PHITEC INGEGNERIA *Versatile Minds*

Engineering services

Finite elements modeling, numerical simulations
Structural analysis, mechanical, thermal, fluid dynamics
Linear, non-linear analysis, dynamic, multi-body

8th Beta International Conference:

Cellbond-Phitec Finite Element Q Series Crash Test Dummy Seating Procedure, ANSA Perspective

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5. Positioning using ANSA direct morphing
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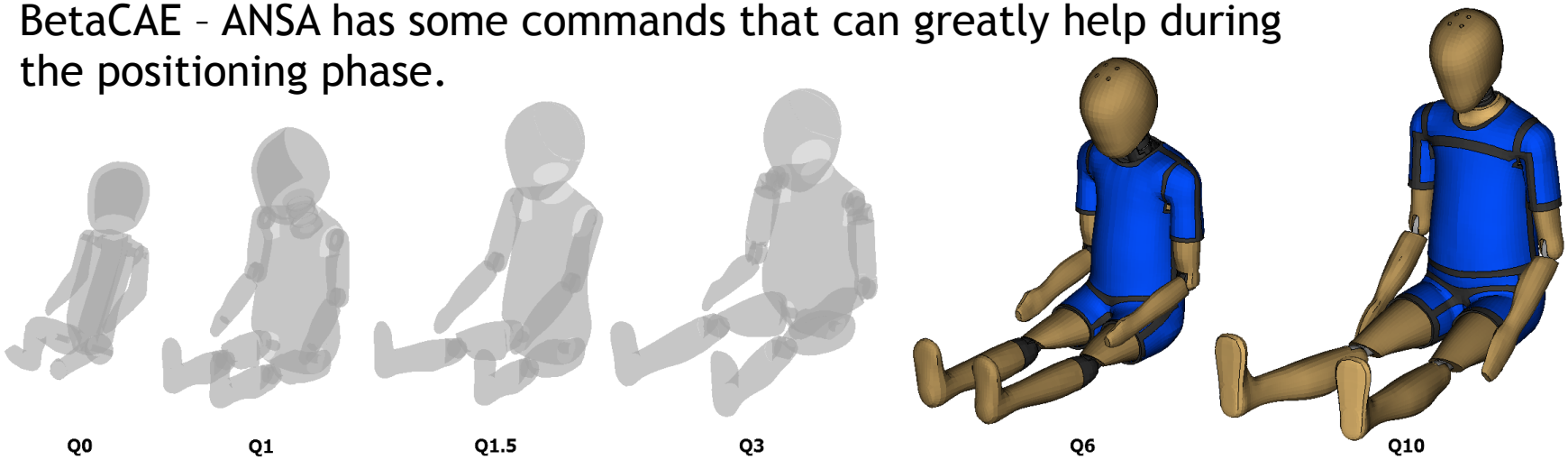
Introduction

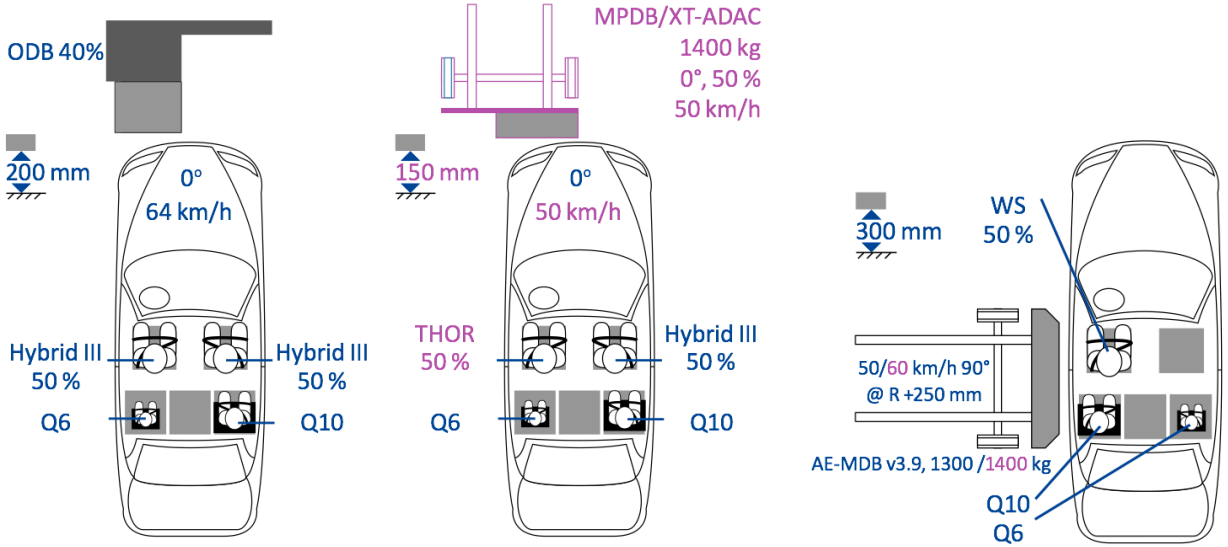
Since 1997 Euro NCAP used biomechanics of child ATDs (P1½ and P3) for the overall evaluation of car safety. This has pushed automotive OEMs to simulate child ATD into the car environment. Q dummies were introduced in 2013 (Q1.5 and Q3) and in 2016 (Q6 and Q10), these types of dummies are fitted with a suit that needs to be properly modified during the positioning and belting phase in order prevent badly shaped element or initial penetration.
The traditional method for the positioning of dummies is to run a dynamic simulation (with the addition of special elements) that will “place” the dummy and its suit into the final seated position.
This method, although highly automated, is time consuming.
BetaCAE – ANSA has some commands that can greatly help during the positioning phase.



Q-dummies usage in NCAP programs, overview

Q-dummies are not currently used in regulatory passive safety, only ECE-R129 requires the usage of Q-dummies.
NCAP programs show how, worldwide, Q-dummies are used:

region	type of test	Q1.5	Q3	Q6	Q10/Q10U
Euro NCAP	ODB (2018), AE-MDB (2018/2020), MPDB (2020)			x	x
C-NCAP	FWRB (2018)		x		
ANCAP	-- like Euro NCAP			x	x
KNCAP	ODB (2018), AE-MDB (2018)			x	x
Latin NCAP	ODB (2018), MDB (2018)	x	x		
ASEAN NCAP	ODB (2018), MDB (2018)	x	x		



Courtesy of:
SafetyWissen by carhs. Empowering Engineers

Q-dummies usage in Euro NCAP, overview

Child Occupant Protection			
	2019	2020 2021	2022 2023
	max. points		
Dyn. Tests Frontal	16	16	16
Dyn. Tests Side	8	8	8
CRS Installation	12	12	12
Vehicle based assessment	13	13	13

Euro NCAP rating is a weighted sum of four different scores:

- Adult Occupant Protection (40%)
- Child Occupant Protection (20%)
- Pedestrian Protection (20%)
- Safety Assist (20%)

The child occupant protection is in turn relevant for the car assessment, child biomechanics is measured (simulated) and points for frontal and lateral test are accumulated.

The installation of the dummy as well as its interaction with the Child Car Seat (CRS) is a crucial aspect to improve biomechanics.

Courtesy of:

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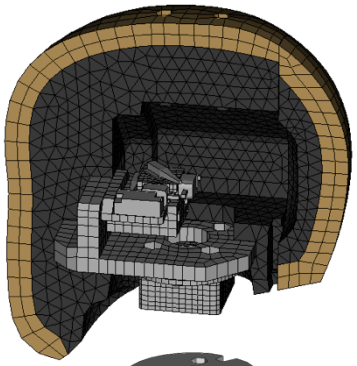
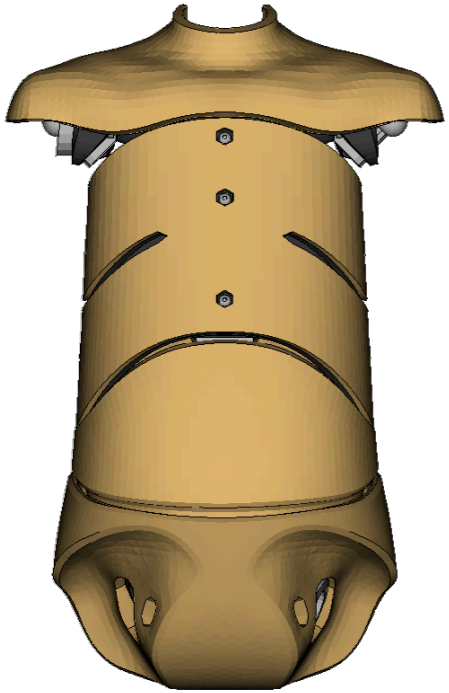
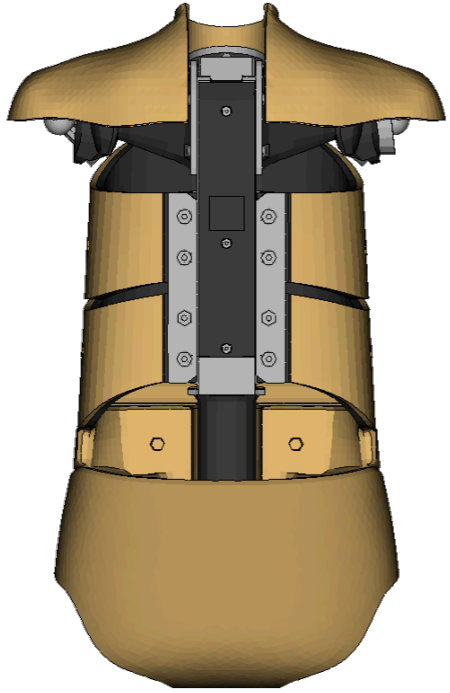
The Q dummy - model creation

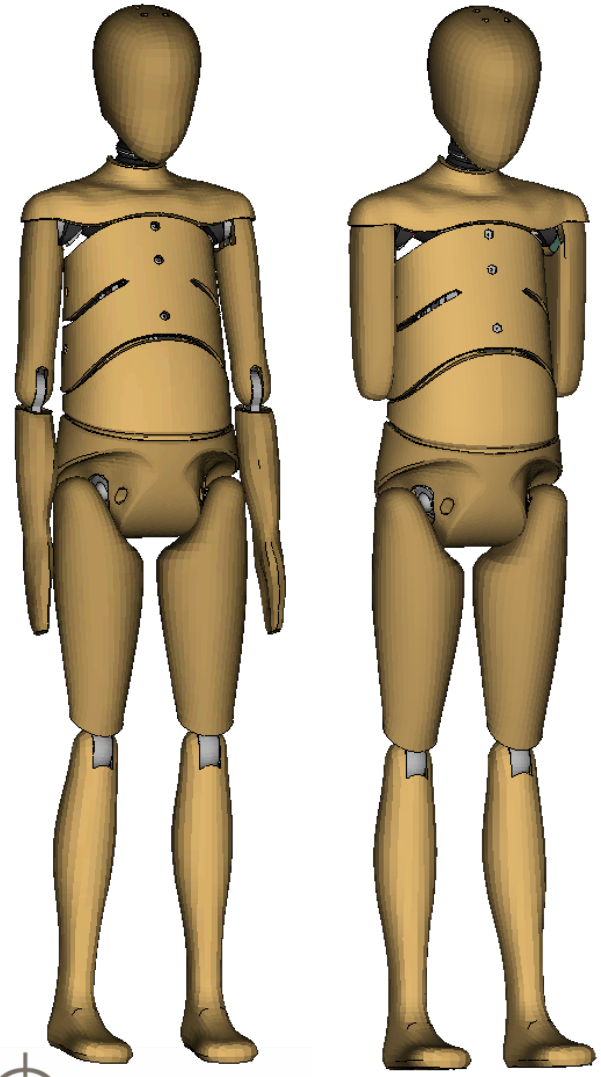
Cellbond-Phitec Q-dummies, Q6 and Q10, are currently under development and will be released by Q4 2019.
The modeling activity started from a complete CAD package, element length was defined for each component in order to have a time step of 1μs without added mass.
Total number of elements for Q10 Upgrade kit (Q10U) is around 300k.







