



Occupant injury simulation model development and neck injury assessment at low impact velocity using MADYMO Active Human Model

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National Forensic Service



Introduction of National Forensic Service

National Forensic Service(NFS)

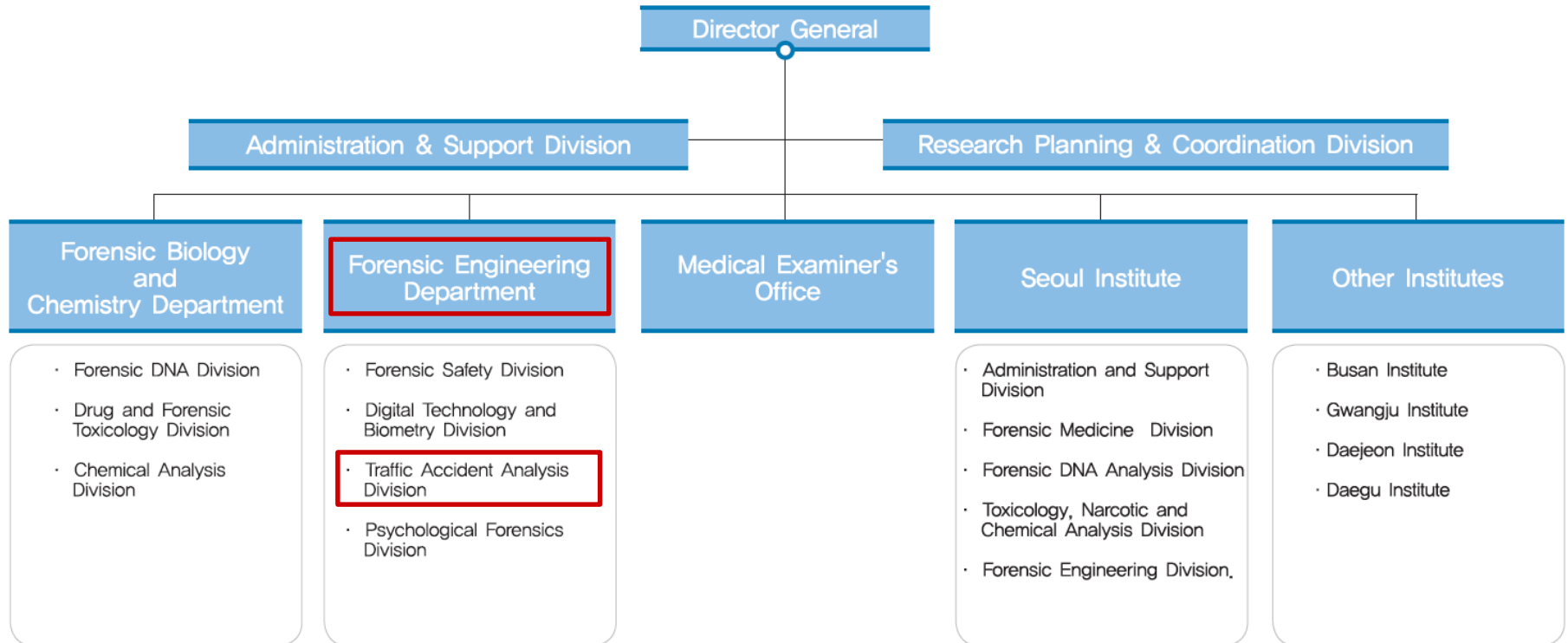
- NFS is government organization under the Ministry of Government Administration and Home Affairs, South Korea.
- NFS provides prompt and accurate analysis of evidences in the field of scientific crime detection such as forensic medicine, forensic science, natural science and engineering, and gene identification.
- NFS also presents criminal evidence through scientific investigation in order to preserve public order and protect civil rights.



Introduction of National Forensic Service

Organization Chart

(2 Departments, 9 Divisions, 1 Center, 5 District Offices)





Introduction of National Forensic Service

Traffic Accident Analysis Division

- Traffic Accident Analysis and Reconstruction
 - Inspection of vehicle defects
 - Analysis of accident speed
 - Human injury evaluation through the impulse on driver and passenger
 - Dynamic interpretation and reconstruction of traffic accidents using computer simulation : MADYMO, PC-Crash
- Identification of Hit-and-Run Car
 - Inspection of hit-and-run of run-over, car-to-car and car-to-pedestrian accident according to analyses of fiber, paint and trace evidence





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1. Backgrounds

- Occupants can have **minor injuries** such as neck tension and muscle strain in low velocity rear-end collisions.
- Some victims of accident **request a lot of medical expenses** even for an accident that has very little possibility of injury.
- Police have increasingly requested injury assessment for such cases to NFS
- Generally, we give evaluation result to police by **referring to related research papers**.
- We also try to **reconstruct** the accident using **computer simulation** and evaluate the possibility of injury.
- MADYMO Active Human Model(AHM) is available to evaluate occupant injuries in low velocity accidents



1. Backgrounds

- An interesting accident case ([A strain of the cervical spine](#))
- The driver and two passengers of the front car requested [expenses for two-week medical treatments](#).
- We notify police that neck injury is unlikely to be serious.





