



Performance Evaluation of the Harmonized 50th & 5th CAE dummies

Nordic LS-DYNA User's Conference 2018

Jianfeng Yao, Ph.D
Volvo Cars Safety Center
Sweden

Gothenburg, Sweden
October 18th, 2018

CONTENTS



- Introduction of the all-new XC60
- CAE-driven process in XC60 development
- Performance evaluation of 50th CAE dummy
- Performance evaluation of 5th CAE dummy
- Summary



THE ALL-NEW VOLVO XC60



- Successor of highly-successful XC60 classic
- Developed based on the SPA platform
- Excellent passive safety performance
 - Boron steel reinforced occupant compartment
 - Advanced airbag system
 - Safety belts with pre-tension and load limiters
- CAE driven development process for passive safety



PASSIVE SAFETY OF THE NEW XC60



VOLVO XC60

Straight front, 35 mph

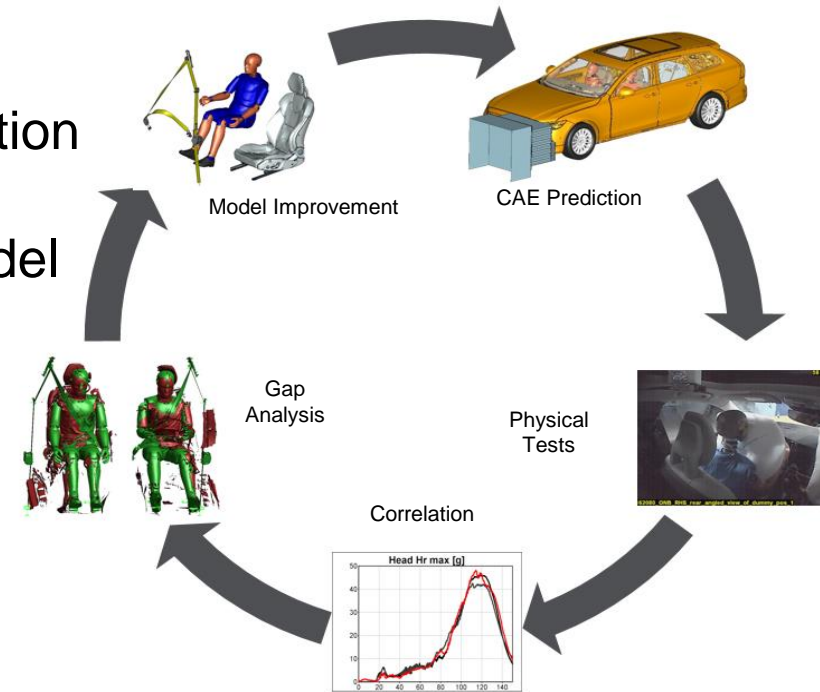
VOLVO XC60

Roll Over, 30 mph

CAE-DRIVEN SAFETY DEVELOPMENT PROCESS



- Only CAE simulations in development phase
- Physical crash tests for verification and certification
- Correlation and gap analysis for continuous model improvement
- Challenges for CAE modelling
 - Failure modelling of new materials.
 - Restraint system modelling
 - Accurate prediction of dummy injury values
 - Others



STATE-OF-THE-ART OCCUPANT SIMULATION



0:d3plot.fz : f426o5342 v426 dwg EUNCAP ODB 40mph LHD : STATE 1 ,TIME 0.00000000E+00



- Occupant simulation with full car model
- More than 10m elements ls-dyna model
- ~20h-30h running time with 480 cores



Interior model:

- Dummies
- Seats & Belts
- Instrument panel
- Carpets
- Driver and Passenger airbag
- IC (Inflatable Curtain)
- Knee airbag

CAE DUMMY PERFORMANCE EVALUATION

- CAE dummy models for evaluation of occupant protection
 - Dummy injury values
 - Dummy kinematics
- Humanetics^R develops and continuously improves dummy models
 - Hybrid III (H3) CAE dummy models in the XC 60 development
 - Harmonized Hybrid III (HH) CAE dummy models for new evaluation
- Evaluated in all legal & rating frontal crash loadcases
 - Same simulation setup except dummy itself
 - Same H-point and posture between dummy models
 - Same belt routing positions
- EuroNCAP and FMVSS 208 loadcases used as example

