SCIENCE
PASSION
TECHNOLOGY

HBM4VT – WG 2

Steering wheel rim simulation setup

Shaw et al. 2004

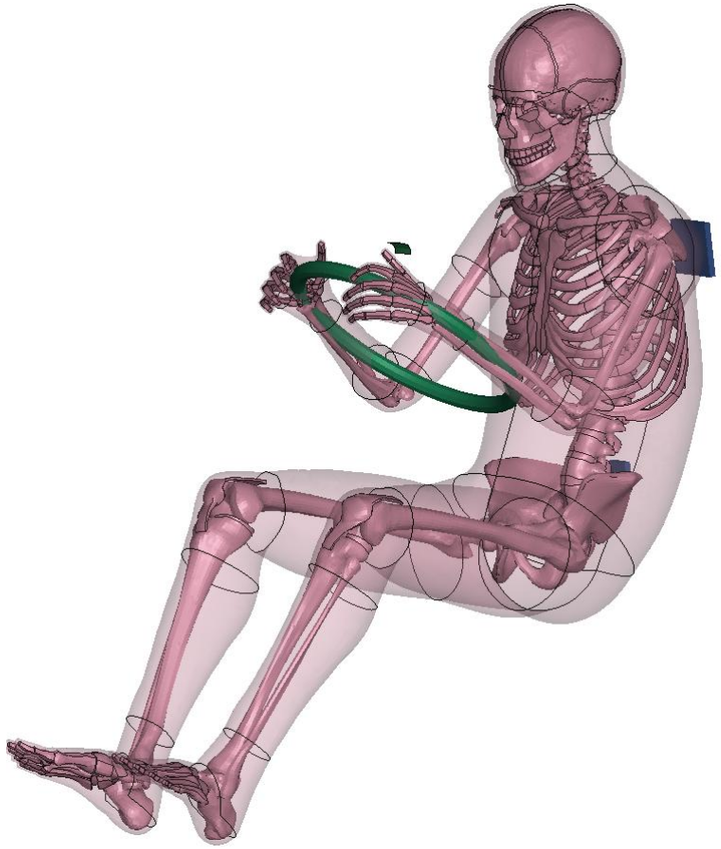
General Overview

Model Setup

Hub tests by Shaw 2004

Key factors to replicate from PMHS tests:

- HBM in seating position
  - Vertebra T6, T8, T10 and T12 as well as pelvis are fixed in space
  - Supporting blocks on L4 and scapula
- Impact 50mm below sternum
- Penetration level of steering wheel controlled
- Measure forces on steering wheel



Development notes

LS-Dyna version used for development:

- R12.2_217 mpp single precision (R12.2-217-gfcd6dde0c9)
- Time step: dt2ms = -4.44E-4 ms (tssfac = 0.9)

HBMs used in testing:

- THUMS v4.1 50th percentile male
- VIVA+ v1.0.0 50th percentile female

Simulation setup

Contact parts
- Control penetration level of steering wheel

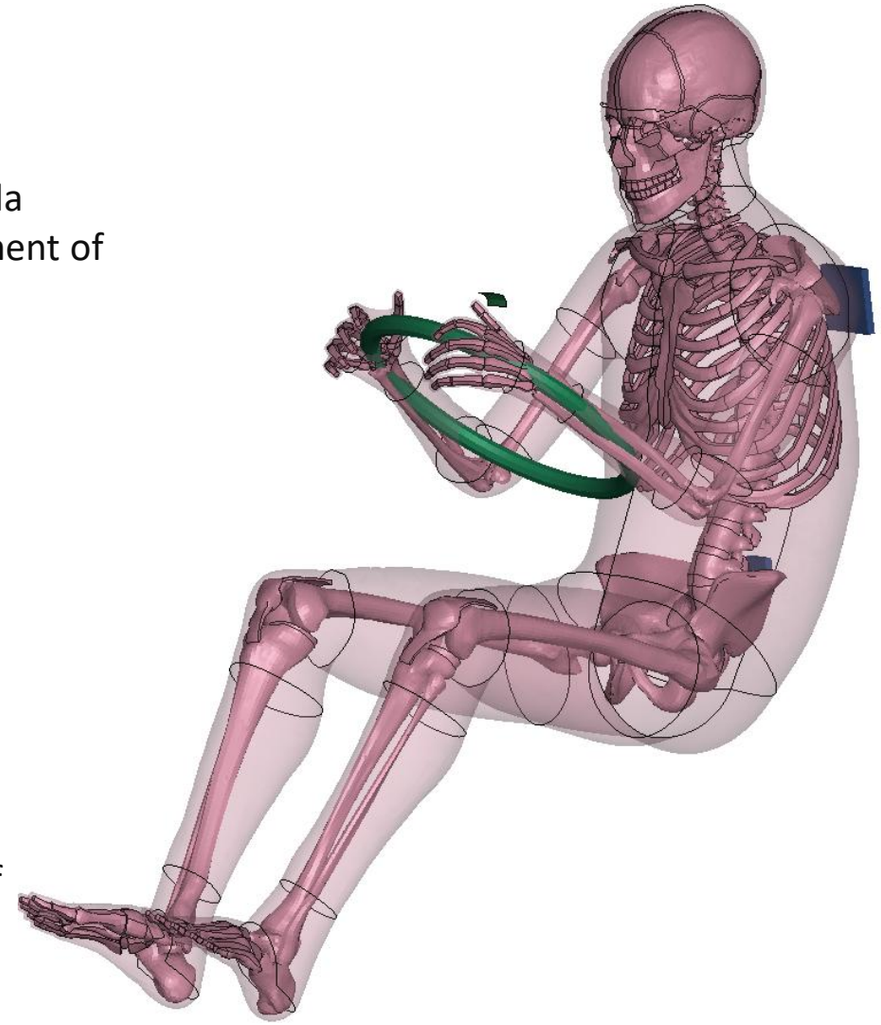
Rigid steering wheel
- Mass: 64kg
- 45° inclined

