

Update in Dummy Model Enhancements and Effective Pre-processing

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Abstract

The FAT and PDB dummy models have been developed for more than a decade. The models are used by almost all OEMs and restraint system suppliers to enhance the passive safety performance of their vehicles. Nevertheless, the PDB is still launching new projects to further enhance the predictability of the ES-2, ES-2re, BioRID-II and WorldSID models. This paper presents the current enhancement projects at a glance.

With the increasing quality of the dummy and the restraint system models, additional details related to model assembly have a significant influence on the overall accuracy. Thus, a more advanced pre-processing to assemble the finite element input is required. Such pre-processing might involve a sequence of pre-simulations and might take pre-stresses into account. In some cases the computational effort for the pre-processing exceeds the time needed to simulate the final load case. The paper presents ideas and solutions to simplify and to speed-up the pre-processing of the above mentioned dummy models without a loss in accuracy. The solutions utilize standard pre-processing tools and scripts as well as LS-DYNA[®] implicit and explicit time-stepping schemes.

Introduction

The requirements for computational dummy models have increased significantly over the past years. Therefore, the validation processes and the validation targets were refined continuously to meet the increasing goals. But to fulfil all the requirements not only the dummy must be taken into account. The complete car surrounding must also be validated accurately. Additionally, the positioning process of the dummies can have an influence on the results. Hence the positioning process must be also very accurate to fulfil the claims of the users.

This paper describes how the seat model can be adjusted in a very similar way to the physical test. In use of this seat, two different positioning methods are described for the dummy model. The state of the art process, where the dummy is put as a rigid into the seat, and a process with a fully deformable dummy, under gravity load are compared.

After positioning the results are compared and the influence on the results is shown. This is done for the BioRID-II and the ES-2 dummy model.

Common process for dummy positioning

Dummy positioning has been carried out since many years in the area of passenger safety. The common process which is currently state of the art is well known and used world wide.

Following is the description of the common state of the art process to position a dummy into the seat:

1. The dummy model is moved by using a pre-processor to the desired position. Out here, most of the limbs can be oriented by using a preprocessor.
To rotate parts of a dummy which will be deformed due to rotation of a body area often a pre-simulation is needed. The following body areas are adjusted by pre-simulations:
 - Position of torso in respect to the pelvis
 - Arm rotation
 - Upper leg rotation
2. After adjusting the dummy model the normal process is to switch the dummy model to rigid. This can be done in different ways which are more or less complicated. The most common method is to cut out the outer shell face of the model and switch this one to rigid. Another very common method is to use a pre-processor which is able to switch complete models to rigid.
A much more time consuming possibility for setting up the simulation the first time is to use the LS-DYNA keyword *DEFORMABLE_TO_RIGID.
3. The third step is then to push the rigid dummy into the deformable seat to the desired H-Point location. The deformed Foam parts of the seat are then used without any pre-stresses in the following crash simulations.

This process often results in positions which are very close to test positions, but the initial conditions are neglected. Normally the initial stresses can be switched on very easily, but due to the fact, that the dummy is pushed by a boundary condition into the seat, it cannot be ensured that the dummy is in equilibrium at the beginning of a crash simulation.

Due to the need of much more accurate simulation results and also due to saving much more costs of tests, the requirement of dummy positioning is getting more and more into the focus. The dummy in simulations should be positioned closer to the test and the physical positions of dummies in different seats must be found without availability of measured positions from tests.

Due to this the positioning process must be enhanced to a more physical process which is quite similar to the actual test procedure. Due to this a positioning under gravity load without any boundary can be the first step in this direction

Positioning under gravity load (example BioRID-II)

The principle idea of this process is not to move a rigid dummy by a boundary into a seat. The deformable dummy should drop into the fully deformable seat model. So at the end of the simulation, the dummy and the seat are deformed and both are in equilibrium in this position.

At first, this approach does not seem to be very complicated, but in a second view the process must be started in a much earlier state.

Seat adjusting:

First of all the seat must be adjusted to the right position. In test labs therefore, the SAE-Manikin (H-Point machine) with HRMD (only for BioRID-II positioning) is used.

By using this H-Point machine the H-Point location, the back rest angle (torso angle) of the seat is adjusted and the back set is determined.

In the following, the result of a simulation with a Model of a SAE-Manikin is described and shown. The model of the SAE-Manikin falls under gravity load into the fully deformable seat. The start point is determined in such a way that no intersections and penetrations to the seat foam are present.

The following figure shows the simulation results of the SAE-Manikin.

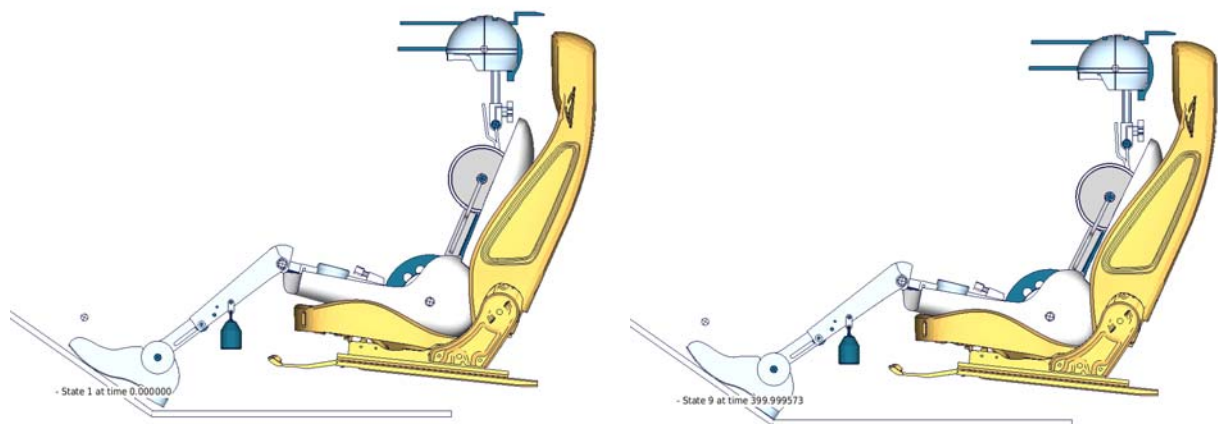


Figure 1: SAE-Manikin positioning LEFT: start state RIGHT: end state of simulation.

The target of the simulation is to position the SAE-Manikin like it is done for the physical tests. This means that the model drops into the seat. After it is very close to equilibrium the SAE-Manikin is pushed backwards by a force on the pelvis of 100 N from 400 to 750 ms simulation time. This is also done in test by pushing a button in front of the pelvis. The entire simulation time is 1000 ms. At the end of the simulation the SAE-Manikin is sitting in equilibrium in the seat and there is no external boundary and load on the model, except the gravity load.

At the end of the simulation the torso angle with respect to the vertical is evaluated. This angle is defined as back rest angle and the requirement for the BioRID-II whiplash tests is 25°. The following figure shows the back rest angle (torso angle) over the time for this simulation.

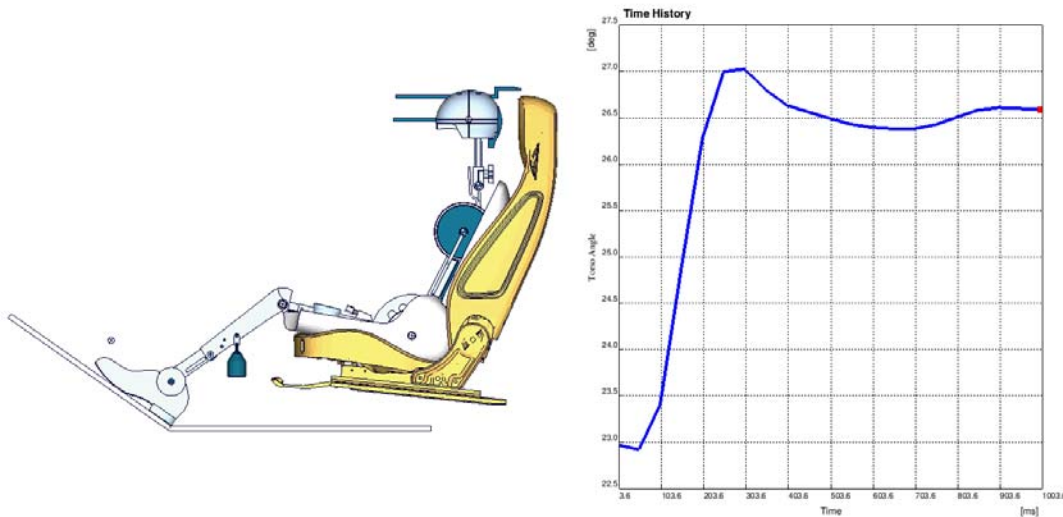


Figure 2: Positioning simulation with SAE-Manikin and torso angle vs. time for simple seat.

It is visible that the simulation ends up with an angle of 26.5°. Requirement for BioRID-II whiplash test is 25° back rest angle.

This result leads to the conclusion that either the seat model has not been positioned right or the foam materials have been defined as too soft in this case. We are now defining that the foam material of the seat is very well tested and the validation of the seat is perfect. So the back rest of the seat must be adjusted to determine a torso angle of 25°.

The positioning simulation is done again with a changed back rest angle (rotated 1.5° forward). So the SAE-Manikin should reach torso angle which is much closer to 25°. The result of this simulation is shown in the following.

