

HBM4VT – WG 2

Impactor simulation setup

Compigne et al. 2004

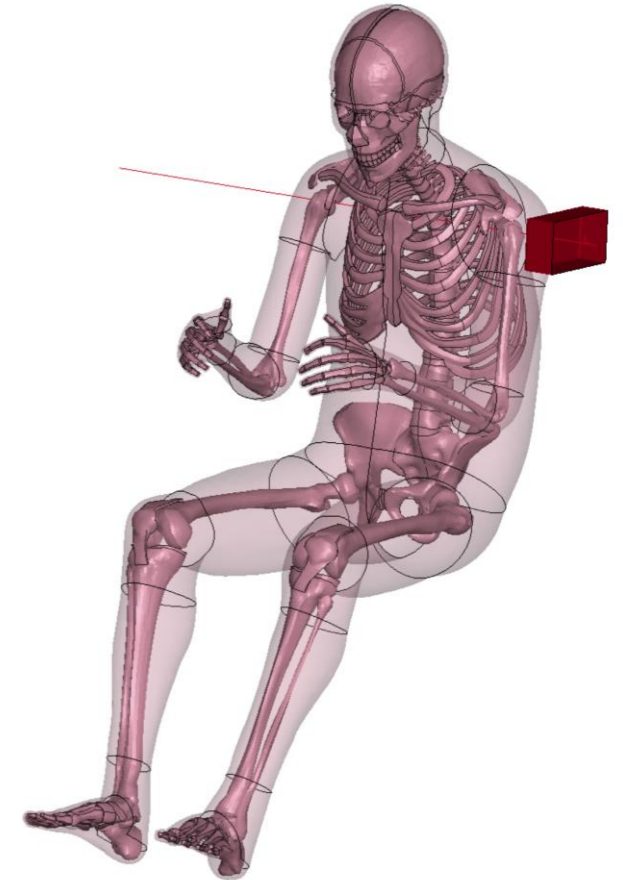
General Overview

Model Setup

Impactor tests by Compigne et al. 2004

Key factors to replicate from PMHS tests:

- HBM in sitting posture
 - Simulation to be performed with occupant model → model rotated to an upright position
- Positioning of extremities
 - No positioning of the lower extremities → hub is only in contact with thorax
 - Repositioning of upper arm w.r.t the lateral axis based on the experimental landmarks



Development notes

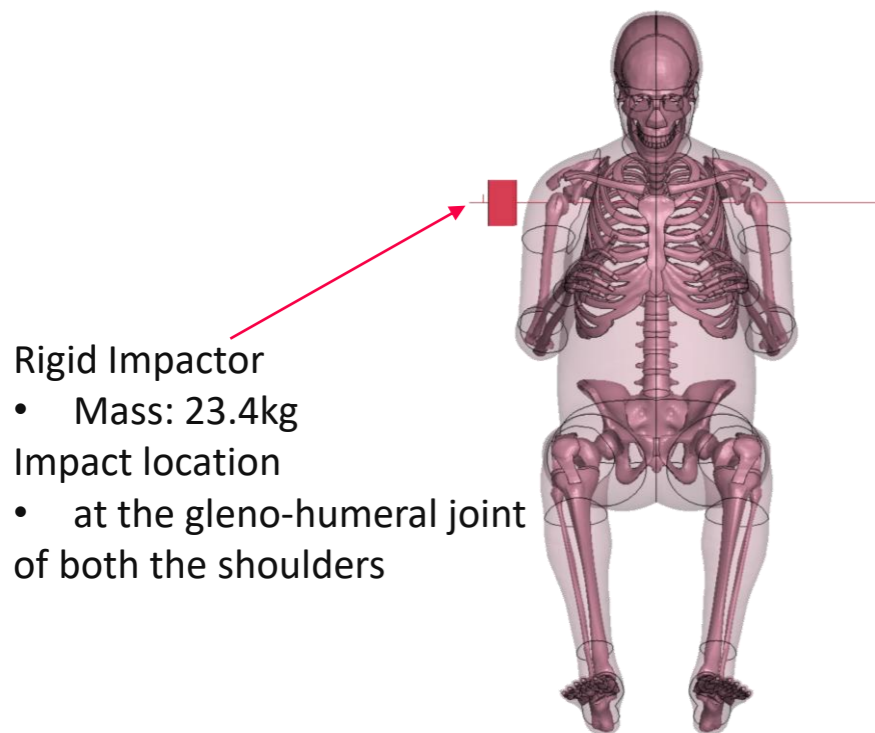
LS-Dyna version used for development:

- 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+ v1.1.0b 50th percentile female
- GHBMC_M50-O_v6-2 50th percentile male

