

**Femur Certification Corridors for the **Inverse Test**  
(**Zero Cross Timing**)**

8th IG GTR9-PH2 meeting

Japan Automobile Standards Internationalization Center (JASIC)

## Background

- At the 7th IG GTR9-PH2 meeting, the BAST method (GTR9-6-07: cut test data during Flex-PLI rebound phase) was agreed to be used in the GTR9 Phase 2 text.
- However, in the BAST method, femur outputs of Flex-PLI, which are not validated in the dynamic certification test of Flex-PLI, are used.
- Therefore, it was requested to BAST or someone to develop a requirement to confirm femur output validity.
- Based on the above situations, Japan volunteered to develop femur **zero cross timing** certification corridors for the **inverse** test **using two methodologies**.

**Methodology (1)**  
**BASt Method**

# Methodology (1)

- Corridor making method
  - ✓ BAST method (TF-RUCC-4-04) , which was used to develop tibia and knee ligaments (ACL, PCL, MCL) corridors.

## Procedure for determination of certification corridors (as established within TEG):

TF-RUCC-4-04

### 1) Definition of reproducibility corridors

CV calculation of all segments of each impactor

Determination of segments for reproducibility corridor

Requirement: CV < 5%

Calculation of pooled means of all seven segments with CV < 5%

Calculation of reproducibility corridors (pooled mean +/- 10%)

### 2) Definition of certification corridors

Determination of reproducible test results

Results supposed to be within reproducibility corridor

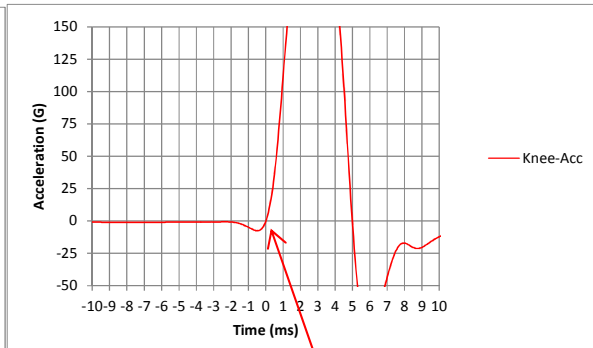
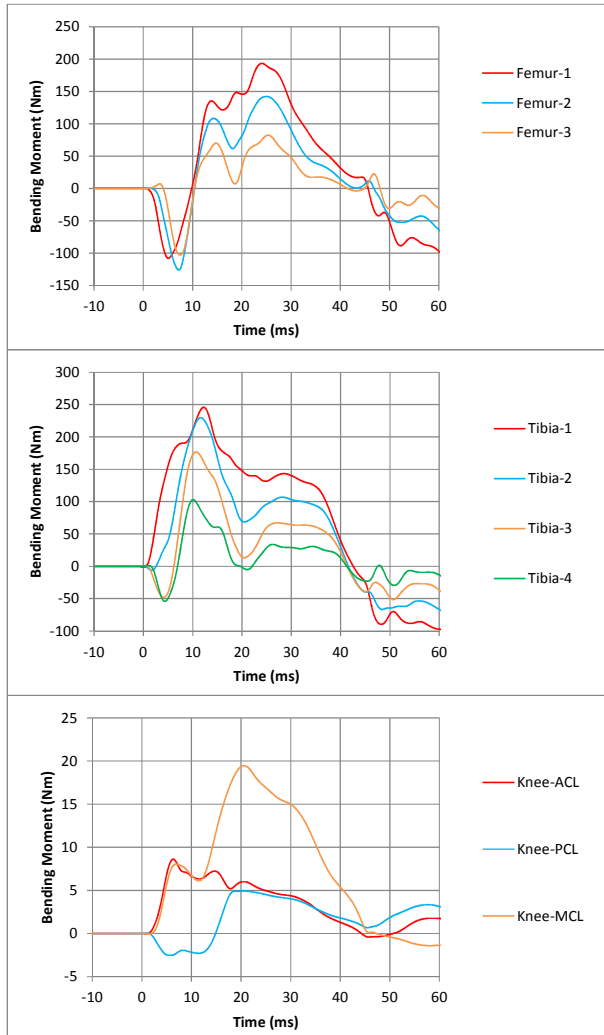
Determination of maxima and minima for each segment

Determination of corridor limits

Consideration of scatter: maxima + 5% / minima -5%

- Test data

- ✓ Master leg (SN01, SN03, E-leg) test data (zero cross timing) which were obtained at the Master test lab (JARI, BAST, Bertrandt) .



Impact timing is determined by knee acceleration output.  
(zero cross timing of knee acceleration is set as impact timing)

1) Definition of reproducibility corridors

- 1.1.) CV calculation of all segments of each impactor  
 1.2.) Determination of segments for reproducibility corridor; Requirement: CV < 5%

| Original Test Data |                            | Zero Cross Timing (ms) |         |         | CV Values                   |         |         |         |
|--------------------|----------------------------|------------------------|---------|---------|-----------------------------|---------|---------|---------|
| lfd Nr.            | Test #                     | Femur 3                | Femur 2 | Femur 1 | CV Values                   | Femur 3 | Femur 2 | Femur 1 |
| P1                 | SN01@JARI, 120328-01       | 41.2                   | 46.6    | 45.4    | Setup 1 - SN01 - JARI       | 1.7%    | 4.9%    | 0.8%    |
| P2                 | SN01@JARI, 120328-02       | 42.6                   | 43.2    | 44.7    |                             | Pass    | Pass    | Pass    |
| P3                 | SN01@JARI, 120328-03       | 42.2                   | 42.6    | 44.8    |                             |         |         |         |
| P4                 | SN03@JARI, 120327-01       | 42.6                   | 43.2    | 45.4    | Setup 2 - SN03 - JARI       | 2.2%    | 1.0%    | 0.9%    |
| P5                 | SN03@JARI, 120327-02       | 42.9                   | 43.3    | 44.6    |                             | Pass    | Pass    | Pass    |
| P6                 | SN03@JARI, 120327-03       | 41.1                   | 42.5    | 44.7    |                             |         |         |         |
| P7                 | E-leg@JARI, 120423-01      | 41.8                   | 42.1    | 44.2    | Setup 3 - E-leg - JARI      | 0.5%    | 0.6%    | 0.1%    |
| P8                 | E-leg@JARI, 120423-02      | 41.8                   | 42.2    | 44.1    |                             | Pass    | Pass    | Pass    |
| P9                 | E-leg@JARI, 120423-03      | 42.2                   | 42.5    | 44.1    |                             |         |         |         |
| P10                | SN01@BAST, 120605-01       | 46.2                   | 45.1    | 44.2    | Setup 4 - SN01 - BAST       | 0.1%    | 0.2%    | 0.2%    |
| P11                | SN01@BAST, 120605-02       | 46.1                   | 45.1    | 44.1    |                             | Pass    | Pass    | Pass    |
| P12                | SN01@BAST, 120605-03       | 46.2                   | 45.2    | 44.3    |                             |         |         |         |
| P13                | SN03@BAST, 120523-01       | 45.5                   | 44.4    | 43.4    | Setup 5 - SN03 - BAST       | 6.8%    | 0.9%    | 0.7%    |
| P14                | SN03@BAST, 120523-02       | 40.7                   | 43.8    | 42.9    |                             | Over 5% | Pass    | Pass    |
| P15                | SN03@BAST, 120523-03       | 40.4                   | 43.7    | 42.9    |                             |         |         |         |
| P16                | E-leg@BAST, 120523-01      | 45.8                   | 44.7    | 43.8    | Setup 6 - E-leg - BAST      | 0.5%    | 0.6%    | 0.5%    |
| P17                | E-leg@BAST, 120523-02      | 46.2                   | 45.1    | 44.2    |                             | Pass    | Pass    | Pass    |
| P18                | E-leg@BAST, 120523-03      | 45.9                   | 44.7    | 43.7    |                             |         |         |         |
| P19                | SN01@Bertrandt, 120612-01  | 42.0                   | 42.4    | 44.0    | Setup 7 - SN01 - Bertrandt  | 0.6%    | 0.5%    | 0.5%    |
| P20                | SN01@Bertrandt, 120612-02  | 41.6                   | 42.0    | 43.6    |                             | Pass    | Pass    | Pass    |
| P21                | SN01@Bertrandt, 120612-03  | 42.0                   | 42.4    | 43.7    |                             |         |         |         |
| P22                | SN03@Bertrandt, 120606-01  | 41.1                   | 41.8    | 44.3    | Setup 8 - SN03 - Bertrandt  | 0.4%    | 0.6%    | 1.4%    |
| P23                | SN03@Bertrandt, 120606-02  | 40.7                   | 41.3    | 43.2    |                             | Pass    | Pass    | Pass    |
| P24                | SN03@Bertrandt, 120606-03  | 40.9                   | 41.7    | 44.1    |                             |         |         |         |
| P25                | E-leg@Bertrandt, 120606-01 | 41.3                   | 41.4    | 42.7    | Setup 9 - E-leg - Bertrandt | 0.4%    | 0.3%    | 0.2%    |
| P26                | E-leg@Bertrandt, 120606-02 | 41.1                   | 41.3    | 42.5    |                             | Pass    | Pass    | Pass    |
| P27                | E-leg@Bertrandt, 120606-03 | 41.4                   | 41.5    | 42.7    |                             |         |         |         |