Support blocks on scapula
- Constrain the movement of scapula via contact

Vertebrae T6, T8, T10, T12 are fixed in space

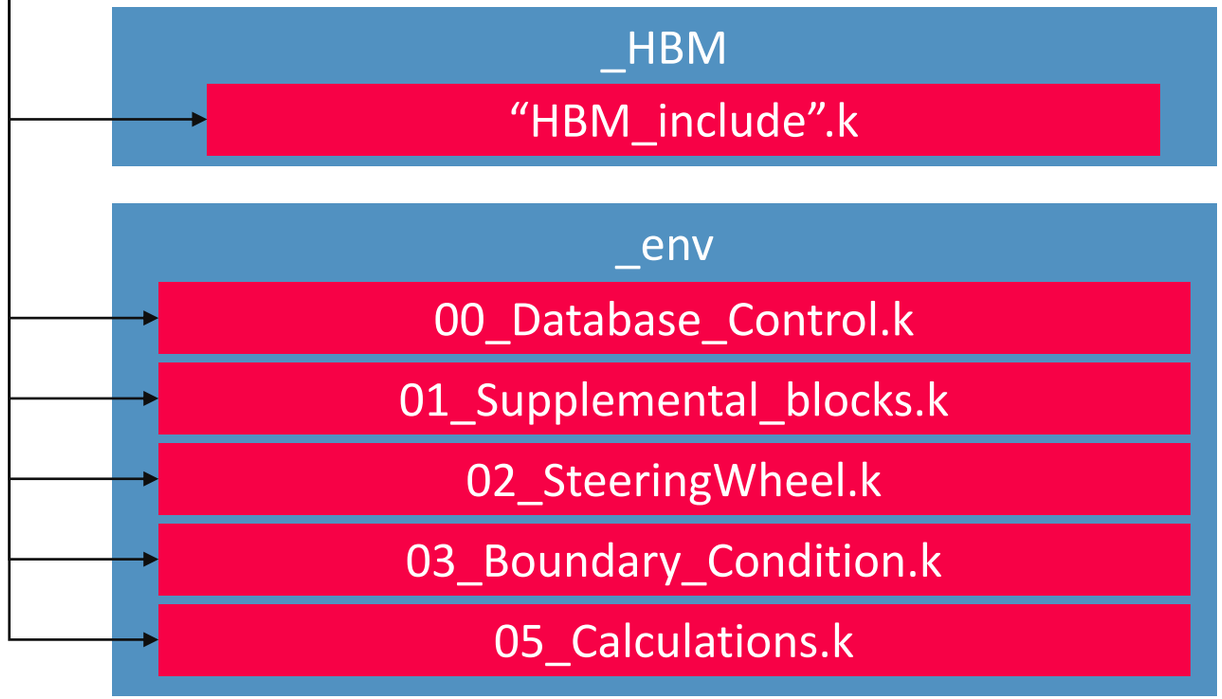
Pelvis is fixed in space

Support blocks on L4
- Constrain the movement of L4 via contact



Overview – steering wheel load case

00_Master_SteeringWheel.k → Single file to be changed
Follow the descripted procedure



→ Add your HBM-include in the folder „_HBM“

Procedure

Setting the parameters

Set up the include files

1) Put the main HBM file in the folder directory "_HBM“
2) Open the main HBM file in a pre-processor
3) Open the file 00_Master_SteeringWheel.k in a text editor
4) Define the main HBM file in the I N C L U D E S section
4) Follow the instructions from STEP 1 to STEP 8 (following slides)

Instrumentation requirements

- Equip your HBM with the required output
  - Strains in cortical bones of ribs

- Note: The required output rate is defined in the file “00_Database_Control.k”
  - 10kHz for contact, cross section and nodal outputs since CFC filtering is applied in Jupyter notebook
  - 1kHz for strain output
- Update all NODE and OBJECT IDs in the HBM ID-file in “…\data\metadata” accordingly (see THUMS file for example)

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and constraints
4) Definition of the location where steering wheel contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) Measure thorax distance and landmark locations
7) Check for intersections of the HBM to the steering wheel
8) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter

Goal:

- Define the load case to be simulated
- Set factor to scale environment to the unit system of the HBM

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) **Define ID for contact sets and constraints**

Goal:

- Define sensible HBM contact set and part IDs

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and constraints
4) **Definition of the location where steering wheel contacts HBM**

Goal:

- Locate points were the steering wheel should impact HBM in default HBM position

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and constraints
4) Definition of the location where steering wheel contacts HBM
5) **Definition of the HBM rotations in order to reach target orientation**

Goal:

- Rotate HBM to target orientation

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
3) Define ID for contact sets and constraints
4) Definition of the location where steering wheel contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) **Measure thorax distance and landmark locations**

Goal:

- Measure distances and define coordinates for landmarks

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global parameter
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4) Definition of the location where steering wheel contacts HBM
5) Definition of the HBM rotations in order to reach target orientation
6) Measure thorax distance and landmark locations
7) Check for intersections of the HBM to the steering wheel

Goal:

- Check for intersections

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
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S T E P 1

Definition of the load case

Define the load case which represents the target penetration level

- *LPL* = 1: low penetration level → 30% of chest depth
- *HPL* = 1: high penetration level → 50% of chest depth

Set only one parameter to 1

	Velocity [m/s]
Low penetration level	4.0
High penetration level	4.0

S T E P 2
Definition of the unit system of the HBM

Define the scale factors depending on the unit system of the HBM

- *UScal*: 0.001 for unit system t-mm-s
- *UScal*: 1 for unit system kg-mm-ms

→ The testbed environment will be scaled by *UnitScal* to the preferred unit system

Define the correct unit system in the Jupyter notebook

- ms_mm_kg
- s_mm_ton

Attention: all parameters in the **main key file** need to be defined in the unit system **kg-mm-ms**

IF the testbed shares node IDs with the HBM, set an ID offset for the HBM

- *IDoff*: default: 0.

