Prozess- und Zerreis-Simulationen von punktförmigen Verbindungen im Automobilbau unter Berücksichtigung unscharfer Prozess-Parameter

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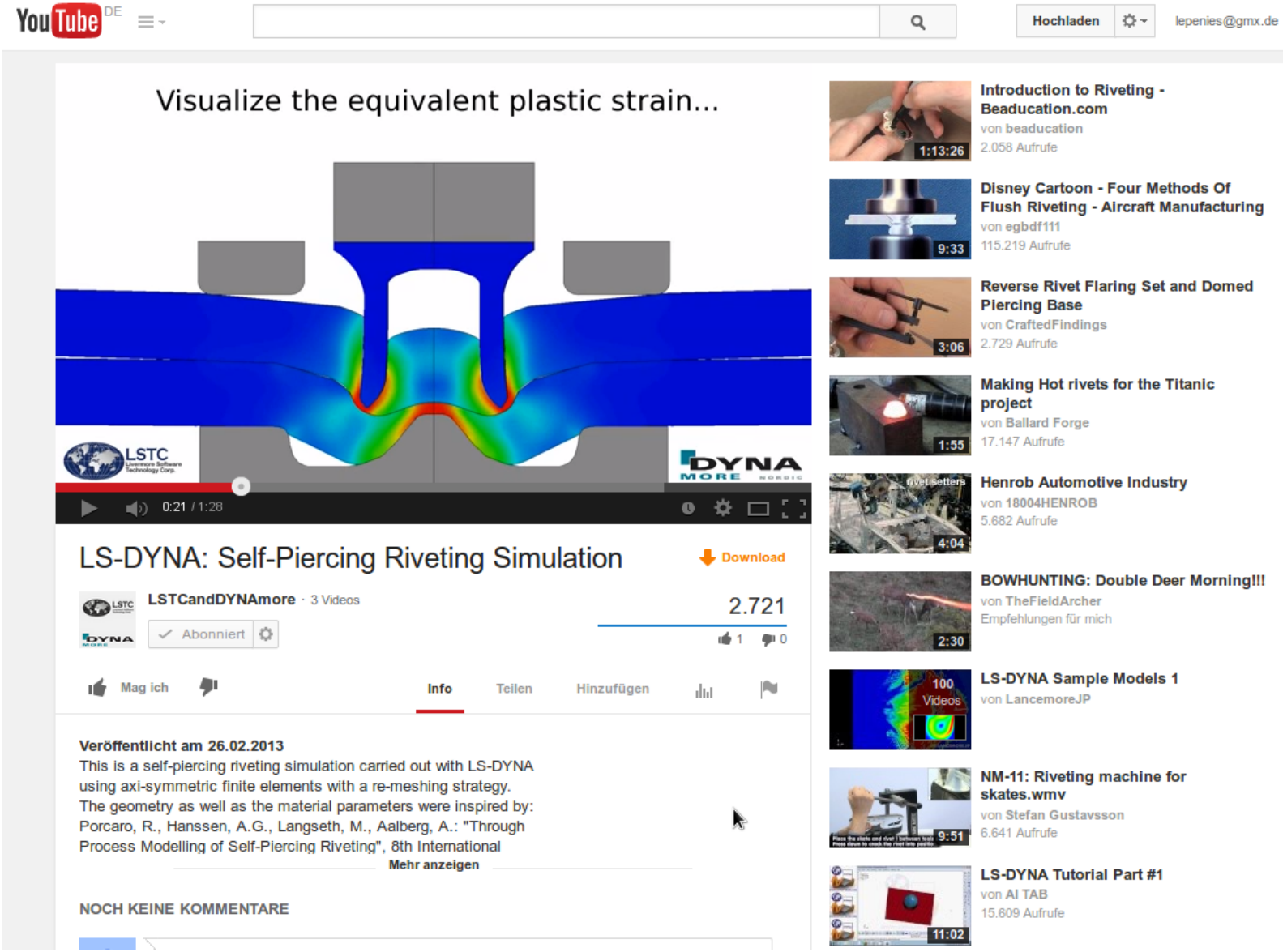
LS-DYNA TV: Beispiel Fügeprozess-Simulation