| Removed: CV Values Over 5% Test Data |                                 |         |         |         |
|--------------------------------------|---------------------------------|---------|---------|---------|
| Ild Nr.                              | Test #                          | Femur 3 | Femur 2 | Femur 1 |
| P1                                   | SN01@JARI, 120328-01            | 41.2    | 46.6    | 45.4    |
| P2                                   | SN01@JARI, 120328-02            | 42.6    | 43.2    | 44.7    |
| P3                                   | SN01@JARI, 120328-03            | 42.2    | 42.6    | 44.8    |
| P4                                   | SN03@JARI, 120327-01            | 42.6    | 43.2    | 45.4    |
| P5                                   | SN03@JARI, 120327-02            | 42.9    | 43.3    | 44.6    |
| P6                                   | SN03@JARI, 120327-03            | 41.1    | 42.5    | 44.7    |
| P7                                   | E-leg@JARI, 120423-01           | 41.8    | 42.1    | 44.2    |
| P8                                   | E-leg@JARI, 120423-02           | 41.8    | 42.2    | 44.1    |
| P9                                   | E-leg@JARI, 120423-03           | 42.2    | 42.5    | 44.1    |
| P10                                  | SN01@BAST, 120605-01            | 46.2    | 45.1    | 44.2    |
| P11                                  | SN01@BAST, 120605-02            | 46.1    | 45.1    | 44.1    |
| P12                                  | SN01@BAST, 120605-03            | 46.2    | 45.2    | 44.3    |
| P13                                  | SN03@BAST, 120523-01            |         | 44.4    | 43.4    |
| P14                                  | SN03@BAST, 120523-02            |         | 43.8    | 42.9    |
| P15                                  | SN03@BAST, 120523-03            |         | 43.7    | 42.9    |
| P16                                  | E-leg@BAST, 120523-01           | 45.8    | 44.7    | 43.8    |
| P17                                  | E-leg@BAST, 120523-02           | 46.2    | 45.1    | 44.2    |
| P18                                  | E-leg@BAST, 120523-03           | 45.9    | 44.7    | 43.7    |
| P19                                  | SN01@Bertrandt, 120612-01       | 42.0    | 42.4    | 44.0    |
| P20                                  | SN01@Bertrandt, 120612-02       | 41.6    | 42.0    | 43.6    |
| P21                                  | SN01@Bertrandt, 120612-03       | 42.0    | 42.4    | 43.7    |
| P22                                  | SN03@Bertrandt, 120606-01       | 41.1    | 41.8    | 44.3    |
| P23                                  | SN03@Bertrandt, 120606-02       | 40.7    | 41.3    | 43.2    |
| P24                                  | SN03@Bertrandt, 120606-03       | 40.9    | 41.7    | 44.1    |
| P25                                  | E-leg@Bertrandt, 120606-01      | 41.3    | 41.4    | 42.7    |
| P26                                  | E-leg@Bertrandt, 120606-02      | 41.1    | 41.3    | 42.5    |
| P27                                  | E-leg@Bertrandt, 120606-03      | 41.4    | 41.5    | 42.7    |
|                                      |                                 |         |         |         |
|                                      |                                 |         |         |         |
|                                      |                                 |         |         |         |
|                                      | (a) Pooled Mean with CV < 5%    | 42.8    | 43.2    | 43.9    |
|                                      | (b) Limit Value Upper: (a) +10% | 47.1    | 47.5    | 48.3    |
|                                      | (c) Limit Value Lower: (a) -10% | 38.5    | 38.8    | 39.5    |

1.3) Calculation of pooled means of all segments with CV < 5%

1.4) Calculation of reproducibility corridors (limit values); pooled mean +/- 10%

## 2) Definition of certification corridors

### Determination of reproducible test results

| Test #                     | Femur 3 | Femur 2 | Femur 1 |
|----------------------------|---------|---------|---------|
| SN01@JARI, 120328-01       | 41.2    | 46.6    | 45.4    |
| SN01@JARI, 120328-02       | 42.6    | 43.2    | 44.7    |
| SN01@JARI, 120328-03       | 42.2    | 42.6    | 44.8    |
| SN03@JARI, 120327-01       | 42.6    | 43.2    | 45.4    |
| SN03@JARI, 120327-02       | 42.9    | 43.3    | 44.6    |
| SN03@JARI, 120327-03       | 41.1    | 42.5    | 44.7    |
| E-leg@JARI, 120423-01      | 41.8    | 42.1    | 44.2    |
| E-leg@JARI, 120423-02      | 41.8    | 42.2    | 44.1    |
| E-leg@JARI, 120423-03      | 42.2    | 42.5    | 44.1    |
| SN01@BASt, 120605-01       | 46.2    | 45.1    | 44.2    |
| SN01@BASt, 120605-02       | 46.1    | 45.1    | 44.1    |
| SN01@BASt, 120605-03       | 46.2    | 45.2    | 44.3    |
| SN03@BASt, 120523-01       | 45.5    | 44.4    | 43.4    |
| SN03@BASt, 120523-02       | 40.7    | 43.8    | 42.9    |
| SN03@BASt, 120523-03       | 40.4    | 43.7    | 42.9    |
| E-leg@BASt, 120523-01      | 45.8    | 44.7    | 43.8    |
| E-leg@BASt, 120523-02      | 46.2    | 45.1    | 44.2    |
| E-leg@BASt, 120523-03      | 45.9    | 44.7    | 43.7    |
| SN01@Bertrandt, 120612-01  | 42.0    | 42.4    | 44.0    |
| SN01@Bertrandt, 120612-02  | 41.6    | 42.0    | 43.6    |
| SN01@Bertrandt, 120612-03  | 42.0    | 42.4    | 43.7    |
| SN03@Bertrandt, 120606-01  | 41.1    | 41.8    | 44.3    |
| SN03@Bertrandt, 120606-02  | 40.7    | 41.3    | 43.2    |
| SN03@Bertrandt, 120606-03  | 40.9    | 41.7    | 44.1    |
| E-leg@Bertrandt, 120606-01 | 41.3    | 41.4    | 42.7    |
| E-leg@Bertrandt, 120606-02 | 41.1    | 41.3    | 42.5    |
| E-leg@Bertrandt, 120606-03 | 41.4    | 41.5    | 42.7    |

2.1) Determination of reproducible test results

2.2) Determination of maxima and minima for each segment

2.3) Determination of corridor limits (maxima + 5%, minima -5%)

2.4) Round 2.3) values to define certification corridors

|                              |      |      |      |
|------------------------------|------|------|------|
| Maximum                      | 46.2 | 46.6 | 45.4 |
| Minimum                      | 40.4 | 41.3 | 42.5 |
| Max. x 1.05                  | 48.6 | 48.9 | 47.7 |
| Min. x 0.95                  | 38.4 | 39.2 | 40.4 |
| Certification Corridor Upper | 49   | 49   | 48   |
| Certification Corridor Lower | 38   | 39   | 40   |