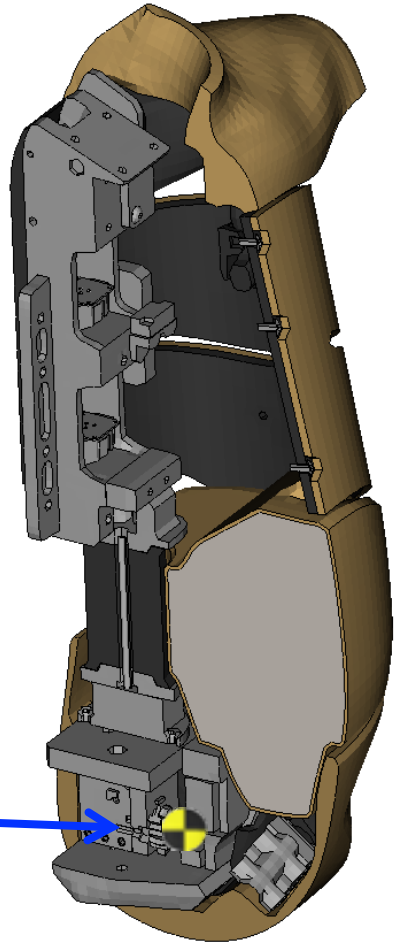
The Q dummy



Q10U are available in two versions:

- Front crash
- Side crash

H-point is defined in the pelvis region and is used for the very first positioning of the dummy inside the car



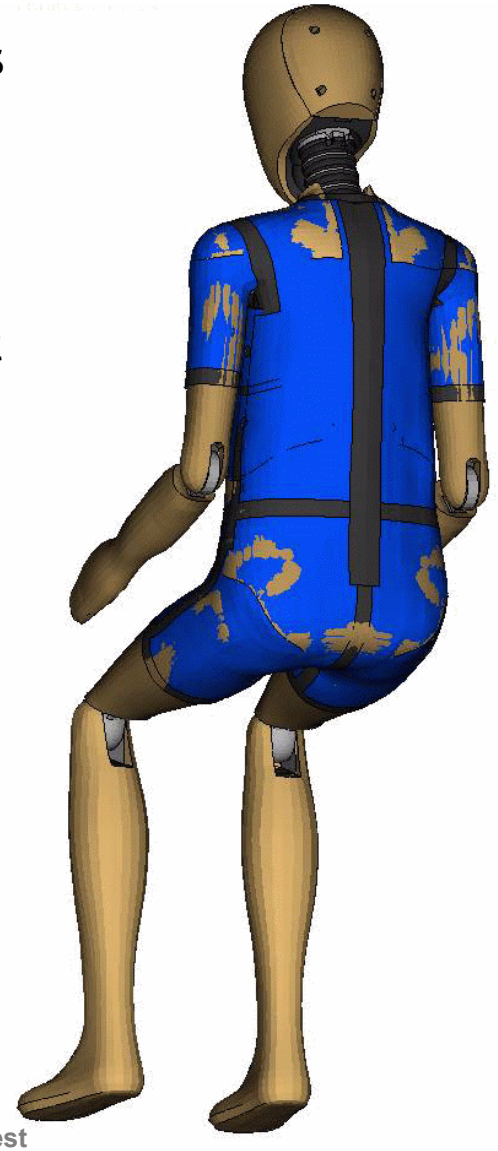
The Q dummy - suit fitting

When the complete dummy is assembled the suit has to be created and fitted on the dummy body.

Because of the lack of CAD data for the suit a simulation procedure has been used:

- reverse engineering from the physical component
- fitting on the dummy, some intersections may be present
- Inflating of the suit and, only when inflated, activation of the contact between dummy and suit
- Deflation of the suit that will now fit perfectly the dummy body

This procedure could be also used for accounting for initial pre-stresses on the suit material using the card: *INITIAL_FOAM_REFERENCE_GEOMETRY

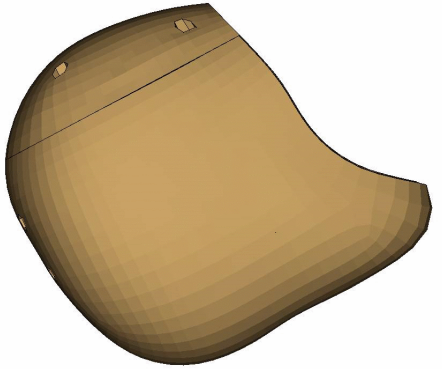


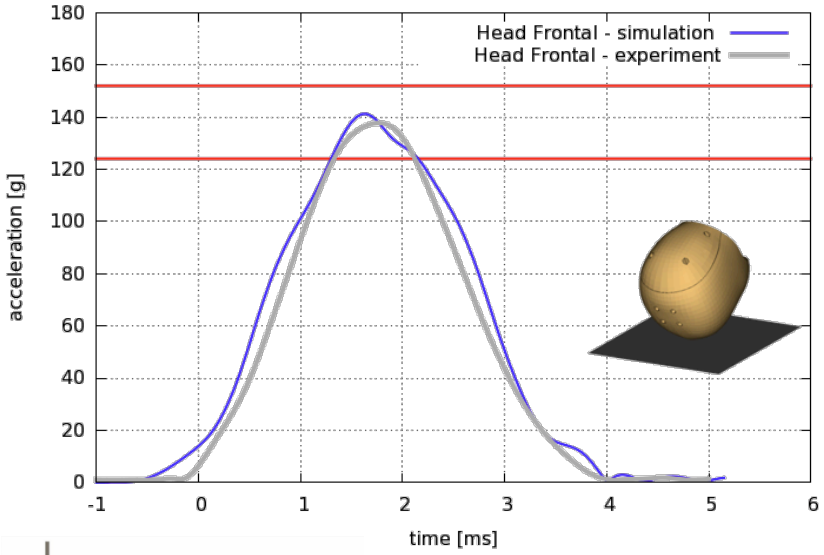
The Q dummy - certification

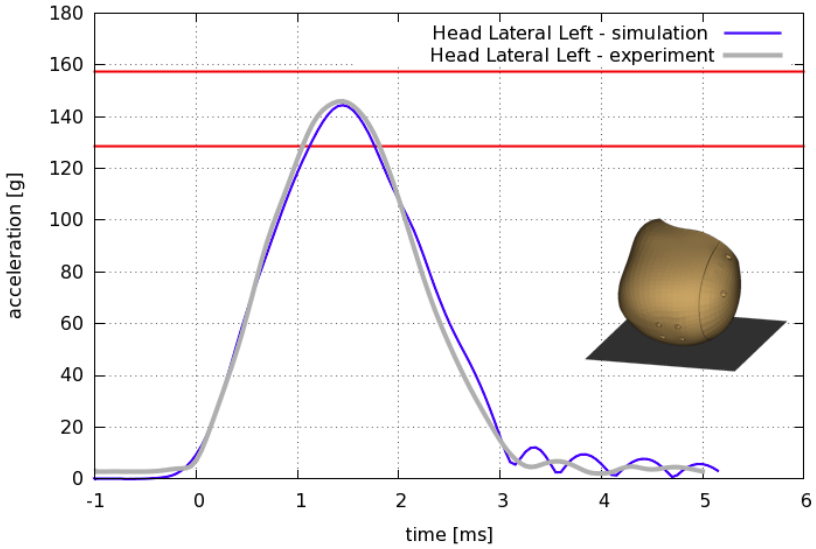
A number of different certification cases are required to check and evaluate dummy accuracy:

- Head drop on rigid surface
- Neck pendulum
- Lumbar spine pendulum
- Abdomen compression

These tests are performed at component level.



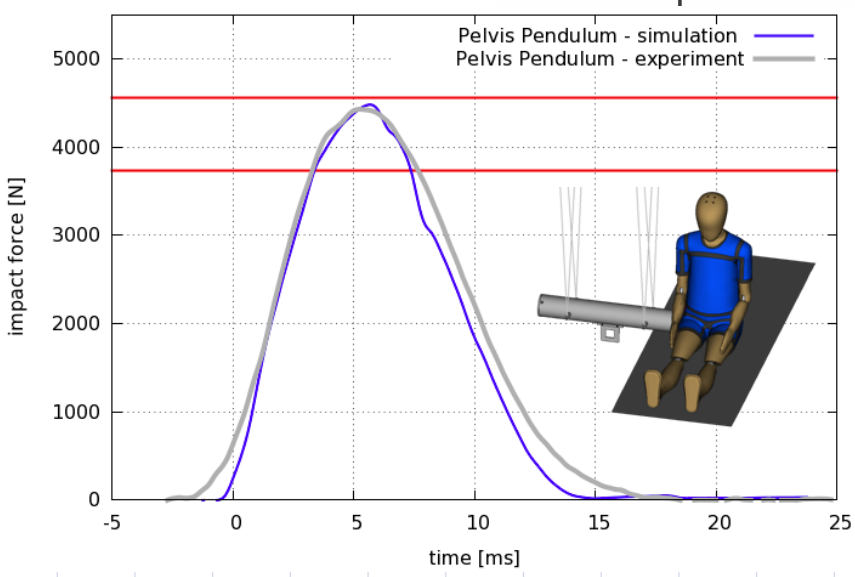


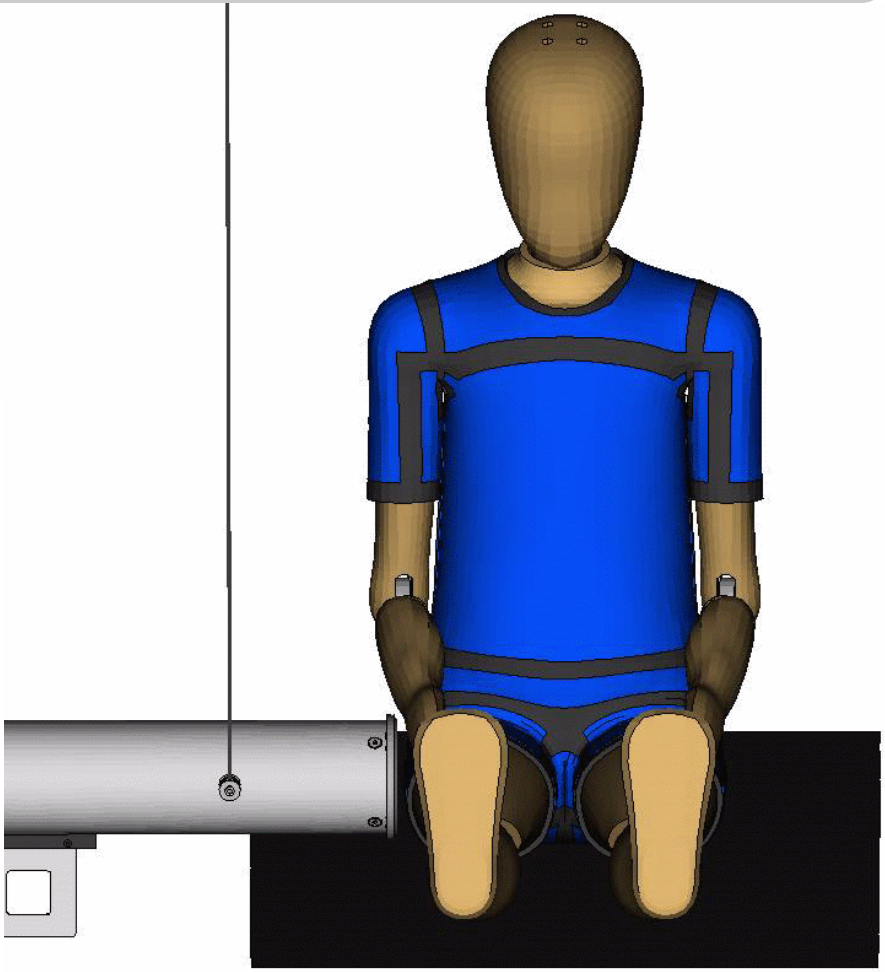


The Q dummy - certification

Other test are performed on the complete dummy:

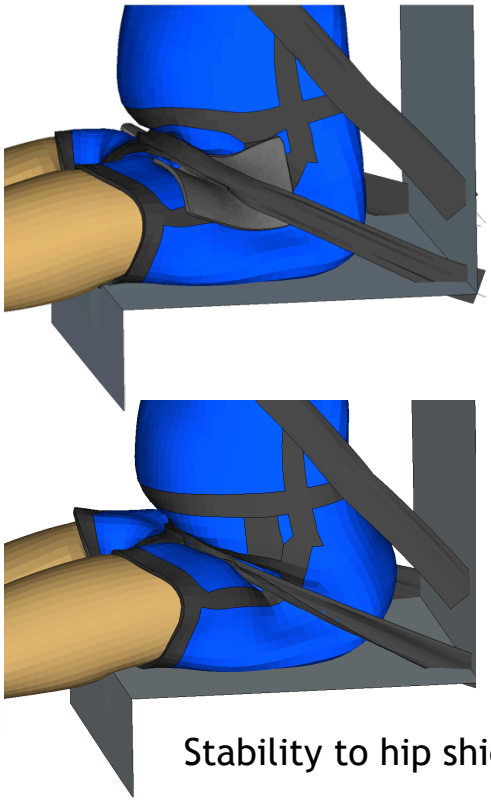
- Thorax pendulum
- Shoulder pendulum
- Pelvis pendulum



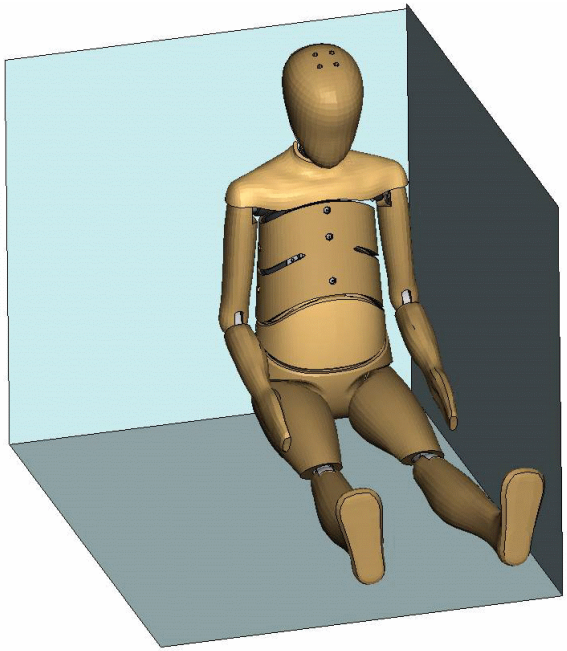


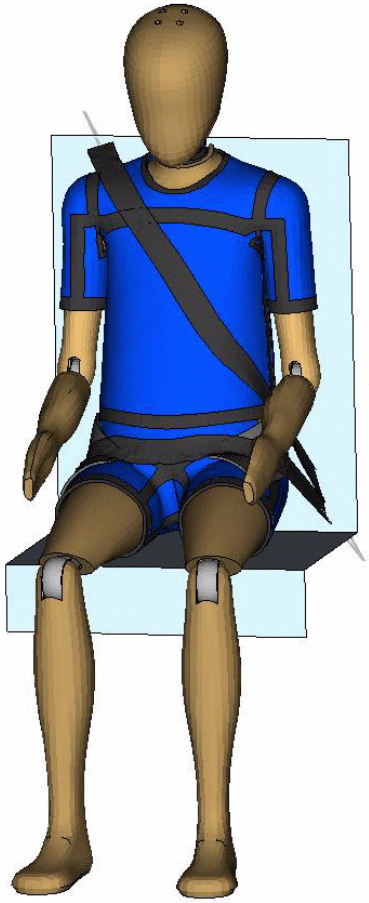
The Q dummy - robustness

Simulation dummies are exposed, during the car development, to high energy impacts. While physical dummies can fail without affecting the complete crash test result a numerical failure in a dummy can affect the simulation output resulting in a total loss of data.
For this reason a variety of robustness tests needs to be done:

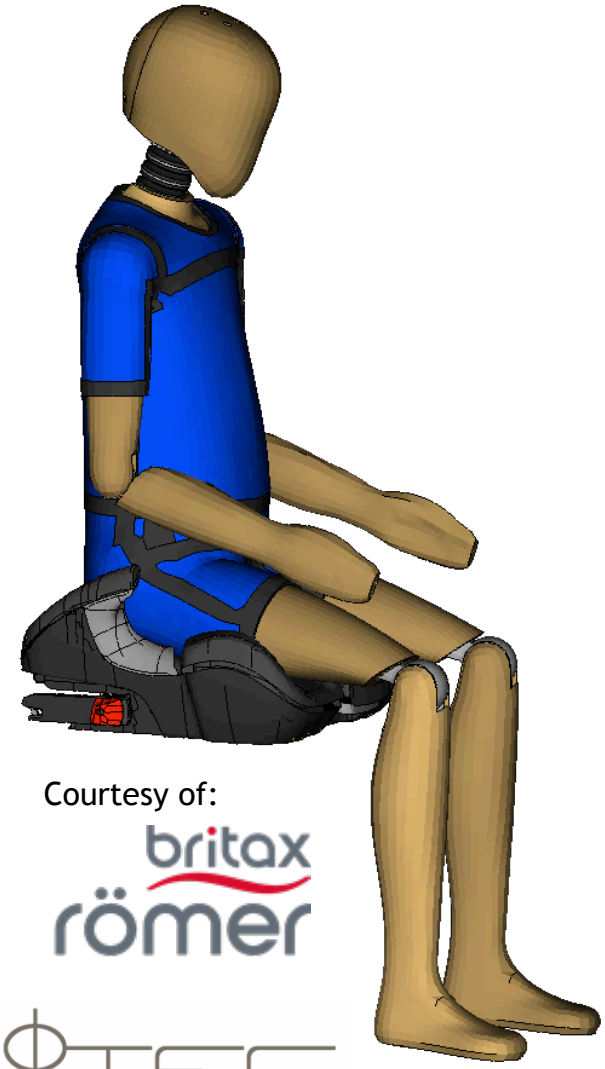


Stability to hip shield removal





Positioning the Q dummy



Courtesy of:

britax römer

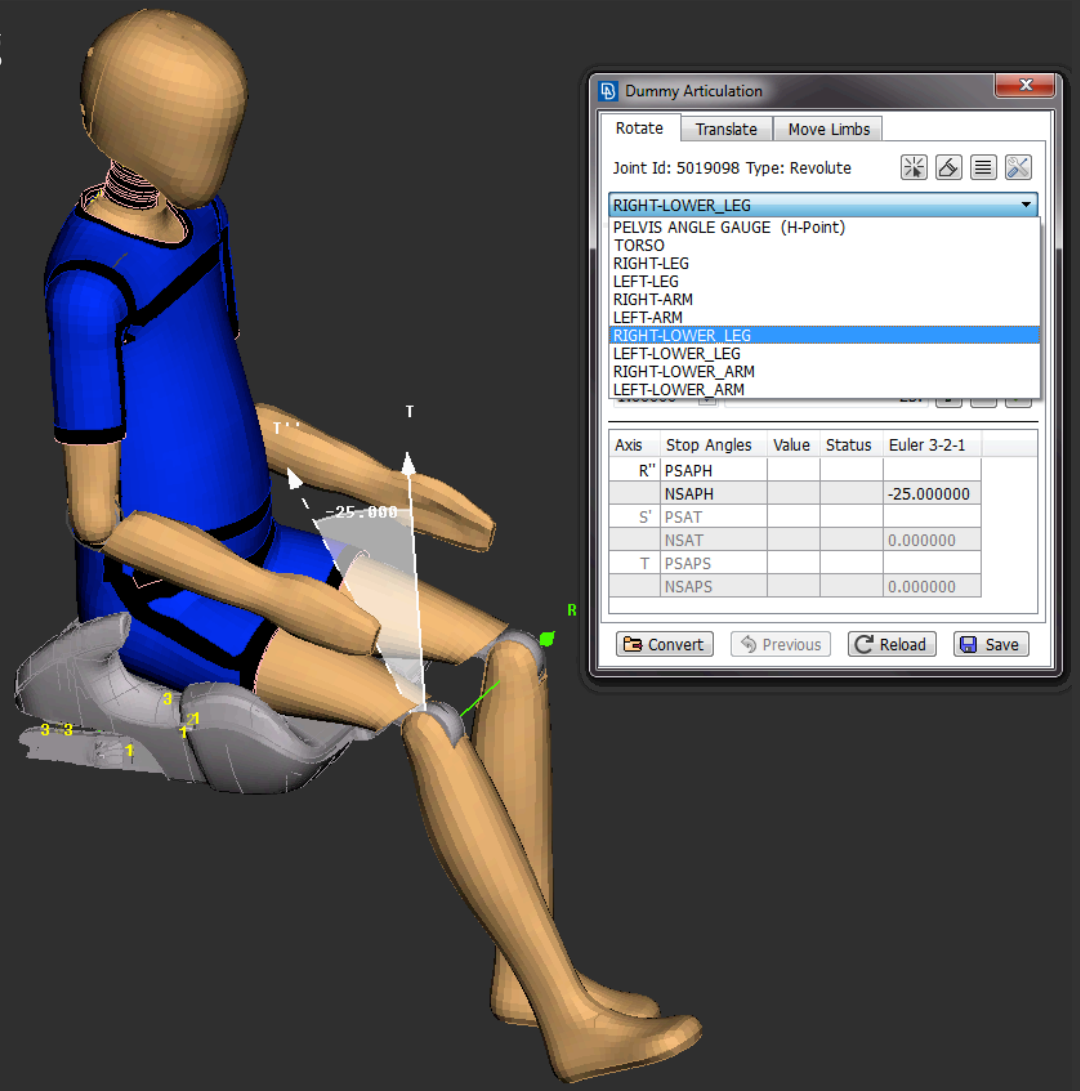
Once the dummy is ready for utilization the next step is to properly position and seat the dummy into the car environment.
Positioning is needed because, according to Euro NCAP, both dummies needs to be installed into the car with a booster seat (Q6) or booster cushion (Q10).
The dummy positioning on the booster-seat or booster-cushion requires finite rotation of dummy limbs and as a consequence there is the risk of creating initial penetrations.

In the present work the Child Car Seat (CRS) is a KidFix^2 R provided by Britax-Römer currently used in Euro NCAP dynamic tests.

Positioning using dummy tree

In order to ease the positioning process, a hierarchy tree is defined between the moveable parts of the dummy.

