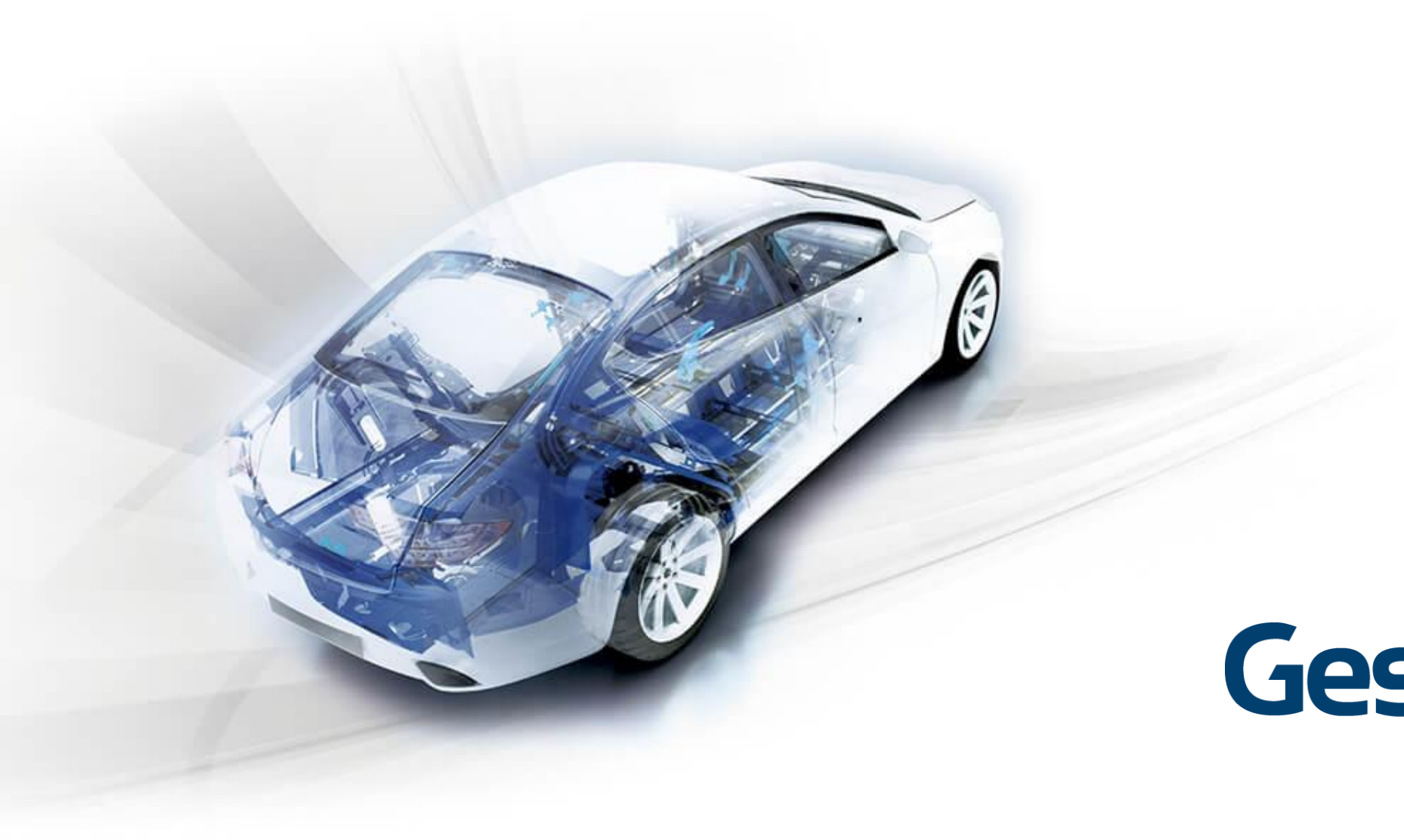


Gestamp

OPTUS

A user defined constitutive model for prediction of localization and crack initiation calibrated by full field measurement

Outline

Optus -

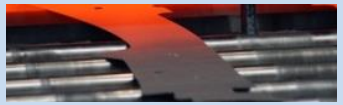
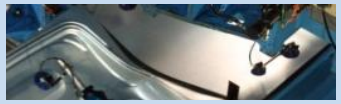
A user defined constitutive model for prediction of localization and crack initiation calibrated by full field measurement

- Gestamp
- Formulation of the constitutive model
- Calibration using full field measurement
- Validation and verification examples

Gestamp Product Portfolio

Product & Technology Development

Wide range of technologies addressing the industry requirements to achieve the right balance between SAFETY, PERFORMANCE, WEIGHT and COST

HOT STAMPING 	WELDING AND ASSEMBLY 	REMOTE LASER WELDING 3D 
COLD STAMPING 	ROLLFORMING 	MACHINING 
HSS STAMPING 	PATCHWORK BLANKS 	MOULDING 
HYDROFORMING 	LASER WELDED BLANKS 	TOOLING 

Global Footprint – Plants

105[(1)(2)] Plants
Industry Leader with Global Presence

21 Countries
Strategic Supplier & Partner

North America
13

South America
13

East Europe
17

West Europe
45

Asia
17

Gestamp plants

(1) The addition of BHAP's plant in Beijing resulting from the JV announced on January 25th, 2018 is subject to approval from the Chinese special commission SASAC, as well as to competition and other government authorities
(2) The addition of Gestamp Sorocaba plant resulting of the acquisition announced on February 13th, 2018 which is subject to the approval of the relevant competition authorities

Global Footprint – R&D Centers

13 R&D Centers

Model overview

Brief history of failure prediction at Gestamp Hardtech

- Development of the OPTUS (**OPT**imal **U**se of high strength **S**teel) model started in 2005
- Cooperation with Ford Forschungszentrum Aachen GmbH, Volvo car corporation and Luleå University of Technology
- Mesh size sensitivity and coarse mesh accuracy

Constitutive model

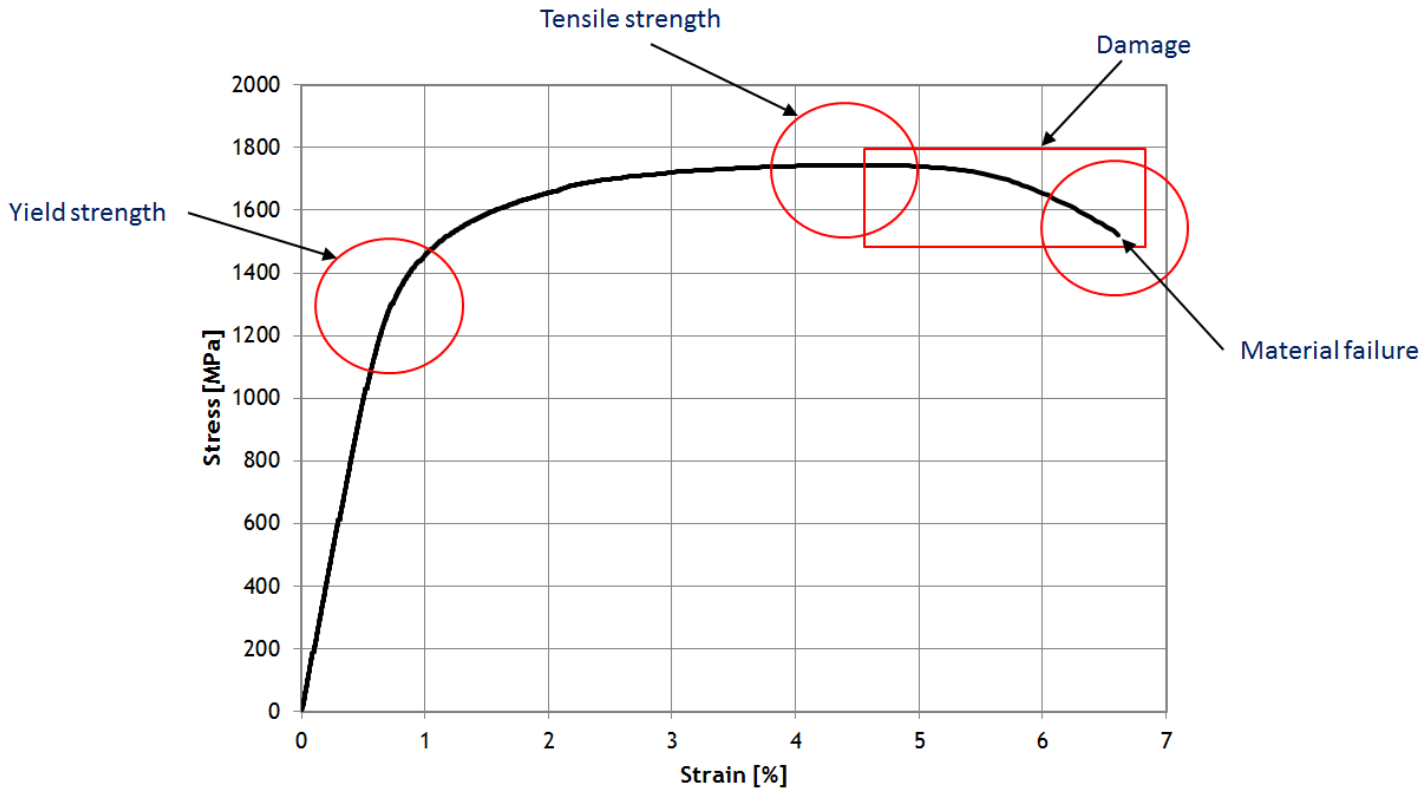
- Elasto-(visco)plastic
- J2 flow theory
- Isotropic hardening

Damage

- Coupled non-linear damage accumulation rule
- Scaled with respect to mesh size

Fracture

- Stress state dependent fracture limit
- Scaled with respect to mesh size



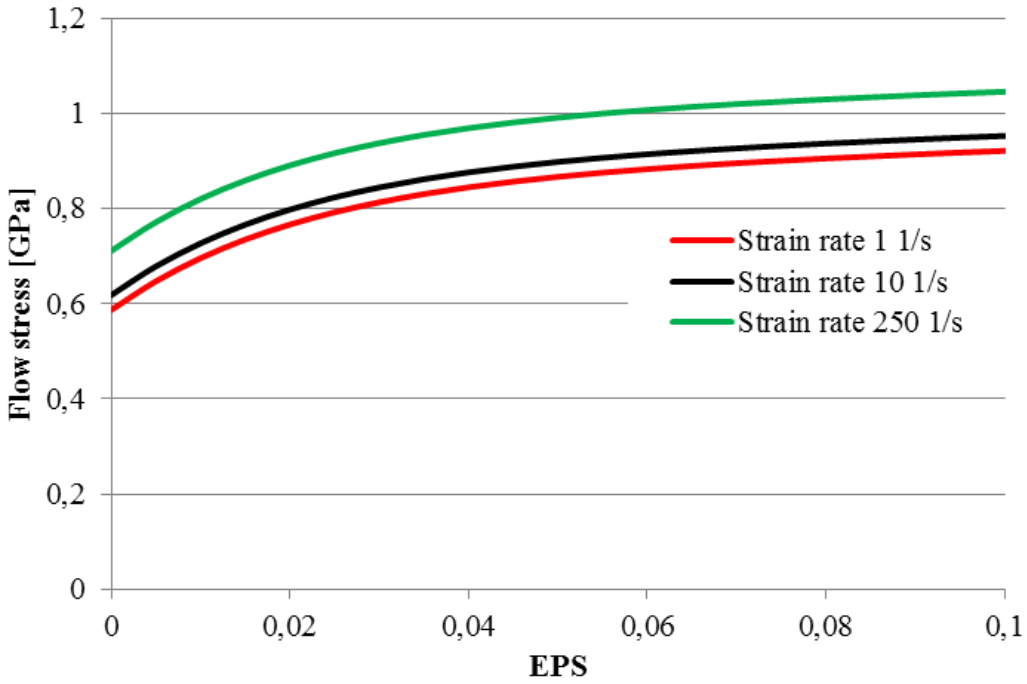
Model overview

- Isotropic von Mises Hardening, $f = \sqrt{3J_2} - \sigma_y = 0$

- Piecewise linear static flow stress curve, $\sigma_{y0}(\bar{\varepsilon}_p)$

- Viscous model, additive formulation

$$\sigma_y = \sigma_{y0}(\bar{\varepsilon}_p) + C_1 \left(\frac{\dot{\bar{\varepsilon}}_p}{C_2} \right)^{1/p}$$