Round  
Round



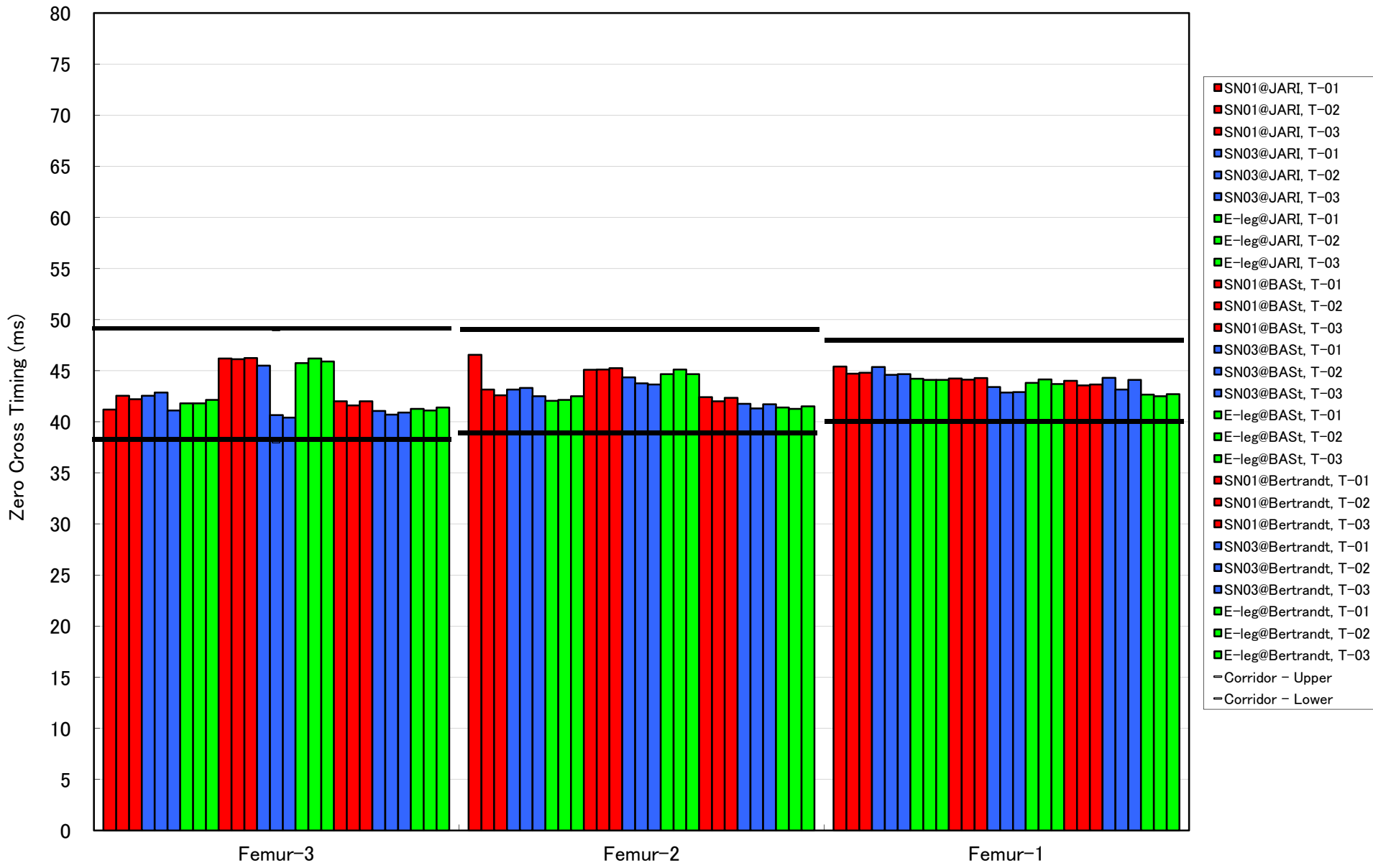
Comparison to certification corridors

| Compared to Certification Corridors |         |         |         |
|-------------------------------------|---------|---------|---------|
| Test #                              | Femur 3 | Femur 2 | Femur 1 |
| SN01@JARI, 120328-01                | 41.2    | 46.6    | 45.4    |
| SN01@JARI, 120328-02                | 42.6    | 43.2    | 44.7    |
| SN01@JARI, 120328-03                | 42.2    | 42.6    | 44.8    |
| SN03@JARI, 120327-01                | 42.6    | 43.2    | 45.4    |
| SN03@JARI, 120327-02                | 42.9    | 43.3    | 44.6    |
| SN03@JARI, 120327-03                | 41.1    | 42.5    | 44.7    |
| E-leg@JARI, 120423-01               | 41.8    | 42.1    | 44.2    |
| E-leg@JARI, 120423-02               | 41.8    | 42.2    | 44.1    |
| E-leg@JARI, 120423-03               | 42.2    | 42.5    | 44.1    |
| SN01@BASt, 120605-01                | 46.2    | 45.1    | 44.2    |
| SN01@BASt, 120605-02                | 46.1    | 45.1    | 44.1    |
| SN01@BASt, 120605-03                | 46.2    | 45.2    | 44.3    |
| SN03@BASt, 120523-01                | 45.5    | 44.4    | 43.4    |
| SN03@BASt, 120523-02                | 40.7    | 43.8    | 42.9    |
| SN03@BASt, 120523-03                | 40.4    | 43.7    | 42.9    |
| E-leg@BASt, 120523-01               | 45.8    | 44.7    | 43.8    |
| E-leg@BASt, 120523-02               | 46.2    | 45.1    | 44.2    |
| E-leg@BASt, 120523-03               | 45.9    | 44.7    | 43.7    |
| SN01@Bertrandt, 120612-01           | 42.0    | 42.4    | 44.0    |
| SN01@Bertrandt, 120612-02           | 41.6    | 42.0    | 43.6    |
| SN01@Bertrandt, 120612-03           | 42.0    | 42.4    | 43.7    |
| SN03@Bertrandt, 120606-01           | 41.1    | 41.8    | 44.3    |
| SN03@Bertrandt, 120606-02           | 40.7    | 41.3    | 43.2    |
| SN03@Bertrandt, 120606-03           | 40.9    | 41.7    | 44.1    |
| E-leg@Bertrandt, 120606-01          | 41.3    | 41.4    | 42.7    |
| E-leg@Bertrandt, 120606-02          | 41.1    | 41.3    | 42.5    |
| E-leg@Bertrandt, 120606-03          | 41.4    | 41.5    | 42.7    |
| Certification Corridor Upper        | 49      | 49      | 48      |
| Certification Corridor Lower        | 38      | 39      | 40      |
|                                     | 100%    | 100%    | 100%    |
|                                     | Pass    | Pass    | Pass    |

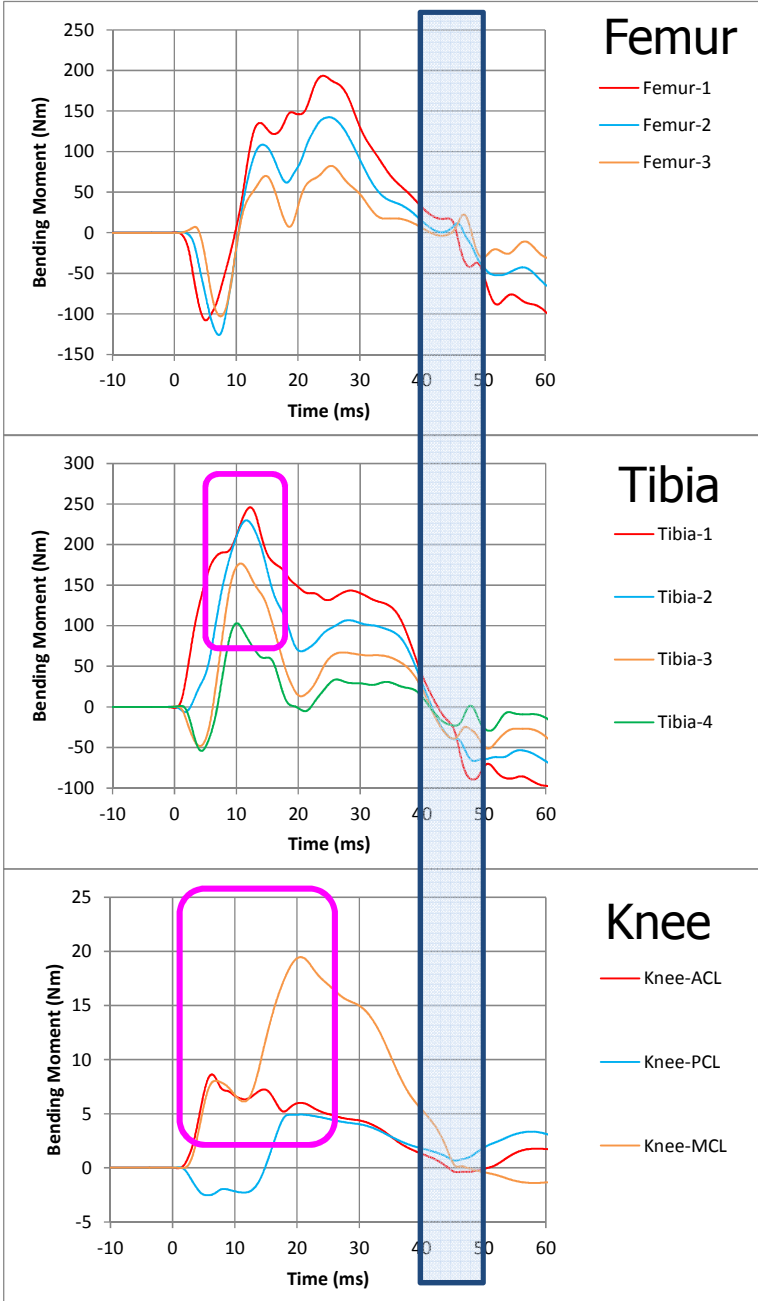
• All test data fall within the certification corridors.


Comparison to certification corridors


• All test data fall with the certification corridors.



# Comparison between Zero Cross Timing Corridor Location of Femur and Maximum Value Generate Timing of Tibia and Knee Outputs

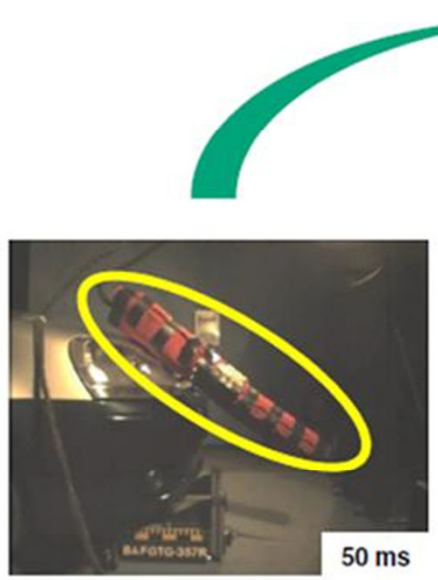


 Zero cross timing corridor location of Femur (around 45 +/- 5 ms)

 Maximum values generate timing of Tibia and Knee outputs (used for Tibia/Knee injury assessment)

- If zero cross timing of femur falls into the developed corridor, it is clear that no concerns to be cut maximum values of Tibia and Knee inappropriately during an inverse certification test.
- The corridor width (around +/- 5 ms) acceptability is evaluated using several car tests. (see following slides)

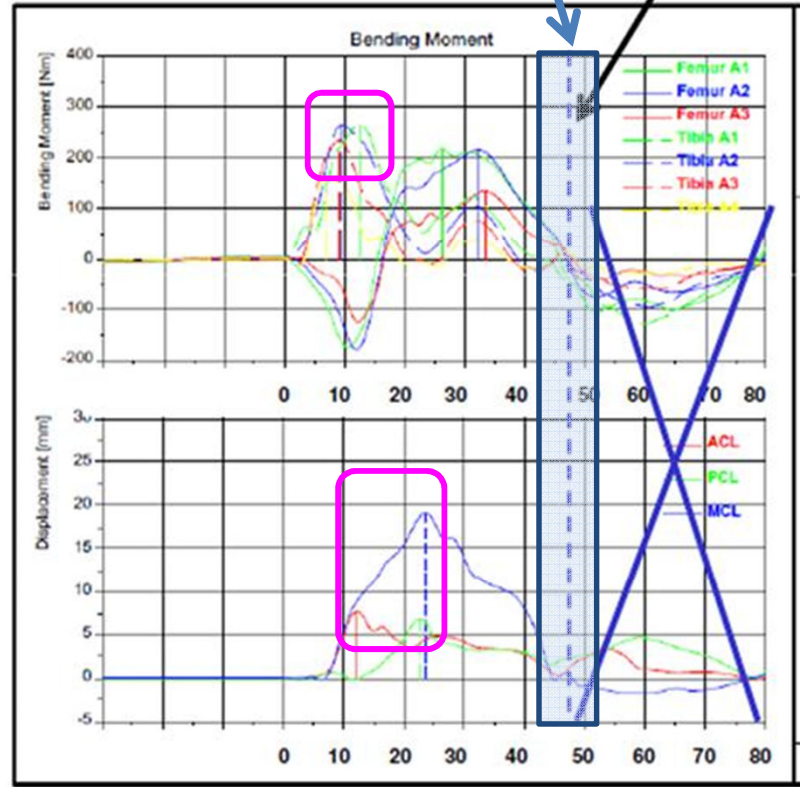
# BASt proposal – Case study (I): Sedan



Zero cross timing

Entire impactor left BAI

**Acceptable**



Zero cross timing corridor width (around +/- 5 ms)