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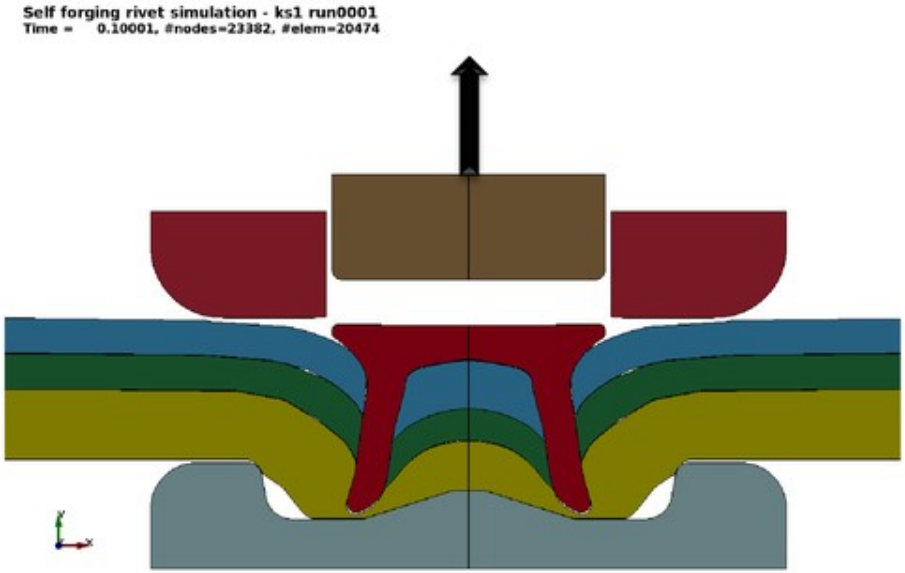
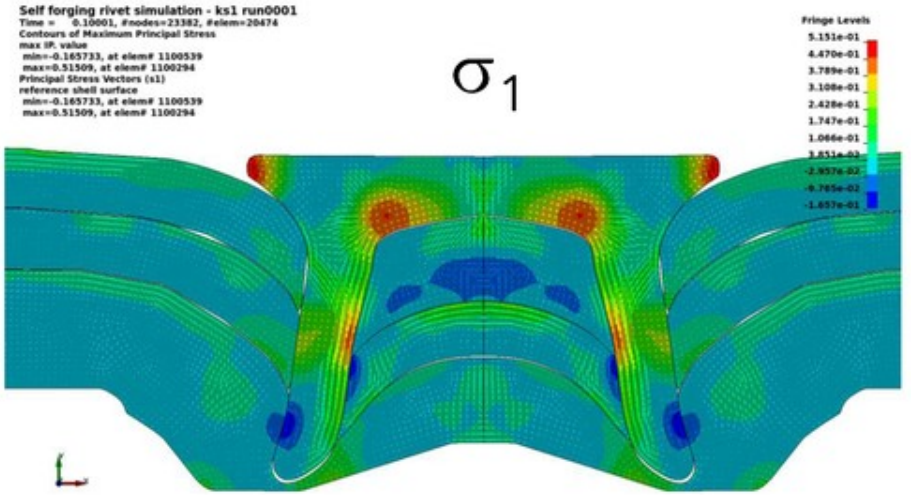
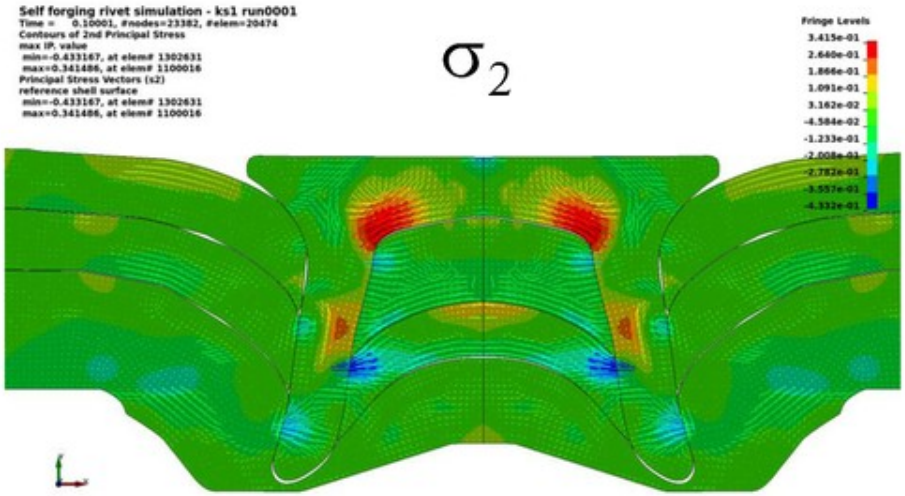
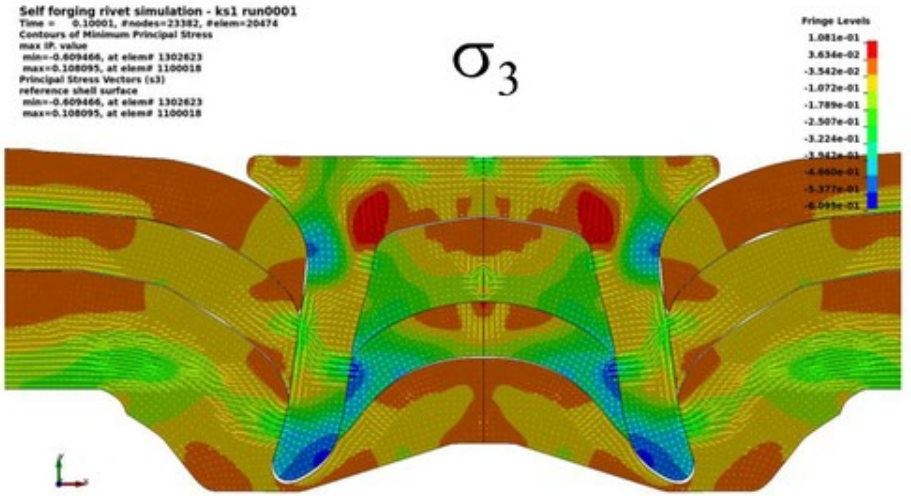
Beispiel einer Fügesimulation mit LS-DYNA









