

FLEX PLI GTR – FE v2.0

IG FLEX GTR9-PH2



28 March 2012

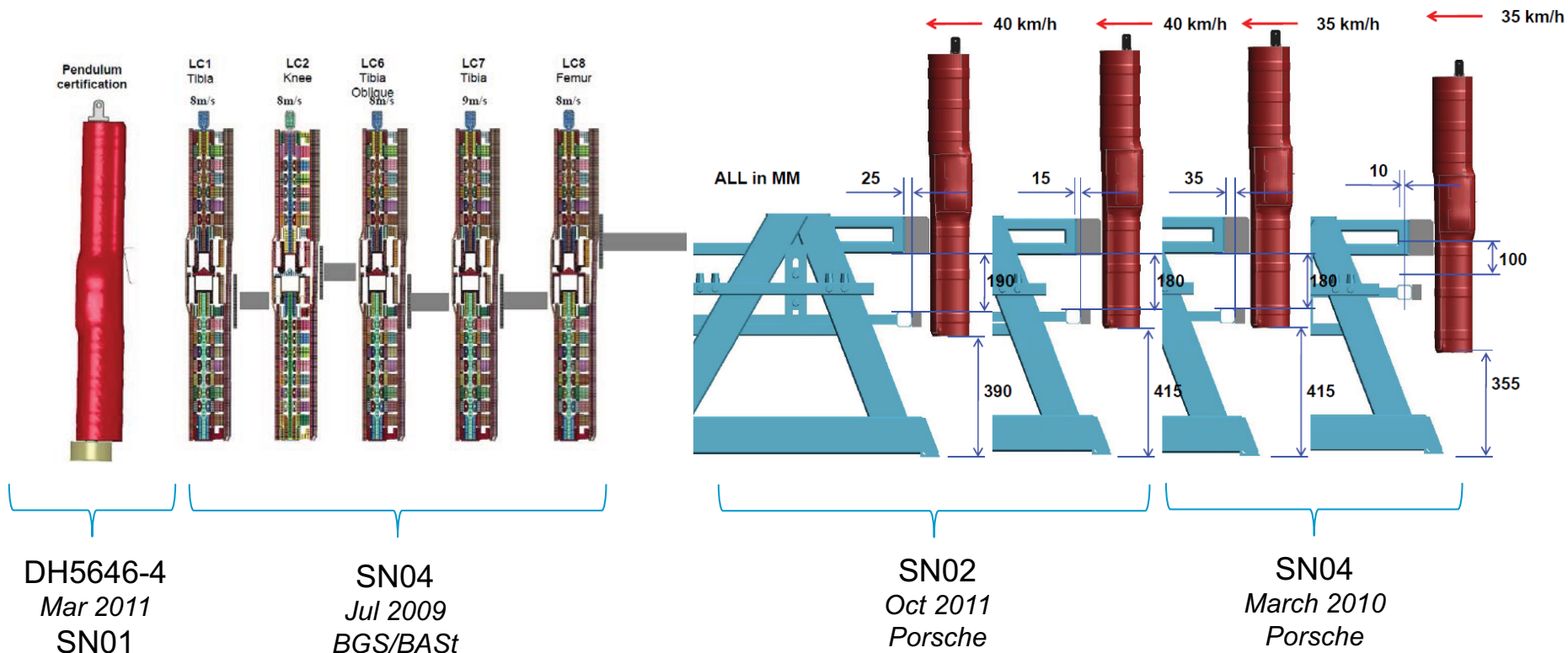
Robert Kant

FLEX PLI GTR v2.0 Summary

- ▶ The Consortium responsible for the FLEX-PLI in LS-DYNA, PAM-CRASH, RADIOSS and ABAQUS code has recently approved and released version 2.0
 - Version 2.0 is available through the Humanetics distribution network
- ▶ The models have been validated against a well-controlled experimental data set
- ▶ Models meet the targets that were set at the start of the project.