Dummy positioning uses rigid body motion and mechanism, all recent dummies available on the market have a tree structure that defines assemblies and connections between them, main formats: PRIMER and LS-PrePost



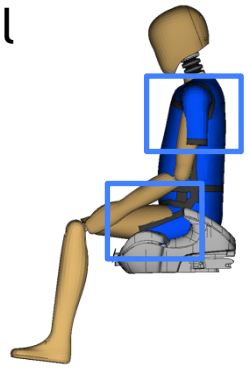
Positioning - potential issues

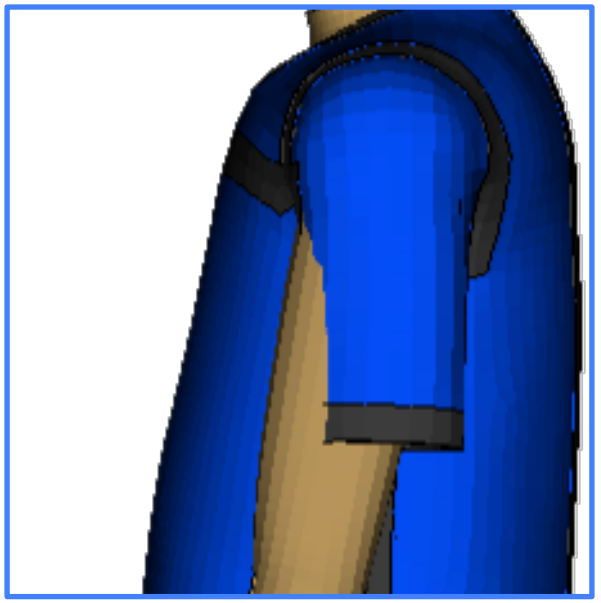
Dummy positioning may introduce initial penetration between the suit and the limbs that will affect results.
This issue can be overcame by using a pre-simulation procedure that moves the dummy limbs to prescribed positions.
The presence of contacts will adapt the suit accordingly.
The use of simulation has advantages:

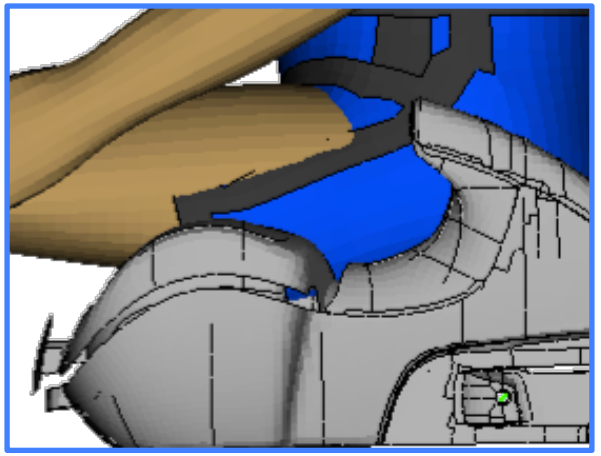
- Guarantee of no initial penetration
- Well known process

And disadvantages:

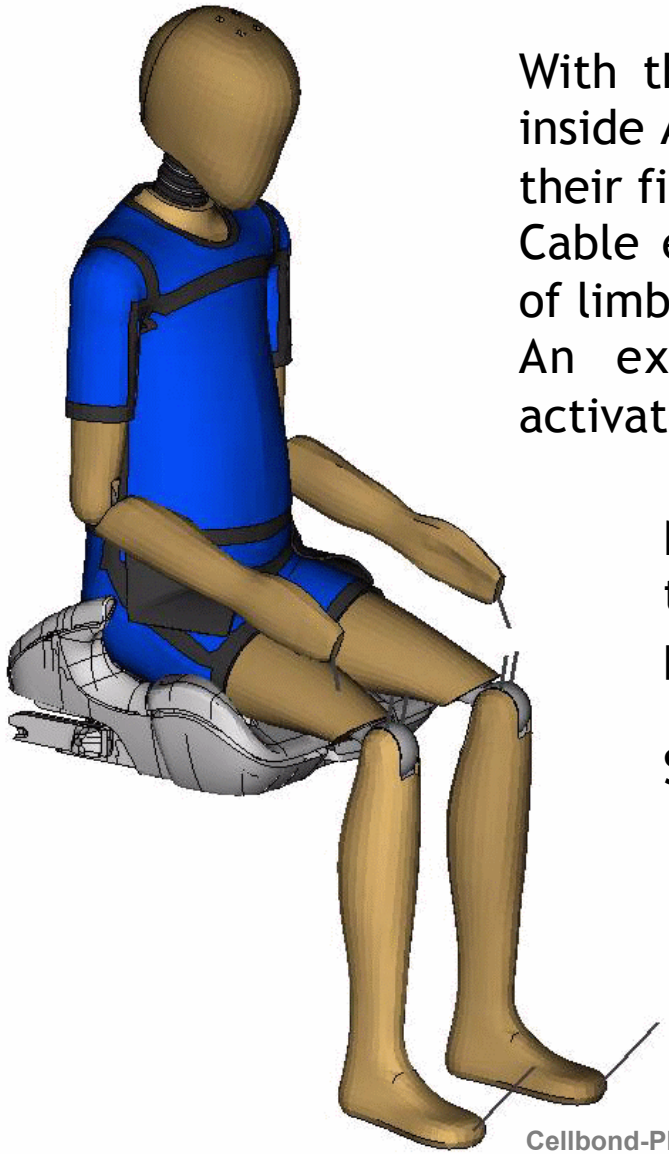
- Long (iterative) and error-prone process
- Belting has to be taken into account
- Final nodal positions will be in global reference frame







Positioning using dynamic (explicit - implicit) simulation



With the pre-simulation procedure, limbs are moved inside ANSA pre-processor (using the dummy tree) and their final position is recorded.
Cable elements are added to guide the displacement of limbs extremities.
An explicit dynamic simulation, with contacts activated and proper critical damping, is run.

Nodal coordinates of the dummy and suit are then substituted into input file allowing for a positioned initial setup of the dummy.

Simulation time 250ms, run time 1h @ 12 cores.

Positioning using ANSA direct morphing

ANSA pre-processor offer an interesting tool for the dummy positioning called “direct morphing”.

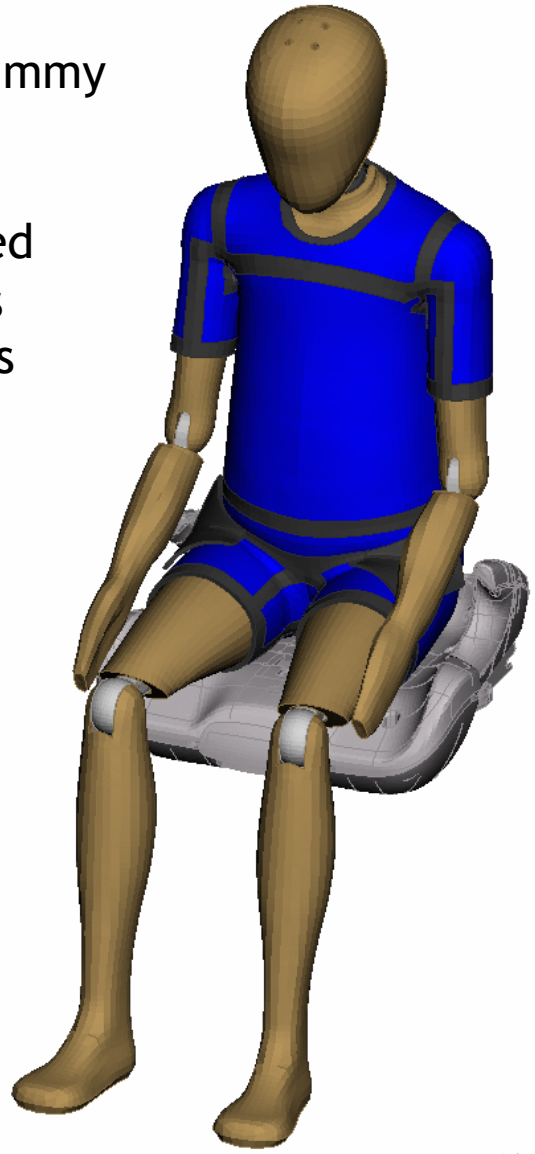
With this tool the limbs movement can be accomplished into the pre-processor environment. Some of the parts of the dummy tree can be defined as rigid while others are allowed to be morphed (deformable).

The use of direct morphing has advantages:

- Very fast and intuitive process
- No initial penetration for small rotations
- Can manage *INCLUDE_TRANSFORM card easily

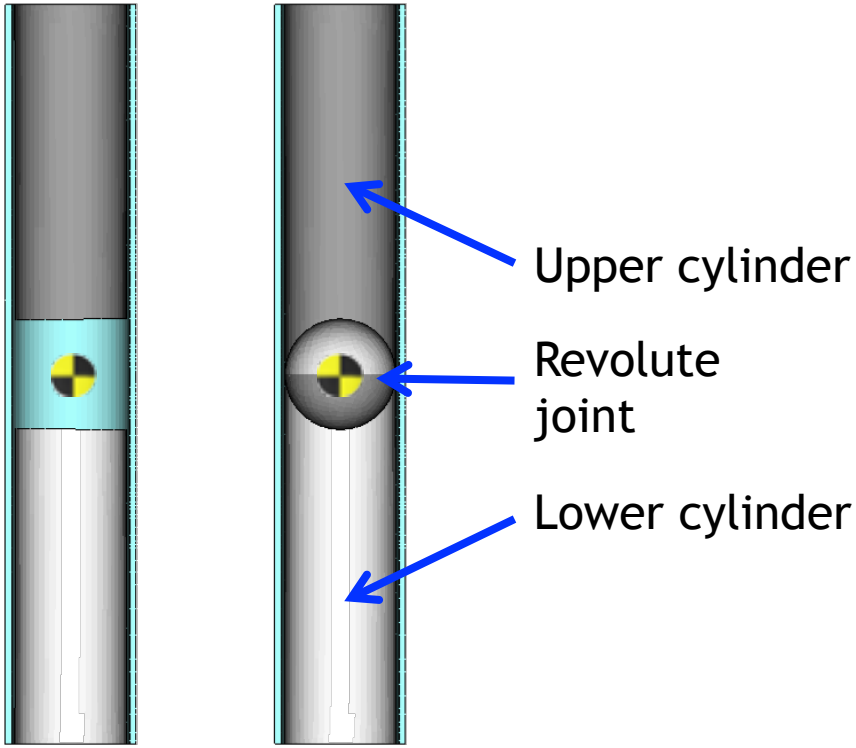
And disadvantages:

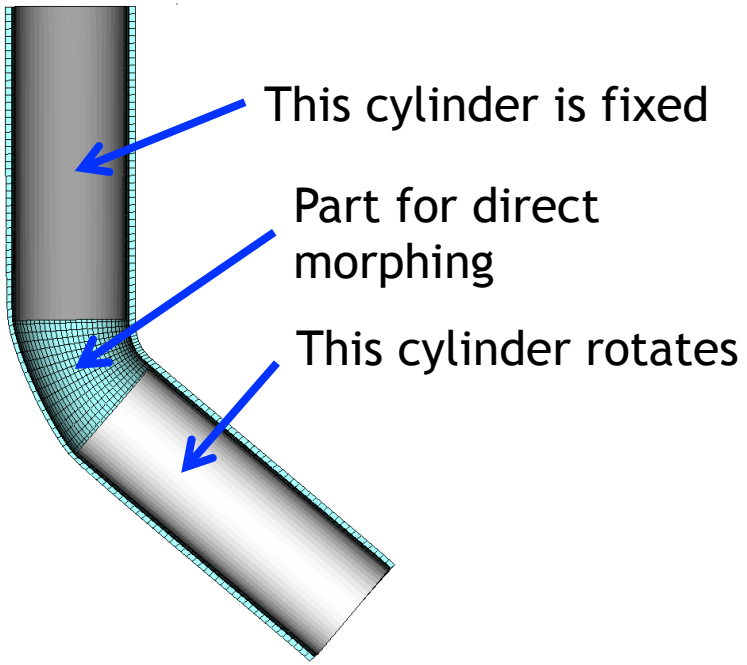
- Deformation may be unrealistic in some cases



