Project, funded by the German National Ministry of Research: Advanced laminated glass modelling for safety FEA

Dr. Martin Konrad, Mark Gevers

TECOSIM Technische Simulation GmbH, Köln, Germany

Abstract:

Laminated glass is used especially for windscreens and sun-roofs in automotive industry. Pedestrian safety and side impact resistance are in focus of the automotive development. For simulation of head impact on windscreen, side and pole impact or roof crush a predictive model of the laminated glass parts is needed. TECOSIM has developed several glass models in deep cooperation with OEMs. For further improvement of the laminated glass model we establish a funded research project. An advanced laminated glass model developed at TECOSIM will respect more physical parameters as state-of-the-art models, e.g. pre-stress situation if the windscreen and shear stiffness of the PVB layer. All knowledge will be carried over to all mayor crash solvers, e.g. LS-DYNA. The presentation shows the actual status of the research project at TECOSIM.

Keywords:

Windscreen, head impact, roof crush, laminated glass, safety.

1 Scope of work

1.1 Improve predictability of glass model

Regarding pedestrian protection the head impact on the windscreen of a car is focused by several legal requirements and many consumer tests (NCAP) all over the world.

Figure 1: Head impact on windscreen

For a predictive finite element analysis an improved laminated glass model of the windscreen is needed.

This investigation is based on an R&D project with FORD using RADIOSS. For further improvements TECOSM establishes a funded project.

Within this project we will investigate on additional parameters and carry over the model to all mayor explicit FEA solver, starting with LS-DYNA. PAM-CRASH and ABAQUS will follow until spring 2011.

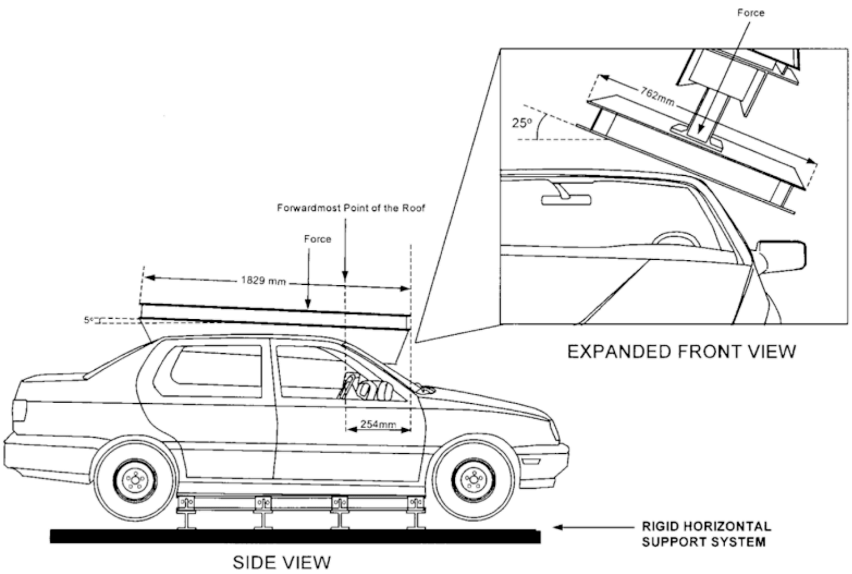

Figure 2: roof crush

Because of respecting physical laminated glass properties the advanced model also improves the behaviour of the windscreen under quasi-static roof crush load case.

1.2 Targets

- Improve laminated glass model for windshield modelling to get better test correlation
- Respect glass failure
- One windshield model for all load cases
- Model has to respecting turn-around-time requirements for full vehicle CAE analysis – no negative effect on time step allowed

2 Modelling technique

2.1 Element formulation

Advanced laminated glass model has to respect:
- One model for all load cases
- Turn-around-time requirements for full vehicle CAE analysis – no negative effect on time step allowed

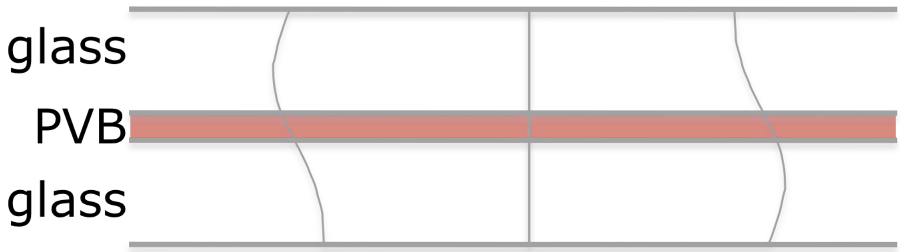

Figure 3: laminated glass of a windscreen

Therefore we choose multi layered shell / user defined integration rule to improve laminated glass model respecting layered rupture of the inner and outer glass as the first solution.

2.2 Mesh influence

We compare the simple elasto-plastic model used by several customers with an advanced meshing strategy respecting glass failure and crack propagation.