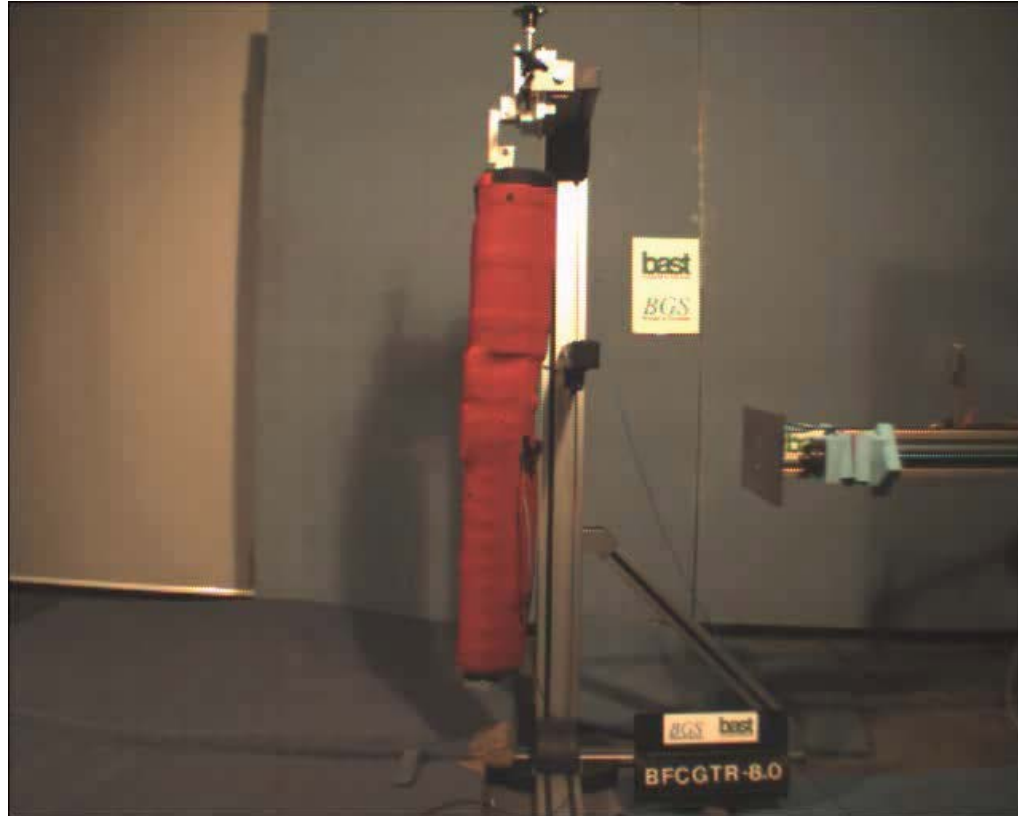
FLEX PLI GTR FE

► Focus validation 10 load cases v2.0



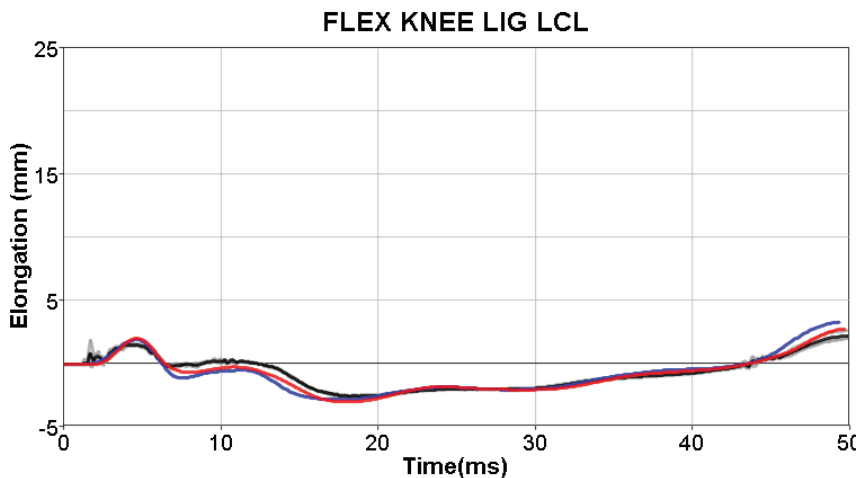
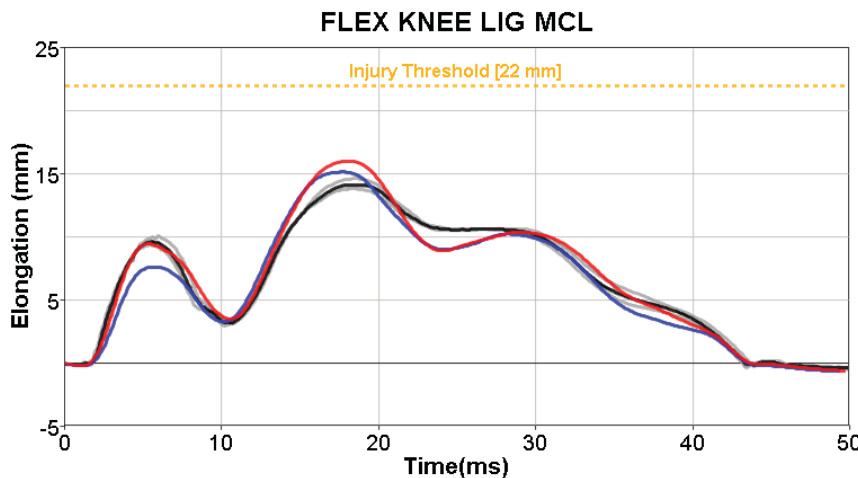
