SCIENCE
PASSION
TECHNOLOGY

HBM4VT – WG 2

Hub simulation setup

Viano et al. 1989

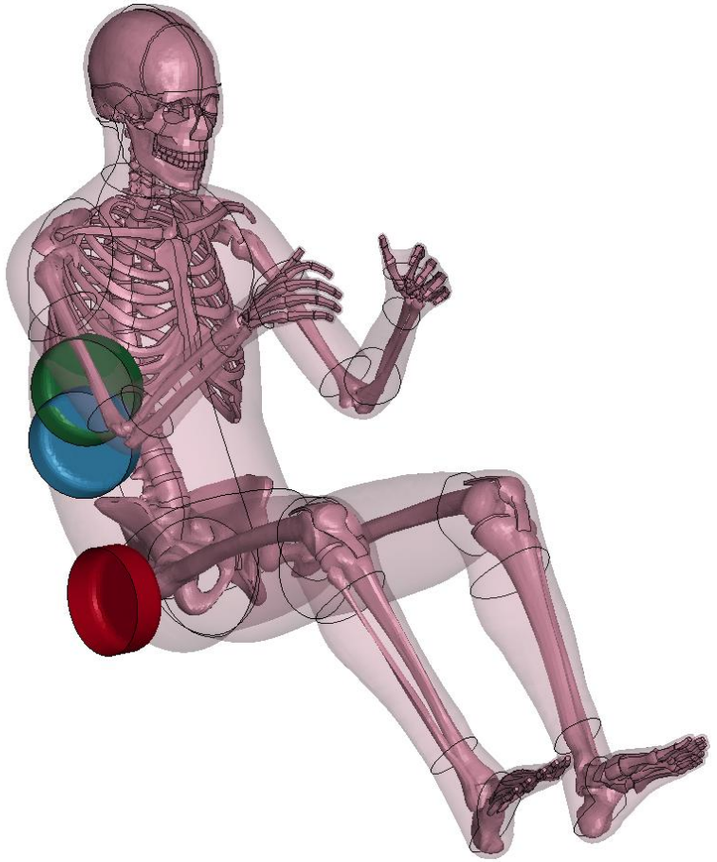
General Overview

Model Setup

Hub tests by Viano 1989

Key factors to replicate from PMHS tests:

- HBM in standing position
  - Simulation can be conducted also with seated model → model is rotated to align sternum angle to standing model
- Extremities fixed above head
  - No positioning of the upper extremities in the simulation → hub is only in contact with thorax
- Measure hub displacement
  - Hub is loaded with impact speed for 10cm traveling length after contact to HBM and is released for the remaining 30cm of traveling length
  - In the simulation the hub is loaded only with initial velocity



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:

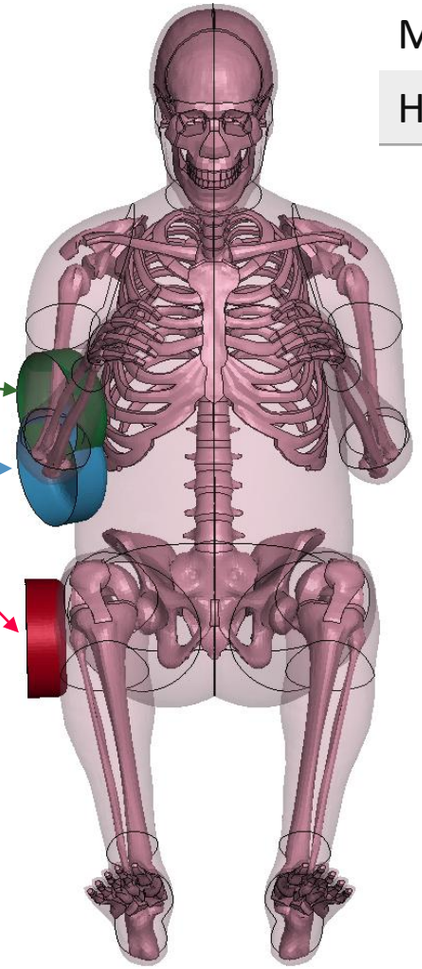
- THUMS v4.1 50th percentile male
- VIVA+ v1.0.0 50th percentile female

