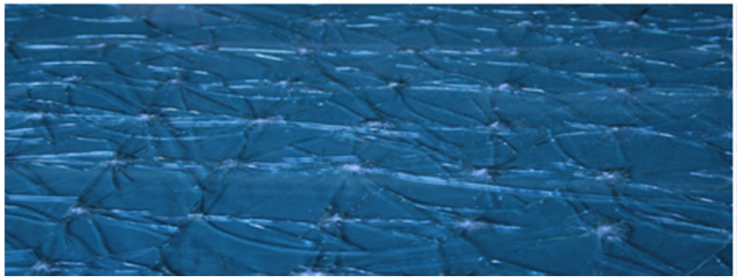

An Approach to capture the Ejection Mitigation Requirements of FMVSS 226 with Finite Element Simulations

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[1] DYNAmore GmbH, 70565 Stuttgart, Germany

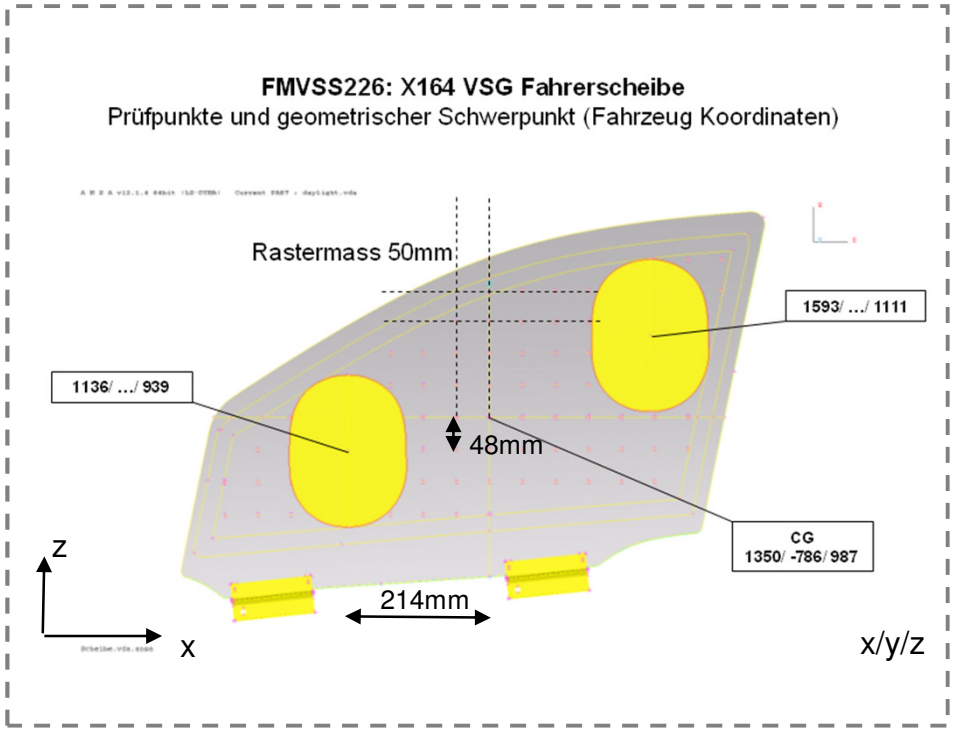
[2] Daimler AG, EP/SPV, 71059 Sindelfingen, Germany

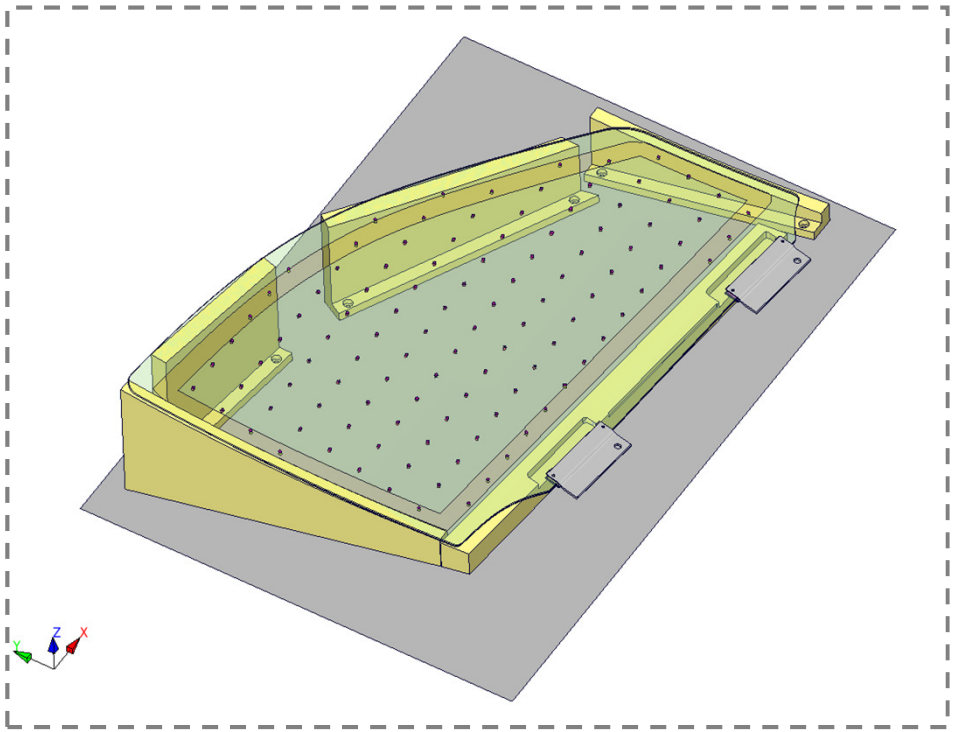
[3] Friedmann & Kirchner, 76865 Rohrbach, Germany