2. Paper survey – Experimental researches

[Volunteer Experiments]

- T. Matsushita et al., “X-Ray study of the human neck motion due to head inertia loading” (SAE Paper 942208)
 - Sled test of low-speed frontal, lateral and rear-end vehicle impact
 - Volunteers : 26 male and female adults, aged 22 to 61 years
 - Velocity change(ΔV) of the sled : 2.5~5.8 km/h
 - Test related clinical findings :
 - 6 subjects reported mild discomfort after the test, but there were no objective changes observed in any medical tests.
 - Majority of these symptoms were localized neck pain, and lasting 2 to 4 days.
 - In all cases the discomfort resolved without treatment or therapy.



2. Paper survey – Experimental researches

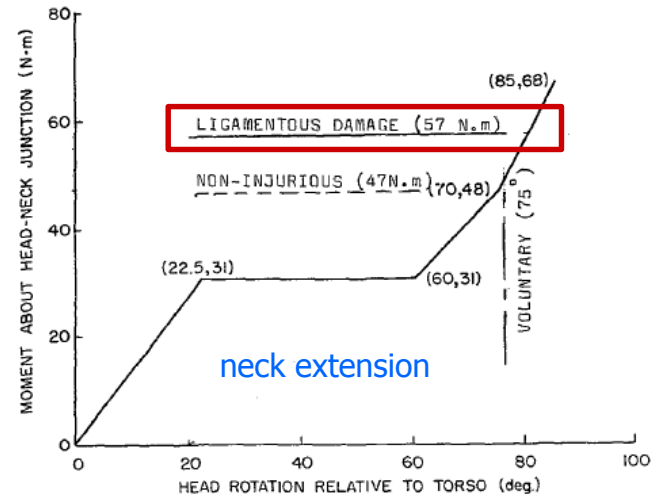
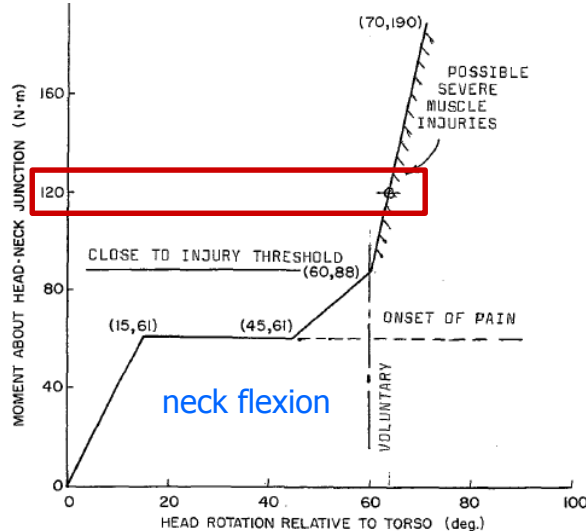
[Volunteer Experiments]

- W. H. M. Castro et al., “Do ‘whiplash injuries’ occur in low-speed rear impact” (European Spine Journal 1997)
 - To determine whether clinical or MRI signs of changes in the cervical spine can be demonstrated following a rear-end collision between two cars in ΔV range from 10 to 15 km/h.
 - Volunteers : 14 men(28 to 47 years old) and 5 women(26 to 37 years old)
 - Discussion :
 - Only **five test subjects** reported symptoms after the car collision. Pain did not persist longer than **1 week**, and occupational disability did not result. The velocity change due to collision **exceeded 11 km/h** with these test subjects.
 - Even the studies with a ΔV of up to **14.2 km/h** and mean acceleration up to 3.6 g, the specific clinical and MRI examination before and after the rear-end collisions **failed to demonstrate persistent symptoms or changes on MRI**.



2. Paper survey – Experimental researches

- Murray K., “Delta-V Thresholds for Cervical Spine Injury”
 - Mertz and Patrick conducted extensive research on the head-neck complex using human volunteers and cadavers.
 - The thresholds are dealt with severe cervical spine injury and mainly utilized in vehicle development field.



Loading corridor for neck flexion(forward bending) and extension(rearward bending) based on Mertz et al. 1973.



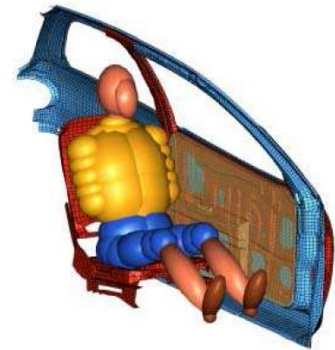
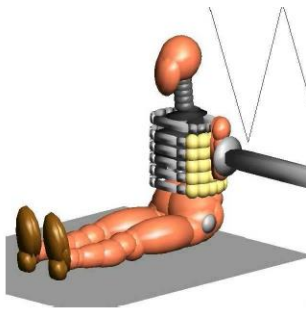
3. Objectives

- To establish the computer simulation process to evaluate occupant neck injury in low velocity rear-end collisions.
- To apply MADYMO Active Human Model(AHM) that was developed by TNO and built based on actual human.
- To evaluate the possibility of neck injuries with computational method.