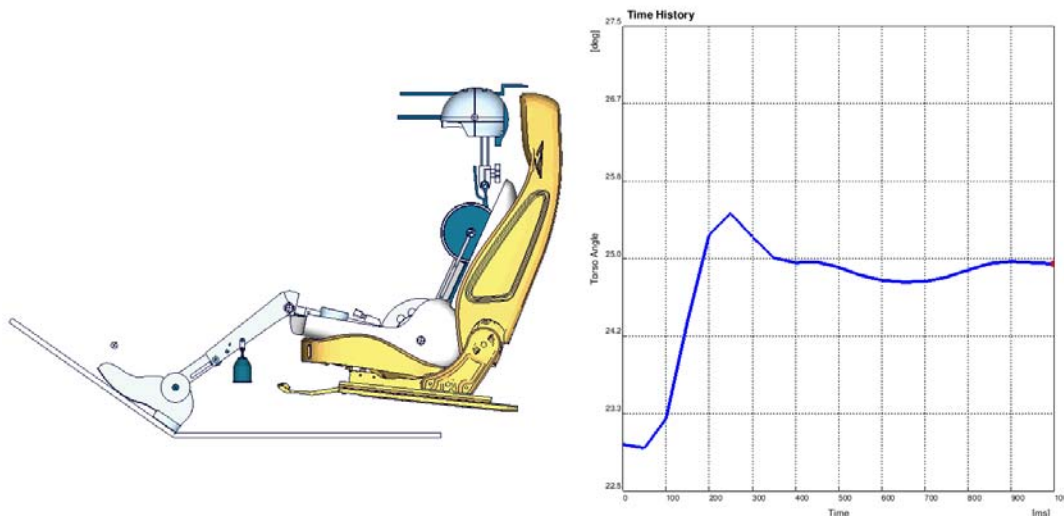


Figure 3: Positioning simulation with SAE-Manikin and torso angle vs. time for simple seat with corrected back rest angle.

The torso angle at the end of the simulation is now very close to 25°. The seat is now adjusted to the right position for BioRID-II positioning. The following additional measurements of the SAE-Manikin are extracted for correct BioRID-II positioning:

- H-Point location $x=-1080$ $z=394$
- Torso angle 25°
- Backset 37 mm

In use of these measurements, the following target position of the BioRID-II can be calculated:

- H-Point location $x=-1080 - 20 = -1060$ mm (+-10mm)
 $z= 394 + 6 = 400$ mm (+-10mm)
- Backset $37 + 15 = 52$ mm (+- 5mm)

Following are additional requirements for the BioRID-II

- Pelvis angle 26.5° (+- 2.5°)
- OC angle 0.0° (+- 1.0°)

Gives a very well defined position where the BioRID-II should be placed in the adjusted seat.

BioRID-II positioning:

In the previous section the seat adjustment was described in a very accurate manner. Due to the results of the previous sections we determined a very accurate description of the position for the BioRID-II for the Whiplash tests.

Due to the different positioning methods and due to the very high tolerances of the position target points there are now again different possibilities to position the BioRID-II into the seat.

BioRID-II positioned in use of standard process:

The standard process uses, as described above, a rigid dummy which is pushed by boundary conditions into the seat. This means no deformations are applied on the Dummy during the positioning process. Also in use of this process, the position of the BioRID-II which was determined by the SAE-Manikin should be reached.

The following position can be reached by using a rigid BioRID-II model:

- H-Point location $x=-1068$ mm desired value -1060 mm (+-10mm)
 $z= 400$ mm desired value 400 mm (+-10mm)
- Backset **56** mm desired value 52 mm (+- 5mm)
- Pelvis angle **27.0°** desired value 26.5° (+-2.5°)
- OC angle **-0.8°** desired value 0.0° (+-1.0°)

It seems to be very difficult to position the BioRID-II without deforming it into the desired borders of the position. The tolerances of the position are really needed to put the model into the seat. But in principle the BioRID-II is correctly positioned.

BioRID-II positioned under gravity load:

Starting point is again the fully deformable BioRID-II model which is floating above the fully deformable seat model. The H-Point position in x direction is exactly above the target H-Point which was calculated from the position of the SAE-Manikin (x = -1060 mm).

Due to this starting point the torso of the BioRID-II shows large intersections to the back rest of the seat. So the BioRID-II is rotated about the H-Point 2° forward, thus no intersections are present in the starting position.

At the beginning of the simulation, the BioRID-II drops into the seat under gravity load. During this phase the pelvis is rotated backwards to reach again the 26.5° pelvis angle. This boundary condition is released before end of the simulation time. So at the end of the simulation (1000 ms) the model is again completely free from boundary conditions. There should be equilibrium between deformed BioRID-II and deformed seat then.

The following position can be reached by using this process for BioRID-II model:

▪ H-Point location	x=-1059 mm	desired value -1060 mm (+-10mm)
	z= 399 mm	desired value 400 mm (+-10mm)
▪ Backset	56 mm	desired value 52 mm (+- 5mm)
▪ Pelvis angle	27.2°	desired value 26.5° (+-2.5°)
▪ OC angle	-1.0°	desired value 0.0° (+-1.0°)

At the end of the positioning process the stresses of all shell and beam elements of the seat are written out in a dynain File. These are used then for initialization in the Whiplash simulation so that the model is in equilibrium at the beginning. For solid elements of the seat foam, the keyword *INITIAL_FOAM_REFERENCE_GEOMETRY is used.

Due to this process the model is completely initialized in equilibrium at the beginning of the whiplash simulation.

Influence of positioning in whiplash test

A comparison of the two positions is shown in the following picture. Light blue shows the result from the rigid positioning process and green the positioning under gravity load.

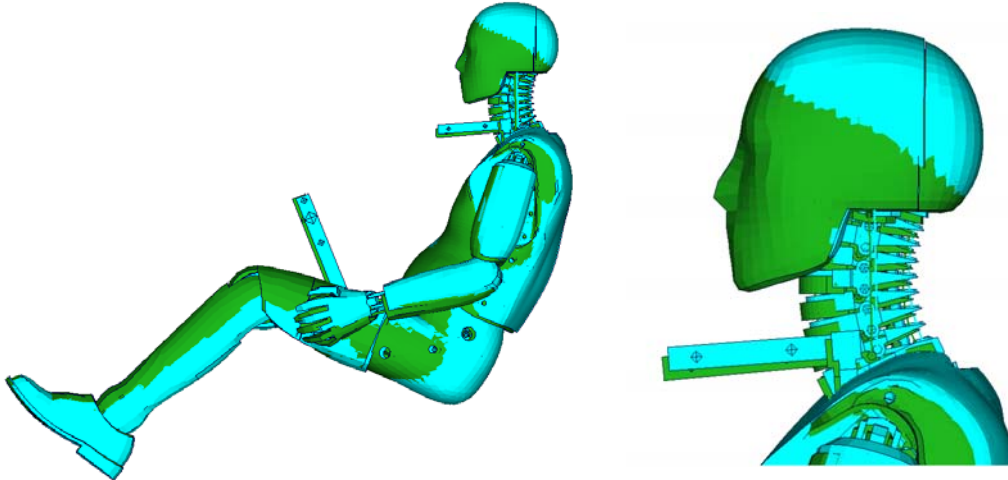


Figure 4: Comparison of BioRID-II positions. Light blue: rigid positioned; Green: deformable positioned under gravity load.

A comparison of the results in a whiplash test (IIWPG Pulse, SRA16-Pulse and SRA24-Pulse) is shown in the following.

Results of EuroNCAP IIWPG Pulse

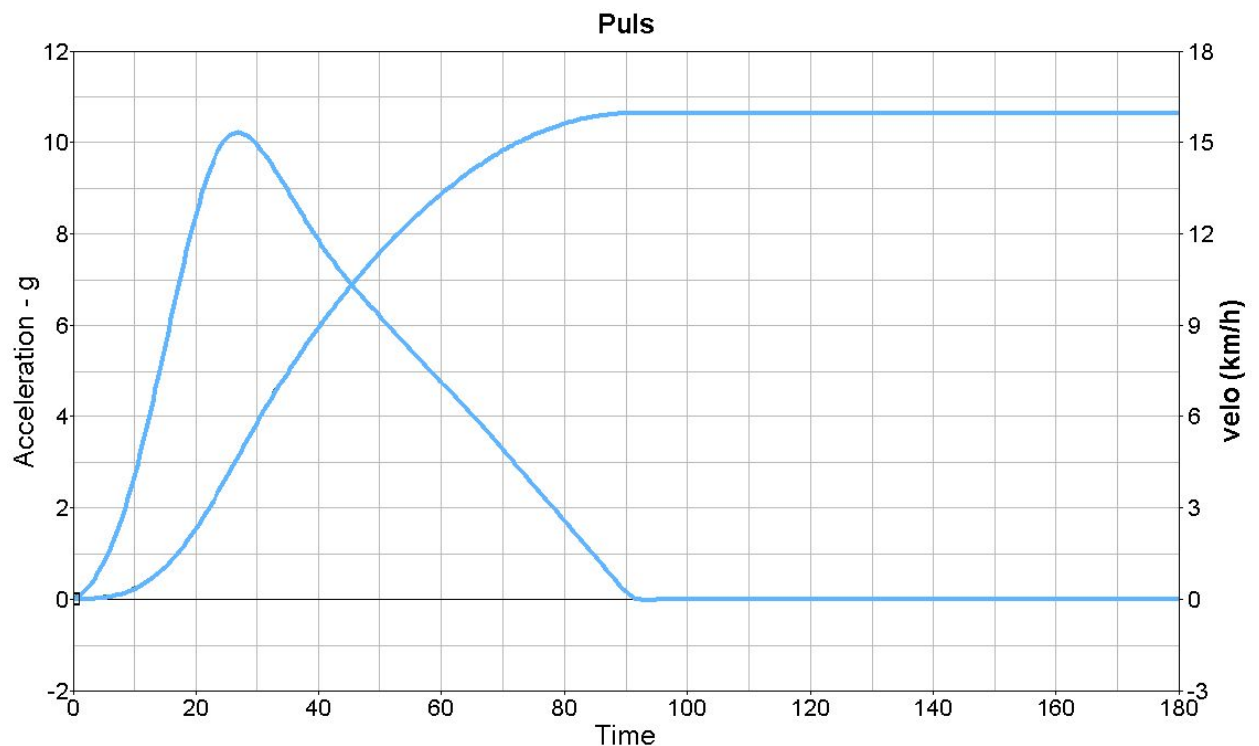


Figure 5: IIWPG Pulse of whiplash simulation.