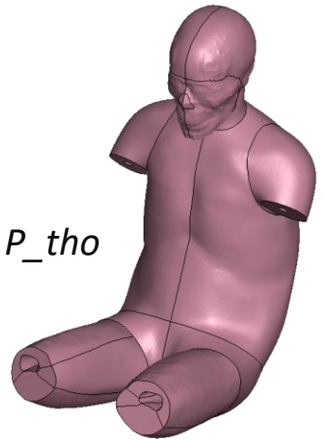
STEP 3

Define ID for contact sets and ID offset if necessary

Define the part set of thorax parts of the HBM

- *P_tho*: ID of the set including parts of the HBM thorax

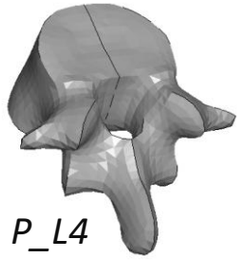
→ This part set will be in contact to the steering wheel



Define the part set including parts of vertebra L4

- *P_L4*: ID of the set including parts of vertebra L4

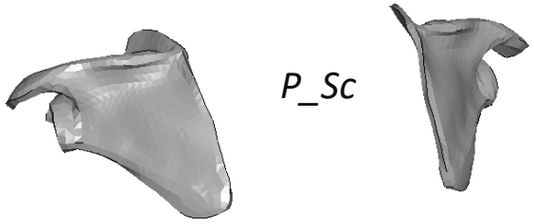
→ This part set will be in contact to the supporting block



Define the part set including both scapula

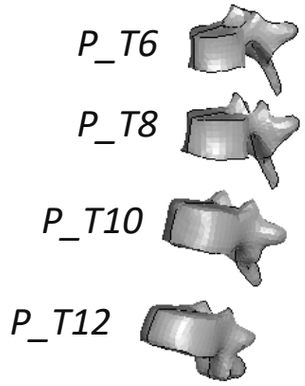
- *P_Sc*: ID of the set including parts of both scapula

→ This part set will be in contact to the supporting block



STEP 3

Define ID for contact sets and ID offset if necessary



Define part ID or node set ID referring parts or nodes on T6, T8, T10, T12 and pelvis. Whether defining a part ID or a node set depends on the material of the vertebrae and pelvis.

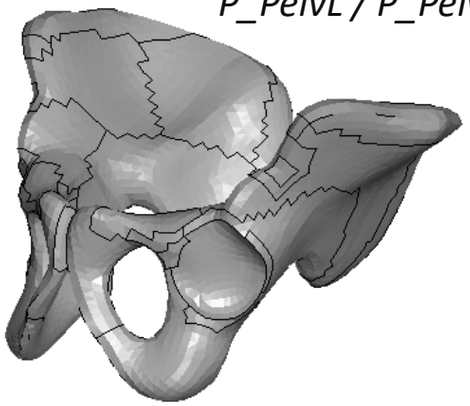
IF vertebrae or pelvis are rigid:

Define the part IDs for pelvis T6, T8, T10, T12 or pelvis. For non rigid parts preserve the default part IDs and proceed with the next parameter.

- *P_T6*: Part ID of rigid vertebra T6 (default: 15000040)
- *P_T8*: Part ID of rigid vertebra T8 (default: 15000050)
- *P_T10*: Part ID of rigid vertebra T10 (default: 15000060)
- *P_T12*: Part ID of rigid vertebra T12 (default: 15000070)
- *P_PelvL*: Part ID of rigid pelvis left (default: 15000080)
- *P_PelvR*: Part ID of rigid pelvis right (default: 15000090)
  - If the pelvis only consists of a single part, define only *P_PelvL* and keep *P_PelvR* as default

→ This parts will be constrained via *BOUNDARY_PRESCRIBED_MOTION_RIGID

P_PelvL / P_PelvR



IF vertebrae or pelvis are deformable:

Define a node set including nodes on T6, T8, T10, T12 or pelvis. If all parts are already defined above, provide an empty part set N_con.

- *N_con*: Node set including nodes on deformable T6, T8, T10, T12 or pelvis

→ This nodes will be constrained via *BOUNDARY_PRESCRIBED_MOTION_SET

STEP 4

Definition of the location where steering wheel contacts HBM

Define the coordinates of the location of the acetabulum centre point (AC) between the left and right acetabulum (in midsagittal plane):