H3 CAE dummy



H3 50th dummy, V8.0.1



H3 5th dummy, V7.0.5

HH CAE dummy

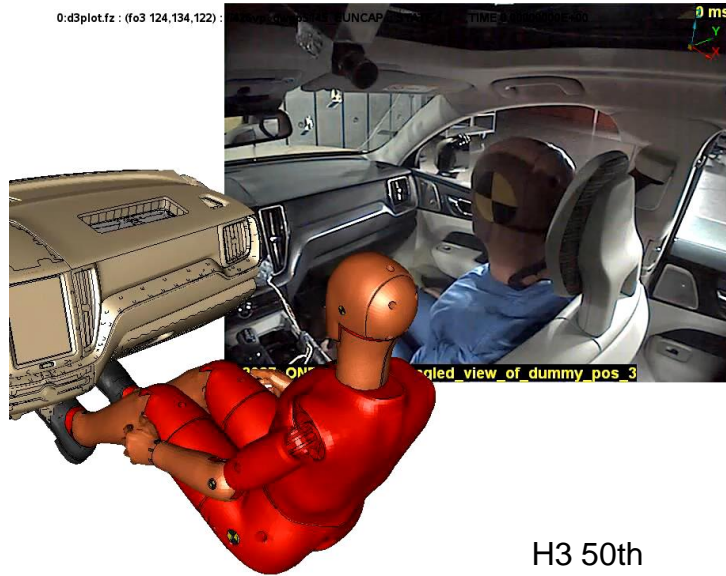


HH3 50th dummy, V1.0



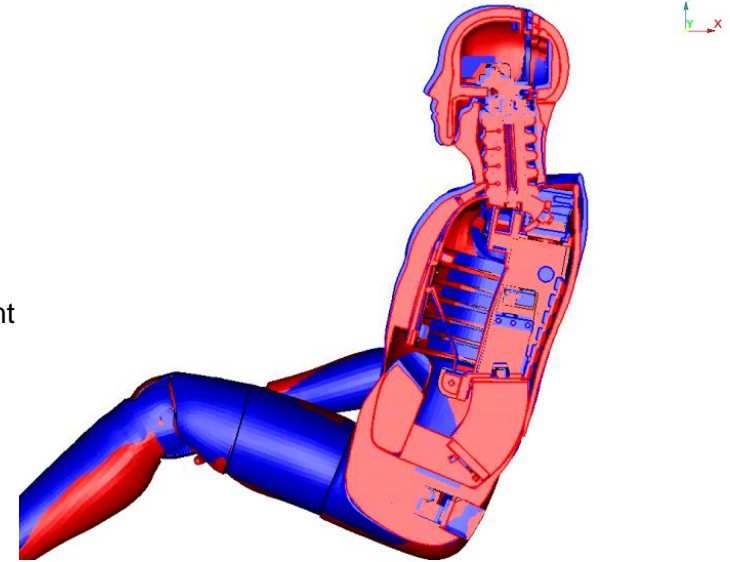
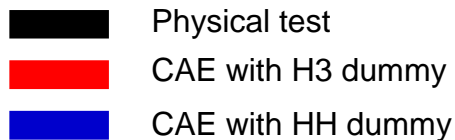
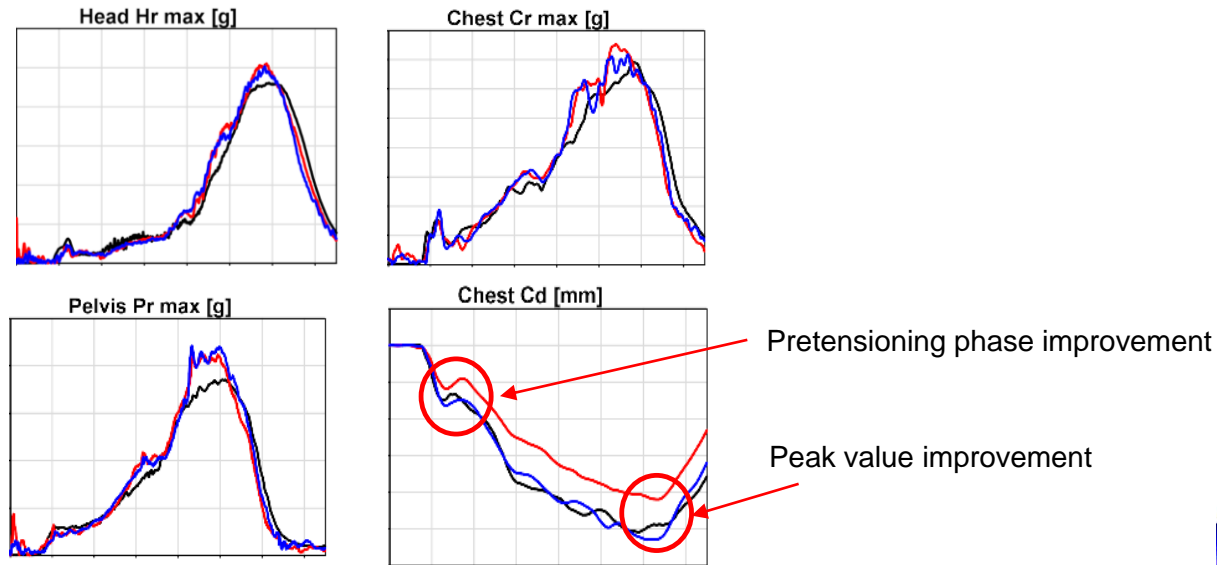
HH3 5th dummy, V2.0