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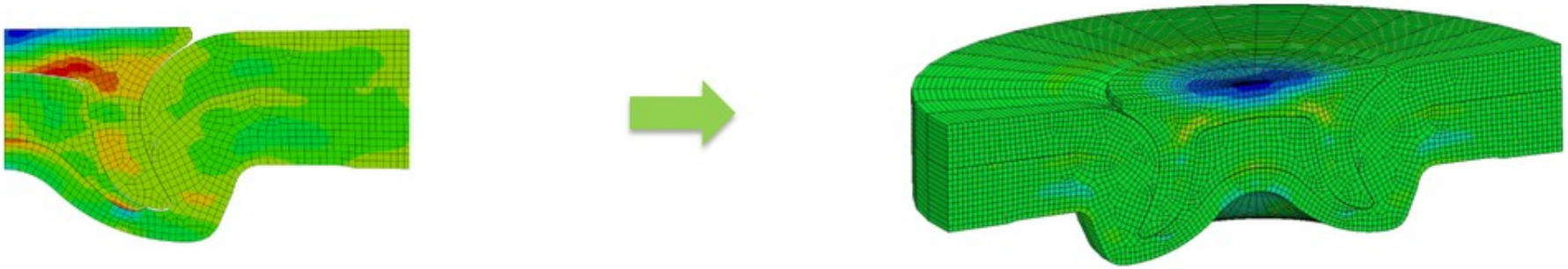
3d-Basismodellerstellung