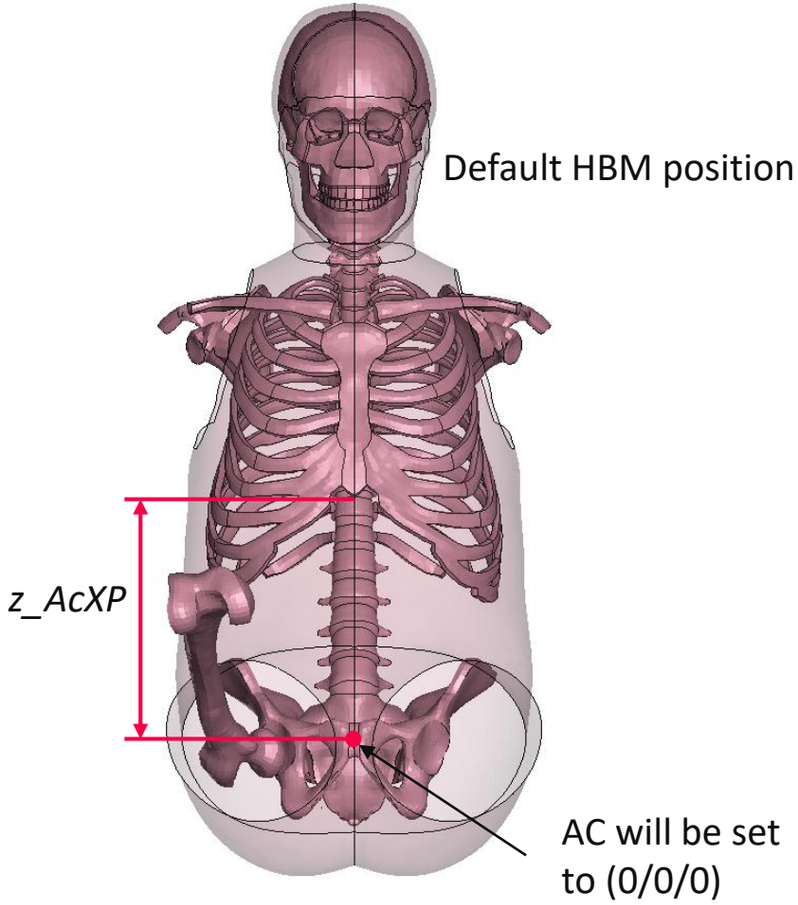
- *x_AC*: x-coordinate of AC in the default HBM position with respect to the global coordinate system
- *y_AC*: y-coordinate of AC in the default HBM position with respect to the global coordinate system
- *z_AC*: z-coordinate of AC in the default HBM position with respect to the global coordinate system

→ The HBM will be transferred so that the AC is at 0/0/0

Define the vertical distance from the acetabulum to the xiphoid process

- *z_AcXP*: vertical distance

→ The steering wheel rim (default positioned at 0/0/0) will be moved to the location 50mm below the xiphoid process



STEP 5

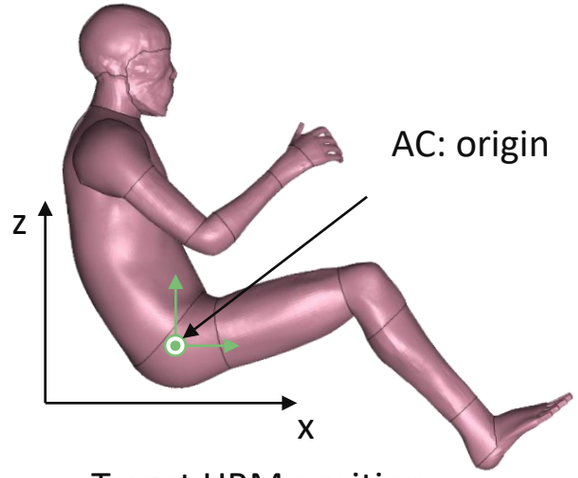
Definition of the HBM rotations to reach target orientation

Check the actual HBM orientation and compare to target orientation as illustrated

Define the flag for all axes:

- *x_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the axis
- *y_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the axis
- *z_rt*: “1” for correct axis orientation and “-1” to rotate the model 180deg about the axis