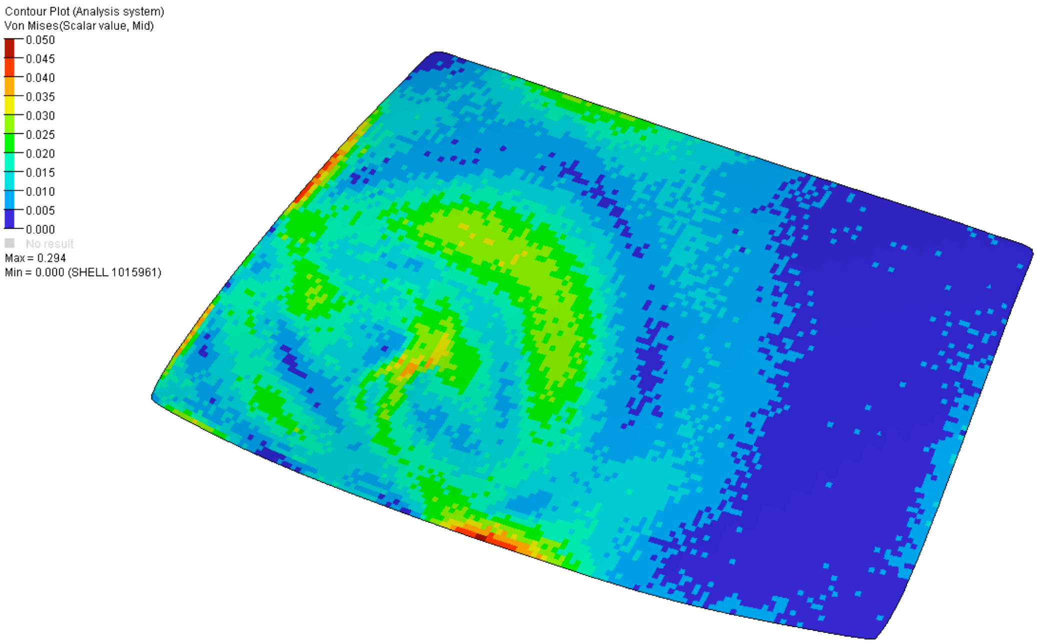

Figure 4: Simple elasto-plastic model with regular quad mesh

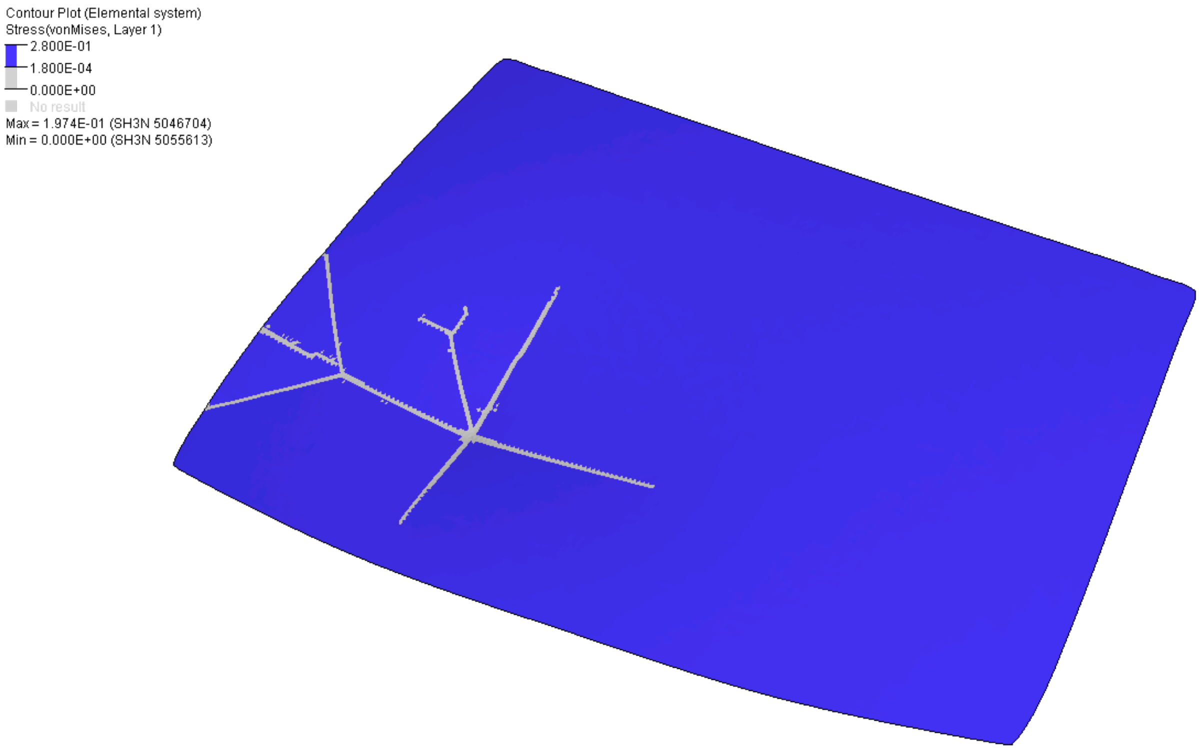

Figure 5: Improved laminated glass model respecting rupture with regular tria mesh