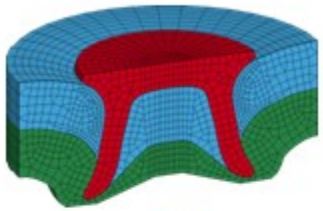
- Mappen der Ergebnisfelder auf 3d-Netz
  - 3D-Netzerstellung + Mapping (*INITIAL_LAG_MAPPING)

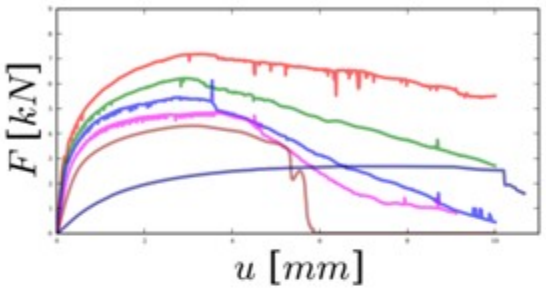


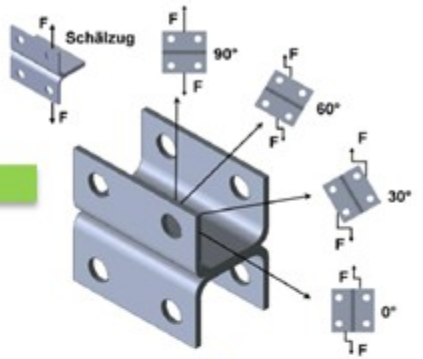
  - Mapping in vorhandenes 3D-Netz (*INITIAL_LAG_MAPPING)

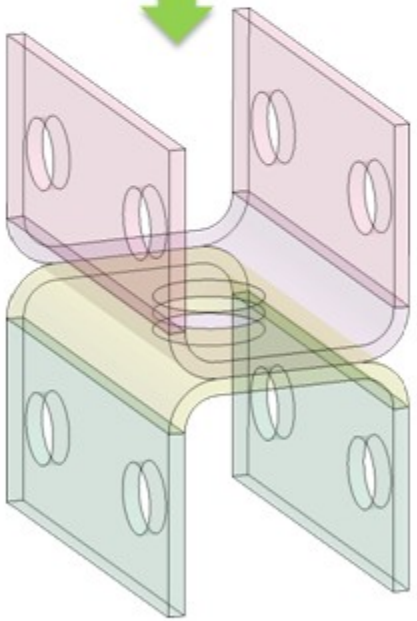
automatisierte Prognose von Verbindungsfestigkeiten ✓

