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automotive CAE GRAND CHALLENGE

Influence of Material Scatter to Simulation Results with ALTAIR RADIOSS

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ALTAIR Engineering

automotive CAE Grand Challenge 2020
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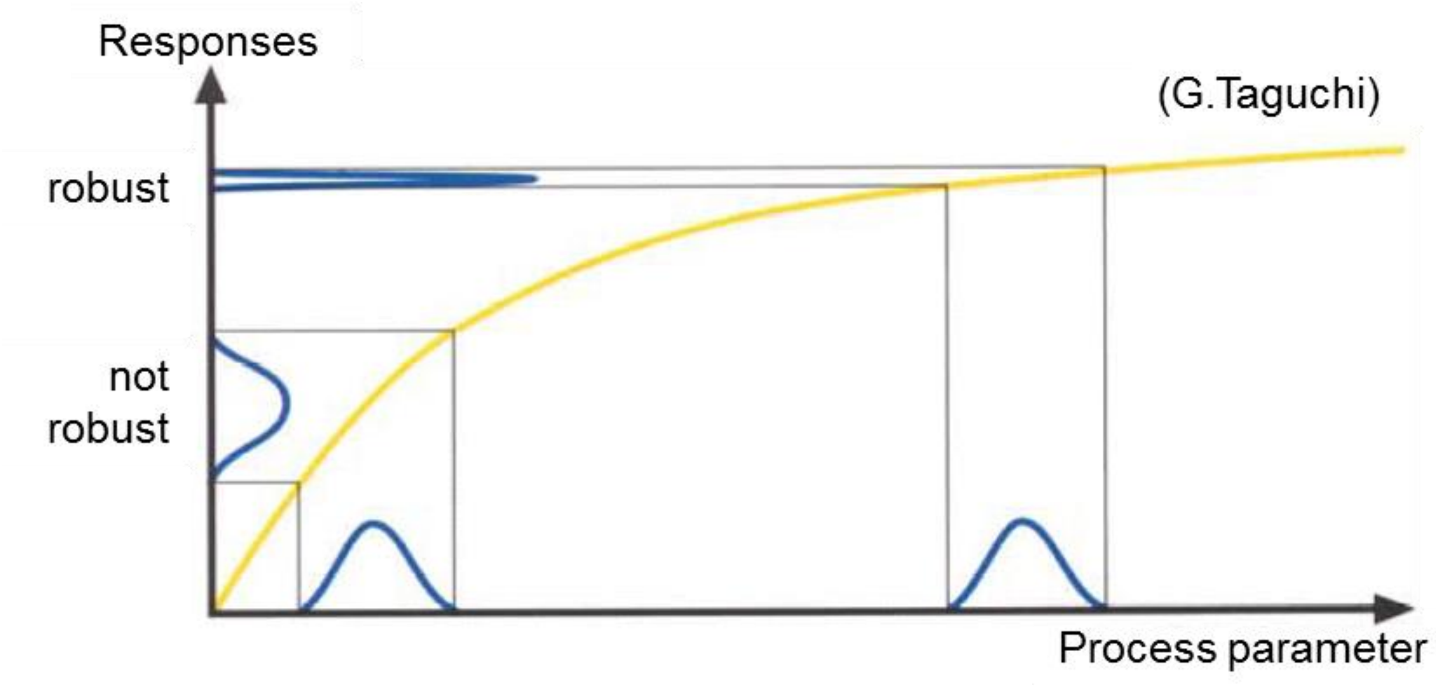
Agenda

- Motivation
- Material test results: What reality shows
- Scatter in simulations
  - Geometrical scatter
  - Material and failure parameter scatter
- Examples
- Conclusion

Motivation



CRASH is chaotic and material parameter sometimes, too.

But there is a need for a robust response.

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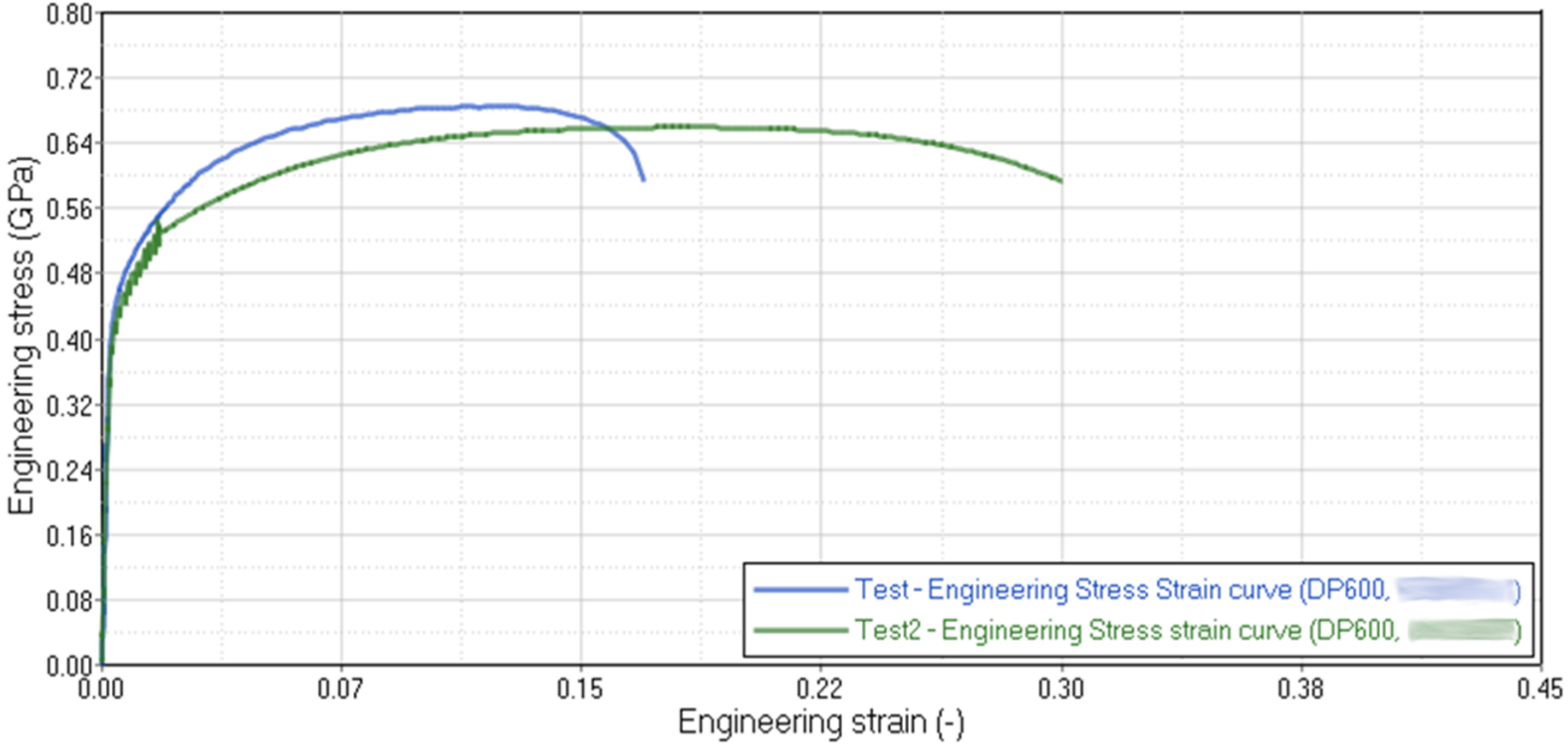
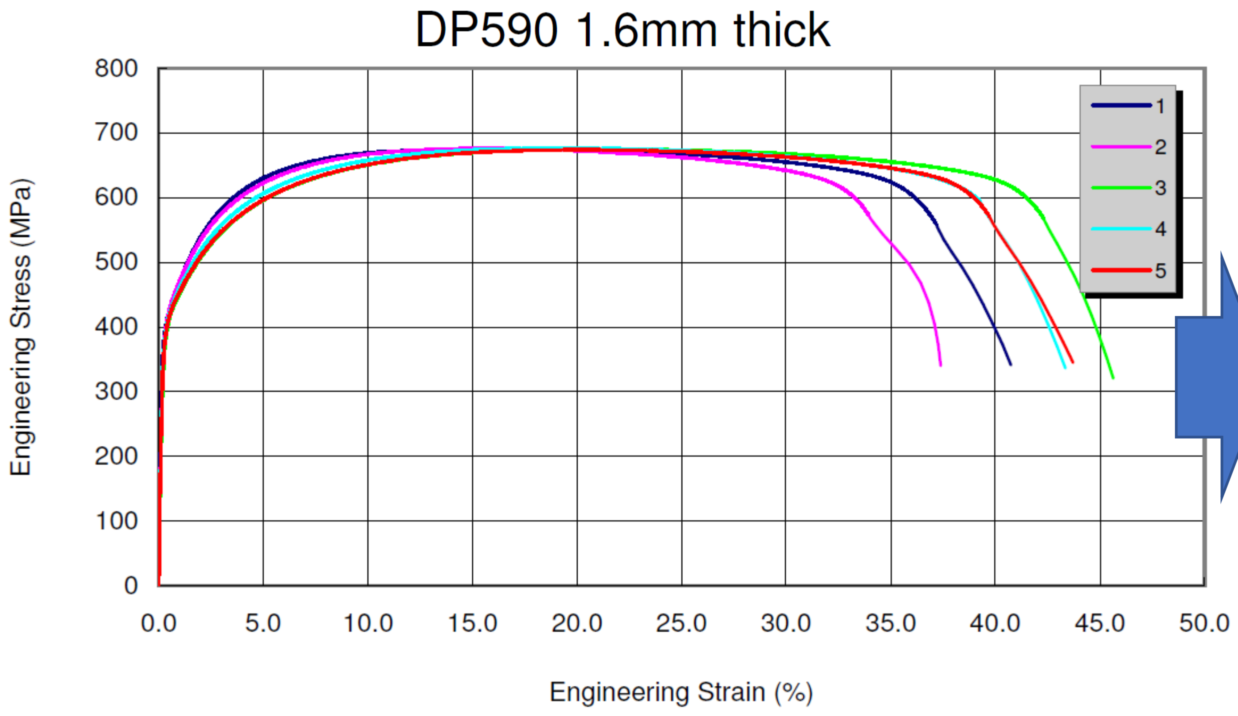
What reality shows (real tests):

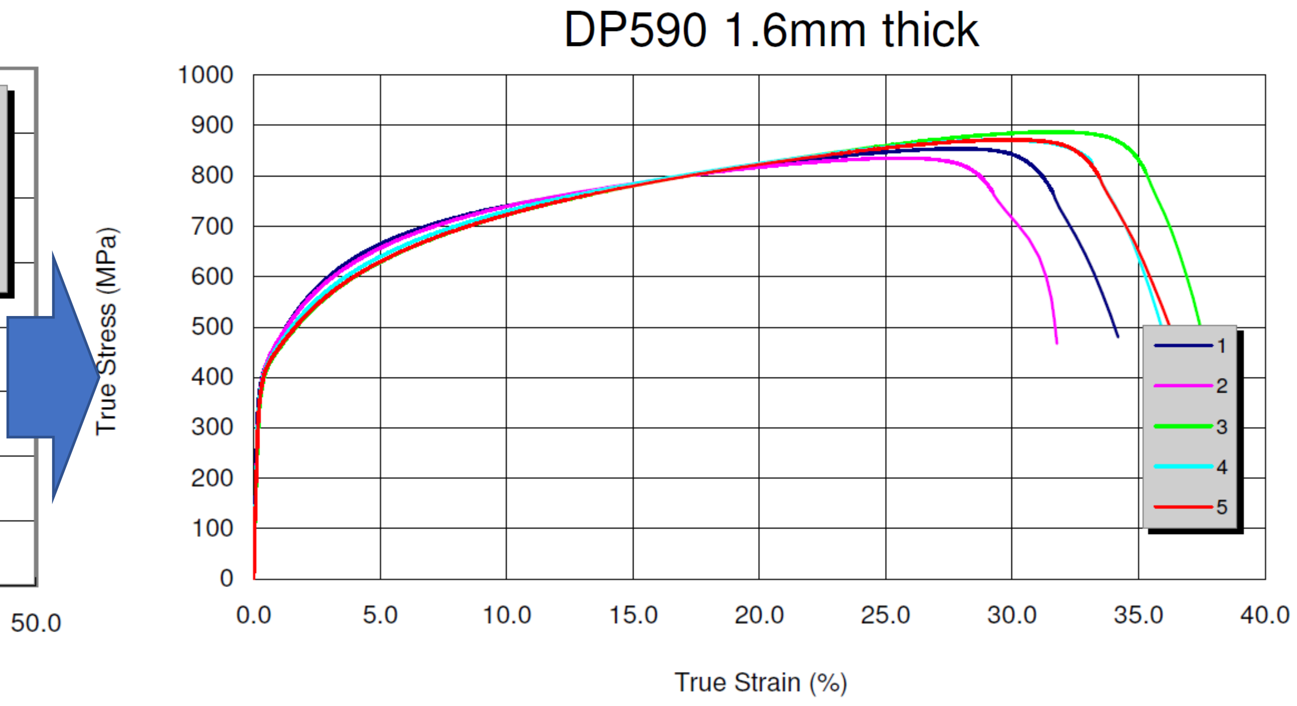
DP600 – Real test results: Material supplier A vs. supplier B