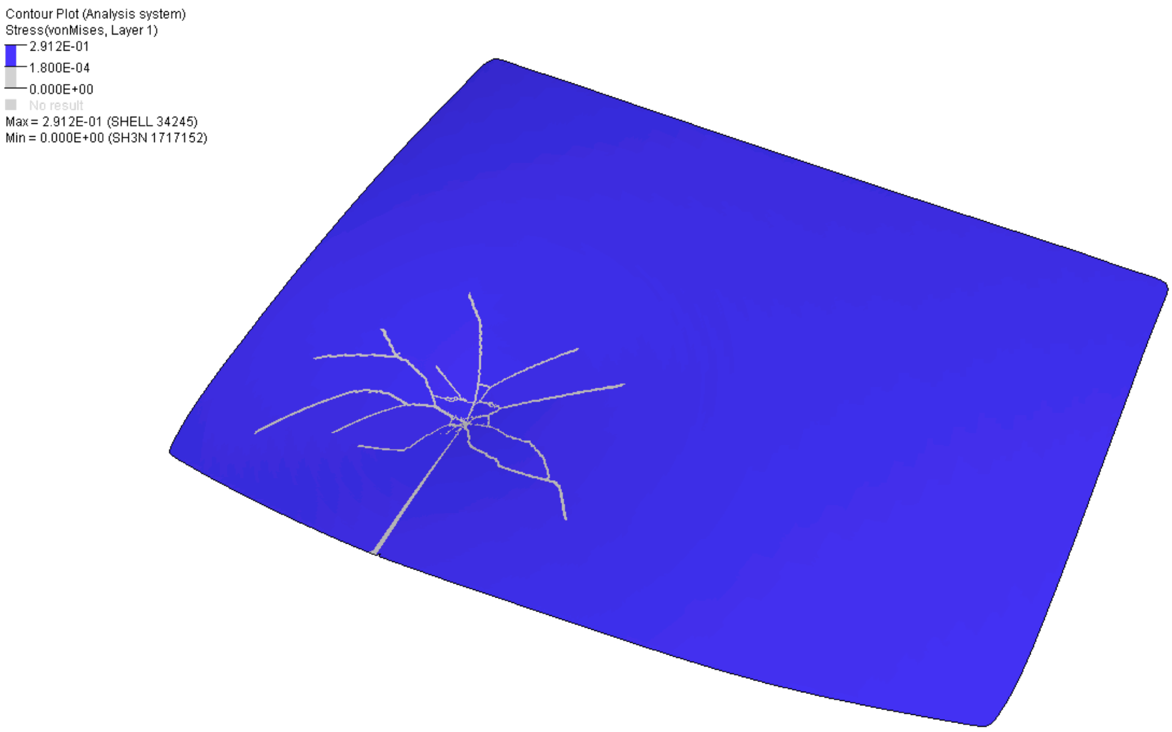

Figure 6: Improved laminated glass model respecting rupture with regular tria mesh

Best visual results with circular tria mesh around impact point.

