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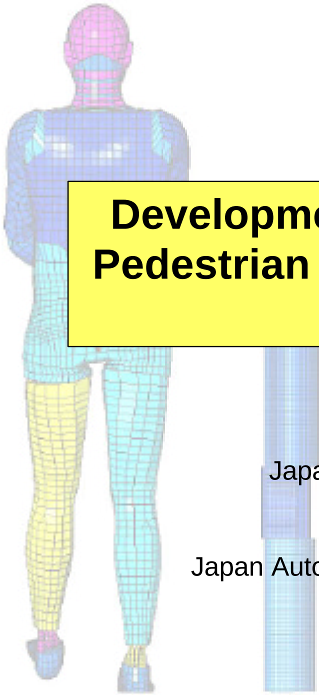
4th Flex-TEG MT
BASt, Bergisch Gladbach



Development of a Biofidelic Flexible Pedestrian Legform Impactor Type GT (FLEX-GT)

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Back ground

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- The flexible pedestrian legform impactor type GT prototype (Flex-GT-prototype (called as Flex-GTα in the previous report[1), 2)])) was developed in Spring 2006.
- In this version, 1) the range of motion of the knee region, 2) the light weight of the bone parts, as well as 3) the biofidelity under assembly level (Thigh-Knee-Leg connected level) are improved.
- However, a validation of the biofidelity under assembly level was not completely conducted, so it still needs to be validated.
- Thus, further validation study on the biofidelity of this impactor, detailed computer simulation analysis was performed.

Methodology

Computer simulation models

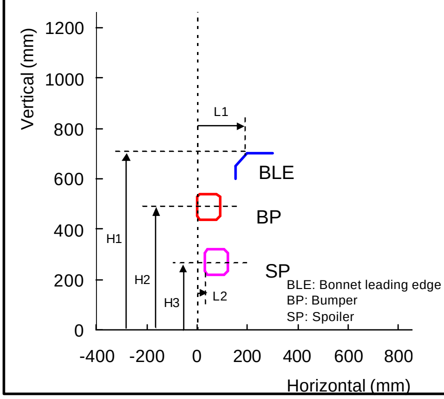
Simplified Car Model Parameters

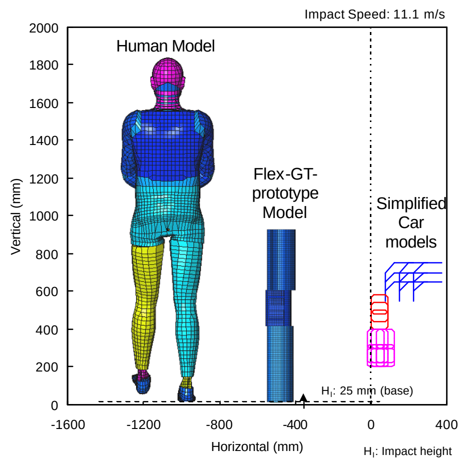
Parameter	Unit	Level 1	Level 2	Level 3
K1 (BLE stiffness*)	mm	0.4	0.6	
K2 (BP stiffness**)	JC***	0.7	0.8	1.0
K3 (SP stiffness**)	JC***	0.6	0.8	1.0
H1 (BLE height)	mm	650	700	750
H2 (BP height)	mm	450	490	530
H3 (SP height)	mm	250	270	350
L1 (BLE lead)	mm	125	200	275
L2 (SP lead)	mm	-20	0	30

* Stiffness is changed by steel plate thickness.