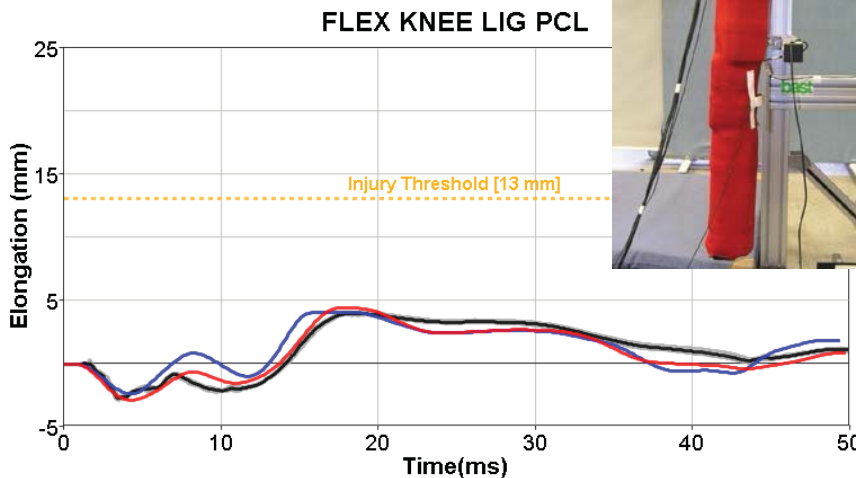
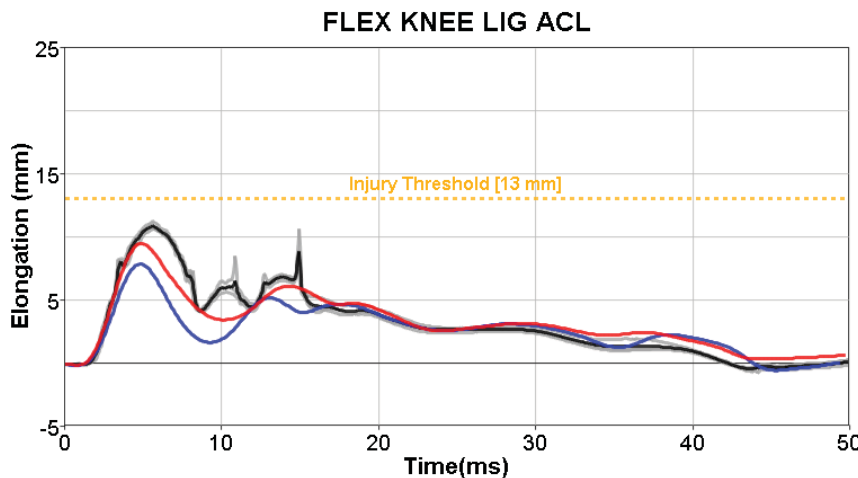
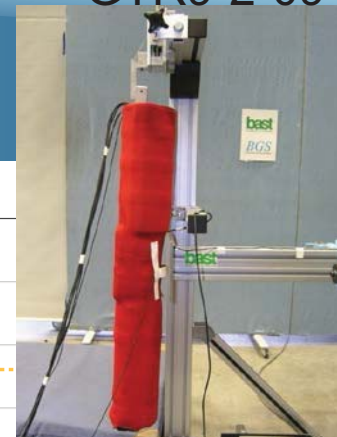
Dec 2010/Jan 2011