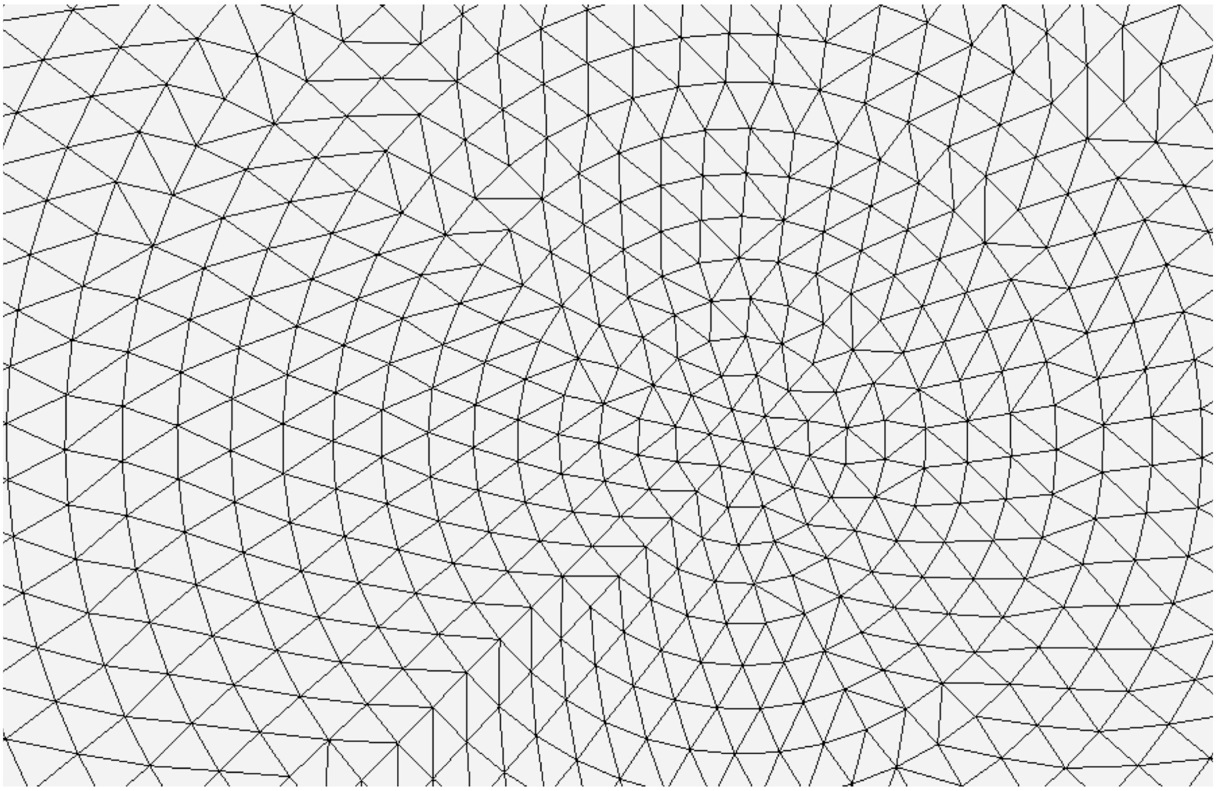

Figure 7: The mesh was generated using HyperMesh, controlled by TEC|WORX automation technology

All benchmark simulations are based on this circular tria mesh (see figure 7).

3 Analysis

3.1 Windshield in vehicle assembly – head impact

TECOSIM starts the investigation in deep cooperation with FORD with a Mondeo component model (model 2007).

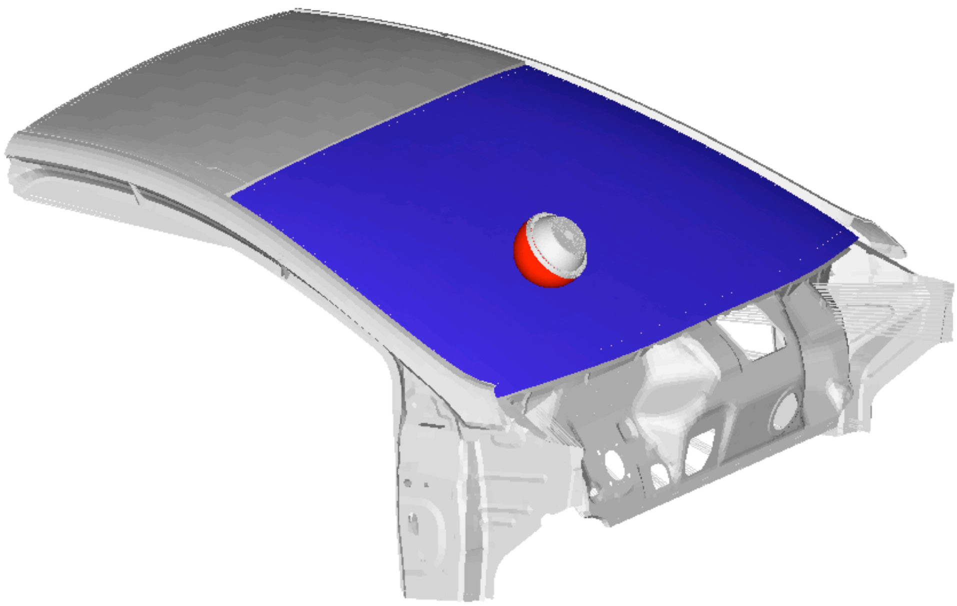

Figure 8: FORD Mondeo (model 2007)

In the first loops we concentrate in investigation on

- mesh desity
- mesh type
- glass properties
- PVB-layer properties
- number of integration points
- over thickness