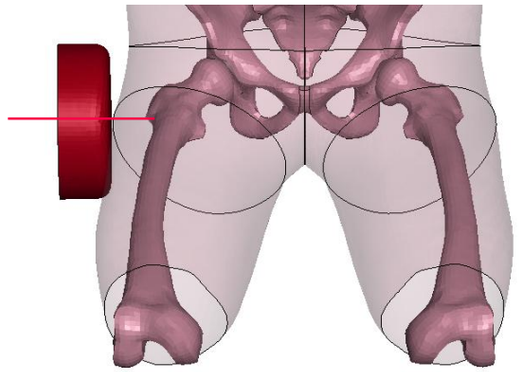
Simulation setup

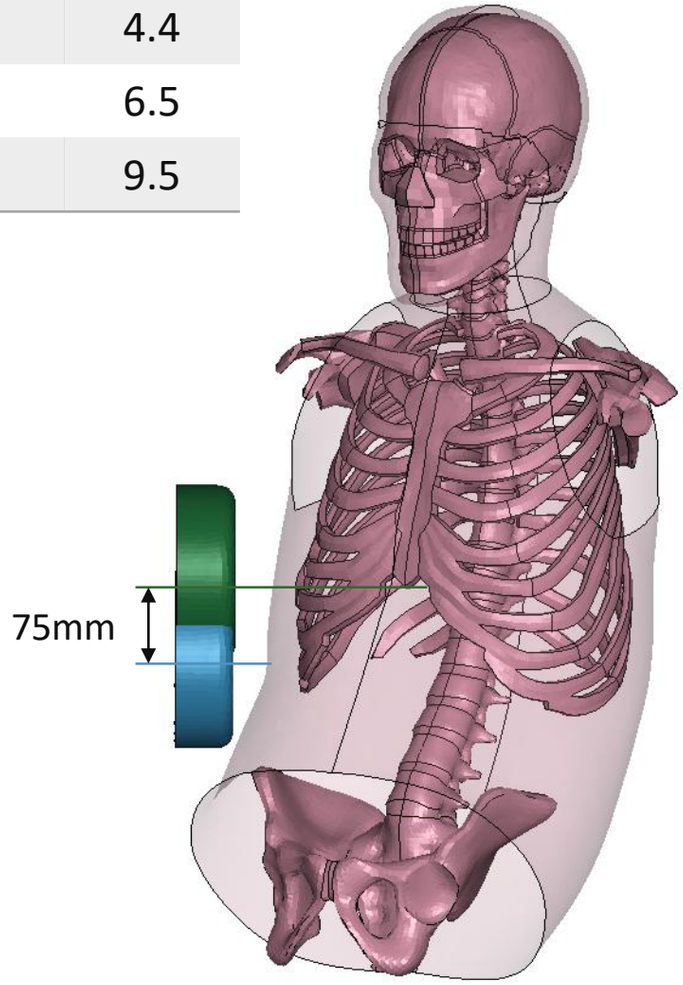
	Pelvis	Abdomen	Thorax
Low speed [m/s]	5.2	4.8	4.4
Medium speed [m/s]	6.8	6.8	6.5
Highest speed [m/s]	9.8	9.4	9.5