Baseline load case 1



- ▶ Almost identical set-up and loading as the standard inverse certification test but optimized to be more suitable as model validation test
 - ▶ No honeycomb !

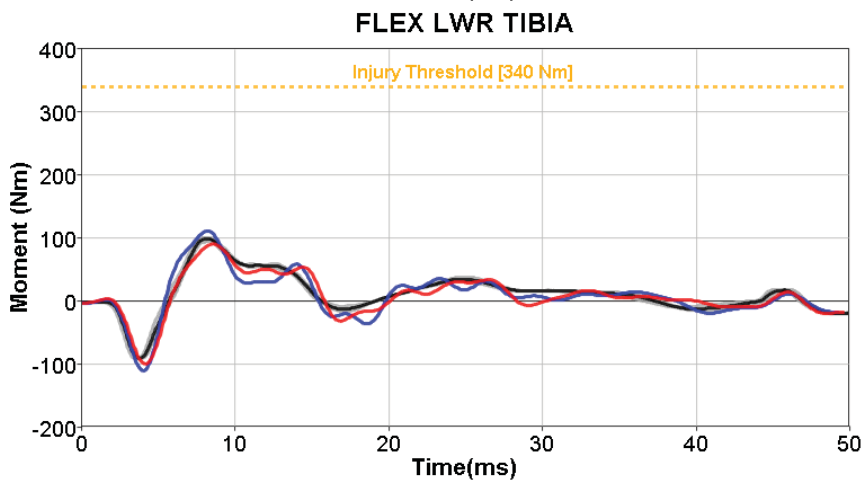
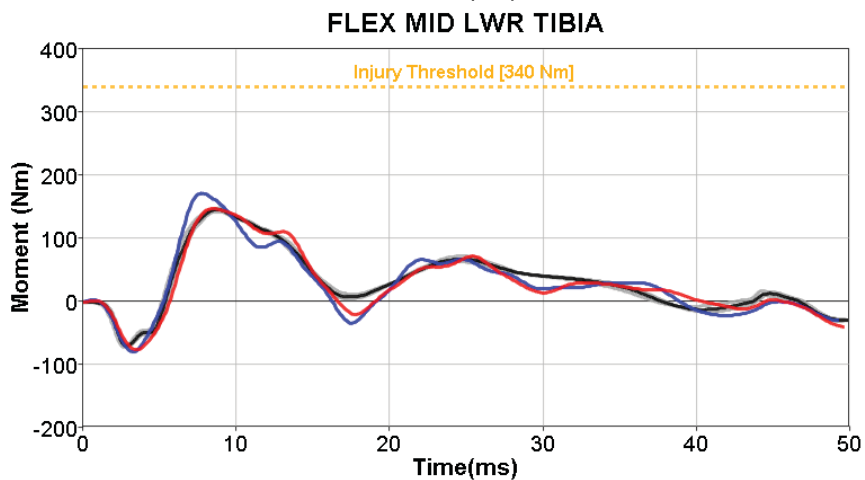
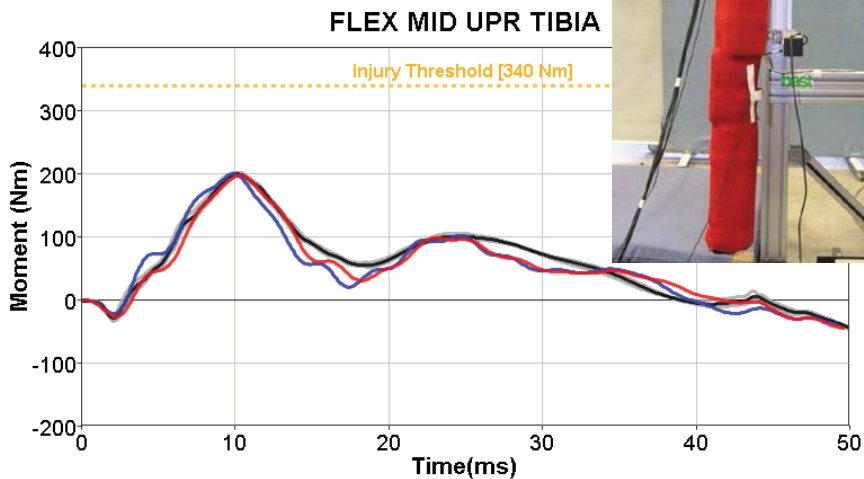
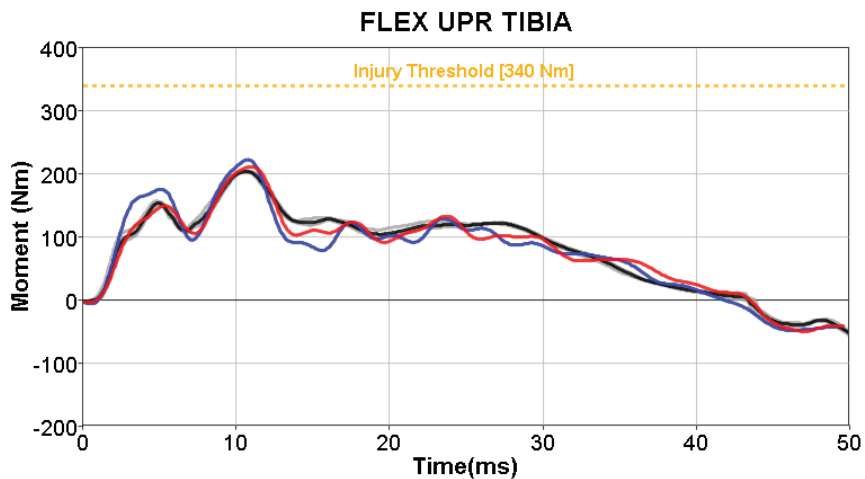
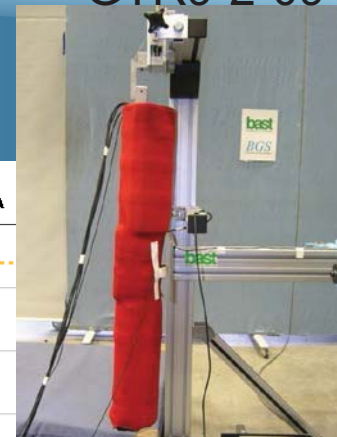
Load Case1 Ligaments