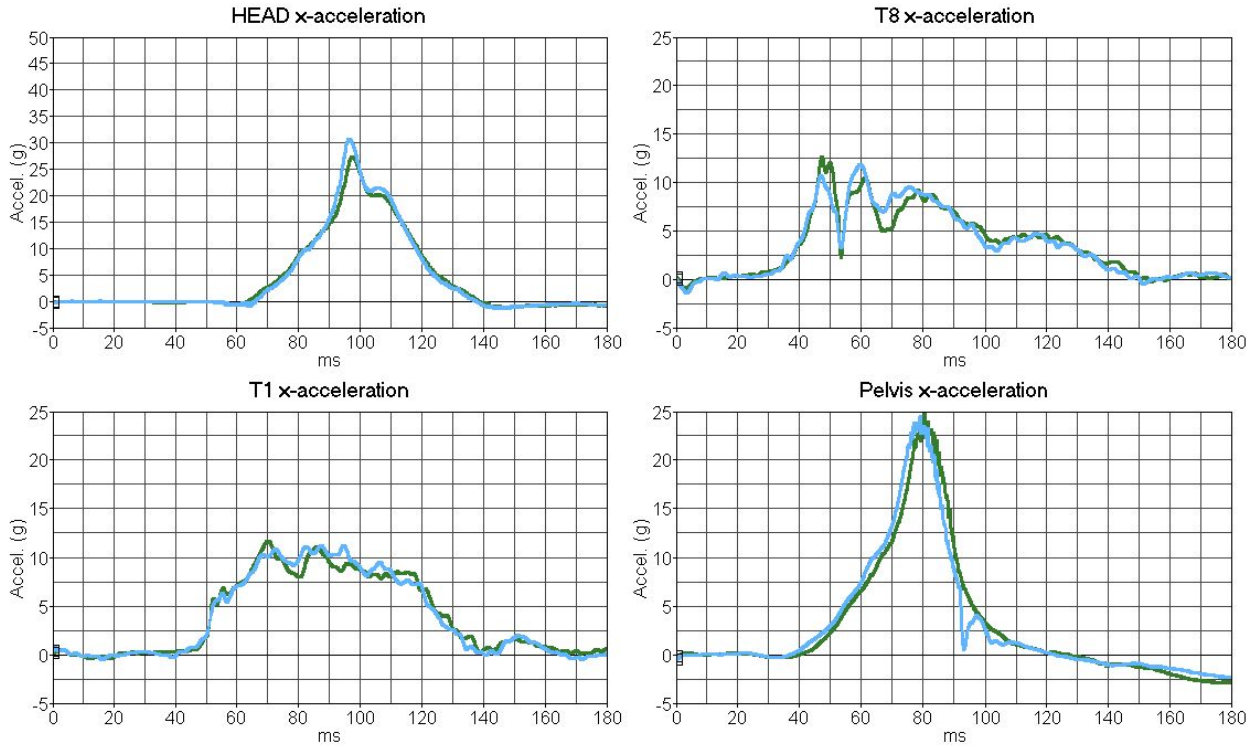


Figure 6: Results of Head, T1, T8 and pelvis x-acceleration. Light blue: rigid positioned; Green: deformable positioned under gravity load.

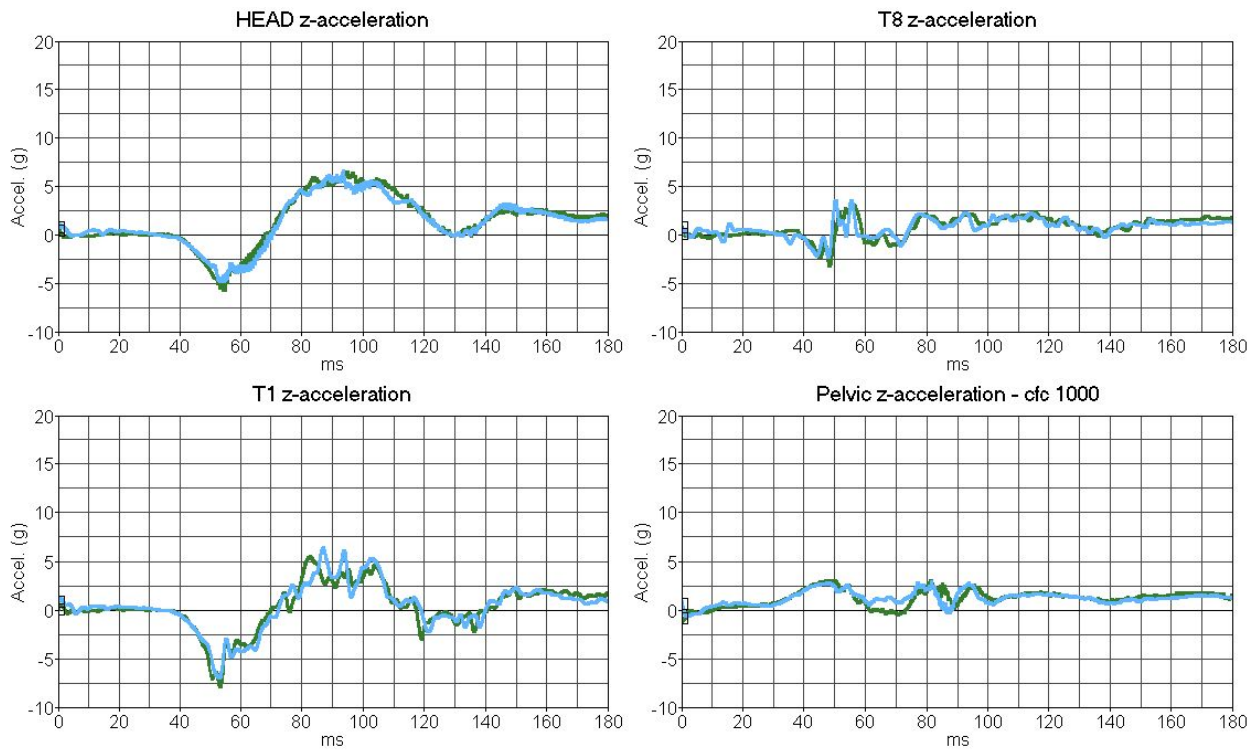


Figure 7: Results of Head, T1, T8 and pelvis z-acceleration. Light blue: rigid positioned; Green: deformable positioned under gravity load.

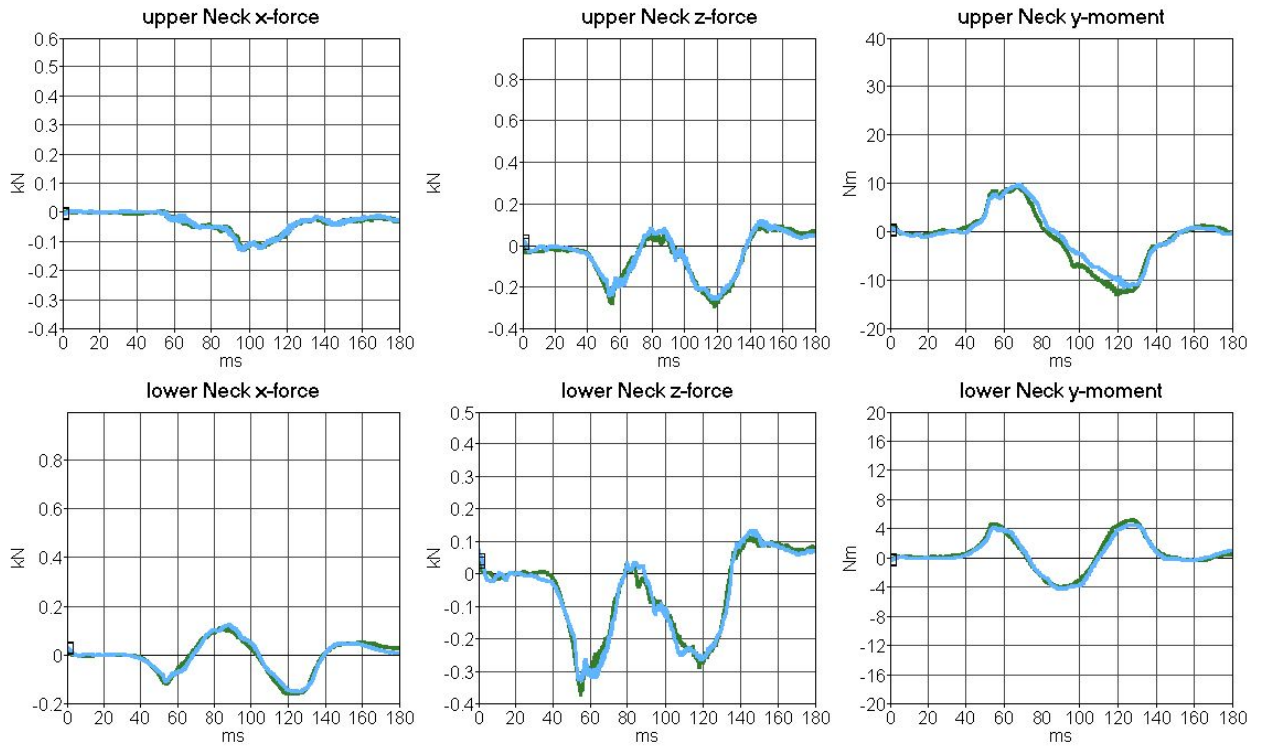


Figure 8: Results of upper and lower neck. Light blue: rigid positioned; Green: deformable positioned under gravity load.