Positioning using ANSA direct morphing

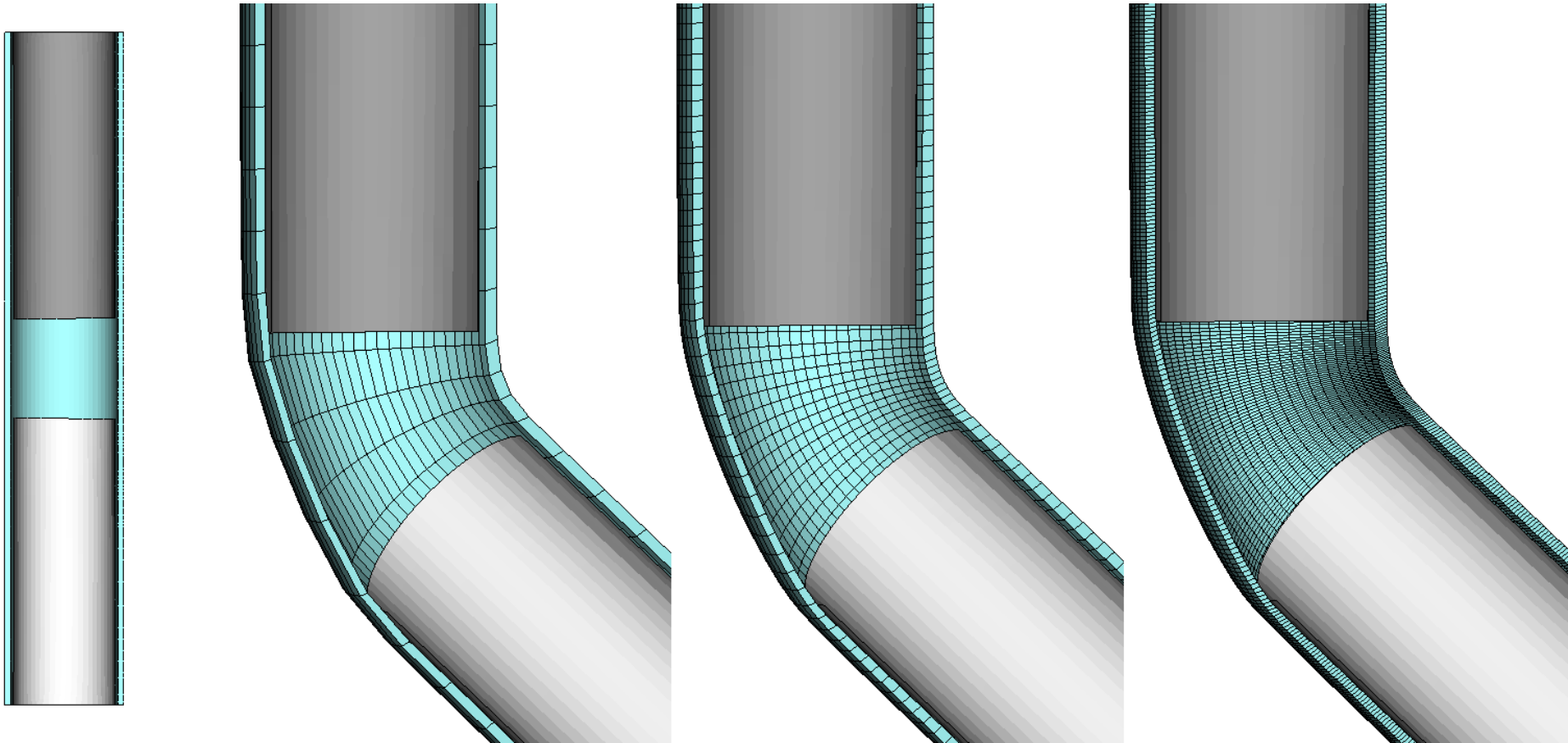
A simplified geometry has been used to test the capabilities of the direct morphing tool, the geometry is extremely simple in order to give an objective evaluation of the final deformation.





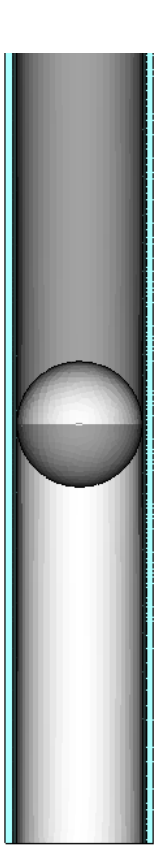
Positioning using ANSA direct morphing

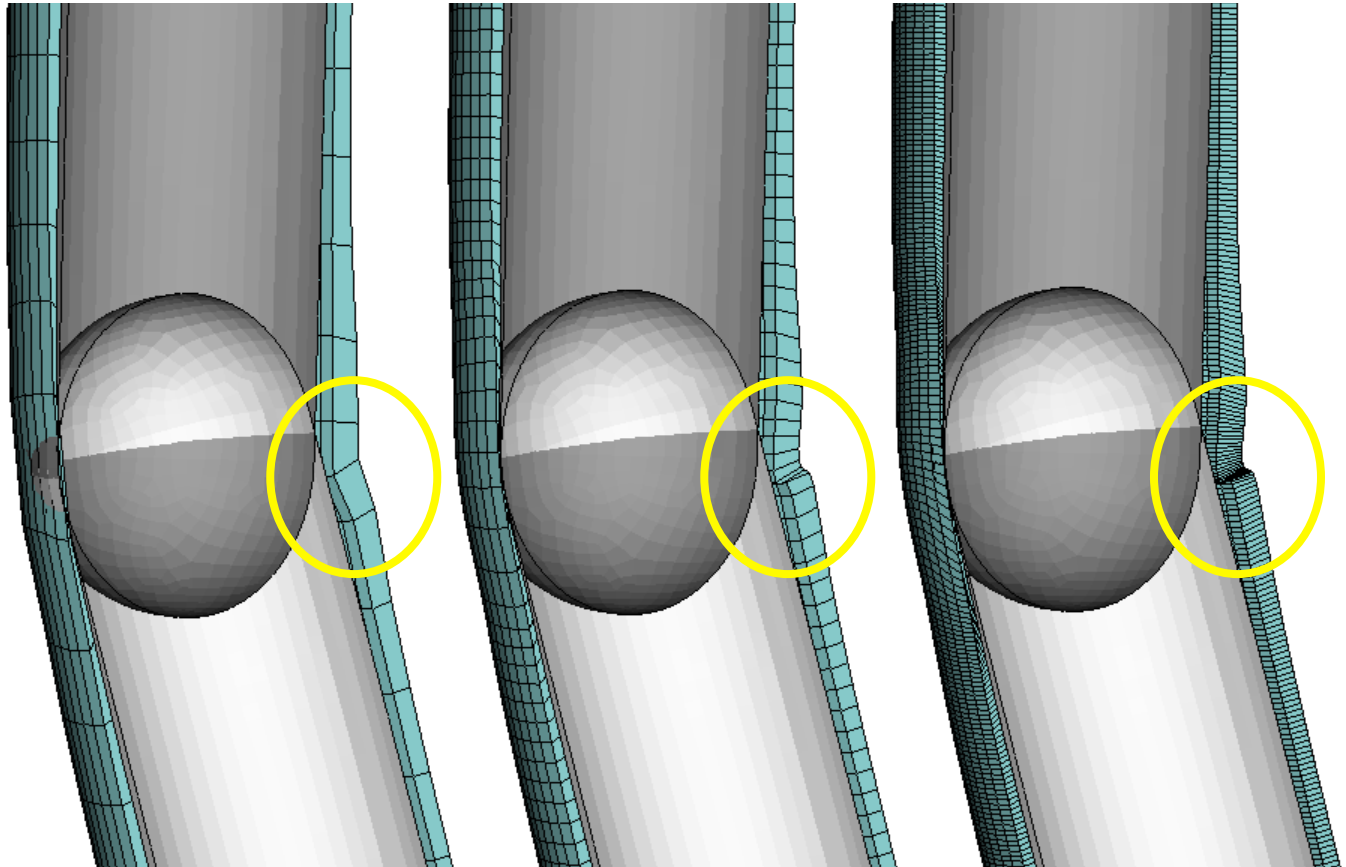
Surprisingly the direct morphing tool produces good results also when the deformable part is not guided.
Stretching of elements can be noticed on the tensioned side, compacting on the compressed side.



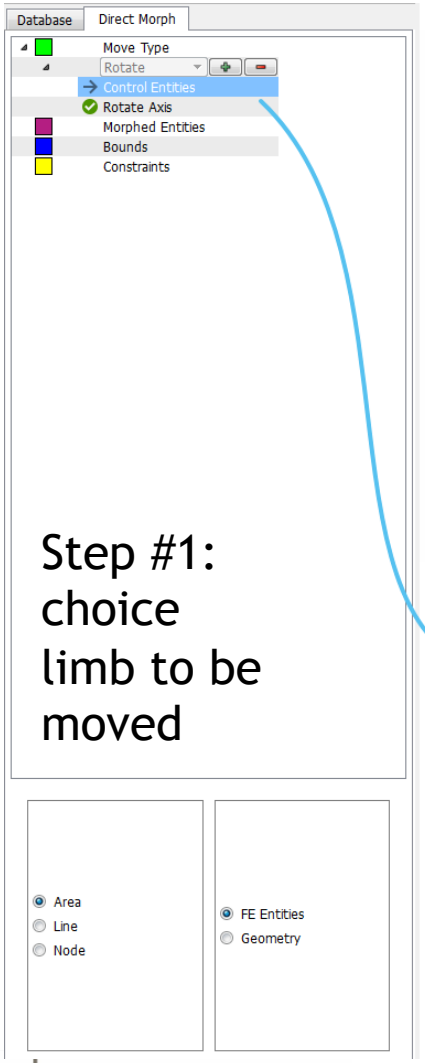
Positioning using ANSA direct morphing

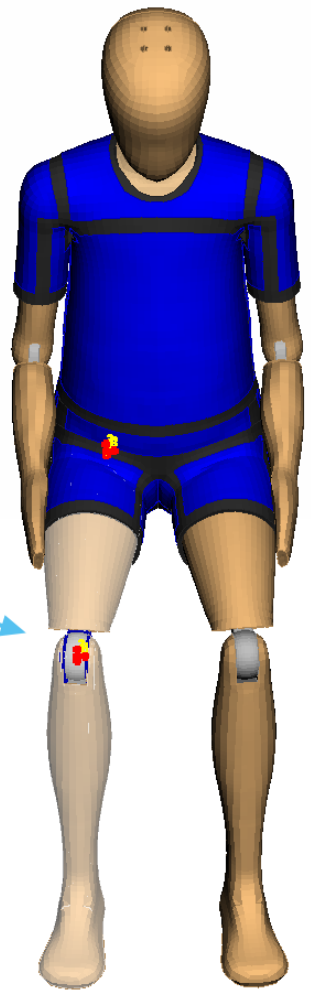
The direct morphing tool does not produce good results when the deformable part is guided by the presence of an hemispherical extremity.
Stretching of elements can be noticed on the tensioned side, compacting on the compressed side produces skewed elements for a smaller total rotation of the cylinders.