Experimental Investigation

Definition of test programme

- FMVSS226: Definition of impact loading on pre-damaged laminated side windows

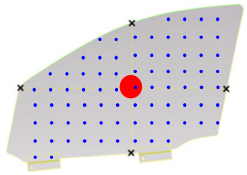


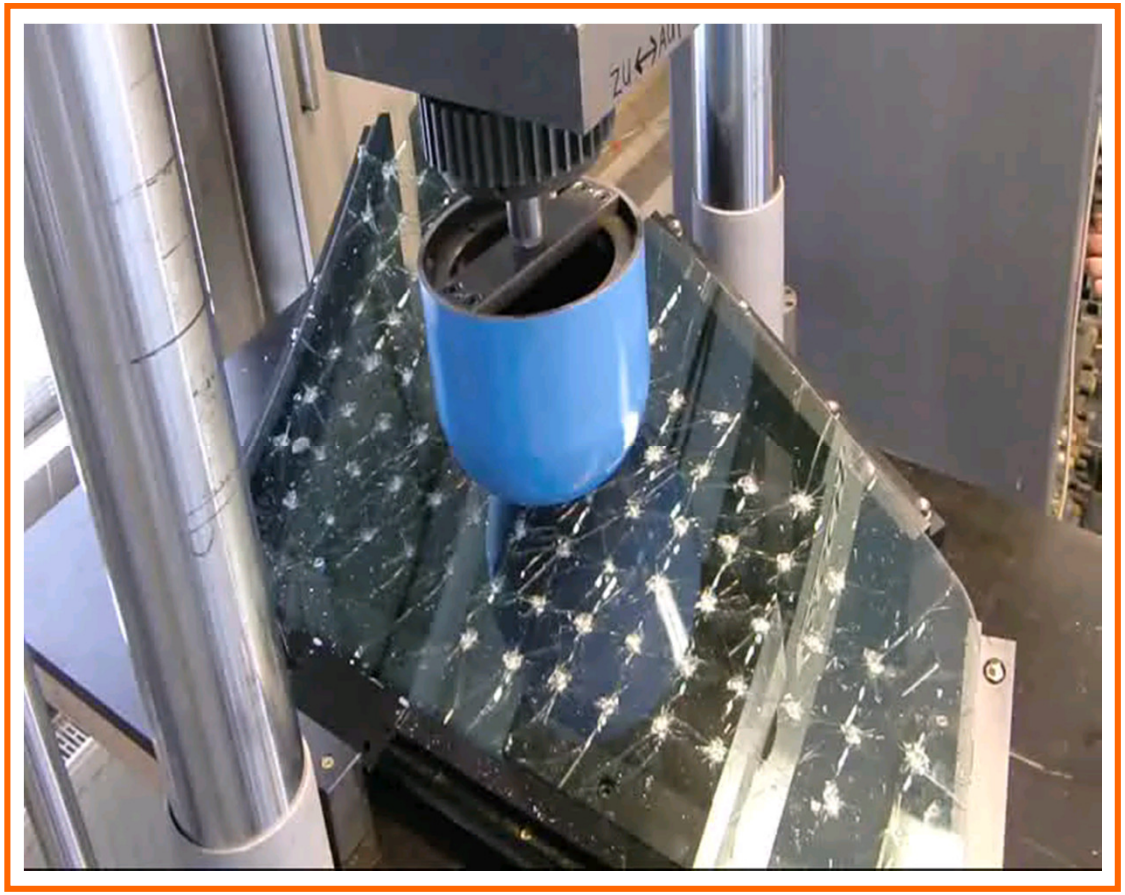


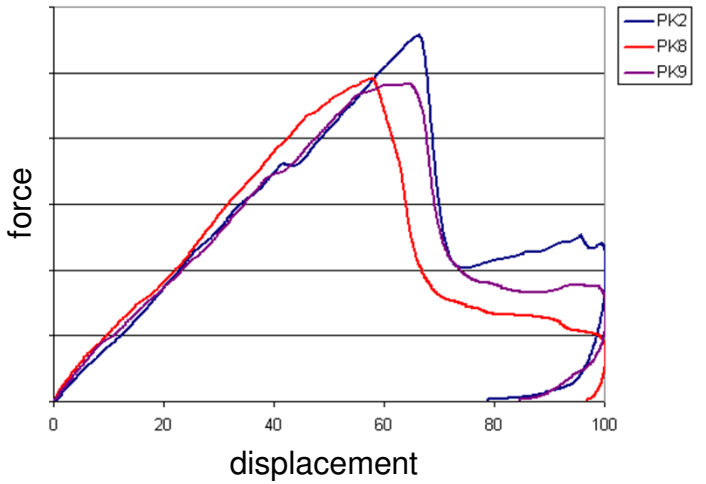
- Laboratory: Friedmann & Kirchner GmbH, Rohrbach, Germany
- Definition of boundary condition for test have been done by finite element studies (support system, impactor geometry, and velocity, degree of pre-damage)
- Definition of glass failure parameters and PVB behavior by small test coupons.

QS tests

- Pre-damaged laminated glass: pre-damaged on both sides by 50mm grid
- QS loading with a velocity of 500 mm/min

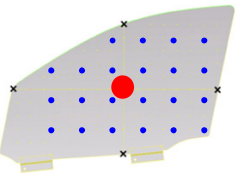


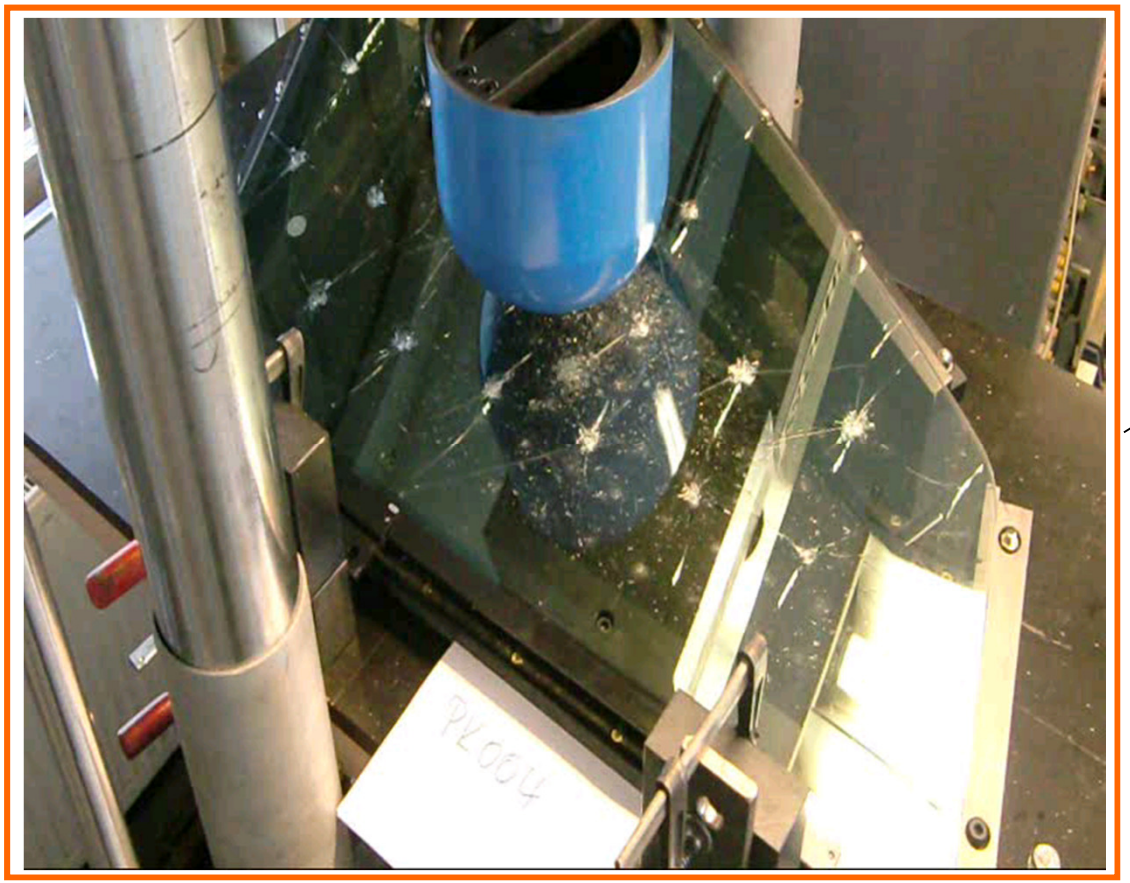


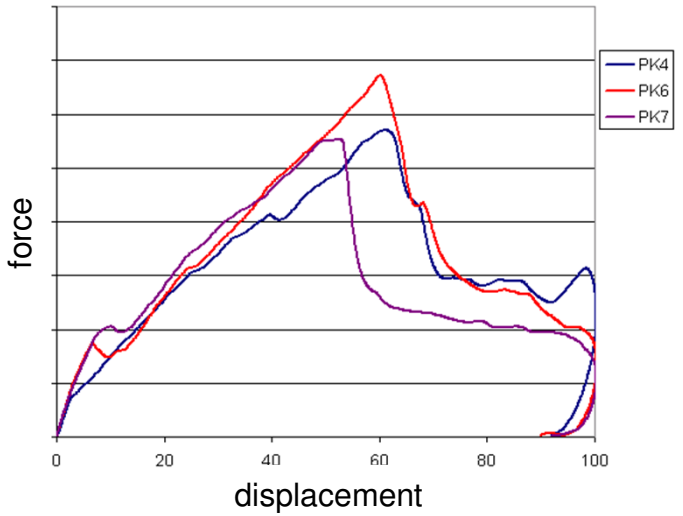


QS tests

- Pre-damaged laminated glass: pre-damaged on both sides by 100mm grid
- QS loading with a velocity of 500 mm/min