Material test results: What reality shows

Applus DatapointLabs

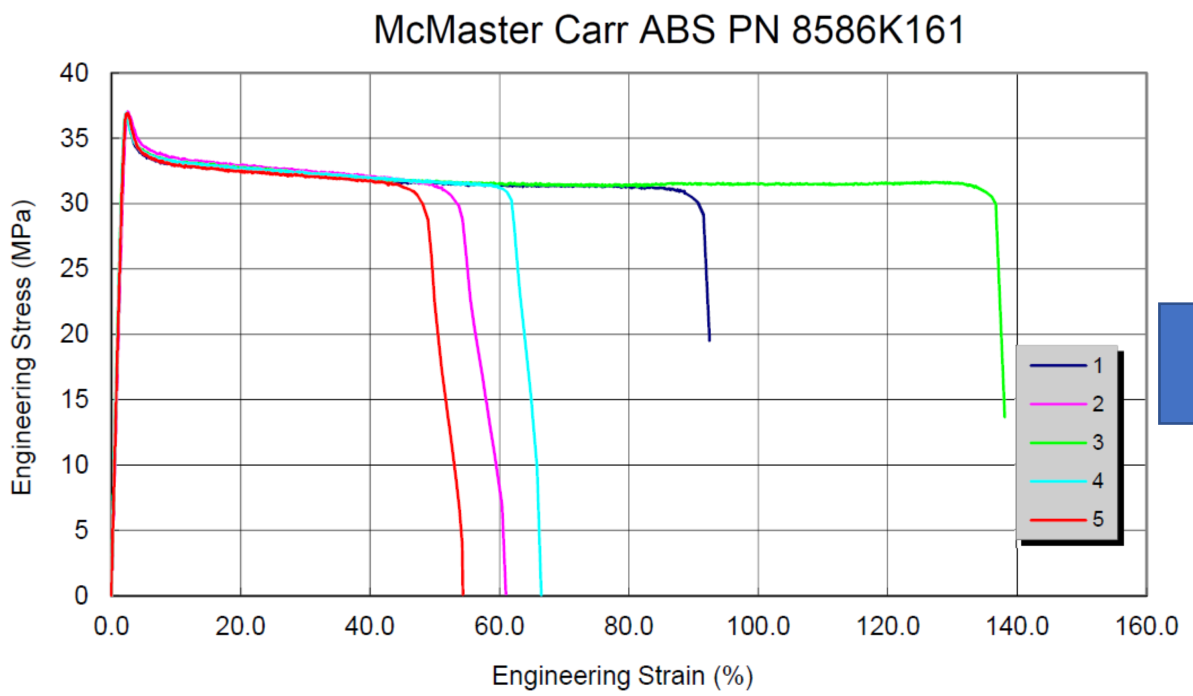




https://www.datapointlabs.com/

Material test results: What reality shows

Applus DatapointLabs



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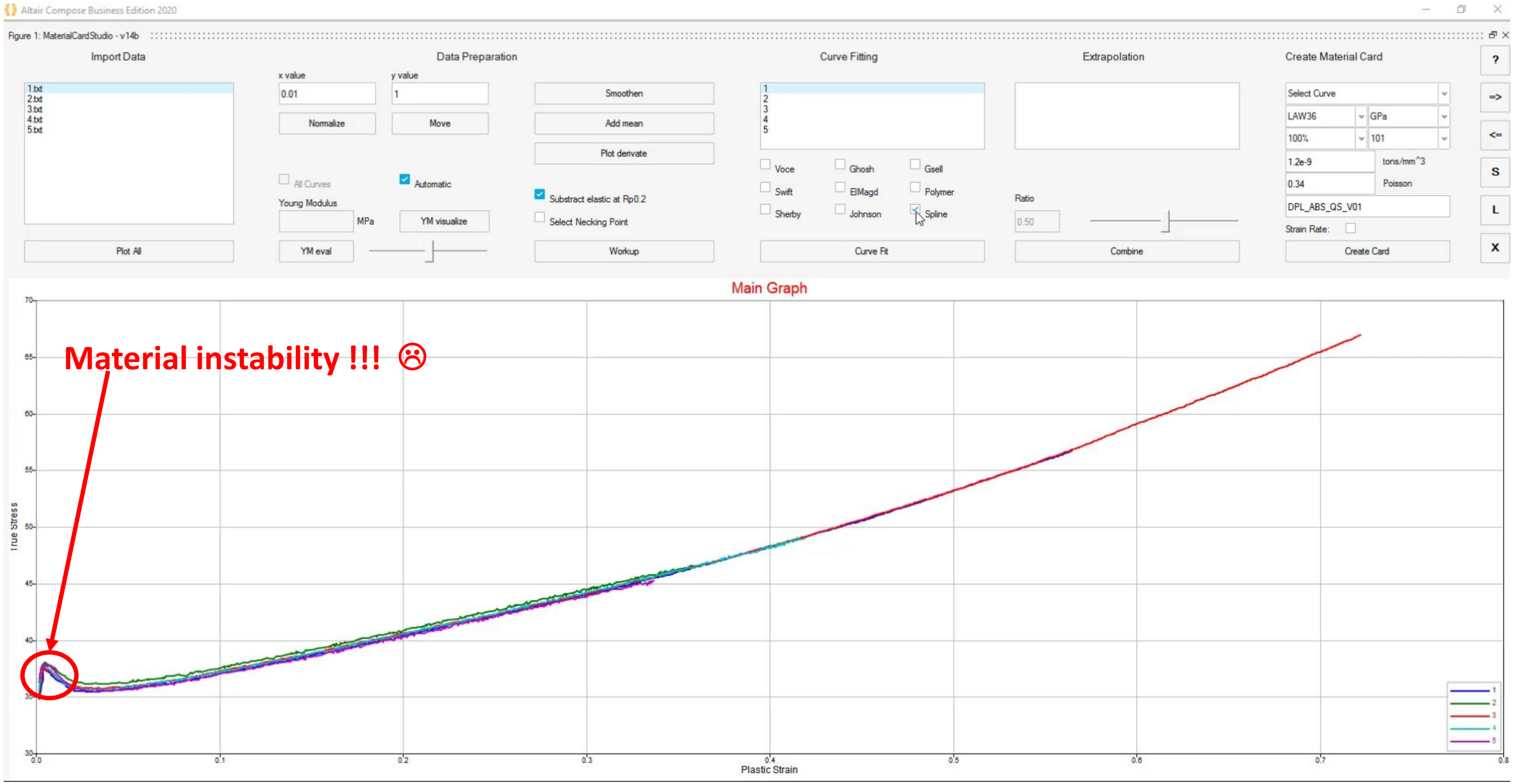
Material test results: What reality shows



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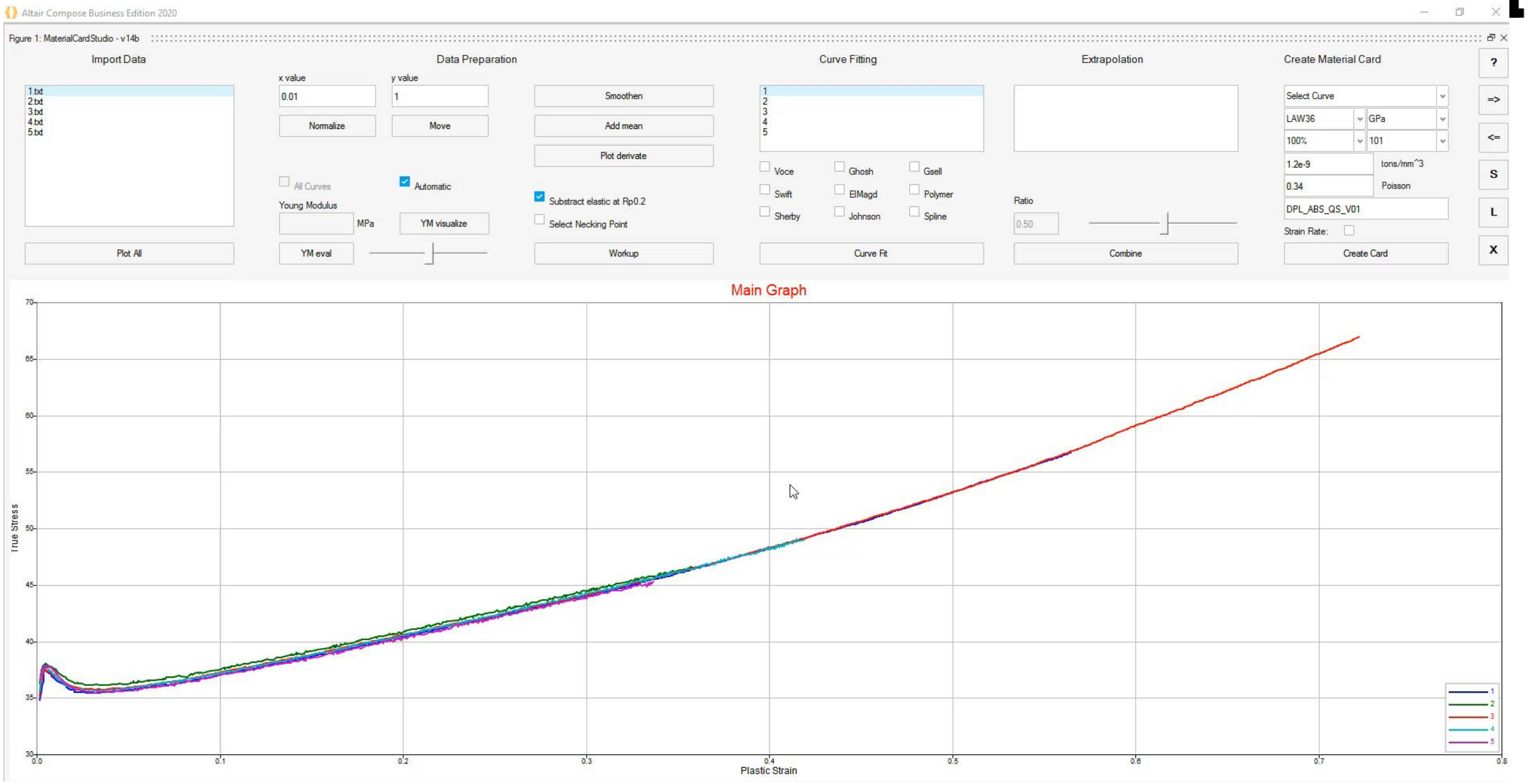
Material test results: What reality shows

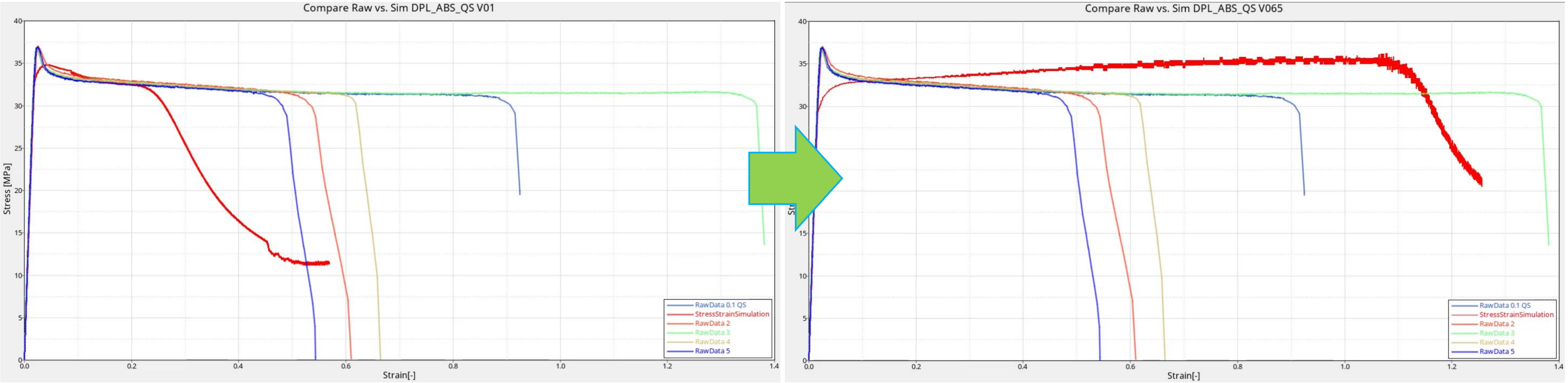


(Video)

Material test results: What reality shows

Simulation results:

Under-estimated material / Over-estimated material



All simulations run stable ☺

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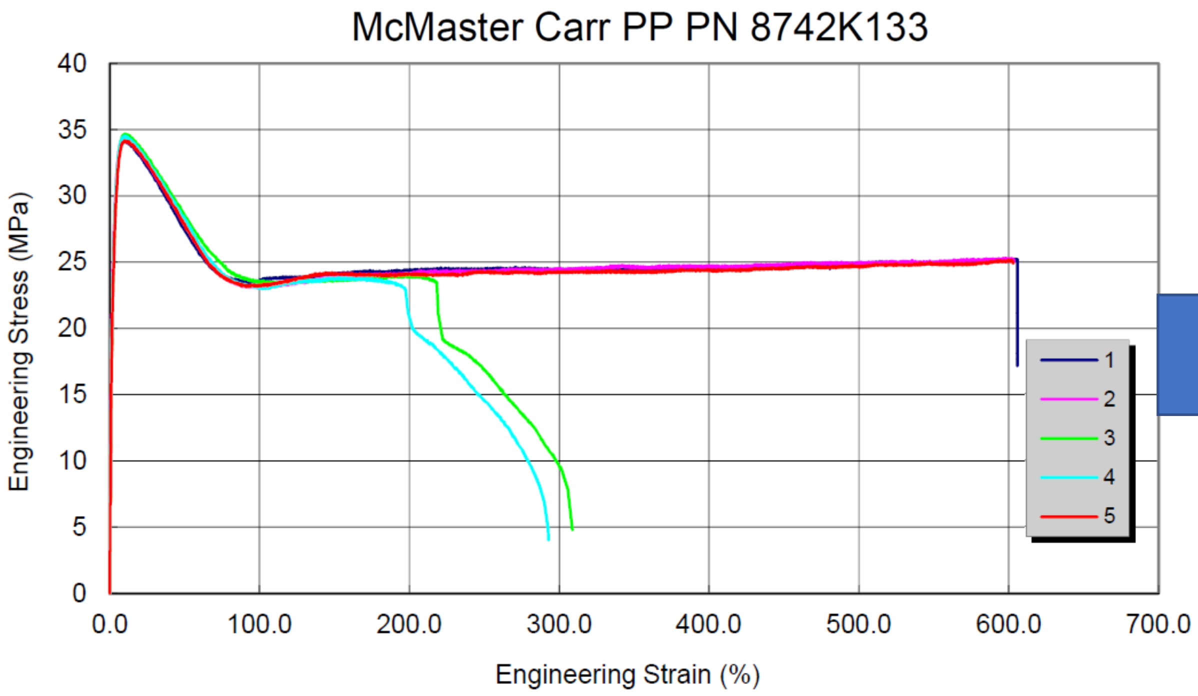
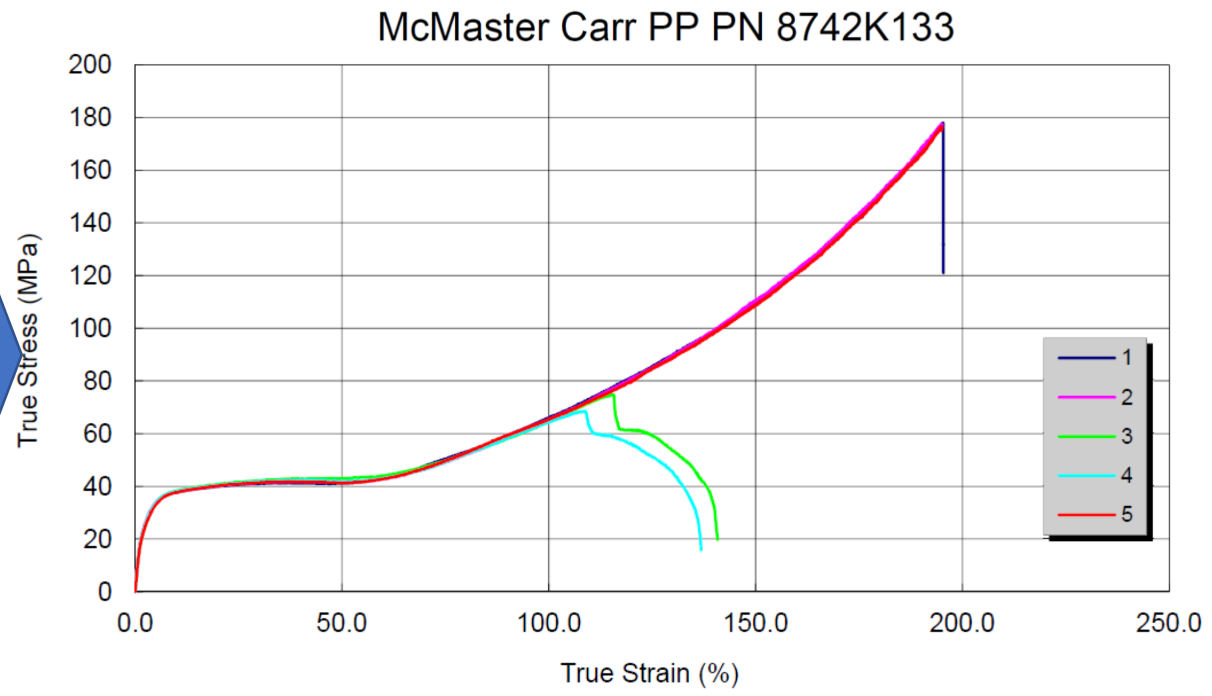
Material test results: What reality shows

Applus DatapointLabs





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Material test results: What reality shows

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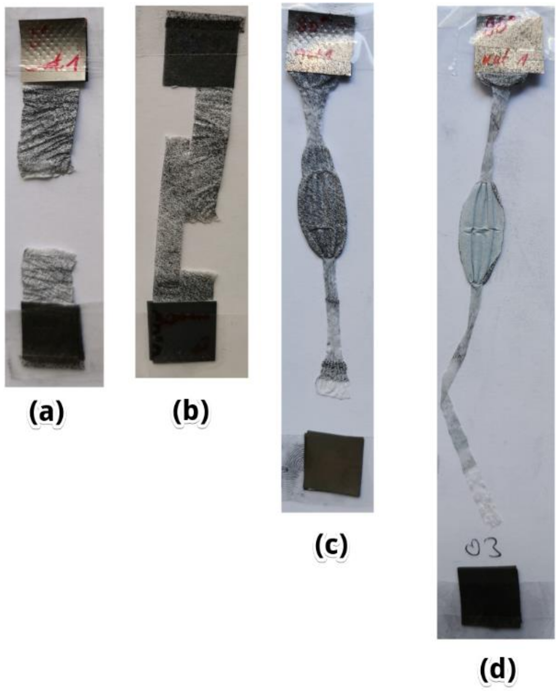
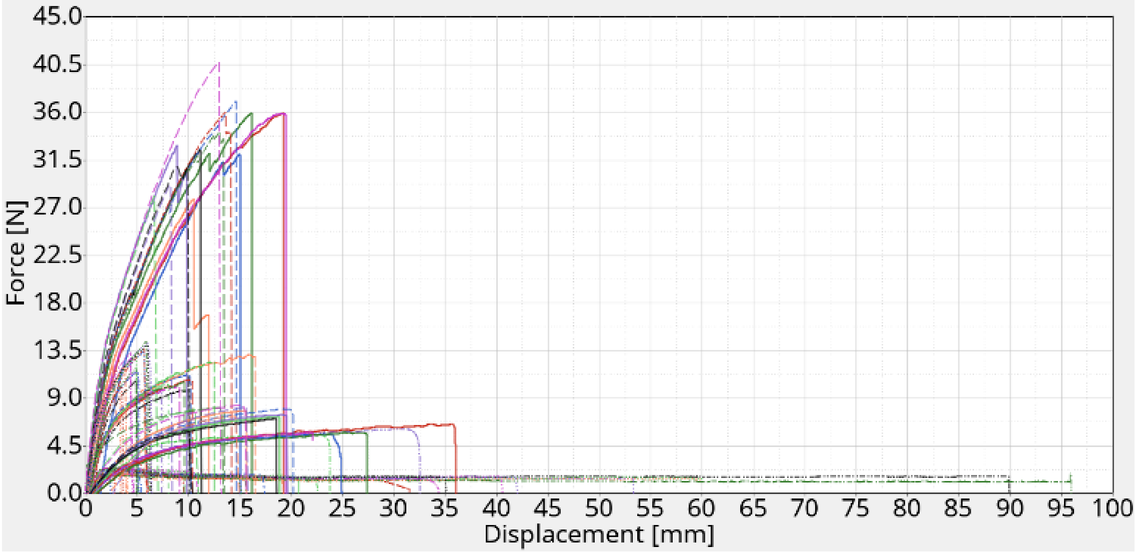
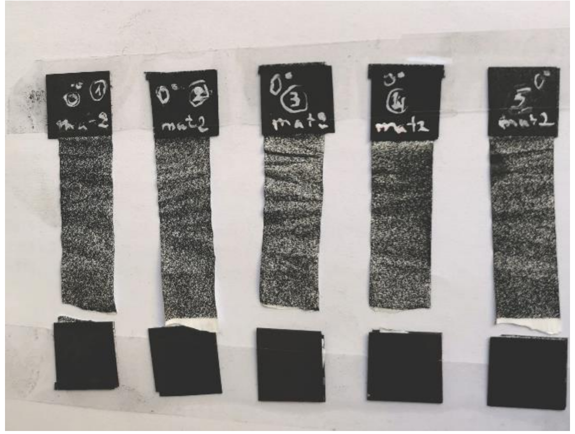
Resultant failure in transverse direction

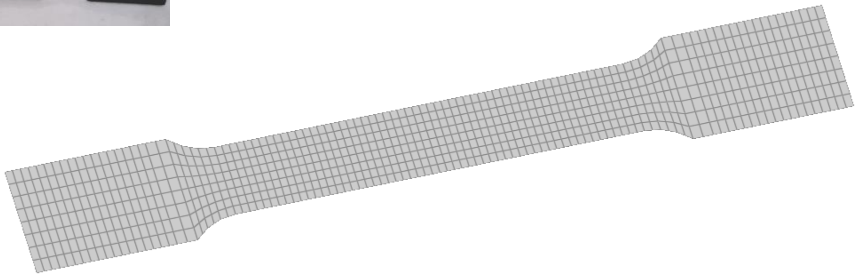


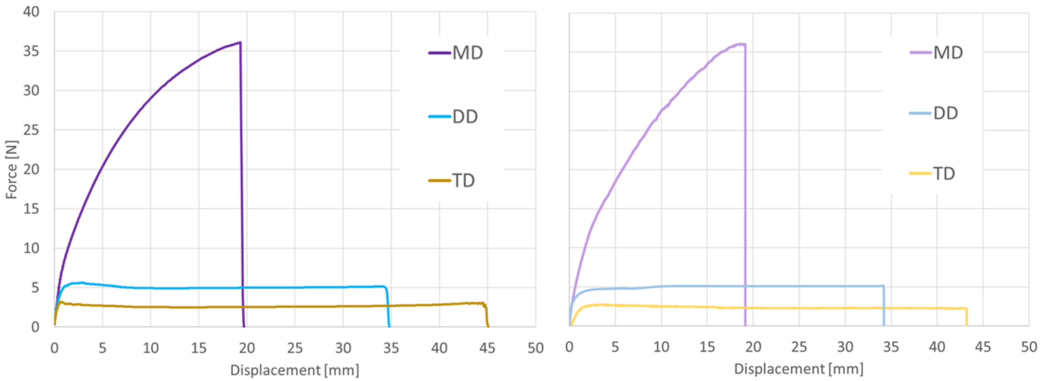
Force-Displacement curves of all tests



Resultant failure in machine direction







Reference: Bulla, M.; Kolling, S.; Sahraei, E. An Experimental and Computational Study on the Orthotropic Failure of Separators for Lithium-Ion Batteries. Energies 2020, 13, 4399.

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Thickness perturbation – Nodal wise

/RANDOM

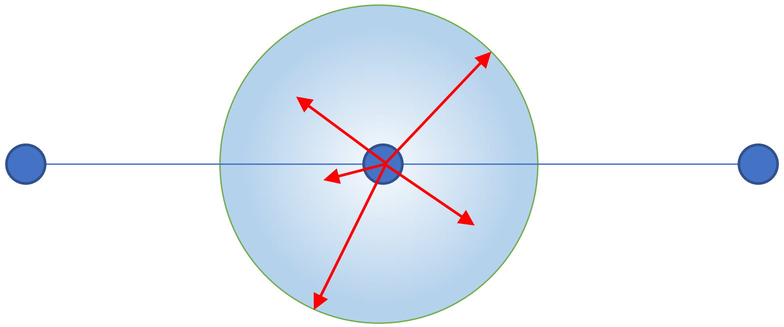
Block Format Keyword

Describes the nodal random noise to check stability of model by introducing random noise on nodal coordinates.

Format

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
/RANDOM/*unit_ID* or									
/RANDOM/GRNOD/*grnd_ID*/*unit_ID*									
Xalea		*Seed*							

Usual value for max. random displacement = 1 µm



Thickness perturbation – Element wise

/PERTURB/PART/SHELL

Block Format Keyword

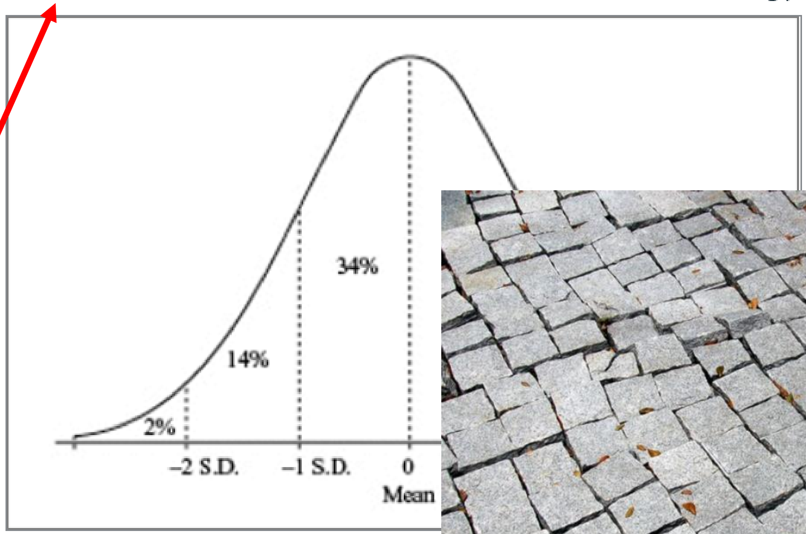
This option can be used to study the robustness of a design by generating different thickness values for every shell element in the specified part group. The random noise scale factors can have either a normal (Gaussian) distribution or random distribution.