Ductile damage = void formation, growth and coalescence

Coupled damage = damage has direct influence on the stress state

$$\sigma = \bar{\sigma}(1 - \mathrm{d}_{\mathrm{crit}}\, D\, \mathrm{h}_{(\sigma_m)})$$

Localization threshold ε_0

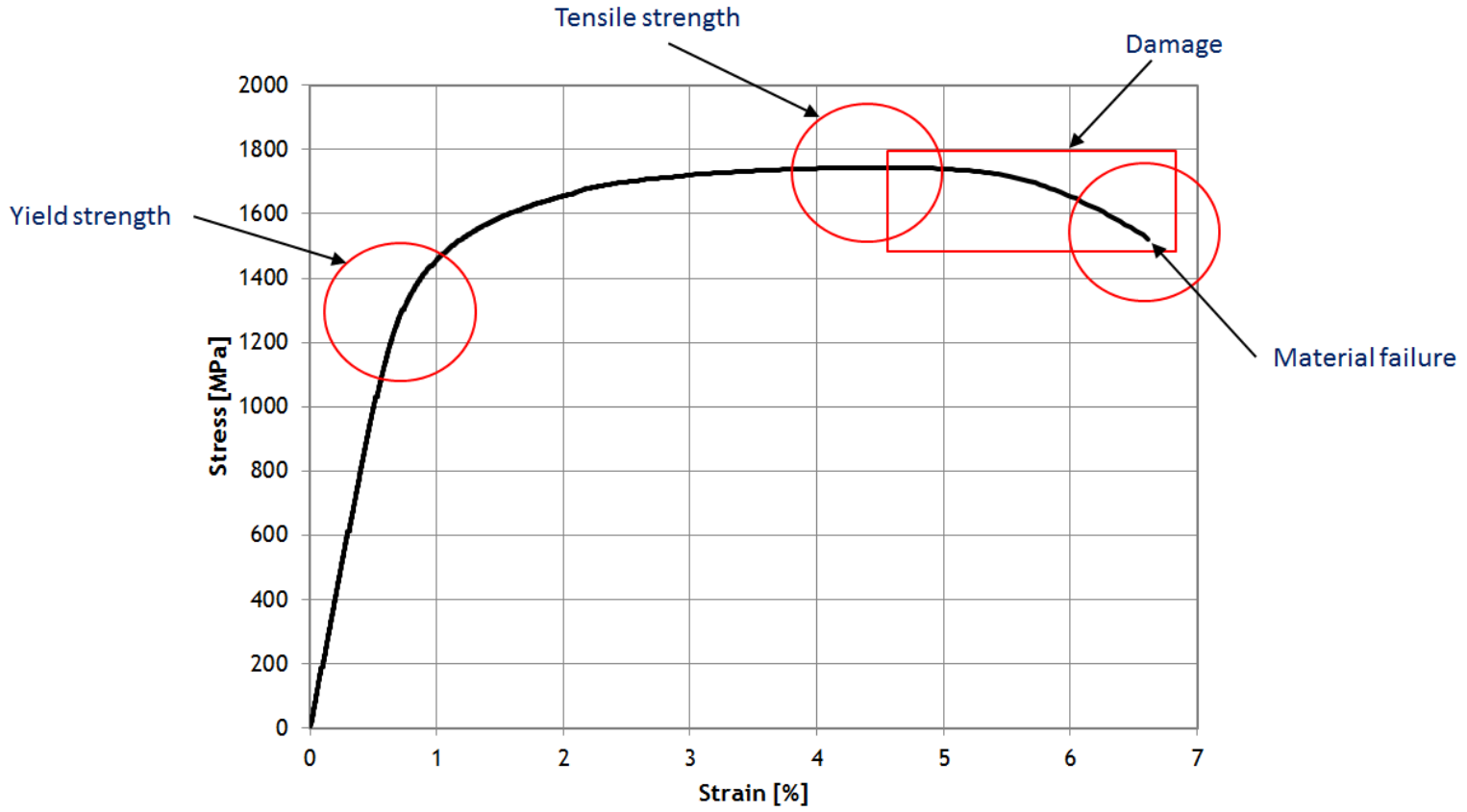
$$if\ \eta \leq \frac{1}{\sqrt{3}}$$

$$H(\bar{\varepsilon}_p) - \frac{1}{2}(\sigma_1 + \sigma_2) = crit$$

$$else$$

$$\frac{4\bar{\sigma}}{3\bar{\varepsilon}_p} - \frac{(\bar{\sigma} - H\bar{\varepsilon}_p)}{\bar{\sigma}^2\bar{\varepsilon}_p}\sigma_1^2 - \sigma_1 = crit$$

$$if\ crit \leq 0\ then\ \varepsilon_0 = \bar{\varepsilon}_p$$



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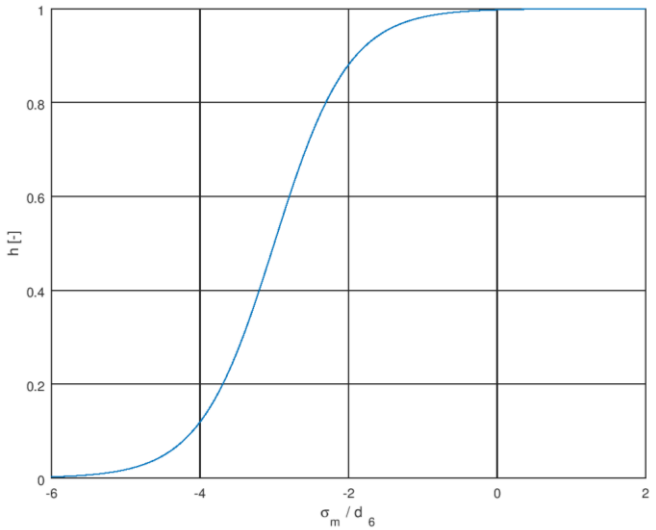
$$if\ crit \leq 0\ then\ \varepsilon_0 = \bar{\varepsilon}_p$$

Damage pressure threshold

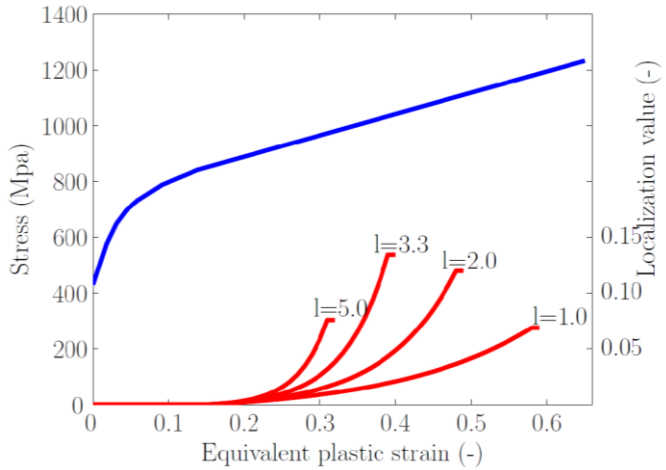
$$h_{(\sigma_m)} = \frac{1}{2}\left(1 + \tanh\left(\frac{\sigma_m}{d_6} + 3\right)\right)$$



Isotropic damage

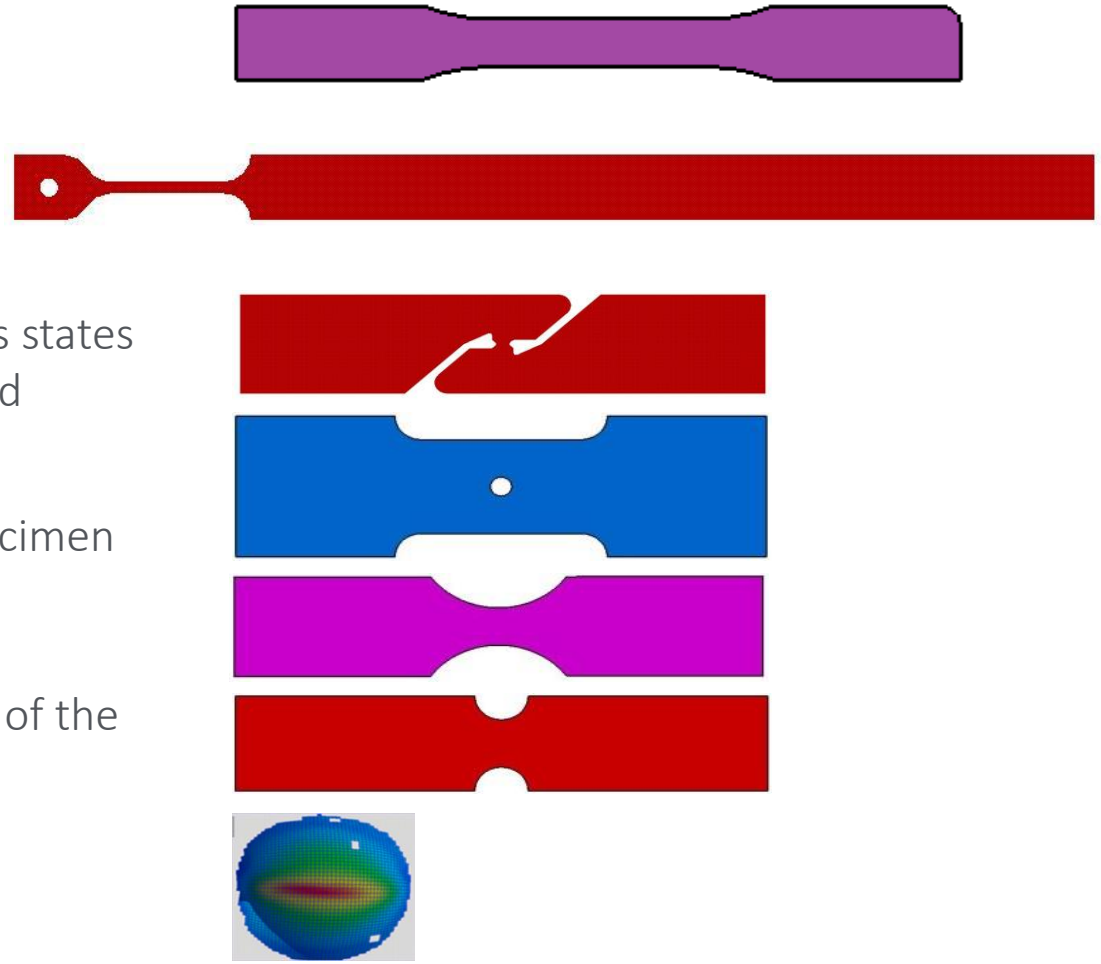
$$if\ \ \bar{\varepsilon}_p \geq \varepsilon_0$$

$$D = A\left(\frac{l}{t}\right)^2 \left(e^{B(\bar{\varepsilon}_p - \varepsilon_0)} - 1\right)$$