Maximum value generates timing regarding Tibia and Knee outputs

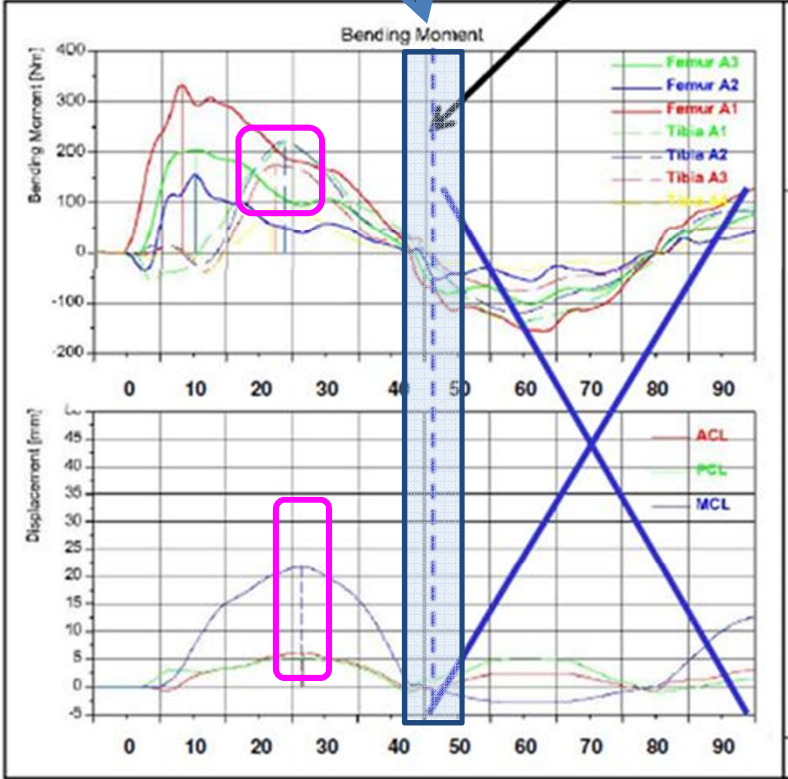
# BASt proposal – Case study (II): SUV



Zero cross timing

Entire impactor left BAI

**Acceptable**



Zero cross timing corridor width (around +/- 5 ms)



Maximum value generates timing regarding Tibia and Knee outputs

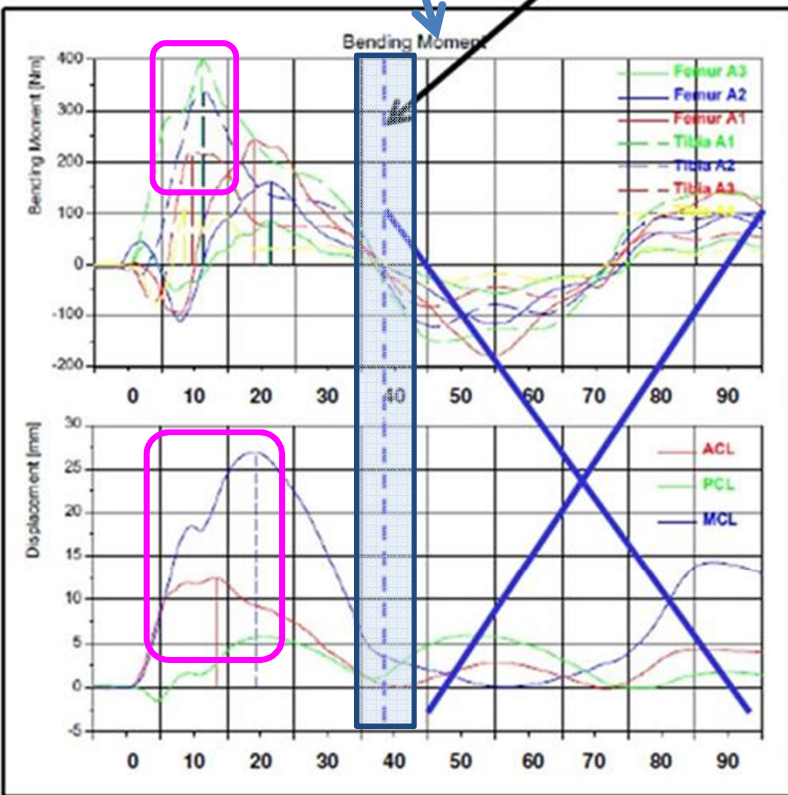
# BASt proposal – Case study (III): FFV



Zero cross timing

Entire impactor left BAI

**Acceptable**



Zero cross timing corridor width (around +/- 5 ms)

Maximum value generates timing regarding Tibia and Knee outputs

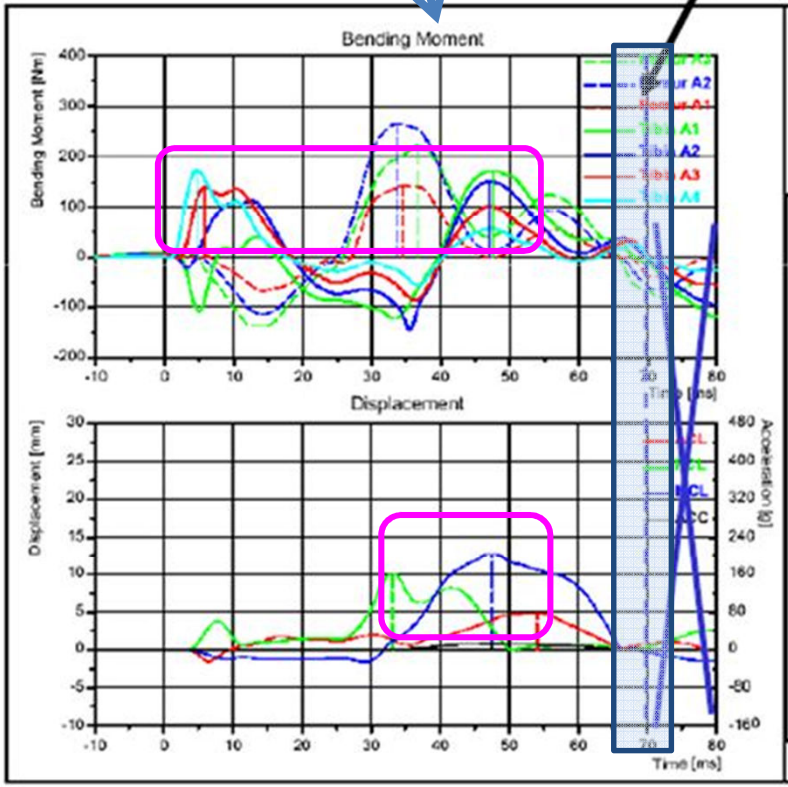
# BAST proposal – Case study (IV): Sports car



Zero cross timing

Entire impactor left BAI

**Acceptable**



Zero cross timing corridor width (around +/- 5 ms)

Maximum value generates timing regarding Tibia and Knee outputs

**Methodology (2)**  
**BASt Method with Modifications**



## Methodology (2)

- Corridor making method
  - ✓ BAST method (TF-RUCC-4-04), which was used to develop tibia and knee ligaments (ACL, PCL, MCL) corridors, with some modifications.

### Procedure for determination of certification corridors (as established within TEG):

**TF-RUCC-4-04**

**Modifications**

#### 1) Definition of reproducibility corridors

CV calculation of all segments of each impactor

Determination of segments for reproducibility corridor

Requirement:  $CV < 5\%$

Calculation of pooled means of all seven segments with  $CV < 5\%$

Calculation of reproducibility corridors (pooled mean  $\pm 10\%$ )

#### 2) Definition of certification corridors

Determination of reproducible test results

Results supposed to be within reproducibility corridor

Determination of Average values

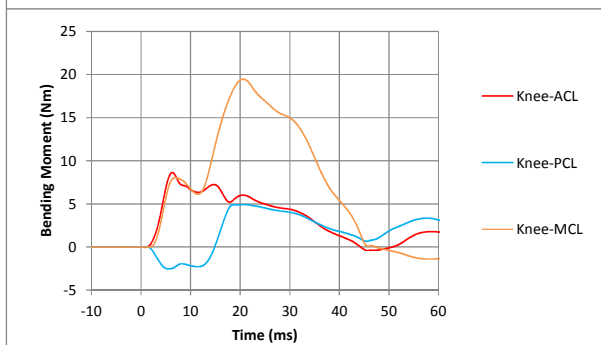
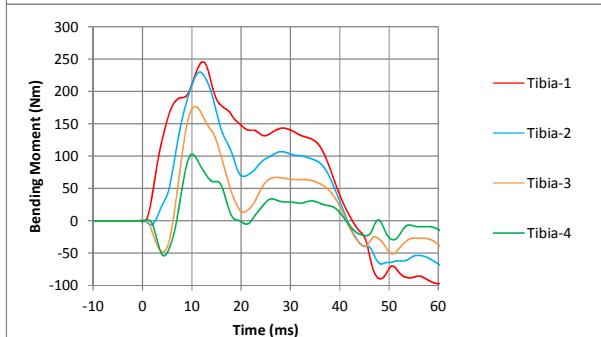
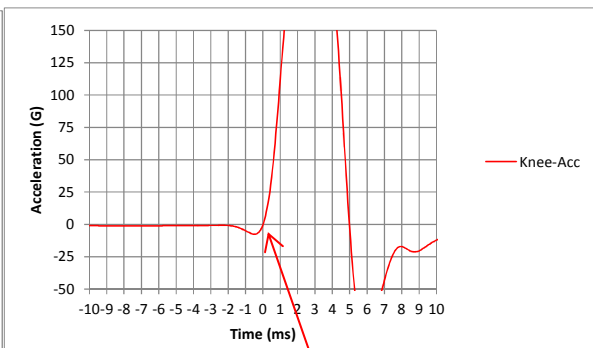
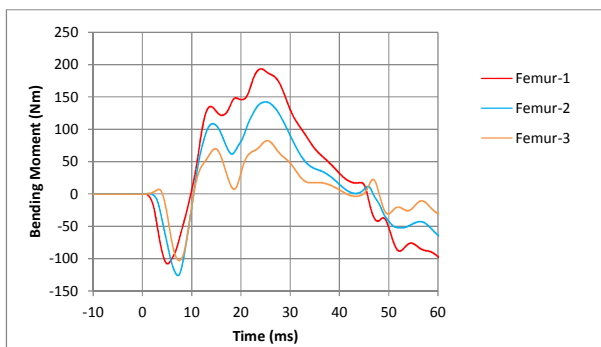
Determination of corridor limits

- Average  $\pm$  Acceptable Tolerance (15 ms)

- Acceptable tolerance ( $\pm 15$  ms) is determined using car test results. (see Appendix 1)

## Same as Methodology (1)

- Test data
  - Master leg (SN01, SN03, E-leg) test data (zero cross timing) which were obtained at the Master test lab (JARI, BAST, Bertrandt) .