4. MADYMO Active Human Model(AHM)

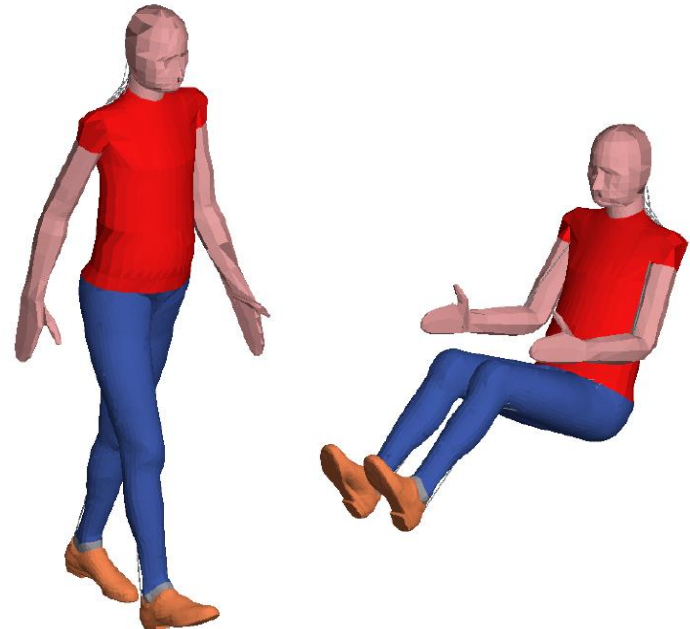
- **MADYMO**(**MA**thematical **DY**namical **MO**del) is a computer program that simulates the dynamic behavior of physical systems emphasizing the analysis of vehicle collisions and assessing injuries sustained by passengers.
- MADYMO has been developed and at TASS(TNO, Netherland) and is based on **Multibody Dynamics** and **Finite Element Method**.





4. MADYMO Active Human Model(AHM)

- AHM is developed and validated by TASS.
- A mid-size model representing the **50th percentile male** is available in a sitting and standing position.
- AHM is applicable to any direction of impact.
- The anthropometry and mass distribution from the database of the **RAMSIS***
 - Standing height : 1.76 m
 - Sitting height : 0.92 m
 - Weight : 75.3 kg



* RAMSIS is 3D human model in the form of a computer software for ergonomic analysis of CAD designs



4. MADYMO Active Human Model(AHM)

- Actuator and realistic muscle elements
→ **Human-like behavior** of neck, spine, upper and lower extremities
- **Co-contraction factor for neck** is changeable by user.
 - no co-contraction : 0.0
 - full co-contraction : 1.0
 - normal co-contraction : 0.7~0.8





4. MADYMO Active Human Model(AHM)

- Model validation is done by TASS.
(25 PMHS* Tests & 10 Human Volunteer Tests)

Blunt Test



Sled Test



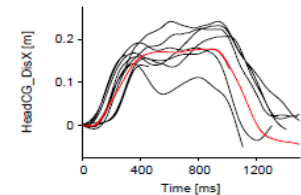
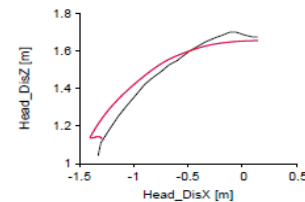
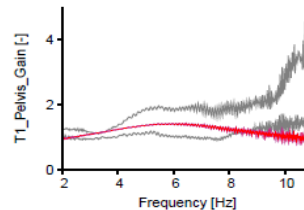
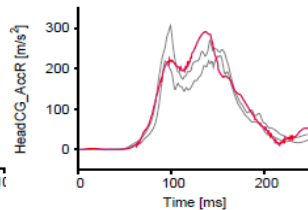
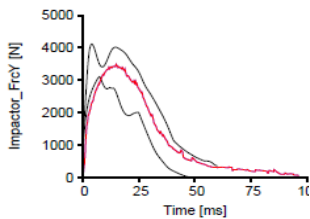
Vibration Test



Pedestrian Test



Braking Test



*PMHS : Post Mortem Human Subject



5. MADYMO Simulation Model Set-up

- **Finite-Element Seat Model**

- Disassemble seat and achieve 3D scan files(*.stl)
- Extract surfaces and generate meshes
- Seat cushion is consist of solid elements
- Rigid elements for bolts and spotwelds
- 58,000 elements and 20,000 nodes