Simulation setup



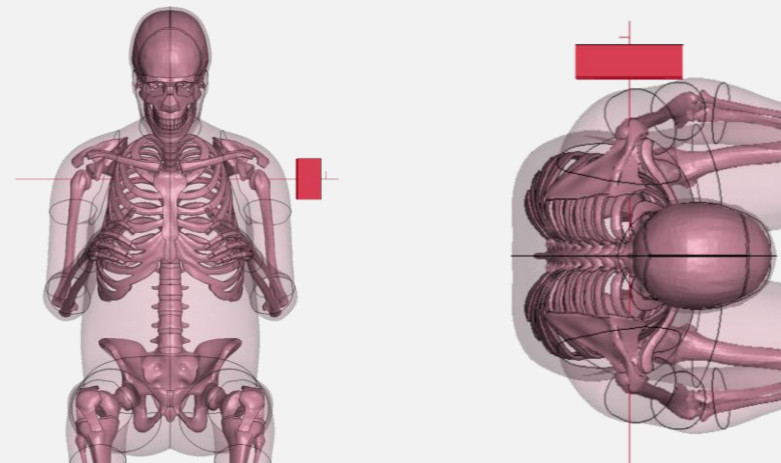
Rigid Impactor

- Mass: 23.4kg

Impact location

- at the gleno-humeral joint of both the shoulders

Left shoulder impact



0 deg

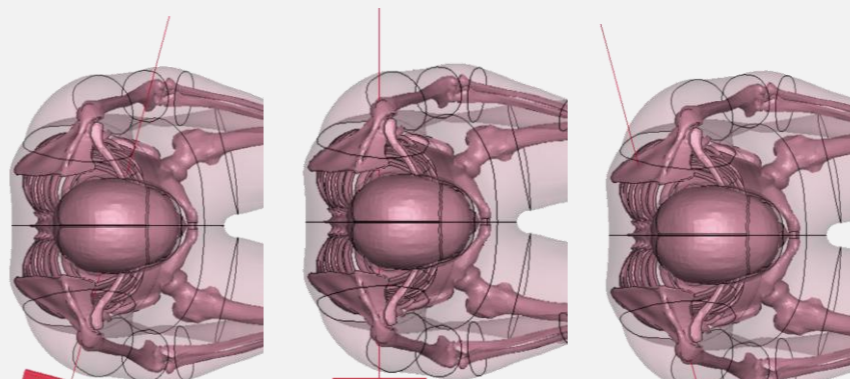
Impact Speed

Velocity [m/s]

HS1	3
HS2	4
HS3	6

@ 0 deg

Right shoulder impact



+ 15 deg

0 deg

- 15 deg

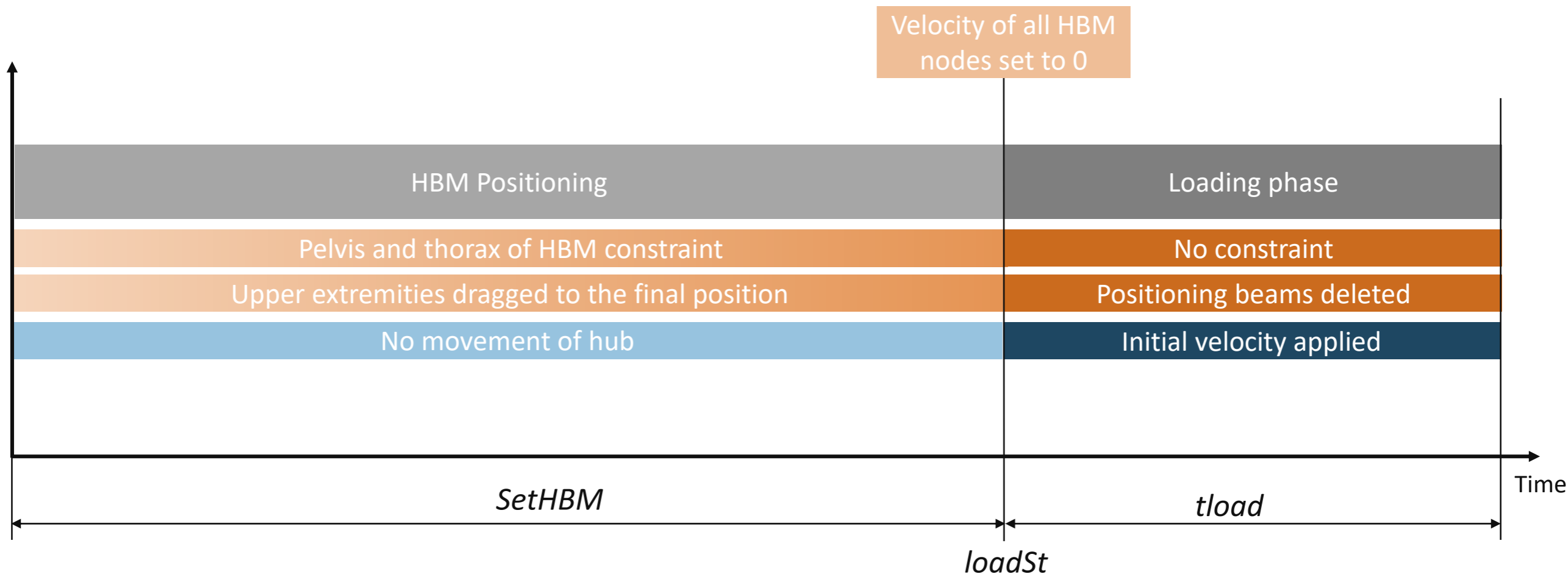
Impact Angle

Angle [deg]