Rigid hub
- Mass: 23.4kg

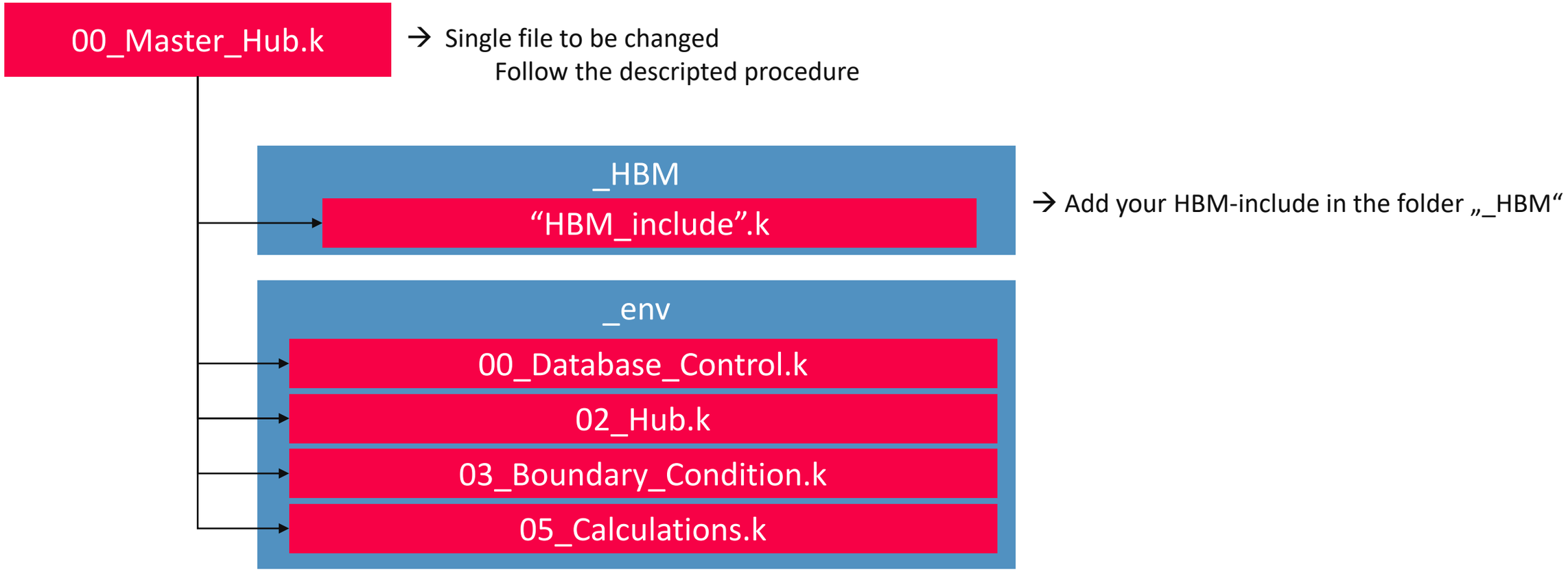
Three impact locations
- Thorax – xiphoid process
- Abdomen – 75mm below xiphoid process
- Pelvis – trochanter major







Overview – hub load case



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_Hub.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 6 (following slides)

Instrumentation requirements

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

- Note: The required output rate is defined in the file “00_Database_Control.k”
  - 10kHz for contact 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 HBM parameter
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations to reach target orientation
5) Check for intersections of HBM to hub
6) Check for the correct impactor location
7) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

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

Goal:

- Set parameters to choose load case (impact location and impactor speed)
- Set factor to scale environment to the unit system of the HBM
- Define sensible HBM contact set

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global HBM parameter
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations to reach target orientation

Goal:

- Locate points were hub should impact HBM in default HBM position
- Correct HBM orientation in case of seated model
- Rotate HBM to target orientation

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case
2) Definition of global HBM parameter
3) Definition of the location where hub contacts HBM
4) Definition of the HBM rotations to reach target orientation
5) Check for intersections of HBM to hub

Goal:

- Fine-tune hub position in case of intersections

Overview on stepwise simulation setup (see following slides)

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Goal:

- Fine-tune hub position in case of deviations

Overview on stepwise simulation setup (see following slides)

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S T E P 1
Definition of the load case

	Pelvis	Abdomen	Thorax
Low speed [m/s]	5.2	4.8	4.4
Medium speed [m/s]	6.8	6.8	6.5
Highest speed [m/s]	9.8	9.4	9.5

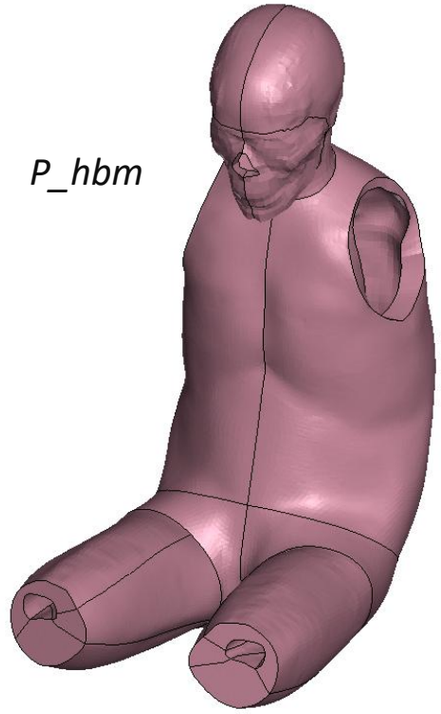
Define load case

- *Imp_H*: set to 1 for impact on hip (set other two parameter to 0)
- *Imp_A*: set to 1 for impact on abdomen (set other two parameter to 0)
- *Imp_T*: set 1 for impact on thorax (set other two parameter to 0)