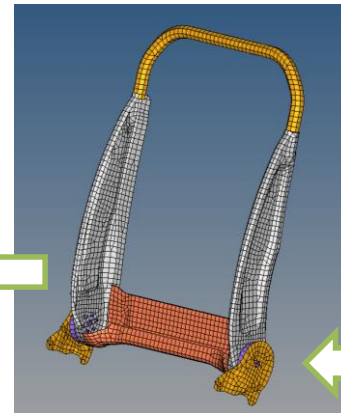
FE Seat Model



Real Seat



Disassembling



Surface & Mesh Generation



3D Scan Files

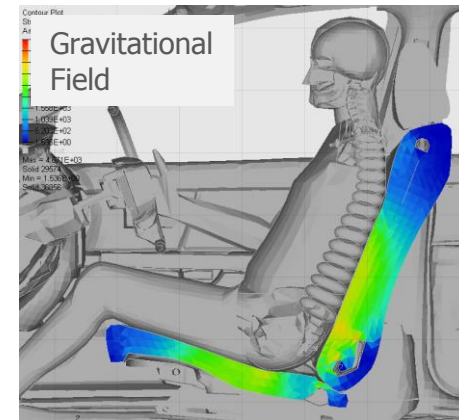


5. MADYMO Simulation Model Set-up

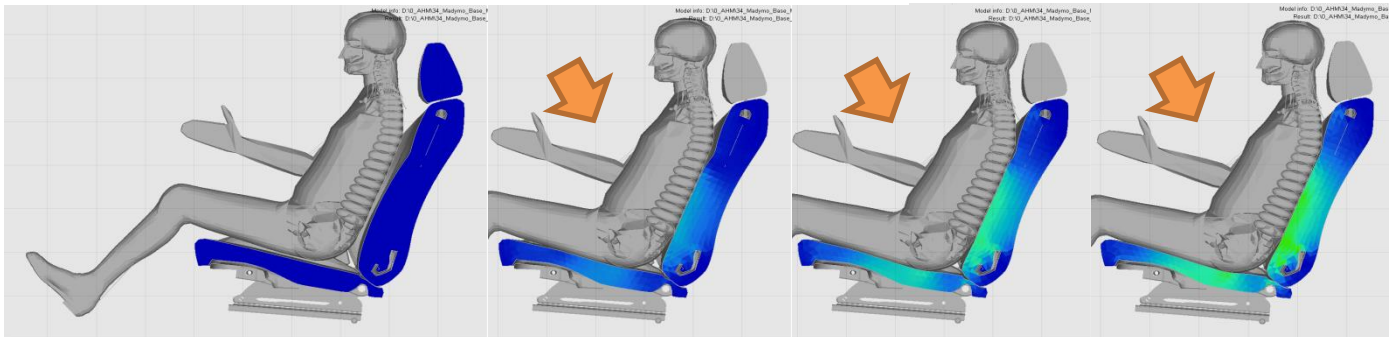
- Pre-Simulation Steps**

- Step 1 : seat positioning simulation was performed to achieve initial deformed seat cushion shape and initial stress
- Step 2 : Dynamic relaxation was also performed in gravitational field

Step 2. Settling & Dynamic Relaxation Simulation



Step 1. Seat Positioning Simulation





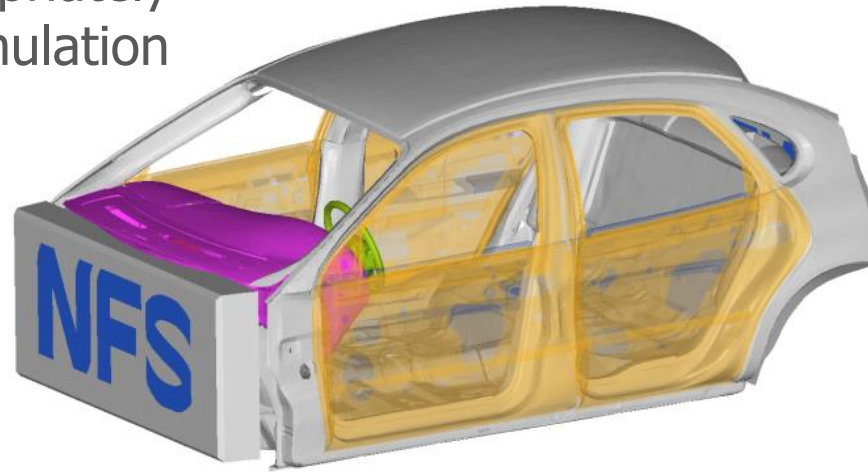
5. MADYMO Simulation Model Set-up

- **Cabin Modeling**
 - Based on LS-Dyna FE model of 'Ford Taurus(MY2001)'
 - The model is available from the website of NCAC
 - Extracted only necessary parts and modified appropriately to the MADYMO simulation



