11th TEG FlexPLI Meeting
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Offices of ACEA, Brussels

ACEA Comments

Content

ACL/PCL threshold (1/4)

FlexGTR measures directly an elongation of ligament cables of a knee substitute (associated with ACL/PCL) which is designed to necessary technical targets (e.g. symmetry effect)

Industry could not gather enough experience with a view on bumper design solutions based on this measurement whereas the bending/shearing of the TRL-LFI ligament element is well known

A validated FE-model of the FlexGTR is not available by now for detailed design studies or associated calculations of exiting test results

ACL/PCL threshold (2/4)

ACL-PCL failure is linked to injuries due to global knee shear loading

Currently, insufficient biomechanical information is available
Reference:
TEG/078 (December 2008)
Discussion on 9.TEG

Pure ACL elongations measurements under shear impact conditions are not known so far (see additional information, page 11 following)

Literature available usually only refers to ACL rupture / failure

Thus, no risk functions are available at all

ACL/PCL threshold (3/4)

The study (Bhalla et al) hypothesizes ACL failures in two tests
a likely ACL failure at 17.8mm and 12.7mm shear displacement
NOT ACL elongation

The study (Kajzer et al) indicates one ACL avulsion at 23mm shear displacement

The study (Teresinski et al) indicates that ACL failure occurred after MCL rupture

See additional information, page 10 following

ACL/PCL threshold (4/4)

General remarks:

The current TRL legform differs considerably from the advanced FlexGTR

bone fracture:	TRL:	indirectly via acceleration
	Flex:	directly via bending moment
knee bending:	TRL:	globally measured via knee bending element
	Flex:	directly associated to MCL elongation
shearing:	TRL:	globally calculated via angle information
	Flex:	possibly by ACL/PCL elongation **(but NO RELIABLE data so far!)**

A simple duplication of the TRL related criteria onto the FlexGTR impactor is not advisable

ACEA does not accept to introduce criteria which are not scientifically supported only in order to follow the TRL impactor philosophy of three criteria

ACEA acknowledges the need of a protection criterion for cruciate ligaments as this could be observed in real accident data (but very rarely!)

However, scientific research is currently not providing a clear ACL/PCL threshold in a car accident situation because isolated ACL ruptures seem to be very difficult to reproduce

Relaxation zone

The request for a relaxation zone in the bumper test zone reflects technical aspects of feasible bumper designs and future worldwide bumper standards

The technical constraints recognized are mainly related to

- towing hooks
- areas of higher bumper stiffness due to other legal requirements
- areas of higher bumper stiffness due to other consumer tests (RCAR)
- areas of higher bumper stiffness of special purpose vehicles
- future sensor components for preventive active safety systems

All gtr experts agreed on this request and consequently a criterion of 250 g (addressed to tibia fracture) was proposed on an area of 264mm length

The relaxation zone is only linked to the bumper test procedure

The relaxation zone is independent from a measuring tool

Recommendations

ACL/PCL threshold:

- Abstain from supporting a mandatory criterion for the FlexGTR
- Risk curves should be the basis to underline any FlexGTR threshold
- More scientific information is needed
  which is addressed to a sophisticated knee element like the FlexGTR
- Criteria without a sufficient data base is absolutely not advisable

A requirement for ACL/PCL cannot be supported by ACEA

Relaxation zone:

- The relaxation zone must be kept in the gtr 9 independent of test tool
- The criterion of the tibia bending moment in the relaxation zone should be modified
- For pragmatic reasons an increase of around 10% is proposed

The relaxation criterion of the tibia bending moment should be set to 380Nm

References

TEG-078 Proposals for ACL, PCL and MLC injury threshold
TEG-114 ACEA comments on 10th TEG

Preamble of the gtr 9, paragraph 115
gtr document INF GR/PS/089 EC feasibility study (TRL)
gtr document INF GR/PS/091 ACEA feasibility study (MATRA)
gtr document INF GR/PS/127 EC pedestrian protection phase 2

UN-GRSP-46-11, Consideration on ACL/PCL Failure Evaluation (Japan)

Bhalla et al., Evaluation of the Response of Mechanical Pedestrian Knee Joint Impactors in Bending and Shear Loading, 18th ESV Conference, Paper #429 (2003)

Teresinski et al., Knee joint injuries as a reconstructive factors in car-to-pedestrian accidents
Forensic Science International, 124 74-82 (2001)

Kajzer et al., Shearing and bending at the knee joint at high speed lateral loading
SAE paper 973326 (1997)

Bose et al., Injury Tolerance and Moment Response of the Knee Joint to Combined Valgus Bending and Shear Loading, Journal of Biomechanical Engineering, Vol.130, No3, 2008

Thank you for your attention

Additional information

EVALUATION OF THE RESPONSE OF MECHANICAL PEDESTRIAN KNEE JOINT IMPACTORS IN BENDING AND SHEAR LOADING

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Paper Number 429

- 1 hypothesized ACL failure at 0.69kN and 12.7mm shear displacement
- 1 hypothesized ACL failure at 1.8kN and 17.8mm shear displacement