50TH PASSENGER KINEMATICS IN EURONCAP ODB



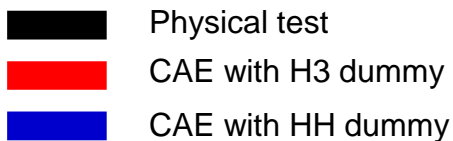
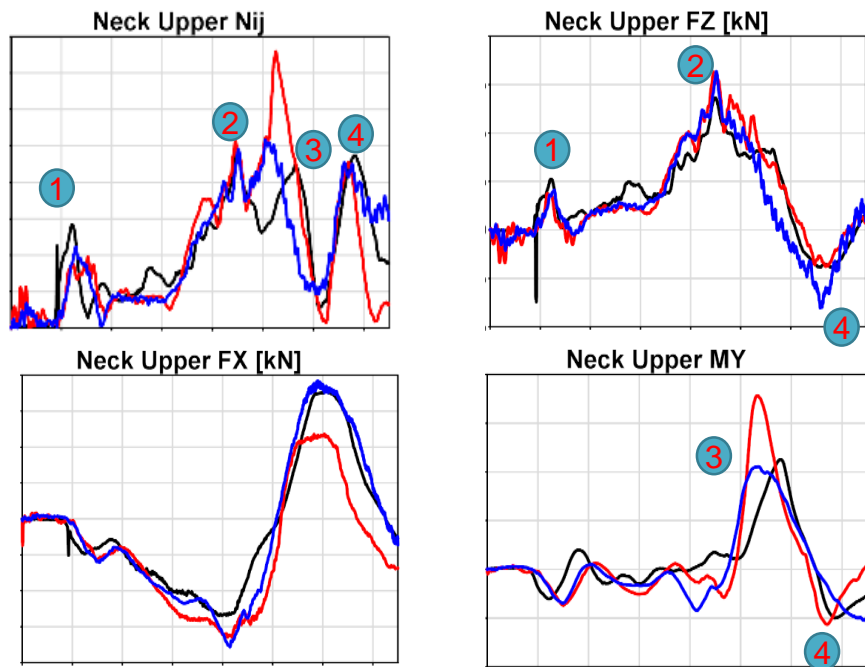
- Good correlation of overall kinematics for both two dummy versions
- Better correlation of head kinematics with HH 50th dummy

50TH PASSENGER -HEAD, CHEST, PELVIS

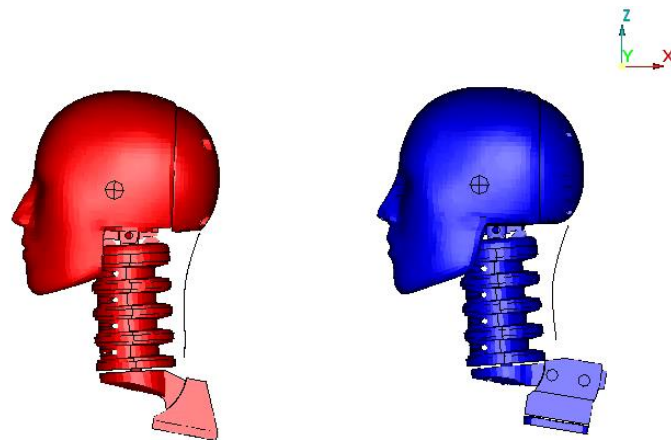


- Improved Cd prediction with HH dummy
- Similar upper body kinematics
- Softer lumbar, abdomen in HH