Define impact severity

- *LS*: set to 1 for low speed (set other two parameter to 0)
- *MS*: set to 1 for medium speed (set other two parameter to 0)
- *HS*: set to 1 for highest speed (set other two parameter to 0)

STEP 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**

Define the part set of HBM

- *P_hbm*: Set ID of the set including legs and thorax without shoulders
- → This part set will be in contact to the hub

STEP 3

Definition of the location where hub 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

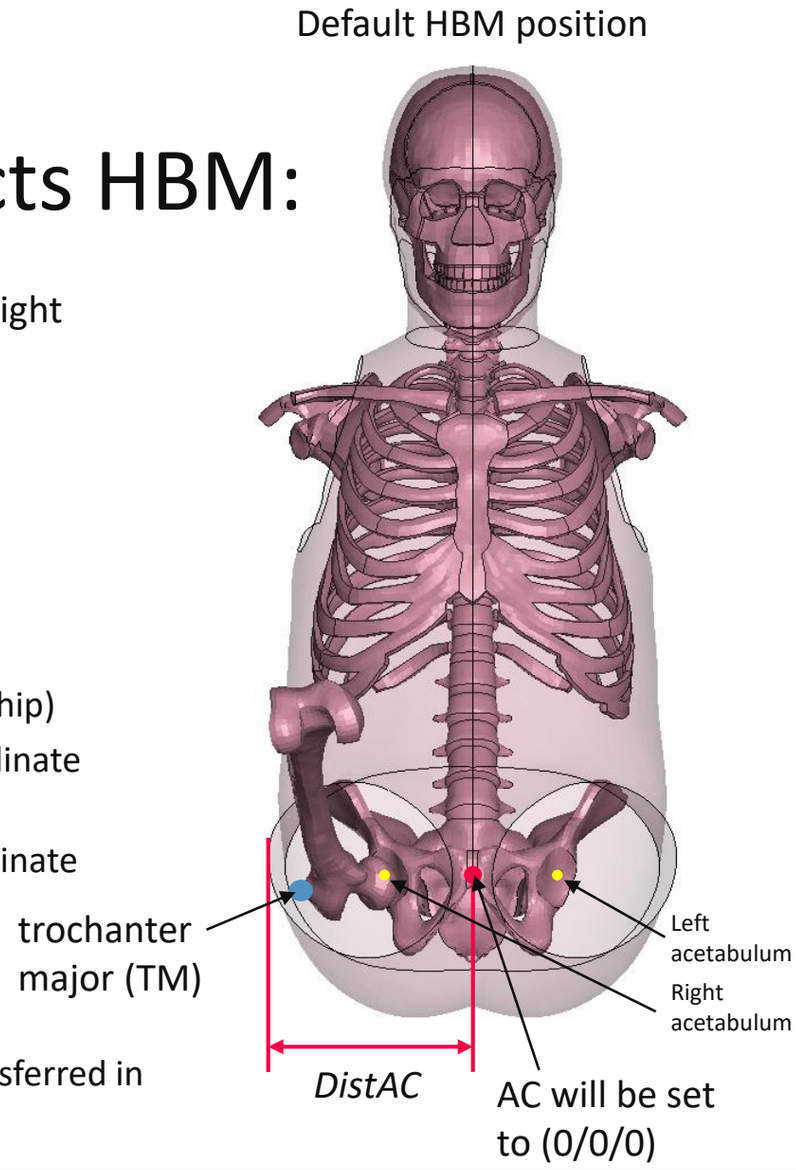
Define the coordinates of the location of the trochanter major in midsagittal plane (Used for impact on hip)

- *x_TM*: x-coordinate of trochanter major in the default HBM position with respect to the global coordinate system
- *z_TM*: z-coordinate of trochanter major in the default HBM position with respect to the global coordinate system