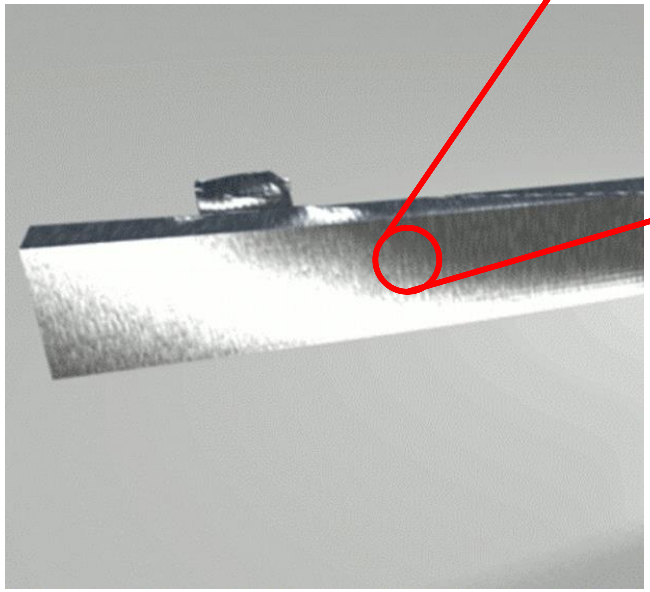
Format

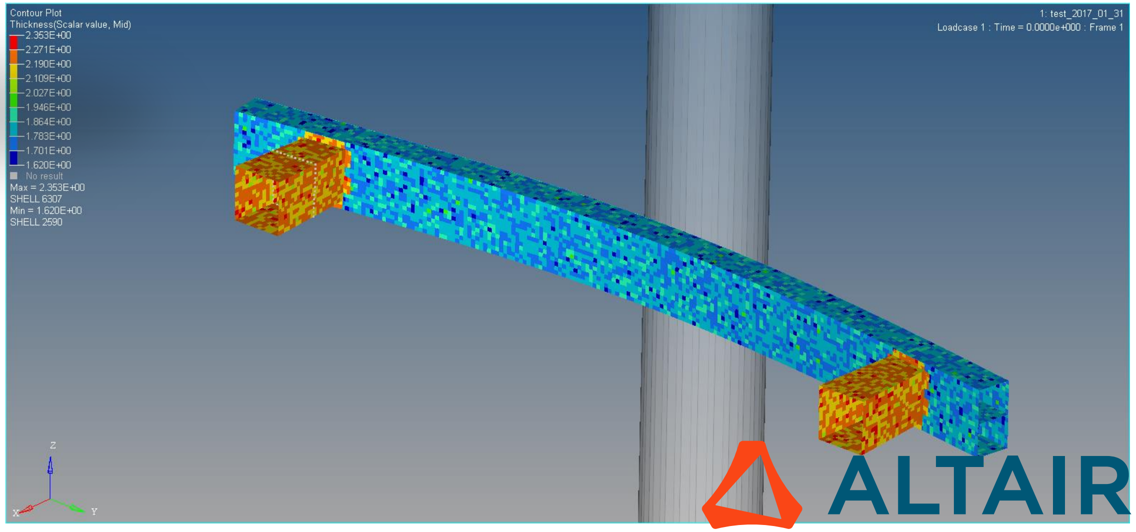
(1)	(2)	(3)	(4)	(5)	(6
/PERTURB/PART/SHELL/ID					
perturb_title					
F_Mean		Deviation		Min_cu	
grpart_ID	parameter				

If *Idistri*=1, the distribution of the scale factors will be random.

If *Idistri*=2, the normal distribution of the scale factors will have the following probability density function.







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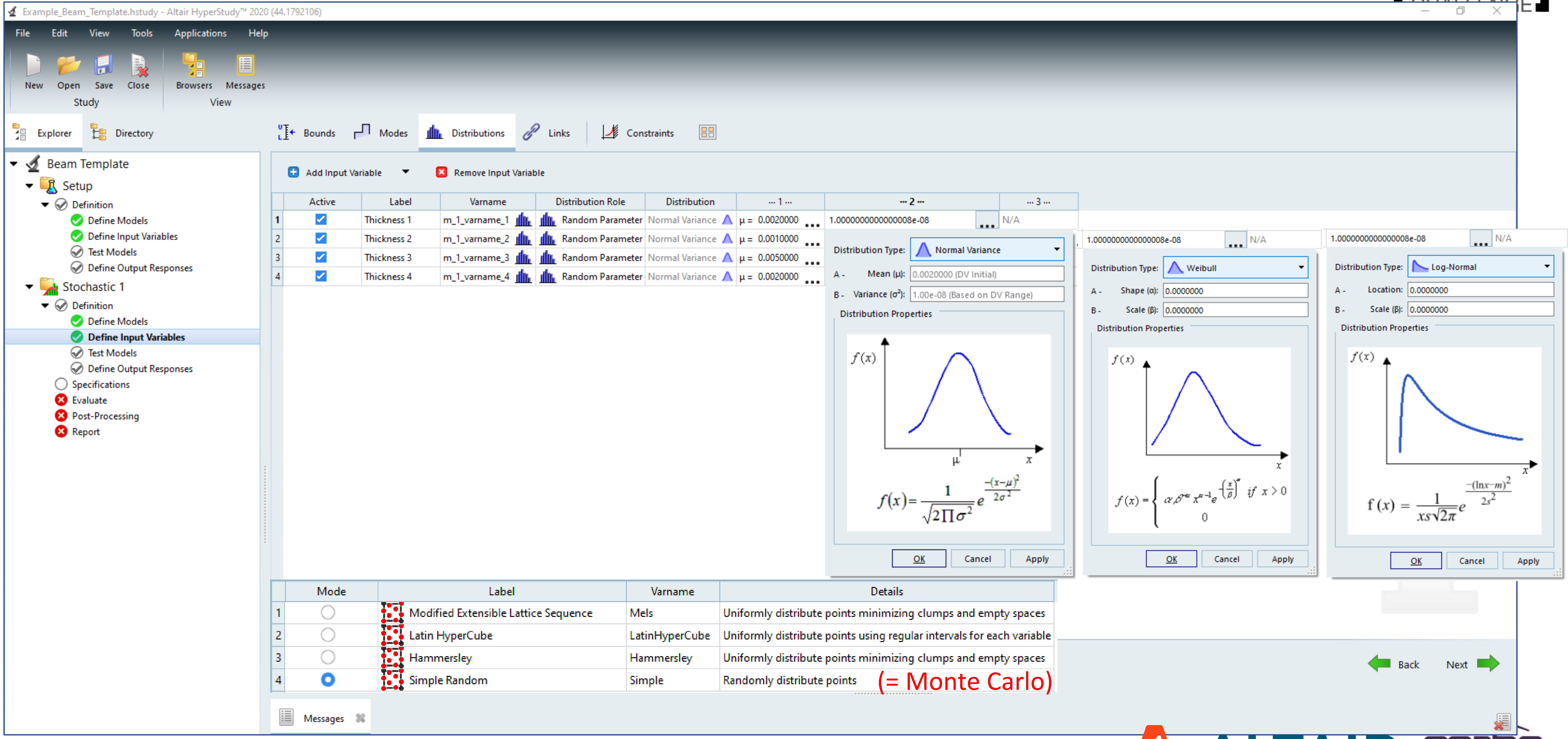
Thickness perturbation – Part wise (material parameter and thickness)



Failure perturbation – Integration point wise

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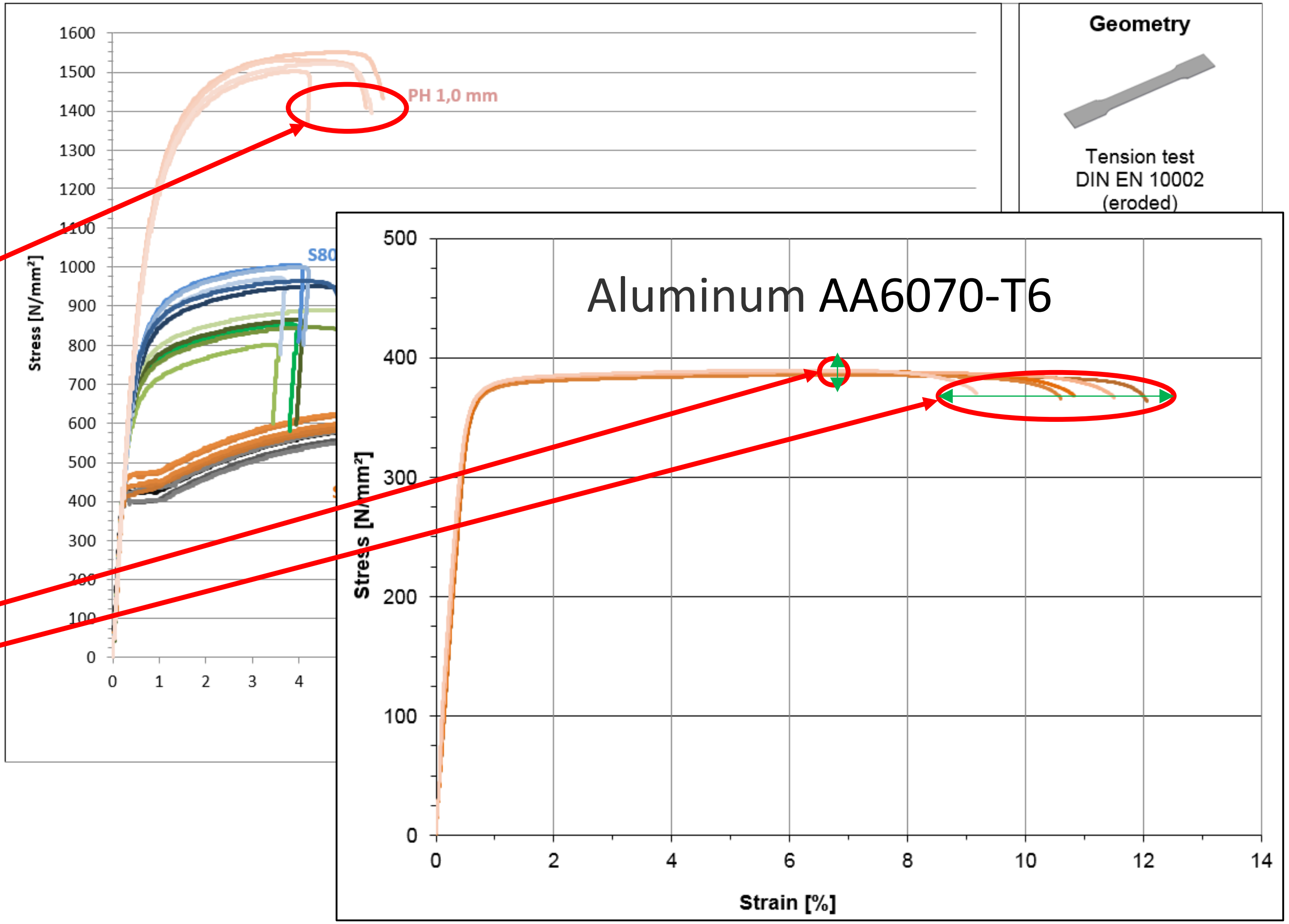
NEW advanced failure criteria (BiQuad)
At least: **0 fitting parameter needed !**

Adding perturbation to fracture limit !

What reality shows:

- Small scattering in max. stress but
- Big scattering in rupture strain



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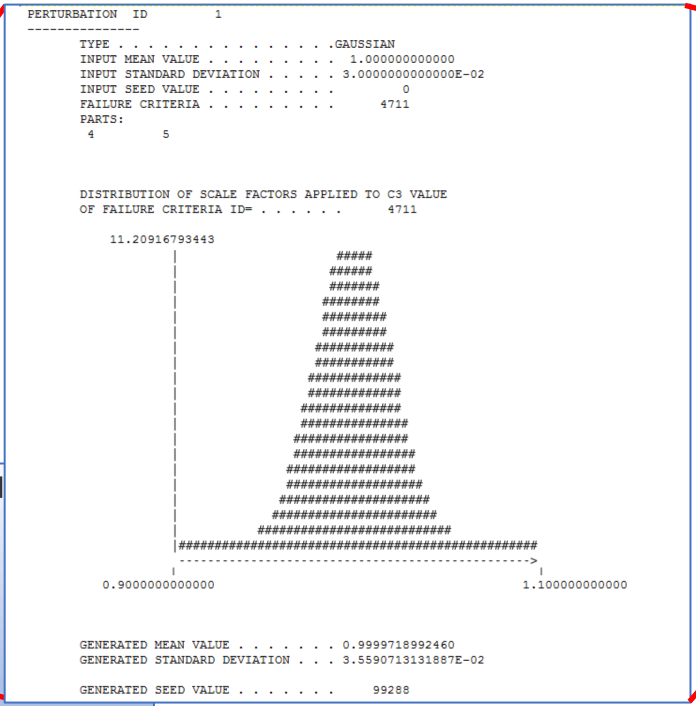
Failure perturbation – Integration point wise

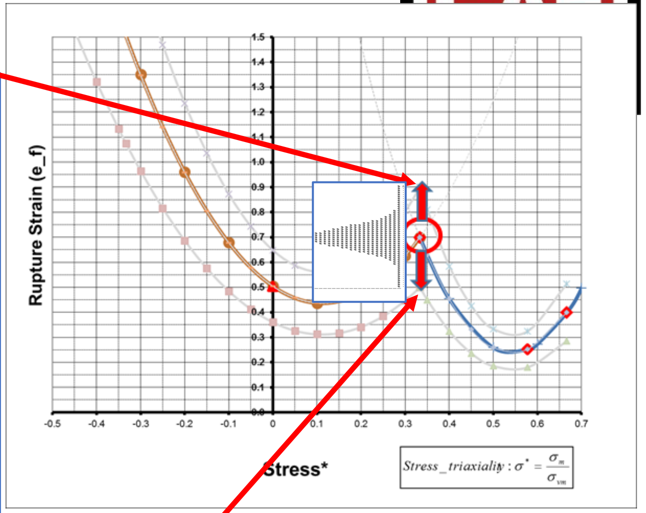
NEW advanced failure criteria (BiQuad)