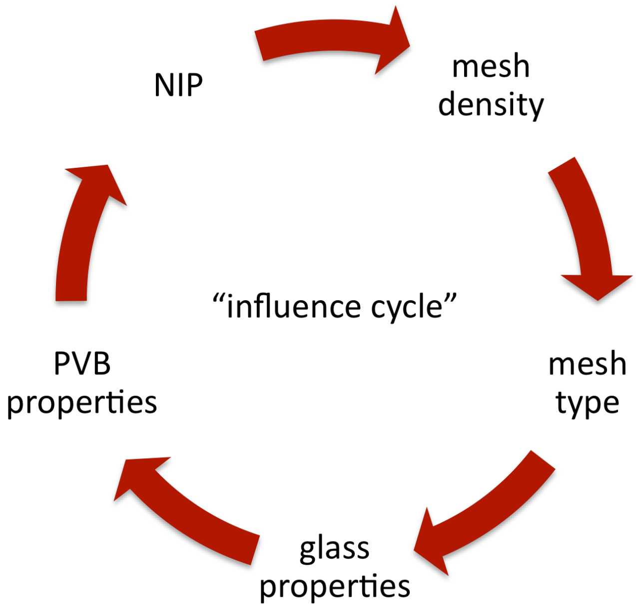

Figure 9: influence cycle – first investigation loop

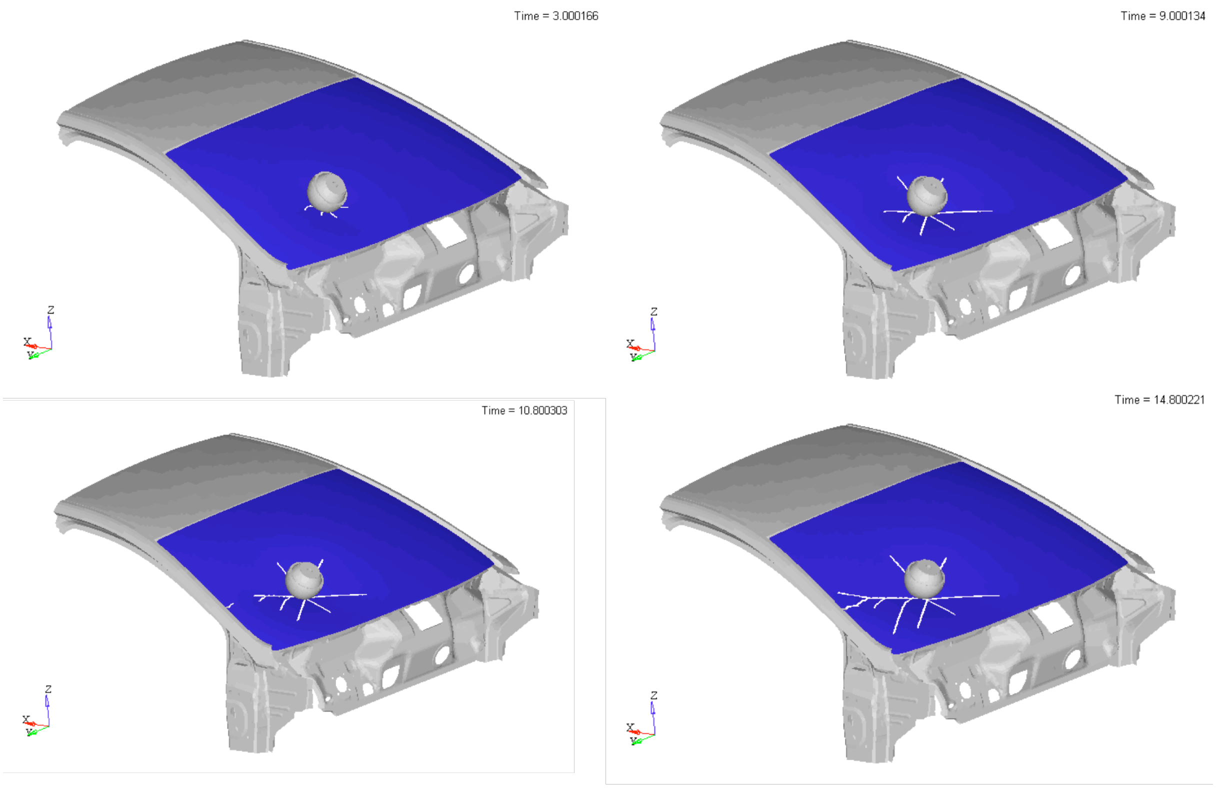

Figure 10: Windscreen circular tria mesh (around impact point)

As result we found a highly improved model behaviour compared to current state-of-the-art modelling technique (see figure 11).

