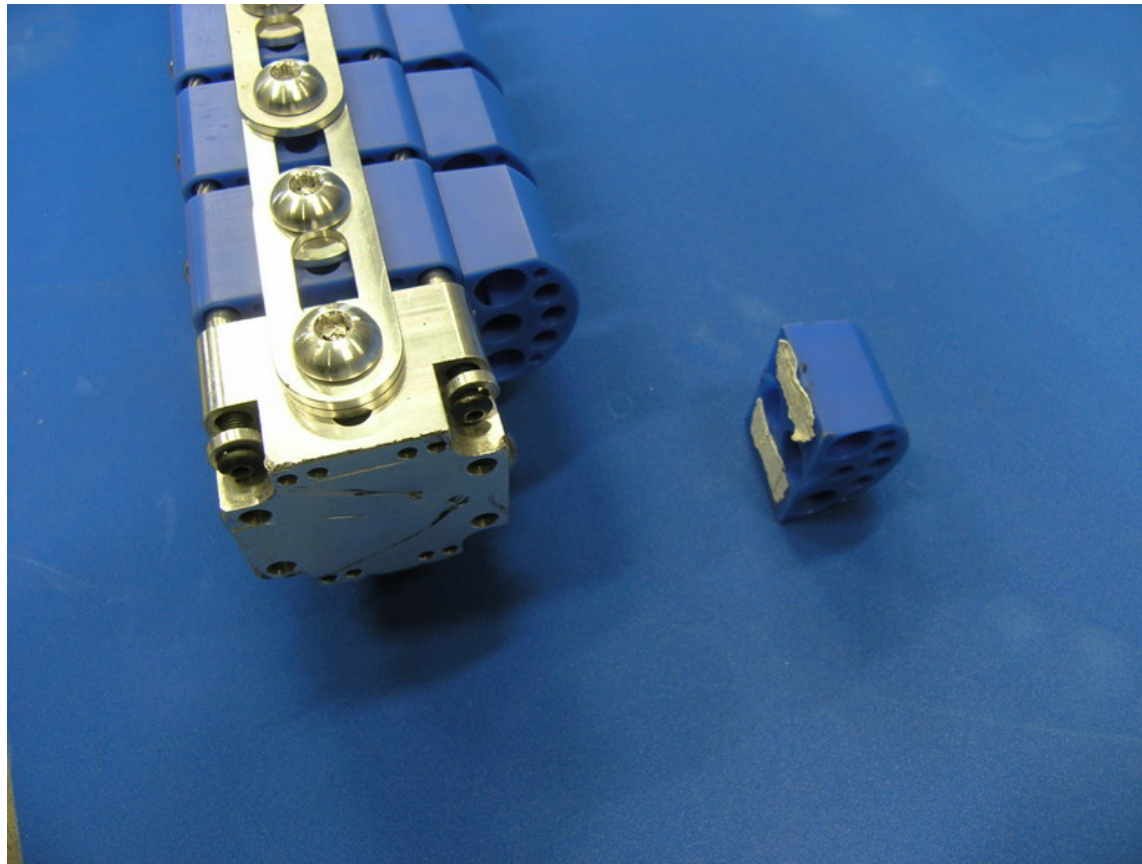
Particularities: Defects

- Scratches at tibia lower end



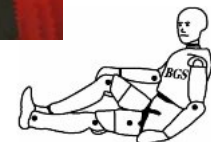
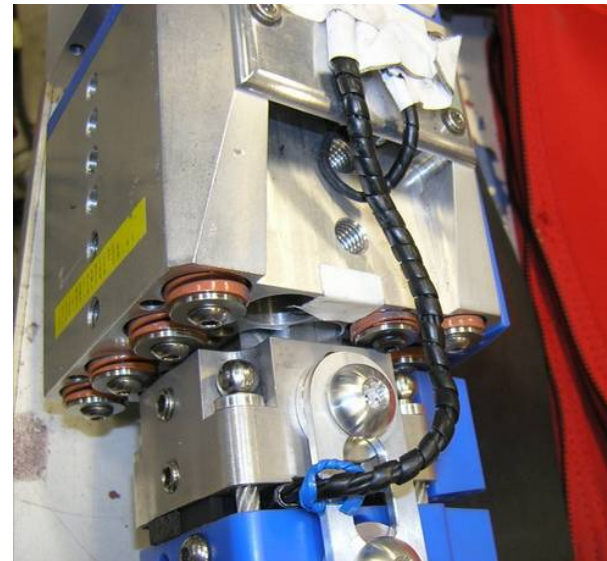
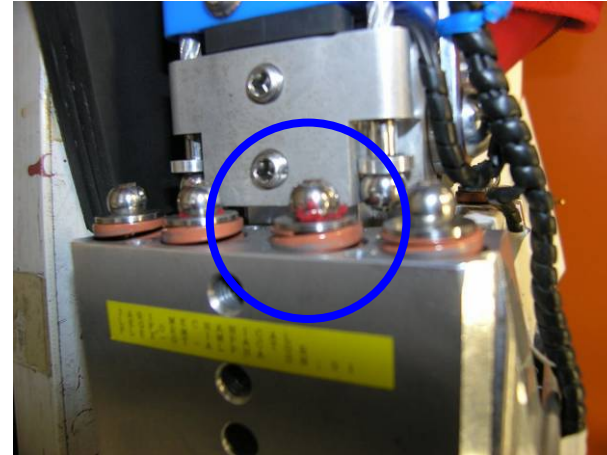
Particularities: Defects

