

Answer for the ACEA Comments on the current
development stage of Flex-PLI, Sep. 2007

Robustness

◆ Legform is as robust as other legform impactors.

- Testing to date indicates that the legform has the potential to offer the required level of robustness.

} Ans.
• We are very pleased to the comment.

◆ Instrumentation wiring is not acceptable

- However, ACEA has some concern with instrumentation cable damage that can be caused by rebound of the legform after the initial vehicle impact. The cables are directly connected to the instrumentation and therefore any cable damage means the legform has to be stripped down completely to 'fault find' and repair. This results in lengthy time delays between tests, which ACEA deems to be unacceptable, particularly for witness certification testing.

} Ans.
• Improvement on the measurement cables will be addressed in the Flex-GTR development.

- The measurement of the bending moments in the femur and the tibia section via strain gauges should be redesigned by installation of a full bridge configuration which is directly attached to the bone elements in order to avoid e.g. strain gauge elongation due to temperature variations.

} Ans.
• Under the current use conditions, we did not have any trouble for the strain gages by temperature variations (Did you have any trouble on that?)
• We would like to address that in the Flex-GTR development, if necessarily.

Version Difference

◆ New version Flex-GT has minor changes, results are comparable with Flex-GT-alpha.

- From the data presented ACEA agrees that the differences between Flex GT and Flex GT-alpha have negligible effect on injury levels and the results are comparable.

Ans.

- We are very pleased to the comment.

Impact height

◆ Impact height 75 mm above ground is acceptable.

- Injury results obtained indicate that the proposed injury limits can be met with both impact heights, the base height of 25 mm or the impact height increased by 50 mm above the base height (to 75 mm above the ground).
- If the increased height is proven to produce more biofidelic results (JARI simulation analysis) then ACEA agrees that this impact height can be used.

Ans.

- We are very pleased to the comment.
- We would like to keep the impact height, 75 mm above from the ground.

Handling

◆ Handling effort is comparable with EEVC WG17 legform.

- ACEA agrees that the handling effort is comparable with EEVC WG 17 legform if no damage to FlexPLI occurs during a test.

Ans.

- We are very pleased to the comment.

Repairing

◆ Repairing and rebuilding is more complicated compared to the EEVC WG17 Legform.

- If the leg is damaged the repair and rebuild is more involved on the FlexPLI due to the number of individual components and the number of sensors.
- In addition, special training is also likely to be required for test engineers due to the additional technical knowledge required to use the more complex FlexPLI.

Ans.

- More easy repairing system will be addressed in the Flex-GTR development, if necessarily.

Ans.

- Training course and user manual will be prepared.

Repeatability

◆ First test results indicate that repeatability is at least acceptable.

- First test data presented indeed indicated that repeatability was within acceptable limits.
- However, for the knee ligaments (specifically ACL and PCL, anterior and posterior cruciate ligaments) a tendency to increasing scatter was noted in more detailed analysis of the test results. This could possibly lead to repeatability issues in further tests and therefore is not acceptable. Further detailed research is necessary on this.

Ans.

- We are very pleased to the comment.

Ans.

- To prevent/reduce knee twist motion, the issue can be solved.
- It will be addressed in the Flex-GTR development.

Test results

◆ Test results of a “good” performing vehicle with WG17 legform were confirmed by Flex-PLI. Function on a “marginal” performing vehicle has to be checked.

- The tests completed to date show that a good performing vehicle (“green” EuroNCAP rating) gives a good performance with the FlexPLI with the currently proposed injury risk thresholds. However, this needs to be double-checked when the injury risk thresholds are finally agreed.
- In addition, it is necessary to compare the WG 17 legform injuries resulting from a marginal performing vehicle with FlexPLI injuries to confirm the above statement.

Ans.

- First of all, how much of the injury risk level of the “green” Euro-NCAP rating?
- The FlexPLI tentative thresholds is 50% injury risk level, so to compare with the Euro-NCAP test results and the FlexPLI test results, targeted injury risk level should be equal.

Compatibility with current passive protection feature

◆ Flex-PLI is compatible with current passive pedestrian protection features in general. Active systems such as deployable bonnet systems require further investigation.

➤ In terms of injury levels, ACEA agrees that a vehicle already achieving a green rating in EuroNCAP lower leg tests could comply with proposed FlexPLI injury criteria with additional countermeasures.

Ans.

- We agreed on that an additional counter measures will be required.

➤ However, with respect to deployable bonnet systems the use of the FlexPLI may result in a different sensor calibration. For example, the contact sensor signal on the Jaguar XK during tests performed on behalf of ACEA was lower than that of the peak amplitude obtained from WG 17 legform. Further investigation is currently ongoing to understand the consequences to system deployment.

Ans.

- We agree on that the difference will occur.

