Advanced Methodology for Predictable Out-of-Position Simulation

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Abstract:

The development of occupant safety systems does not only require an accurate numerical In-Position model but also an Out-of-Position (OoP) simulation model. To meet the needs of OoP simulation Takata-Petri developed an advanced methodology to ensure a faster, better and more efficient system development. This methodology includes basically the device for thrust measurement, the Out-of-Position Pendulum, the ESI Sim-Folder and the CPM-Method. A lot of tests were conducted with flat and folded airbags. It could be proved that the numerical OoP models are able to predict the effects of folding pattern modifications. Although many additional challenges should be set, OoP simulation is not far away from a fully integrated development tool equal to current tools for In-Position simulation.

Keywords:

Inflator, Thrust measurement, Mass flow calculation, airbag folding, Petri-Folding, OoP pendulum, Out of position

1 Introduction

The development of occupant safety systems requires an accurate numerical Out-of-Position (OoP) simulation. Currently the Corpuscular-Method (CPM) seems to be a promising approach to predict the interaction process between airbag system and occupant in OoP situations [1]. However, the integration of OoP simulation as a fully integrated development tool needs to accomplish certain challenges. On the one hand OoP tests have a higher variation in comparison to In-Position loadcases. Hence, it's often difficult to evaluate the predictability of the OoP simulation model. On the other hand the efforts to set up an OoP model are much higher compared to numerical In-Position models. Moreover, the experience has shown that the model input data must be much more detailed and precise.
To meet the needs of OoP simulation Takata-Petri developed an advanced methodology to ensure a faster, better and more efficient system development.

2 Basics of Advanced Methodology

2.1 Thrust measurement

One of the most relevant and sensitive steps for OoP simulation is the calculation of the inflator mass flow. Currently the tank test with its average temperature method for mass flow calculation is state of the art. For In-Position simulation it seems to be an accurate and reliable method. Alternatively Takata-Petri developed a thrust measurement method [2] by the means of numerical simulation (see Figure 1). The advantages of this test method are the simple test setup and the high quality of the results, whereby a special in-house-software has been developed to generate relevant simulation input data directly after the test procedure. Additionally the thrust measurement method represents a proper validation possibility as the boundaries are more comparable to those of an airbag system. As can be seen in Figure 2 the calculation of thrust measurement by CPM shows a good correlation to the test.

Figure 1: Thrust measurement test setup

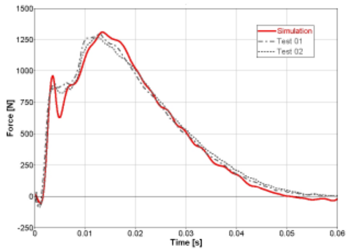

Figure 2: Thrust forces of test and simulation (CPM)

2.2 Airbag folding

Takata-Petri mostly uses the so-called Petri-Folding pattern [3]. To fold the numerical airbag model in realistic manner that is comparable to the hardware the whole folding process affected by the sliders has to be simulated. To ensure flexibility and efficiency Takata-Petri uses the Sim-Folder® [4], which is a simulation-based airbag folder supporting not only the folding simulation itself but also major process steps like stitching of flat airbag parts, inserting the inflator into the airbag or pushing the folded package into the module housing. More reliability during setting up the model is given through the integrated preview function.

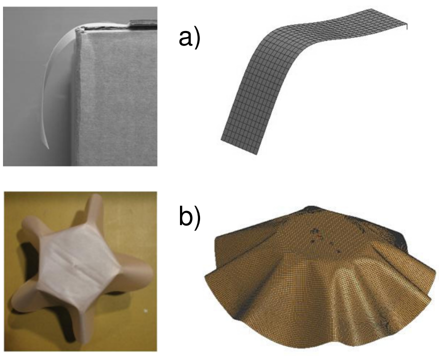

Figure 3: Correlation between test and simulation
a) Deflexion test b) Drape test

For an accurate folding simulation precise fabric input data is required. Meanwhile biaxial fabric tests and the picture frame test are standard methods for fabric validation. But folding simulation praxis has shown that bending characteristic of fabric influences the folding stability and therefore the results significantly. For this reason two more tests can be recommended: the bending test [5] and the drape test [6]. The aim of the first test is to measure the deflexion whereas the second test allows the determination of the fabric drape which is mainly influenced by the bending stiffness. To address bending stiffness it is necessary to superimpose membrane elements with shells. Figure 3 shows the correlation of bending, drape test and simulation.