Verbindungstyp generieren

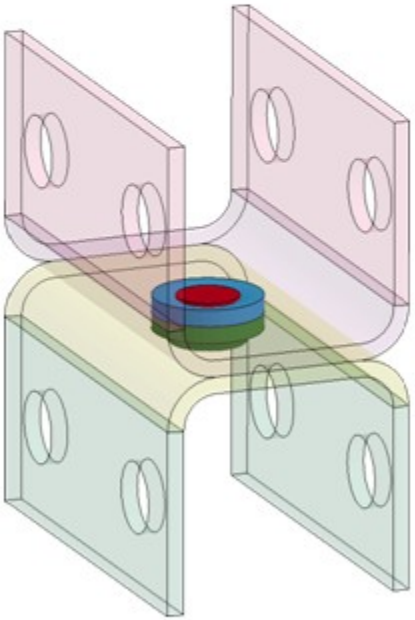




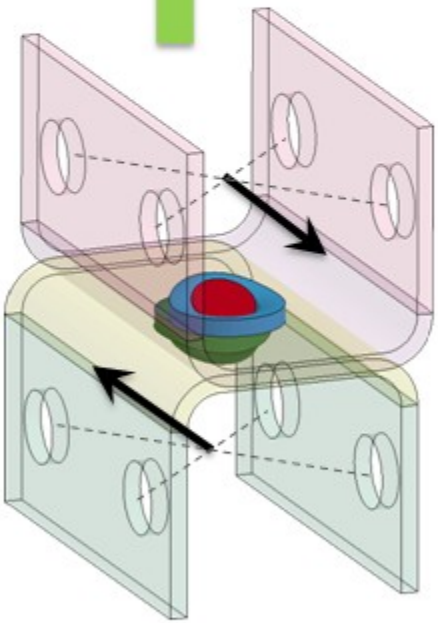




Basismodell erstellen/wählen



Basismodell zusammenfügen



Basismodell belasten