50TH PASSENGER - NECK

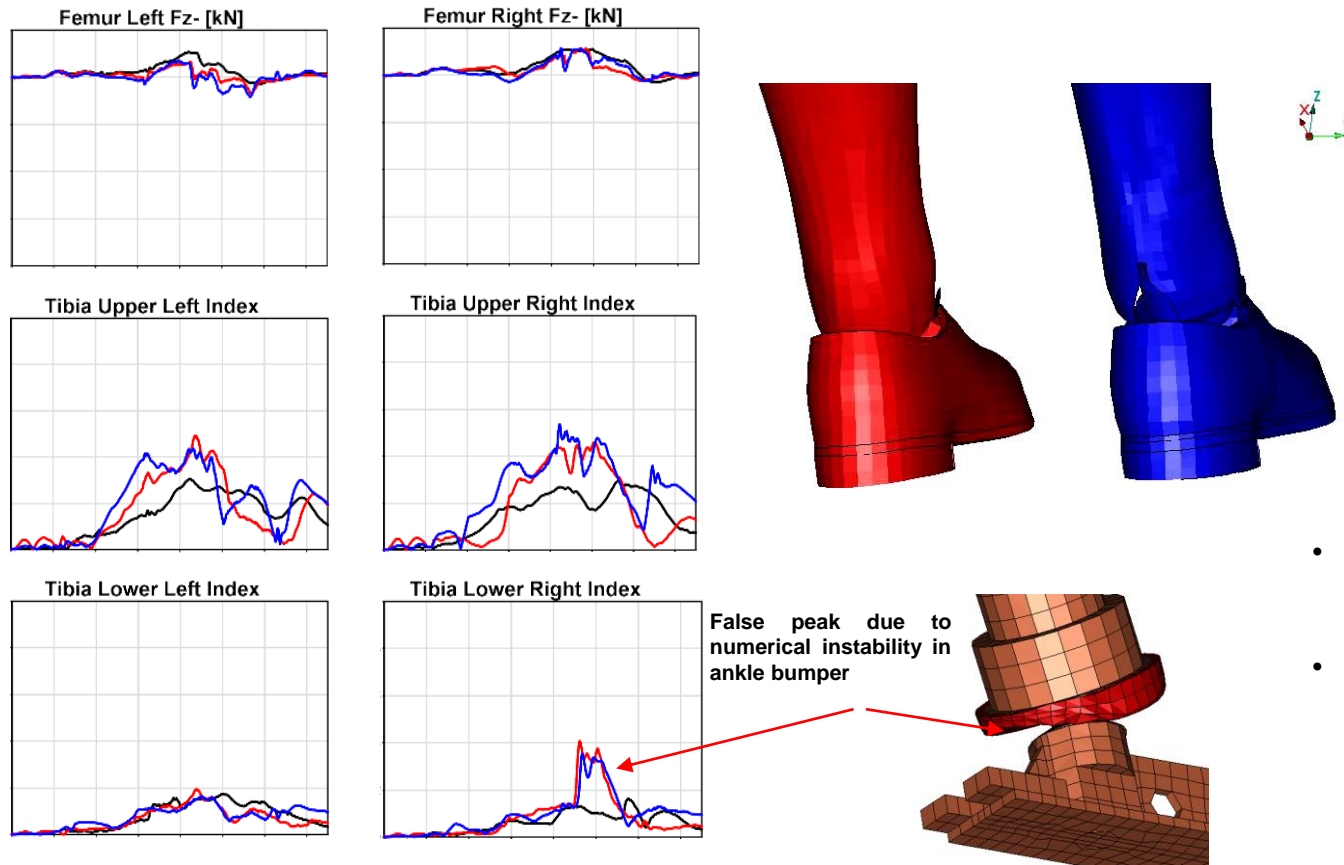


$$N_{ij} = \frac{F_z}{F_{zc}} + \frac{M_{ocy}}{M_{yc}} \quad M_{ocy} = M_y - (d * Fx)$$



- Improved correlation of the Nij with the HH 50th dummy
- Further improvement needed to correlate the timing of the 3rd Nij peak for the HH dummy.
- Lower torsional stiffness of the HH neck