→ HBM will be rotated to reach target orientation

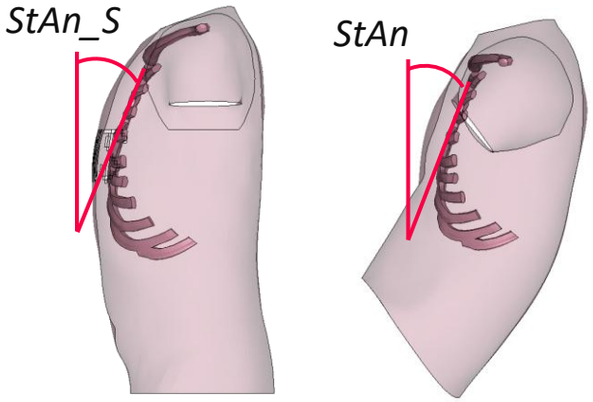


Target HBM position

Measure the sternum angle between the center of attachment of 4th to 2nd rib relative to frontal plane

- *StAn*: angle in default posture of HBM used here (insert a positive value)
- *StAn_S*: angle in default posture of corresponding standing HBM (insert a positive value)
  - If the used HBM is already in standing posture, define both angles as 0 and no rotation is applied to the hub
  - If no standing posture of the HBM is available, define both angles as 0 and no rotation is applied to the hub

→ The hub will be rotated in a way so that the steering wheel impact orientation on the seating HBM equals the steering wheel impact orientation on the standing HBM



STEP 6
Measure thorax distance and landmark locations

Save the file “00_Master_SteeringWheel.k” and open it in a pre-processor

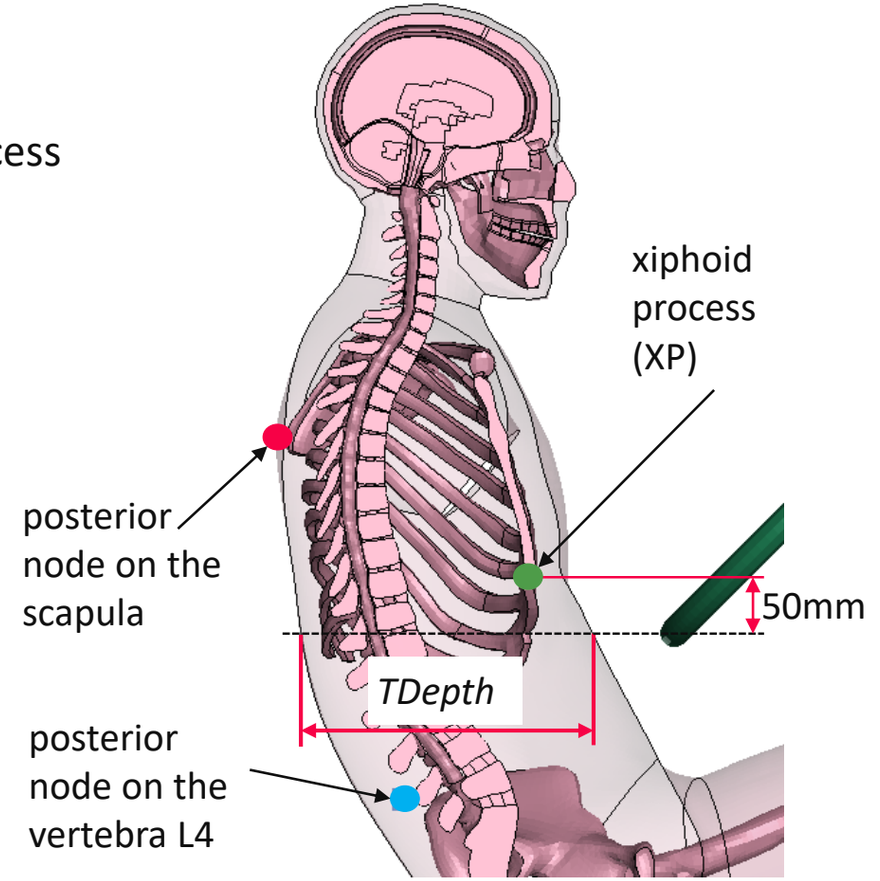
Measure the torso depth at the impact site being 50mm below the xiphoid process
- *TDepth*: horizontal depth of torso