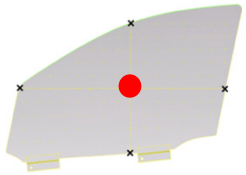


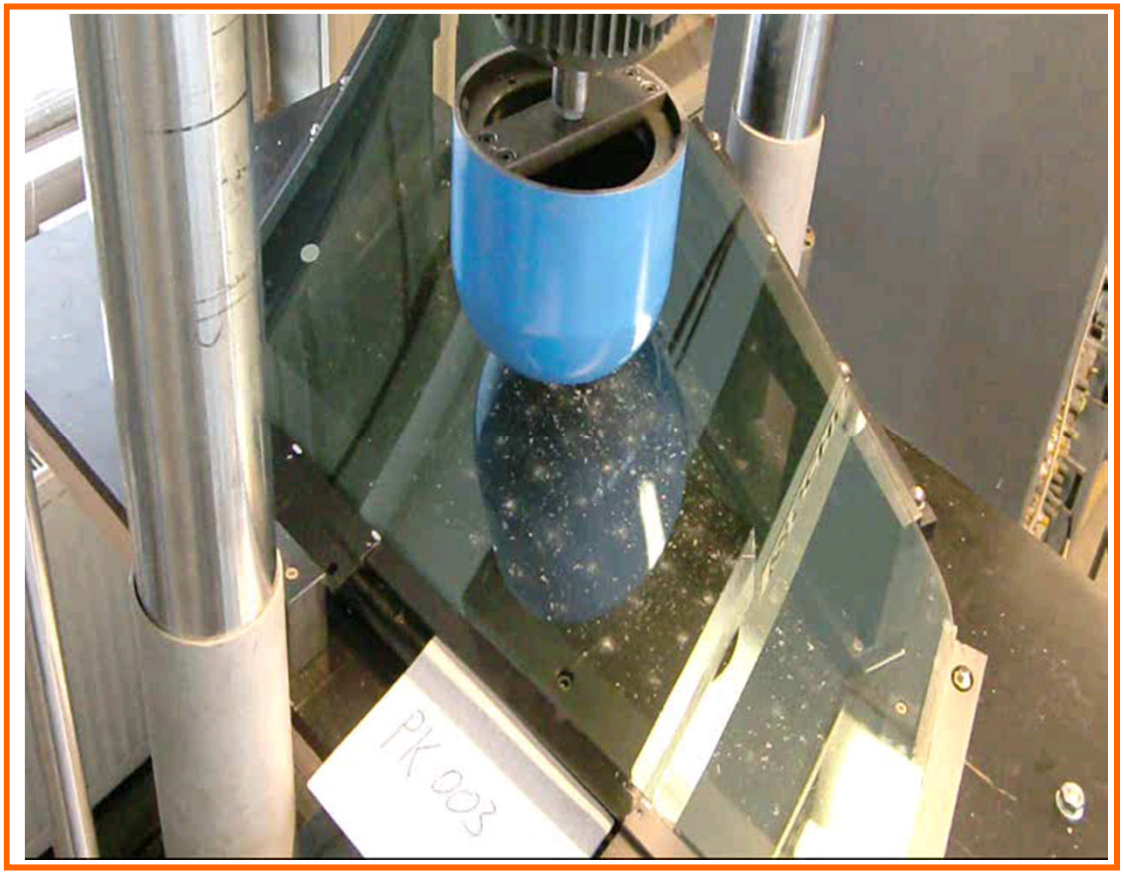


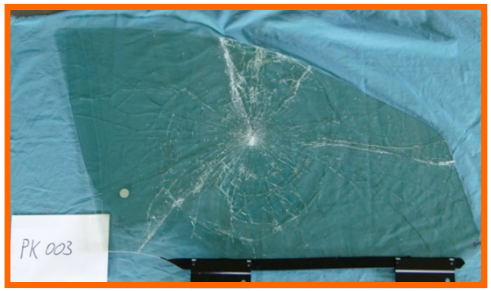


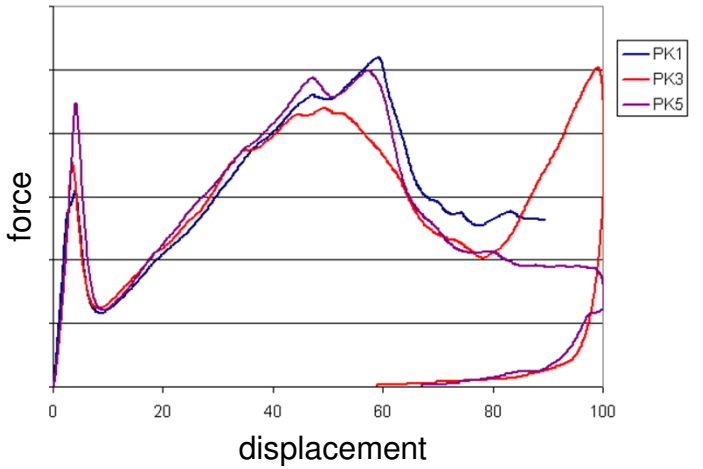
QS tests

- Undamaged laminated glass: impact in center point
- QS loading with a velocity of 500 mm/min