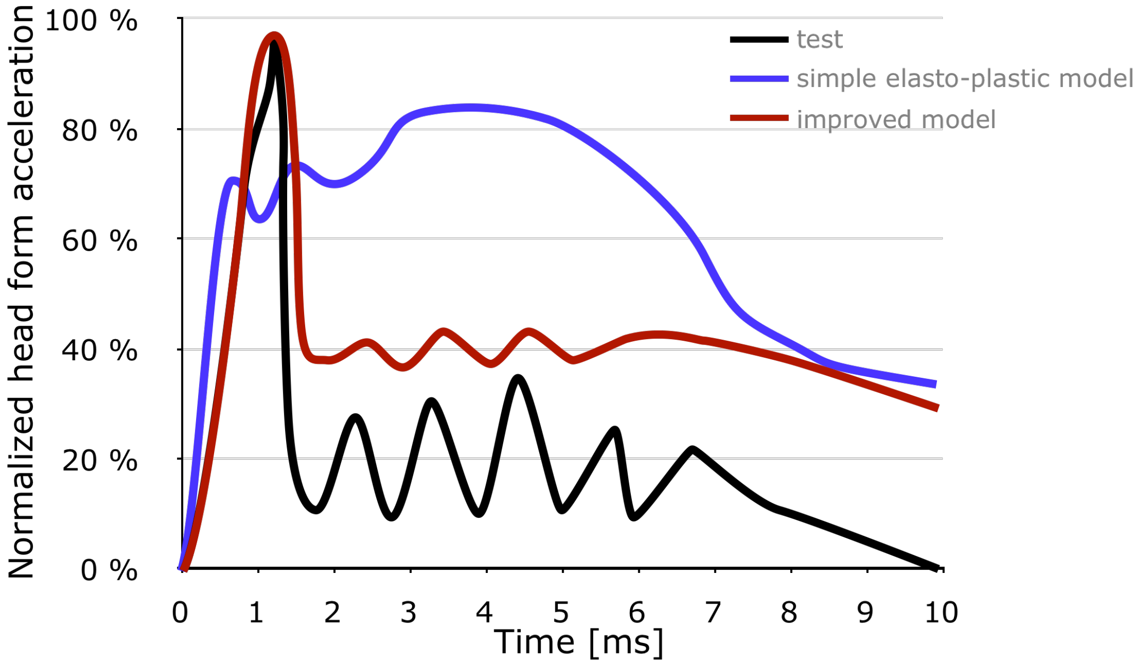

Figure 11: normalized head form acceleration over impact time

The improved model shows

- High influence of glass rupture stress on first head form acceleration
- Influence of glass rupture stress on "after first peak area" is less
- Influence of PVB stiffness is less
- Influence of mesh technique is less:
- So regular tria mesh (layered shells) usable.

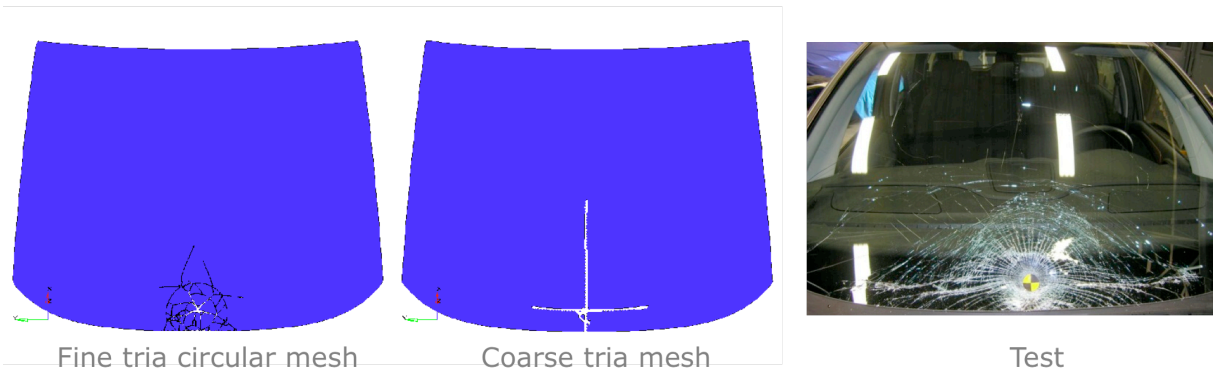

Figure 12: rupture behaviour (impact in cowl area)

But the rupture area in test is much bigger than in simulation (see figure 12). The influence of non-physical rupture direction to head form acceleration is less. We think the smaller rupture area results in too high head form acceleration after first peak (see figure 11).

3.2 Roof crush

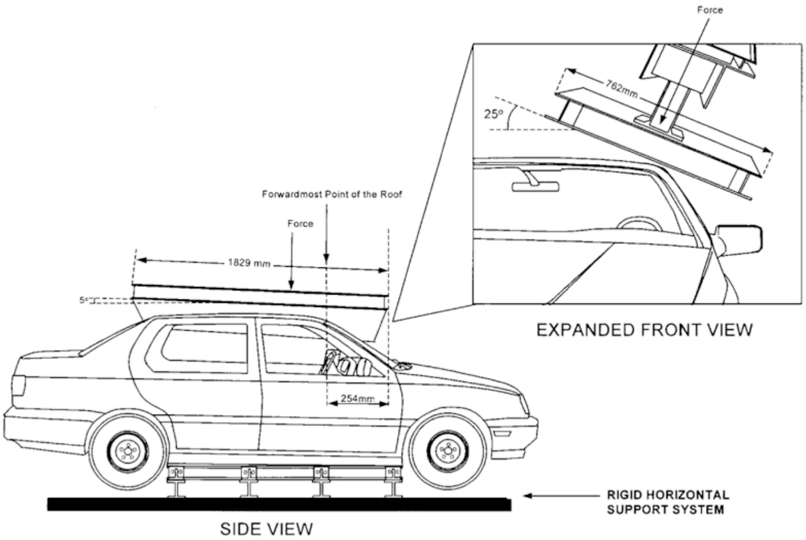

Figure 13: roof crush load case

For roof crush load case the advanced laminated glass model show significant improvement of model predictability without any changes of the windscreen model used for head impact (see figure 14).