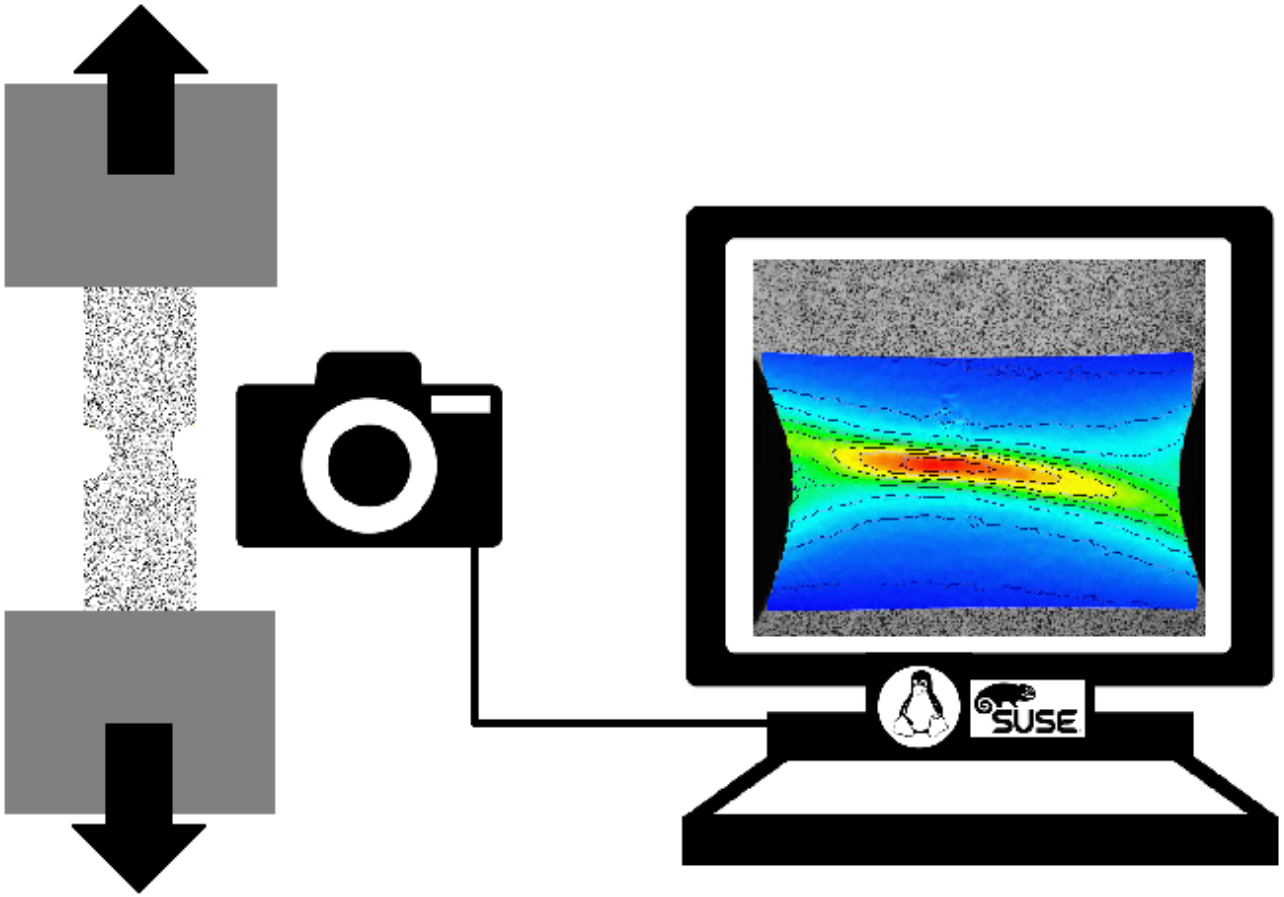


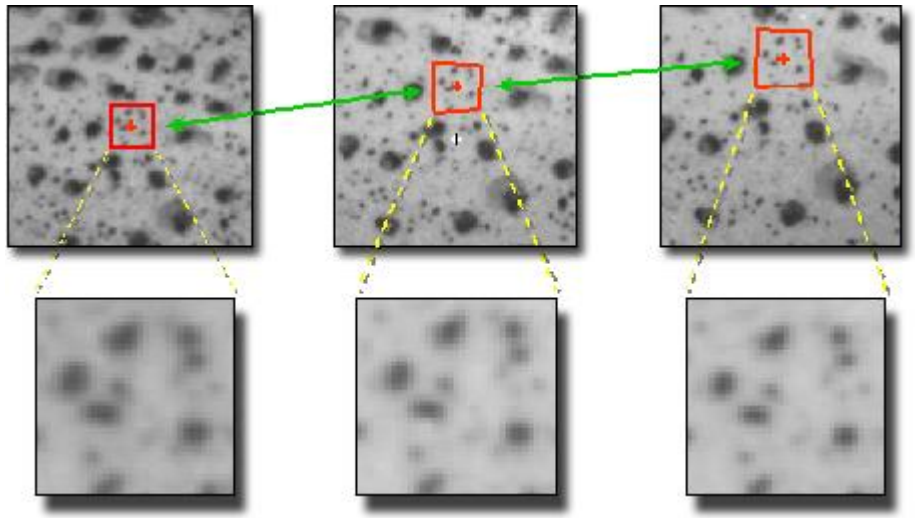
Material characterization

Property	Test method
Flow stress	Standard tensile test
Strain rate dependency	Tensile test at different strain rates
Strain to fracture	Tensile test on specimens representing different stress states Local failure strain just before fracture initiation is used
Damage function	Force-displacement test result of the plane strain specimen
Element size dependent failure strain	Measured strain distribution across the localized area of the plane strain specimen