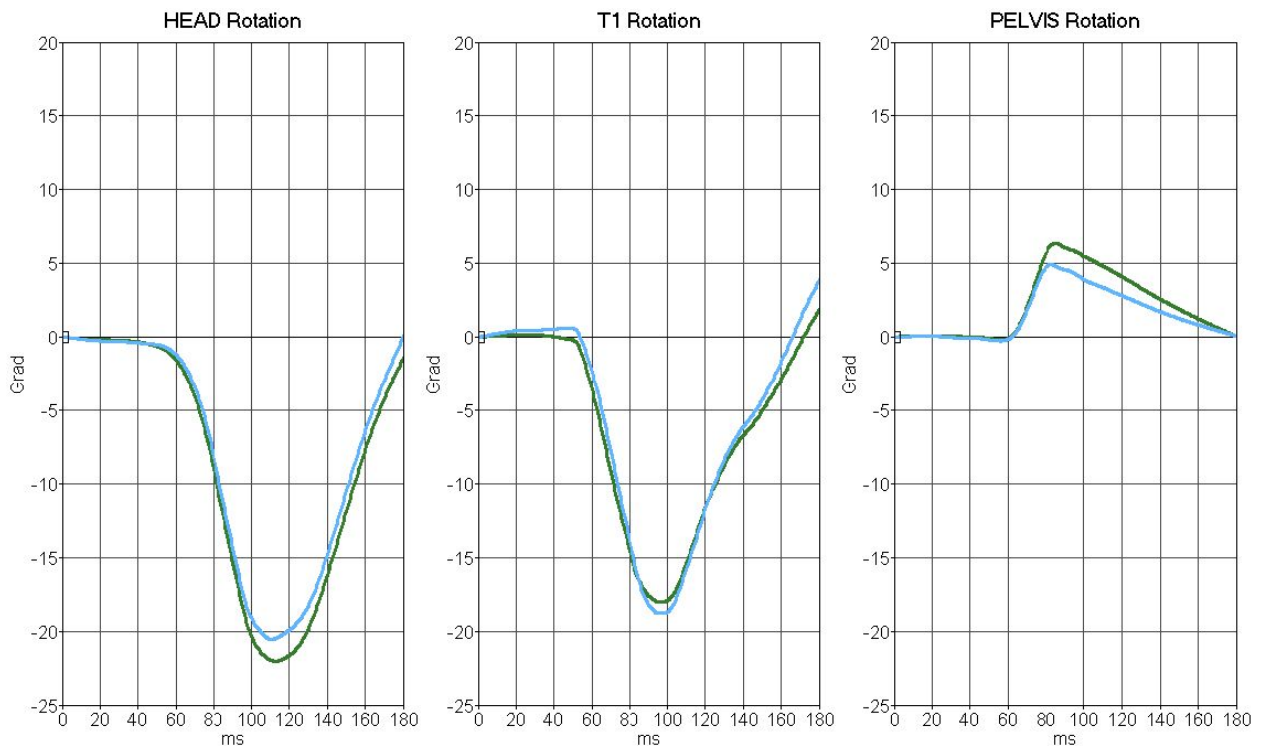


Figure 9: Results of Head, T1 and pelvis rotation. Light blue: rigid positioned; Green: deformable positioned under gravity load.

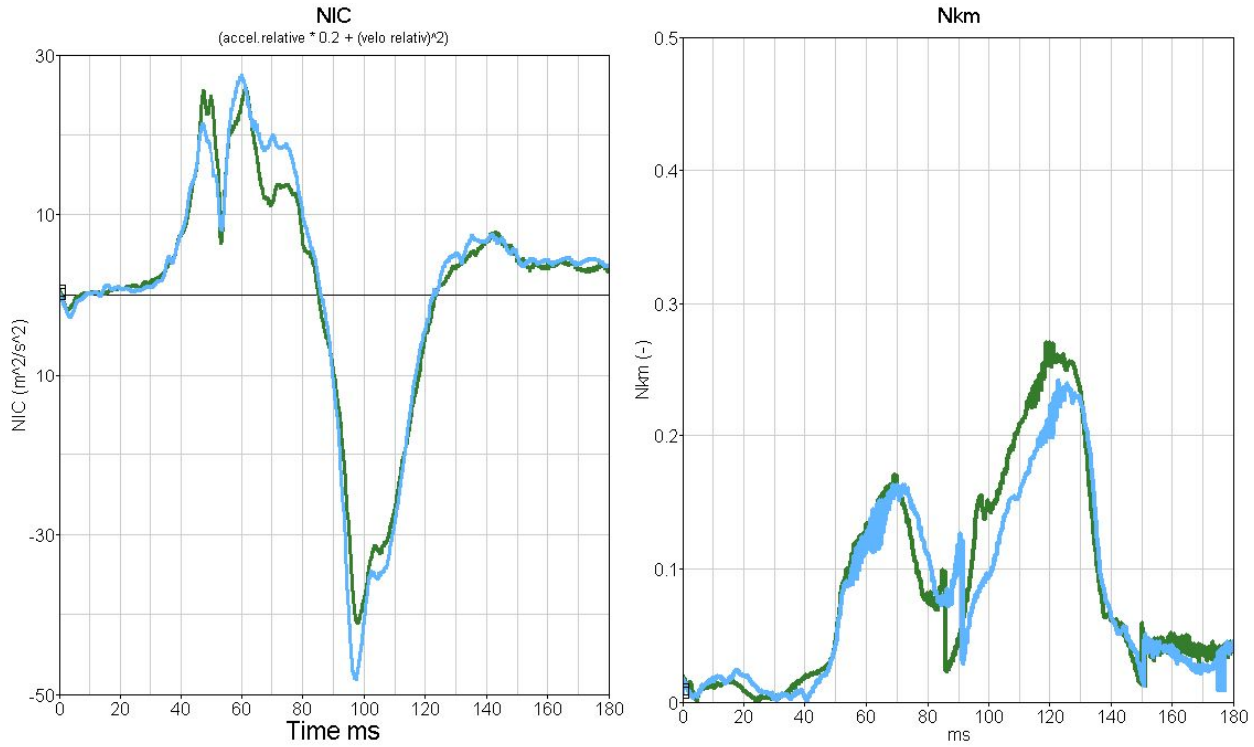


Figure 10: Results of NIC and Nkm. Light blue: rigid positioned; Green: deformable positioned under gravity load.

Results of EuroNCAP SRA16 Pulse

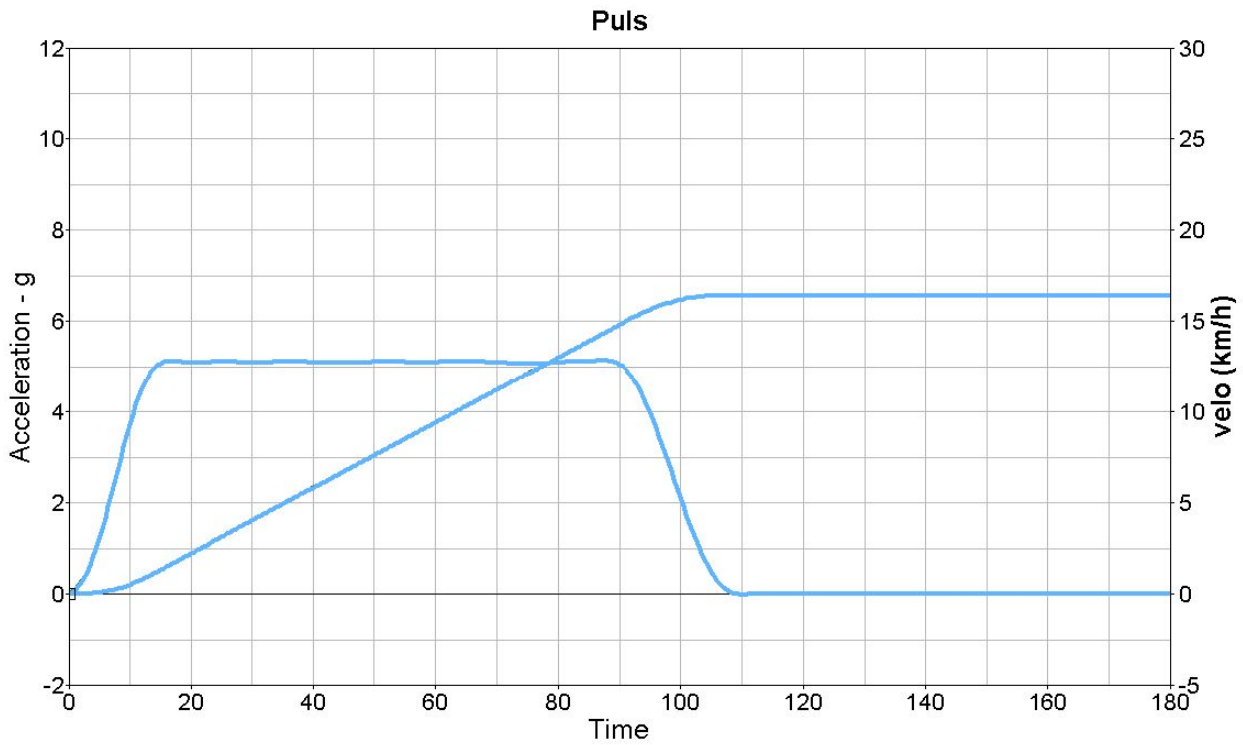


Figure 11: IIWPG Pulse of whiplash simulation.