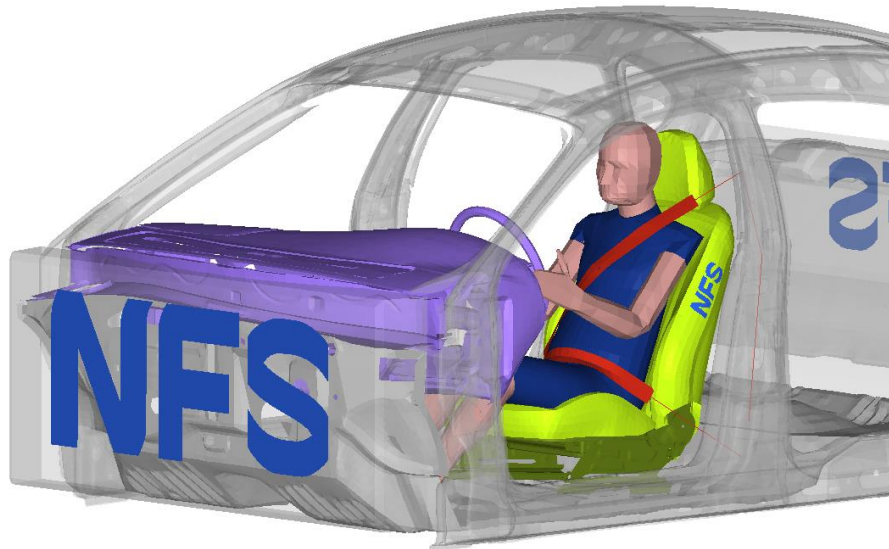
**Finite Element Model of
Ford Taurus**

Model Year 2001
Version 3



5. MADYMO Simulation Model Set-up

- **Final Model Set-up (Driver side only)**
 - Seat, Cabin and AHM were integrated
 - FE Seat belt was also adopted
 - The cabin and seat mount was supported to a free joint that moves according to 'pre-scribed motion'





6. Integrated Simulation Process

- Vehicle impact simulation(PC-Crash) and occupant analysis simulation(MADYMO) were performed sequentially

Vehicle Impact with PC-Crash

PC-Crash : a momentum-based vehicle accident simulation software



6 D.O.F* vehicle motion

Vehicle motion from PC-Crash is used as the input motion of MADYMO.



Occupant Analysis with MADYMO

Prescribed Joint Motion of the vehicle



*D.O.F : Degrees Of Freedom



6. Integrated Simulation Process

- Applied simulation methods and software techniques

**Momentum-
based
Simulation**



**Multibody
Dynamics
Simulation**



**Finite-Element
Simulation**



3D SCAN S/W

- 3D Scan for real seat frame and cushion
- 3D surface generation with **RapidForm**

Pre, Post S/W

- Finite element meshing with **Hypermesh**
- Mesh conversion with **MadyX Converter**
- Simulation result posting with **Hyperview**

CAE* S/W

- Vehicle-To-Vehicle impact simulation with **PC-Crash**
- Finite element mesh handling with **LS-Dyna** input deck
- Occupant injury simulation with **MADYMO & AHM**

*CAE : Computer-Aided Engineering



7. Simulation Result – A case study

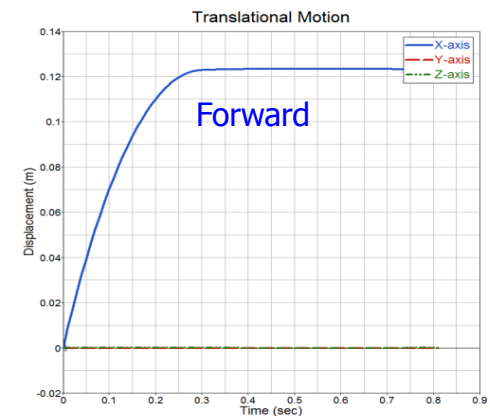
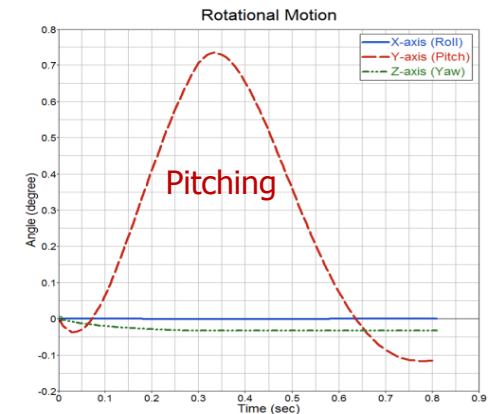
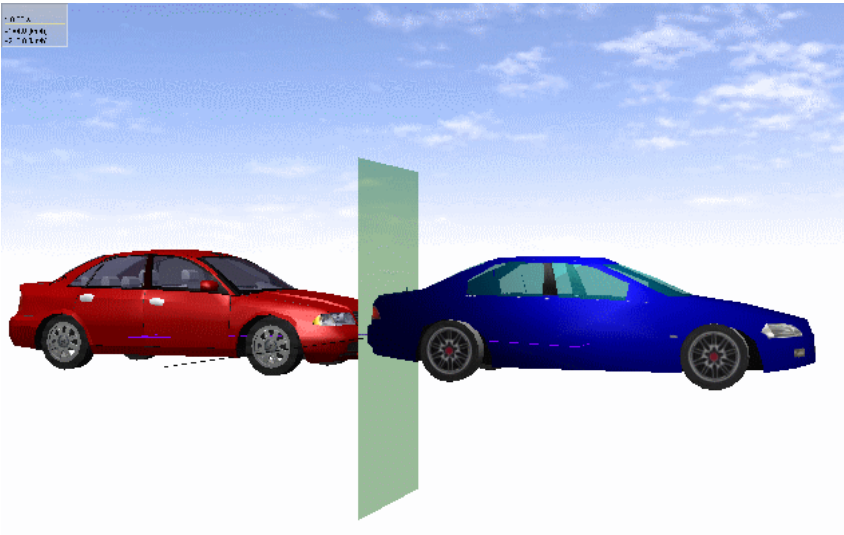
- A rear-end collision video from car black-box
- The male driver of the front car requested **expenses for two-week medical treatments**.