— Tests — Avg — v1.1 — v2.0

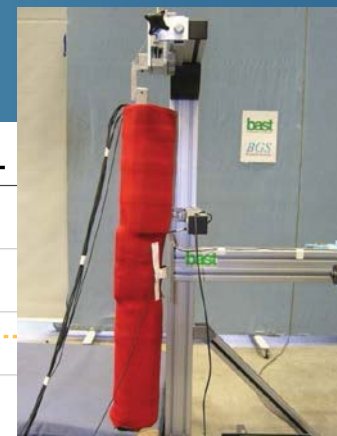
Typical improvements obtained for v2.0 w.r.t. v1.1

Load Case1 Moments

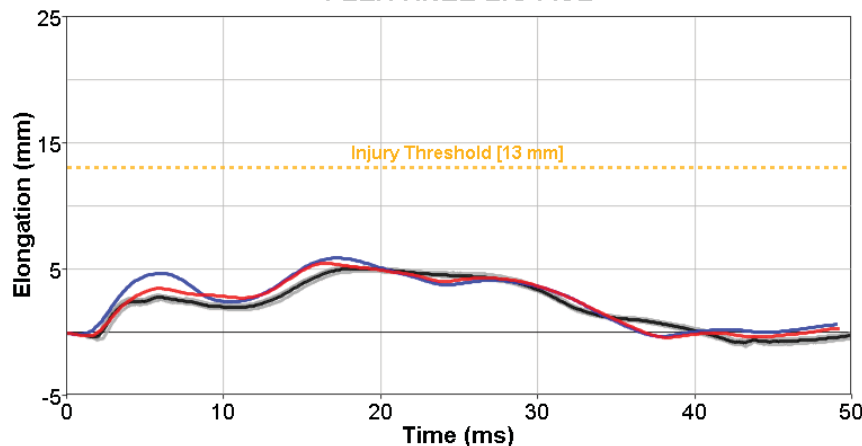


— Tests
 — Avg
 — v1.1
 — v2.0

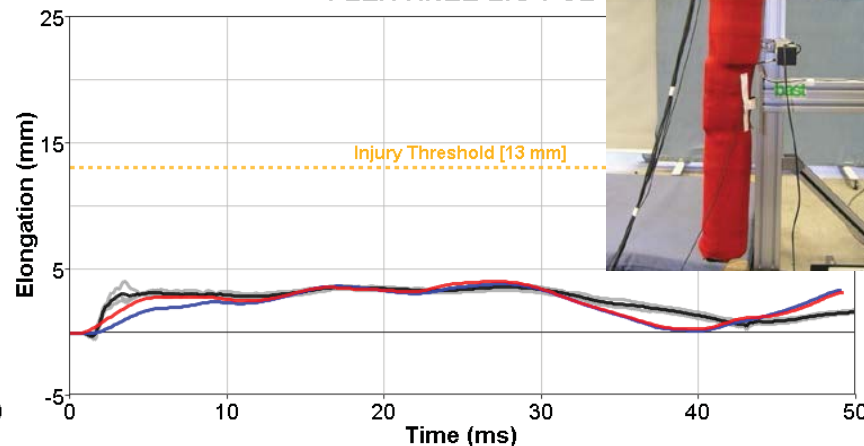
Load Case 2 Ligaments



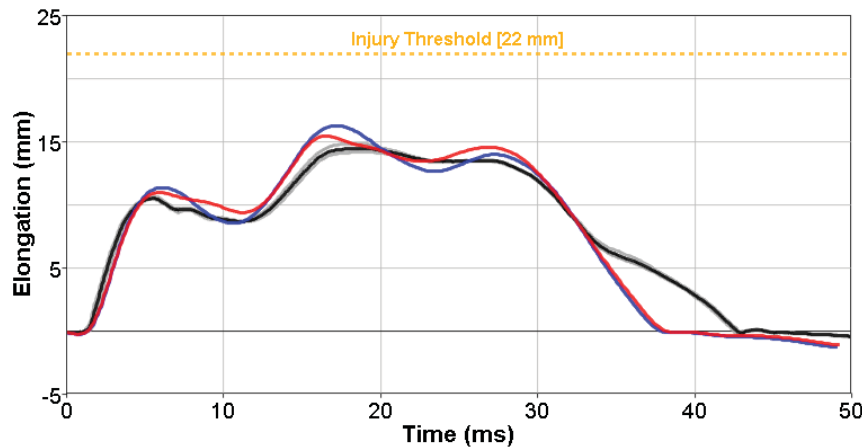
FLEX KNEE LIG ACL



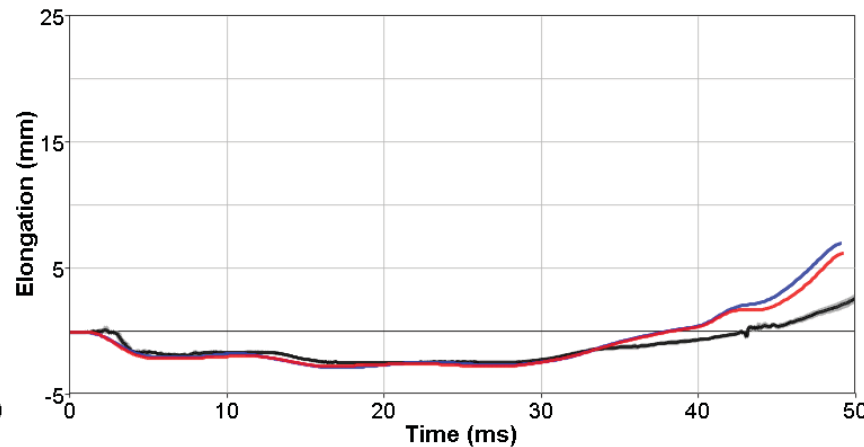
FLEX KNEE LIG PCL



FLEX KNEE LIG MCL

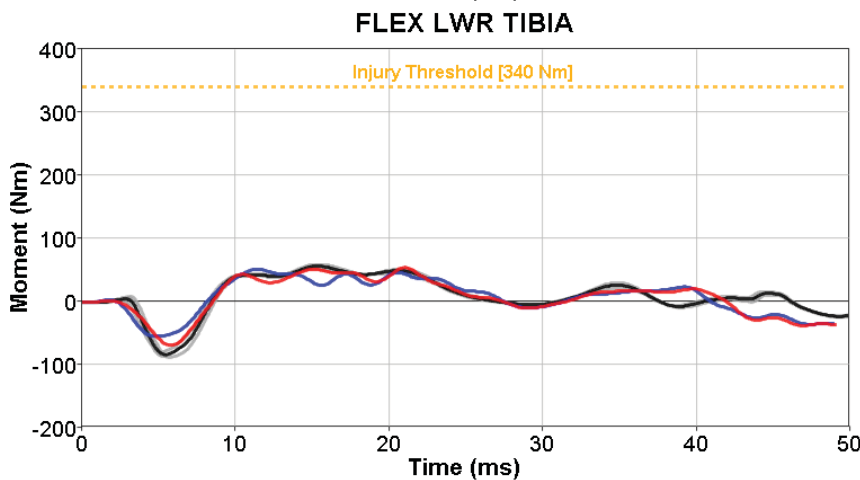
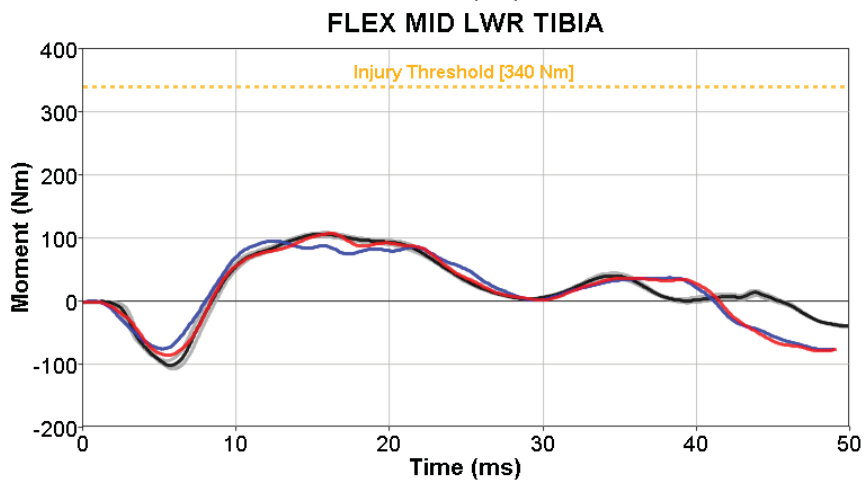
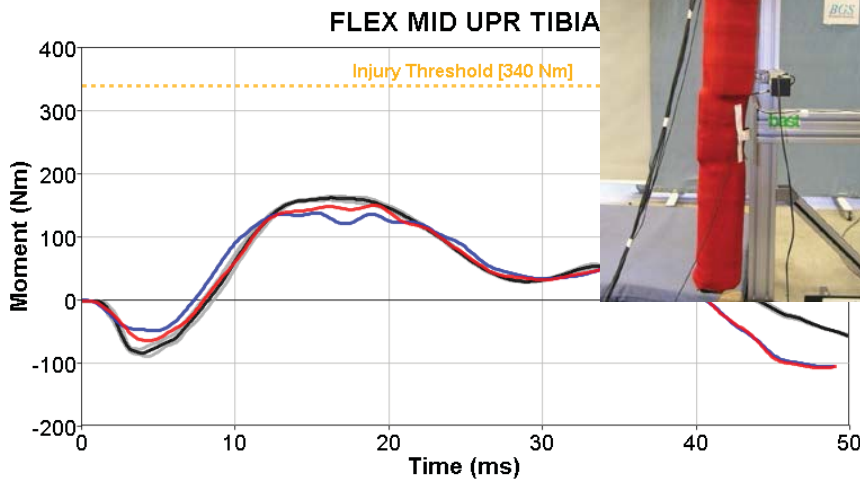
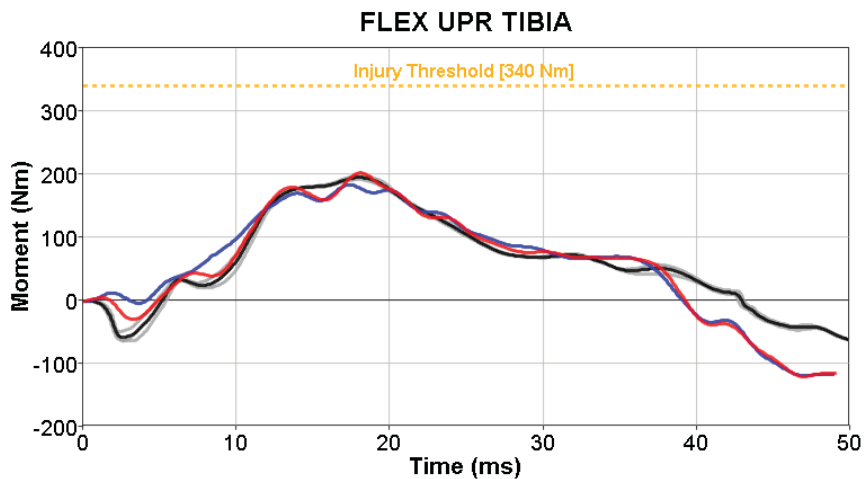
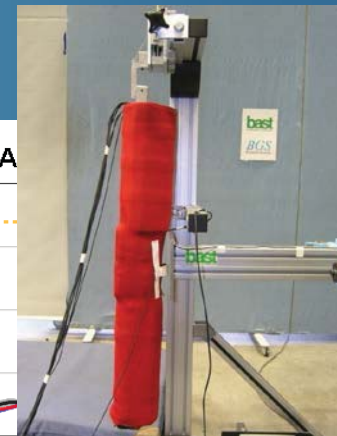


FLEX KNEE LIG LCL



— Tests — Avg — v1.1 — v2.0

Load Case 2 Moments



— Tests
 — Avg
 — v1.1
 — v2.0

Table instruction (see next two slides)

	Pendulum	Inverse & P-RIG
Peak error	Red If curves do not fit into certification corridors	Red > 20%
		Yellow 10-20%
Peak timing difference (msec)	Red > 12ms	Red > 4ms
		Yellow 2..4 ms

1. Peak value unit: moment in Nm; elongation in mm;
2. Percentage error = (CAE-TEST)/TEST;
Positive (+) percentage error means CAE *magnitude* greater than test, when both CAE and test are of the same sign.
3. Peak Δt : in msec, positive (+) means test peaks *earlier* than CAE
4. All peak values errors obtained from average test curve and CAE simulation curves for all load cases.