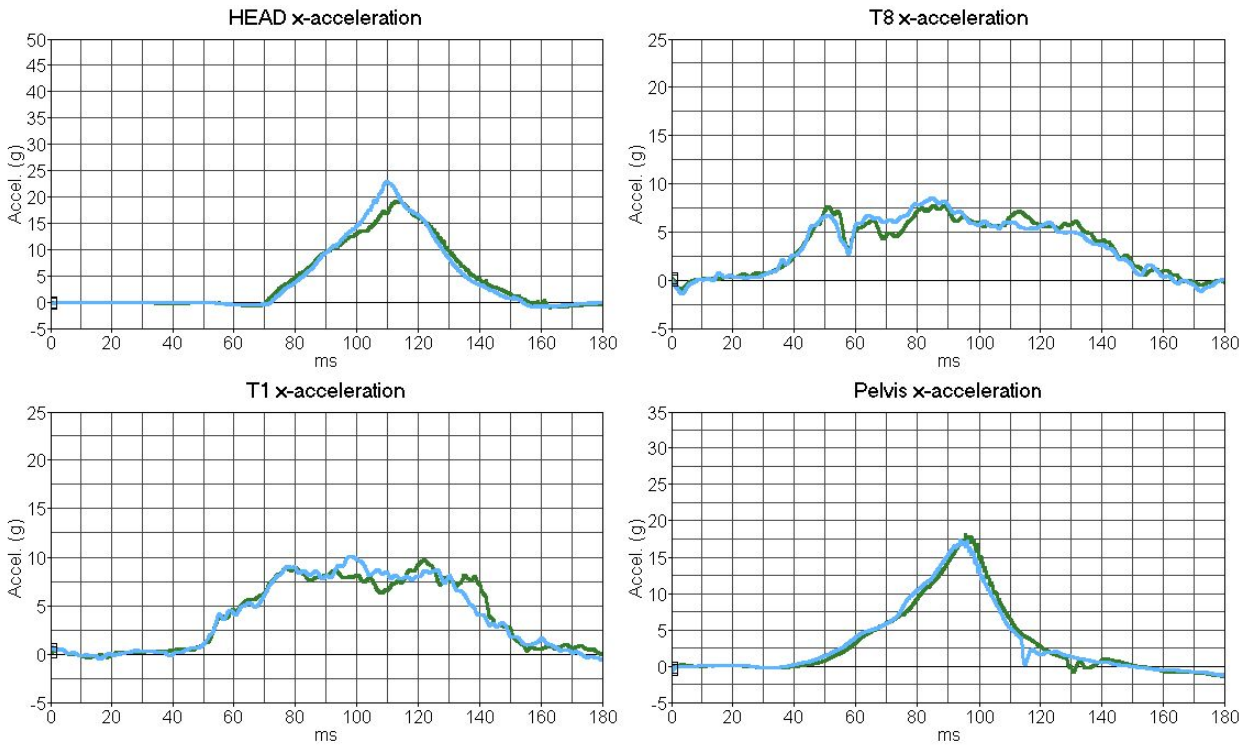


Figure 12: Results of Head, T1, T8 and pelvis x-acceleration. Light blue: rigid positioned; Green: deformable positioned under gravity load.

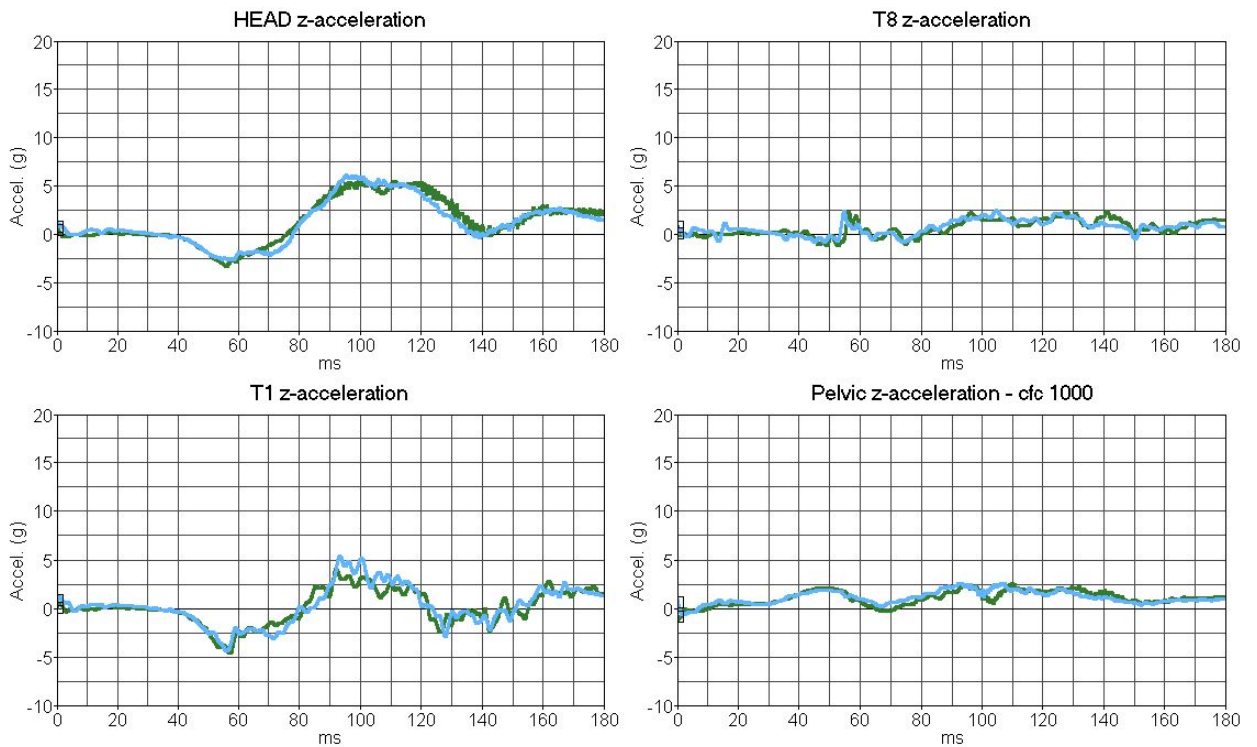


Figure 13: Results of Head, T1, T8 and pelvis z-acceleration. Light blue: rigid positioned; Green: deformable positioned under gravity load.

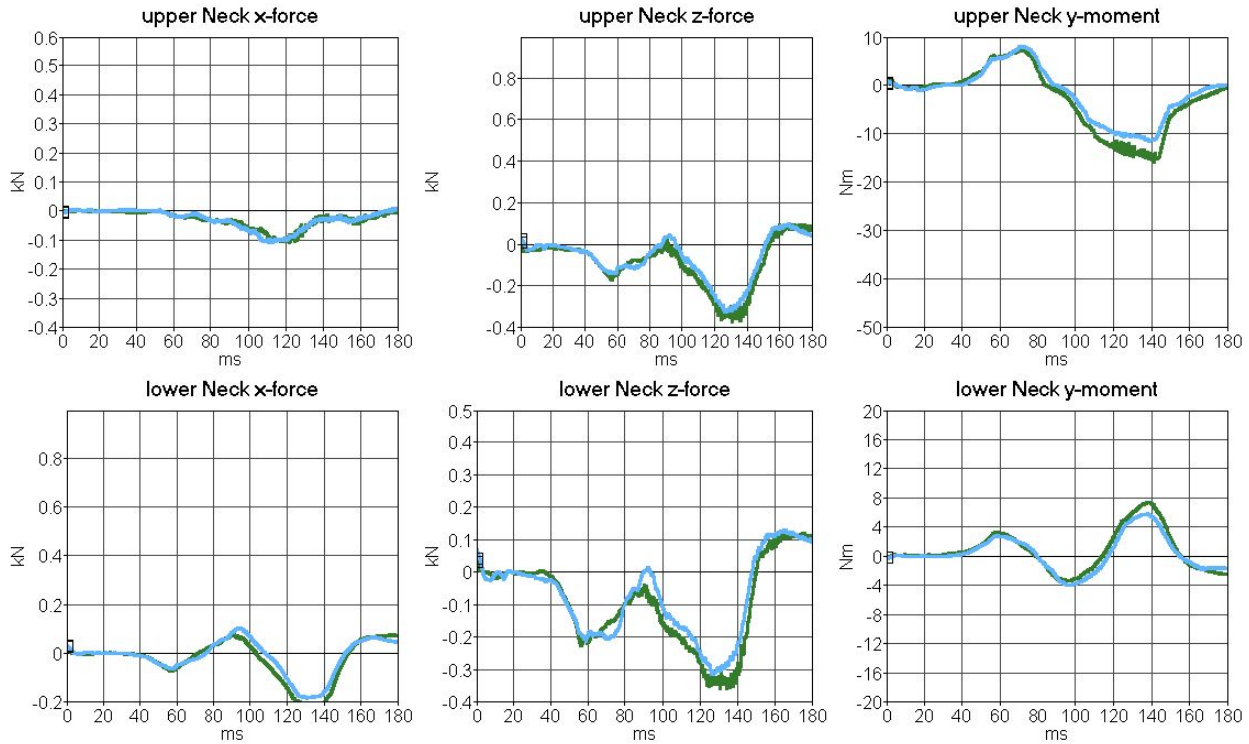


Figure 14: Results of upper and lower neck. Light blue: rigid positioned; Green: deformable positioned under gravity load.

