TEG-127

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Technical Background Information Document for the UN-ECE GRSP explaining the Derivation of Threshold Values and Impactor Certification methods for the FlexPLI version GTR agreed by the FlexPLI-TEG at their 9th Meeting

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1) Tibia Threshold Value: 340 Nm

At the 8th GRSP Flex-TEG meeting on May 19th, 2009, two proposals for the tibia threshold value of the FlexPLI version GTR (also called Flex-GTR) were made by JAMA and BASt, coming to different conclusions.

a) 380 Nm (JAMA)

JAMA derived the Flex-GTR tibia bending moment threshold using a linear transition equation between human and Flex-GTR Finite Element (FE) models derived from computer simulation results. The average human tibia bending moment threshold value was taken from an injury risk curve of the 50th percentile male for tibia fracture, taking into account scaled male and female PMHS data from Nyquist et al. (1985) and Kerrigan et al. (2004) under modification of the standard tibia length and standard tibia plateau height, making the assumption that the height scale factor and length scale factor should correlate to each other. The Weibull Survival Model was used to develop the injury probability function. The proposed final threshold value resulted in 380 Nm.

b) 302 Nm (BASt)

BASt derived the Flex-GTR tibia bending moment threshold also using the corresponding transition equation between human and Flex-GTR FE models. The average human tibia bending moment threshold value was taken from an injury risk curve of the 50th percentile male for tibia fracture, taking into account scaled male PMHS data from Nyquist et al. (1985) using the standard tibia plateau height provided by DIN 33402-2 German anthropometrical database. The cumulative Gaussian distribution was used to develop the injury probability function. The calculated threshold value under consideration of possible scatter of test results and of a reproducibility corridor derived from inverse certification test results was 302 Nm.

A comparison of both approaches revealed that the calculated threshold values mainly depend on

- the underlying set of PMHS data
- the consideration of female and / or male data
- the use of scaled or unscaled data
- the particular anthropometrical database based on which human data are scaled
- the injury risk to be covered
- the statistical procedure to develop an injury probability function

As consensus for both approaches BASt proposed a rounded average value of 340 Nm for maximum tibia bending moment threshold.

In parallel to BASt proposing a rounded average value, JAMA conducted a correlation study on the EEVC WG 17 PLI tibia acceleration and FlexPLI tibia bending moment. As a result, they found that the 170 g EEVC WG 17 PLI tibia acceleration in gtr 9 was correlated to 343 Nm Flex-GTR tibia bending moment

As this was almost the value proposed by BASt as average value between the BASt and former JAMA proposals, the group agreed at the 9th TEG meeting on September 3rd – 4th, 2009, on a consensus of the rounded value of 340 Nm.

2) MCL Elongation Threshold Value: 22 mm

a) 22 mm (JAMA)

JAMA developed an MCL injury risk function as average function between the risk functions from Ivarsson et al. (2004) and Konosu et al. (2001), latter one revised using the Weibull Survival Model. In this function, a 50% risk of knee injury in terms of MCL rupture corresponded to a human knee bending angle of 19 degrees. This value was converted to 19.1 mm MCL elongation, using a corresponding transition equation from computer simulation. After incorporating the effect of muscle tone the threshold value was calculated at 21 mm. As this value was converted to 16.9 degrees of EEVC WG 17 PLI knee bending angle by using a corresponding transition equation which would be by 11 % more conservative than the currently defined GTR threshold value of 19 deg, a 5% more conservative approach, equal to 18 deg EEVC WG 17 PLI knee bending angle was proposed and transformed to 22 mm MCL elongation, using the same transition equation as before.

b) 22 mm (BASt)

As BASt is not in the position to validate or double-check those results, they investigated a direct correlation between the EEVC WG 17 PLI knee bending angle and the FlexPLI MCL elongation as verification of the JAMA results. A transition equation was developed, based on hardware test results of different vehicle categories and idealized tests. Thus, a knee bending angle of 19 degrees would correspond to 22.7 mm MCL elongation. In order to provide at least the same level of protection as the current GTR, a threshold value of 22 mm was proposed which was in line with the JAMA proposal

At the 9th GRSP Flex-TEG meeting on September 3rd - 4th, 2009, the group agreed on a Flex-GTR threshold value for MCL elongation of 22 mm.

3) ACL/PCL Elongation Threshold Value

a) Mandatory with a threshold of 13 mm (BASt)

Currently, no injury risk curve for cruciate ligament injuries is available. BASt proposed to therefore use the results of PMHS tests described by Bhalla et al. (2003), stating that below a shear displacement of 12.7 mm sufficient protection is provided to the cruciate ligaments. Thus, and in the absence of more data but having in mind that the FlexPLI should provide at least the same level of protection as the EEVC WG 17 PLI, BASt proposed a mandatory threshold value of 13 mm for ACL/PCL.

b) Monitoring against a threshold of 13 mm (JAMA)

In contrast, JAMA stated that the percentage of isolated ACL/PCL injuries in real world data is low (less than 3%) and the biomechanical data is limited (only 2 data are available from Bhalla et al. (2003), which does not allow development of an injury probability function. Therefore, the tentative threshold value should be set for monitoring, subject to future modification to the tentative threshold based on additional biomechanical data.

c) No consideration (ACEA)

As pointed out by both, BASt and JAMA, the biomechanical data available to define an injury risk curve is limited. In addition, it is felt that ACL/PCL elongation usually corresponds to MCL elongation. In addition, the gtr concept does not provide for the monitoring of certain criteria. ACEA therefore proposes to abstain from defining an injury threshold for ACL and PCL.

At the 9th GRSP Flex-TEG meeting on September 3rd - 4th, 2009, the group could not agree an injury threshold for ACL/PCL elongation.

➔ **GRSP is requested to either come to a conclusion or to provide guidance on this.**

4) Certification methods

Two different FlexPLI certification methods have been developed in the course of the last years.

a) Pendulum test (JAMA/JARI)

From the beginning, JARI developed the pendulum test as an easily applicable, highly reproducible and repeatable test enabling the test lab to make a quick check up of the impactor’s general functionality before each test series. The current manufacturer of the legform, FTSS, modified the pendulum test by hanging the legform upside down and applying an additional mass to the thigh to generate loading levels similar to those of real vehicle tests. JAMA/JARI also showed that essentially no rate sensitive materials are used for the major structures of the Flex-GTR and thus, in their point of view, as a certification test there should be no concern as to the difference in timings between the pendulum test and real vehicle test.

b) Inverse certification test (BASt)

On the other hand, BASt saw the need for a certification test with impactor loadings and test conditions similar to those during real vehicle tests. Therefore, the inverse certification test was developed, providing realistic impact conditions in terms of loadings, kinematics and timings, enabling the test lab to ensure that the impactor works as intended under the impact conditions occurring in real vehicle tests. The proposed test setup is in line with the recommendations of EEVC Working Group 17 who refused for the same reasons as BASt a pendulum test with their impactor for certification purposes.

At the 9th GRSP Flex-TEG meeting on September 3rd - 4th, 2009, the group agreed on a hybrid approach, using the inverse certification tests before each homologation test series and after every 30 tests while the pendulum function test needs to be carried out after every 10 tests in case the certification is not been done by using the inverse certification.