50TH PASSENGER -FEMUR, TIBIA



- Modelling of the ankle bumper may need to be improved
- Softer shoe-padding in HH 50th dummy

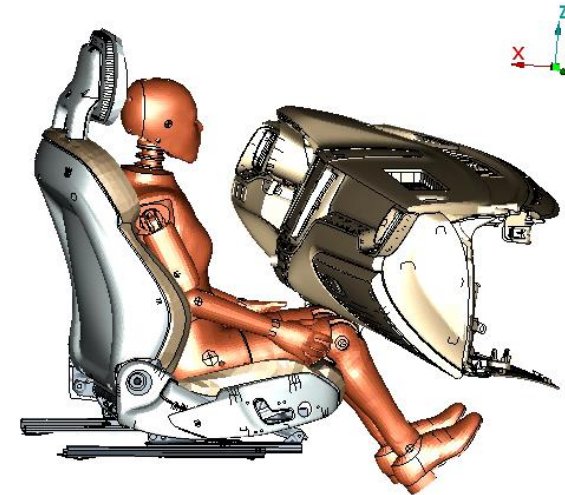
INJURY PREDICTION OF UNBELTED 05TH DUMMY



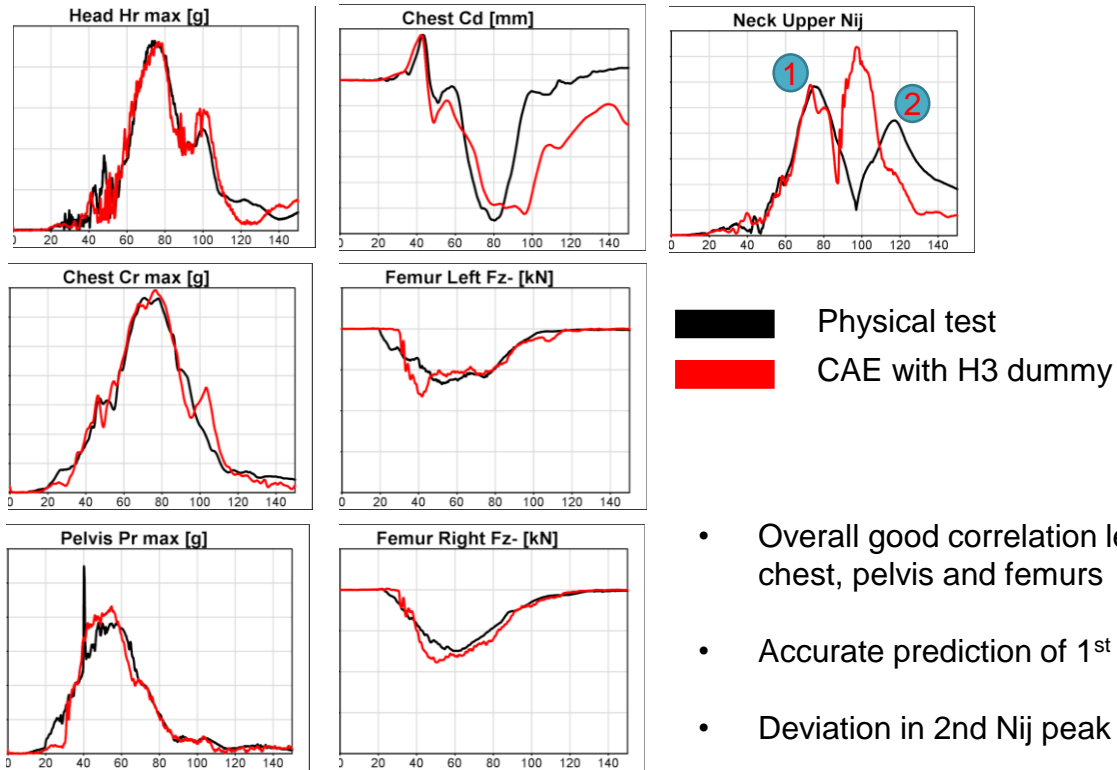
- FMVSS208 unbelted loadcase legal requirement in USA
 - Full width front impact at 25 mph with 5th HIII dummies
- Challenge: Prediction of N_{ij} for 5th dummy
 - Higher loading to neck due to unbelted torso
 - Complex neck movement: flexion, extension, rotation
 - N_{ij} based on F_x , F_z and M_{yc} - all three need to be correlated
 - Smaller denominator for 5th dummy compared with 50th dummy
 -> N_{ij} is sensitive to small variations

$$N_{ij} = \frac{F_z}{F_{zc}} + \frac{M_{ocy}}{M_{yc}} \quad M_{ocy} = M_y - (d * F_x)$$