N15	-15
Z	0
P15	+15

@ 1.5 m/s

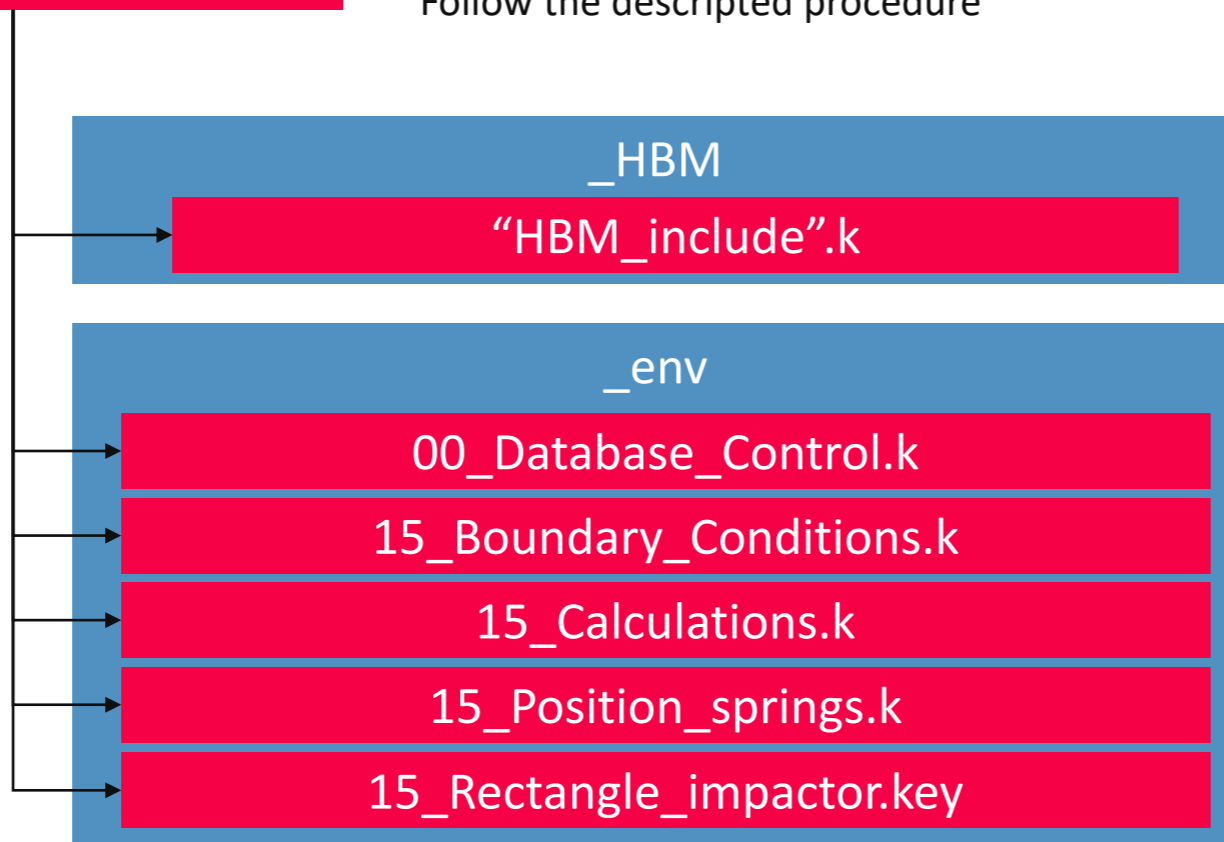
Simulation phases



Overview – hub load case

00_Master_Hub.k

→ Single file to be changed
Follow the described 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_Hub.k in a text editor
- 4) Define the main HBM file in the I N C L U D E S section
- 5) Follow the instructions from STEP 1 to STEP 8 (following slides)

Instrumentation requirements

- 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
- 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 ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub
- 7) Define attachment nodes for positioning beams
- 8) Run simulation and check results

Overview on stepwise simulation setup (see following slides)

1) Definition of the load case

Goal:

- Define the impact direction
- Define the impact velocity
- Define the impact angle

Overview on stepwise simulation setup (see following slides)

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

Goal:

- 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 ID offset if necessary

Goal:

- Define sensible HBM contact set

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 ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation**

Goal:

- Define the position and orientation of the HBM
- Define the lateral distance between AC and the most outer point of upper arm

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 ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of landmark and location where hub contacts HBM**

Goal:

- Localise points where hub should impact HBM in default HBM position
- Define the landmark for arm positioning

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 HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub**
 - Define nodes for evaluation
 - Offset hub if there is intersection

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 ID offset if necessary
- 4) Definition of the HBM landmarks & rotations in order to reach target orientation
- 5) Definition of the location where hub contacts HBM
- 6) Define Nodouts and check for intersections of the HBM to the hub
- 7) Define attachment nodes for positioning beams**
 - Define how extremities are moved during positioning

Overview on stepwise simulation setup (see following slides)

- 1) Definition of the load case
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- 3) Define ID for contact sets and ID offset if necessary
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- 7) Define attachment nodes for positioning beams
- 8) Run simulation and check results

STEP 1

Definition of the load case

Define impact direction

- Imp_L: set to 1 for left side impact (set other parameter to 0)
- Imp_R: set to 1 for right side (set other parameter to 0)

Define impact velocity

- LS: 1.5 m/s low speed impact (only set to 1 if Imp_R is 1, else 0)
- HS1: 3 m/s high speed impact
- HS2: 4 m/s high speed impact
- HS3: 6 m/s high speed impact

Define impact angle

- Im_0: direct lateral impact (should always be 1 if Imp_L = 1)
- Im_P15: +15 deg lateral impact
- Im_N15: -15 deg lateral impact

(Set the load case parameters based on this table)

Impact direction	Impact velocity	Impact angle
Left shoulder (Imp_L)	HS1	Im_0
	HS2	
	HS3	
Right shoulder (Imp_R)	LS	Im_N15
		Im_0
		Im_P15

STEP 2

Definition of global HBM parameter

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

- U_Scal: 0.001 for unit system t-mm-s
 - U_Scal: 1 for unit system kg-mm-ms
- The testbed environment will be scaled by *UScal* 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

STEP 3

Define ID for contact sets and ID offset if necessary

Define the part set of the HBM

- P_hbm : ID of the set including all HBM parts

→ This part set will be damped

Define the part set of all skin parts of the HBM

- P_hski : ID of the set including all skin parts

→ This part set will be in contact to the impactor

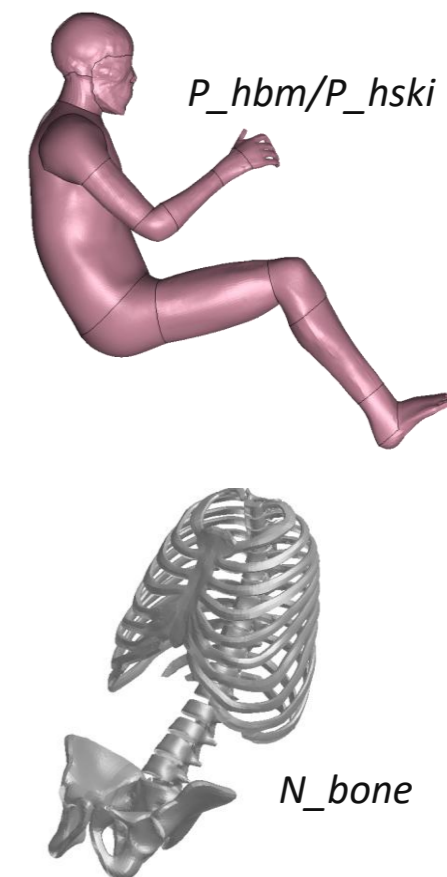
Define the node set including several nodes on the bones of the pelvis and the thorax (e.g. choose three nodes per bone, not all nodes of a bone are required to be constrained)

- N_bone : ID of the set including nodes on bones of pelvis, spine and ribs

→ This node set will be constrained in the settling phase (do not choose nodes belonging to rigid materials or rigid bodies)

If the test setup shares node IDs with HBM, define an ID offset for the HBM

- $IDoff$: default: 0.