In comparison with bending tests, the relative timing of knee damage in shear tests is difficult to evaluate. The knee shear forces are seen to have a steadily increasing trend with shear displacement. Since tibial-spine gouging/plowing is likely an ongoing process, a drop in forces is likely due to ACL damage. Thus, it is hypothesized that the early peak in shear forces (at 12.7 mm of shear displacement, 693N shear force) in Test 2.2 is due to ACL failure. Similarly, ACL failure in Test 2.1 occurs at a shear force of 1839N and a shear displacement of 17.8 mm.

injury in the PMHS shear tests. Nevertheless, it is clear that the tolerance for shear displacement is at least 12.7mm (PMHS test 2.2) and possibly much higher, as

EVALUATION OF THE RESPONSE OF MECHANICAL PEDESTRIAN KNEE JOINT IMPACTORS IN BENDING AND SHEAR LOADING

REVIEW OF REAL WORLD PEDESTRIAN KNEE INJURIES

Isolated injuries to the ACL were also rare (in 2 cases out of 165) in lateral impacts.

The described knee injury mechanism in the defined lateral car-to-pedestrian accidents leads to the assumption that ACL rupture occurs after MCL rupture (but before PCL rupture) (Teresinski et al, 2001) *)

Isolated ACL avulsion seems to be difficult to replicate in PMHS tests.
A injury-risk function is currently not known.

*) unpublished BASt information, 10. TEG meeting, December 2010

Relevant injury mechanism

Table 3.1 Ligament avulsion as initial damage in shearing tests.

TEST #	Time [ms]	Shear. Force [kN]	Shear. Disp. [mm]	Time [ms]	Bend. Mom. [Nm]	Bend. Angle [°]	Ligaments ACL	PCL	MCL	LCL	Dia. or Meta.* Femur	Tibia	Epiphyses Femur	Tibia
16S	4.9	2.7	23	4.5	752	-4.9	●							

* : Diaphysis or Metaphysis ● : Ligament avulsion

Table 3.2 Diaphysis or metaphysis fracture as initial damage in shearing tests.

TEST #	Time [ms]	Shear. Force [kN]	Shear. Disp. [mm]	Time [ms]	Bend. Mom. [Nm]	Bend. Angle [°]	Ligaments ACL PCL MCL LCL	Dia. or Meta.* Femur	Tibia	Epiphyses Femur	Tibia
4S	6.6	2.9	28	5.0	398	-1.9		■1			
5S	7.0	N.A.	31	7.0	N.A.	-4.6		[illegible]	[illegible]	[illegible]	[illegible]
17S	5.9	2.5	26	5.5	511	-1.1		[illegible]	[illegible]	[illegible]	[illegible]
20S	6.5	3.1	N.A.	6.2	593	N.A.		[illegible]	[illegible]	[illegible]	[illegible]
Ave.	6.5	2.9	28	5.9	501	-2.5					
SD	0.5	0.3	2	0.9	98	1.8					

* : Diaphysis or Metaphysis ■1 : Comminuted supracondylar fracture ■2 : Transverse fracture

23mm shear displacement before ACL failure

Table 3.3 Epiphysis fracture as initial damage in shearing tests.

TEST #	Time [ms]	Shear. Force [kN]	Shear. Disp. [mm]	Time [ms]	Bend. Mom. [Nm]	Bend. Angle [°]	ACL	PCL	MCL	LCL	Dia. or Meta.* Femur	Tibia	Epiphyses Femur	Tibia
8S	5.0	2.4	12	4.4	321	-1.5	(●)							▲
9S	6.1	3.3	27	6.5	422	-4.6							▲	
12S	3.1	1.6	13	3.1	545	-4.1	(●)		(●)					▲
13S	3.7	2.3	14	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]					

Kajzer et al., Shearing and bending at the knee joint at high speed lateral loading SAE paper 973326 (1997)

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Injury Tolerance and Moment Response of the Knee Joint to Combined Valgus Bending and Shear Loading

. Therefore, characterization of knee stiffness for combined loading and the associated injury tolerances is necessary for developing vehicle countermeasures to mitigate pedestrian injuries. Isolated knee joint specimens (n = 40) from postmortem human subjects were tested in valgus bending at a loading rate representative of a pedestrian-car impact. The effect of lateral shear force combined with the bending moment on the stiffness response and the injury tolerances of the knee was concurrently evaluated. In addition to the knee moment-angle response, the bending angle and shear displacement corresponding to the first instance of primary ligament failure were determined

An injury threshold function for the knee in terms of bending angle and shear displacement was determined by performing regression analysis on the experimental data. The threshold values of the bending angle (16.2 deg) and shear displacement (25.2 mm) estimated from the injury threshold function were in agreement with previously published knee injury threshold data.