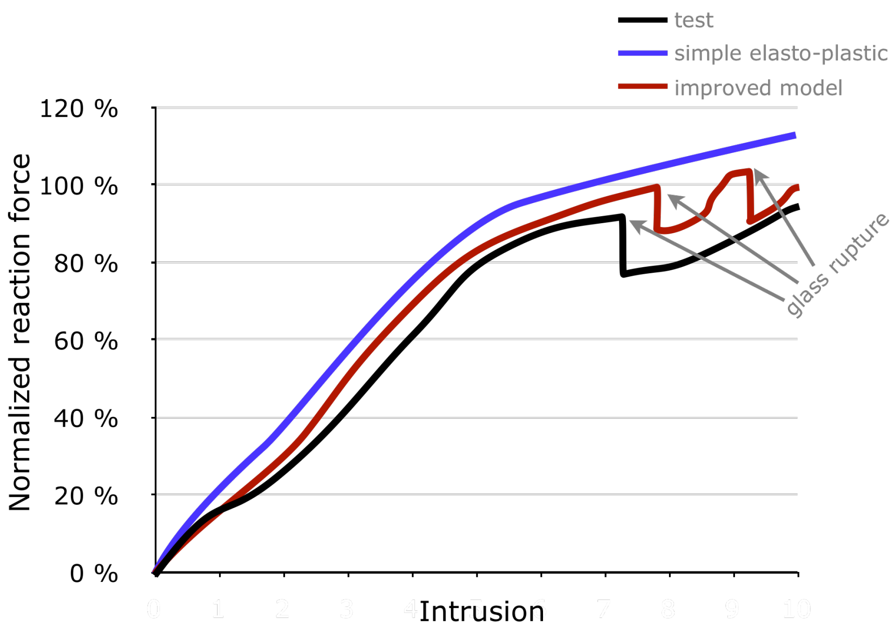

Figure 14: roof crush – normalized reaction force over intrusion

4 Conclusion

- Advanced laminated glass modelling technique gives high improvements in head form impact simulation.
- Modelling technique with multi layered shell respecting laminated glass layers (glass-PVB-glass) works with physical material properties (nearly no tuning needed).
- Fulfilling full vehicle time step is possible.
- The improved model has also a positive impact on roof crush load case.
- The addition of model-setup and simulation using multi-layered shells time is less.
- Behaviour after first breakage should be improved in further investigation – PVB influence seems to be less for model used in this investigation.
- Additional influence parameters have to be found.

5 Outlook

5.1 Next steps

- To improve the laminated glass behaviour after first breakage a deeper understanding of pre-stress resulting from production process and assembly is needed.

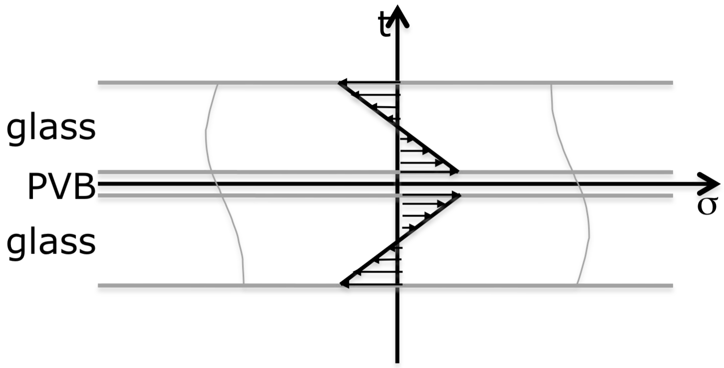

Figure 15: pre-stresses in laminated glass because of production process

- Mapping of pre-stress data to the different integration points over the shell thickness must be possible for the laminated shell property.
- Using shell elements might not be sufficient because pre-stress is a non-thin phenomena.
- Different rupture strain of glass in traction and compression direction has to be respected.

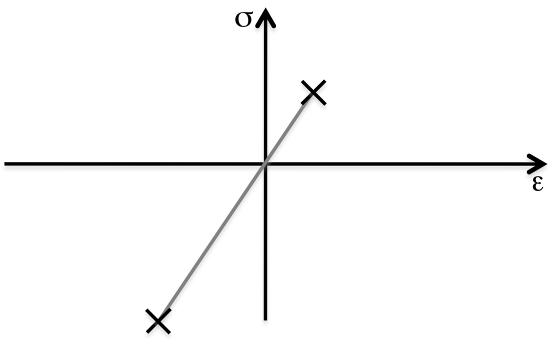

Figure 16: different glass rupture stress in traction and compression direction

- Decoupling of outer and inner glass sheet has to be realized because of distribution of stress under bending load