STEP 4

Definition of the HBM landmarks & rotations to reach target orientation

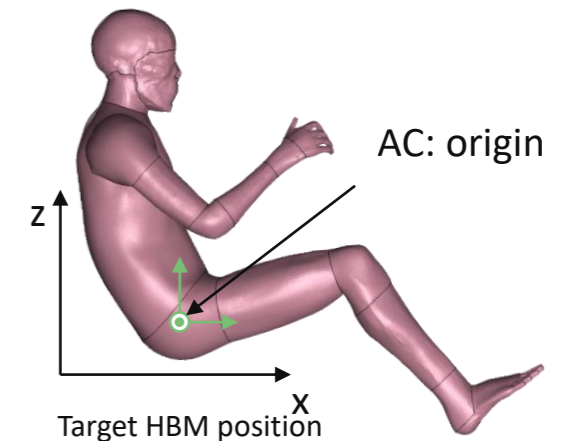
Define the coordinates of the location of the acetabulum centre point (AC) between the left and right acetabulum (in midsagittal plane):

- 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

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 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
- HBM will be rotated to reach target orientation



STEP 4

Definition of the HBM landmarks & rotations to reach target orientation

Measure the angle between the acetabulum centre (AC) and centre point on the greater tubercle region of the proximal humerus (GH) relative to frontal plane

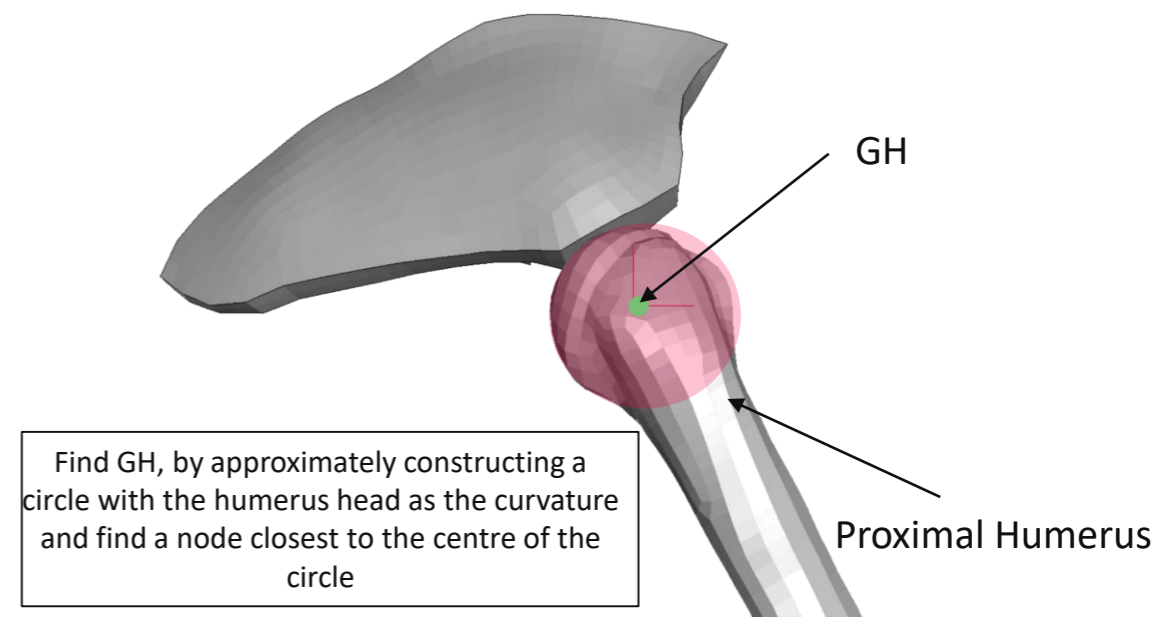
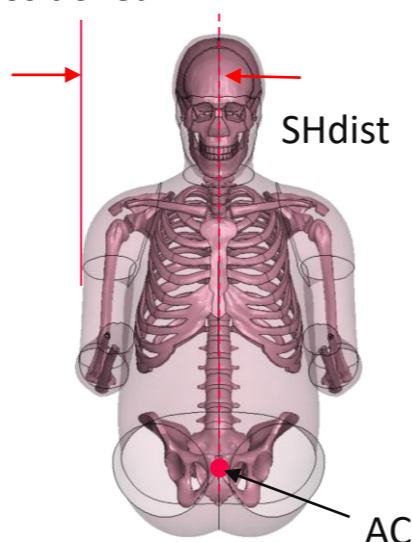
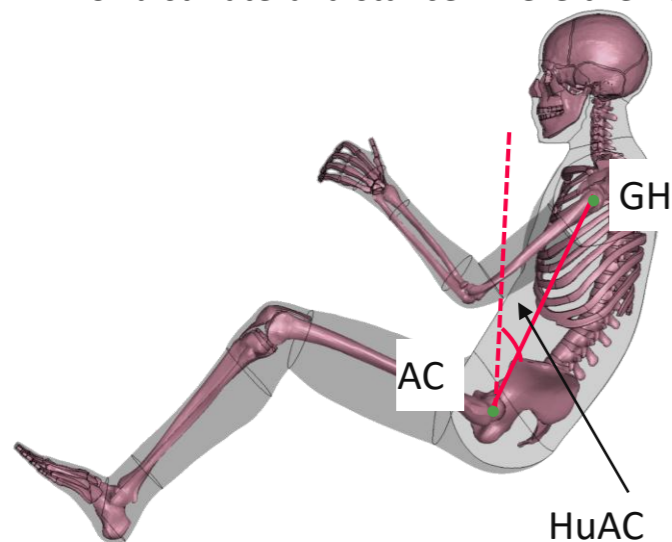
- *HuAC*: angle between AC and GH in default posture of the HBM used here