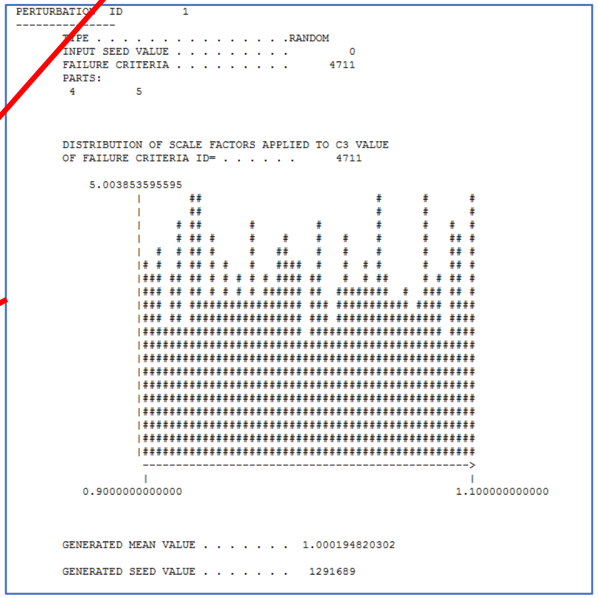
At least: **0 fitting parameter needed !**

Adding perturbation to fracture limit !

```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|
/FAIL/BIQUAD/1
# New failure criteria: BIQUAD
#                  c1                  c2                  c3                  c4
                  0.0                 0.0                 0.7                 0.0
#        P_thickfail    Select   S_Flag
                  .0         1        0
#  Fail_ID (optional)
    4711
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```