→ The maximal steering wheel penetration is calculated on basis of *TDepth*

Define the x and z coordinate of the posterior node on the vertebra L4
- *x_L4*: x-coordinate of the posterior node on the vertebra L4
- *z_L4*: z-coordinate of the posterior node on the vertebra L4

Define the coordinates of the posterior node on the scapula
- *x_Sc*: x-coordinate of the posterior node on the scapula
- *y_Sc*: y-coordinate of the posterior node on the scapula
- *z_Sc*: z-coordinate of the posterior node on the scapula

→ The initial position of the supporting blocks will be calculated based on this coordinates



STEP 7

Measure thorax distance and landmark locations

Save the file “00_Master_SteeringWheel.k” and open it in a pre-processor

IF the steering wheel has intersections to the HBM, adjust the steering wheel offset

- *SW_off*: distance in x (positive value: steering wheel is moved away from HBM)

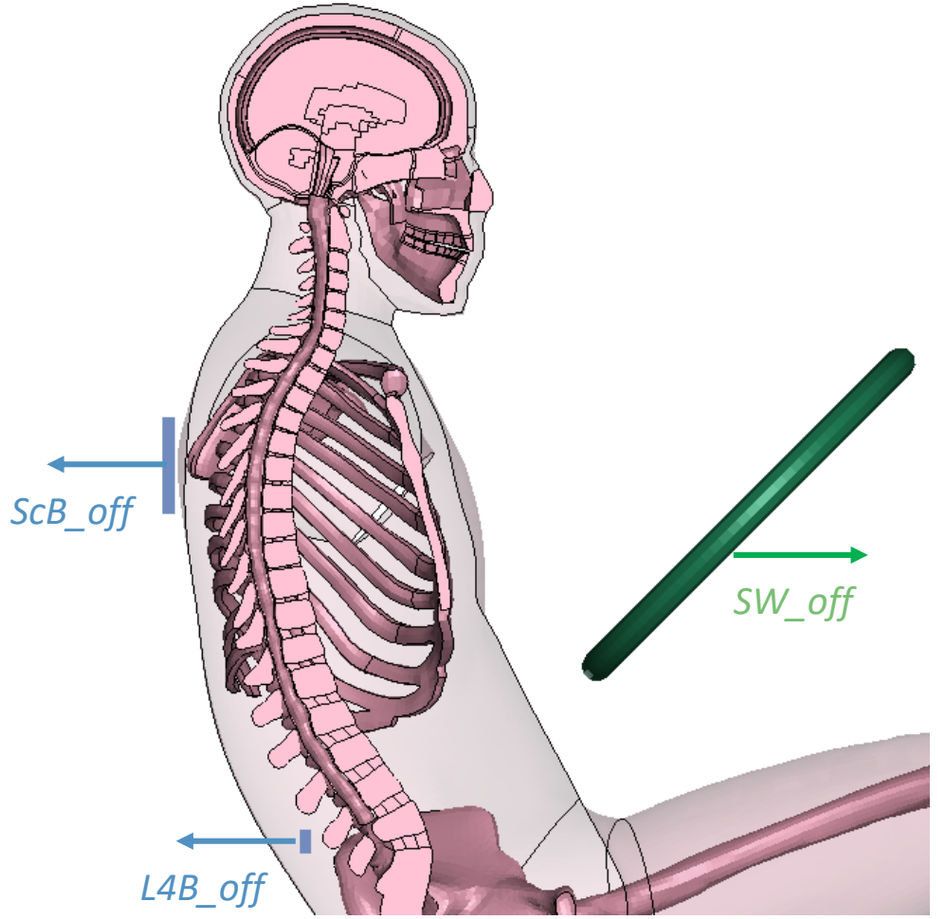
Note: Keep a clearance between steering wheel rim and HBM of at least 20mm to facilitate filtering of the force signal in the assessment notebook

IF the supporting blocks have intersections to the scapula, adjust the blocks offset

- *ScB_off*: distance in x (positive value: blocks are moved away from HBM)

IF the supporting block has intersections to the L4 vertebra, adjust the block offset

- *L4B_off*: distance in x (positive value: blocks are moved away from HBM)