Define the distance between the AC and the most anterior point on the pelvis

- *DistAC*: distance in medial direction

→ The hub (default positioned at 0/0/0) will be moved to the location of the trochanter major and transferred in anterior direction to avoid intersections with the HBM



STEP 3

Definition of the location where hub contacts HBM:

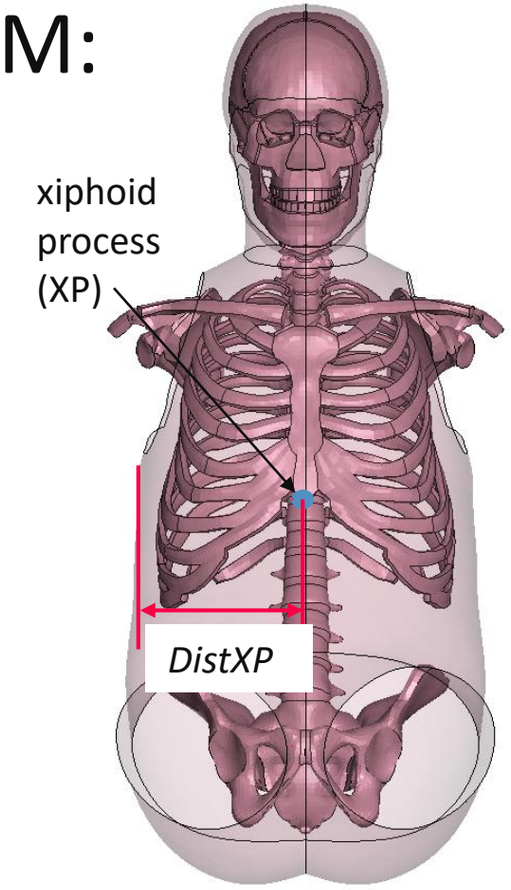
Define the coordinates of the location of the xiphoid process in midsagittal plane (Used for impact on thorax)

- *x_XP*: x-coordinate of xiphoid process in the default HBM position with respect to the global coordinate system
- *z_XP*: z-coordinate of xiphoid process in the default HBM position with respect to the global coordinate system

Define the distance between the xiphoid process and the most medial point on the thorax

- *DistXP*: distance in medial direction

→ The hub (default positioned at 0/0/0) will be moved to the location of the xiphoid process and transferred in medial direction to avoid intersections with the HBM



Default HBM position

STEP 3

Definition of the location where hub contacts HBM:

Define the distance from XP to the intrathoracic surface of the vertebrae in horizontal plane

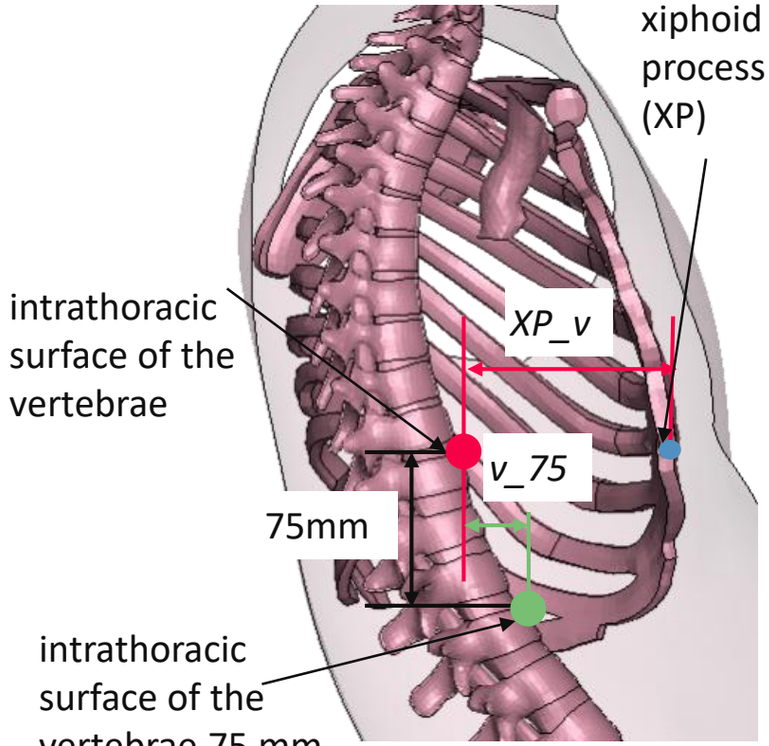
- *XP_v*: distance in posterior direction