7. Simulation Result – A case study

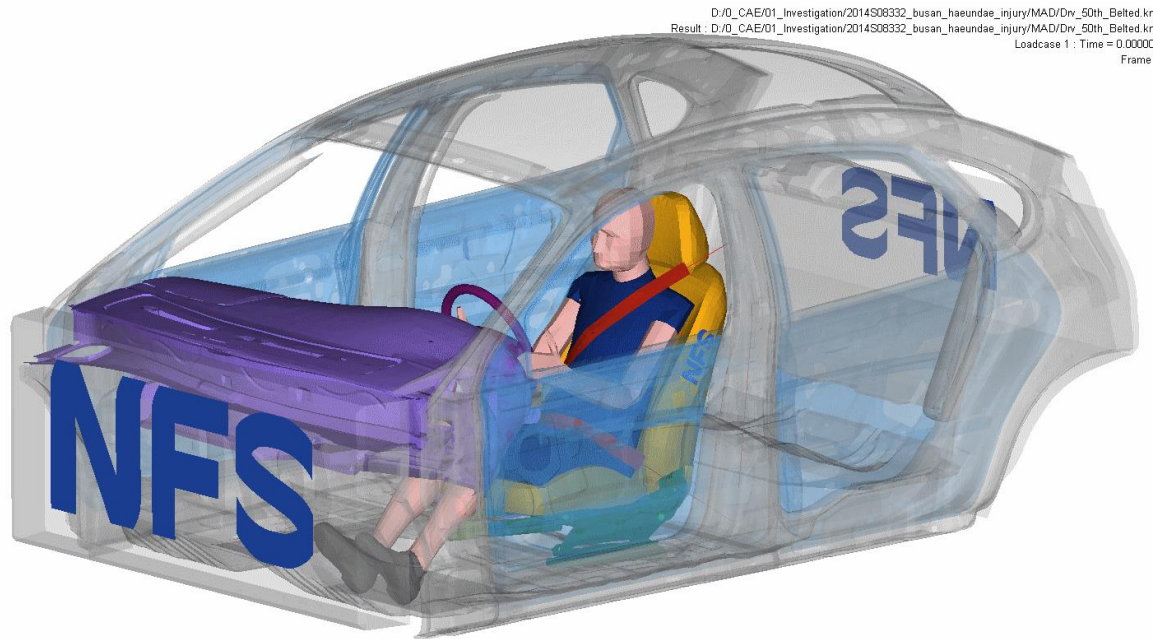
- Vehicle impact simulation was performed with PC-Crash
- Approaching velocity of the rear car was set to 5 km/h
- The forward displacement of front car was 0.12 m