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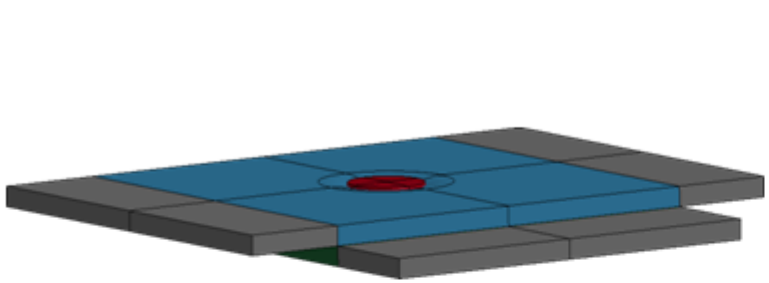
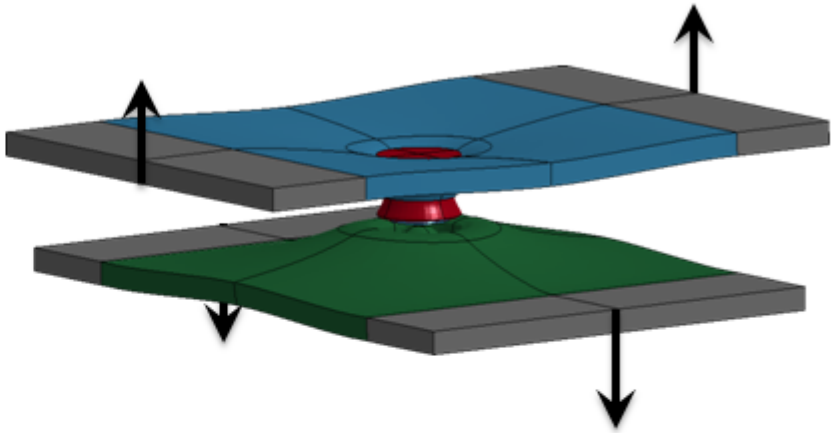
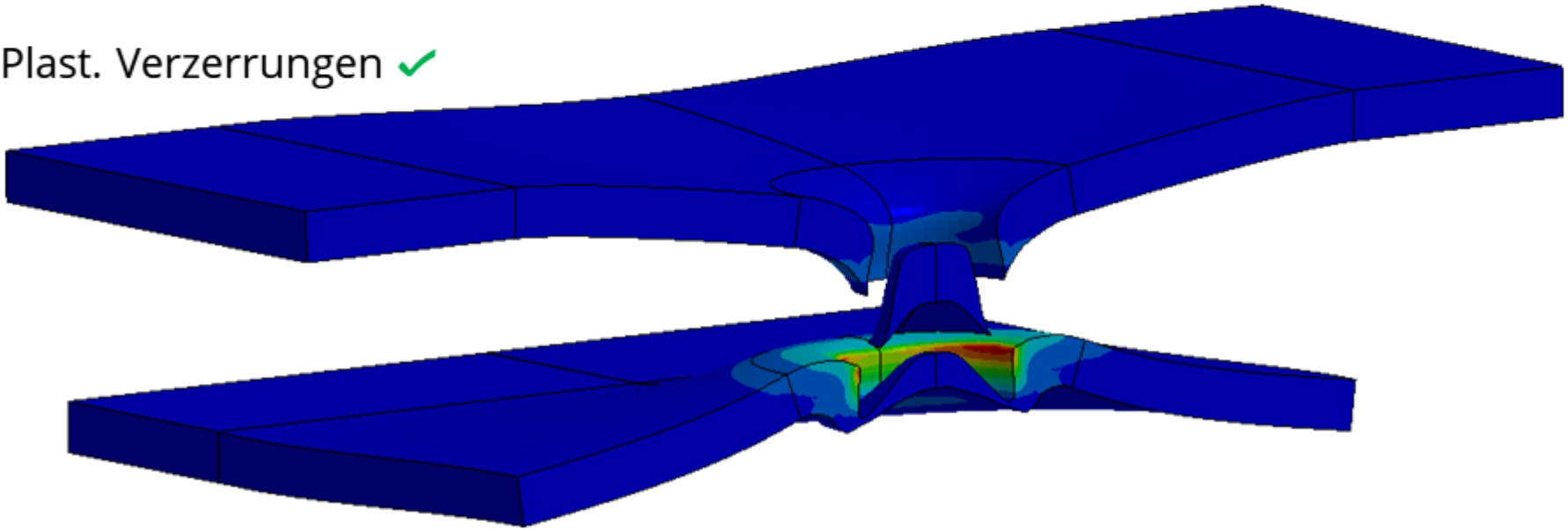
Cross Tension Test