→ The hub will be offset so that force direction leads through thorax CoG in the thoracic load case (approx. 2cm anterior of the in intrathoracic surface of the vertebrae)

Define the distance to the intrathoracic surface 75 mm below the level selected for the thoracic impact

- *v_75*: distance in posterior direction

→ The hub will be offset so that force direction leads through thorax CoG in the abdominal load case (approx. 2cm anterior of the in intrathoracic surface of the vertebrae)



Default HBM position

STEP 4

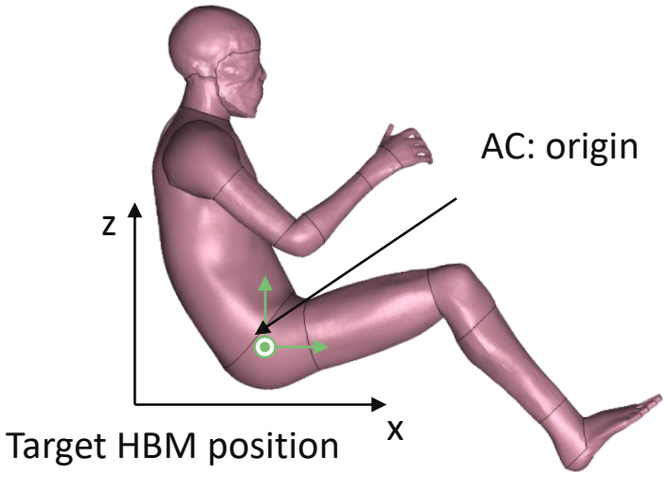
Definition of the HBM rotations to reach target orientation

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

Define the flag to 1 or -1 for all axes:

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

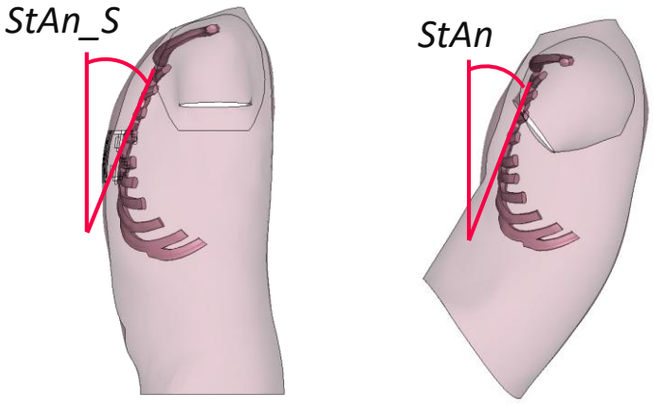
→ The HBM will be rotated to reach target orientation



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
- *StAn_S*: angle in default posture of corresponding standing HBM
  - 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 hub impact orientation on the seating HBM equals the hub impact orientation on the standing HBM



STEP 5
Check for intersections of HBM to hub

Save the file “00_Master_Hub.k” and open it in a pre-processor
Check for intersections and set values if needed:

IF test bed share node IDs with HBM, set an ID offset for the HBM

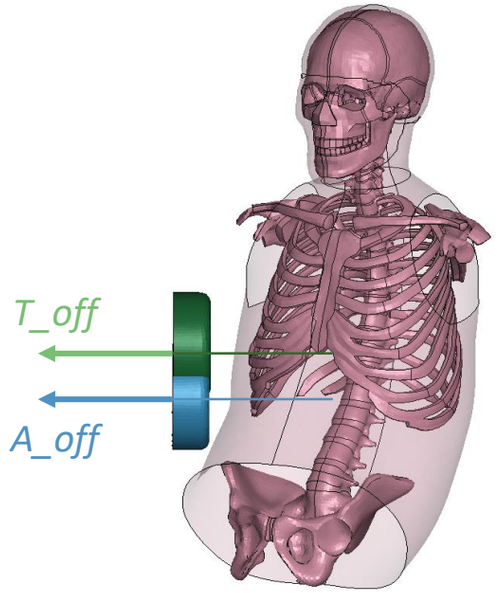
- *IDoff*: default: 0.