7. Simulation Result – A case study

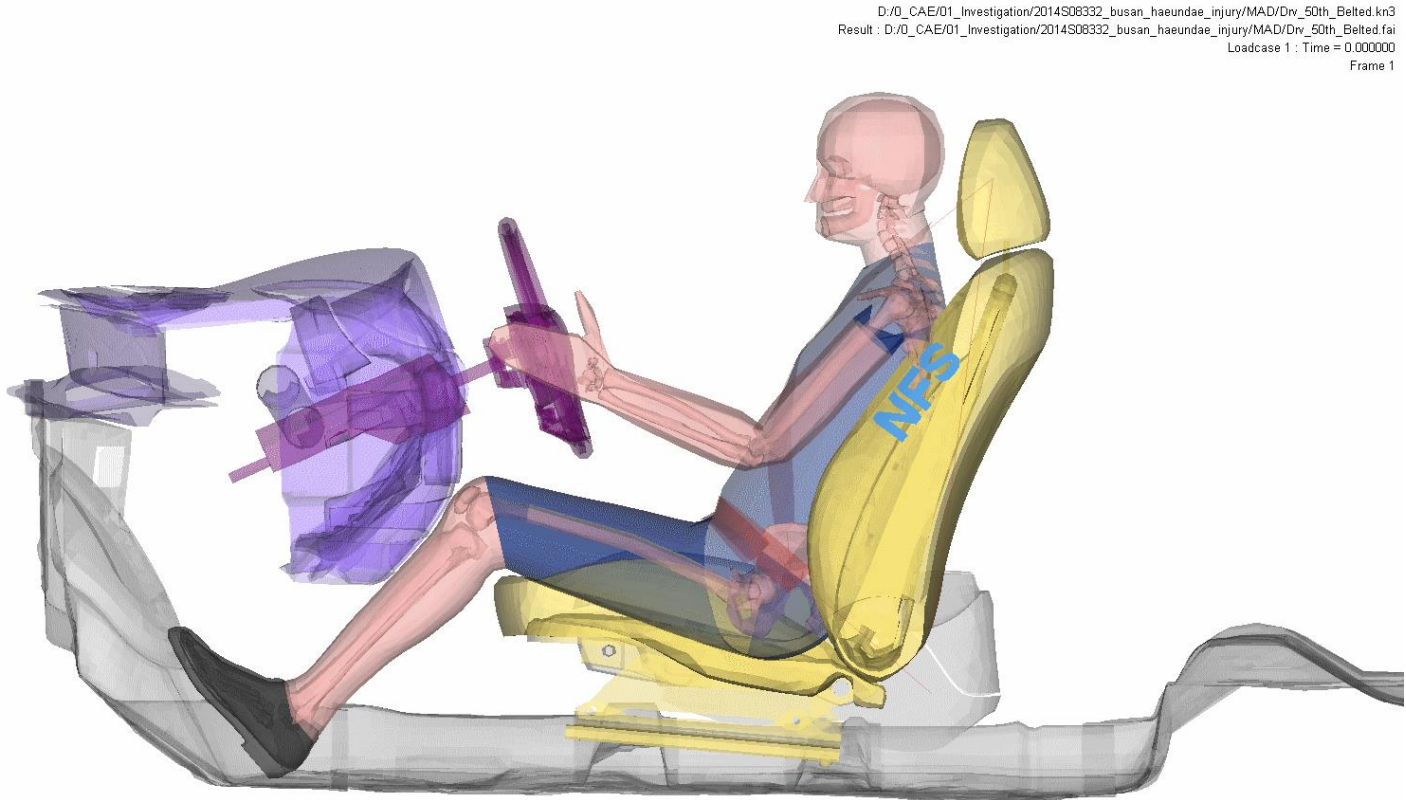
- Vehicle motion from PC-Crash was used for the input of occupant simulation
- Runtime : approximately 4 hours (with a 4-cpu workstation)