** Stiffness is changed by joint characteristics.

*** JC: Joint characteristics

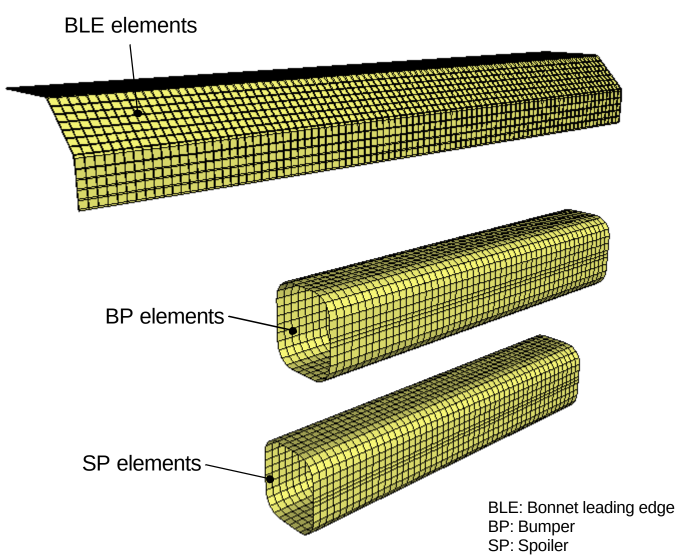




As for the Flex-GT-prototype model, Impact height (H_I) base + 50 mm and base + 75 mm is also calculated.