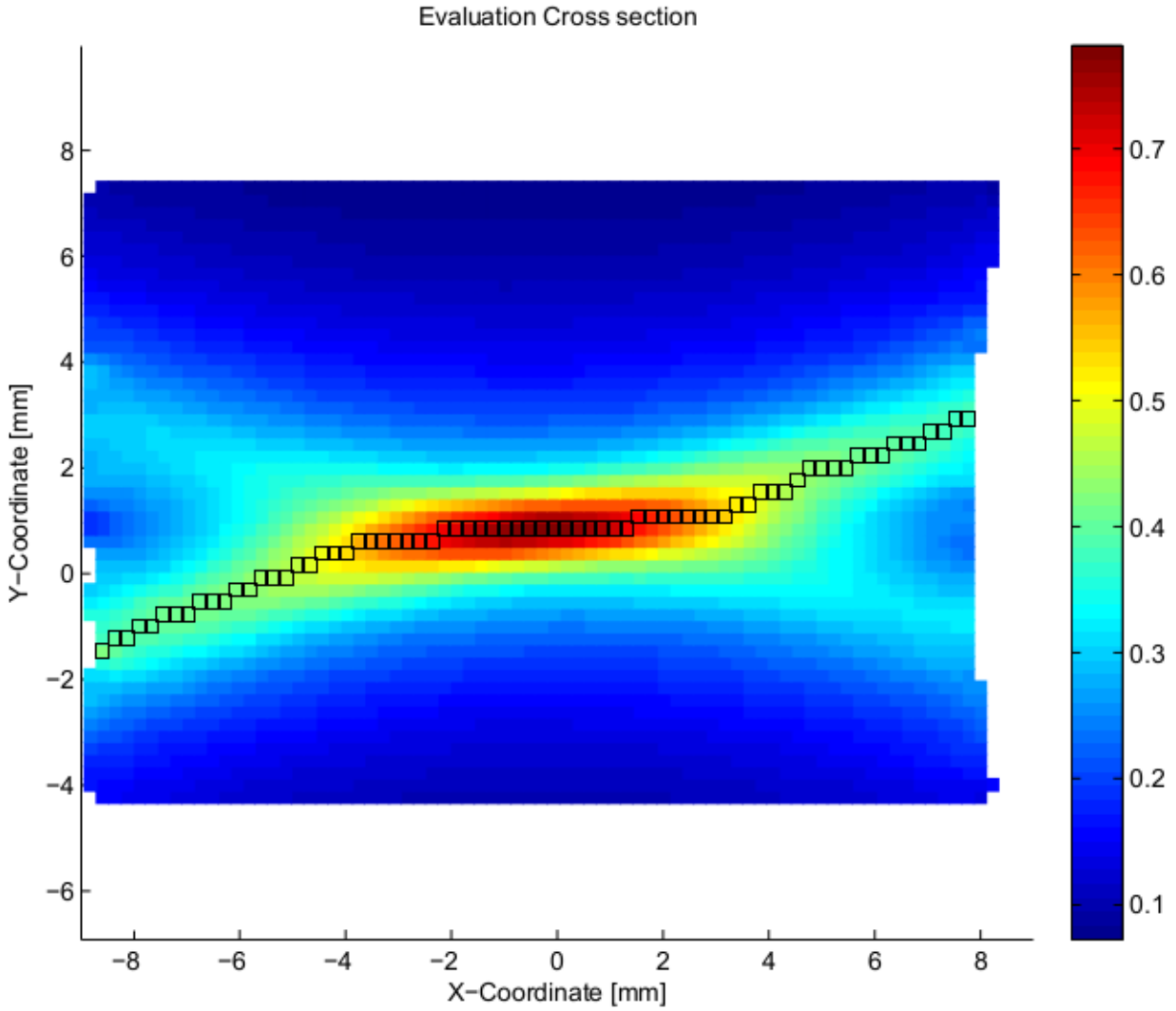
Material characterization

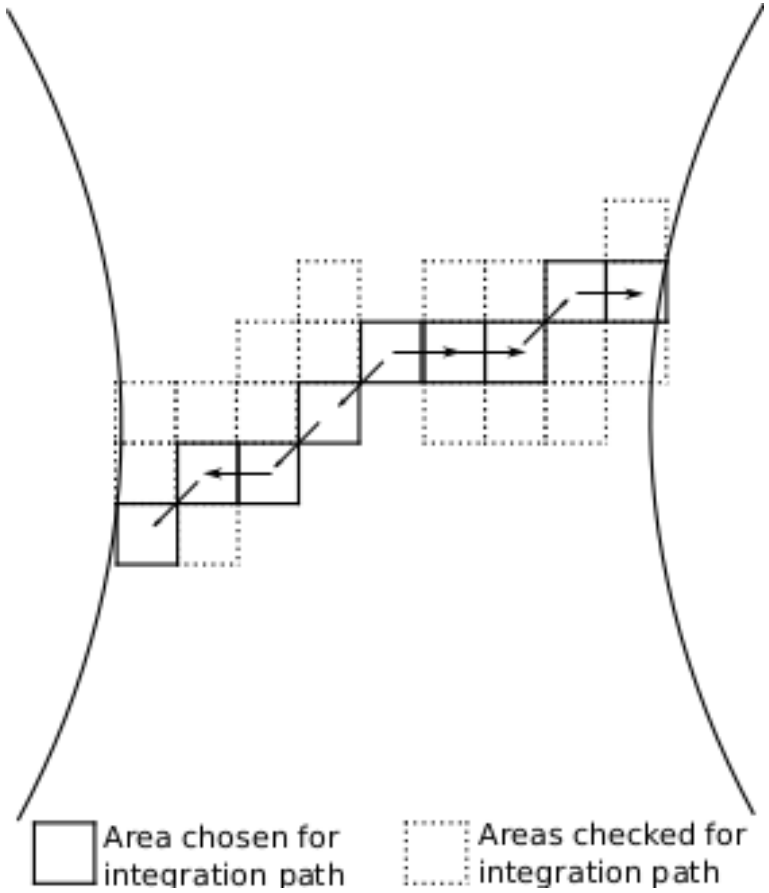




http://www.isi-sys.com/principle-of-digital-image-correlation/

Material characterization

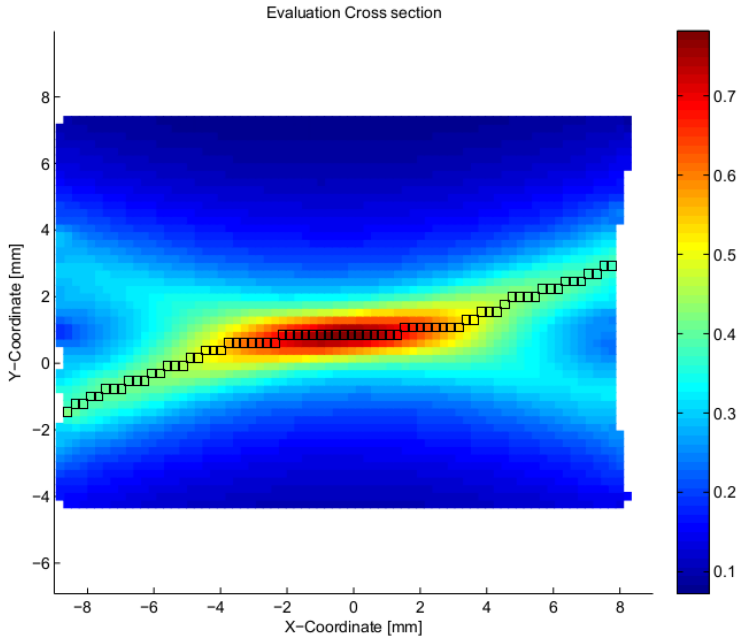


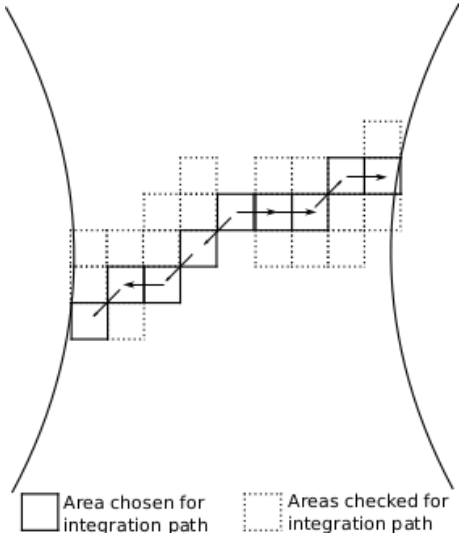


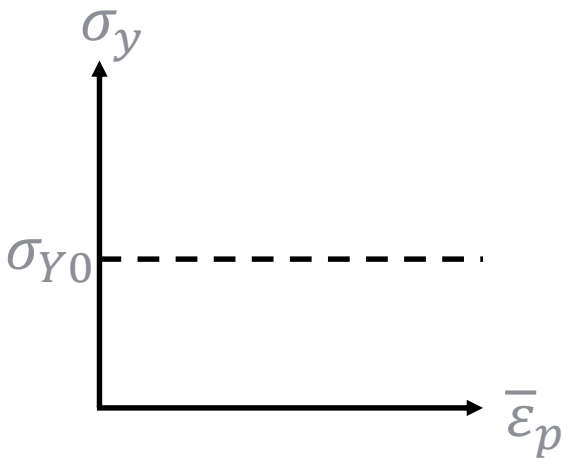
Material characterization

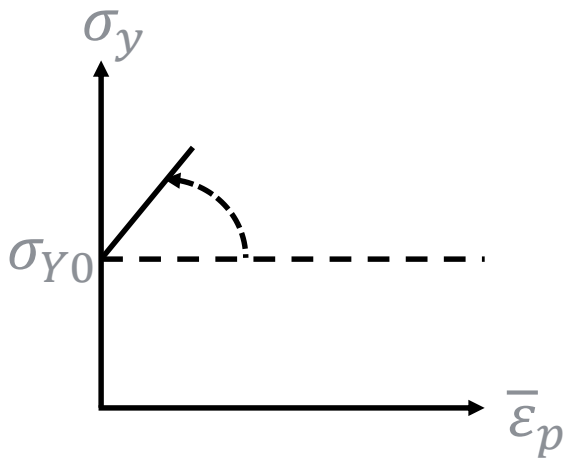
For each time step:

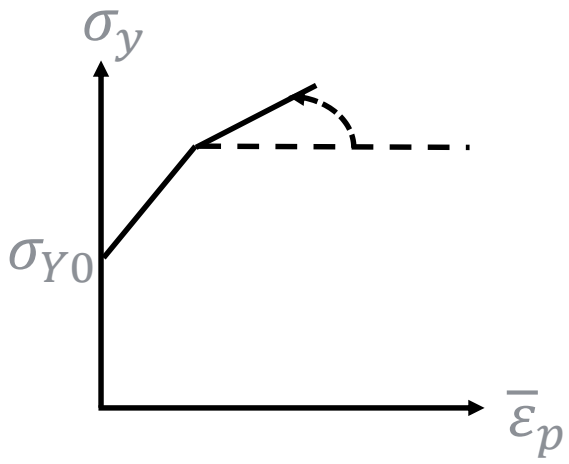
1. Compute stress
2. Integrate cross-section force
3. Compare with measured force
4. New estimate on H