```
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
/PERTURB/FAIL/1
# Pertrubation for failure criteria: BIQUAD
#          Mean_value           Deviation             Min_cut             Max_cut      Seed   Idistri
                  1.0                0.03                 0.9                 1.1         0         2
#GrPart_ID
     4711
#---1----|----2----|----3----|----4----|----5----|----6----|----7----|----8----|----9----|---10----|
```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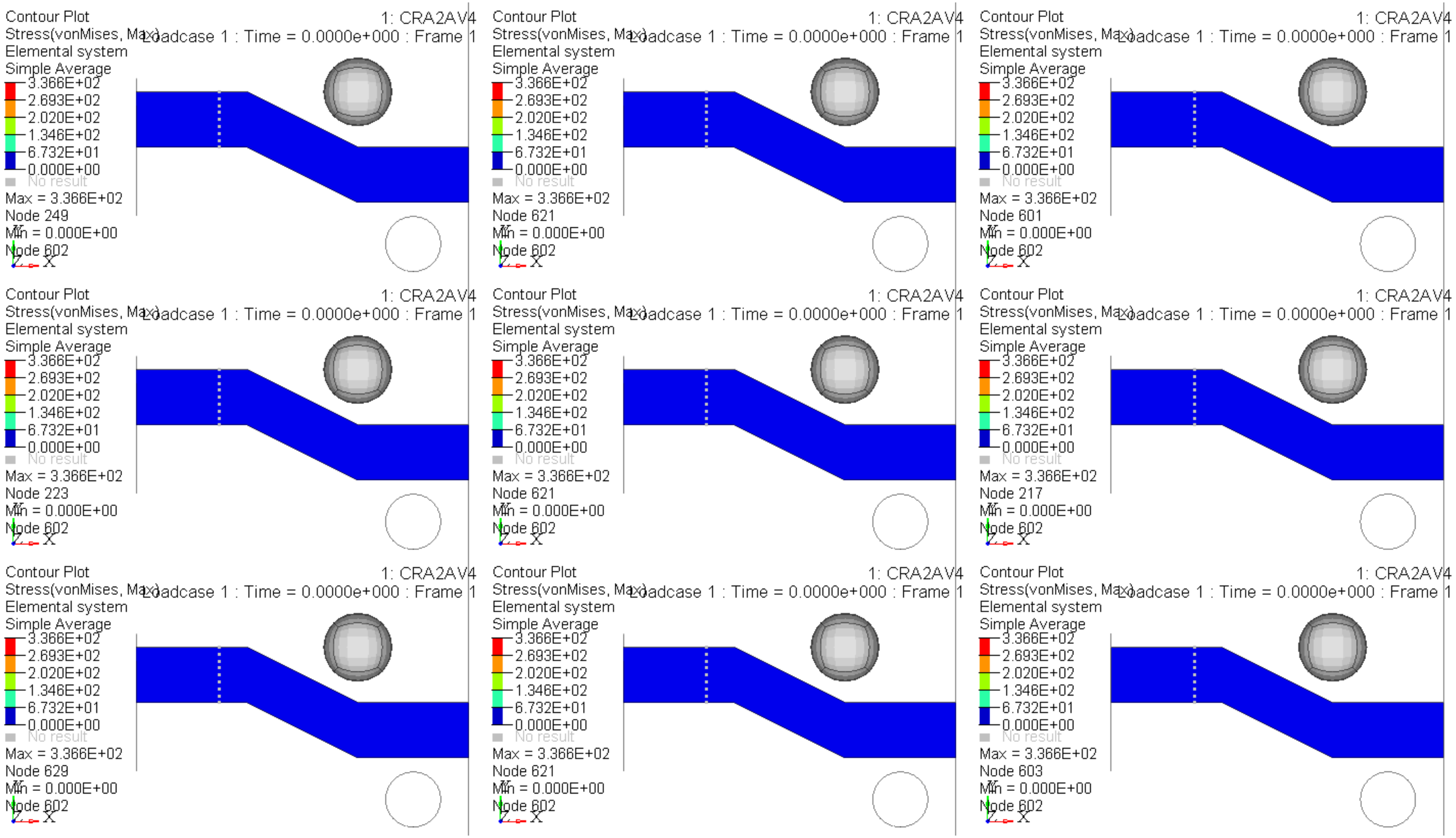
Failure perturbation – Integration point wise



2020

Failure perturbation – Integration point wise

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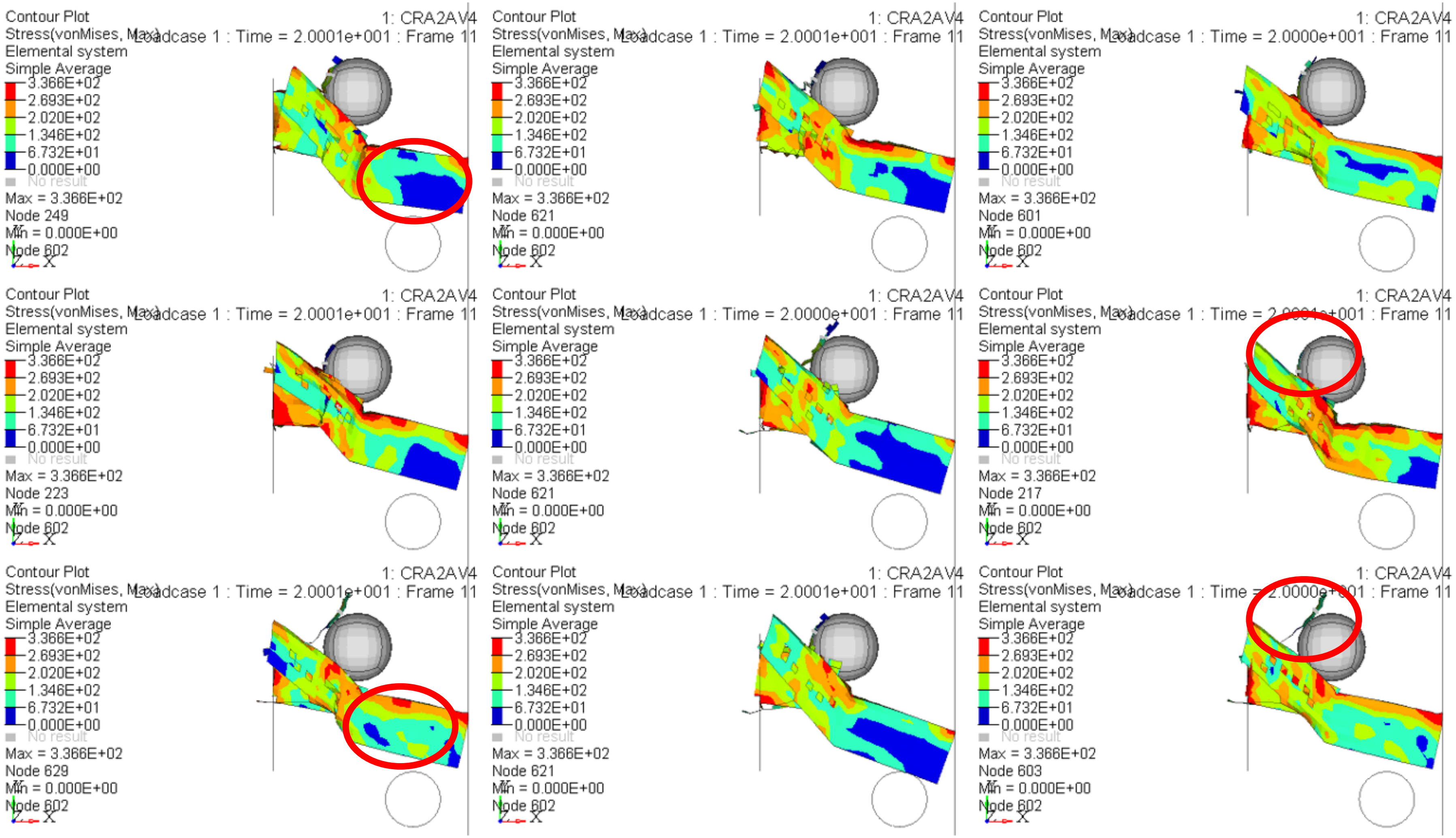

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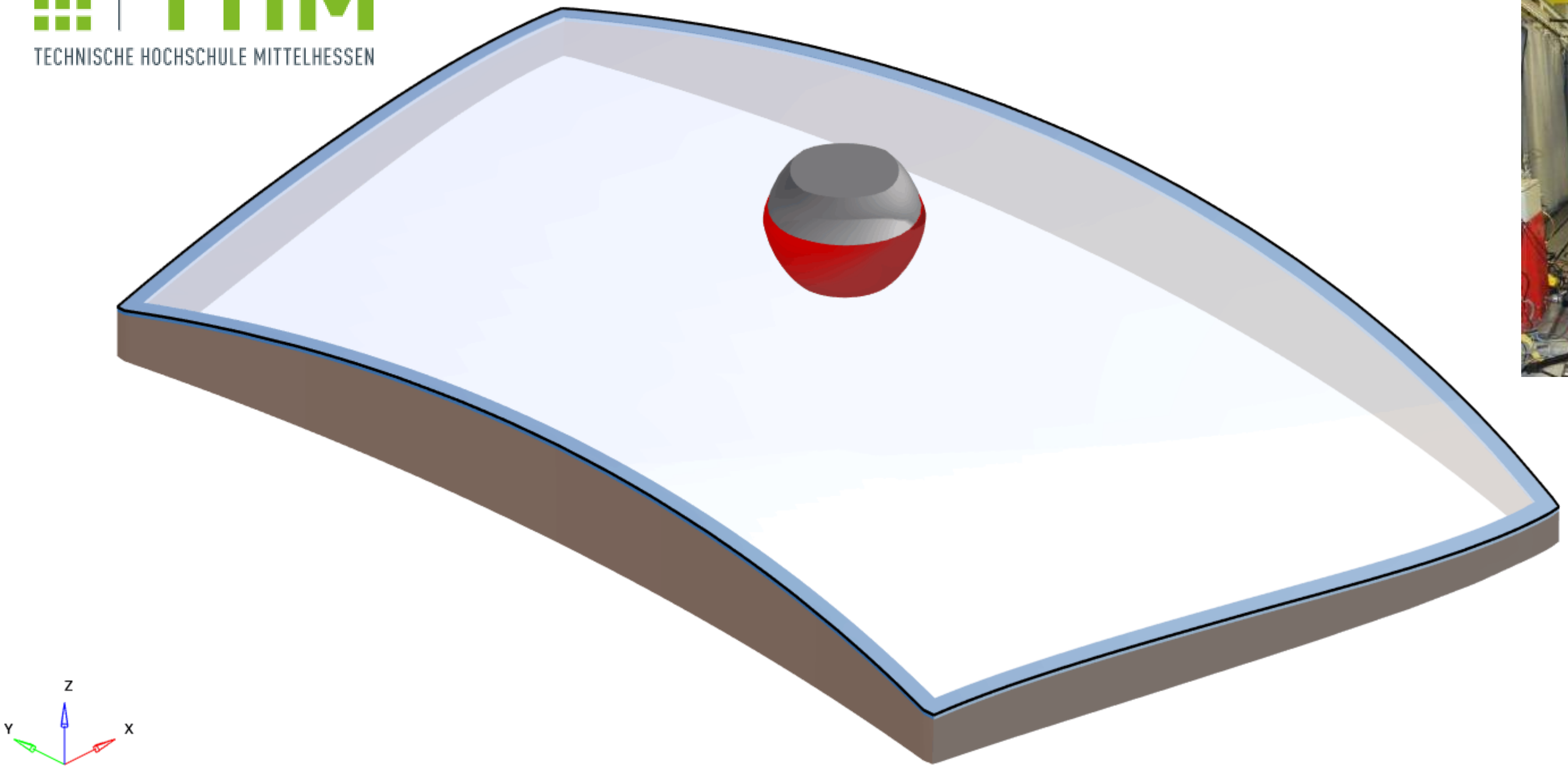
Failure perturbation – Integration point wise: /FAIL/ALTER



Reference: C. Alter, S. Kolling, J. Schneider: "An enhanced non–local failure criterion for laminated glass under low velocity impact." International Journal of Impact Engineering 109: 342-353, 2017.

Failure perturbation – Integration point wise: /FAIL/ALTER

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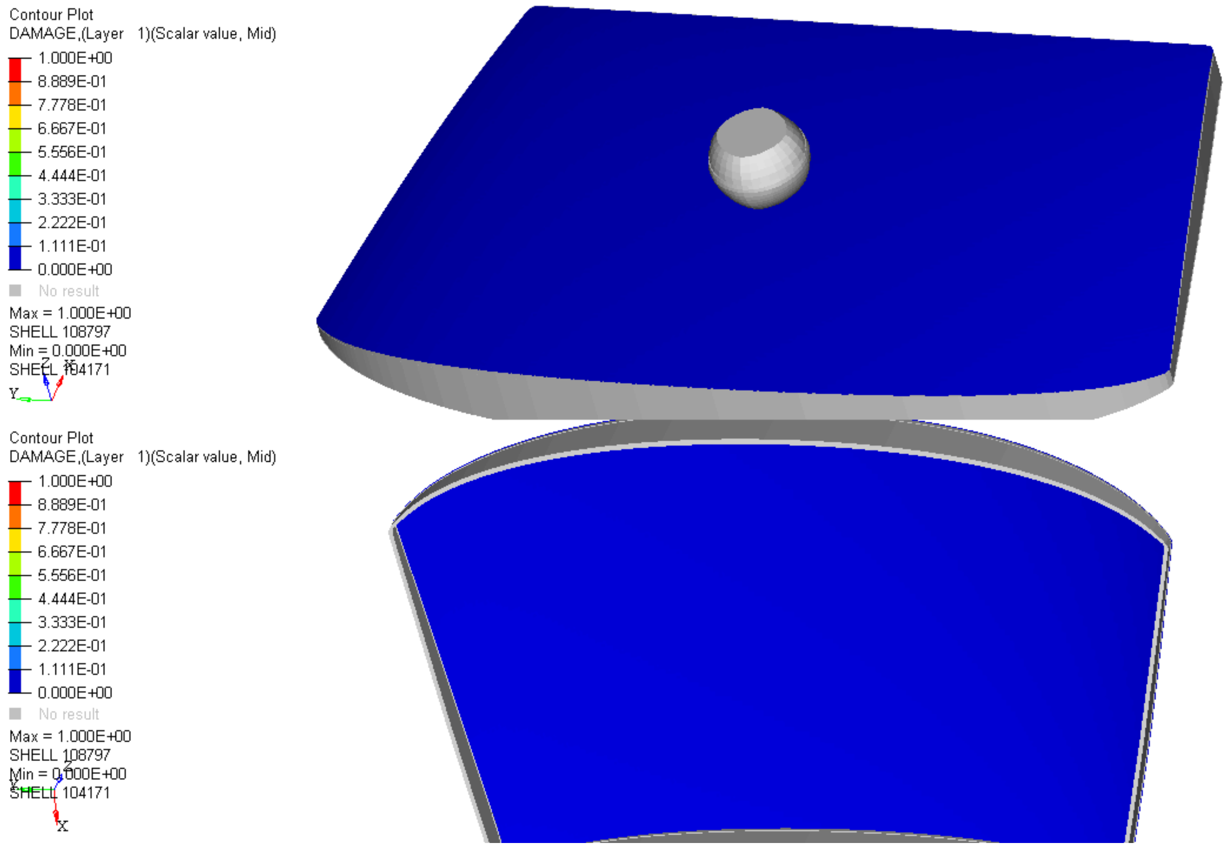
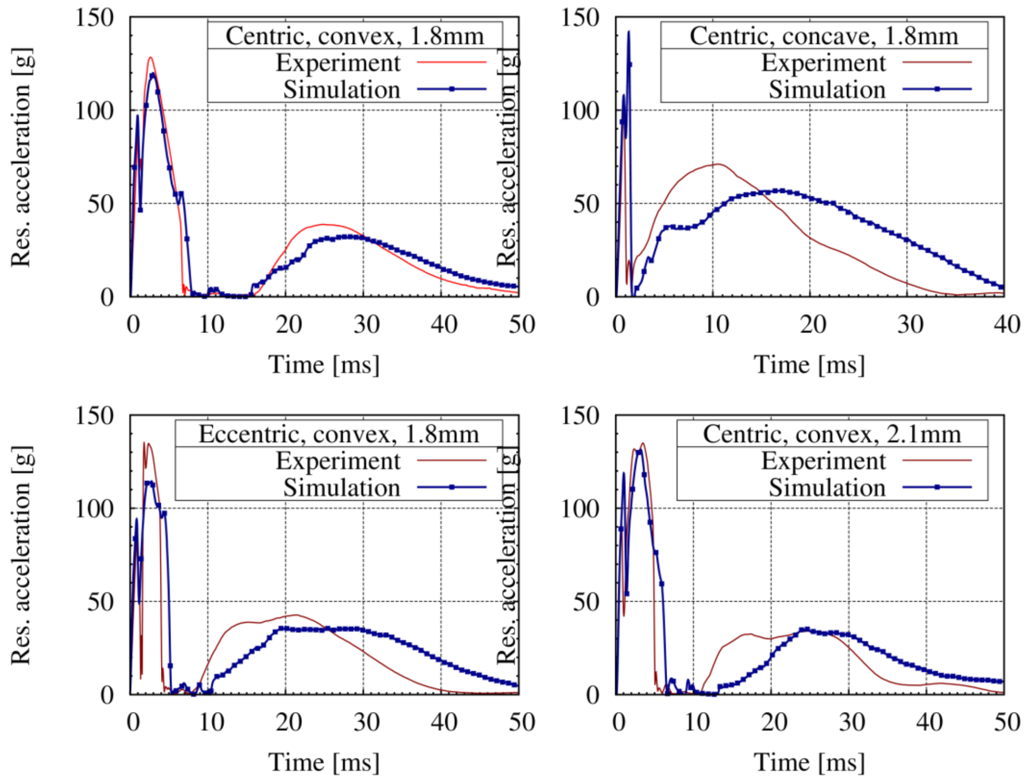


(RADIOSS simulation results using /FAIL/ALTER + enhancement by C. Brokmann)



Comparison of measured and computed acceleration.

Reference: C. Alter, S. Kolling, J. Schneider: "An enhanced non–local failure criterion for laminated glass under low velocity impact." International Journal of Impact Engineering 109: 342-353, 2017.