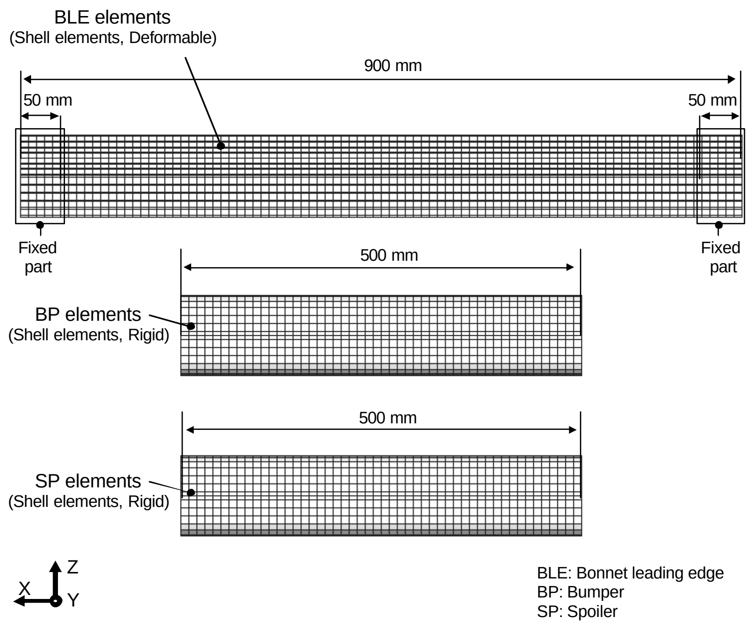
Explanation of Simplified Car Model

Over view – oblique front projection drawing



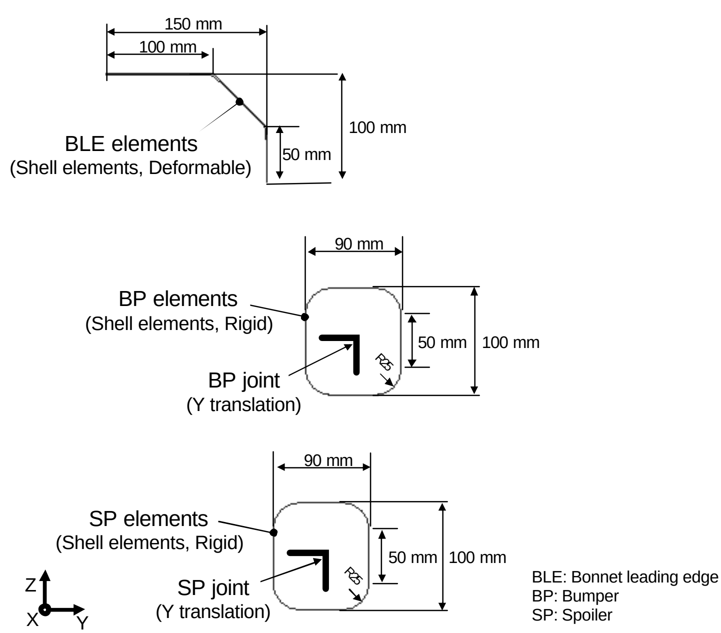
Explanation of Simplified Car Model

Frontal view of the car



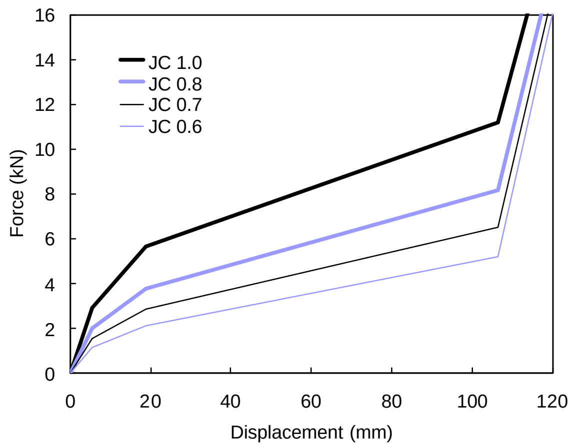
Explanation of Simplified Car Model

Side view of the car



Explanation of Simplified Car Model

BP and/or SP joint properties of the simplified car model



Specifications of the simplified car models (total 18 types)

Based on design of experiment method, L18 orthogonal table is utilized

Simplified Car model specifications

Simplified Car Model ID	K1 (BLE stiffness*) mm	K2 (BP stiffness**) JC***	K3 (SP stiffness**) JC***	H1 (BLE height) mm	H2 (BP height) mm	H3 (SP height) mm	L1 (BLE lead) mm	L2 (SP lead) mm
S1	0.4	0.7	0.6	650	450	250	125	-20
S2	0.4	0.7	0.8	700	490	270	200	0
S3	0.4	0.7	1.0	750	530	350	275	30
S4	0.4	0.8	0.6	650	490	270	275	30
S5	0.4	0.8	0.8	700	530	350	125	-20
S6	0.4	0.8	1.0	750	450	250	200	0
S7	0.4	1.0	0.6	700	450	350	200	30
S8	0.4	1.0	0.8	750	490	250	275	-20
S9	0.4	1.0	1.0	650	530	270	125	0
S10	0.6	0.7	0.6	750	530	270	200	-20
S11	0.6	0.7	0.8	650	450	350	275	0
S12	0.6	0.7	1.0	700	490	250	125	30
S13	0.6	0.8	0.6	700	530	250	275	0
S14	0.6	0.8	0.8	750	450	270	125	30
S15	0.6	0.8	1.0	650	490	350	200	-20
S16	0.6	1.0	0.6	750	490	350	125	0
S17	0.6	1.0	0.8	650	530	250	200	30
S18	0.6	1.0	1.0	700	450	270	275	-20

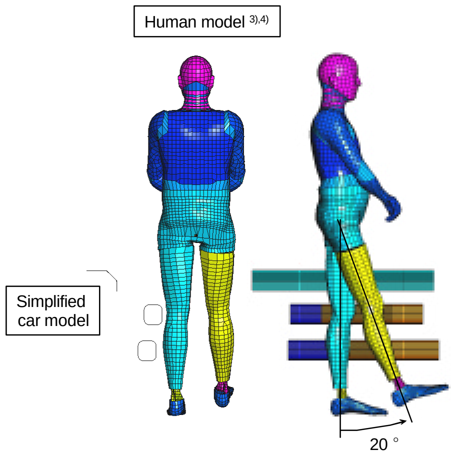
* Stiffness is changed by steel plate thickness.