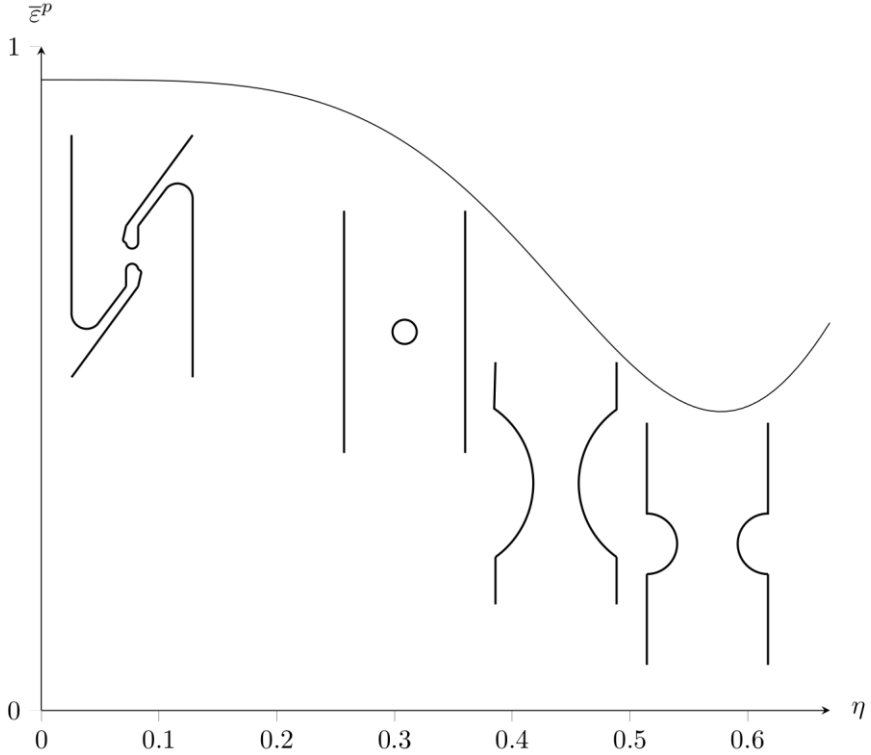


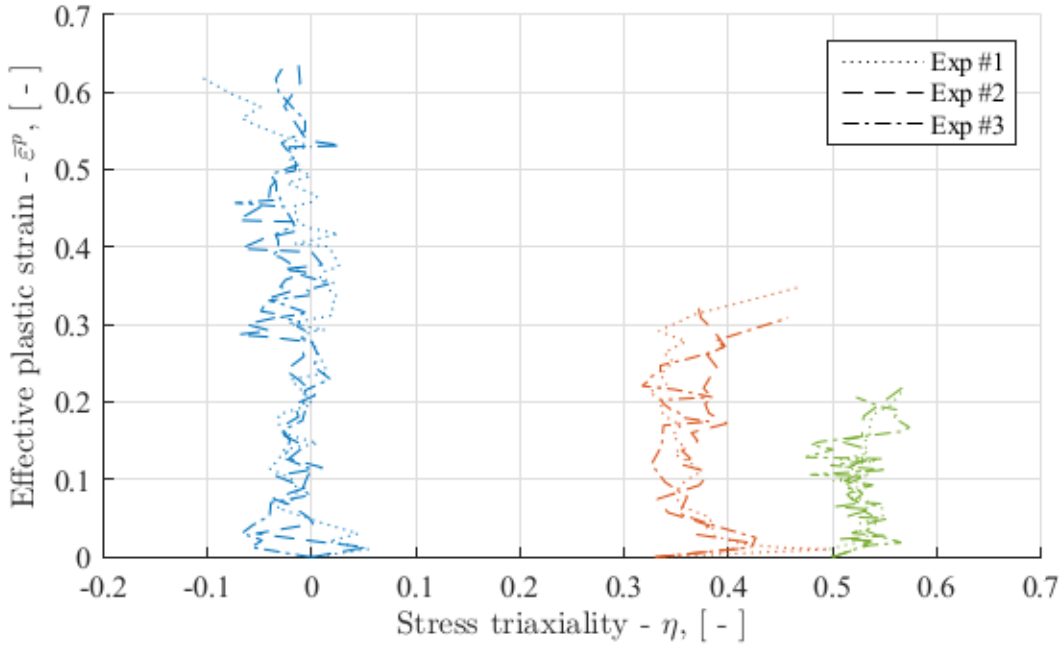


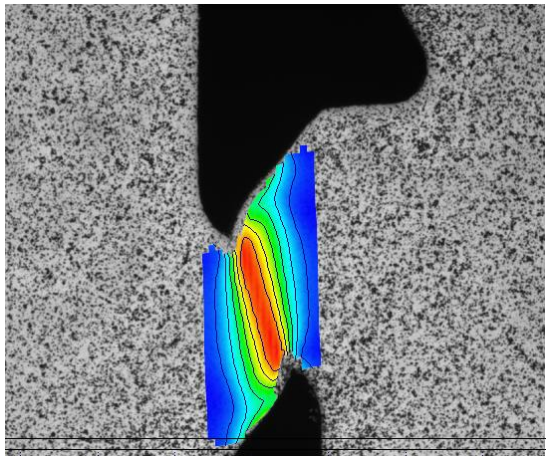


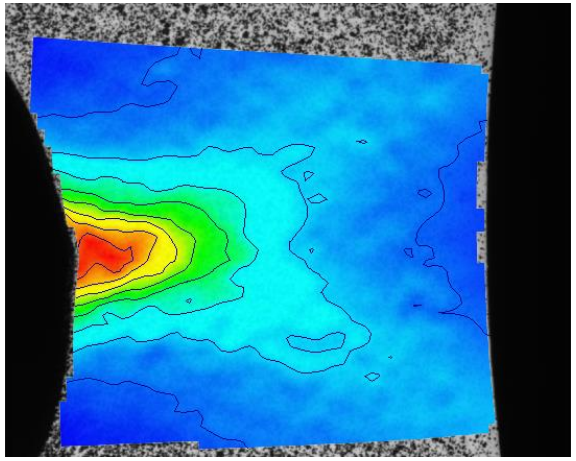


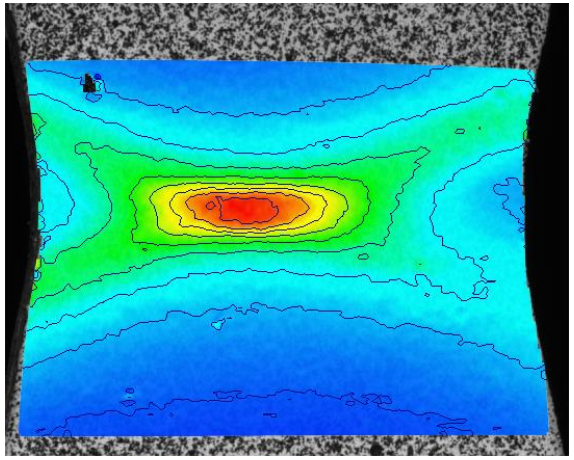
Material characterization

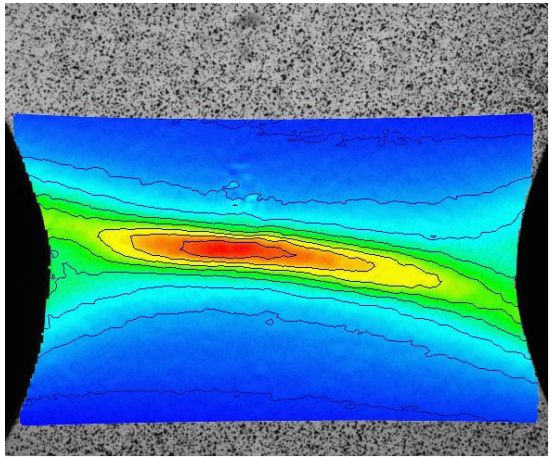




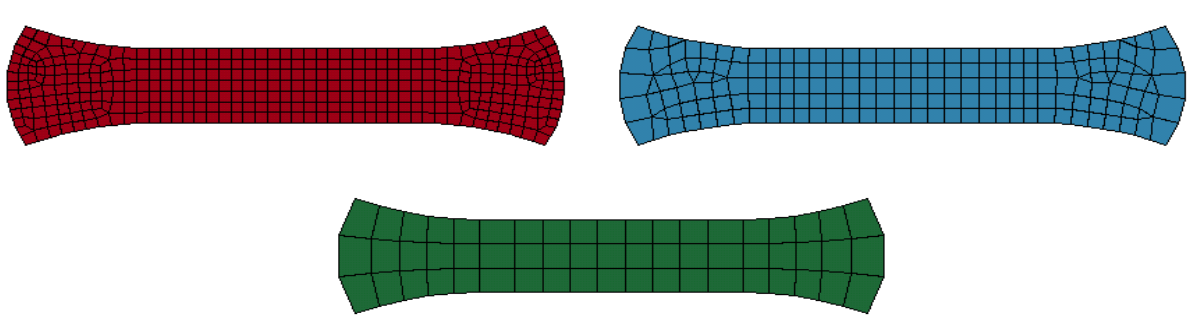


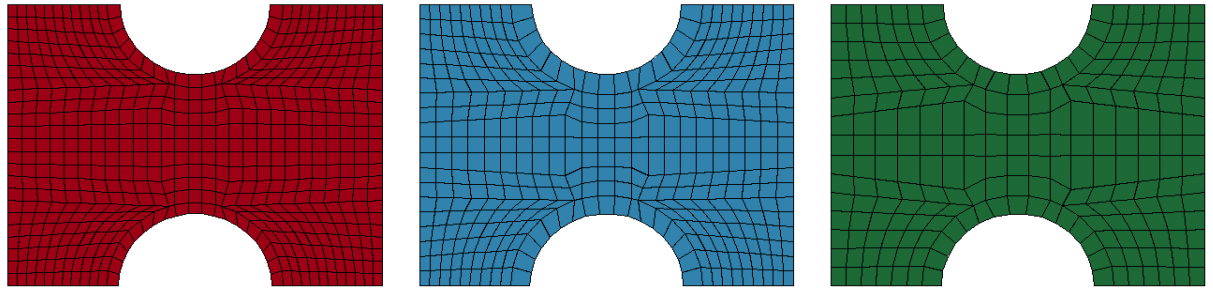