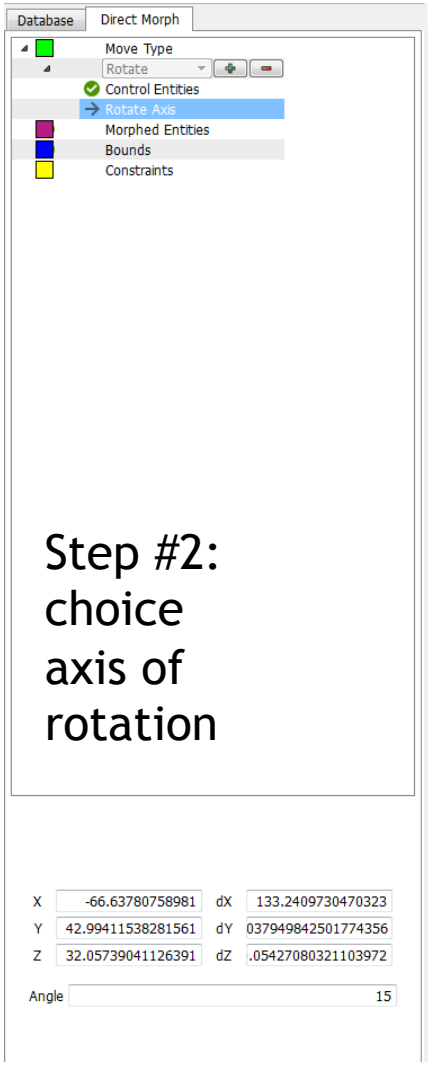


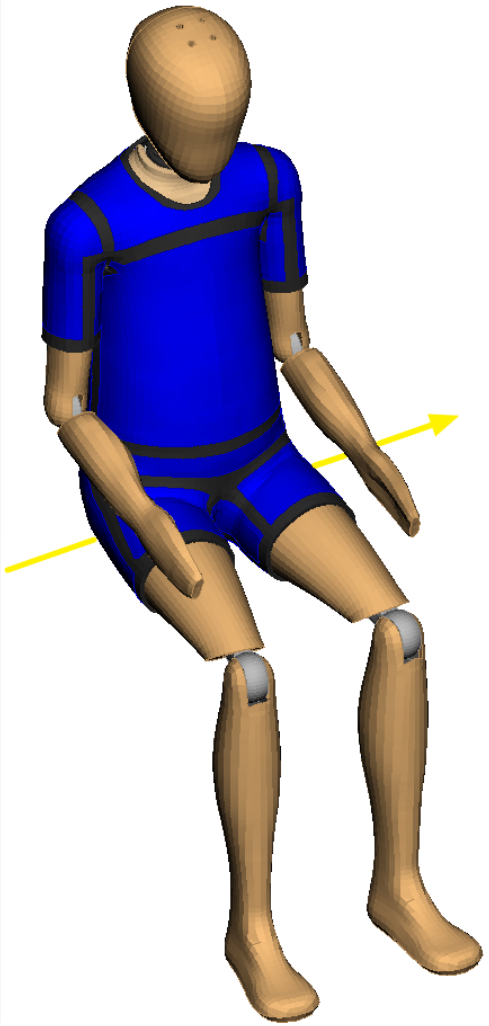


Direct morphing on dummy suit

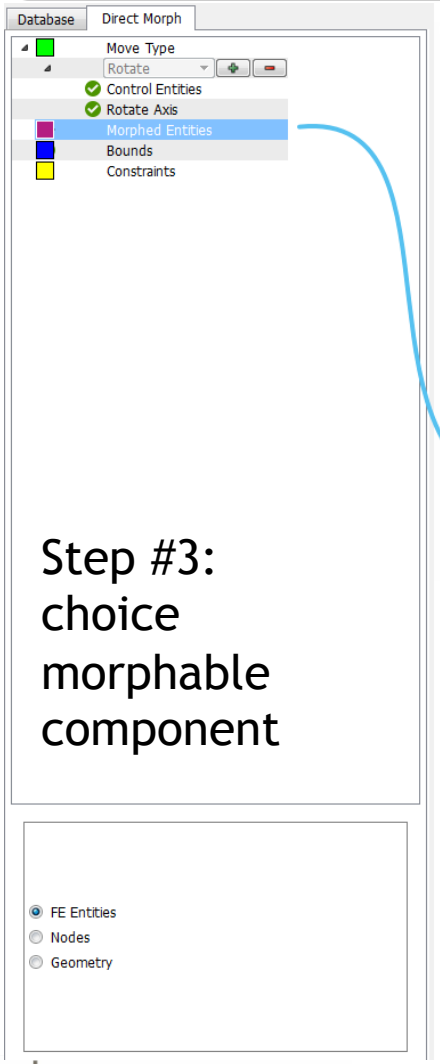




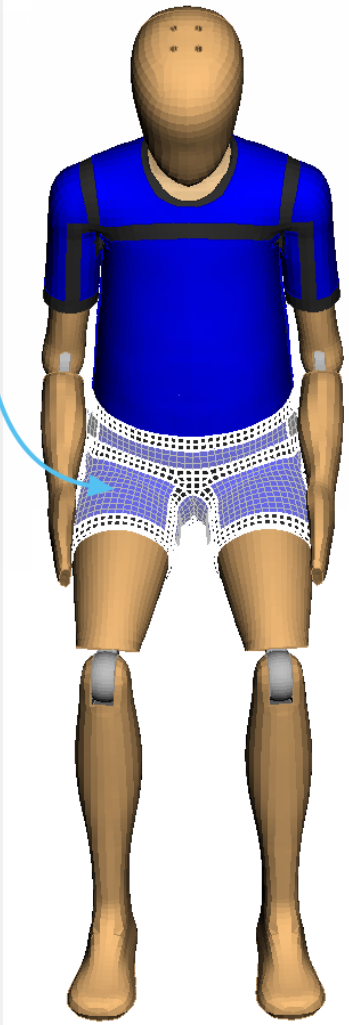


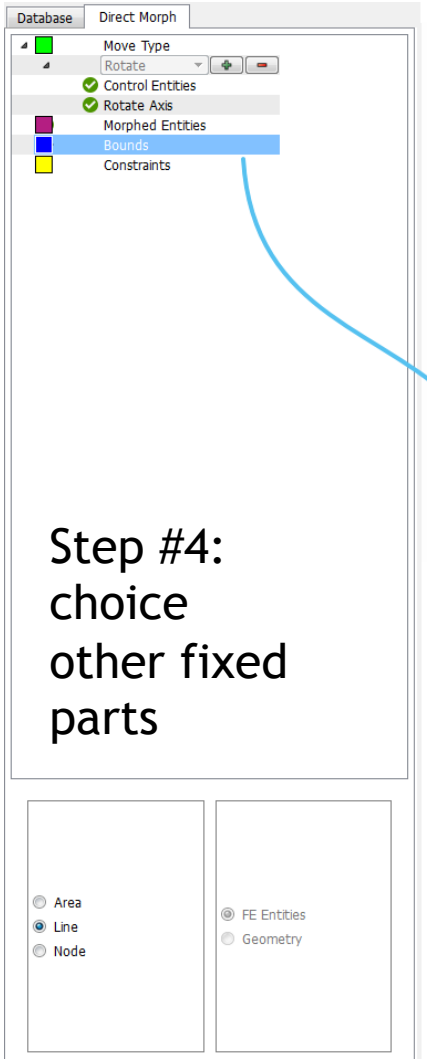


Direct morphing on dummy suit

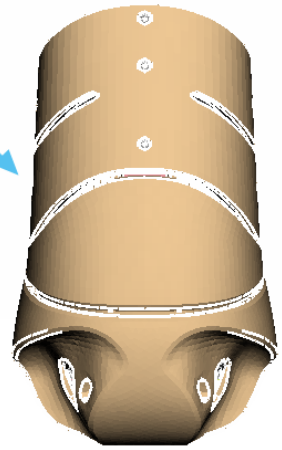


Step #3: choice morphable component



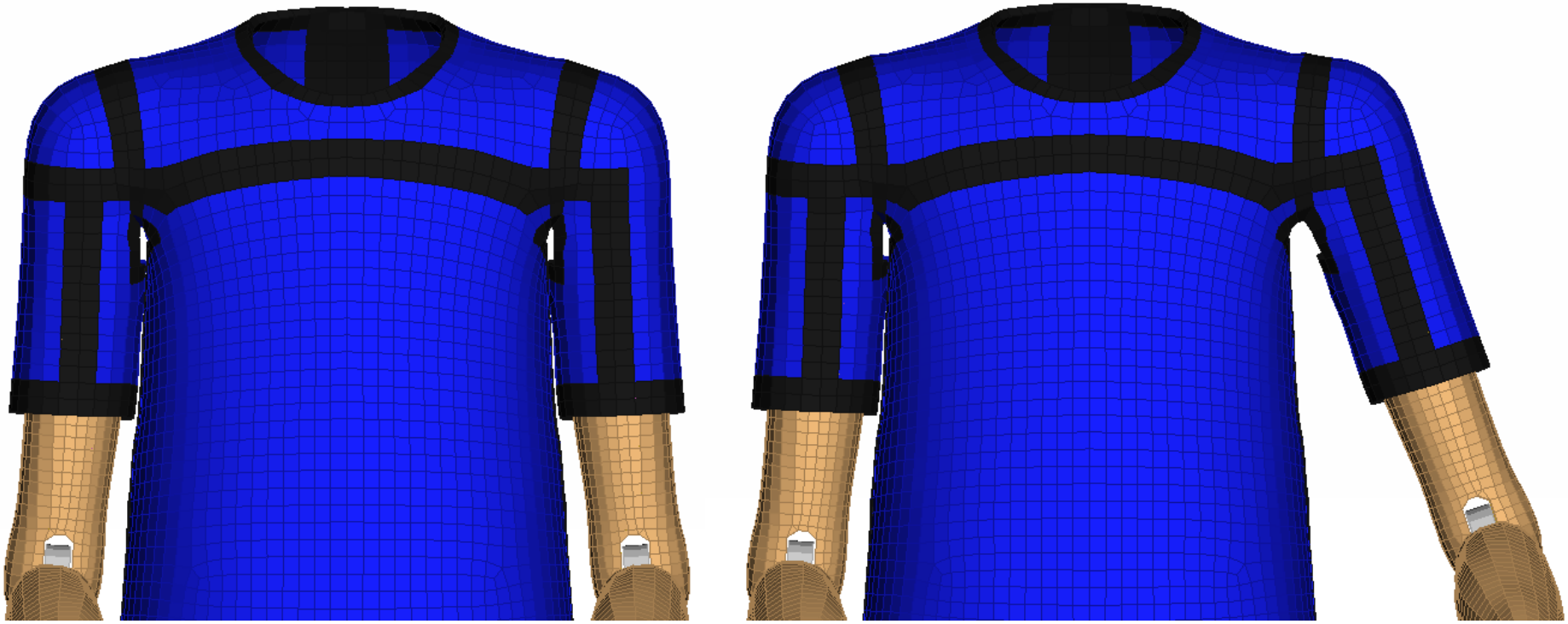


Step #4: choice other fixed parts

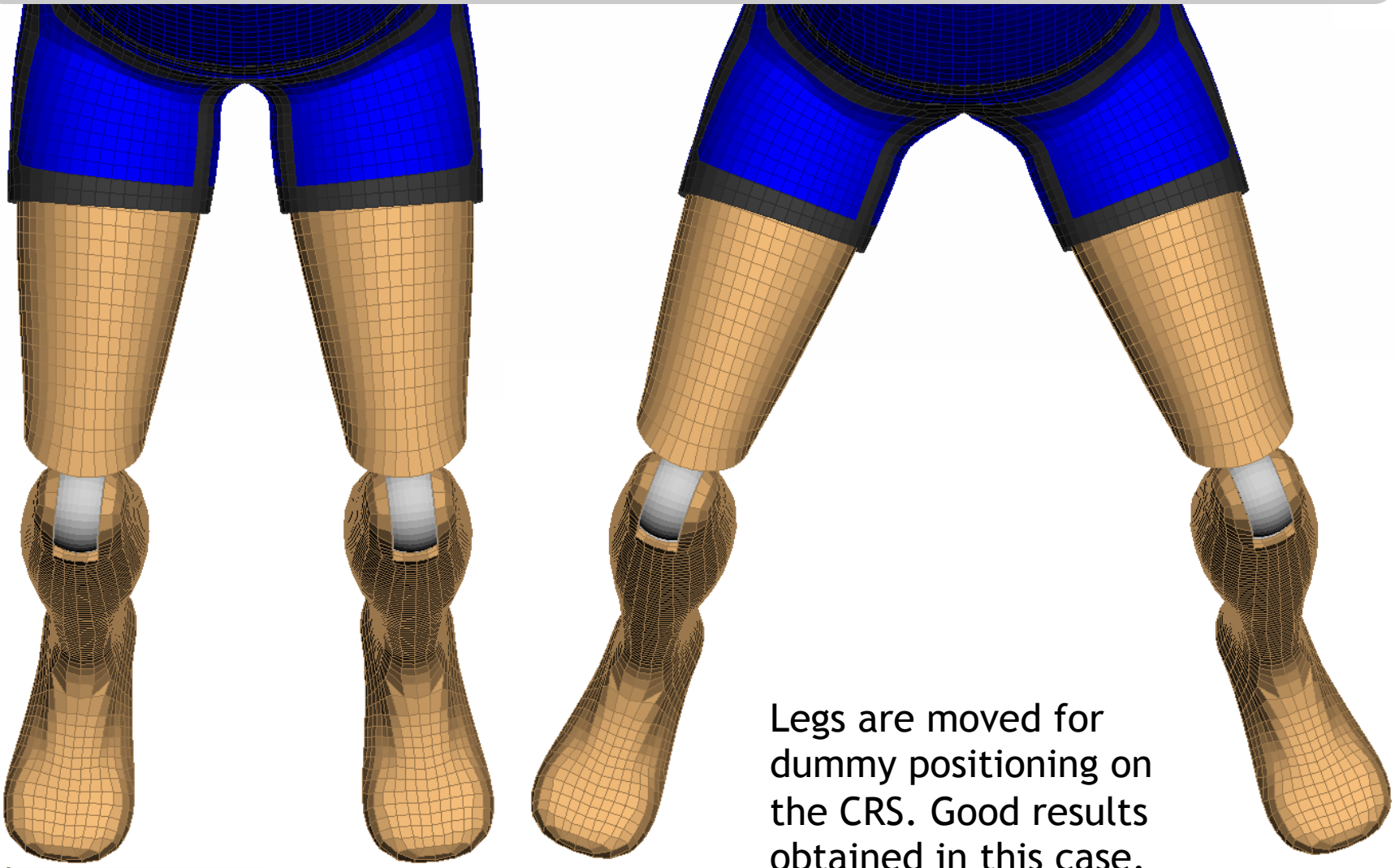


Typical dummy morphing scenario