** Stiffness is changed by joint characteristics.

*** JC: Joint characteristics

BLE: Bonnet leading edge, BP: Bumper, SP: Spoiler

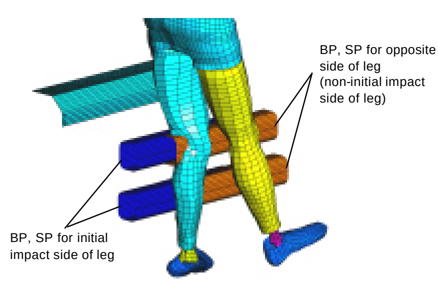
Posture of the human model



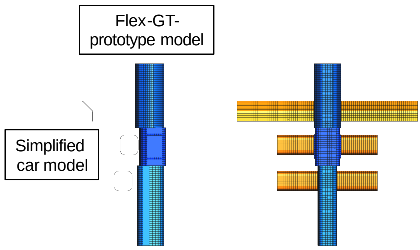
a) Back view of HM   b) Side view of HM

HM: Human Model

Setting of the simplified car model for the human model



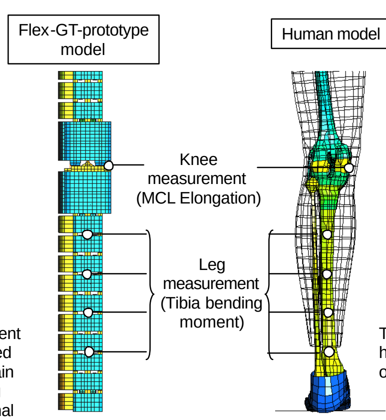
Front placement position of the Flex-GT-prototype model to the simplified car model



a) Side view of SCM   b) Frontal view of SCM

SCM: Simplified car model

Measurement points of the human model and the Flex-GT-prototype model

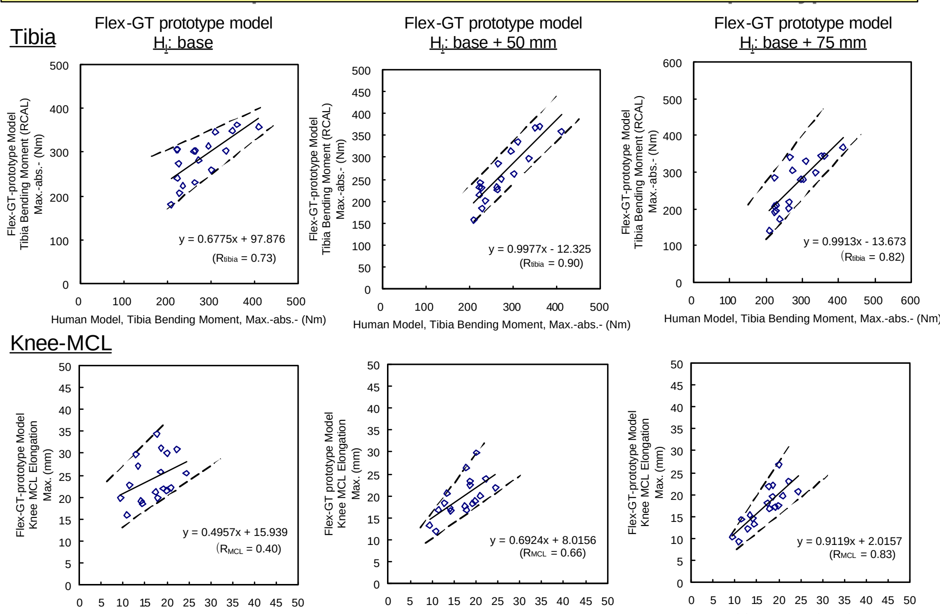


In this study, tibia bending moment of Flex-GT-prototype is estimated from each part of bone core strain using bone core 3 point bending test results not using conventional dynamic 3 point leg bending test like before (dynamic 3 point bending test include high inertia force of leg then difficult obtain appropriate conversion values).

Tibia bending moment of human model can be obtained directory

Results

Results: Relationship between the Human model and Flex-GT prototype model



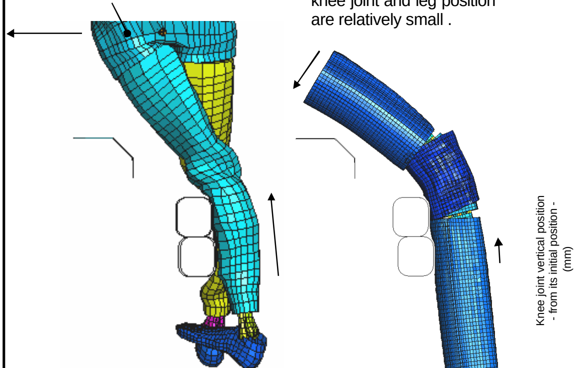
- To lift up the impact height of the Flex-GT can be obtained better correlation to the human one.