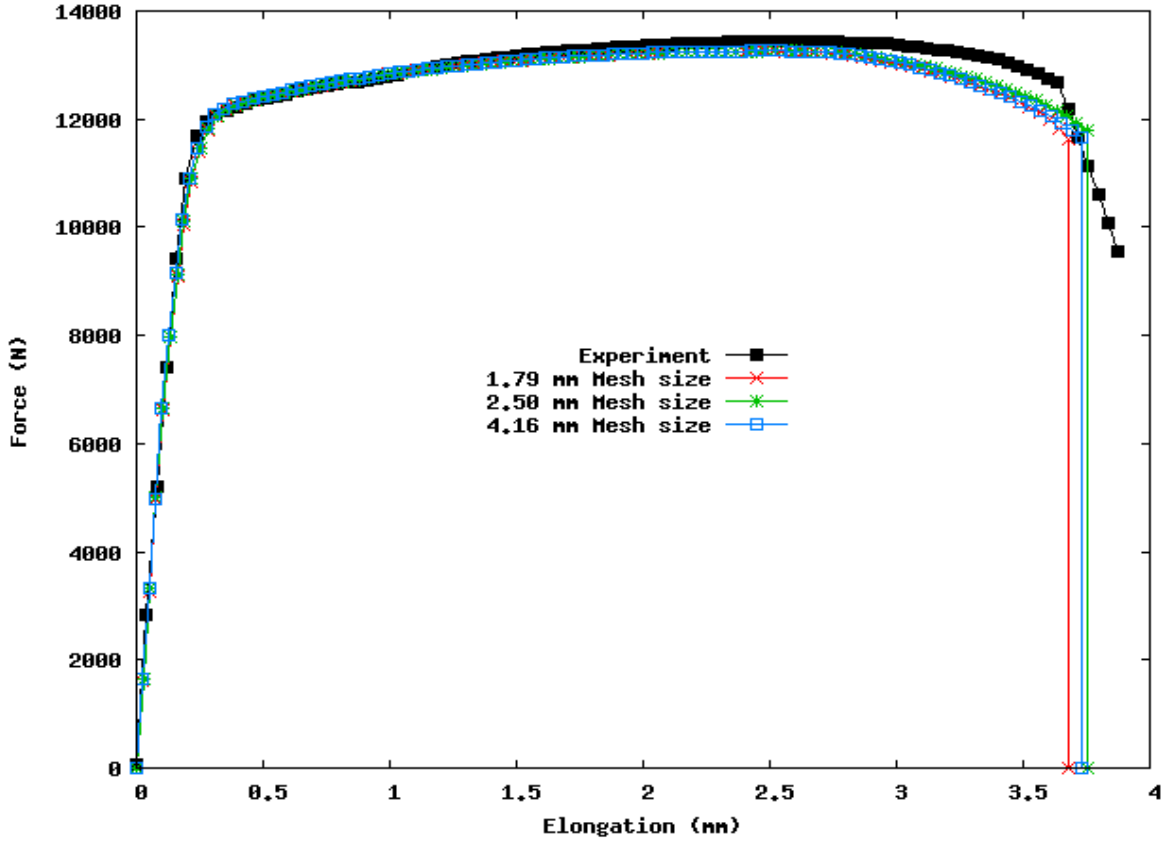


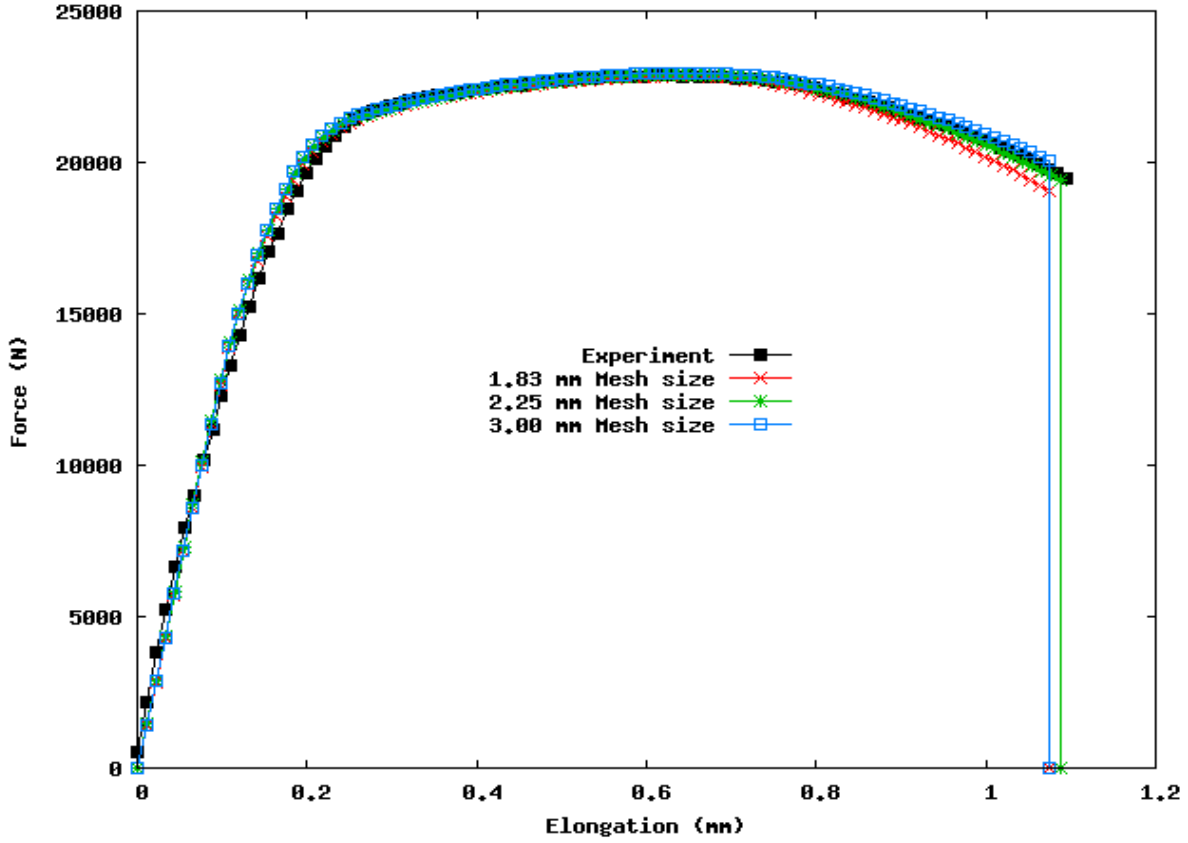


Verification



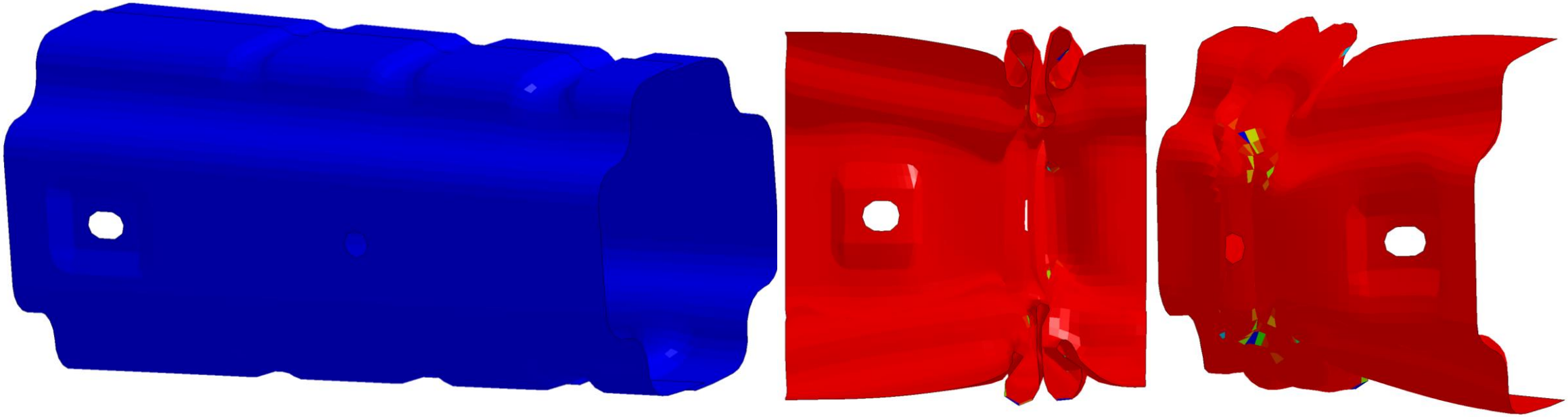




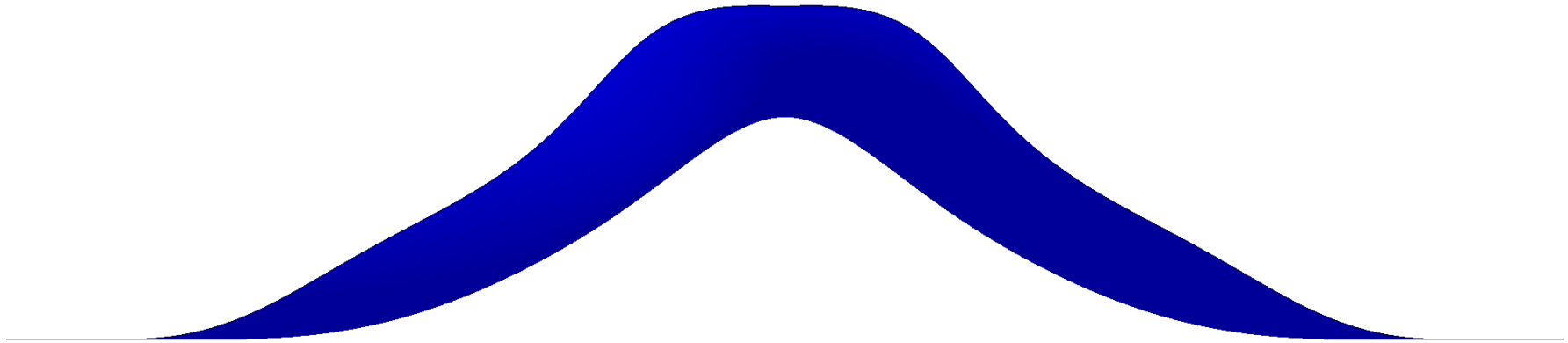


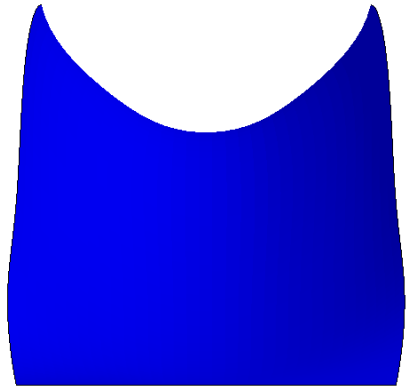
Generic crash box

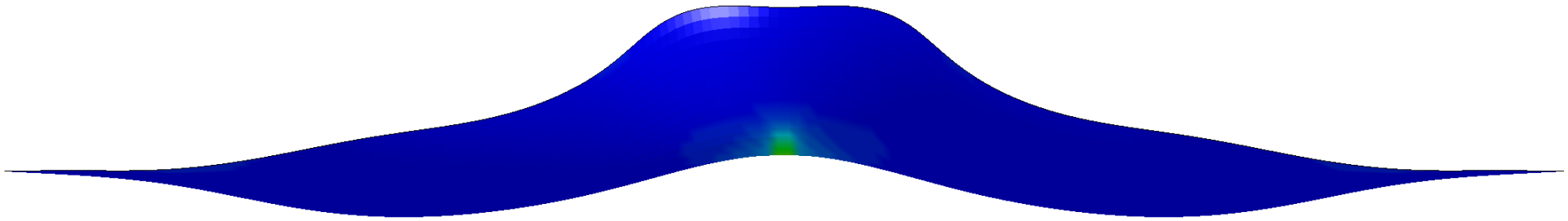
Material grade not used for crash boxes, only illustration of failure prediction