2.3 Out-of-Position Dummy Pendulum

It is obvious that the OoP test procedure should be simplified to reduce efforts of both simulation and testing. Main simplification is the transformation of the H305 dummy into a pendulum, which rotates around the H-Point [7]. The pendulum is equipped with a detailed device representing the masses of pelvis and legs. It offers several advantages:

- Positioning according to the FMVSS208 specifications can be done very fast and easily.
- High reproducibility of tests because of minor influencing factors
- Quick set-up of numerical model as only the steering wheel model with its airbag system is needed only.
- Detailed reconstruction of pendulum test kinematics by LS-DYNA® since rotation point, upper torso and head are equipped with accelerometers and gyro sensors.

In order to prepare the model for the numerical simulation the modified H305-FTSS-Dummy [8] has been applied. All body parts below the lower lumbar spine were eliminated. The pendulum can be positioned easily by current pre-processors through defining the angles of rotation point, thorax and head. Figure 4 shows the OoP pendulum and the corresponding LS-DYNA® model.

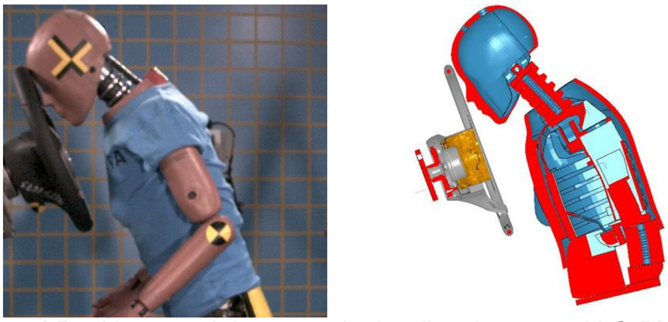

Figure 4: Out-of-Position pendulum test device (hardware and LS-DYNA3D model)

3 Predictability of OoP Simulation

In this study three series of OoP pendulum tests where conducted to evaluate the predictability of OoP simulation (see Figure 5):

- Series I: OoP pendulum test with flat airbag
- Series II: OoP pendulum test with Petri-Folding
- Series III: OoP pendulum test with modified Petri-Folding

All tests are without cover and the airbag housing mounted on a production steering wheel is undeformable. The first tests series with flat airbags where conducted to exclude the influence of folding pattern and to have a first estimation of correlation quality. In the series II the airbag was folded completely by sliders (Petri-Folding) whereby last test series was with modified slider shapes.

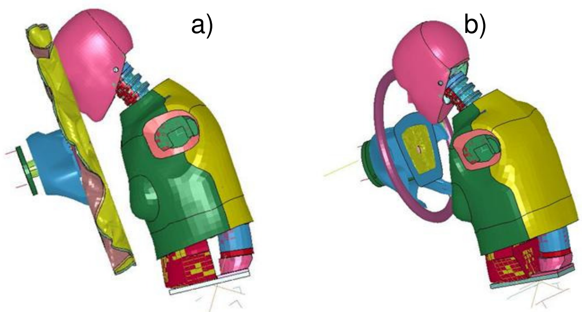

Figure 5: Numerical model of OoP pendulum with a) flat airbag b) folded bag

Figure 6 shows test average and simulation curves and kinematics for series I. **It should be mentioned that this good correlation quality was achieved without any validation process of the whole model.** Same result quality could be obtained for series II and III.