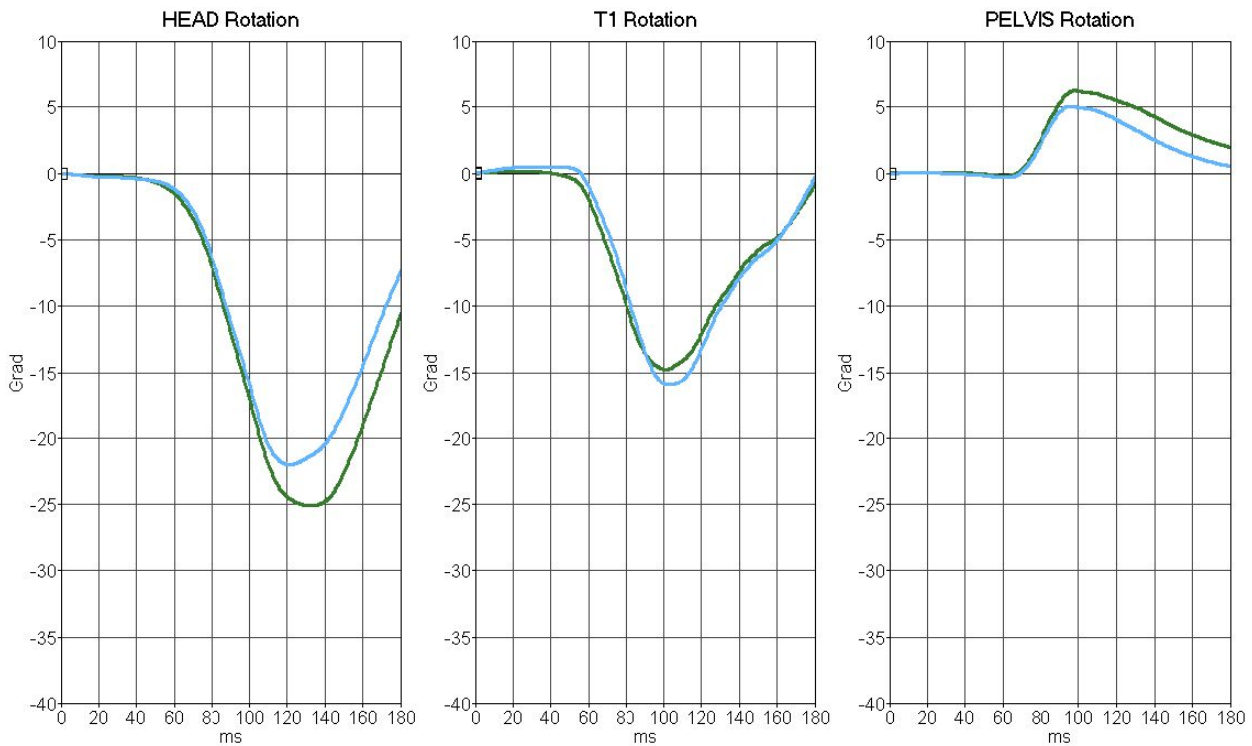


Figure 15: Results of Head, T1 and pelvis rotation. Light blue: rigid positioned; Green: deformable positioned under gravity load.

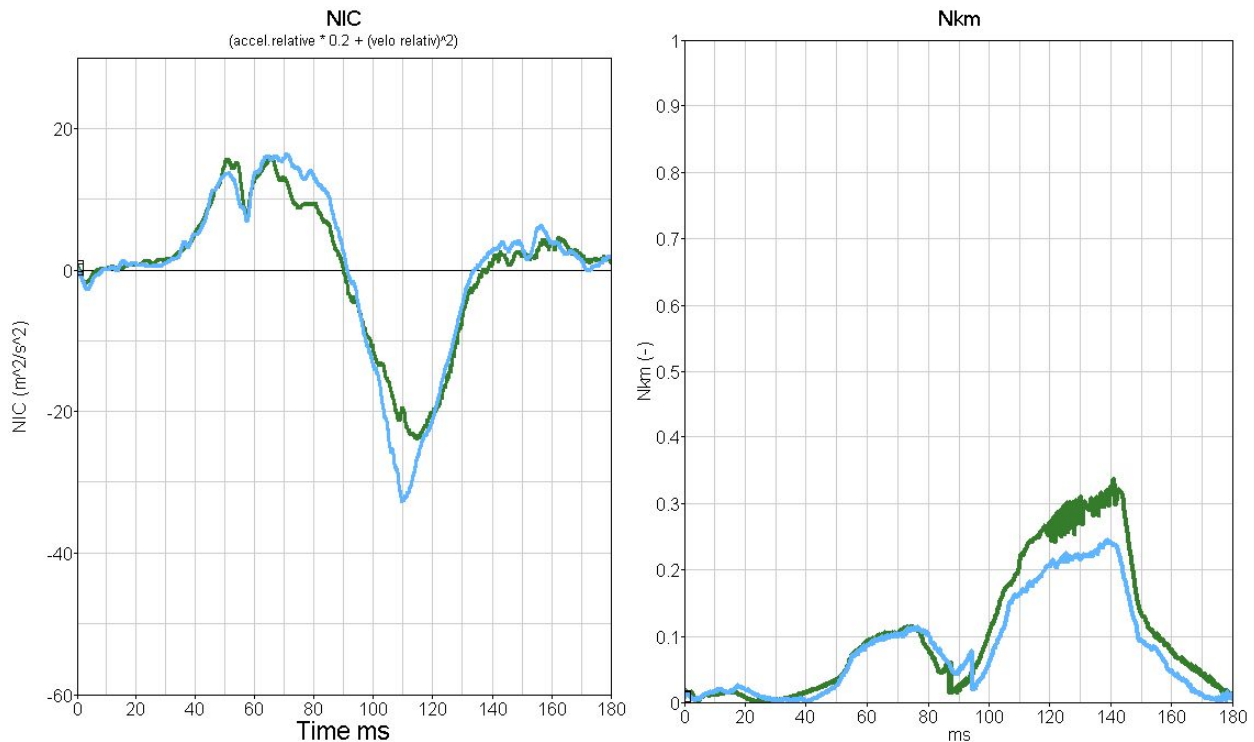


Figure 16: Results of NIC and Nkm. Light blue: rigid positioned; Green: deformable positioned under gravity load.

The results are very similar for most of the signals. The accelerations in x- and z- direction are very close and show only very small sensitivity to the positioning method.

Due to the fact, that the back set is very similar between the two positions, the contact time is also very close together. The upper and lower neck forces and moments show a little bit more difference. This small difference leads to bigger changes in the injury values of the BioRID-II, for example the Nkm value changes from 0.32 (BioRID-II positioned rigid) to 0.24 (BioRID-II positioned deformable). That a value of about 25% in the case of the SAR16 Pulse.

	NKM IIWPG-Pulse	NKM-SRA16-Pulse
Euro NCAP critical value	0.15 - 0.55 - 0.69	0.12 - 0.35 - 0.5
BioRID-II rigid positioned	0.26	0.32
BioRID-II deformable positioned	0.24	0.24
Difference in %	8%	25%

These changes in the NKM can lead to a better or also to a worse rating of a seat. The differences due to the positioning process are remarkable in the complete kinematic of the BioRID-II. The rotations of Head, T1 and pelvis are the signals which show the major differences. As a consequence, the kinematic is the main issue which influences the results of the BioRID-II. If the kinematic changes, it depends a lot on the seat geometries as to how the results of the BioRID-II change.

In our example the seat consists of a very flat Headrest. If the Headrest has a more curved shape, the results of the BioRID-II can change much more due to the positioning process, because of the different kinematics.

Influence of positioning in side impact

The BioRID-II seems to be the most sensitive model on positioning aspects. In our example, only an influence on the injury criteria was visible. To determine this influence in a different surrounding we have chosen the ES-2 Dummy in a normal sedan car in a pole test. The position itself is determined by a test. So there was no positioning of the SAE-Manikin done.

We have again chosen the two different seating procedures to position the Dummy into the seat. Firstly the dummy is put as rigid into the seat and second one the dummy drops down as fully deformable under gravity load in the fully deformable seat.

The figure below shows the result of the two different positioning methods. Light blue shows the result from the standard positioning process and green the positioning under gravity load.

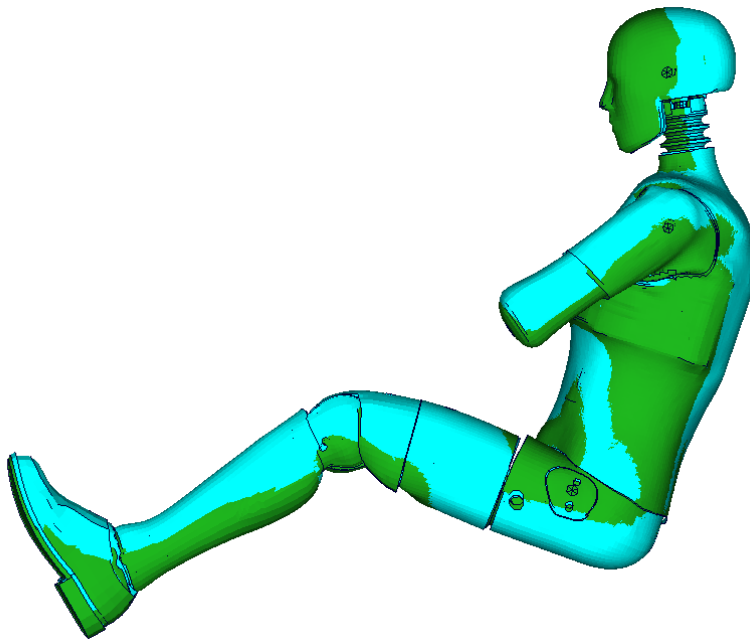


Figure 17: Comparison of ES-2 positions. Light blue: rigid positioned; Green: deformable positioned under gravity load.