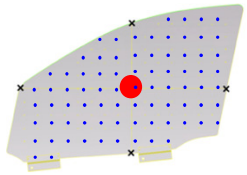


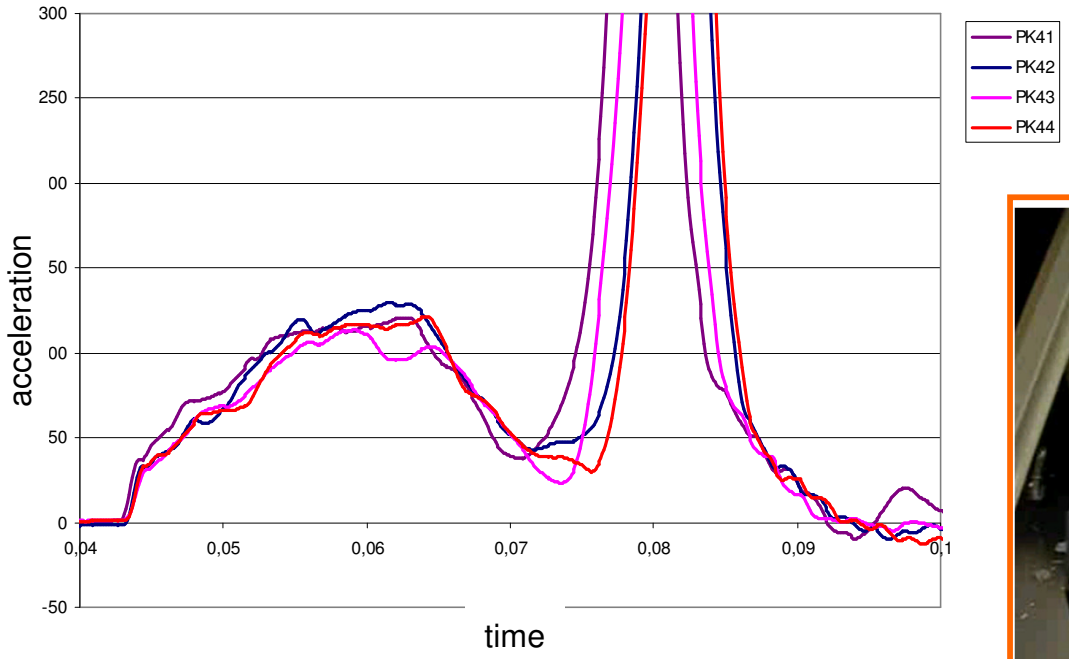




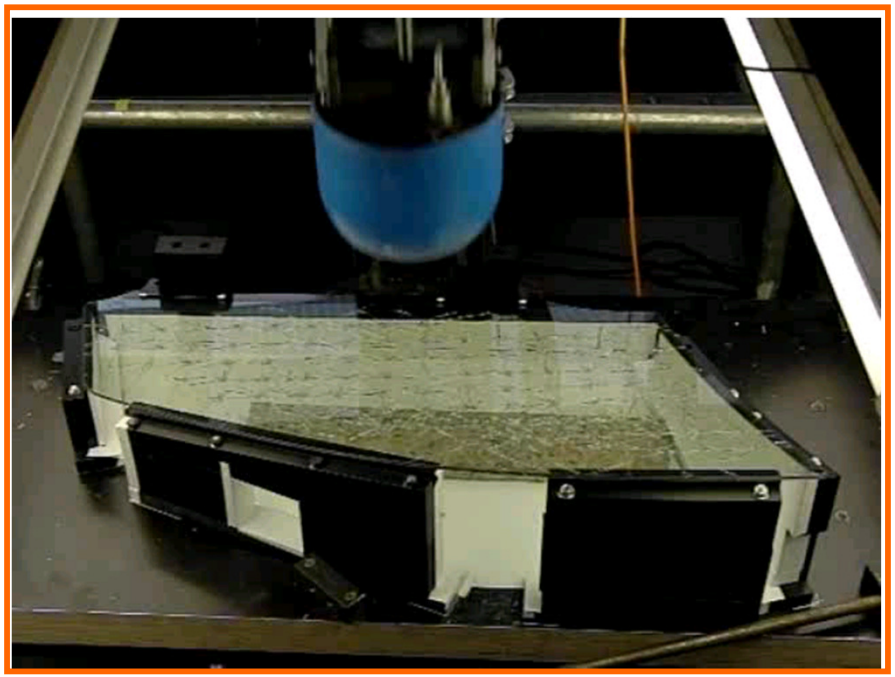
Dynamic test setup

- Predamaged laminated glass: predamaged on both sides by 50mm grid
- Dynamic loading by 5m/s



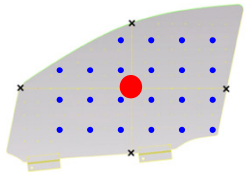


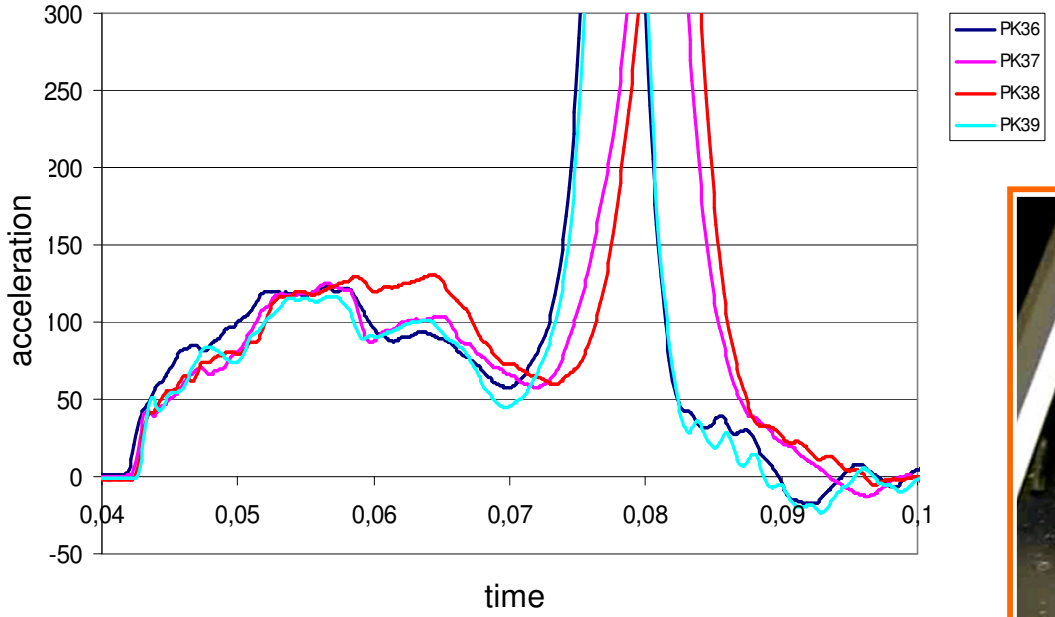
dynamic, v= 5 m/s



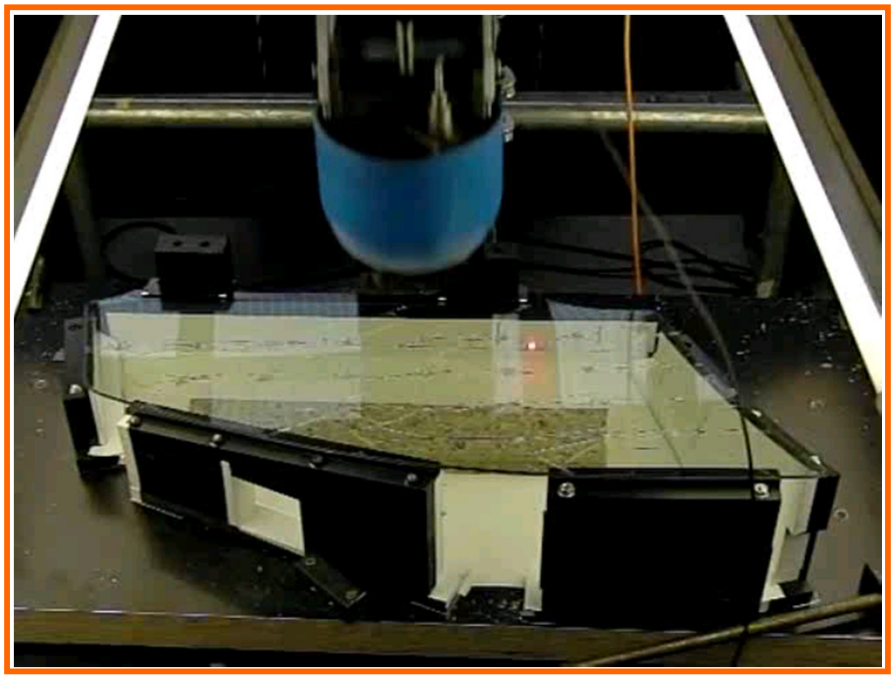
Dynamic test setup

- Predamaged laminated glass: predamaged on both sides by 100mm grid
- Dynamic loading by 5m/s