→ HBM will be rotated to reach the upright position

NOTE!! Always enter a positive value for the angle

Define the lateral distance between AC and the most outer point of upper arm

- *SHdist*: lateral distance where the hub will be positioned



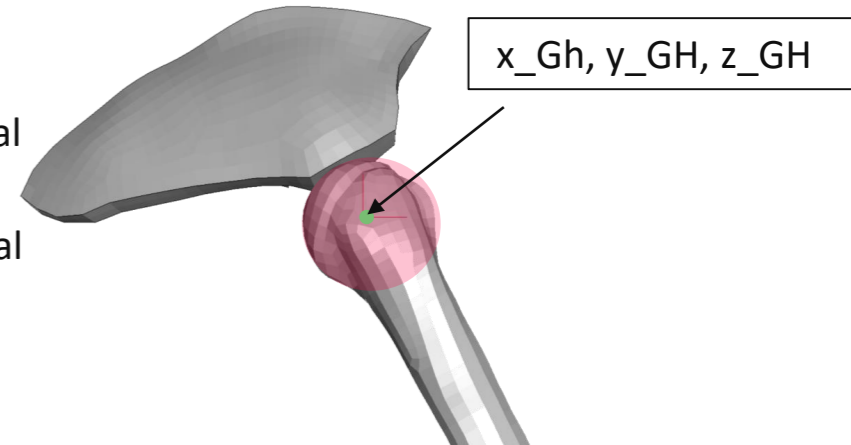
STEP 5

Definition of landmark and location where hub contacts HBM

Save this file "00_Master_Hub_.k" and open it in a pre-processor

Then, define the coordinates of the centre point on the greater tubercle region of the proximal humerus (GH) :

- x_{Gh} : x-coordinate of the node on GH in the rotated HBM position with respect to the global coordinate system
 - y_{Gh} : y-coordinate of the node on GH in the rotated HBM position with respect to the global coordinate system
 - z_{Gh} : z-coordinate of the node on the mid glenoid fossa of scapula in the rotated HBM position with respect to the global coordinate system
- These co-ordinates are used as reference for arm positioning



Note: Use the right arm co-ordinates
x and y co-ordinates always negative

STEP 5

Definition of landmark and location where hub contacts HBM

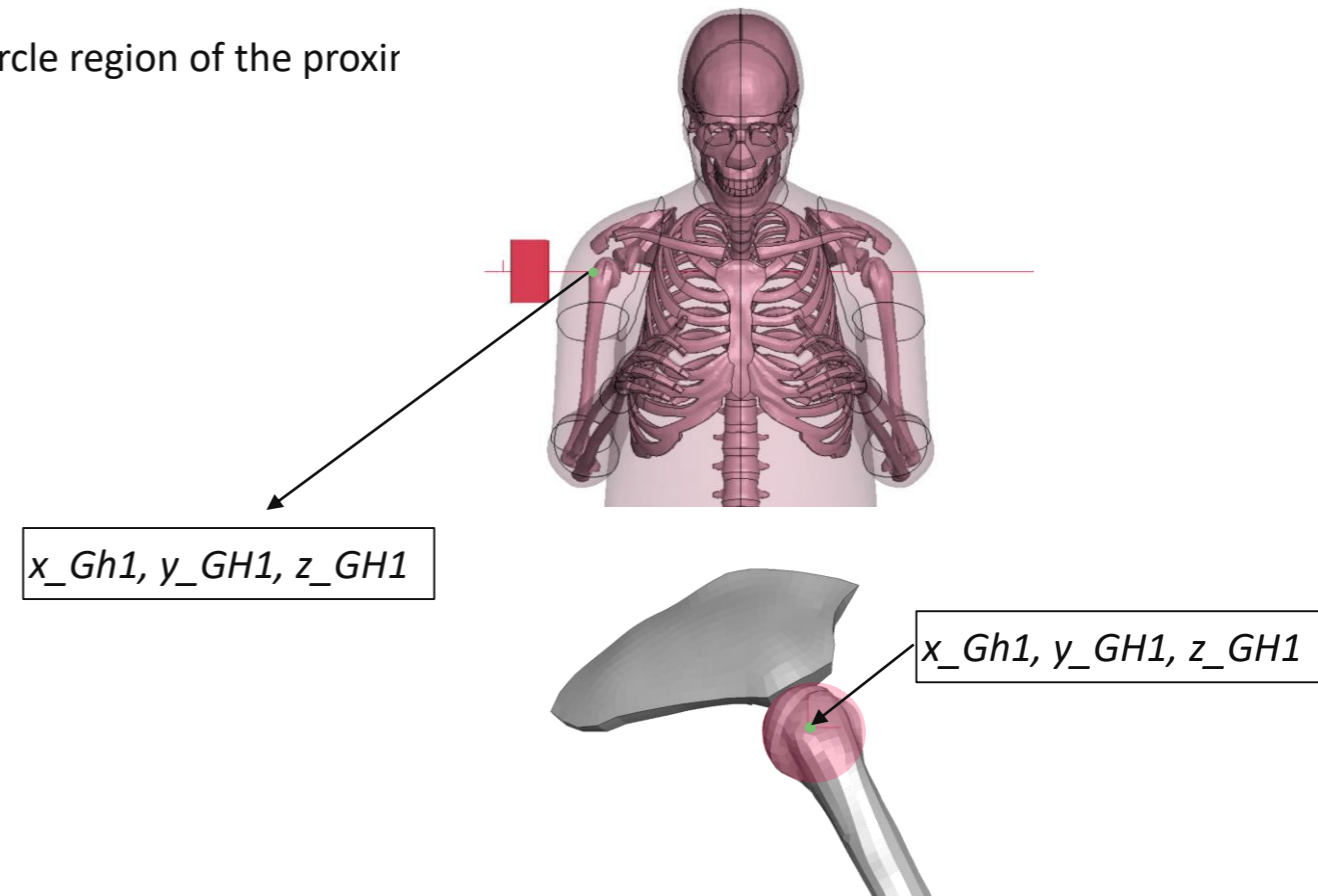
Then, define the coordinates of the centre point on the greater tubercle region of the proxir humerus (GH) where the impactor should strike:

- x_{Gh1} : same value as x_{Gh}
- y_{Gh1} : same value as y_{GH}
- z_{Gh1} : same value as z_{GH}

→ These co-ordinates are used to position the impactor

Note: Use the right arm co-ordinates
x and y co-ordinates always negative

(Update of x_{Gh1} , y_{Gh1} , z_{Gh1} might be required. Check STEP 8)



STEP 6

Define Nodouts and check for intersections of HBM to the hub

IF the hub has intersections to the HBM, adjust the hub offset

- H_{off} : distance in y (positive value: hub moves away from HBM)

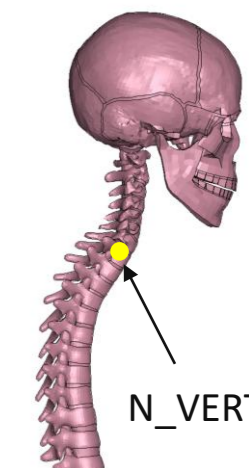
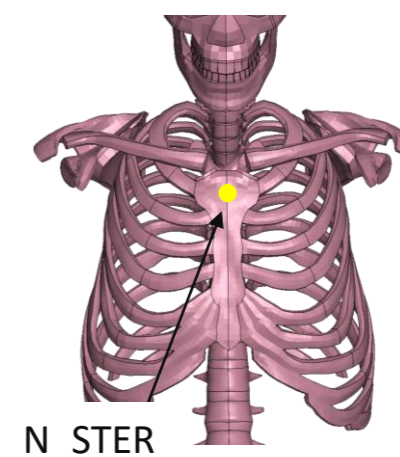
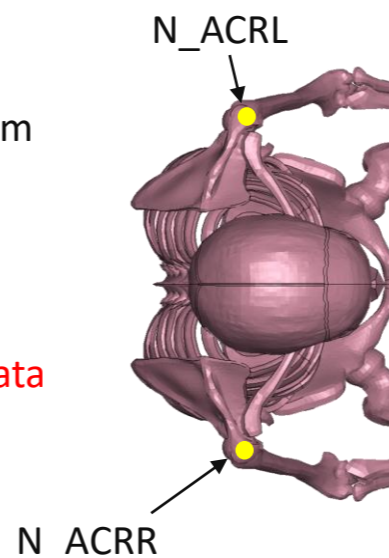
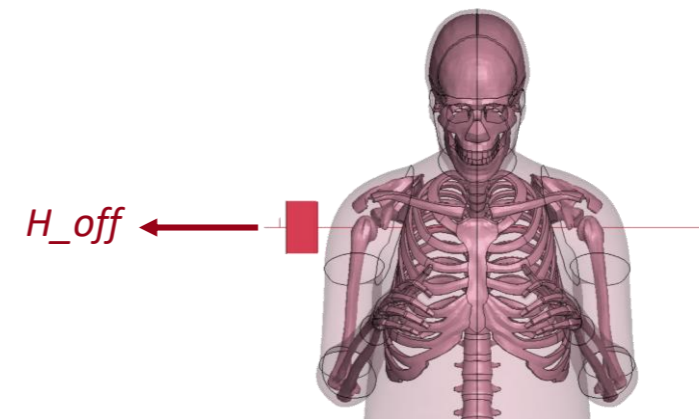
Note: Keep a clearance between hub and HBM of at least 30mm to facilitate filtering of the force signal in the assessment notebook