Plast. Verzerrungen ✓



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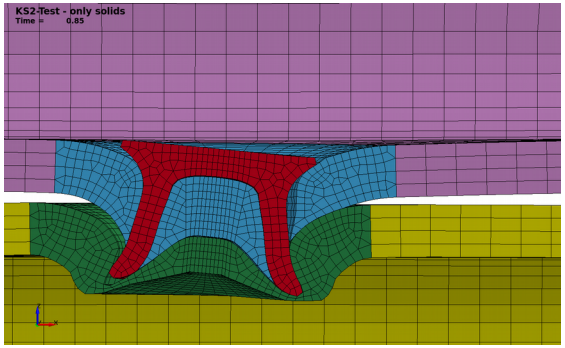
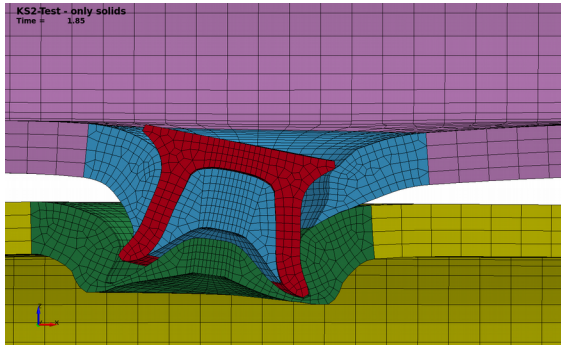
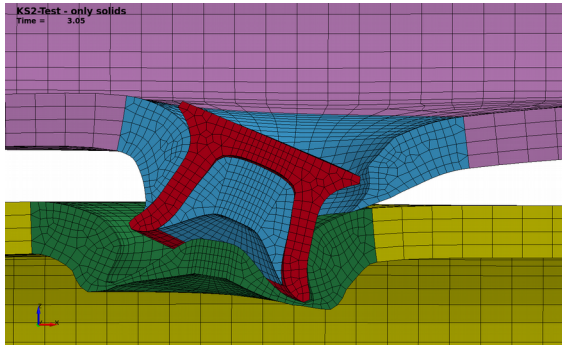
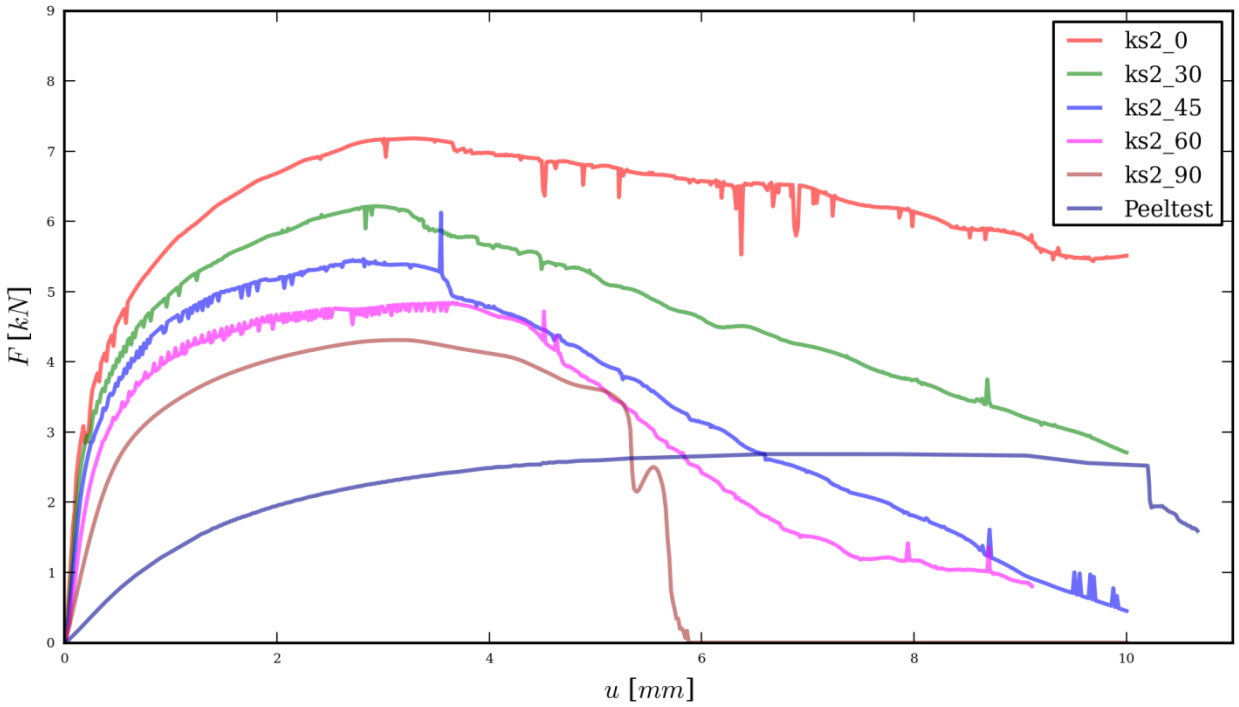
Prognose der Kraft-Verformungs-Abhängigkeiten 3d

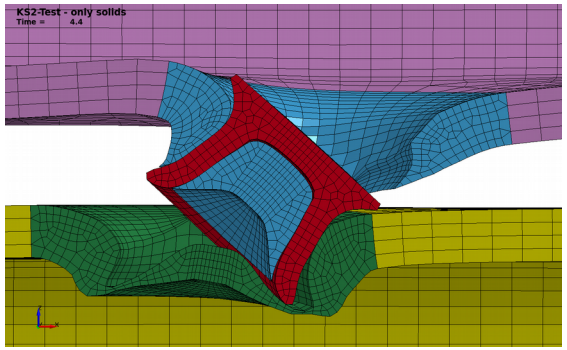
- Feinmodell-Simulationen für KS2-Probe und Schälzugversuch

