Real Time Biofidelic positioning of Human Models with ANSA

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1 Use of HBMs by the automotive industry

The use of Human Body Models, for safety simulations, in the automotive industry, has not been widespread for various reasons. One was that the specific models had not reached expected sophistication levels as they are mainly used in the research phase and not in production. Nevertheless, from their first introduction in late nineties until now, a lot of development and research effort has been invested. The parallel growth in computational power during the same period resulted in much more complex and realistic models that can cover the needs of the occupant safety engineering community.

During the last years the advent of autonomous driving made the use of HBMs a necessity -more than a luxury-. The many out of position load cases that fully autonomous vehicles are subject to, makes the use of traditional ATDs designed for specific load cases (front, side, etc.) inadequate and call for more accurate capture of the Human body behavior during an accident and injury mechanics.

Same time, as more interest is turned onto other vulnerable road users such as pedestrians and riders of any kind of two wheeled vehicles HBMs offer a solution for that case too.

2 Problems positioning an HBM for safety applications

The main problem currently prohibiting the wide use of HBMs in production for safety simulations is the difficulty in handling, positioning, and articulating. As with ATD models, HBM models usually come in two “design” positions, one is seated and the other standing. Unfortunately, this is where the similarities end. ATDs represent a mechanical device where the different moving parts are separated clearly. So, there are very few meshes shared between different parts that need to be deformed during articulation. The kinematic model is very simple since it consists of assemblies mostly connected with mechanical joints such as revolute and spherical joints.
In contrary HBMs have continuous solid meshes that span along more than one parts of the human body, representing various tissues such as muscles, skin, ligaments etc. The more accurate the modeling the more complex the meshes.
At the same time, the kinematic model of the human body is implicitly defined through the connectivity of the tissues, the contact of the various parts and the anatomy of the skeleton. Simplifications found in an ATD such as, a revolute joint representing the knee are nowhere to be found and even the simplest joint such as the knee, is an order of magnitude more complex than its mechanical counterpart. These two factors make the handling of HBMs especially difficult.

3 A novel approach

Pre-simulation has been until now the only way to position an HBM into the final position for a specific load case. Pre-simulation itself is not without problems and disadvantages. The procedure is cumbersome and lengthy in terms of time as it requires a simulation run. Moreover, the simulation itself is not trying to replicate the phenomenon itself but rather a different one that will hopefully have the same result. Specifically, while the position of a real human is the product of voluntary contractions of specific muscle groups, pre-simulation is based on forces applied directly on the bones through a set of cables or springs trying to position the bones on the final position. But these forces have no similarity with the forces applied by the muscles. The actual kinematics of the human skeleton cannot be reproduced by such a procedure. Producing the specific loading is no easy task, and the results are not always the best.

To solve this problem, we followed a novel approach. The goal set was to produce a software tool that would make the positioning of an HBM as easy as that of an ATD. To meet this goal, we relied on two technologies already existing in ANSA. The Multi Body Solver and Morphing.
The first step includes building a kinematic model of the human body that can predict the actual movement of the skeleton when positioning the limbs.
After this first step, we can follow two strategies. Either perform a pre-simulation or try to morph the meshes. ANSA offers both approaches but, in this paper, we are focusing on the second one which is novel.
The second step is to find all the tissues affected by the movement and apply morphing algorithms on them, so they follow along and adapt at the same time to the new bone positions. This whole process must be captured, encapsulated, and offered to the engineers in a software tool that is easy to use and that operates just like the already existing tool for ATDs. Just as ATD models include specific metadata describing the kinematic mechanism, the same way we extended these metadata to contain much more complex kinematics and the needed information for the morphing to work. All this metadata is prepared by BETA CAE Systems and is distributed for use with a specific HBM model.

4 Practical Applications

The first HBM we worked upon is the GHBMC M50 Occupant model in collaboration with Elemance LLC and the GHBMC consortium.

We first focused on the Knee, Shoulder and Hip Joints to be able to position the seated version of the HBM on an automotive seat and place the hands on the steering wheel and feet on the pedals.