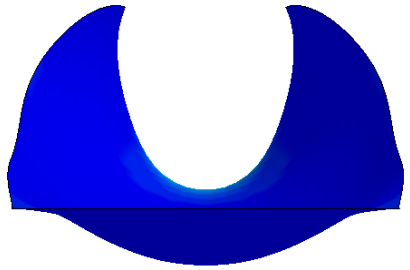


Optus 3









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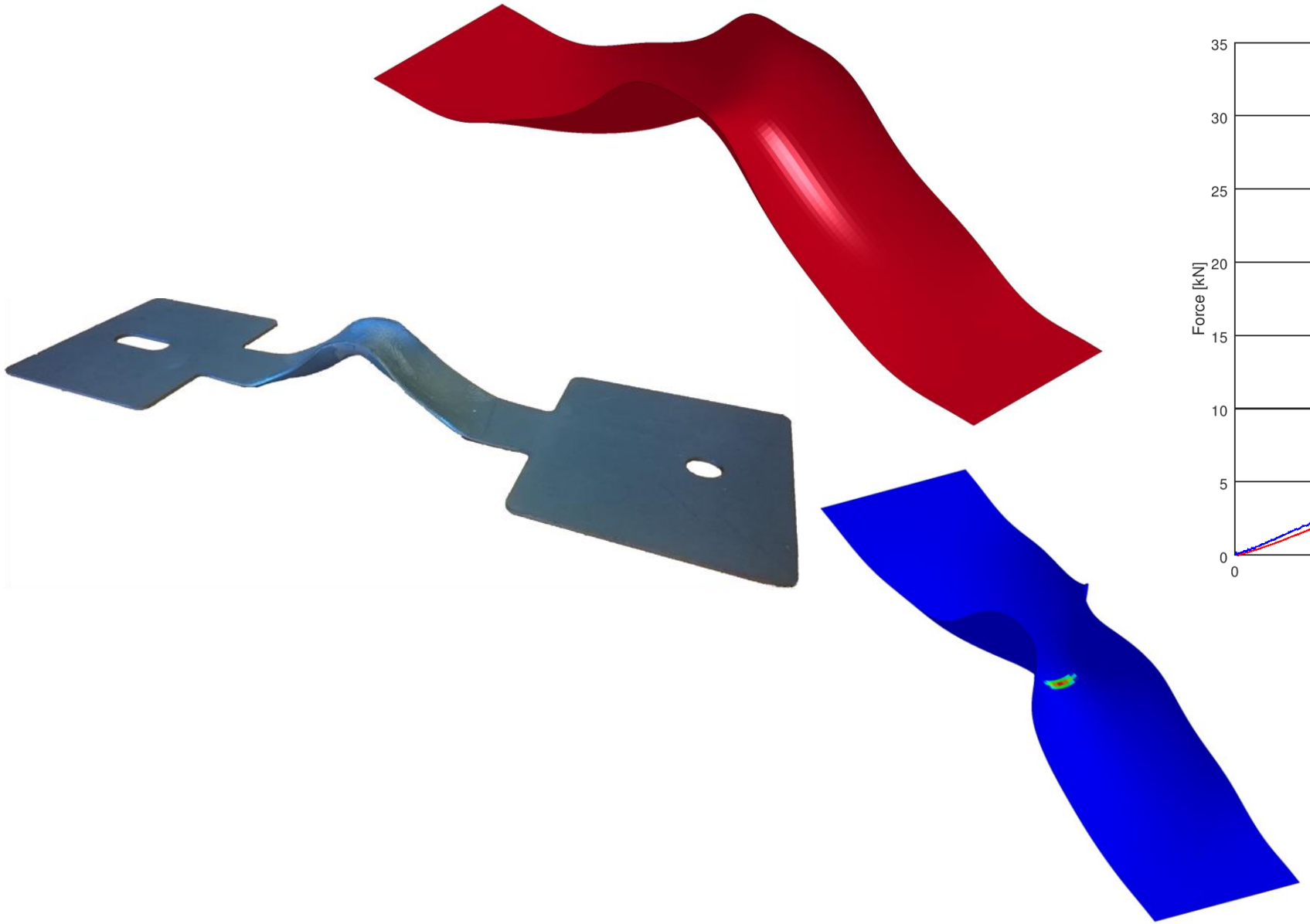
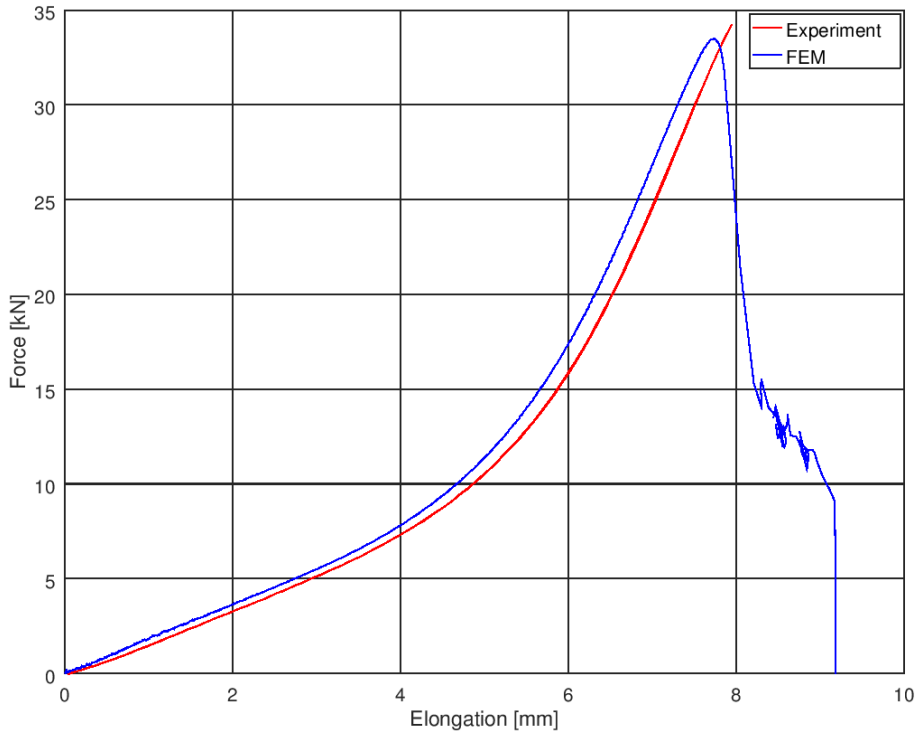
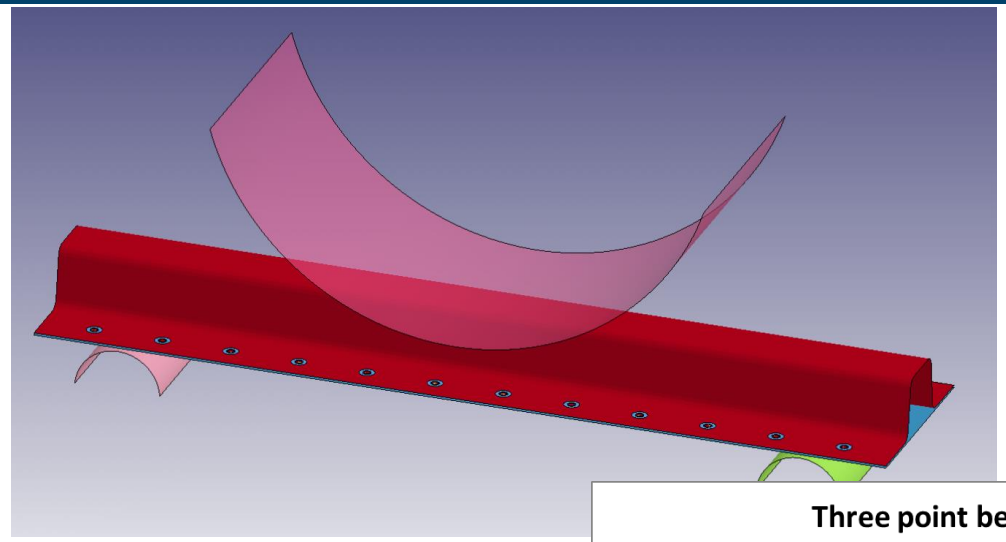
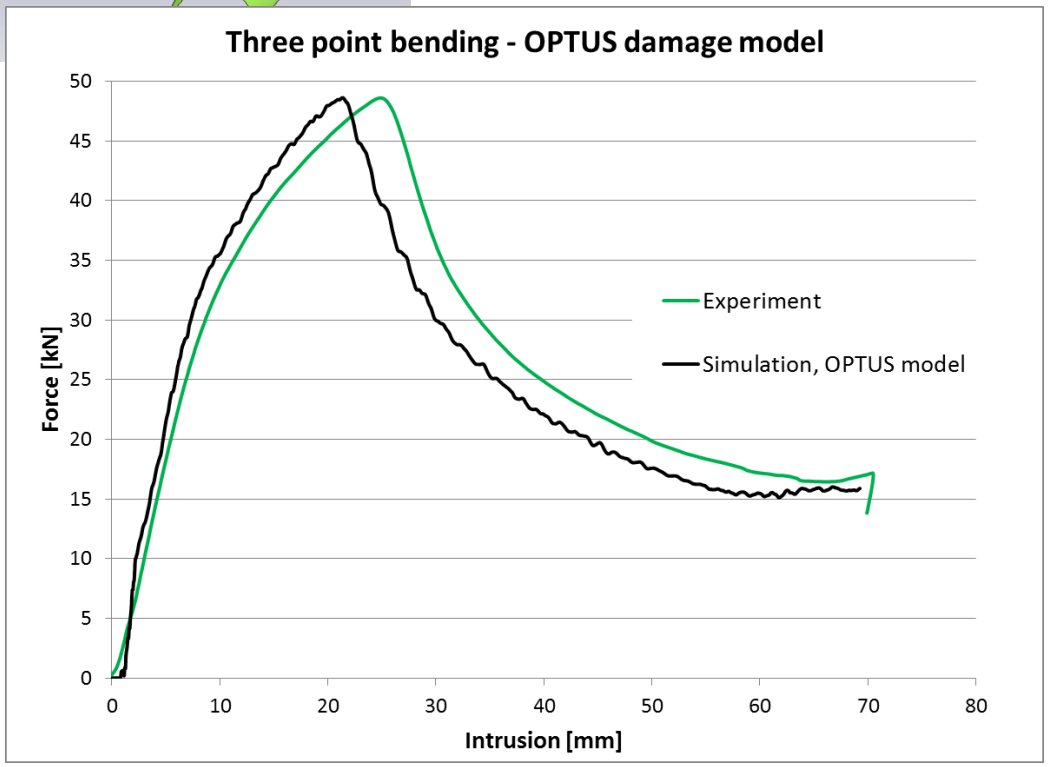
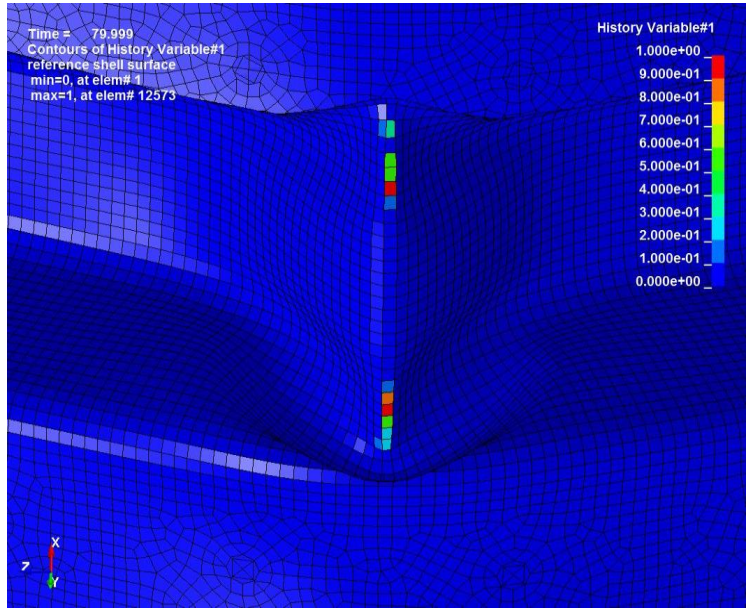