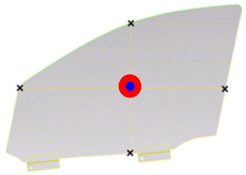


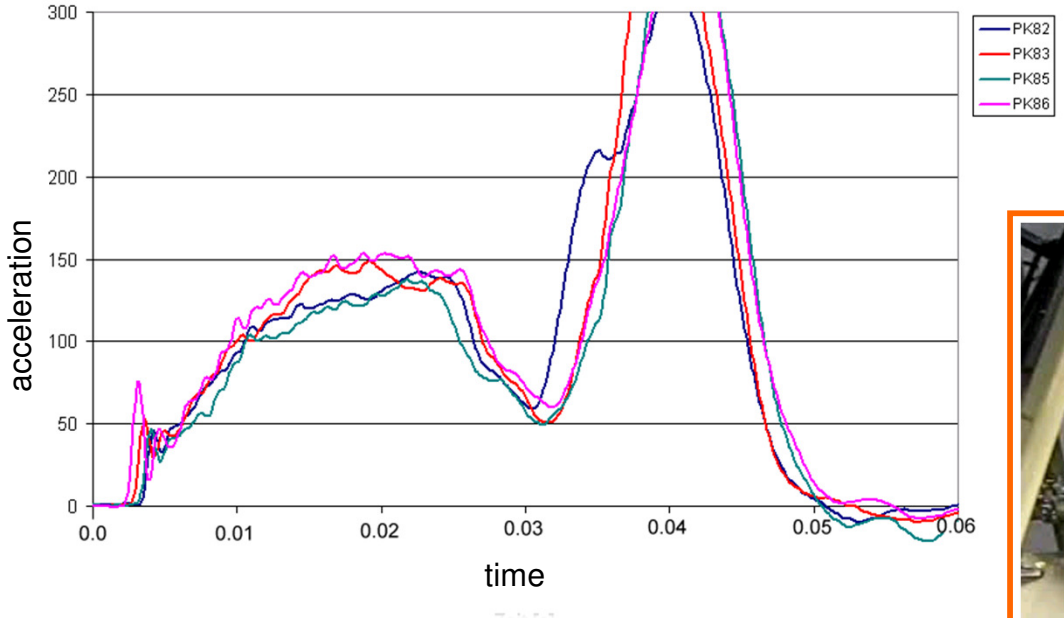
dynamic, v= 5 m/s



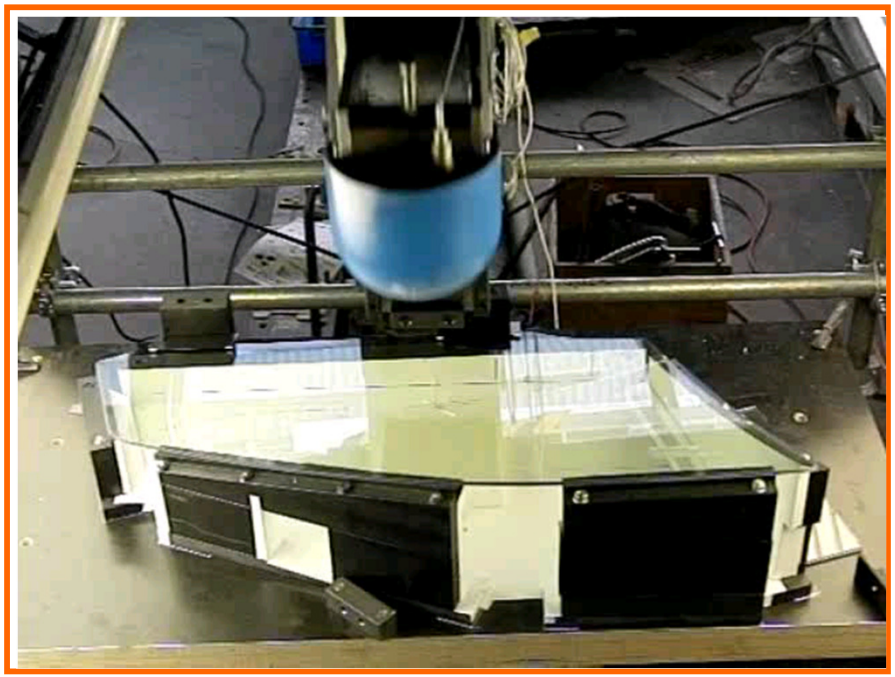
Dynamic tests

- Initially damaged glass (midpoint), impact of v=5m/s
- Loading midpoint



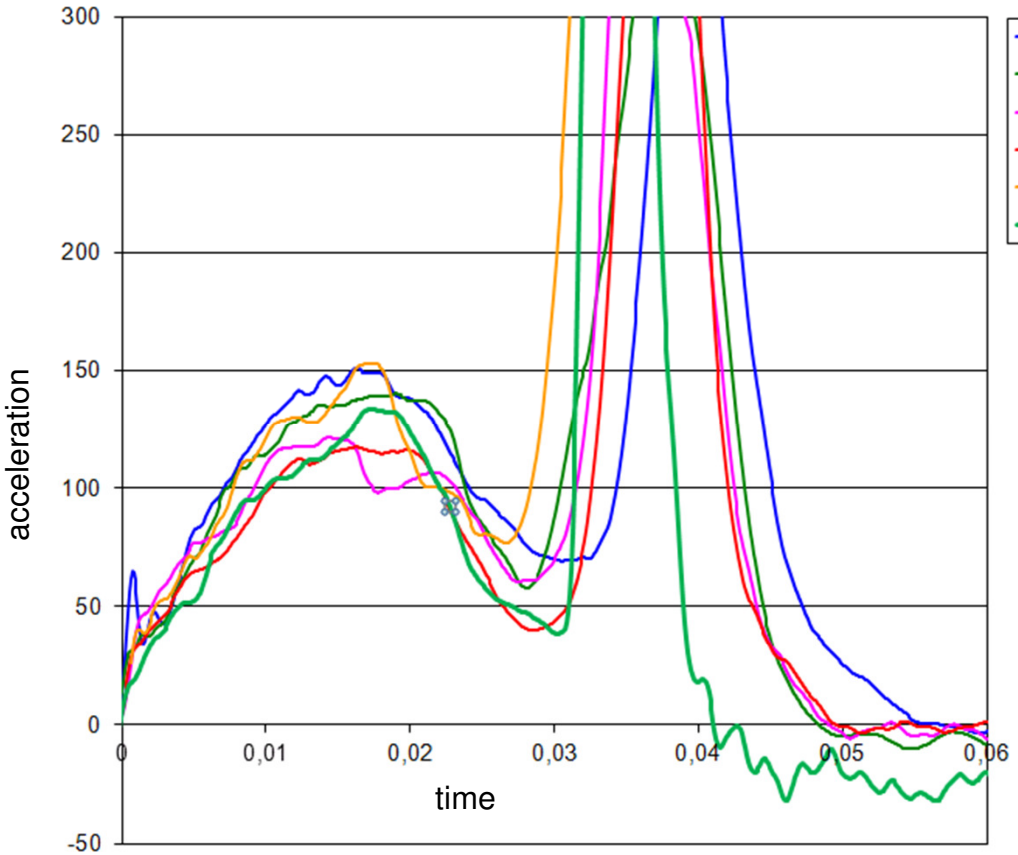


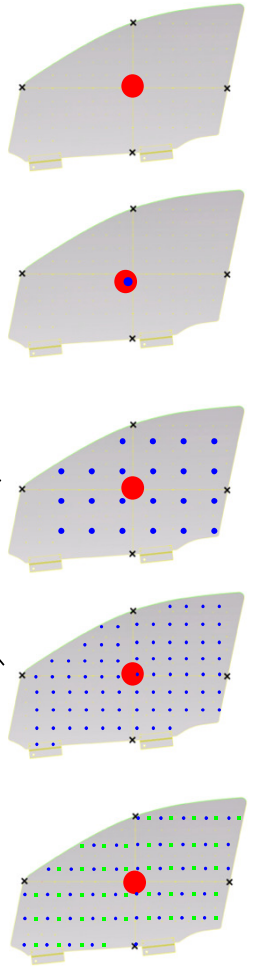
dynamic, v= 5 m/s



Dynamic tests: Impact on midpoint

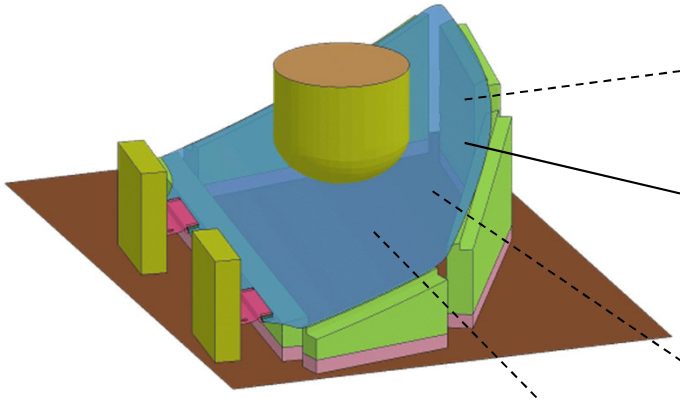
- Comparison of dynamic loading of 5m/s (averaged results)





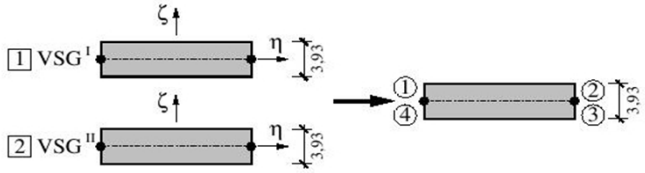
Possibilities to set up model for laminated glass