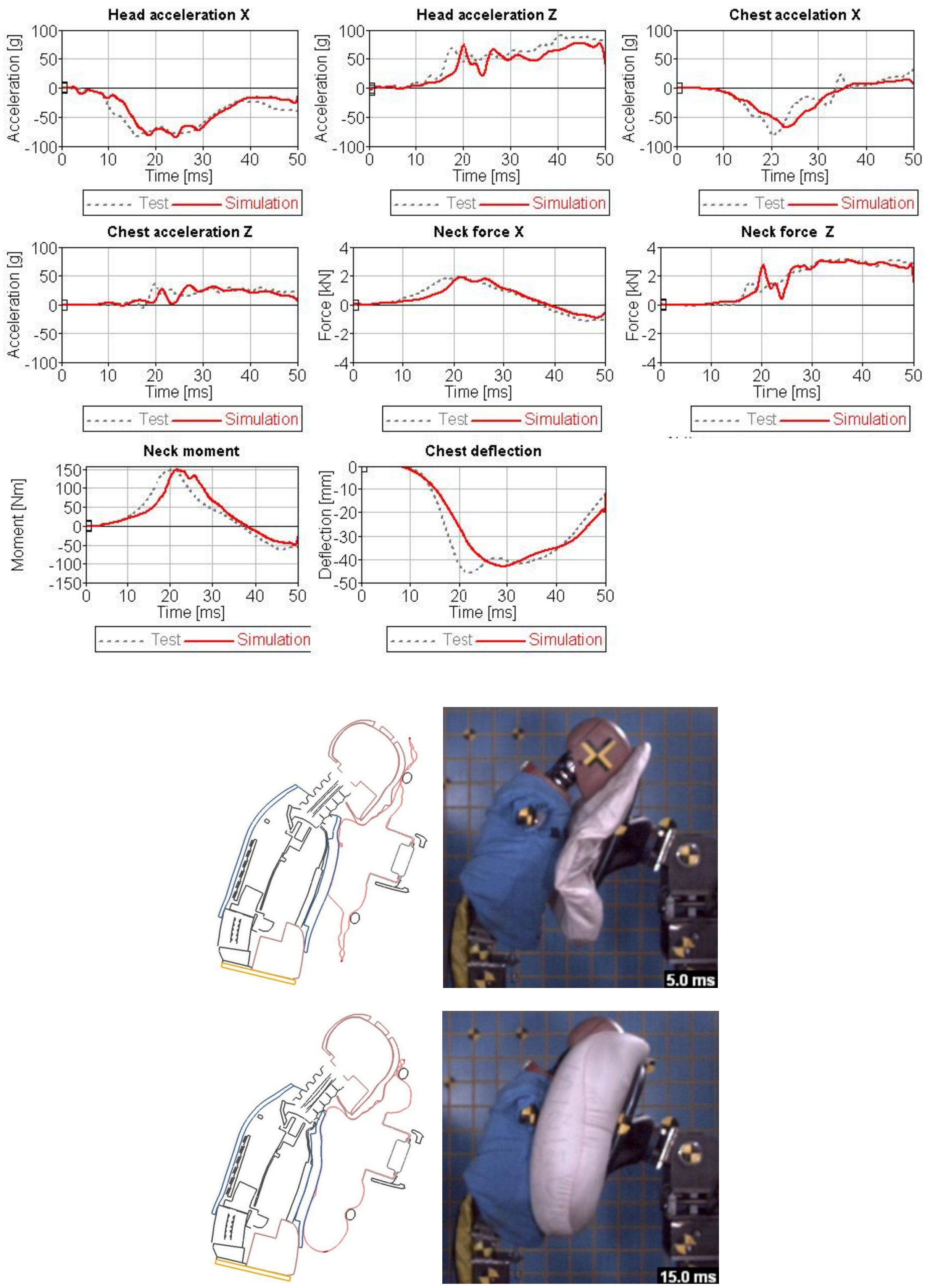

Figure 6: Correlation between test curves (average) and simulation plus OoP pendulum kinematics

The next goal was to decide whether the numerical OoP models are able to show same trends like tests because of the modifications in the folding pattern. Therefore test series II were compared with series III, whereby the injury criteria were normalized to reference values according FMVSS208 for a better weighting of decreasing/increasing of injury loads. Both test and simulation are showing same relevant mentionable trends (Figure 7). These are mainly the reduction neck tension forces by approx.