It is visible that the positions are not much different. The position under gravity load has a slightly bigger pelvis angle and seems to sit a little bit lower. The Head/Neck seems to be a little bit more forward positioned.

The main dummy output results are compared in the following:

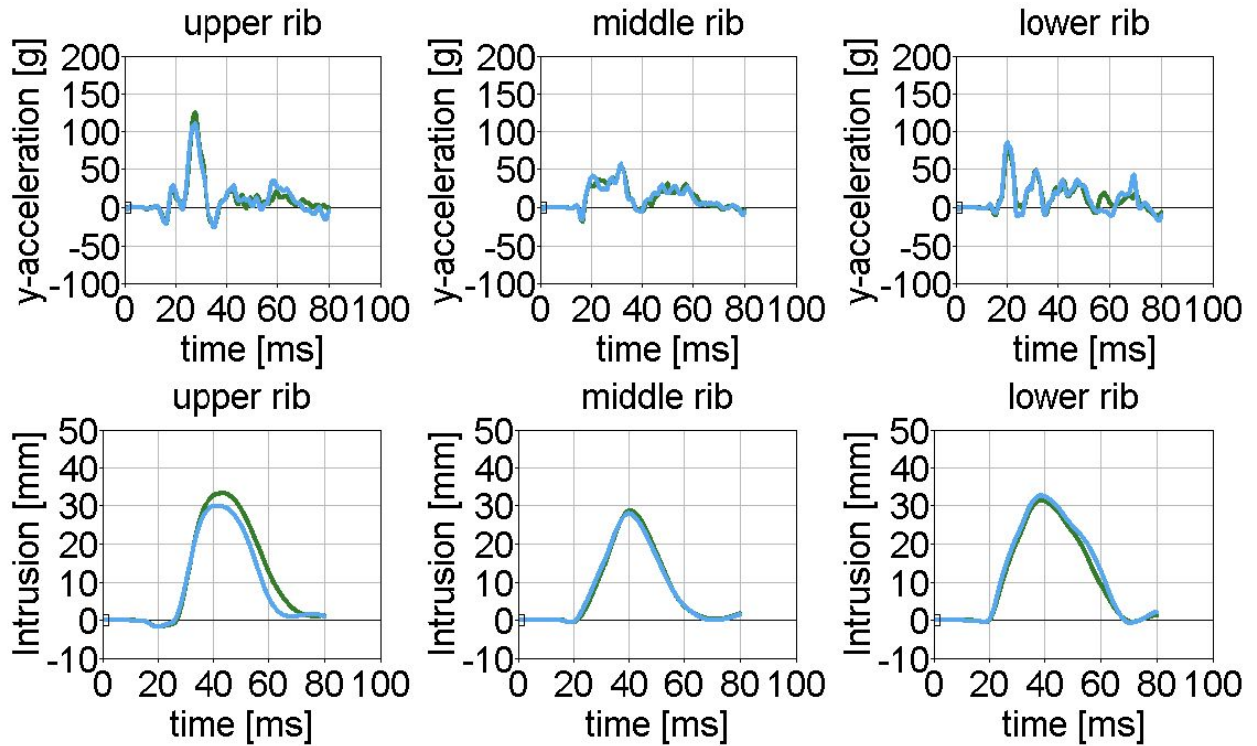


Figure 18: Results ES-2 ribs. Light blue: rigid positioned ; Green: deformable positioned under gravity load.

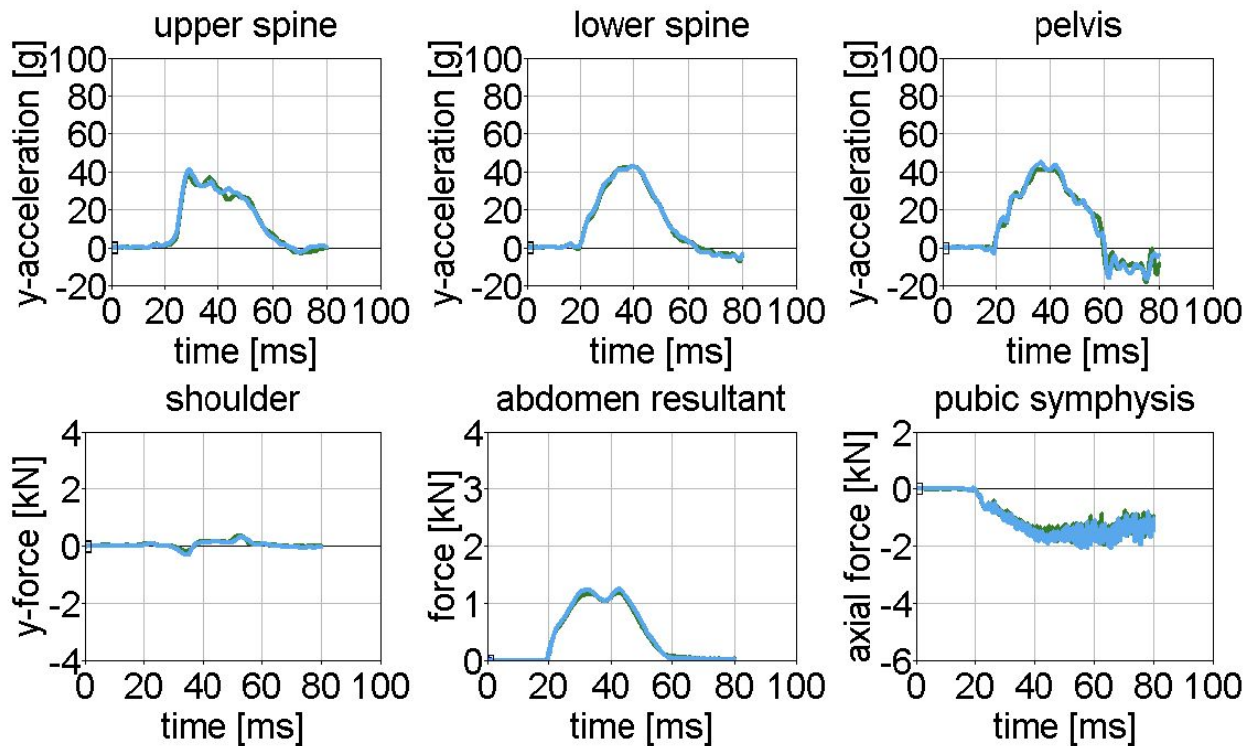


Figure 19: Results of ES-2 spine, pelvis, shoulder abdomen and pubic symphysis. Light blue: rigid positioned; Green: deformable positioned under gravity load.

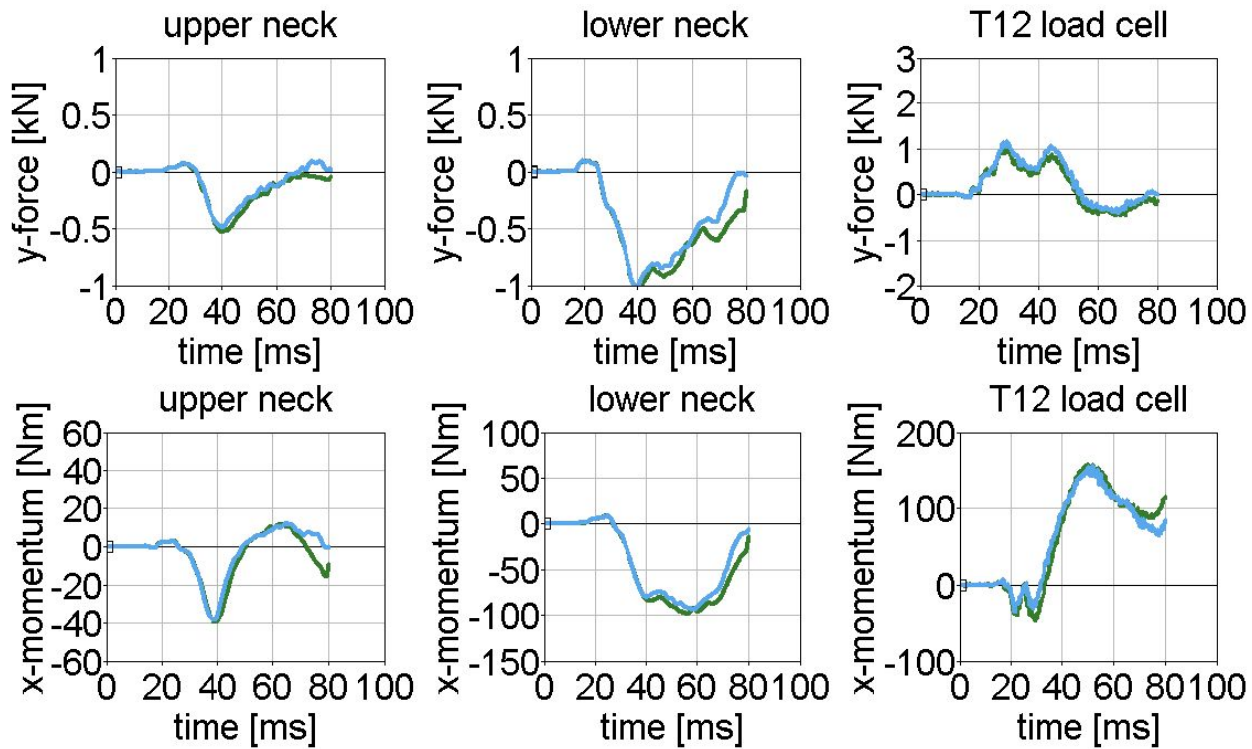


Figure 20: Results of ES-2 upper and lower neck. Light blue: rigid positioned; Green: deformable positioned under gravity load.