Arms are moved for dummy positioning purposes as well as for improving the belt passage.
This type of deformation is well handled by the direct morphing tool.

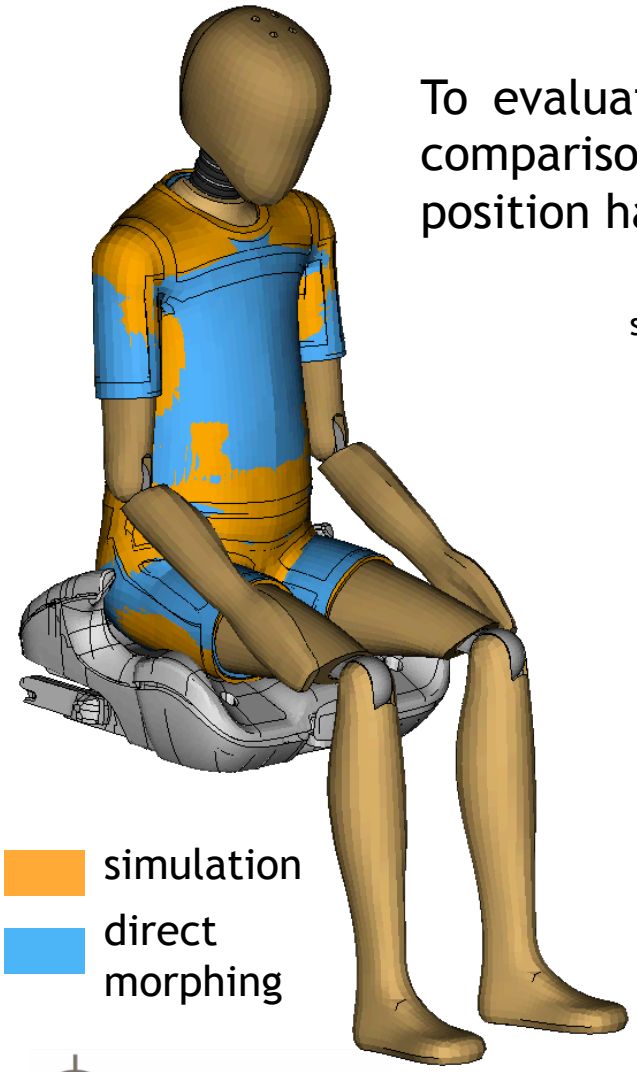


Typical dummy morphing scenario



Legs are moved for dummy positioning on the CRS. Good results obtained in this case.

Comparison of final position

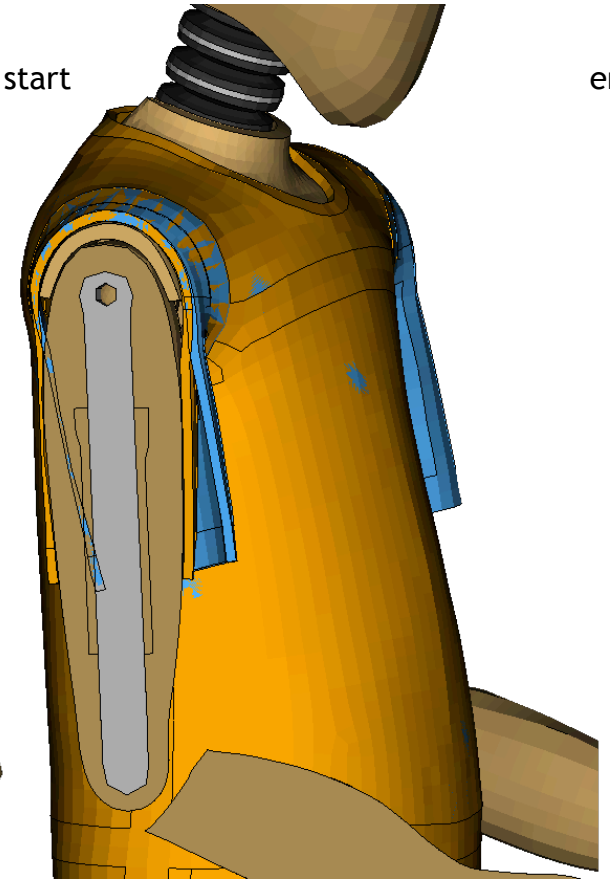


simulation

direct morphing

To evaluate the effectiveness of the proposed procedure a comparison with the simulated result of the final nodal position has been made.