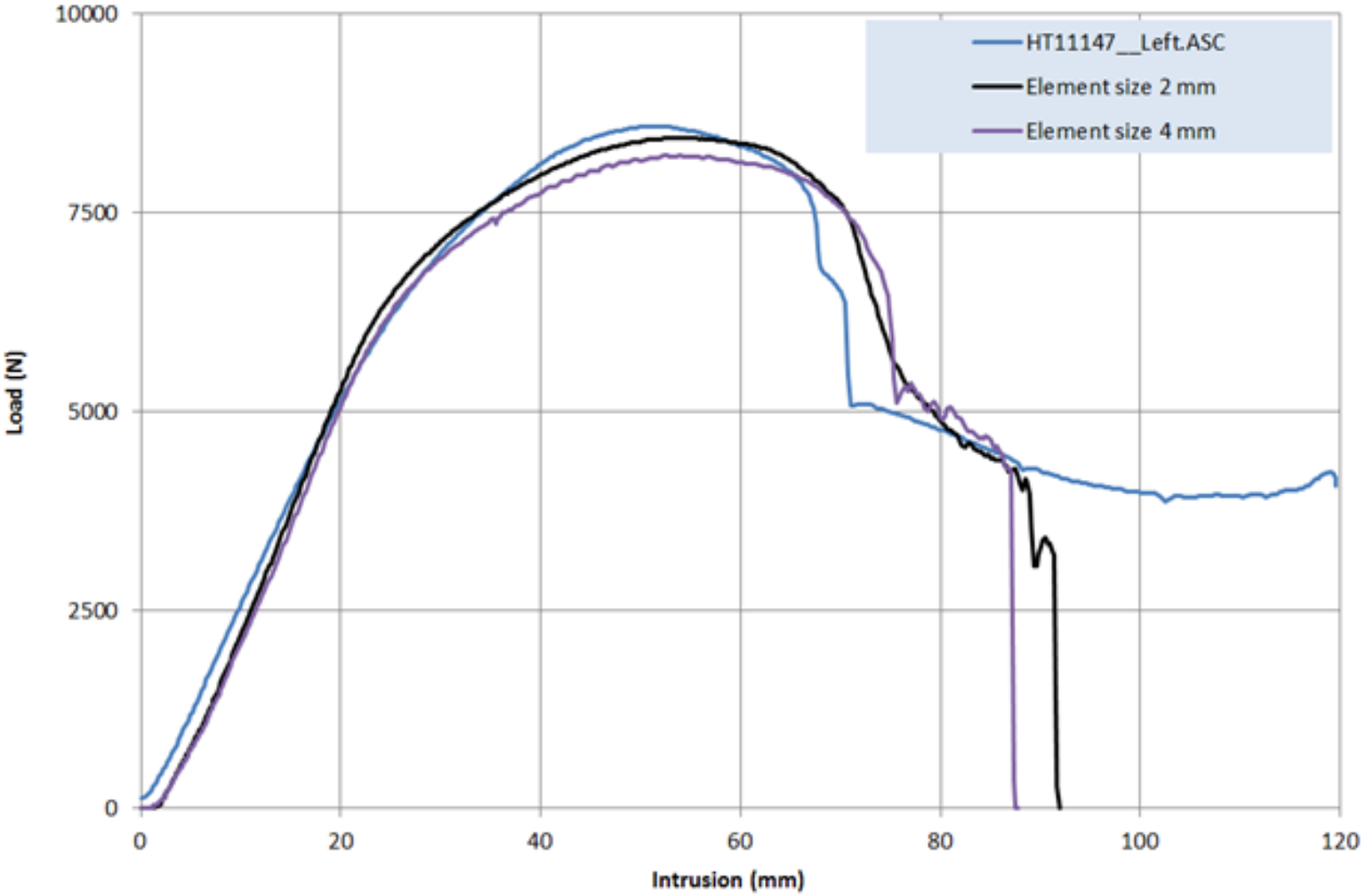
Hat profile



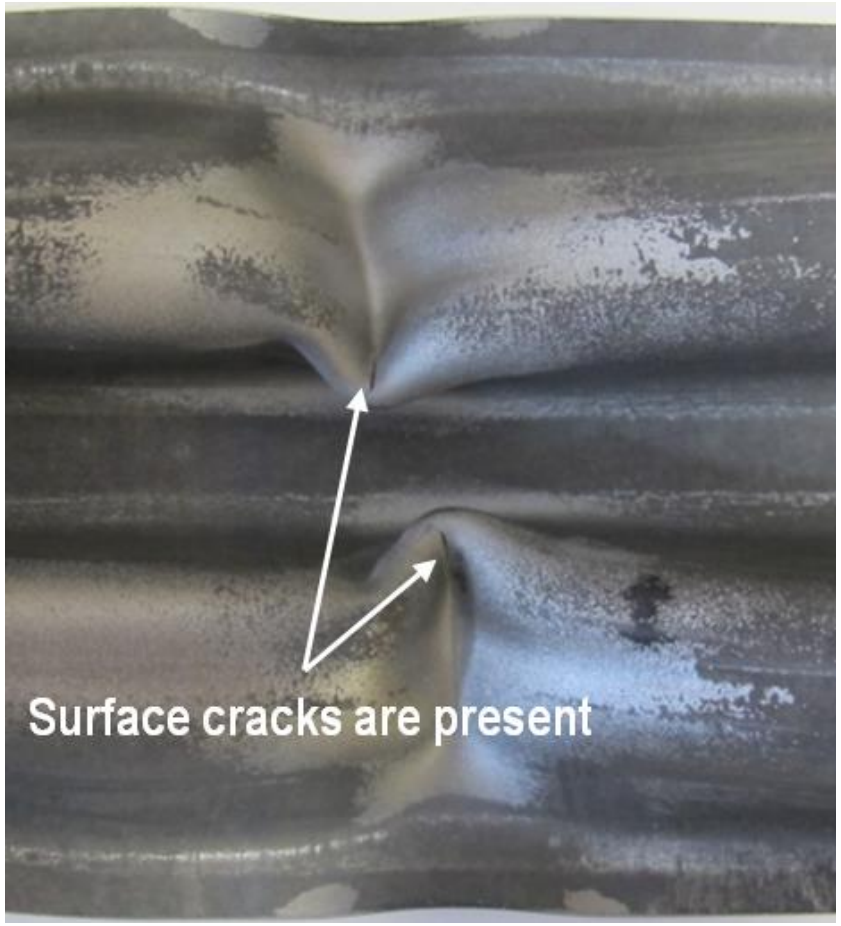




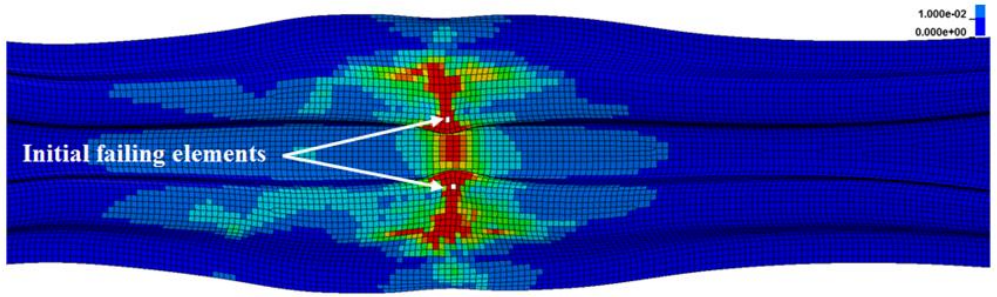
Side impact beam



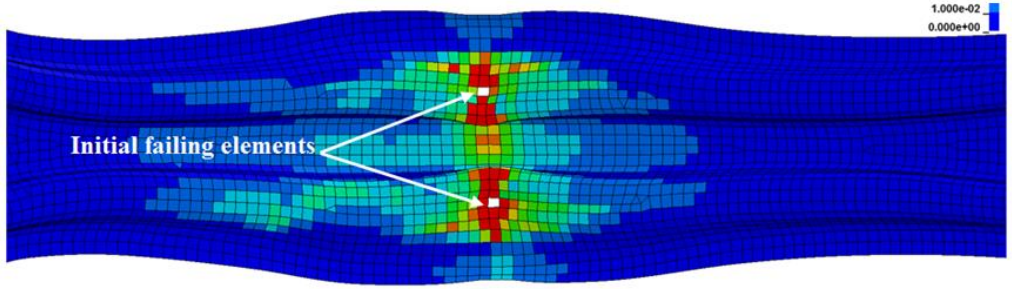
Side impact beam



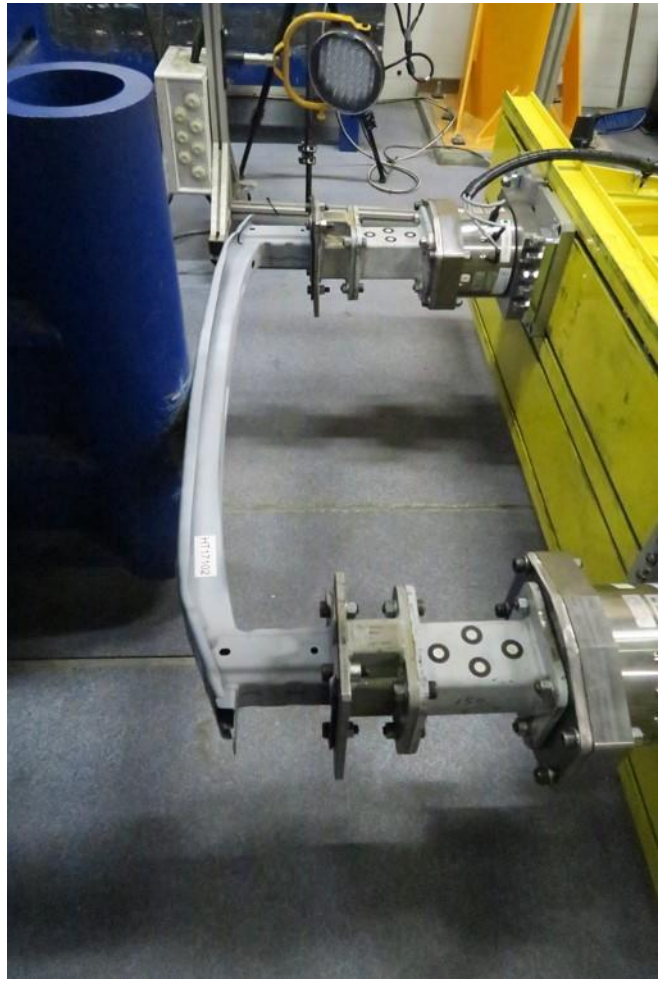
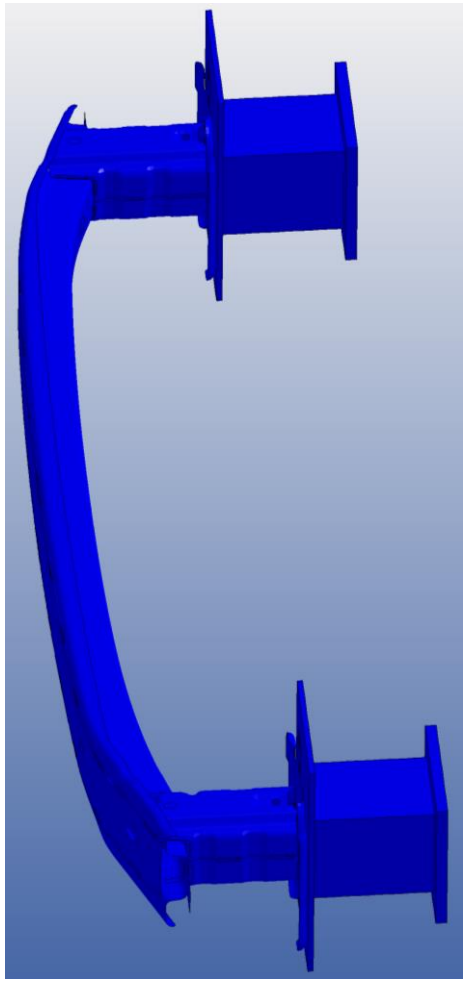
2 mm mesh size

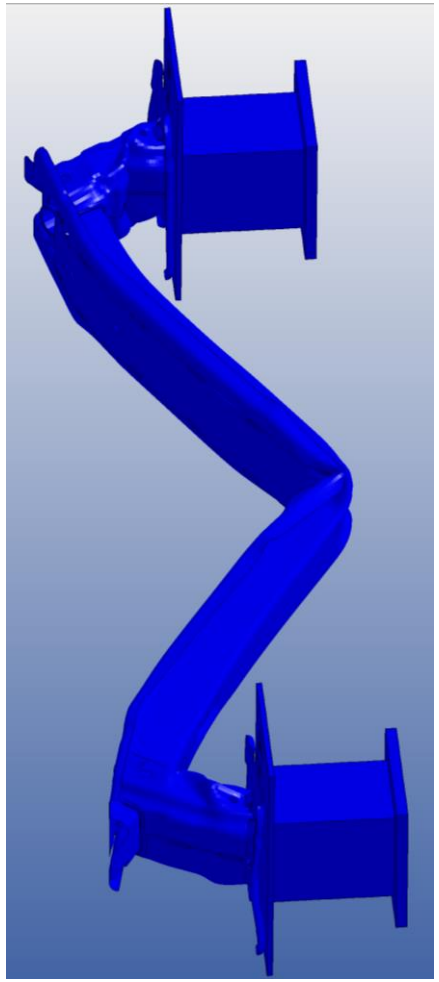


4 mm mesh size

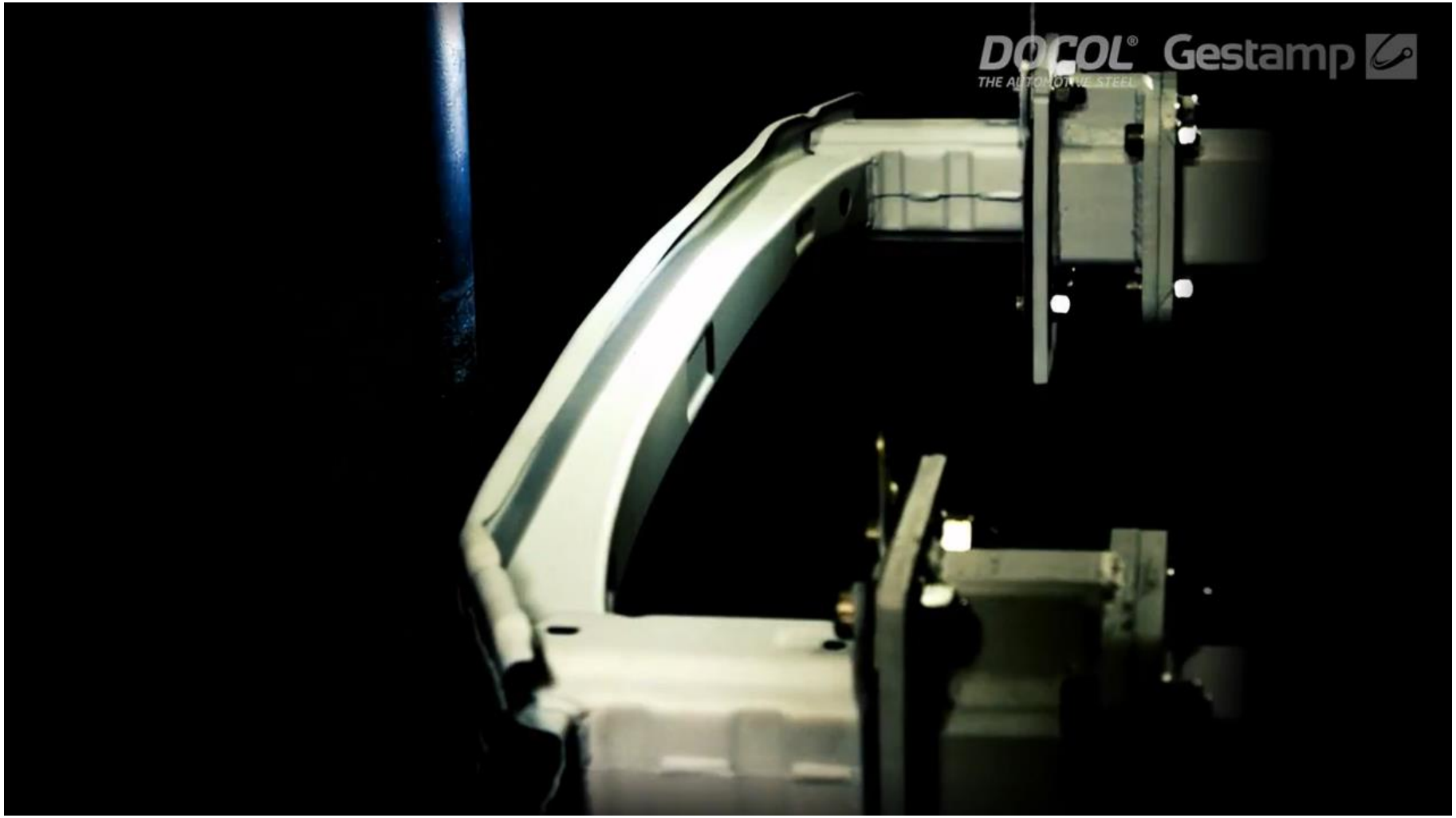


Gestamp Hardtech and SSAB, Docol 2000



Gestamp Hardtech and SSAB, Docol 2000



YouTube search: Docol 2000

https://www.youtube.com/watch?v=00JTKIPcNDw

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- R Östlund, D Berglund and M Oldenburg: Failure Analysis of a hat profile with tailored properties subjected to axial compression, CHS2 (2013)
- R Östlund, M Oldenburg, H-Å Häggblad and D Berglund: Evaluation of localization and failure in boron alloyed steels with different microstructure compositions, Journal of Materials Processing Technology (2014)

Full field measurement and evaluation

- J Eman, K-G Sundin and M Oldenburg: Spatially resolved observations of strain fields at necking and fracture of anisotropic hardened steel sheet material, Int Journal of Solids and Structures (2009)
- S Marth, H-Å Häggblad, M Oldenburg and R Östlund: Post necking characterization for sheet metal materials using full field measurement, Journal of Materials Processing Technology (2016)
- S Marth, H-Å Häggblad and M Oldenburg: A comparison between stepwise modelling and inverse modelling methods for characterization of press hardened sheet materials, CHS2 (2017)

CHS² 2019 - 7th International Conference on Hot Sheet Metal Forming of High Performance Steel

7th INTERNATIONAL CONFERENCE
on Hot Sheet Metal Forming of High-Performance Steel

For the third time, the CHS² conference will be held where the press hardening technology was invented and industrialized.

CHS² 2019 will be arranged in Luleå, Sweden, 2nd – 5th June 2019.

http://www.chs2.eu/

Gestamp

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