Dummy Type	F_{zc} [N] Tension	F_{zc} [N]* Compression	M_{yc} [Nm] Flexion	M_{yc} [Nm]* Extension
Hybrid III; male 50%	6806	-6160	310	-135
Hybrid III; female 5%	4287	-3880	155	- 67

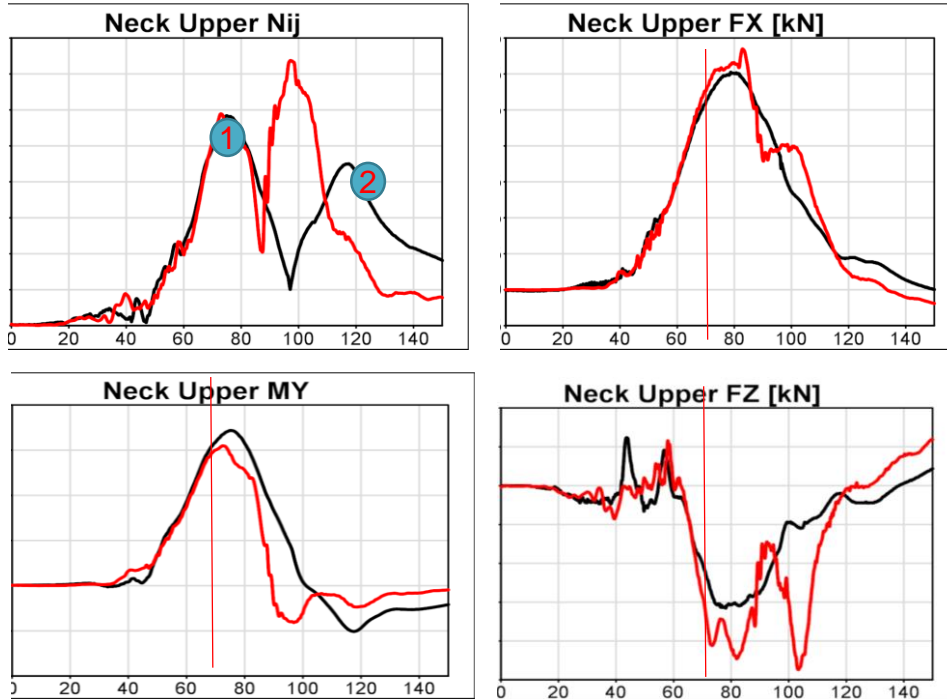


INJURY VALUES PREDICTION WITH H3 05TH



- Overall good correlation level achieved for injury parameters of head, chest, pelvis and femurs
- Accurate prediction of 1st Nij peak both magnitude and timing
- Deviation in 2nd Nij peak both magnitude and timing
- Animation shows that the neck rotation motion around Z-axis between CAE and test is different. CAE neck behaved too soft

NECK INJURY PARAMETERS WITH H3 05TH

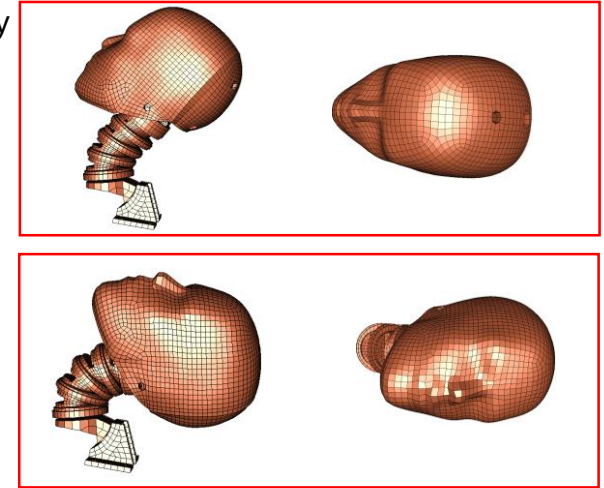


Physical test
CAE with H3 dummy

70 ms

Side view

Top view



Good correlation of upper neck force and moment until 70 ms.
Neck mainly had an extension motion