Additional Comments

◆ Right leg

- The FlexPLI represents a right leg only. Therefore ACL and PCL results are dependant on the side of the vehicle that is impacted, thus making pedestrian test results asymmetrical. This is not the case for WG 17 legform, which (assuming symmetrical vehicle design) allows injury results from one side of the vehicle to be read across to the opposite side. Whether and how this will be incorporated in any future legislation needs to be understood as it could result in additional testing.

◆ Knee twist

- In addition, the legform is performing better during tests at vehicle centre line or at impact points in areas almost perpendicular to impact direction, most likely due to unavoidable rotation. As the FlexPLI additionally assesses 'knee twist' (ACL and PCL) which tends to increase with greater curvature, this may necessitate changes to front end designs to be "flatter". ACEA believes further work is necessary to understand these effects.

Ans.

- To prevent/reduce knee twist motion, the issue can be solved.
- It will be addressed in the Flex-GTR development.

Additional Comments, contd.

◆ Current certification procedure

- The current certification procedure (in the latest documents also called repeatability and reproducibility evaluation test and assembly test) seems insufficient and does not give detailed information on the calibration status of the test equipment components; in general it is just a functional test for the overall legform. Therefore, either justification is necessary that this test procedure is sufficient or certification and calibration procedures for the components of the legform and the sensors should be defined.

Ans.

- Unfortunately, we did not explain about the detail of Flex-GT certification procedures.
- We would like to circulate the detailed certification test procedures, so could you review the contents?

◆ MCL Criteria

- Regarding the criteria for the bending angle the correlation (transfer function) between bending angle and ligament elongation (MCL) should be illustrated in an extra TEG paper (see table "tentative threshold" of TEG/22/). This would close the gap between the 50%-injury-risk level for bending angle and the actually measured ligament elongation value

Ans.

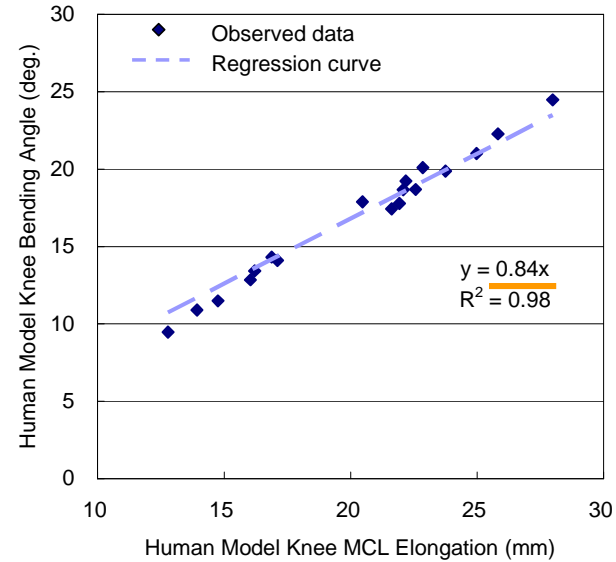
- We described the relationship between the bending angle and MCL of the human model in the next page (Page 9).
- We used the relationship.

Relationship between the Knee Bending Angle and Knee MCL Elongation of Human Model

Base Simulation:

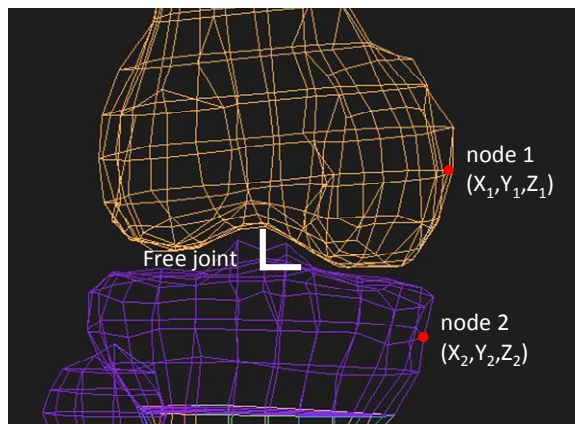
Konosu A. et al, DEVELOPMENT OF A BIOFIDELIC FLEXIBLE PEDESTRIAN LEGFORM IMPACTOR Type GT (FLEX-GT), 20th ESV, Paper No. 07-0178.