Impact timing is determined by knee acceleration output.  
(zero cross timing of knee acceleration is set as impact timing)

**Same as Methodology (1)**

- 1.1.) CV calculation of all segments of each impactor
- 1.2.) Determination of segments for reproducibility corridor; Requirement: CV < 5%

1) Definition of reproducibility corridors

| Original Test Data |                            | Zero Cross Timing (ms) |         |         | CV Values                   |         |         |         |
|--------------------|----------------------------|------------------------|---------|---------|-----------------------------|---------|---------|---------|
| lfd Nr.            | Test #                     | Femur 3                | Femur 2 | Femur 1 | CV Values                   | Femur 3 | Femur 2 | Femur 1 |
| P1                 | SN01@JARI, 120328-01       | 41.2                   | 46.6    | 45.4    | Setup 1 - SN01 - JARI       | 1.7%    | 4.9%    | 0.8%    |
| P2                 | SN01@JARI, 120328-02       | 42.6                   | 43.2    | 44.7    |                             | Pass    | Pass    | Pass    |
| P3                 | SN01@JARI, 120328-03       | 42.2                   | 42.6    | 44.8    |                             |         |         |         |
| P4                 | SN03@JARI, 120327-01       | 42.6                   | 43.2    | 45.4    | Setup 2 - SN03 - JARI       | 2.2%    | 1.0%    | 0.9%    |
| P5                 | SN03@JARI, 120327-02       | 42.9                   | 43.3    | 44.6    |                             | Pass    | Pass    | Pass    |
| P6                 | SN03@JARI, 120327-03       | 41.1                   | 42.5    | 44.7    |                             |         |         |         |
| P7                 | E-leg@JARI, 120423-01      | 41.8                   | 42.1    | 44.2    | Setup 3 - E-leg - JARI      | 0.5%    | 0.6%    | 0.1%    |
| P8                 | E-leg@JARI, 120423-02      | 41.8                   | 42.2    | 44.1    |                             | Pass    | Pass    | Pass    |
| P9                 | E-leg@JARI, 120423-03      | 42.2                   | 42.5    | 44.1    |                             |         |         |         |
| P10                | SN01@BAST, 120605-01       | 46.2                   | 45.1    | 44.2    | Setup 4 - SN01 - BAST       | 0.1%    | 0.2%    | 0.2%    |
| P11                | SN01@BAST, 120605-02       | 46.1                   | 45.1    | 44.1    |                             | Pass    | Pass    | Pass    |
| P12                | SN01@BAST, 120605-03       | 46.2                   | 45.2    | 44.3    |                             |         |         |         |
| P13                | SN03@BAST, 120523-01       | 45.5                   | 44.4    | 43.4    | Setup 5 - SN03 - BAST       | 6.8%    | 0.9%    | 0.7%    |
| P14                | SN03@BAST, 120523-02       | 40.7                   | 43.8    | 42.9    |                             | Over 5% | Pass    | Pass    |
| P15                | SN03@BAST, 120523-03       | 40.4                   | 43.7    | 42.9    |                             |         |         |         |
| P16                | E-leg@BAST, 120523-01      | 45.8                   | 44.7    | 43.8    | Setup 6 - E-leg - BAST      | 0.5%    | 0.6%    | 0.5%    |
| P17                | E-leg@BAST, 120523-02      | 46.2                   | 45.1    | 44.2    |                             | Pass    | Pass    | Pass    |
| P18                | E-leg@BAST, 120523-03      | 45.9                   | 44.7    | 43.7    |                             |         |         |         |
| P19                | SN01@Bertrandt, 120612-01  | 42.0                   | 42.4    | 44.0    | Setup 7 - SN01 - Bertrandt  | 0.6%    | 0.5%    | 0.5%    |
| P20                | SN01@Bertrandt, 120612-02  | 41.6                   | 42.0    | 43.6    |                             | Pass    | Pass    | Pass    |
| P21                | SN01@Bertrandt, 120612-03  | 42.0                   | 42.4    | 43.7    |                             |         |         |         |
| P22                | SN03@Bertrandt, 120606-01  | 41.1                   | 41.8    | 44.3    | Setup 8 - SN03 - Bertrandt  | 0.4%    | 0.6%    | 1.4%    |
| P23                | SN03@Bertrandt, 120606-02  | 40.7                   | 41.3    | 43.2    |                             | Pass    | Pass    | Pass    |
| P24                | SN03@Bertrandt, 120606-03  | 40.9                   | 41.7    | 44.1    |                             |         |         |         |
| P25                | E-leg@Bertrandt, 120606-01 | 41.3                   | 41.4    | 42.7    | Setup 9 - E-leg - Bertrandt | 0.4%    | 0.3%    | 0.2%    |
| P26                | E-leg@Bertrandt, 120606-02 | 41.1                   | 41.3    | 42.5    |                             | Pass    | Pass    | Pass    |
| P27                | E-leg@Bertrandt, 120606-03 | 41.4                   | 41.5    | 42.7    |                             |         |         |         |

Same as Methodology (1)

Removed: CV Values Over 5% Test Data

| lfd Nr. | Test #                     | Femur 3 | Femur 2 | Femur 1 |
|---------|----------------------------|---------|---------|---------|
| P1      | SN01@JARI, 120328-01       | 41.2    | 46.6    | 45.4    |
| P2      | SN01@JARI, 120328-02       | 42.6    | 43.2    | 44.7    |
| P3      | SN01@JARI, 120328-03       | 42.2    | 42.6    | 44.8    |
| P4      | SN03@JARI, 120327-01       | 42.6    | 43.2    | 45.4    |
| P5      | SN03@JARI, 120327-02       | 42.9    | 43.3    | 44.6    |
| P6      | SN03@JARI, 120327-03       | 41.1    | 42.5    | 44.7    |
| P7      | E-leg@JARI, 120423-01      | 41.8    | 42.1    | 44.2    |
| P8      | E-leg@JARI, 120423-02      | 41.8    | 42.2    | 44.1    |
| P9      | E-leg@JARI, 120423-03      | 42.2    | 42.5    | 44.1    |
| P10     | SN01@BAsT, 120605-01       | 46.2    | 45.1    | 44.2    |
| P11     | SN01@BAsT, 120605-02       | 46.1    | 45.1    | 44.1    |
| P12     | SN01@BAsT, 120605-03       | 46.2    | 45.2    | 44.3    |
| P13     | SN03@BAsT, 120523-01       |         | 44.4    | 43.4    |
| P14     | SN03@BAsT, 120523-02       |         | 43.8    | 42.9    |
| P15     | SN03@BAsT, 120523-03       |         | 43.7    | 42.9    |
| P16     | E-leg@BAsT, 120523-01      | 45.8    | 44.7    | 43.8    |
| P17     | E-leg@BAsT, 120523-02      | 46.2    | 45.1    | 44.2    |
| P18     | E-leg@BAsT, 120523-03      | 45.9    | 44.7    | 43.7    |
| P19     | SN01@Bertrandt, 120612-01  | 42.0    | 42.4    | 44.0    |
| P20     | SN01@Bertrandt, 120612-02  | 41.6    | 42.0    | 43.6    |
| P21     | SN01@Bertrandt, 120612-03  | 42.0    | 42.4    | 43.7    |
| P22     | SN03@Bertrandt, 120606-01  | 41.1    | 41.8    | 44.3    |
| P23     | SN03@Bertrandt, 120606-02  | 40.7    | 41.3    | 43.2    |
| P24     | SN03@Bertrandt, 120606-03  | 40.9    | 41.7    | 44.1    |
| P25     | E-leg@Bertrandt, 120606-01 | 41.3    | 41.4    | 42.7    |
| P26     | E-leg@Bertrandt, 120606-02 | 41.1    | 41.3    | 42.5    |
| P27     | E-leg@Bertrandt, 120606-03 | 41.4    | 41.5    | 42.7    |

1.3) Calculation of pooled means of all segments with CV < 5%

1.4) Calculation of reproducibility corridors (limit values); pooled mean +/- 10%

|                                 |      |      |      |
|---------------------------------|------|------|------|
| (a) Pooled Mean with CV < 5%    | 42.8 | 43.2 | 43.9 |
| (b) Limit Value Upper: (a) +10% | 47.1 | 47.5 | 48.3 |
| (c) Limit Value Lower: (a) -10% | 38.5 | 38.8 | 39.5 |