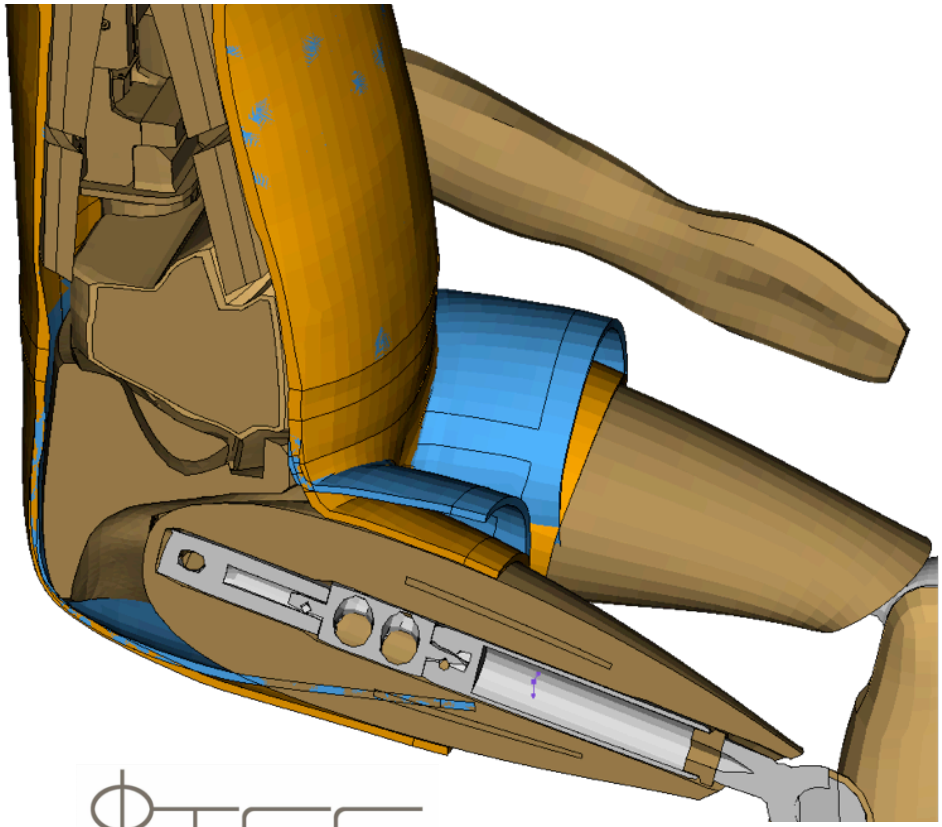
start

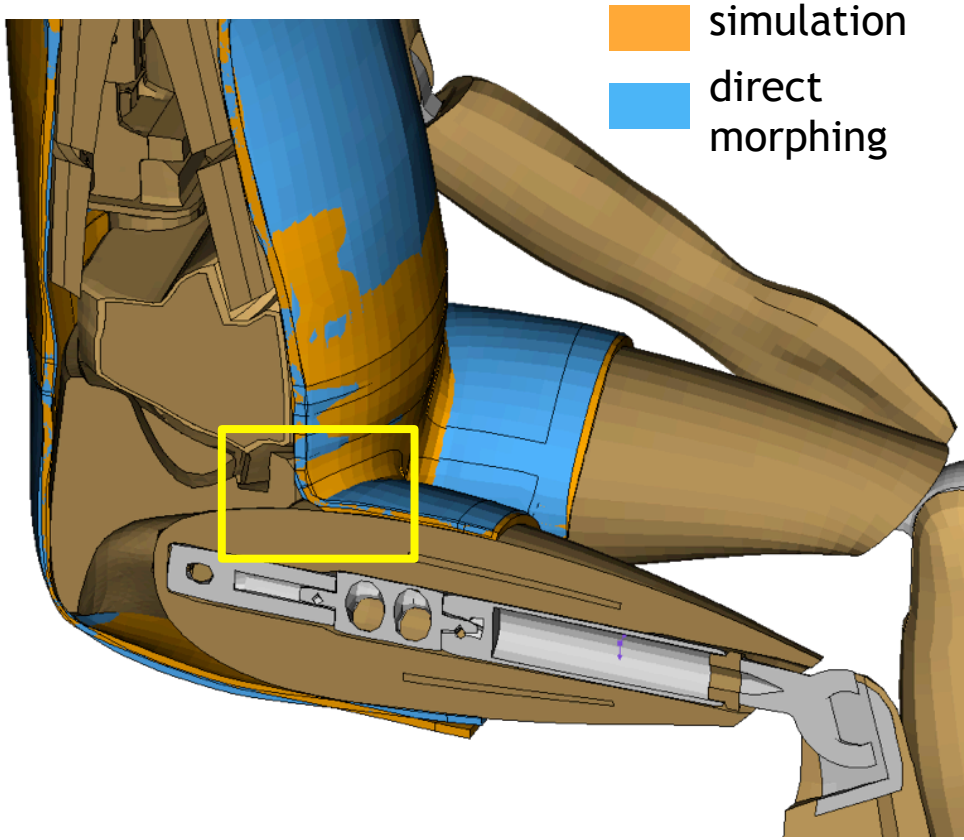


end

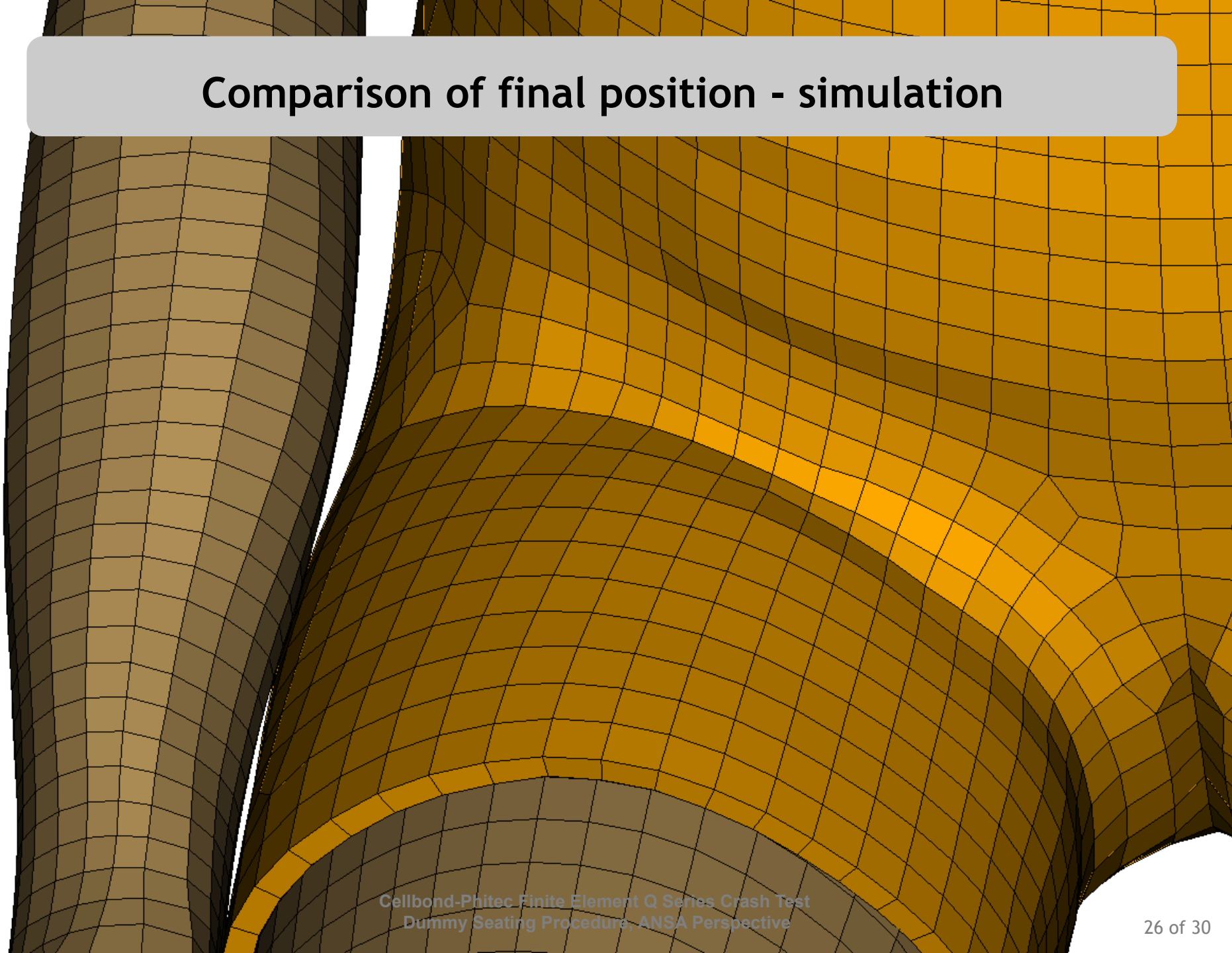
Comparison of final position

Section on the leg shows that the direct morphed suit match closely the simulated one. On the thighs the suit edge is almost in the same position.
On the pelvis thigh corner there is a compaction of the elements.

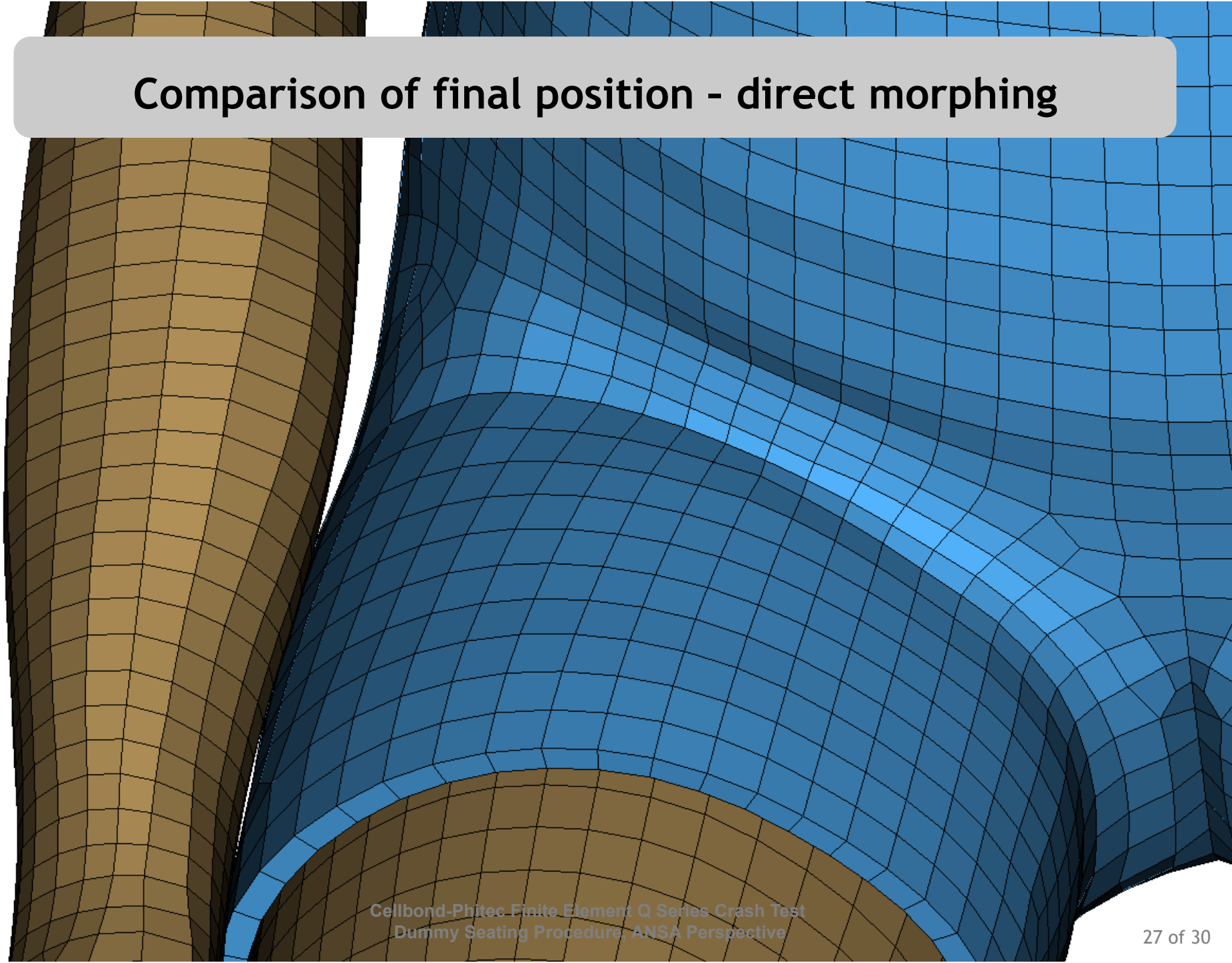




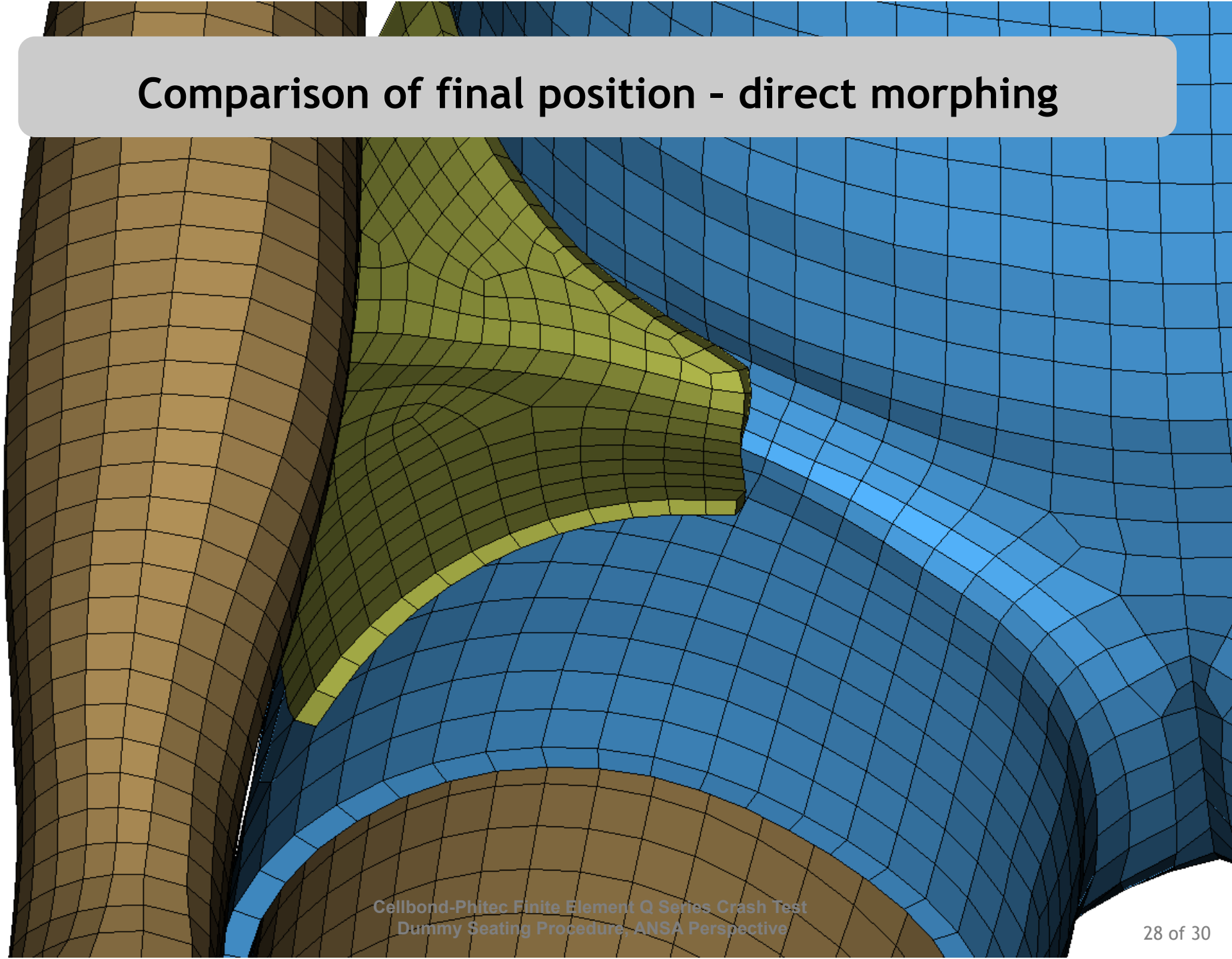
Comparison of final position - simulation



Comparison of final position - direct morphing



Comparison of final position - direct morphing



Conclusions and Future Developments

- ANSA provides a fast and intuitive tool to position the dummy using its hierarchy tree
- For recent dummies (Q10U) the deformation of suit and hip shield can be an iterative and error prone process
- The direct morphing tool can be used to deform suit and hip shield realistically without affecting the dummy model (no initial penetrations)
- Modified geometry can be saved in local coordinate system instead of global coordinate system
- Further improvement of the process can be obtained by:
  - Better quality of the morpher
  - Adding the capability of defining symmetrical deformations

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