Modeling the knee needed to consider the gliding of the patella on the femur, while the tibia rotates around a moving axis of rotation around the femur. At the same time all the tissues must be morphed. This includes quadriceps, biceps tendons, ligaments, and skin. The results are very good, the movement very natural and penetrations between the meshes are avoided.

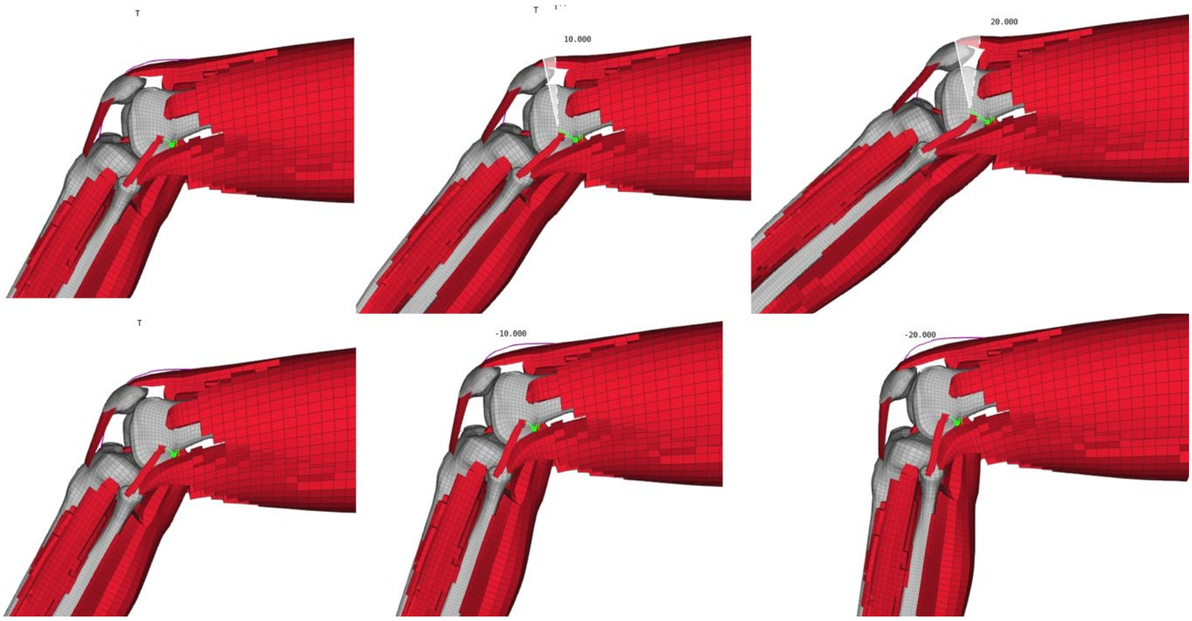

Fig.1: Knee model of the GHBMC M50 Occupant, extension, and flexion

The Hip joint is the easiest of the three as it can be easily modelled with a spherical joint.

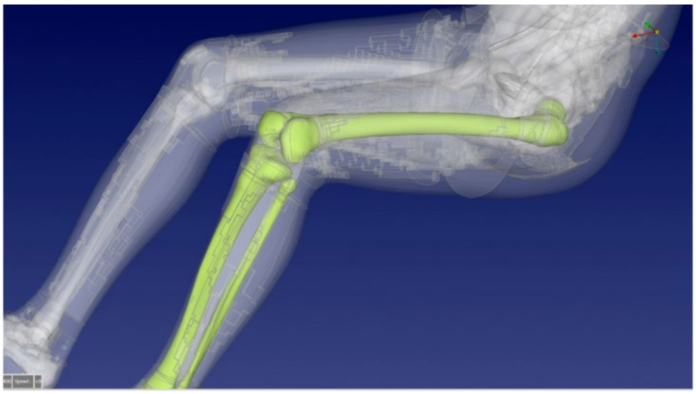

Fig.2: Modelling of the Hip Joint

The shoulder joint is a very good example of how movements that are simple in an ATD can be extremely complex in an HBM. The proposed methodology proves successful even with such complex cases. The shoulder joint consists of three bones the humerus the scapula and the clavicle. To raise the arm, all three bones rotate. The clavicle rotates around the sternum, while the scapula performs both rotation and translation around an imaginary axis as the bone is floating on the back of the rib cage. Big muscle groups must be morphed at the same time.