2) Definition of certification corridors

Determination of reproducible test results

| Test #                       | Femur 3 | Femur 2 | Femur 1 |       |
|------------------------------|---------|---------|---------|-------|
| SN01@JARI, 120328-01         | 41.2    | 46.6    | 45.4    |       |
| SN01@JARI, 120328-02         | 42.6    | 43.2    | 44.7    |       |
| SN01@JARI, 120328-03         | 42.2    | 42.6    | 44.8    |       |
| SN03@JARI, 120327-01         | 42.6    | 43.2    | 45.4    |       |
| SN03@JARI, 120327-02         | 42.9    | 43.3    | 44.6    |       |
| SN03@JARI, 120327-03         | 41.1    | 42.5    | 44.7    |       |
| E-leg@JARI, 120423-01        | 41.8    | 42.1    | 44.2    |       |
| E-leg@JARI, 120423-02        | 41.8    | 42.2    | 44.1    |       |
| E-leg@JARI, 120423-03        | 42.2    | 42.5    | 44.1    |       |
| SN01@BAsT, 120605-01         | 46.2    | 45.1    | 44.2    |       |
| SN01@BAsT, 120605-02         | 46.1    | 45.1    | 44.1    |       |
| SN01@BAsT, 120605-03         | 46.2    | 45.2    | 44.3    |       |
| SN03@BAsT, 120523-01         | 45.5    | 44.4    | 43.4    |       |
| SN03@BAsT, 120523-02         | 40.7    | 43.8    | 42.9    |       |
| SN03@BAsT, 120523-03         | 40.4    | 43.7    | 42.9    |       |
| E-leg@BAsT, 120523-01        | 45.8    | 44.7    | 43.8    |       |
| E-leg@BAsT, 120523-02        | 46.2    | 45.1    | 44.2    |       |
| E-leg@BAsT, 120523-03        | 45.9    | 44.7    | 43.7    |       |
| SN01@Bertrandt, 120612-01    | 42.0    | 42.4    | 44.0    |       |
| SN01@Bertrandt, 120612-02    | 41.6    | 42.0    | 43.6    |       |
| SN01@Bertrandt, 120612-03    | 42.0    | 42.4    | 43.7    |       |
| SN03@Bertrandt, 120606-01    | 41.1    | 41.8    | 44.3    |       |
| SN03@Bertrandt, 120606-02    | 40.7    | 41.3    | 43.2    |       |
| SN03@Bertrandt, 120606-03    | 40.9    | 41.7    | 44.1    |       |
| E-leg@Bertrandt, 120606-01   | 41.3    | 41.4    | 42.7    |       |
| E-leg@Bertrandt, 120606-02   | 41.1    | 41.3    | 42.5    |       |
| E-leg@Bertrandt, 120606-03   | 41.4    | 41.5    | 42.7    |       |
| Average                      | 42.7    | 43.2    | 43.9    |       |
| Average + 15 ms              | 57.7    | 58.2    | 58.9    |       |
| Average - 15 ms              | 27.7    | 28.2    | 28.9    |       |
| Certification Corridor Upper | 58      | 58      | 59      | Round |
| Certification Corridor Lower | 28      | 28      | 29      | Round |

2.1) Determination of reproducible test results

2.2) Determination of average values

2.3) Determination of corridor limits  
(Average + 15 ms, Average - 15 ms)

2.4) Round 2.3) values to define certification corridors

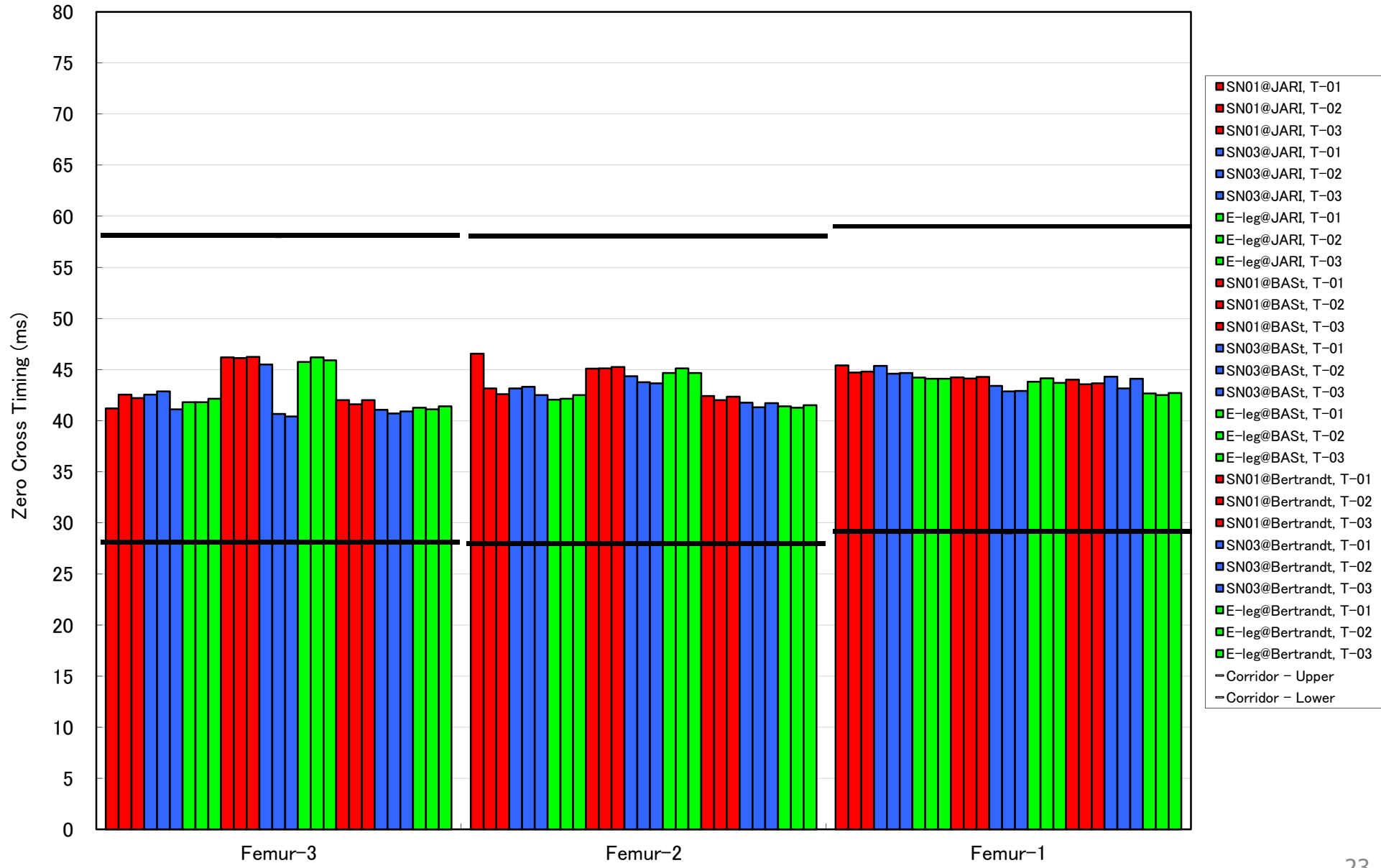
Comparison to certification corridors

| Compared to Certification Corridors |         |         |         |
|-------------------------------------|---------|---------|---------|
| Test #                              | Femur 3 | Femur 2 | Femur 1 |
| SN01@JARI, 120328-01                | 41.2    | 46.6    | 45.4    |
| SN01@JARI, 120328-02                | 42.6    | 43.2    | 44.7    |
| SN01@JARI, 120328-03                | 42.2    | 42.6    | 44.8    |
| SN03@JARI, 120327-01                | 42.6    | 43.2    | 45.4    |
| SN03@JARI, 120327-02                | 42.9    | 43.3    | 44.6    |
| SN03@JARI, 120327-03                | 41.1    | 42.5    | 44.7    |
| E-leg@JARI, 120423-01               | 41.8    | 42.1    | 44.2    |
| E-leg@JARI, 120423-02               | 41.8    | 42.2    | 44.1    |
| E-leg@JARI, 120423-03               | 42.2    | 42.5    | 44.1    |
| SN01@BAST, 120605-01                | 46.2    | 45.1    | 44.2    |
| SN01@BAST, 120605-02                | 46.1    | 45.1    | 44.1    |
| SN01@BAST, 120605-03                | 46.2    | 45.2    | 44.3    |
| SN03@BAST, 120523-01                | 45.5    | 44.4    | 43.4    |
| SN03@BAST, 120523-02                | 40.7    | 43.8    | 42.9    |
| SN03@BAST, 120523-03                | 40.4    | 43.7    | 42.9    |
| E-leg@BAST, 120523-01               | 45.8    | 44.7    | 43.8    |
| E-leg@BAST, 120523-02               | 46.2    | 45.1    | 44.2    |
| E-leg@BAST, 120523-03               | 45.9    | 44.7    | 43.7    |
| SN01@Bertrandt, 120612-01           | 42.0    | 42.4    | 44.0    |
| SN01@Bertrandt, 120612-02           | 41.6    | 42.0    | 43.6    |
| SN01@Bertrandt, 120612-03           | 42.0    | 42.4    | 43.7    |
| SN03@Bertrandt, 120606-01           | 41.1    | 41.8    | 44.3    |
| SN03@Bertrandt, 120606-02           | 40.7    | 41.3    | 43.2    |
| SN03@Bertrandt, 120606-03           | 40.9    | 41.7    | 44.1    |
| E-leg@Bertrandt, 120606-01          | 41.3    | 41.4    | 42.7    |
| E-leg@Bertrandt, 120606-02          | 41.1    | 41.3    | 42.5    |
| E-leg@Bertrandt, 120606-03          | 41.4    | 41.5    | 42.7    |
| Certification Corridor Upper        | 58      | 58      | 59      |
| Certification Corridor Lower        | 28      | 28      | 29      |
|                                     | 100%    | 100%    | 100%    |
|                                     | Pass    | Pass    | Pass    |