Target: Increase the Robustness – Example #1

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- **Frontal Impact on Rigid wall**

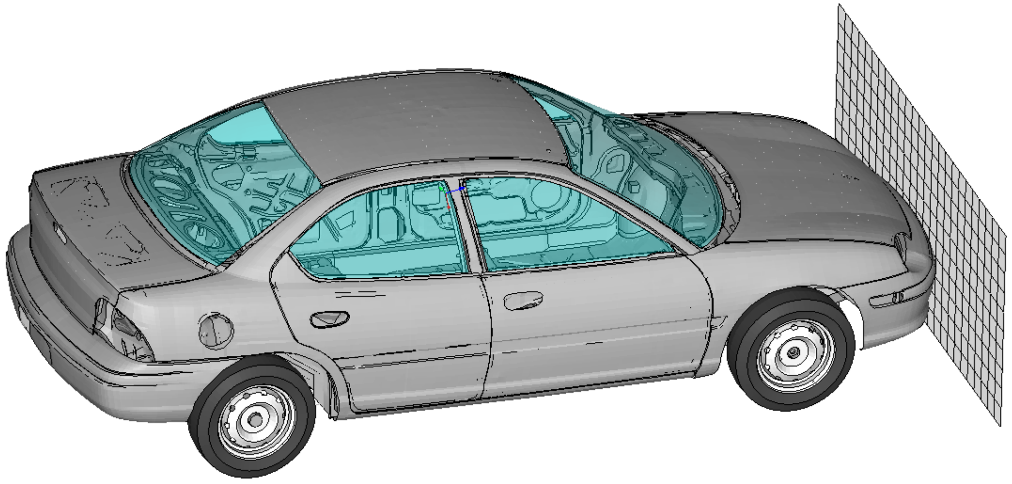
Model Unit: mm, s, Ton

Initial Velocity: 12.3 m/s

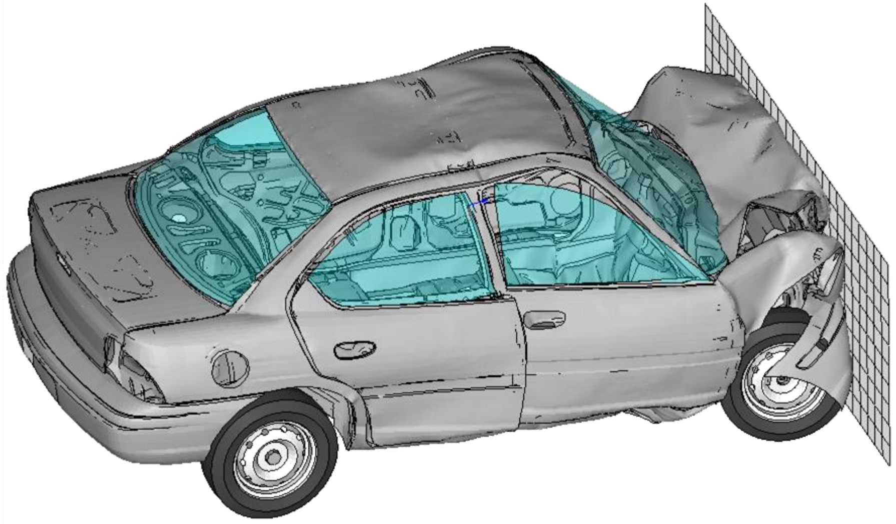
Total Mass : 1.219 Ton

Random Noise: 1.0 E-6 mm

Total	
Elem. 1D	4243
Elem. 2D	1055037
Elem. 3D	2860
Total Elem.	1062140



T = 00.00 ms



T = 80.00 ms

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Target: Increase the Robustness – Example #1

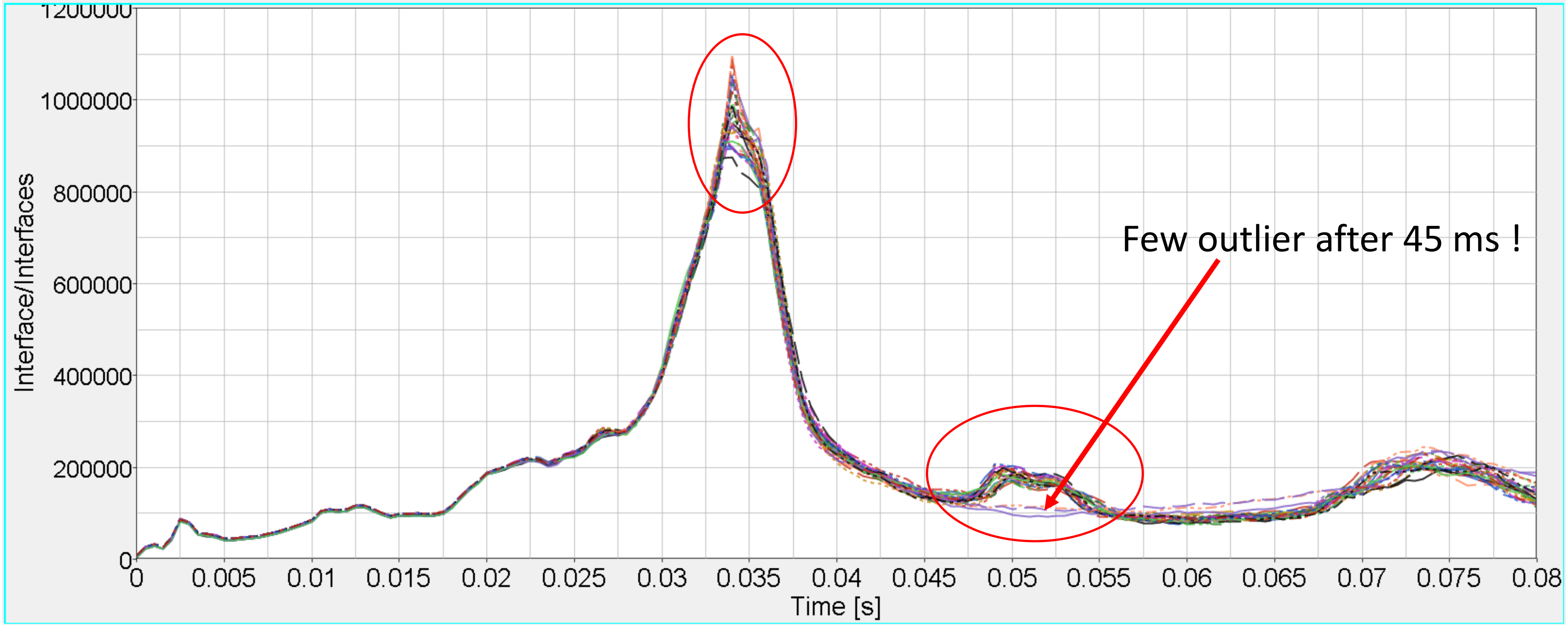
25 Runs

Variation:

Random Noise: 1.0 E-6 mm

Seed variation (0.00 to 0.90)

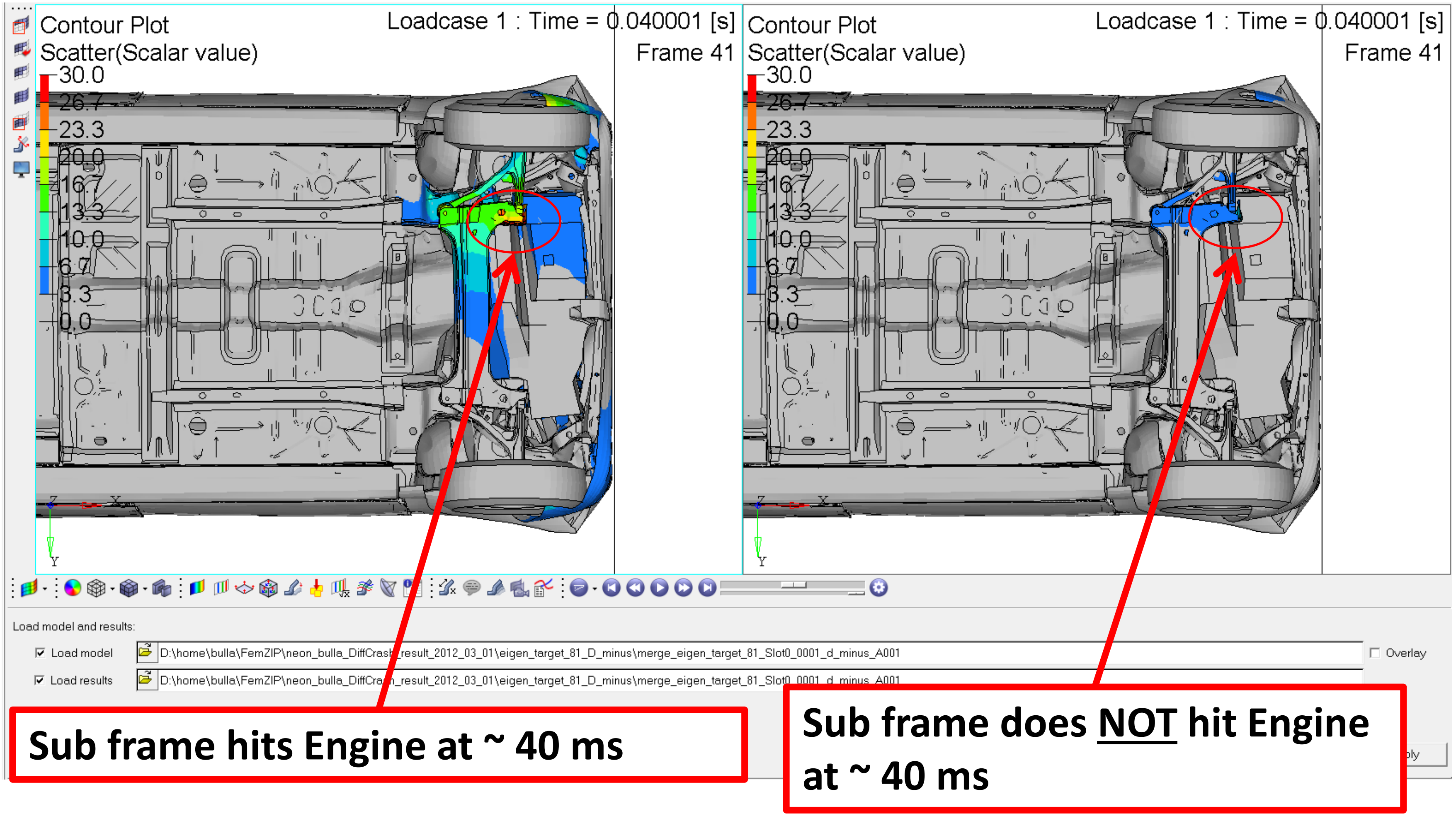
Overall Maximum RigidWall Force



What is the Source of this results Dispersion (in time and space) ?

Target: Increase the Robustness – Example #1

Results: What is the Source (in time and space) of this results Dispersion ?



➔ Small variations can lead to big differences in final results

Target: Increase the Robustness – Example #2

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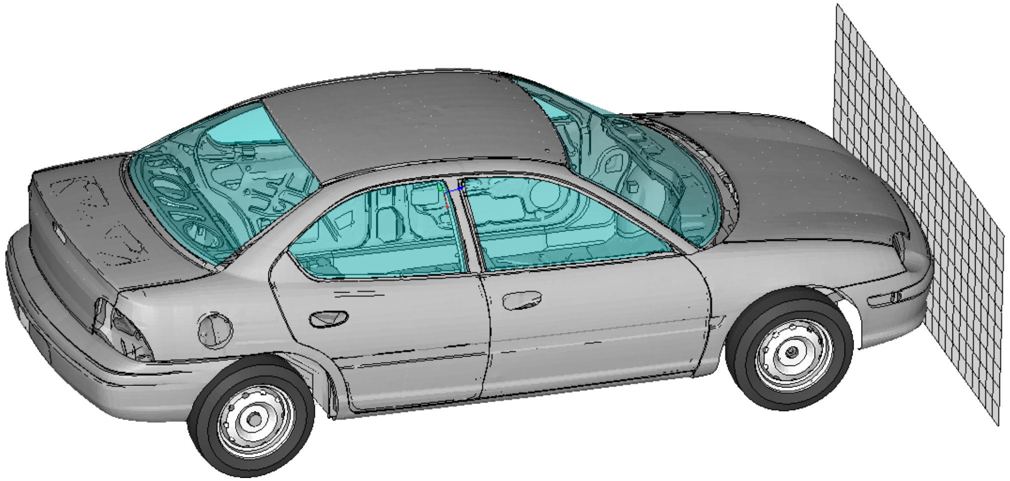
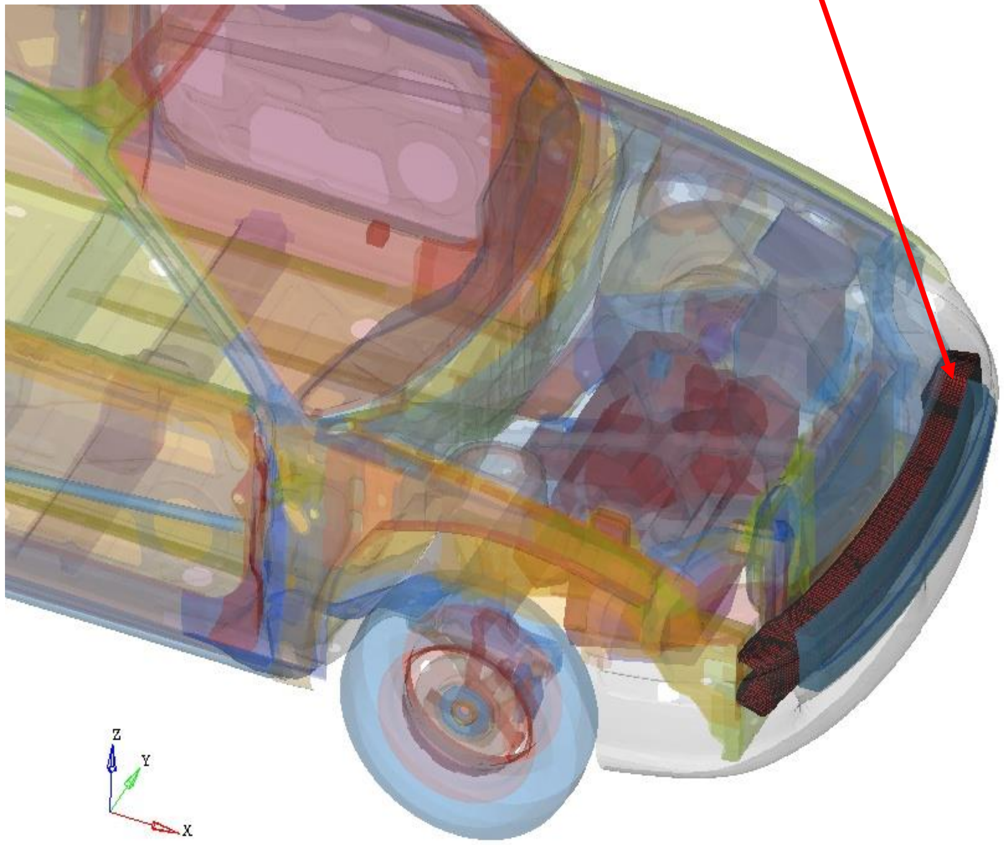
“Physical Variable”: Thickness of the Front Bumper Cross Beam

Original Thickness: 1.956 mm

➔ Increasing the thickness

- **+10%: 2.122 mm**
- **+100% : 3.912 mm**





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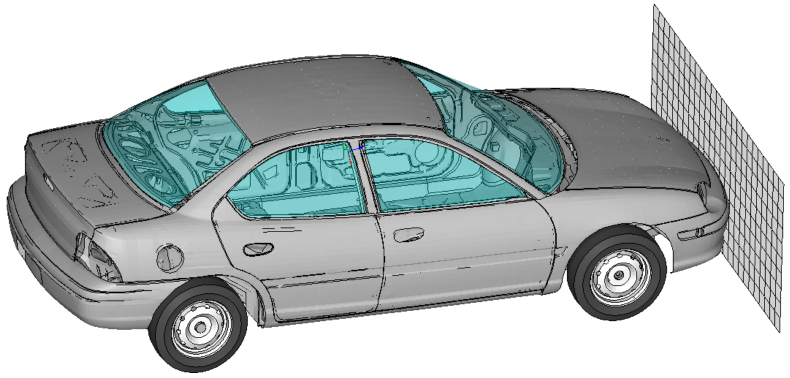
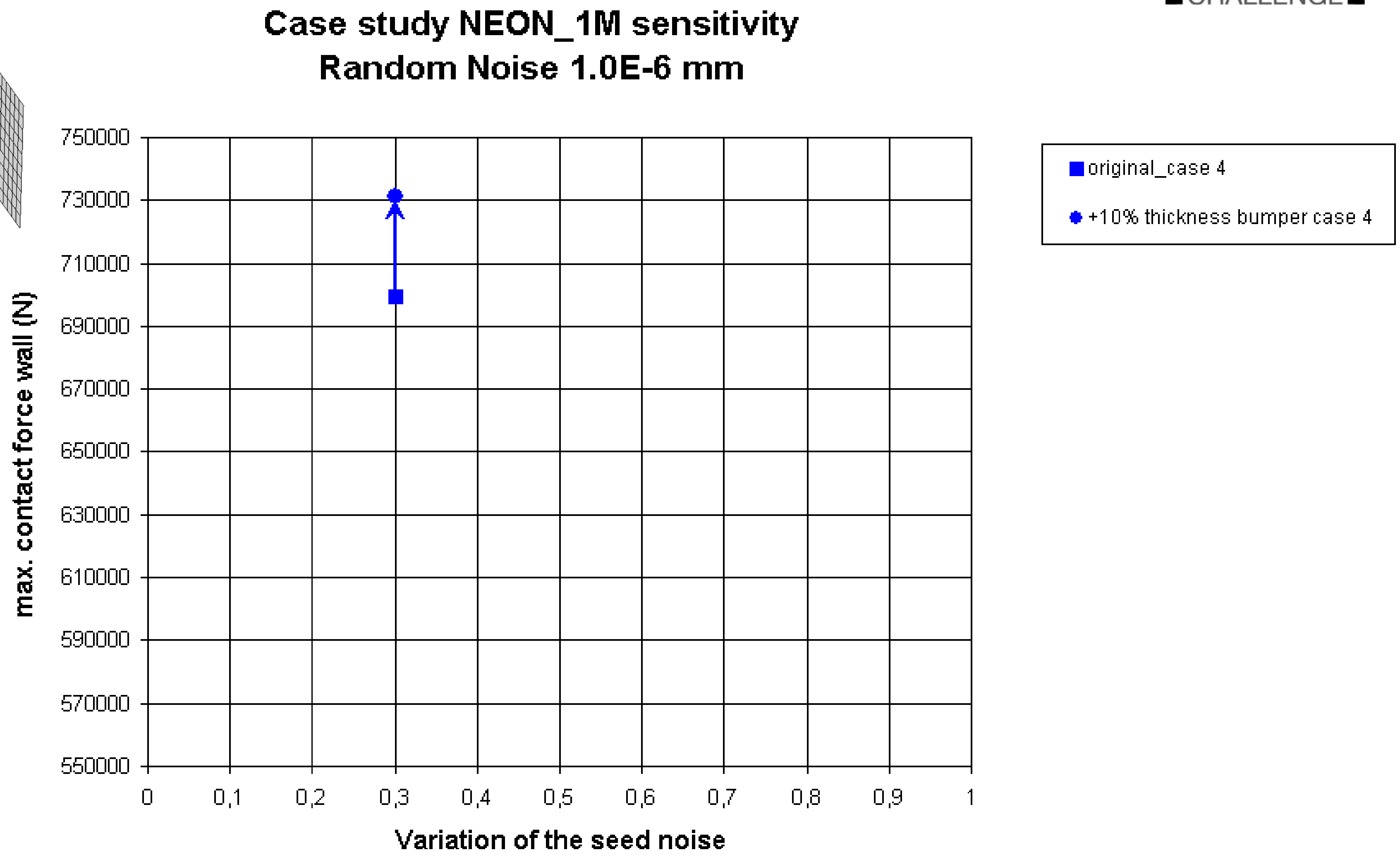
Target: Increase the Robustness – Example #2





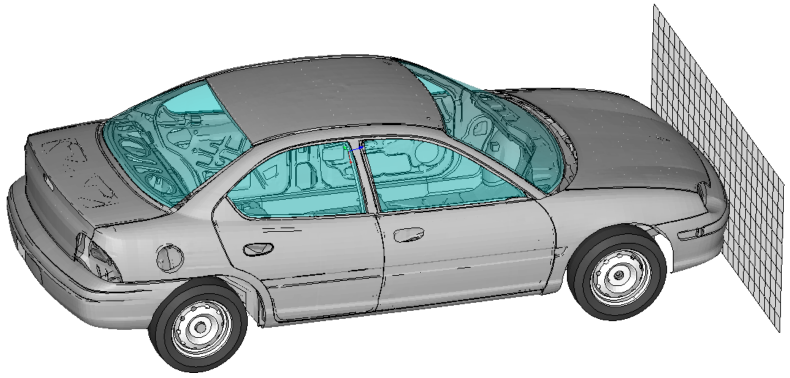
Conclusion after 1st run:

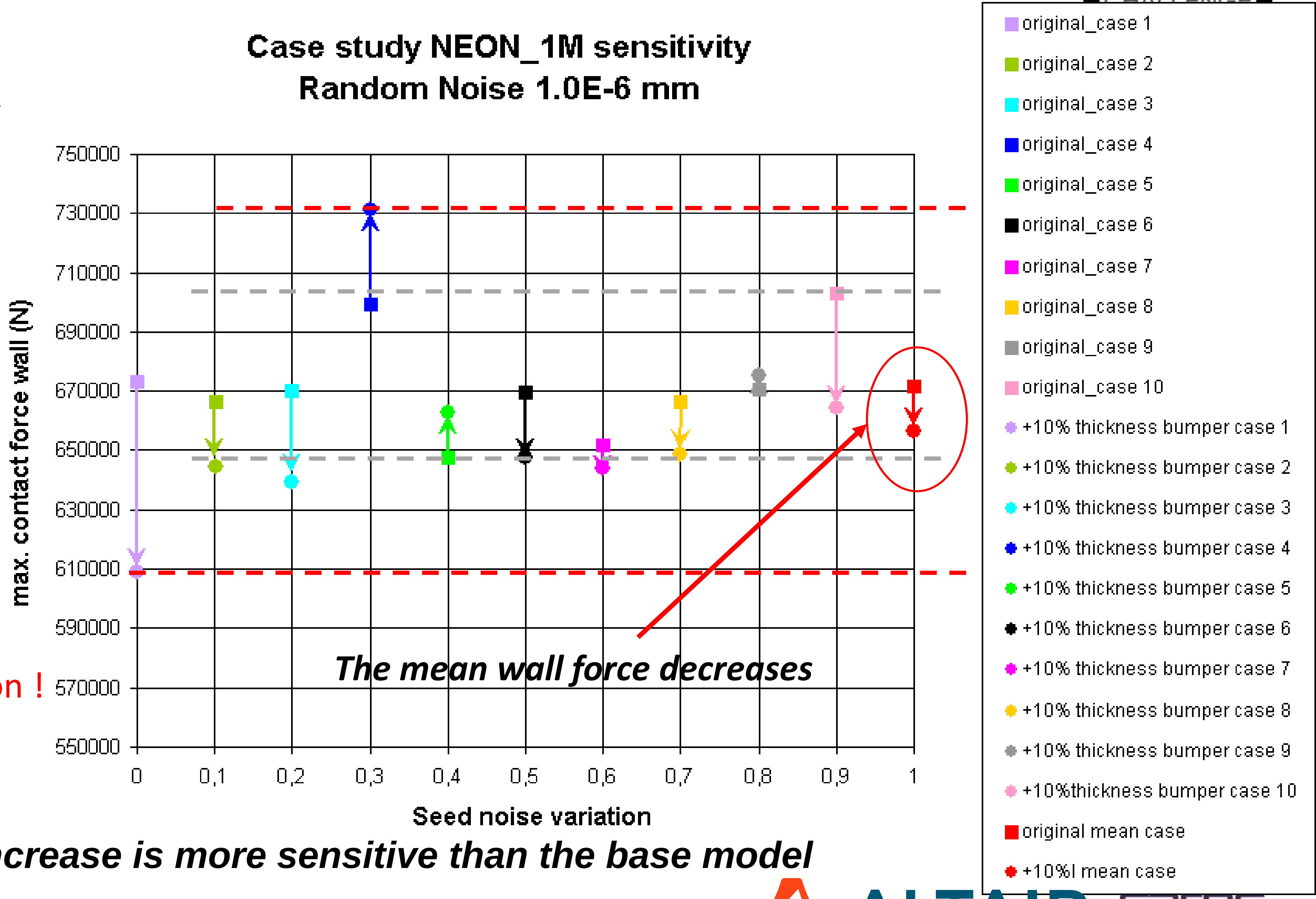
Increasing the thickness of the bumper beam leads to