7. Simulation Result – A case study

- Driver motion on the left-view



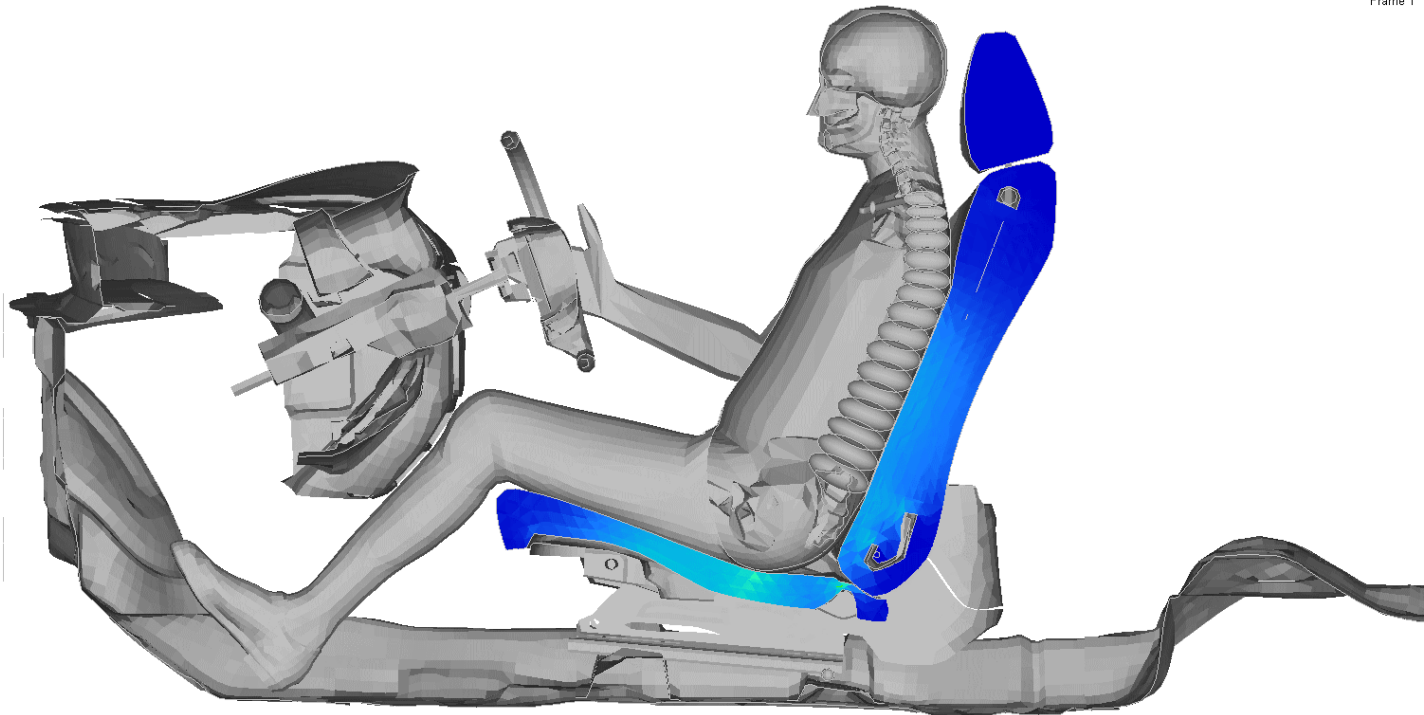


7. Simulation Result – A case study

- Change of the seat cushion stress can be observed

Contour Plot
Stress(vonMises, Max)
Analysis system
2.000E+04
1.778E+04
1.556E+04
1.333E+04
1.111E+04
8.889E+03
6.667E+03
4.445E+03
2.222E+03
2.756E-01
■ No result
Max = 5.594E+04
Solid 37243
Min = 2.756E-01
Solid 39641

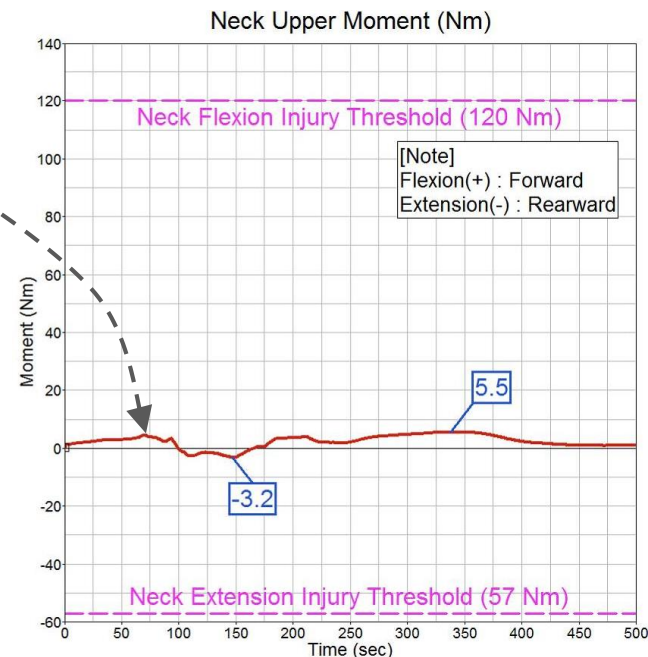
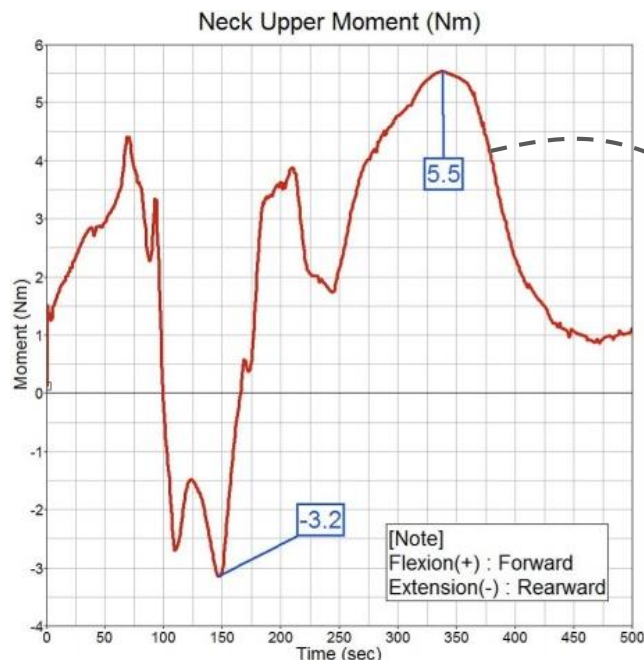
D:/0_CAE/01_Investigation/2014S08332_busan_haeundae_injury/MAD/Drv_50th_Belted.kn3
Result : D:/0_CAE/01_Investigation/2014S08332_busan_haeundae_injury/MAD/Drv_50th_Belted.fai
Loadcase 1 : Time = 0.000000
Frame 1





7. Simulation Result – A case study

- Comparison of the neck moment with respect to the thresholds based on Mertz et al. 1973.
- Neck moments are 5.6% on extension and 4.6% on flexion approximately.





8. Discussion & Limitation

- Because there is no threshold to evaluate extremely minor neck injury, quantitative evaluation may be not appropriate. Thus comparison between neck moments and the thresholds shows only **qualitative evaluation** results.
- Personal physical status, medical history of illness, unexpected occupant posture and unique seat features can not be considered.
- We show **the simulation result addition to the volunteer experiment researches** and recommend Police that;
 - a few days of outpatient treatment could be acknowledged
 - long-term hospital treatment or excessive compensation demands need to be investigated carefully.



9. Conclusion

- Occupant neck injury assessment model was established using MADYMO Active Human Model.
- Integration of 3D SCAN and CAE technologies is required to utilize Active Human Model.
- Overall occupant motion during minor accident could be [intuitively demonstrated](#).
- It is the first attempt that Active Human Model was applied in the filed of forensic science.



Thank You

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