STEP 8

Run simulation and check results

IF the settling phase for the blocks is not long enough, change duration [ms]

- *SetHBM*: duration of settling phase (default: 100ms)

IF the duration of load is too short, change duration [ms]

- tload: duration of load phase (default: 70ms)

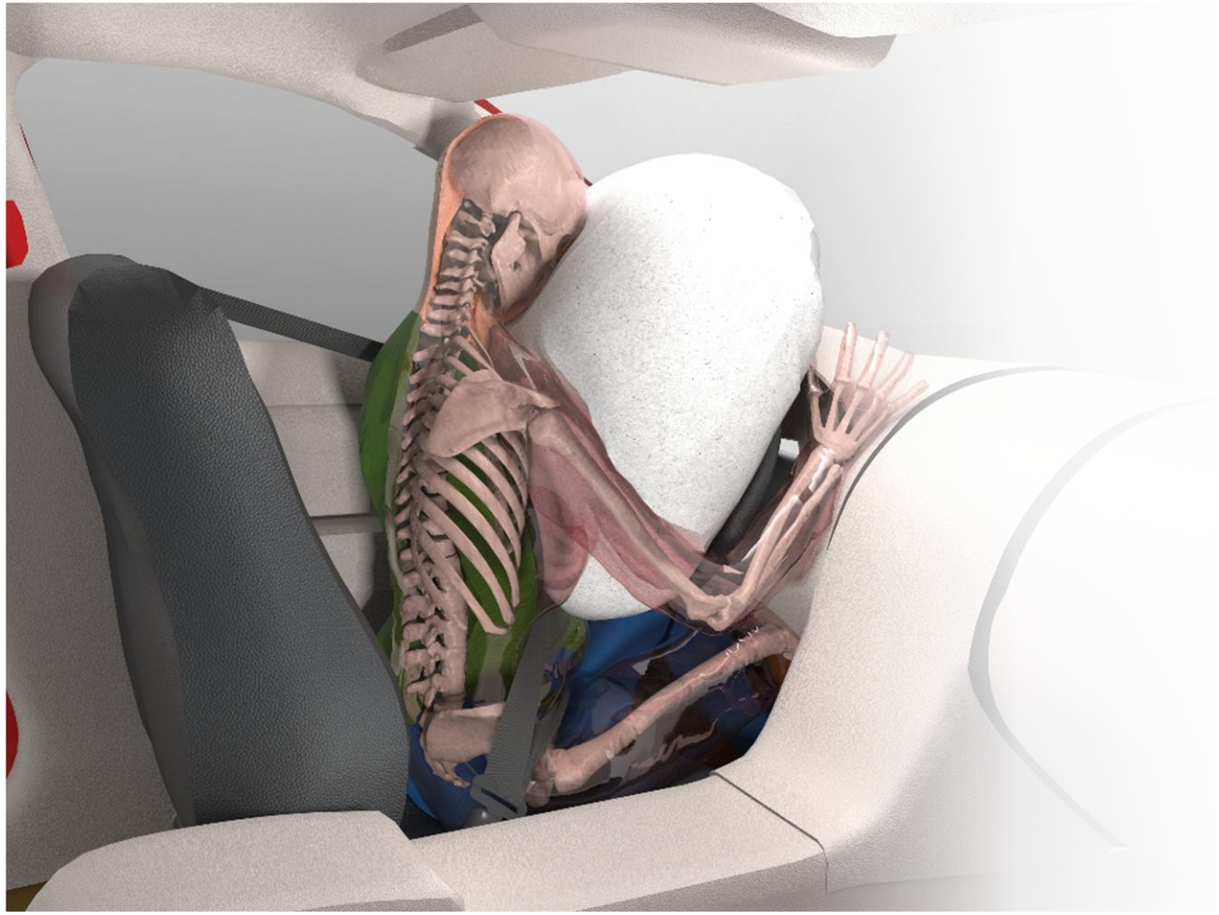
IF contact issues occur, modify DEPTH flag for contact HBM to environment

- *Depth*: default: 25

Final checks

Check following in the final simulation

- The load duration must be long enough for the steering wheel to reach the maximal penetration level, which is defined at the time of contact of the steering wheel rim to the contact part.



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