Peak Value and timing errors for v1.1

Peak (err %)	Femur-1	Femur-2	Femur-3	Tibia-1	Tibia-2	Tibia-3	Tibia-4	ACL	MCL	PCL	LCL
pendulum3	189.4 (-0.18%)	136.8 (-0.32%)	84.1 (-5.39%)	248.1 (-1.93%)	197.3 (-3.68%)	150.8 (-1.86%)	101.0 (-3.79%)	9.6 (-1.26%)	24.5 (+3.48%)	5.3 (+16.75%)	-3.8 (+23.43%)
Peak Δt	6.64	8.34	10.34	6.74	-4.56	-6.26	-5.56	4.14	3.14	1.14	6.24
LC1	157.6 (+12.03%)	-125.57 (-5.07%)	-102.13 (-10.05%)	224.14 (+9.18%)	202.08 (0.23%)	172.4 (+17.5%)	112.8 (+12.7%)	7.9 (-27.5%)	15.2 (-7%)	4.1 (2.8%)	-2.8 (+9.7%)
Peak Δt	-0.65	0.35	0.00	0.00	-0.30	-1.10	0.00	-0.85	-0.75	+1.9	-0.5
LC2	185.6 (-10.6%)	140.9 (-11.4%)	62.3 (-20.3%)	184.4 (-5.8%)	139.8 (-14.5%)	97 (-10%)	-54.37 (-34.56%)	6.0 (+16.6%)	16.4 (+12.3%)	3.9 (+7.1%)	-2.8 (+14.5%)
Peak Δt	-0.05	-0.65	-0.6	+0.25	-0.2	-2.2	+0.35	-0.9	-0.5	+0.45	-1.4
LC6	138.6 (-4.1%)	108 (-4.2%)	-84.60 (-16.61%)	209.6 (+9.9%)	187.5 (+9.6%)	132.0 (-0.5%)	82.9 (-8.4%)	10.1 (-16.5%)	14.1 (+5.6%)	4.1 (+6.4%)	-2.3 (0%)
Peak Δt	-0.95	0.45	0.40	-0.5	-0.1	-1.2	-0.2	-0.15	+0.3	-0.1	-2.1
LC7	167.9 (+4.2%)	-134.25 (-6.81%)	-112.72 (-8.32%)	251 (+10%)	224.3 (4.2%)	187.5 (+21.1%)	125.2 (+18.7%)	9.1 (-33.0%)	16.6 (+1.9%)	4.56 (-2.2%)	-3.1 (+7.7%)
Peak Δt	-1.45	0.05	0.05	-0.2	-1.0	-1.1	-0.35	-1.35	-1.4	+0.3	-1.65
LC8	283.9 (+9.85%)	224.7 (-3.2%)	188.2 (+17.7%)	187.3 (+13.9%)	194.2 (+17.65%)	-129.65 (+5.12%)	-78.96 (-3.03%)	6.6 (+9.0%)	13.3 (+66.44%)	5.6 (-20.0%)	-2.16 (67.75%)
Peak Δt	0.3	-0.25	-0.55	-4.15	-0.9	-1.15	-2.50	-1.5	-2.9	-0.8	-1.4
FG1584-85-86	171.98 (-15.05%)	144.47 (-10.87%)	88.95 (-8.44%)	177.38 (-9.11%)	177.26 (-12.54%)	146.08 (-0.80%)	85.59 (25.35%)	3.84 (52.54%)	-1.55 (-8.57%)	2.51 (-2.06%)	9.77 (10.11%)
Peak Δt	2.20	1.50	1.70	-0.30	1.40	1.00	2.30	1.77	-1.83	-0.48	0.47
FG1578-79-80	164.42 (-15.48%)	134.67 (-10.68%)	86.42 (-1.93%)	162.56 (-14.77%)	206.14 (-14.07%)	145.60 (-11.46%)	83.00 (-14.32%)	4.16 (44.35%)	-1.70 (-9.69%)	2.73 (6.98%)	10.84 (12.96%)
Peak Δt	1.10	2.01	1.40	0.40	0.70	1.60	2.10	0.57	-1.62	0.41	0.05
FG1244-45	163.23 (-2.75%)	136.67 (-10.74%)	86.03 (-2.75%)	117.84 (-17.47%)	150.68 (-17.51%)	127.46 (-0.44%)	77.90 (12.77%)	3.36 (3.13%)	-1.83 (2.87%)	2.96 (-3.14%)	10.47 (0.91%)
Peak Δt	-1.10	0.30	1.10	0.20	-0.40	0.40	1.20	0.01	-0.33	-0.12	0.39
F1256-1257	180.22 (+13.99%)	175.93 (+19.39%)	142.09 (+30%)	307.92 (-5.91%)	308.93 (+4.39%)	290.27 (+6.46%)	145.56 (+2.85%)	11.25 (+24.84%)	19.93 (+6.27%)	5.42 (+4.41%)	-3.65 (+8.0%)
Peak Δt	-0.60	-0.40	-0.60	-1.50	-0.30	-1.40	-1.40	-8.49	-0.55	-0.20	0.05