| Simulation ID | Human Model | Human Model | Human Model |
|---------------|-----------------------------|---------------------------|---|
| | Knee Bending Angle | Knee MCL Elongation | Ratio |
| | HM _{KBA} (deg.) | HM _{MCL} (mm) | HM _{MCL} /HM _{KBA} (mm/deg.) |
| S01 | 14.8 | 11.5 | 0.78 |
| S02 | 16.9 | 14.3 | 0.85 |
| S03 | 25.8 | 22.3 | 0.86 |
| S04 | 22.1 | 18.7 | 0.85 |
| S05 | 22.6 | 18.7 | 0.83 |
| S06 | 13.9 | 10.9 | 0.78 |
| S07 | 21.9 | 17.8 | 0.81 |
| S08 | 17.1 | 14.1 | 0.82 |
| S09 | 23.7 | 19.9 | 0.84 |
| S10 | 21.6 | 17.4 | 0.81 |
| S11 | 16.0 | 12.9 | 0.80 |
| S12 | 20.5 | 17.9 | 0.87 |
| S13 | 25.0 | 21.0 | 0.84 |
| S14 | 22.2 | 19.2 | 0.87 |
| S15 | 16.2 | 13.4 | 0.83 |
| S16 | 22.9 | 20.1 | 0.88 |
| S17 | 28.0 | 24.5 | 0.87 |
| S18 | 12.8 | 9.5 | 0.74 |
| | Average | | <u>0.83</u> |



$$HM_{MCL} = (0.83 \text{ or } 0.84) \times HM_{KBA}$$

Definition of Knee bending angle and Knee MCL Elongation of Human Model in This study



- Human Model Knee Bending Angle: Directory obtained from the Free joint output at the knee joint
- Human Model Knee MCL Elongation: Estimated using following formula; $((X_1 - X_2)^2 + (Y_1 - Y_2)^2 + (Z_1 - Z_2)^2)^{0.5}$

Additional Comments, contd.

◆ Tibia Criteria

- In the draft GTR there is an exemption zone defined for the legform test where the deceleration limit is 250g. How can the higher threshold limit for the rigid TRL legform be translated to the proposed measurement criteria of the FlexPLI?

Ans.

- The tentative threshold value of Flex-PLI is already 50% injury risk level.
- How we set a threshold value for the exemption/relaxation zone will be discuss in the Flex-TEG meeting.

◆ CAE Model

- Finally, CAE models and their associated robust correlations for standardized cases (i.e. calibration tests) and the effect of variability on different vehicle front-end configurations are not yet available but crucial for vehicle design.

Ans.

- When the Flex-GTR is accepted by PS-GTR, a Flex-GTR CAE Model will be developed by a dummy production maker or a computer software maker.

◆ Ageing behavior and wear

- Ageing behavior and wear of the fiber glass “bones” and of the rubber “skin and flesh” as well as of the plastic segments of the FlexPLI needs to be investigated.

Ans.

- Basically, these materials have high repeatability (TEG-013).
- Plus, we can check the impactor damageability (especially for bone core and knee ligaments) by conducting dynamic assembly certification test.
- So, if the impactor fail the dynamic assembly certification test requirements, new parts can be used.
- Aging behavior of these parts will be investigated continuously.

Summary

◆ Measurements

- Robustness – A connection box or separate connectors need to be added into the cable lines (preferably within the confines of the legform) to eliminate the need for a complete strip-down if cable damage occurs. Reconsideration of the measurement of bending moment is recommended.

Ans.

- We would like to address that in the Flex-GTR development, if necessarily.

◆ For Deployable system

- Deployable bonnet sensor performance - This issue needs to be fully understood.

Ans.

- It will be made clear under the deployable system testing.

◆ Comparison

- Good / marginal results comparison between FlexPLI and WG 17 legform - Additional FlexPLI testing is required to establish comparison with a vehicle performing marginal with WG 17 legform.

Ans.

- Additional tests results are very useful for the discussion.

◆ Front end curvature

- Additional tests are required on vehicles with high plan curvature to establish radius/angle limitations.

Ans.

- Additional tests results are very useful for the discussion.

◆ Sports car

- Additional tests are to be carried out with a car which has a flat front (sports car) with a “conventional” design, i.e. no “soft nose” design.

Ans.

- Additional tests results are very useful for the discussion.

◆ Asymmetrical test results

- Further understanding is required as to whether and how this will be incorporated into future legislation. In principle, the test tool must reflect symmetrical vehicle structures and should not require additional tests.

Ans.

- To prevent or to reduce/prevent knee twist motion, the issue can be solved.

Requires of ACEA, contd.

◆ Ageing behavior and wear

- Ageing behaviour and wear of the fibre glass “bones” and of the rubber “skin and flesh” as well as of the plastic segments of the FlexPLI needs to be investigated.

} Ans.
• Answered in the Page 10.

◆ Transfer function

- The illustration of the transfer function (bending angle to MCL elongation) is needed.

} Ans.
• Answered in the Page 9.

◆ Relaxation/Exemption zone

- Extra set of proposed criteria is required for the exemption zone of the GTR legform test.

} Ans.
• It will be discussed in the Flex-TEG meeting.

◆ CAE models

- A simulation model needs to be made available.

} Ans.
• Answered in the Page 10.