- Separation of lowest segment impact face

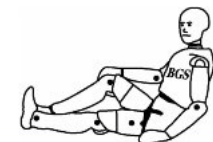
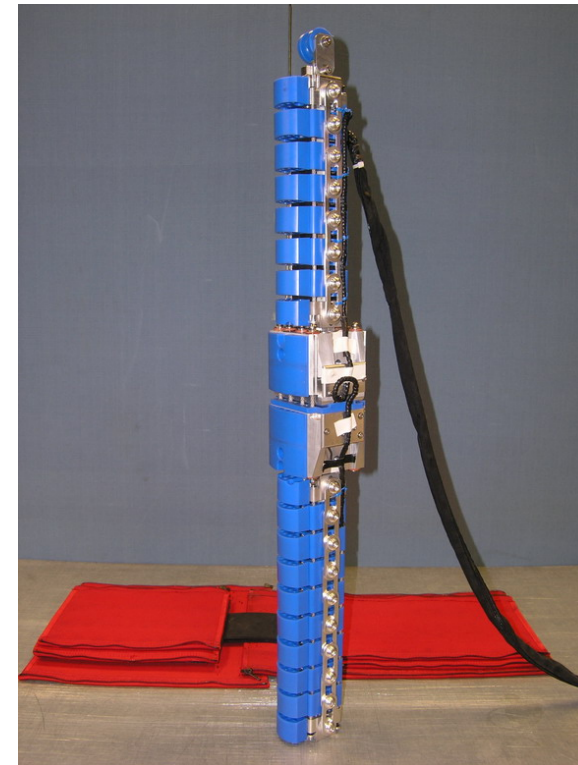


Particularities: Defects

- Neoprene skin:
 - Zippers very sensitive
 - Skin gets caught in spring ends
 - Skin damaged by sharp edges of knee

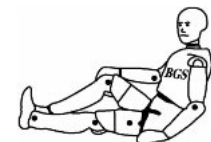


- Introduction
- Special Issues
 - Impact height
 - Differences GT α – GT
 - Sensitivity error
- Performed test series
 - Overview
 - Test series in details: A-Class, Golf, XK, Q7, test rig, inverse tests
- Results
 - Test results
 - Certification results
 - Handling and usage of the impactor
- Conclusions



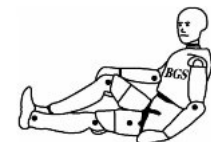
Conclusions (1)

- Robustness of test tool
 - Legform is as robust as other legform impactors.
 - Instrumentation wiring is not acceptable
- New version Flex GT has minor changes, results are comparable with Flex GT α .
- Impact height 75 mm above ground is acceptable.
- Handling/Repairing
 - Handling effort is comparable with EEVC WG 17 legform.
 - Repairing and rebuilding is more complicated compared to the EEVC WG 17 legform.
- Preparations for the test laboratory are comparatively negligible, but significantly more data channels than in other pedestrian protection impactor tests are needed.



Conclusions (2)

- First test results indicate that repeatability is at least acceptable.
- Test results of a “good” performing vehicle with WG 17 legform were confirmed by Flex PLI. Function on a “marginal” performing vehicle has to be checked.
- FlexPLI is compatible with current passive pedestrian protection features in general. Active systems such as deployable bonnet systems require further investigation.



Thank you
for your attention

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