- Model setup according to experimental conditions
- Various modelling possibilities for the laminated glass structure

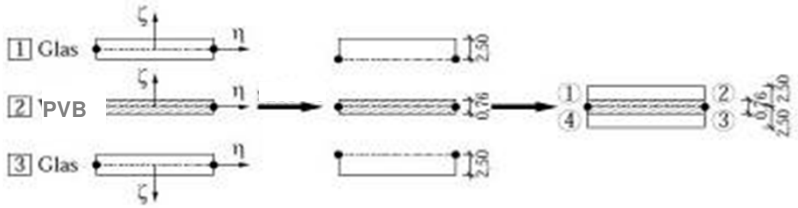


Coincident shell elements

A

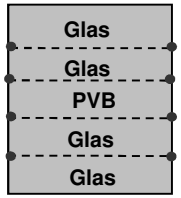


B



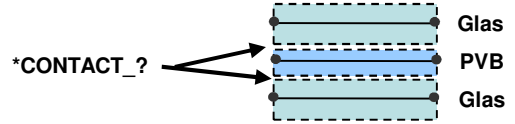
Solid elements

C



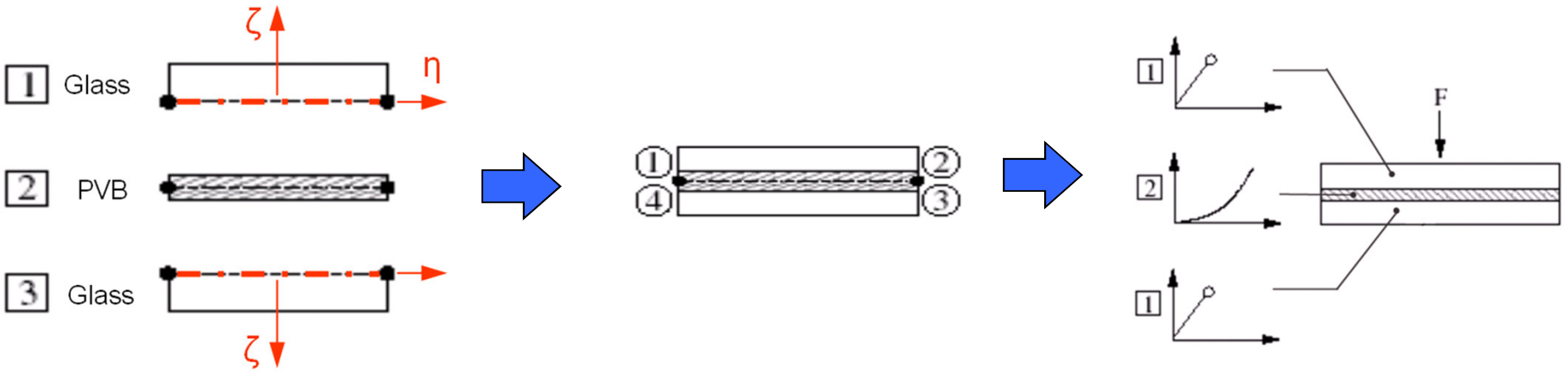
Layered shell elements

D



Chosen modelling technique: B

- Three coincident shells elements in thickness direction.
  i.e. all shells use the same nodal information..
- Each shell represents one part of the layup: Glass/PVB/Glass
- Calibration is done by modifying the material properties of the individual parts.

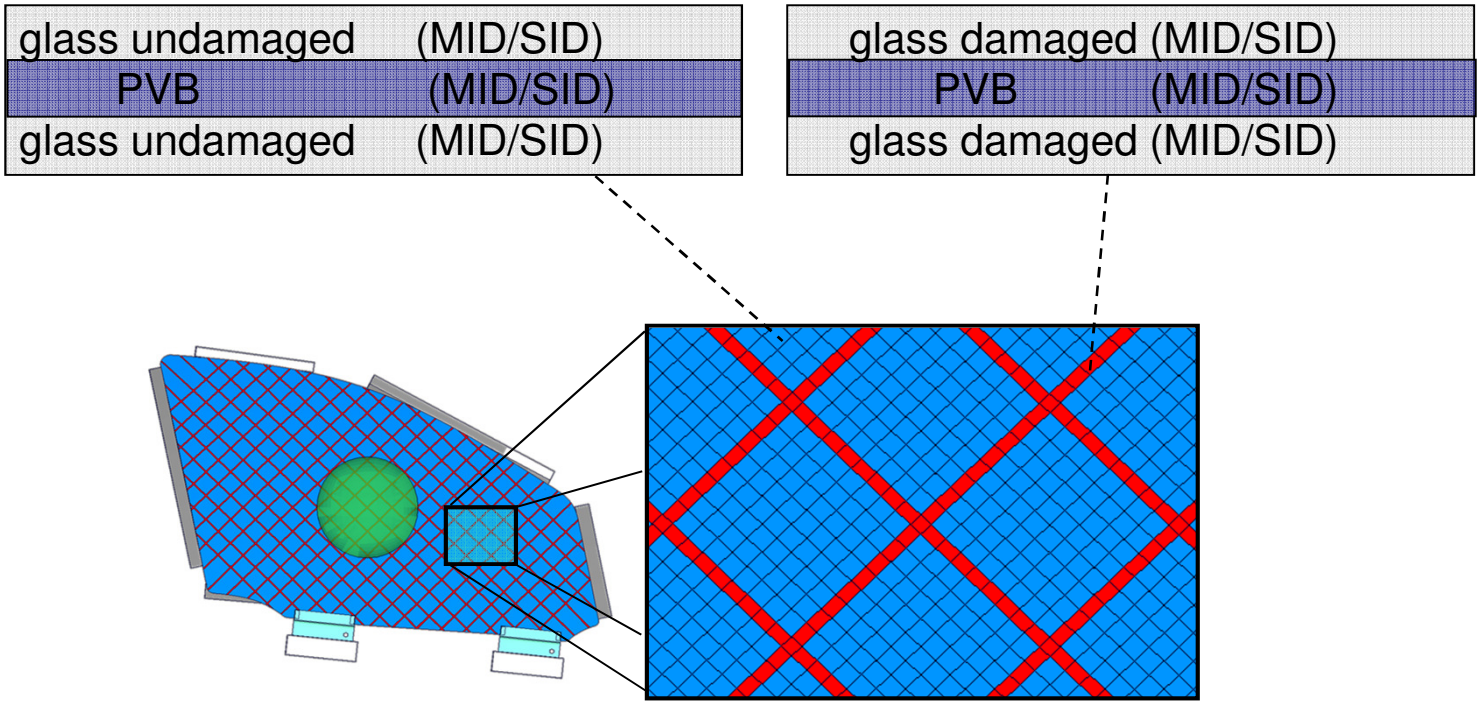


- The characteristic element length in the whole part is about 2.2-2.5mm;
  the total thickness of the part is 4.7mm.

Modelling technique: B with enhancements

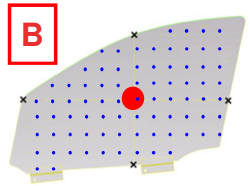
- The representation of the pre-damaged glass is enhanced by elements representing discrete cracks (one element row) modelled wit different PID and different material parameters.
- Such parameters are defined via reverse engineering.