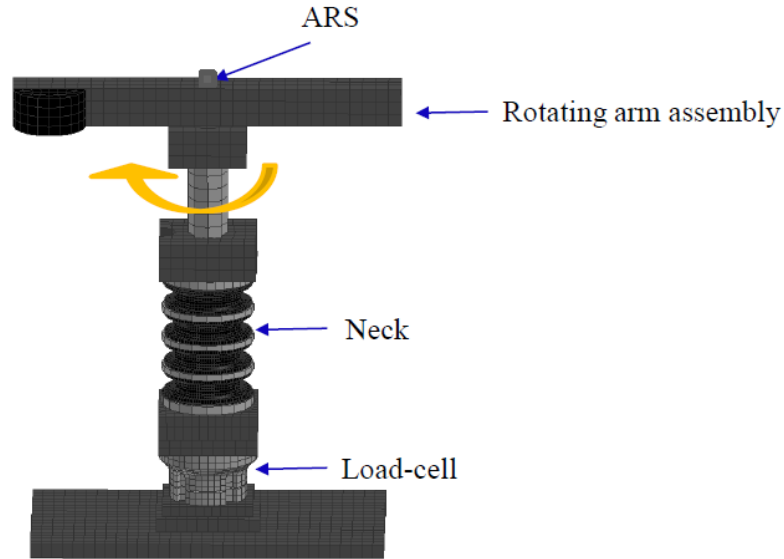
After 70 ms, neck started to twist around Z axis, which lead to quick drop of My and became negative at 90 ms. This led to too early 2nd Nij peak

$$N_{ij} = \frac{F_z}{F_{zc}} + \frac{M_{ocy}}{M_{yc}} \quad M_{ocy} = M_y - (d * F_x)$$

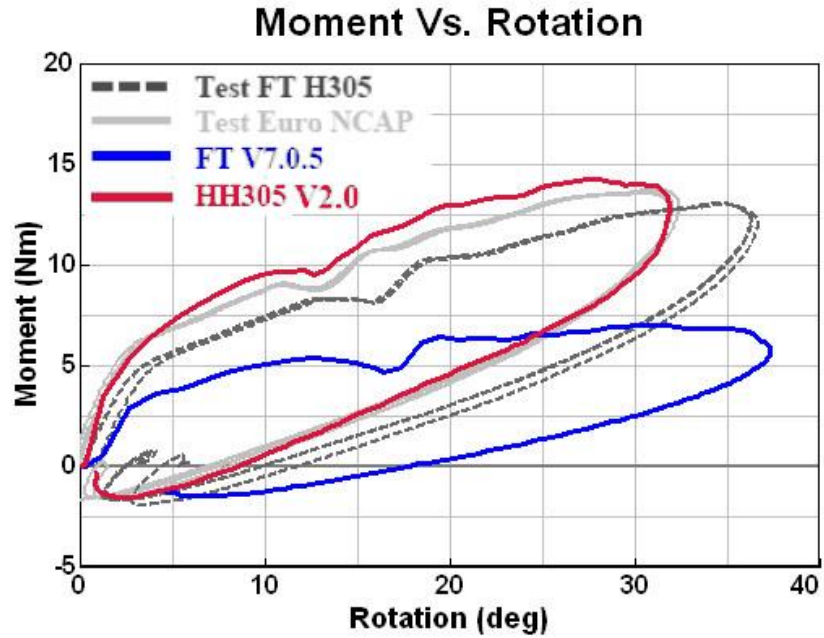
NECK MODELLING IMPROVEMENT BY HUMANETICS



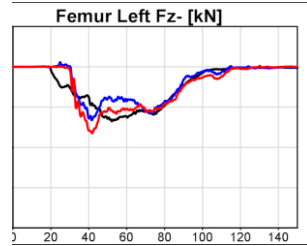
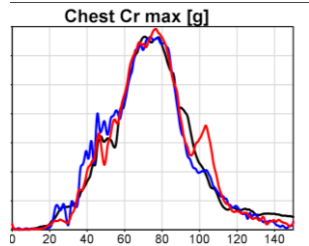
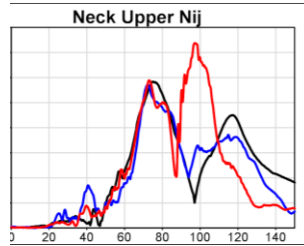
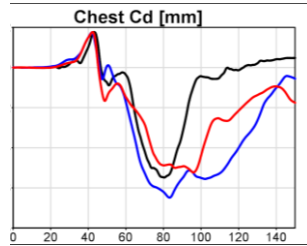
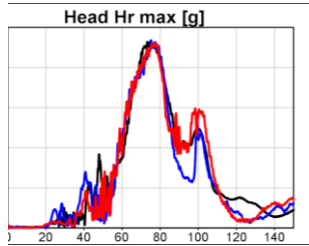
Neck Without Cable, Probe mass 2.65 Kg, Probe speed 2.5 m/s