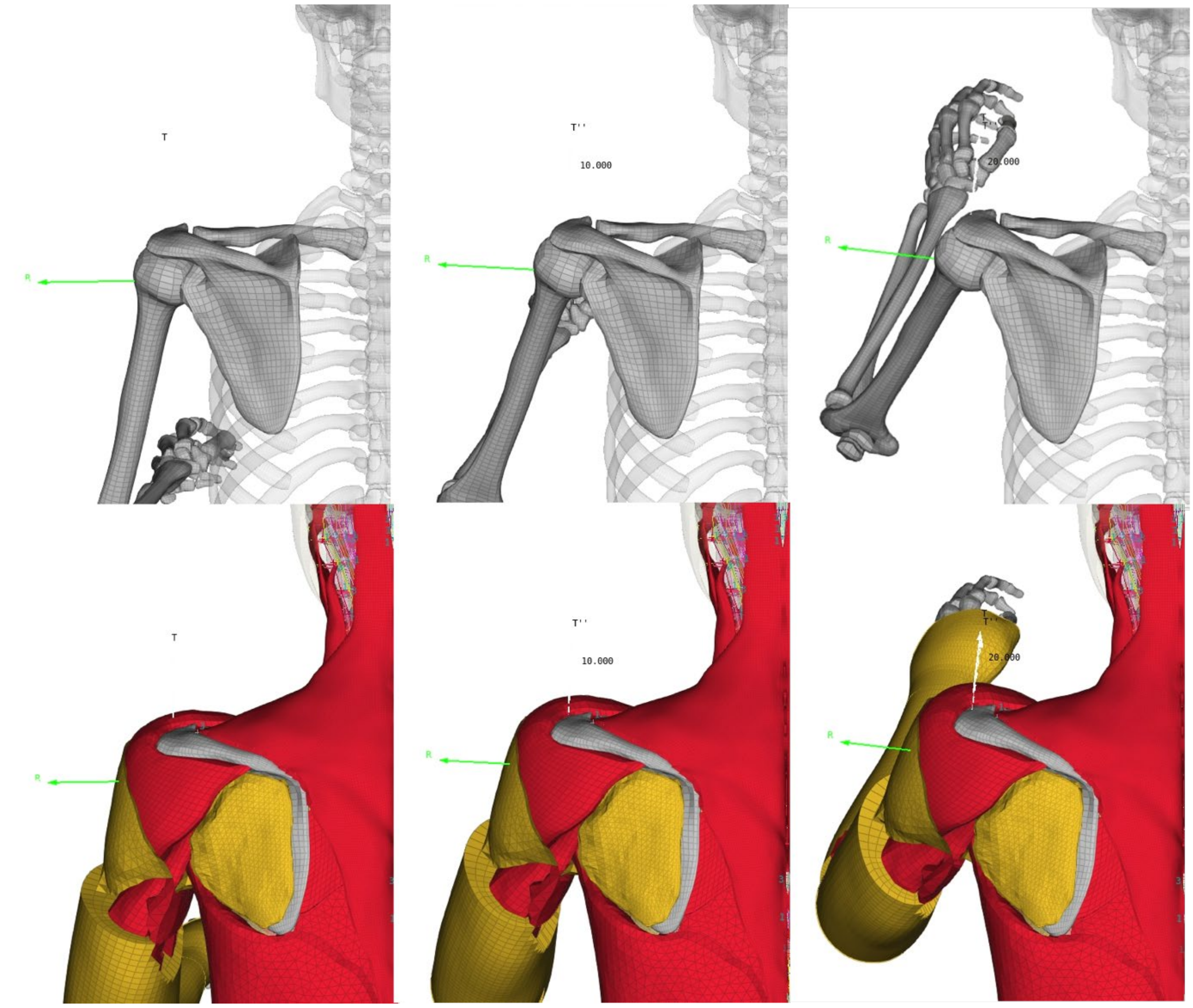

Fig.3: Modelling a simple arm raise involves three bones performing complex movements.