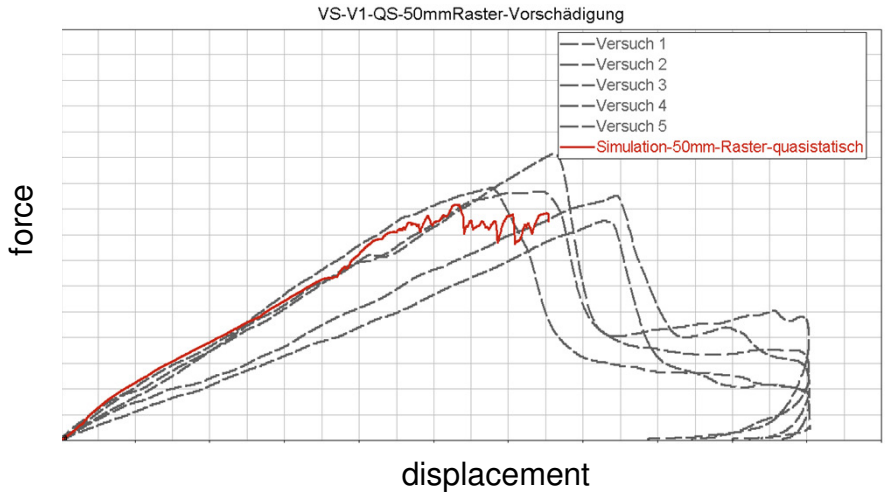
- Hence all we find 6 material sets in the glass part: 6 material and 6 Sections cards are necessary:

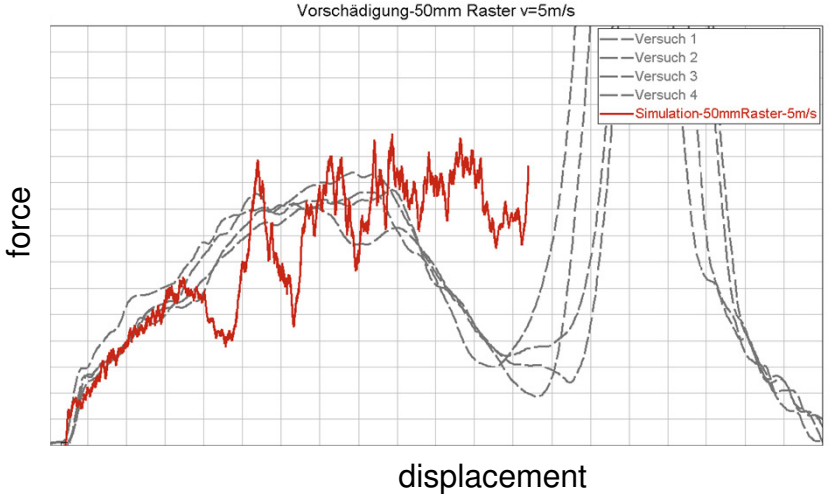


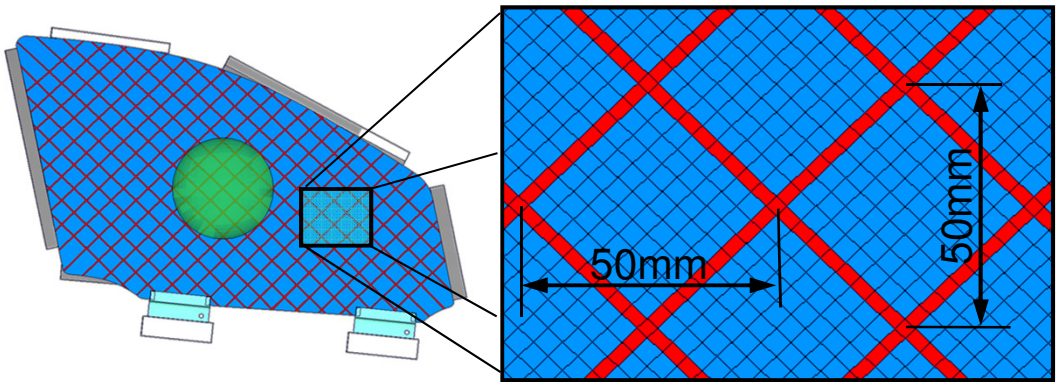
Modelling technique: B with enhancements

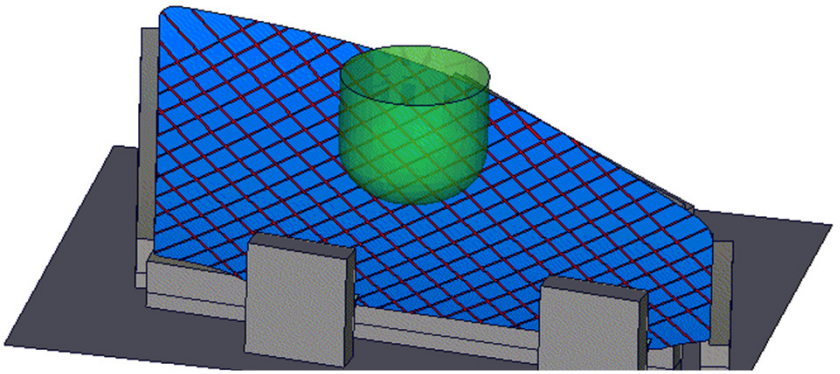
- Model setup as shown
- 50mm grid is applied with pre-defined crack-lines
- Acceleration for qs und dynic loading at5m/s