Define the node IDs on the bones which has to be tracked

- N_{ACRL} : Node ID on the midpoint of the left acromion
- N_{ACRR} : Node ID on the midpoint of the right acromion
- N_{STER} : Node ID on the midpoint of the manubrium part of the sternum
- N_{VERT} : Node ID of the dorsal T1 vertebrae

→ *DATABASE_HISTORY_NODE will be generated for these nodes

Important!! Update these NODE IDs in the HBM_ID.def file in data\metadata accordingly



STEP 7

Define attachment nodes for positioning beams

Define the node IDs for the landmarks to be positioned

R = right, L = left

- N_epiL/N_epiR : Node at mid of epicondyle

Define the coordinates of landmarks in updated "00_Master_Hub.k" file

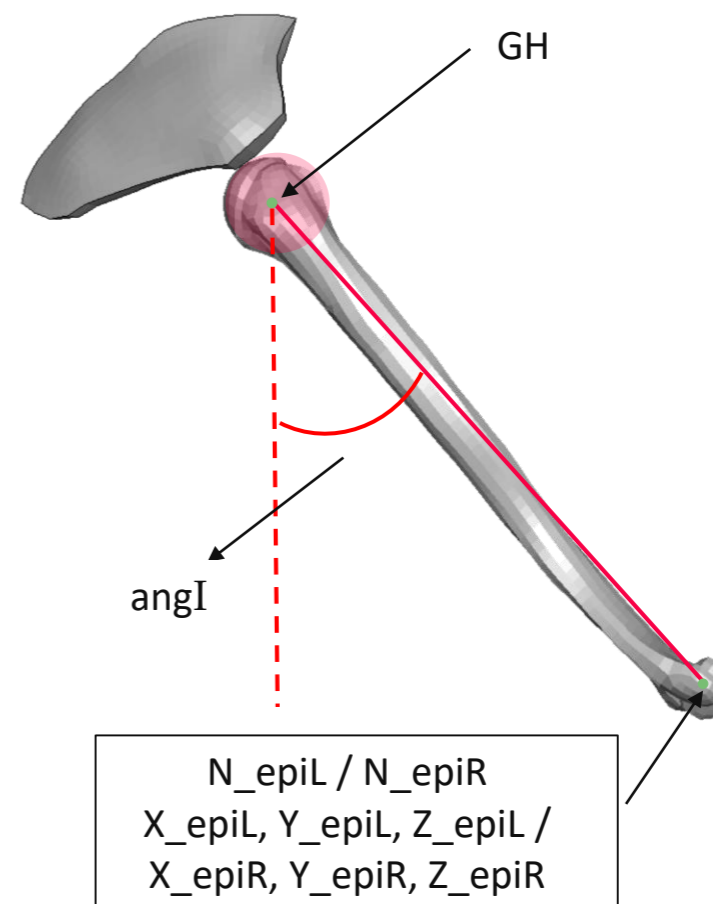
- X_epiL/X_epiR : x-coordinates of the mid epicondyle
- Y_epiL/Y_epiR : y-coordinates of the mid epicondyle
- Z_epiL/Z_epiR : z-coordinates of the mid epicondyle

Define the angle between GH & N_epiR

- $angI$: angle between GH and mid epicondyle with relative to the frontal plane

→ Based on these reference coordinates the upper arm gets positioned based on the experimental angle of approx. 19 deg

NOTE!! Always enter a positive value for the angle



STEP 8

Run simulation and check results

Check the d3plot and adapt the parameters if needed:

If the upper arm does not reach the target position, change duration

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

IF positioning beams do not fully compress, increase tension force (insert value in kN)

- *Fbeam*: default: 0.2 kN

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

- *Depth*: default: 5

Check the impacting location after positioning simulation

- If there is a considerable difference update the new impact location

Important!!

If the impactor is not on the desired location after positioning (refer the figure beside), go to STEP 5 update the new nodal co-ordinates of GH after positioning from the simulation and re-run the simulation. ONLY UPDATE x_{Gh1} , y_{Gh1} , z_{Gh1} , DO NOT CHANGE x_{Gh} , y_{Gh} , z_{Gh} .



x	-	Actual impact location
●	-	Tolerable impact location +/- 5mm from the actual impact location in the x, z-axis



Vehicle Safety Institute

Graz University of Technology

Inffeldgasse 13/6
8010 Graz Austria
www.vsi.tugraz.at

Desiree Kofler

desiree.kofler@tugraz.at

+43 316 873 30350

Felix Ressi

felix.ressi@tugraz.at

+43 316 873 30363

Corina Klug

corina.klug@tugraz.at

+43 316 873 30329