30% and an increase of both HIC 15 and neck flexion moment. That means that changing the shape of the sliders will decrease neck tension forces significantly but will increase head and neck flexion loads. Overall the numerical model predicts same trends as the tests.

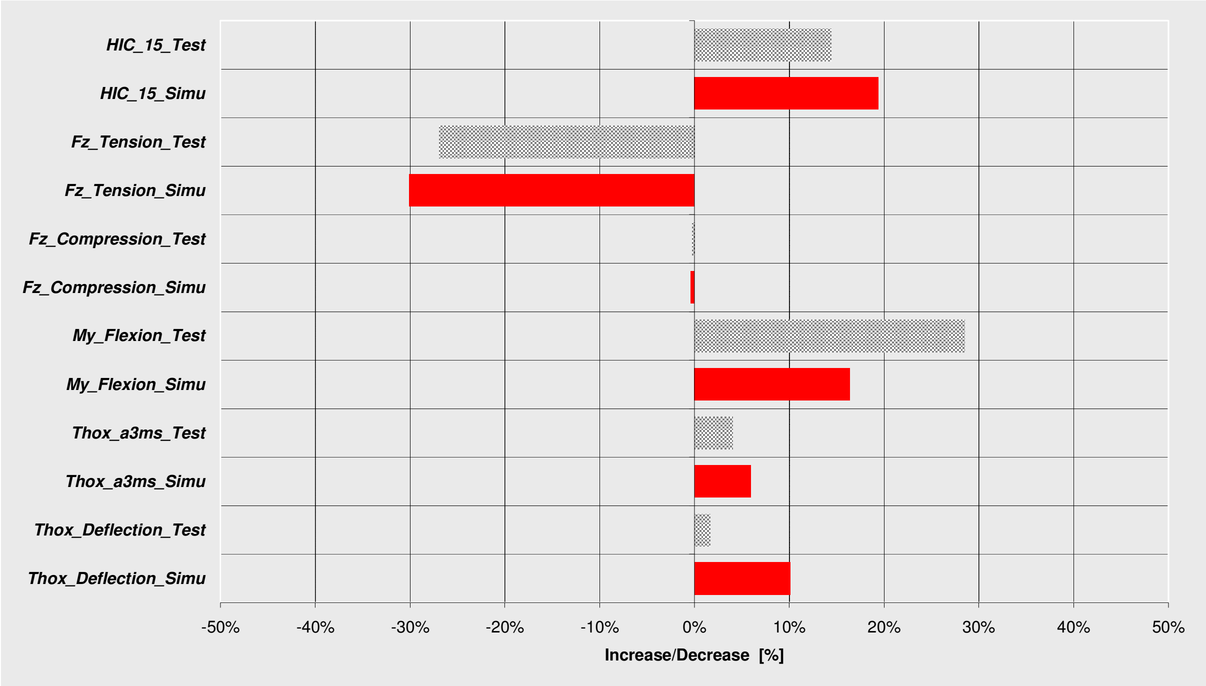

Figure 7: Proportional changes of test and simulation (series III compared to series II)

4 Conclusions

With advanced methodology of Takata-Petri which includes basically the device for thrust measurement, the Out-of-Position Pendulum, the LS-DYNA® CPM-Method and the Sim-Folder® of ESI a benchmark in Out-of-Position simulation has been set. The advanced method allows faster and much more predictable statements in a very early step of the airbag system development. Although many additional challenges should be set, OoP simulation is not far away from a fully integrated development tool equal to current tools for In-Position simulation.

5 References

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