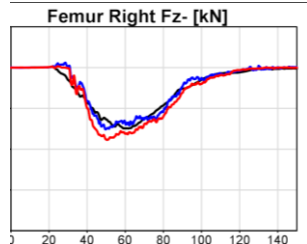
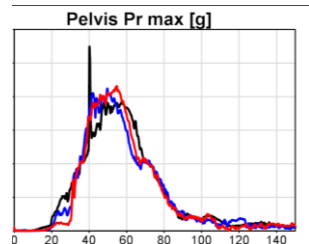
According to Humanetics, a major improvement of neck torsional stiffness correlation has been achieved.



INJURY VALUES PREDICTION WITH HH3 05TH

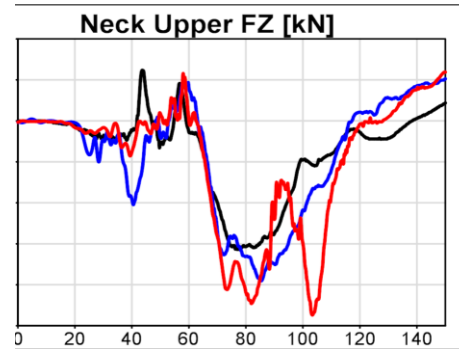
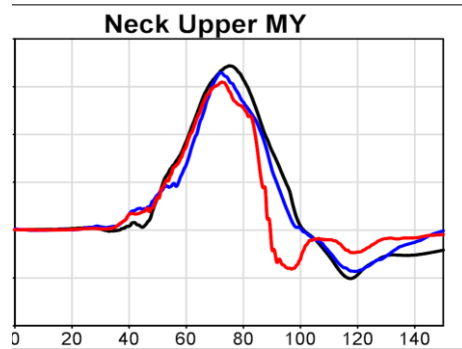
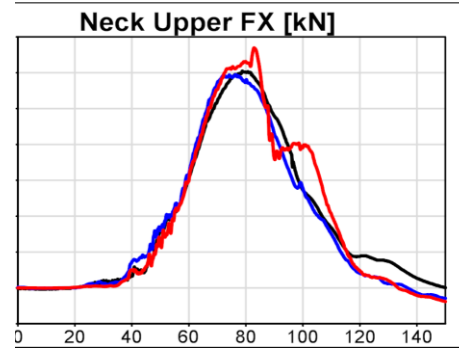
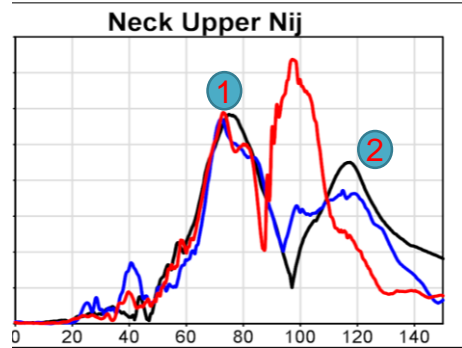


Physical test
CAE with H3 dummy
CAE with HH3 dummy



- Good correlation level achieved for injury parameters of head, chest, pelvis and femurs
- Accurate prediction of 1st Nij peak both magnitude and timing
- Acceptable prediction of 2nd Nij peak both magnitude and timing

NECK INJURY PARAMETERS WITH HH3 05TH



- Physical test
- CAE with H3 dummy
- CAE with HH dummy

Good correlation of 1st upper neck Nij peak both magnitude and timing

Improved correlation of 2nd upper neck Nij peak especially regarding timing

Improved correlation for all Nij components: Fx, Fz, My

SUMMARY



- Ls-dyna and Humanetics CAE dummies were effective tools for the development of the restraint systems of the all-new XC60.
- Overall satisfying kinematics and injury prediction ability with both HIII and Harmonized CAE dummies
- Improved prediction accuracy for Chest Deflection with Harmonized 50th CAE dummy
- Improved neck injury prediction with Harmonized 50th CAE dummy and 5th CAE dummy.