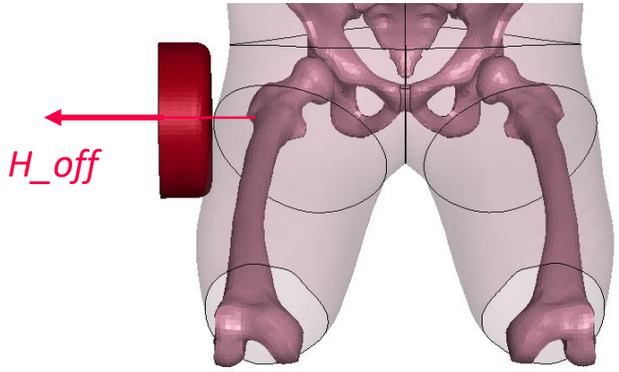
If the hub has intersections to the HBM, translate the hub in force direction

positive value: hub is moved away from HBM

- *T_off*: offset for impact on thorax
- *A_off*: offset for impact on abdomen
- *H_off*: offset for impact on hip

Note: Keep a clearance between hub and HBM of at least 50mm to facilitate filtering of the force signal in the assessment notebook

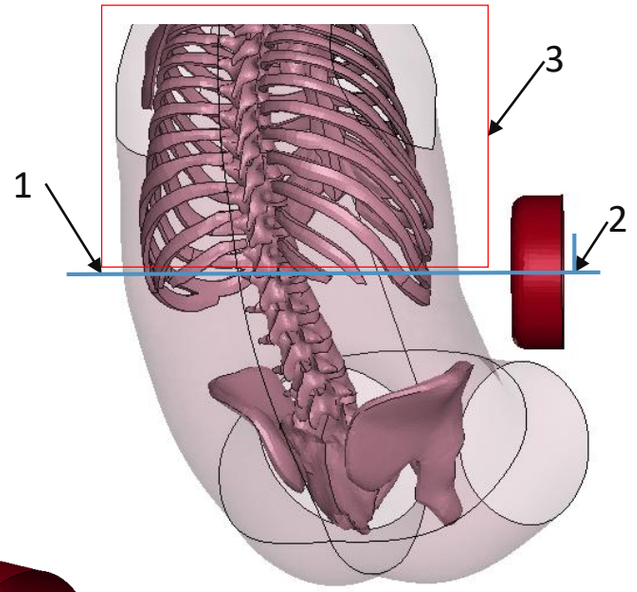


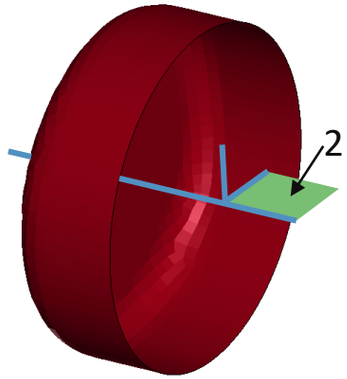


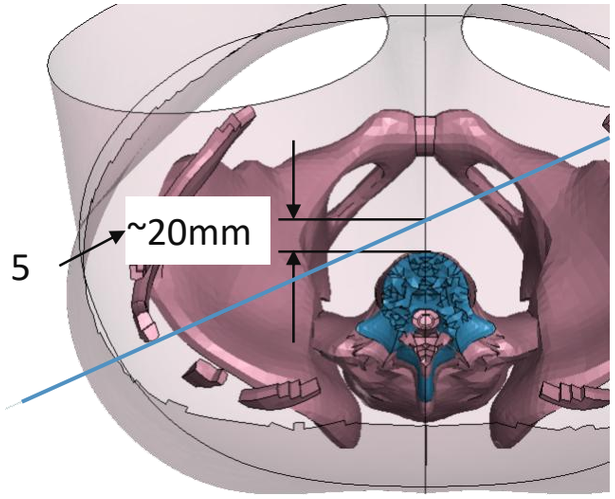
STEP 6
Check for the correct impactor location

Check for the correct impactor location for the thoracic and abdominal load case (no check needed for the hip load case)