Having modelled these joints, the way described and the rest with simple joints (spherical, cylindrical) we were able to position the GHBMC on a drivers position and perform the simulation.
It's worth noting that from the user perspective the process is not at all different than setting up a normal occupant load case with an ATD. All standard ANSA functionality including restraints setup, seat kinematics and positioning work exactly as with ATD. In this regard the implementation of the tool is totally transparent to the user.

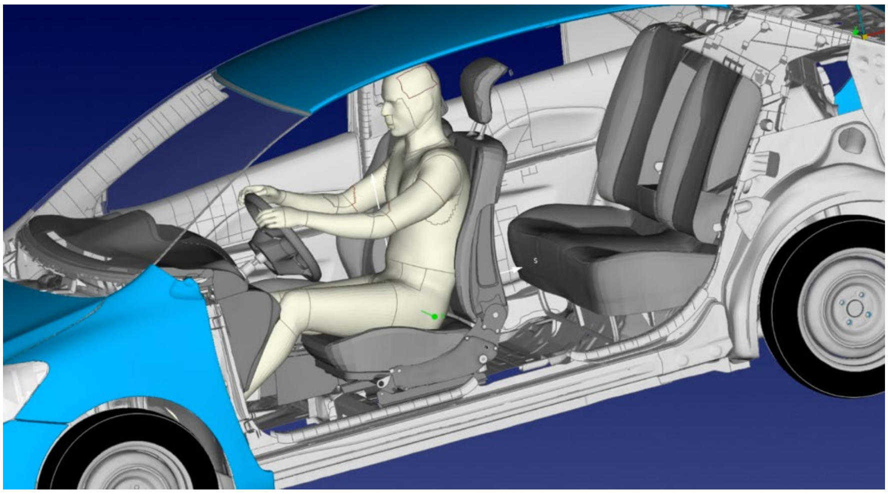

Fig.4: Interactive positioning of an HBM

5 Challenging seating load cases

Moving the limbs of the model is most of the times enough for the model to be used in a seated load case. In the case of autonomous vehicles though it is important to be able to place the model on a reclined seat. The reclined position lies somewhere between the seated model and the upright (pedestrian) one. The most important requirement in positioning the model in such a position is to be able to bend the spine, as the final position involves the rotation of the hips and the bending of the spine. Specifically, the lumbar part of the spine is mainly involved for the movement of the lower part while the cervical spine is used for the positioning of the head. A complex kinematic model of the spine was created treating each vertebra as a separate rigid body and connecting them with bushes. The full system runs through a dynamic simulation so it can realistically capture the kinematics.

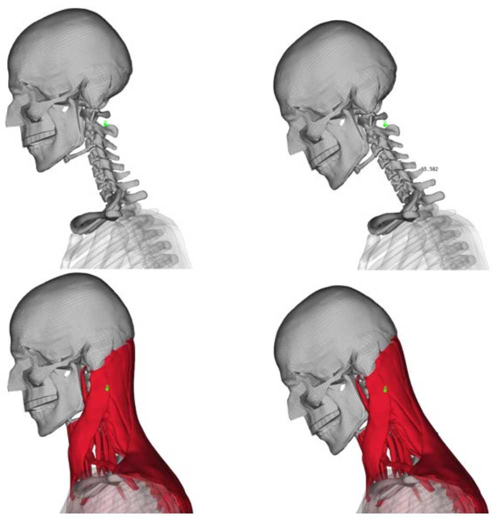

Fig.5: Cervical spine flexion

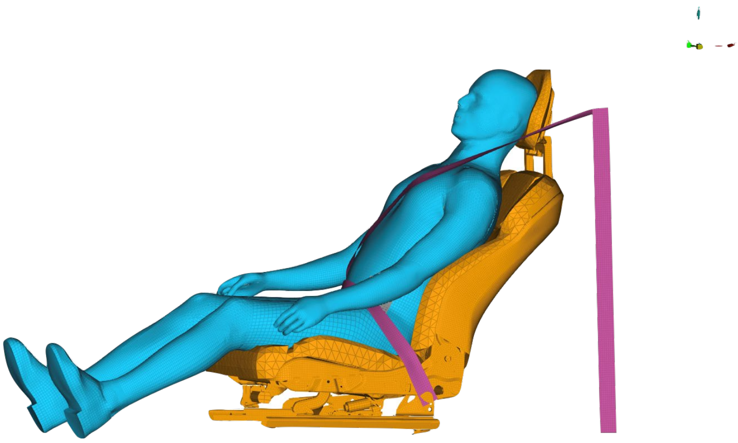

Fig.6: Positioning the GHBMC M50 in a reclined position, together with seat kinematics and restraining