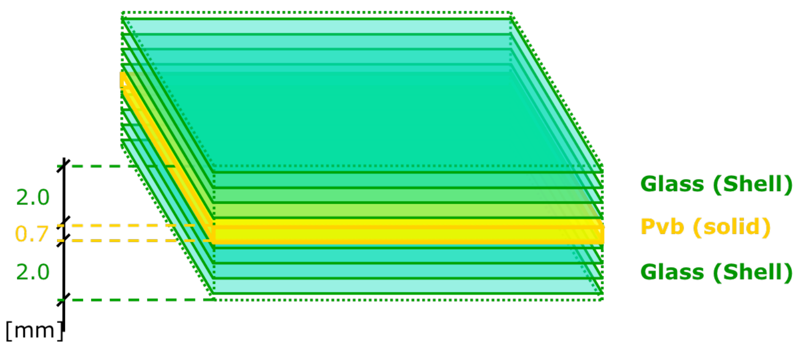

Figure 17: next step: shell-solid-shell model

- Respecting physical properties and understanding physical phenomena
- will result in further improvement of glass model with a highly predictive behaviour for all load cases

5.2 Influence parameters on laminated glass model

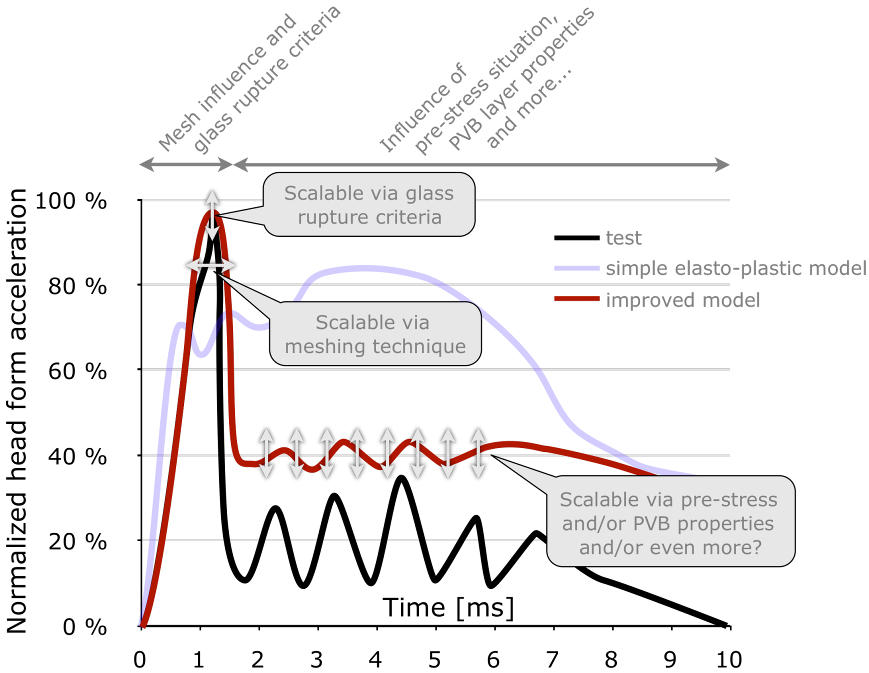

Figure 18: influence areas of different parameters

For further model improvements a deeper understanding of internal physical behaviour of the laminated glass is needed. Additional parameters have to be respected. Because of the higher complexity of the "influence cycle" (compare figure 9 with figure 19) for further improvements use of statistical analysis is needed. TECOSIM currently investigates on an automatic optimization process of the known physical parameters to improved laminated glass model.

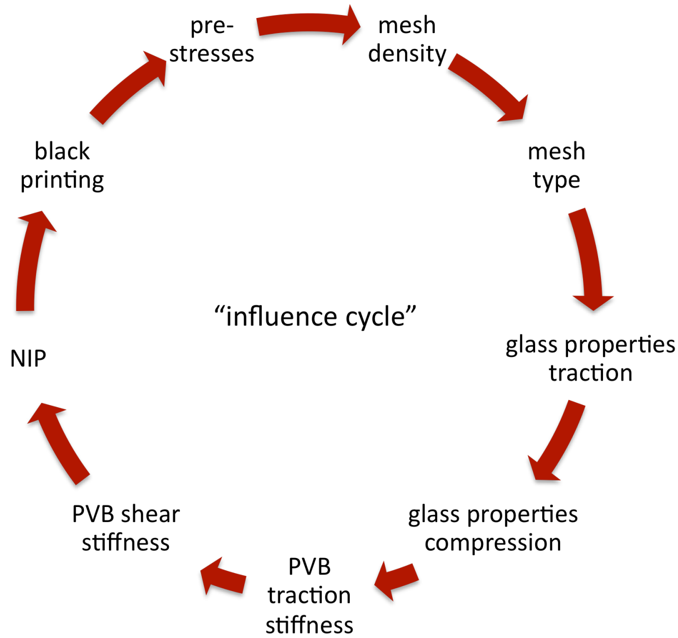

Figure 19: influence cycle with additional parameters

So there is more to come – stay tuned.