1) Rotate the model to reach a horizontal orientation of the of the hub beam
2) Use the hub coordinate system as indication and align the green plane to horizontal
3) Hide all elements above the beam
4) Rotate the model to top view
5) Measure the distance between the intrathoracic surface of the vertebrae to the beam in sagittal plane. The distance should be approximately 20mm.
6) In case of a deviation, adapt following parameters:
   - *XP_v* for the thoracic load case
     - Increased value moves the hub towards the vertebra
   - *v_75* for the abdominal load case
     - Increased value moves the hub away from the vertebra





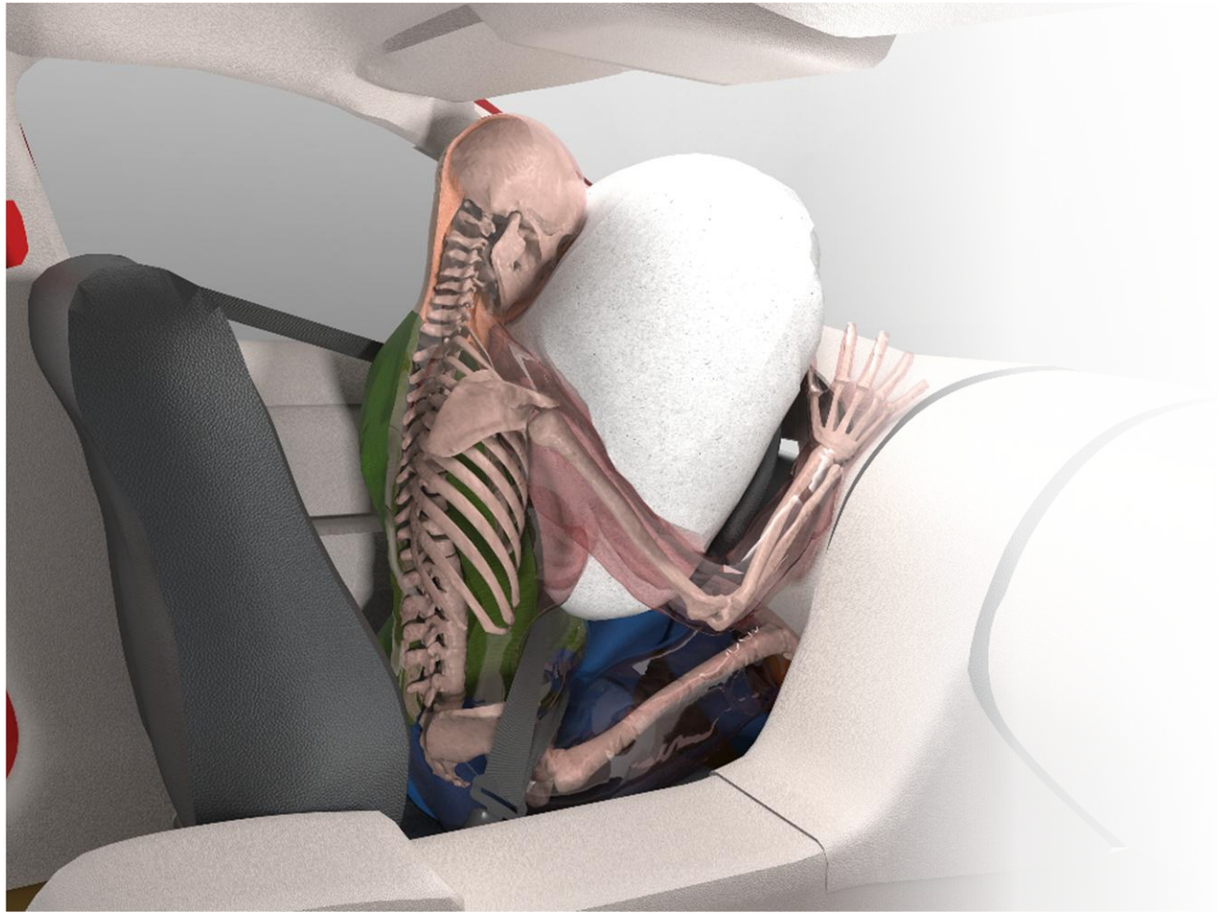


S T E P 7

Run simulation and check results

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

- *Depth*: default: 25



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