Discussions

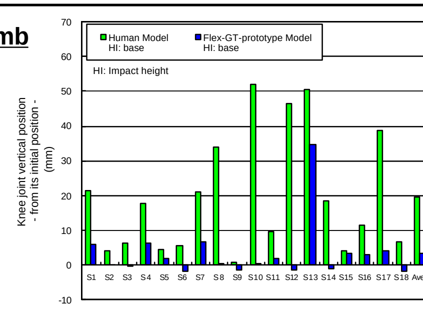
Upper body effect (1): Lifting up the lower limb

Upper body tend to stay at the initial position because of its high inertia, as a result, upper body tend to lift up the knee joint and leg positions vertically.

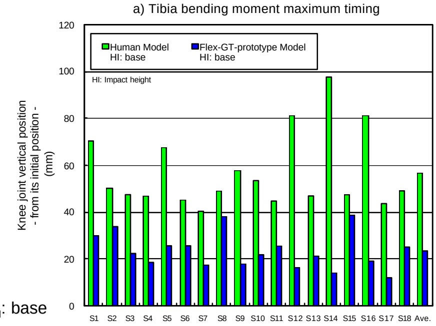
Impactor lift up motions of knee joint and leg position are relatively small .



a) Human model, H_i: base   b) Flex-GT-prototype model, H_i: base

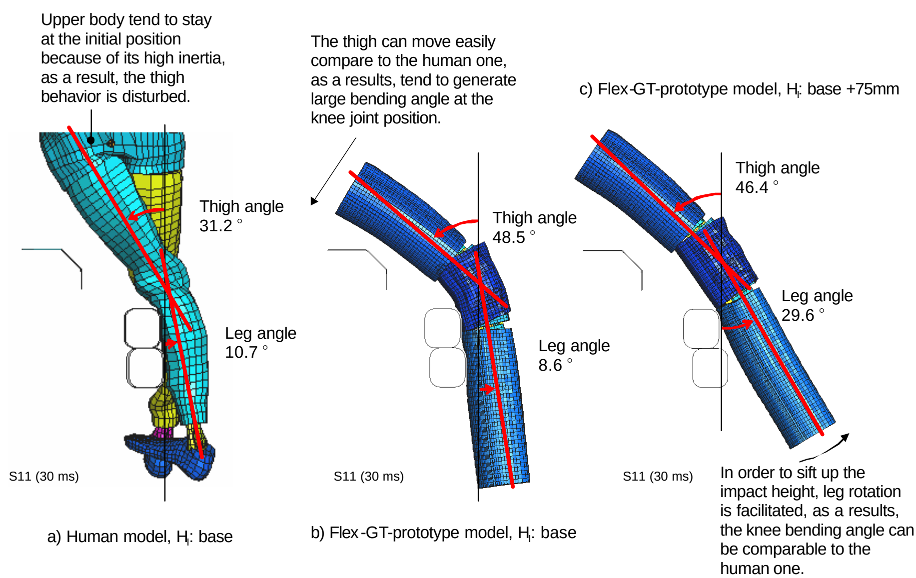


a) Tibia bending moment maximum timing

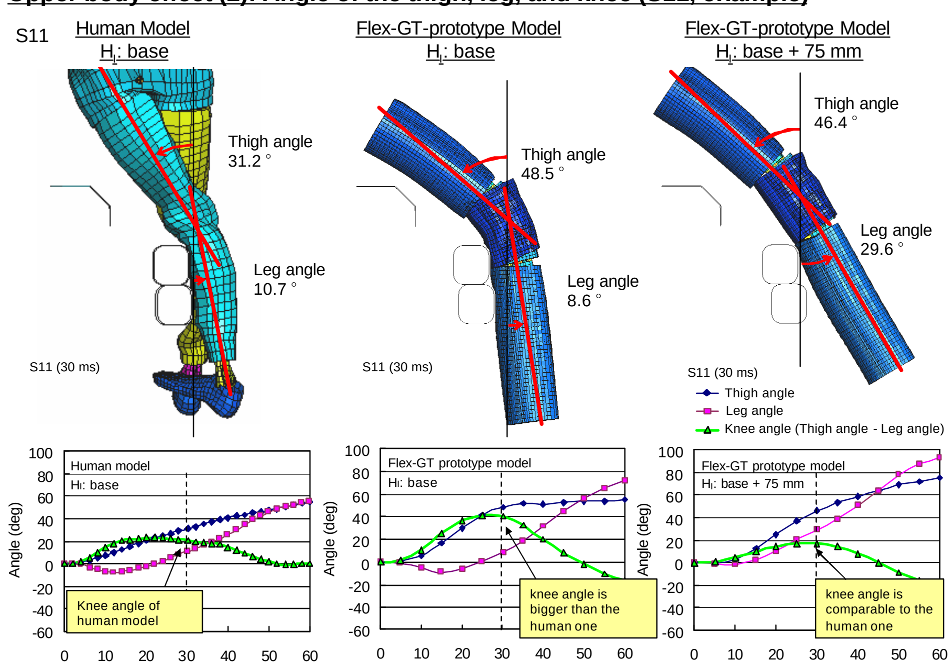


b) Knee MCL elongation maximum timing

Upper body effect (2): Inhibition of thigh behavior



Upper body effect (2): Angle of the thigh, leg, and knee (S11, example)



Discussions and Conclusions

- From the results of this analysis, an impact height 50-75 mm higher than the base (25 mm) more correlated with the human model. One of the reasons for this is seemed as to be the effect of the presence or absence of the human upper body.
- The human upper body has great inertia force because of its size in mass relative to the leg, which tends to stay relatively at the initial position even after the leg crashes into a car. Therefore, during impact with a car, the upper body tends to lift up the leg overall.
- It is highly possible that these differences cause the difference in the loading condition on the tibia and the knee medial collateral ligament, and it is suggested that changing the impact height of the pedestrian legform impactor have effects to correct these differences.
- Moreover, the human upper body has the effect of inhibiting thigh movement due to its great inertia force.
- As mentioned above, the human upper body has great inertia force because of its size in mass relative to the leg, which tends to stay relatively at the initial position even after the leg crashes into a car. Therefore, during impact into a car, it inhibits thigh behavior to prevent the thigh from falling against the car.