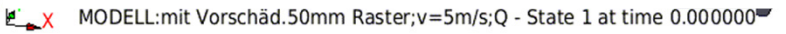






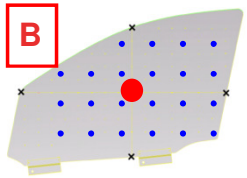


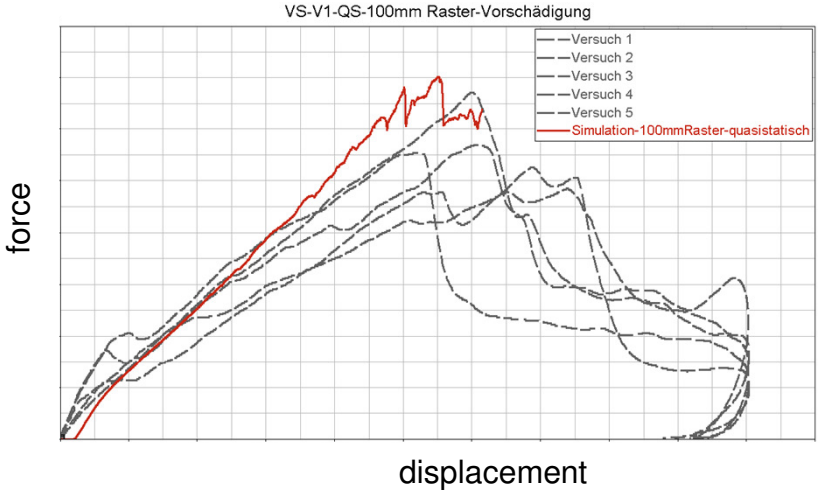


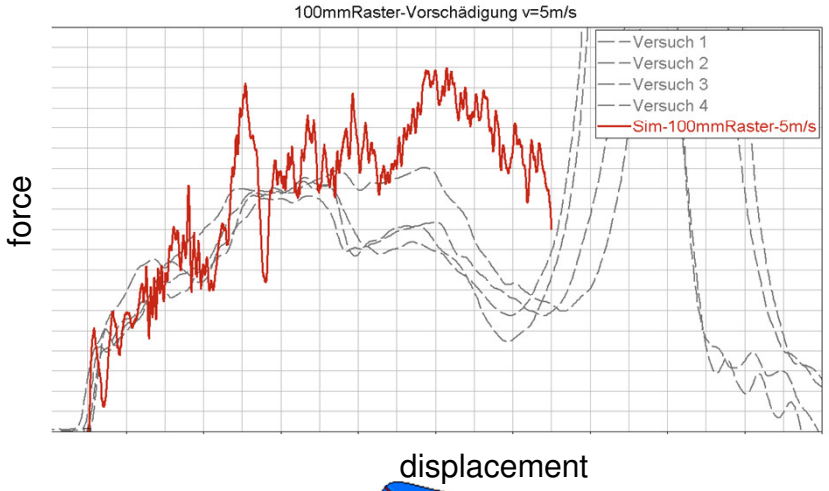


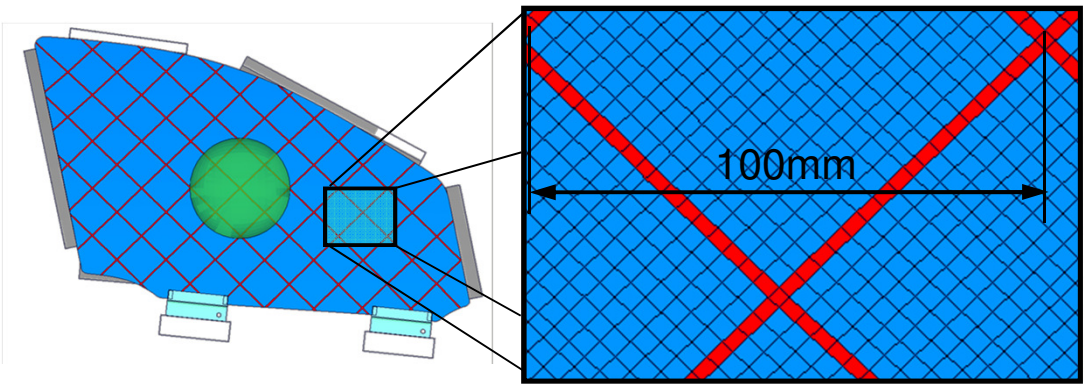
Modelling technique: B with enhancements

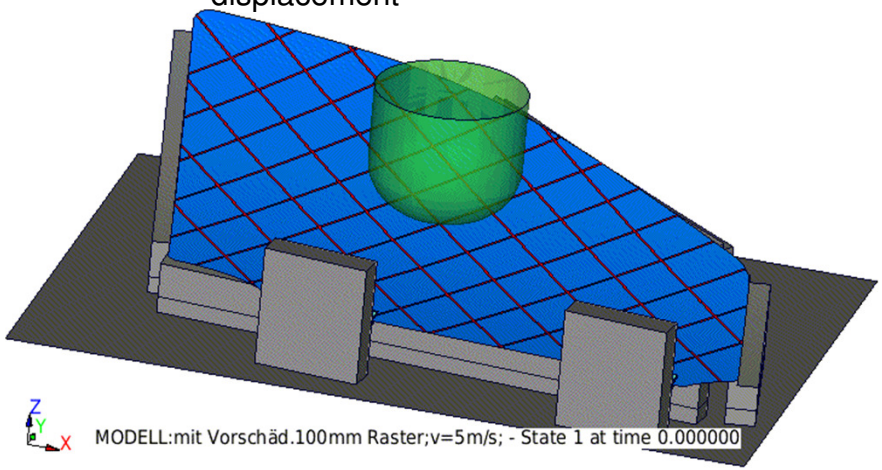
- Model setup as shown
- 100mm grid is applied with pre-defined crack-lines
- Acceleration for qs und dynic loading at5m/s





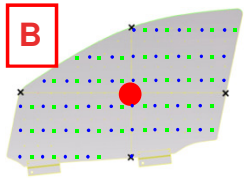


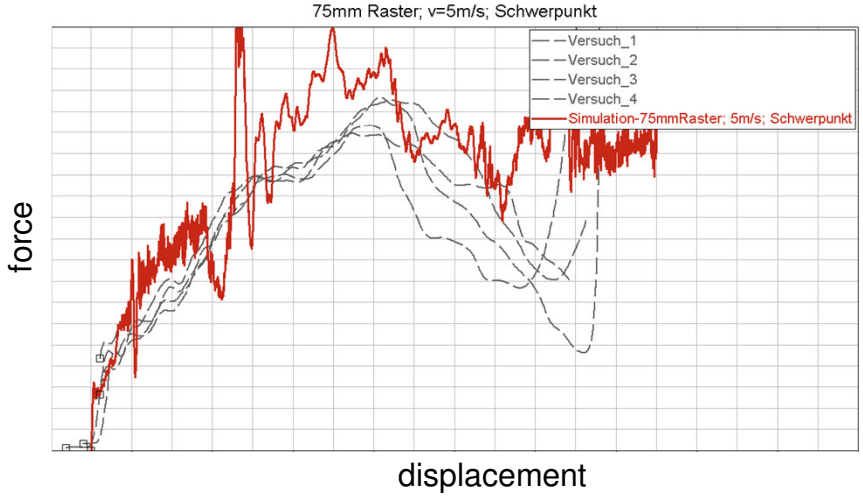


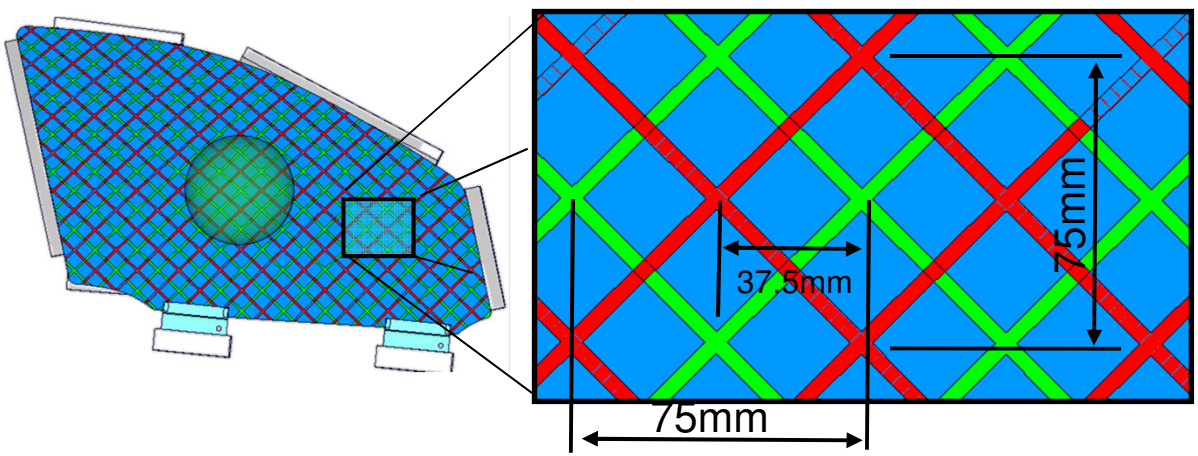


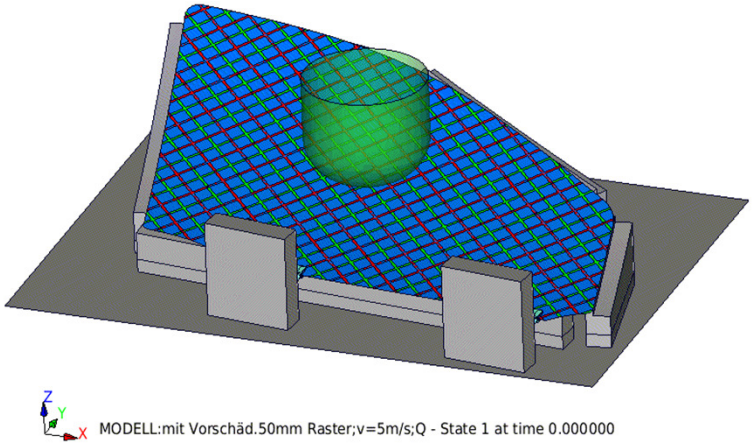
Modelling technique: B with enhancements

- Model setup as shown
- 75mm grid is applied with pre-defined crack-lines (final rule)
- Acceleration for qs und dynic loading at5m/s









Summary

- The present model requires a mesh that assumes pre-defined crack pattern based on experimental studies. The results gained so far are promising, since the parameters identified can be gained very quickly.
- The crack lines must, however, be used in the final model. Consequently the client has to define requirements according FMVSS226 that third party sub-contractors must meet.
-
- The general approach looks very promising. Further experimental studies with other side window geometrical data will be used as calibration means

FIN