- ***Increase of the wall force***

→ Sounds logically

Target: Increase the Robustness – Example #2





Conclusion after 10 runs

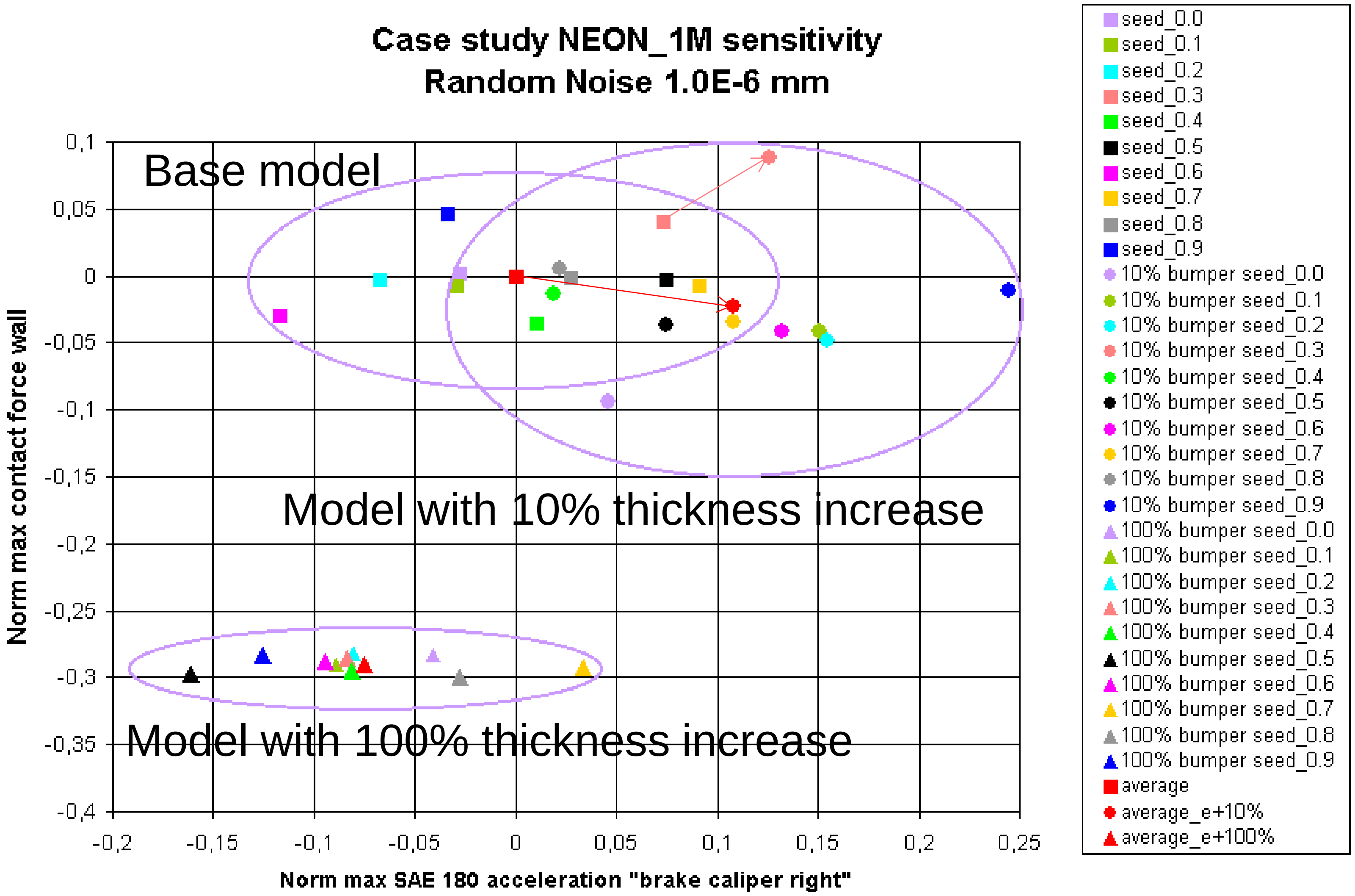
Increasing the thickness of the bumper beam leads to

- ***Decrease of the wall force***

➔ Only 1 run leads to wrong conclusion !

The model with 10% thickness increase is more sensitive than the base model

Target: Increase the Robustness – Example #2



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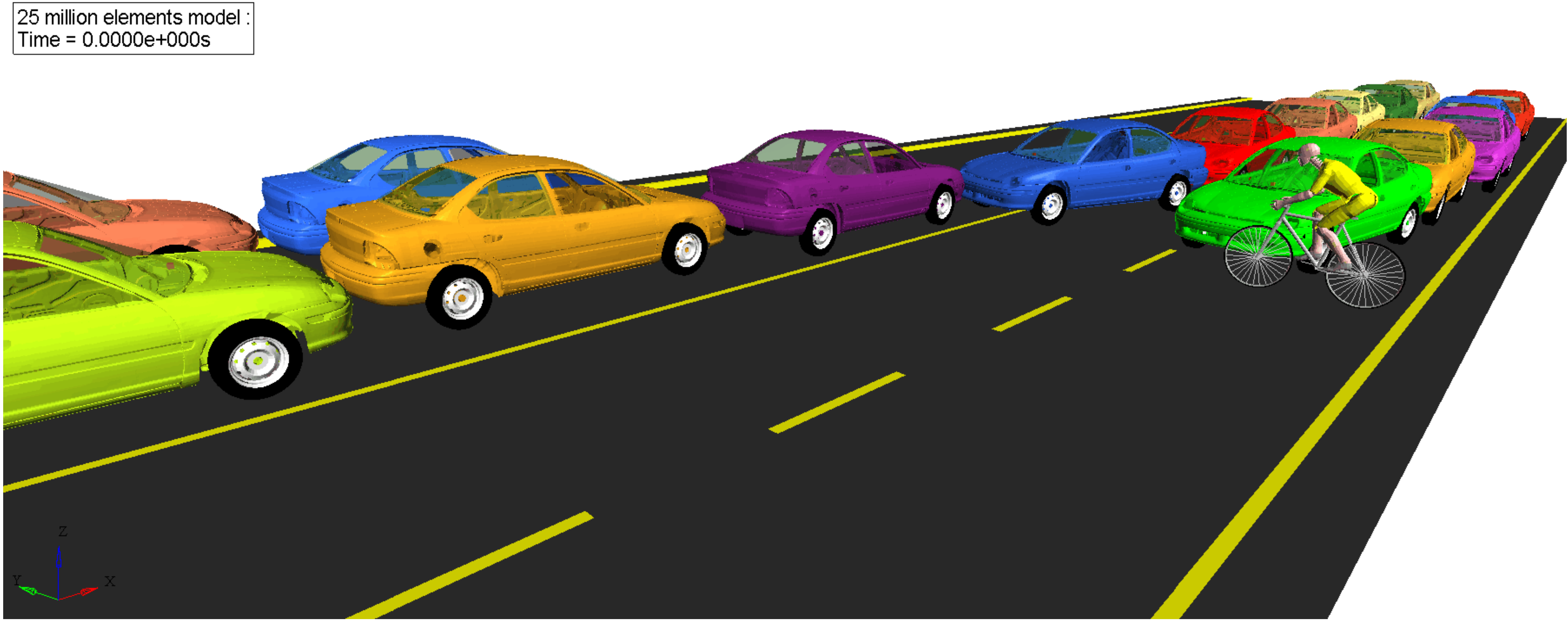
Huge simulation models are not an issue, today !



Conclusion

CRASH is chaotic !

Material properties are **not** always homogeneously distributed within a part.

They have always **tolerances.**

A <u>DESIGN</u> IS ROBUST IF ITS SENSITIVITY TO SMALL CHANGES IS LOW

- Robustness is more important than optimality. A « good enough » robust solution is better than a sensitive optimal solution.
- Robustness of design should be a key objective for optimization
- REPEATABILITY is important in the design process (with /PARITH/ON, Radioss delivers always the same results, when run is started twice)
- **Uncertainties (material, geometric tolerances, …) must be accounted for**

RADIOSS offers predictive <u>material</u> and <u>failure</u> models,
applicable for modeling and considering most of known physical effects.

➔ Anyway, there are still a lot to opportunities for improvements ! Lot of work ahead !

➔ We are fully open for participation in research projects and new developments !

Thank you for your attention !

Open for questions…

Marian Bulla

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