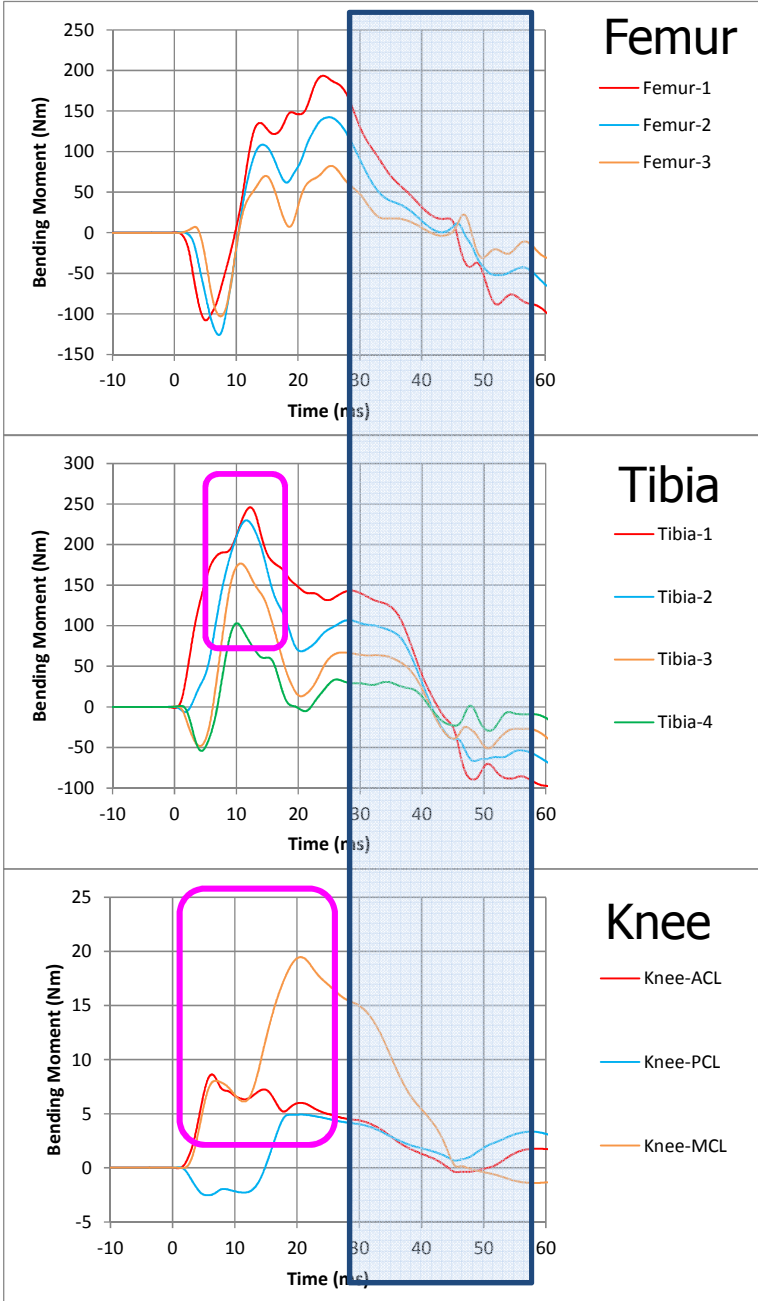
• All test data fall within the certification corridors.


Comparison to certification corridors


• All test data fall with the certification corridors.



# Comparison between Zero Cross Timing corridor for Femur and Maximum values generate timing of tibia and knee outputs



 Zero cross timing corridor  
(around 42 +/- 15 ms)

 Maximum values generate timing of  
Tibia and Knee outputs  
(used for Tibia/Knee injury assessment)

- If zero cross timing of femur falls into the developed corridor, it is clear that no concerns to be cut maximum values of Tibia and Knee inappropriately during an inverse certification test.
- The corridor width (around +/-15 ms) acceptability is already evaluated using several car test results. (see Appendix 1)



## Summary

- Japan developed femur **zero cross timing** certification corridors for the **inverse** test voluntarily using **two different methodologies** with Master leg (SN01, SN03, E-leg) test data (**zero cross timing**) which were obtained at the Master test lab (JARI, BAST, Bertrandt)

### <Methodology (1)>

- ✓ Femur-3: 38-49 (ms), Femur-2: 39-49 (ms), Femur-1: 40-48 (ms)

### <Methodology (2)>

- ✓ Femur-3: 28-58 (ms), Femur-2: 28-58 (ms), Femur-1: 29-59 (ms)

- All Master leg test data falls into the above corridors.
- In the BAST method, zero cross timing is used to cut rebound phase test data. Therefore, Japan proposes to set femur **zero cross timing** certification corridors for the **inverse** test which are obtained by Methodology (1) or Methodology (2).

# **Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing**

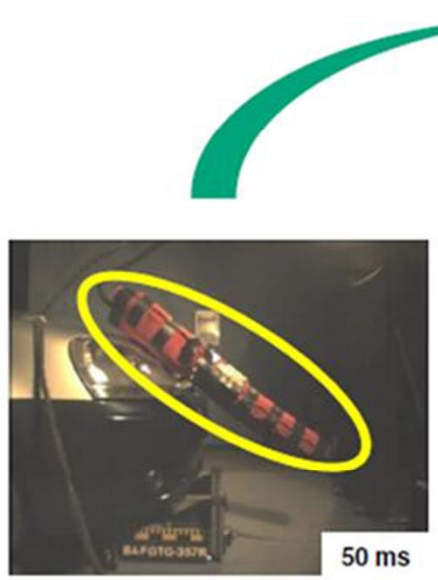
## **Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing**

- Acceptable tolerance of zero cross timing is determined using car test results which are described in the BAST document (GTR9-6-07).

# Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing

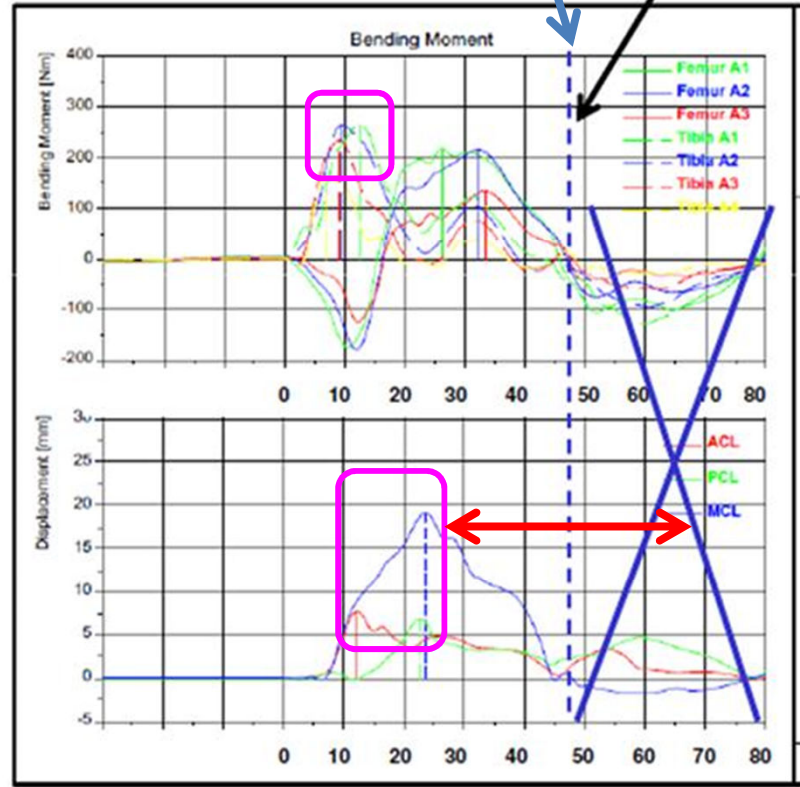
GTR9-6-07

## BASt proposal – Case study (I): Sedan



Zero cross timing

Entire impactor left BAI



Maximum value generates zone of Tibia and Knee ligaments

Acceptable tolerance of zero cross timing

around +/- 20 ms in the maximum

# Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing

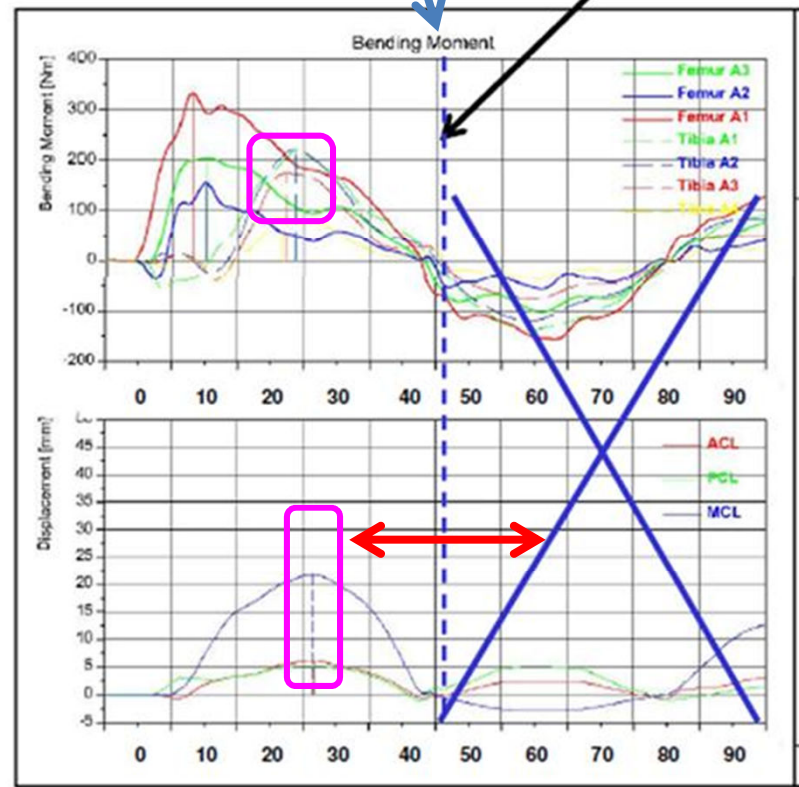
GTR9-6-07

## BASt proposal – Case study (II): SUV



Zero cross timing

Entire impactor left BAI



Maximum value generates zone of Tibia and Knee ligaments

Acceptable tolerance of zero cross timing around +/- 15 ms in the maximum

# Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing

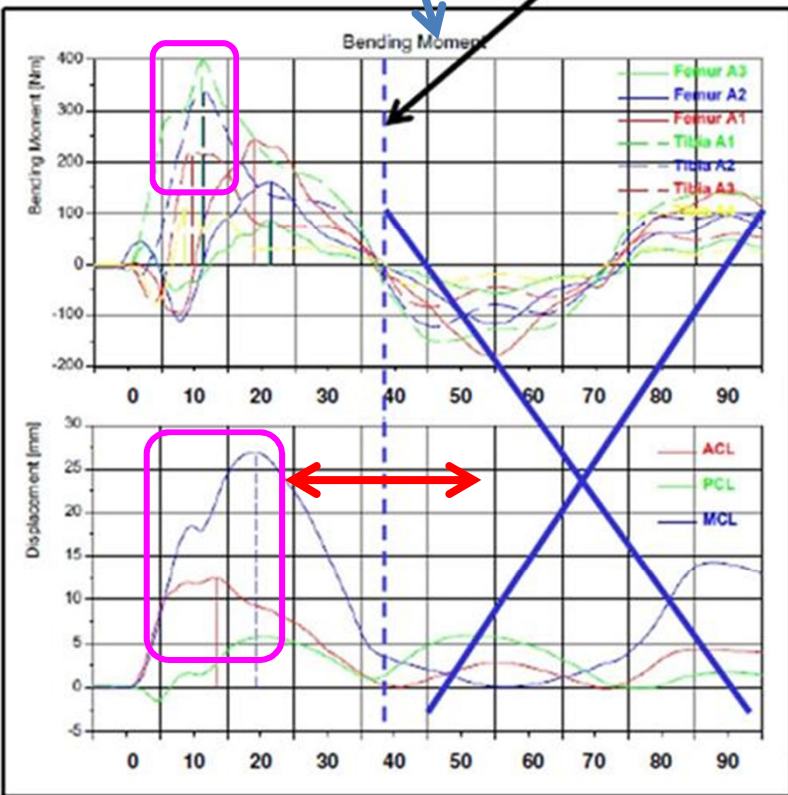
GTR9-6-07

## BASt proposal – Case study (III): FFV



Zero cross timing

Entire impactor left BAI



Maximum value generates zone of Tibia and Knee ligaments

Acceptable tolerance of zero cross timing

around +/- 15 ms in the maximum

# Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing

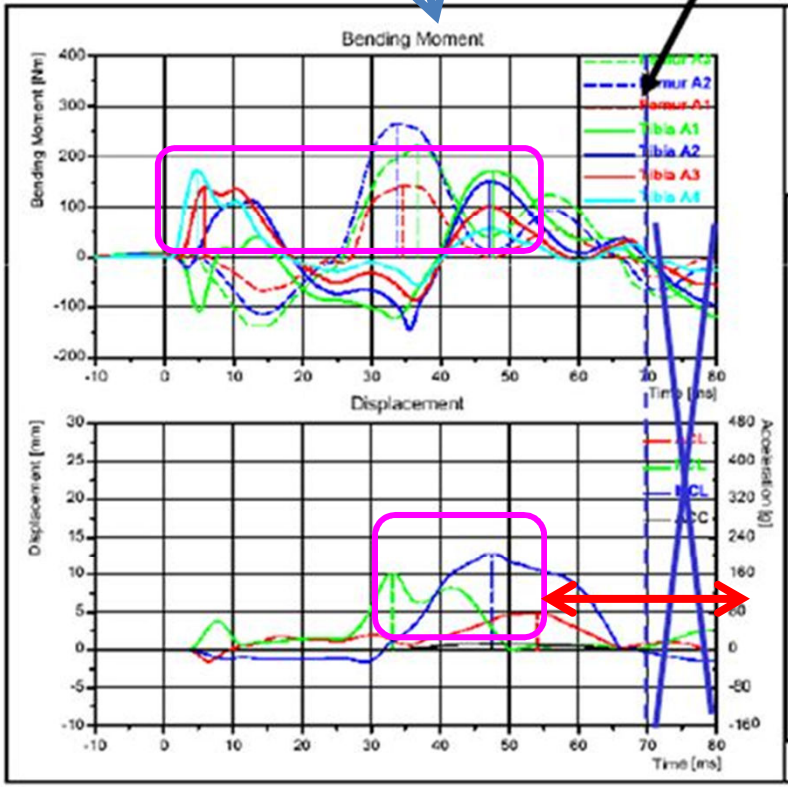
GTR9-6-07

## BAST proposal – Case study (IV): Sports car



Zero cross timing

Entire impactor left BAI



Maximum value generates zone of Tibia and Knee ligaments

Acceptable tolerance of zero cross timing

around +/- 15 ms in the maximum

## Appendix 1: Determination of Acceptable Tolerance for Zero Cross Timing

### Summary

- Acceptable tolerance of zero cross timing is determined using car test results which are described in the BAST document (GTR9-6-07).
- Based on the analysis, acceptable tolerance is determined as around +/- 15 ms.



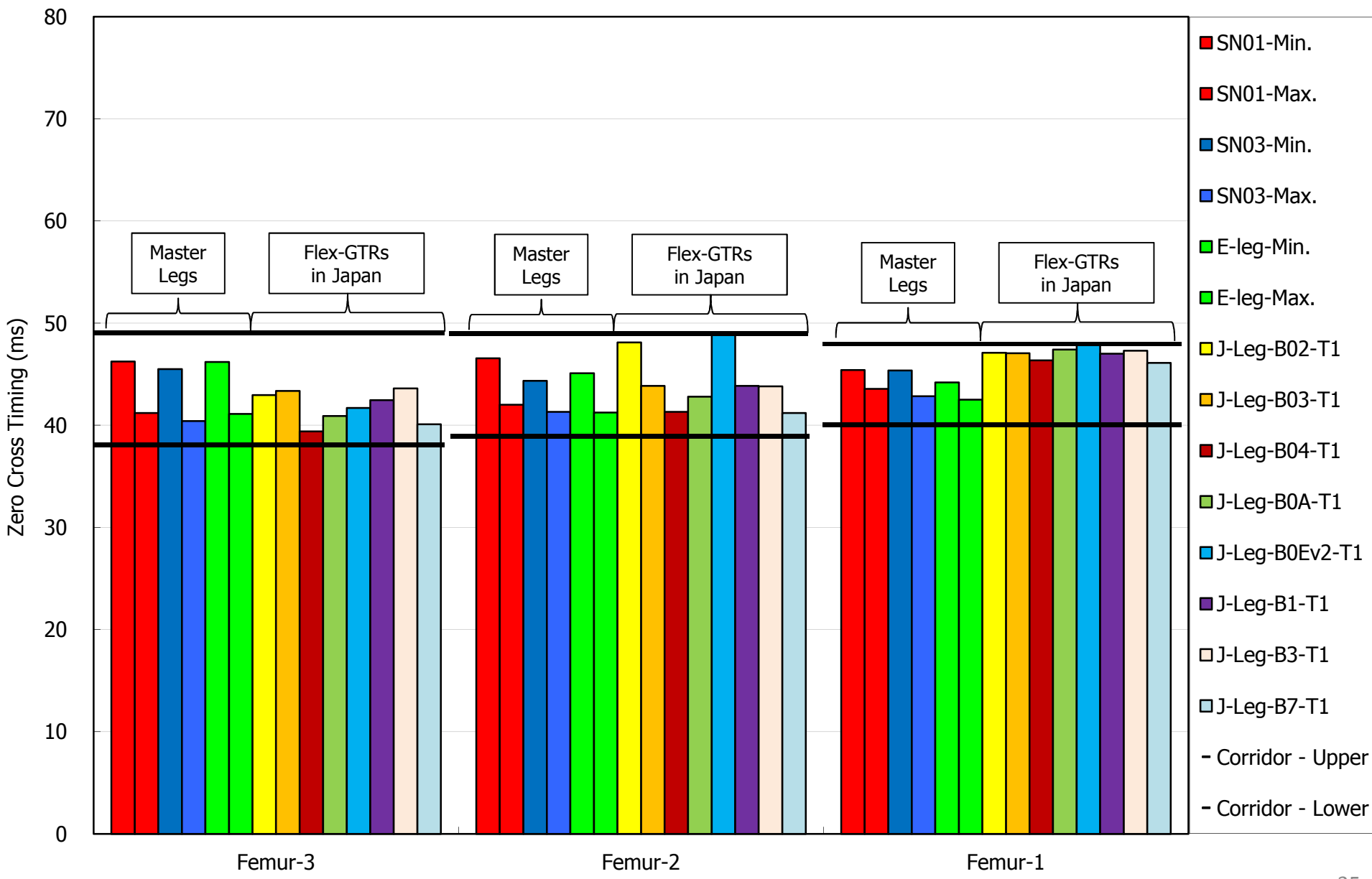
**Appendix 2: Comparison to certification corridors**  
**(Flex-GTRs in Japan)**

## Appendix 2: Comparison to certification corridors (Flex-GTRs in Japan)

- Additionally, **zero cross timing** of Flex-GTRs in Japan at **inverse** test data were randomly selected then compared to the certification corridors.
  - ✓ Flex-GTRs in Japan:
    - J-Leg-B series (delivered before 12 June 2012)
- INFO: All of the Flex-GTRs fall into the latest Tibia and Knee Ligaments maximum value **inverse** test corridors (developed by TF-RUCC, then accepted by IG GTR9-PH2 at the 4th meeting in Sep. 2012).

### Appendix 2: Comparison to certification corridors (Flex-GTRs in Japan)

All test data falls within the certification corridors obtained by [Methodology \(1\)](#).



### Appendix 2: Comparison to certification corridors (Flex-GTRs in Japan)

• All test data falls within the certification corridors obtained by [Methodology \(2\)](#).