- It is considered that shifting the impact position of the pedestrian legform impactor upwards especially facilitates rotation of the leg region of the pedestrian legform impactor, and as a result, the load occurring on the knee part has the same effect as in the human body.

Discussions and Conclusions, contd.

- Additionally, it has a chance that the difference in distribution of mass between the human body and the pedestrian legform impactor, while in the human body the bone part is very light in weight and a flesh part covers most of the mass, affects to the human and impactor differences.
- In the regulatory purpose pedestrian legform impactor, it is difficult to reduce the mass of the bone part to be equivalent to that of the human body because of various limitations such as incorporation of measuring censors, endurance, and testability.
- Moreover, to change the current impactor specification has a high risk for the developments itself (unexpected issue will be happened, that's from our a lot of experiments).
- To keep the current specification of the impactor and to select best impact heights is therefore one of a good practical method we believe.

References

1) UN/ECE/WP29/GRSP/INF-GR-PS/Flex-TEG: Information on the Flexible Pedestrian Legform Impactor GT Alpha (Flex-GT-alpha), TEG-021 (2006)
2) UN/ECE/WP29/GRSP/INF-GR-PS/Flex-TEG: Evaluation Activities on Injury Assessment Ability of the Flexible Pedestrian Legform Impactor GT Alpha (Flex-GT-alpha), TEG-022 (2006)
3) Takahashi Y., Kikuchi Y., Mori F., and Konosu A.: Advanced FE Lower Limb Model for Pedestrians, Proc. 18th International Technical Conference on the Enhanced Safety of Vehicles, Paper Number 218 (2003)
4) Takahashi Y., Kikuchi Y., and Mori F.: Development of a Finite Element Model for the Pedestrian Pelvis and Lower Limb, Society of Automotive Engineers World Congress, SAE paper No. 2006-01-0683 (2006)

Thank you for your attentions!