6 Vulnerable road users

Modelling the spine opens more possibilities for HBM use not only for occupants but for other vulnerable road users such as riders of motorcycles and bicycles. Starting from the seated position it was possible to flex the spine so the model could move to a riding position. Morphing of the internal organs in the abdomen resulted in a penetration free mesh, although more study and research must be conducted to better understand the positioning of the various organs and tissues during such changes of posture.

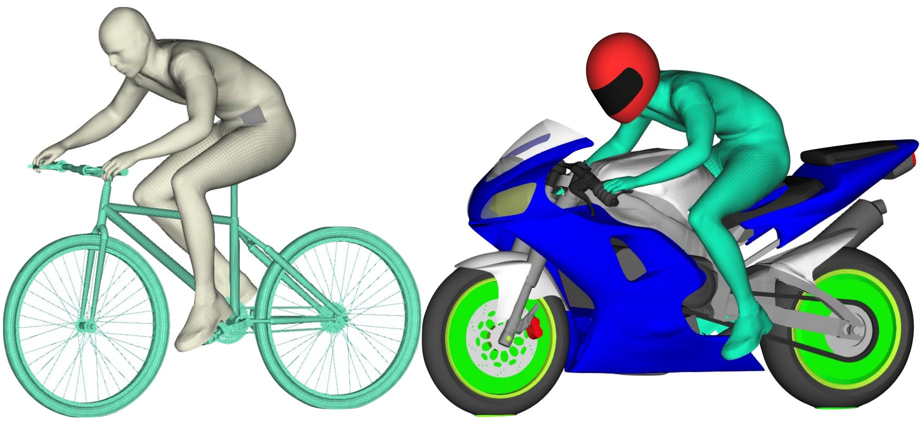

Fig.7: Positioning of the GHBMC M50 on a bicycle and a motorcycle.

7 Next Steps

The use of the tool up to now has proven that the methodology used is very promising and can help the spread of use of HBMs. Nevertheless, there are a lot of work still to be done. A lot is already in progress. We are currently working to prepare meta data files for all the available and widely used HBMs in the industry. These include:

- All GHBMC models both occupant and pedestrian.
- GHBMC models for RADIOSS and VPS
- THUMS v6 LS-DYNA Model

Moreover, we are researching and experimenting with further sophistication of the kinematic model. There are still parts of the human kinematics that have been modelled with a rather simplified way. The feet and wrists are good examples of areas where we can built much more accurate models. In parallel we try to adapt our morphing algorithms to produce as much realistic results as possible and adapted to each case.

8 Summary

The advent of autonomous driving with its many out-of-position load cases, makes the use of HBMs in safety simulations a necessity. Moreover, safety simulations for other vulnerable road users such as, pedestrians and cyclists are increasingly needed, and HBMs can address this need too.

Positioning of an HBM though, has always been a challenge. BETA CAE Systems has always taken up the challenge to industrialize advanced methods and produce tools that push simulation technology to its next steps.

ANSA, in its latest version offers a novel solution to this complex problem, making the positioning and handling of an HBM, as easy as with an ATD model. Using an advanced integrated MBD solver in parallel with morphing algorithms, engineers are provided with real time articulation and positioning of a HBM within an easy user interface. While the user just articulates the human model with the mouse in a most direct way, the biofidelic joint modelling guarantees realistic model movements and the generation of a ready-to-run model without the need of pre-simulation. Of course, in case the user wishes to run a re-simulation this can also automatically be set up. Furthermore, all tools and procedures available for ATDs (restraints, coupled dummy-seat movement etc.) are also available for the HBM models. Thus, the positioning of HBMs and ATDs are treated in the same manner within the pre-processor offering the liberty to the engineer to perform the analysis he wishes.

9 Literature

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