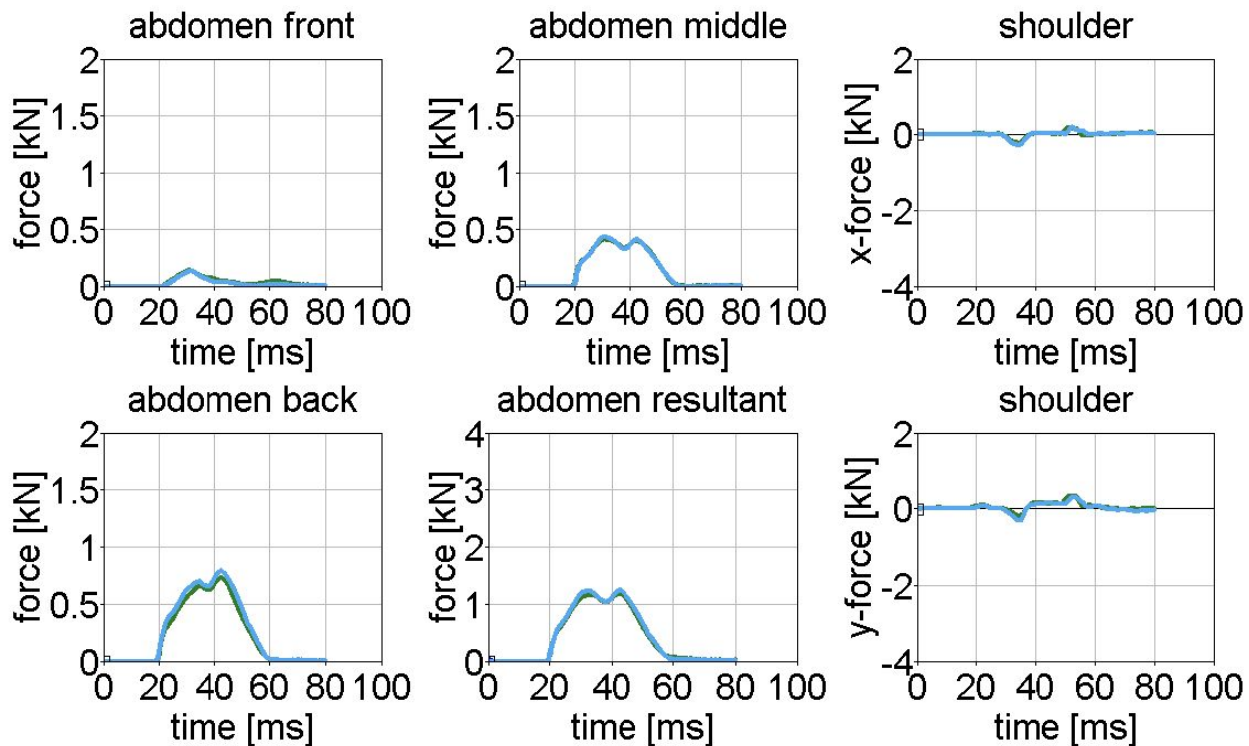


Figure 21: Results of ES-2 abdomen and shoulder. Light blue: rigid positioned; Green: deformable positioned under gravity load.

Despite the different head and neck positions, the results of them are very equivalent. Also in the lower body, the results are nearly the same.

Only the result of the upper rib is more different. The rigid positioned dummy has a higher rib deflection as the deformable positioned dummy.

This example shows again the sensitivity of the arm kinematic in side impact. In this example a minor positioning change leads to a different rib deflection from 34 mm to about 32 mm.

Also the example of the ES-2 shows that the influence in this example is not very big. But it also shows the sensitivity of the load cases. Due to the constant increasing claims to the models to get more accurate results, the positioning process has an increasing influence on the results.

Foresight of dummy positioning

The positioning process can have an influence on the Dummy results. The positioning of the Dummy for simulations should be done as close as possible to the test procedure. In this way the influence of the positioning process can be reduced.

The major disadvantage of the positioning under gravity load is the computational time. The computational time of the SAE-Manikin is about 5 hours on 192 cpus. The computational time for the BioRID-II positioning simulation takes about 8 hours and both simulations must be repeated several times.

A further disadvantage is that the process in physical test is a more static process and in our simulations it is a kind of dynamic dropping down of the Dummy.

Due to these reasons, the question arises for implicit simulations for dummy positioning. DYNAmore has begun doing this by testing out the dummies and also different seat models.

First step of the work is to position the SAE-Manikin into the simple seat by using implicit LS-DYNA solver. The first simulations are running very good.

The model being used is the same as was used in the beginning of the paper for the SAE-Manikin simulation under gravity load. The starting position of the SAE-Manikin was changed a little bit, in such a way that the contact of the SAE-Manikin to the Seat has a better convergence at the beginning.

The simulation runs as a static implicit analysis. Due to this, all dynamic behavior of the model has no influence on the results. This seems to be more close to the test process.

In the following figure a comparison of the implicit and explicit end position of the SAE-Manikin is depicted. The green model is the explicit and the yellow model is the implicit one.

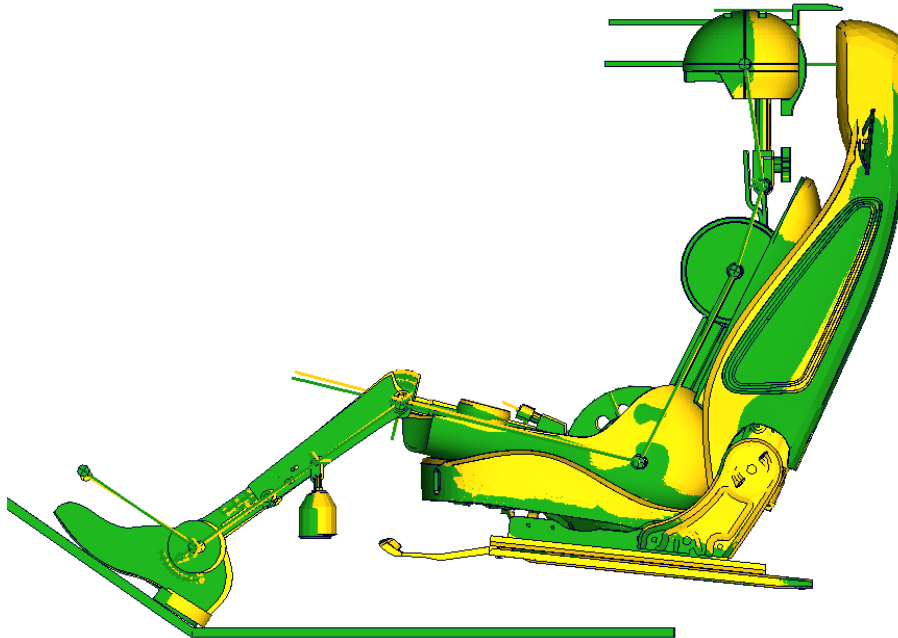


Figure 22: positions compared between explicit and implicit. GREEN: explicit; YELLOW: implicit.

H-Point location, torso angle and back set are very similar. So the dynamic effects of the explicit solutions seem not to have a major influence on the end position. But what about the computational time? The following Table compares the timings of the two simulations.

Model	number of cpus	elapsed time
SAE-Manikin explicit	8 cpus	10 hours 35 min
SAE-Manikin explicit	192 cpus	2 hours 33 min
SAE-Manikin implicit	8 cpus	3 hours 9 min

The comparison of the computational time indicates that the implicit solution can be reached in the same time as the explicit, but with the use of much lower computational resources. The implicit solution is about three times faster than the explicit one. So from the hardware state of today, the implicit simulation can be run easily on a local workstation without using a cluster.

Conclusion

The paper described different possibilities to put a dummy into a seat model and shows the influence on the results of these different methods.

The basis for these positioning simulations is the adjustment of the seat by using the SAE-Manikin. The SAE-Manikin is used in test to adjust the seat to the desired H-Point location and the back rest angle. The simulation is defined as close as possible to the test process to get the same position in simulation. For this seat adjustment simulations, the seat model must also be validated very accurately, especially the foam parts. If not, a comparable position to the test cannot be reached.

The influence of the positioning methods is very small on the majority of the dummy output signals. But in some cases we see a change of about 25% in some injury criteria. Also some individual signals can change, like the side impact example showed.

Due to the actual requirements to get much more accurate results from the simulations, this paper showed that the positioning process also has an influence on the results. Target should be to position the dummies in simulation in the same way like it is done in the test. So the positioning should not be carried out in an approximate manner. It seems that the complete behavior of the dummy under gravity load must be taken into account.

At the current state of the art, the simulation time for positioning under gravity load does not seem to be adaptive. The simulation time is too large for dummy positioning and users must wait a long time until the dummy is positioned correctly into the seat.

A big step forward is to simulate the positioning process using the implicit method. The computational time for that is only 30% of the explicit one.

For the future, dummy positioning using the implicit method should be investigated further. Especially the dummy models should be changed in this direction, so that they also can be used implicit.

This is what DYNAmore has started for the BioRID-II. The next release of the BioRID-II will also run implicit and the positioning process can then be done more accurately without losing too much time.

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