Peak value and timing errors for v2.0

Peak (err %)	Femur-1	Femur-2	Femur-3	Tibia-1	Tibia-2	Tibia-3	Tibia-4	ACL	MCL	PCL	LCL
pendulum3	186.95 (-1.48%)	133.82 (-2.46%)	82.11 (-7.65%)	249.18 (-1.52%)	201.58 (-1.56%)	153.28 (-0.25%)	102.64 (-2.26%)	9.94 (2.02%)	24.40 (2.93%)	5.05 (11.17%)	-3.58 (15.89%)
Peak Δt	9.84	7.74	8.94	-2.16	1.34	6.04	5.74	6.64	2.24	0.24	5.44
LC1	175.20 (24.54%)	-124.34 (-5.99%)	-110.20 (-2.94%)	212.65 (3.58%)	199.43 (-1.08%)	148.13 (1.01%)	92.25 (-7.81%)	9.56 (-12.64%)	16.09 (13.02%)	4.51 (12.79%)	-2.96 (15.73%)
Peak Δt	-0.05	0.05	0.30	0.30	0.20	-0.30	0.50	-0.75	-0.25	-0.35	-0.30
LC2	182.01 (8.49%)	130.74 (3.38%)	73.36 (-6.12)	203.28 (3.82%)	151.81 (-7.17%)	108.85 (1.06%)	-68.50 (-17.55)	5.53 (8.18%)	15.55 (6.77%)	4.09 (12.00%)	-2.67 (-5.0)
Peak Δt	-1.85	-1.65	-0.80	0.05	2.80	0.60	0.35	-2.00	-2.00	-0.85	+0.05
LC6	148.15 (2.50%)	108.64 (-3.62%)	-79.95 (-21.19%)	182.36 (-4.37%)	176.29 (3.06%)	151.03 (13.87%)	92.50 (2.22%)	12.36 (2.79%)	13.20 (-0.98%)	3.88 (0.05%)	-1.95 (-15.51%)
Peak Δt	-1.55	-0.45	0.30	0.55	0.00	-0.20	0.70	-0.85	-2.10	-0.10	-2.45
LC7	191.01 (18.56%)	-133.11 (-7.60%)	-118.62 (-3.52%)	241.71 (5.89%)	218.67 (1.53%)	162.67 (5.04%)	103.53 (-1.87%)	10.70 (-20.00%)	17.49 (7.32%)	4.91 (5.41%)	-3.19 (12.26%)
Peak Δt	-1.25	-0.55	-0.15	-0.30	-1.00	-0.30	-0.45	-1.45	-1.20	-1.60	-1.95
LC8	279.94 (8.34%)	257.27 (10.00%)	182.05 (13.80%)	152.22 (-7.45%)	157.34 (-4.70%)	-129.22 (4.77%)	-83.44 (2.46%)	6.57 (8.09%)	9.99 (24.91%)	6.08 (-13.80%)	-1.53 (19.18%)
Peak Δt	-0.30	-0.45	-0.85	0.8	-1.60	0.05	-0.60	-0.90	-2.2	-0.40	-0.90
FG1584-85-86	181.14 (-10.53%)	156.92 (-3.19%)	95.55 (-2.71%)	188.27 (-3.53%)	182.98 (-9.72%)	148.97 (1.16%)	82.08 (20.00%)	3.84 (52.54%)	7.10 (20.00%)	2.51 (-2.06%)	9.77 (10.00%)
Peak Δt	1.80	1.60	0.60	-0.10	0.20	0.90	2.20	1.77	-1.32	-0.48	0.47
FG1578-79-80	169.67 (-15.40%)	138.01 (-8.46%)	89.35 (1.39%)	175.56 (-7.96%)	205.67 (-14.27%)	146.03 (-11.20%)	84.71 (16.67%)	4.55 (58.06%)	-1.76 (-6.73%)	2.93 (13.03%)	11.43 (19.22%)
Peak Δt	1.60	3.50	2.10	0.60	0.70	1.50	2.20	1.18	-1.85	-0.59	-0.03
FG1244-45	169.61 (-8.91%)	142.48 (-6.94%)	88.23 (-0.27%)	119.74 (-16.14%)	154.44 (-15.46%)	131.03 (2.35%)	81.84 (18.47%)	3.66 (12.41%)	-1.90 (6.66%)	3.10 (1.36%)	11.20 (7.97%)
Peak Δt	-0.10	0.90	1.90	1.20	0.50	1.40	2.20	0.93	0.18	0.43	1.16
FG1256-57	138.69 (-12.28%)	131.94 (-10.46%)	101.34 (-7.28%)	307.95 (-5.90%)	281.78 (-4.79%)	249.11 (-8.64%)	134.54 (-4.93%)	9.93 (10.00%)	18.23 (-2.83%)	5.16 (-0.66%)	-3.35 (-0.71%)
Peak Δt	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	0.00

v2.0 injury signal predictability

	Pendulum	LC1	LC2	LC6	LC7	LC8	FG1584-85-86	FG1578-79-80	FG1244-45	FG1256-57
MCL	24.40 (2.93%)	16.09 (13.02%)	15.55 (6.77%)	13.20 (-0.98%)	17.49 (7.32%)	9.99 (24.91%)	7.10 (20.00%)	-1.76 (-6.73%)	-1.90 (6.66%)	18.23 (-2.83%)
Peak Δt	2.24	-0.25	-2.00	-2.10	-1.20	-2.2	-1.32	-1.85	0.18	0.00
Highest Tibia	249.18 (-1.52%)	212.65 (3.58%)	203.28 (3.82%)	182.36 (-4.37%)	241.71 (5.89%)	157.34 (-4.70%)	188.27 (-3.53%)	205.67 (-14.27%)	154.44 (-15.46%)	307.95 (-5.90%)
Peak Δt	-2.16	0.30	0.05	0.55	-0.30	-1.60	-0.10	0.70	0.50	0.00

- ▶ Almost all of the injury channels (MCL and tibia moment) show less than 15% peak error for the full leg load cases.
 - This applies for all codes
- ▶ Errors larger than 15% could be explained/defended
 - Mainly caused by environment uncertainty like initial position and barrier uncertainty

Future work

- ▶ The Group wishes to proceed as soon as the hardware and corresponding certification conditions are frozen and approved by the committees involved.
 - Guarantee that the model represents the finalized hardware.

- ▶ A second future goal is to validate the models against new test data that is generated with several hardware legs at different test labs, in order to better understand potential variability.