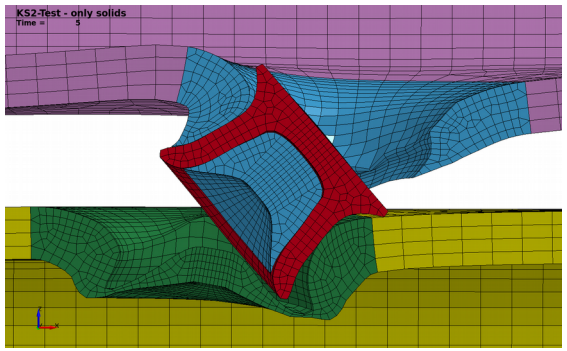












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*MAT_SPOTWELD (*MAT_100)

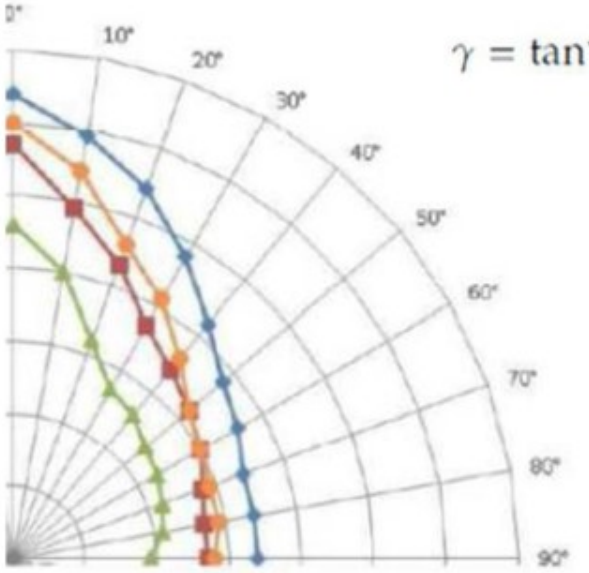
- New failure model OPT=11 for beam elements, where failure depends on loading direction via curves

OPT = 11 invokes a resultant force based failure criterion for beams. With corresponding load curves or tables LCT and LCC, resultant force at failure F_{fail} can be defined as function of loading direction γ (curve) or loading direction γ and effective strain rate $\dot{\varepsilon}$ (table):

$$F_{\text{fail}} = f(\gamma) \quad \text{or} \quad F_{\text{fail}} = f(\gamma, \dot{\varepsilon})$$

with the following definitions for loading direction (in degree) and effective strain rate:

$$\gamma = \tan^{-1}\left(\left|\frac{F_{\text{shear}}}{F_{\text{axial}}}\right|\right), \qquad \dot{\varepsilon} = \left[\frac{2}{3}\left(\dot{\varepsilon}_{\text{axial}}{}^2 + \dot{\varepsilon}_{\text{shear}}^2\right)\right]^{1/2}$$

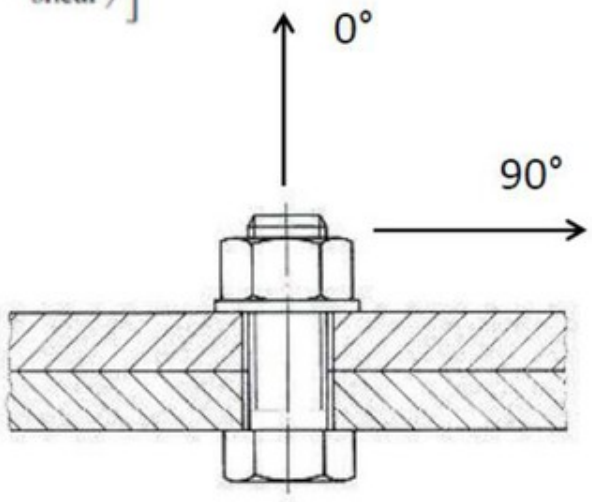


ISO thread

round thread

trapezoidal thread

buttress thread



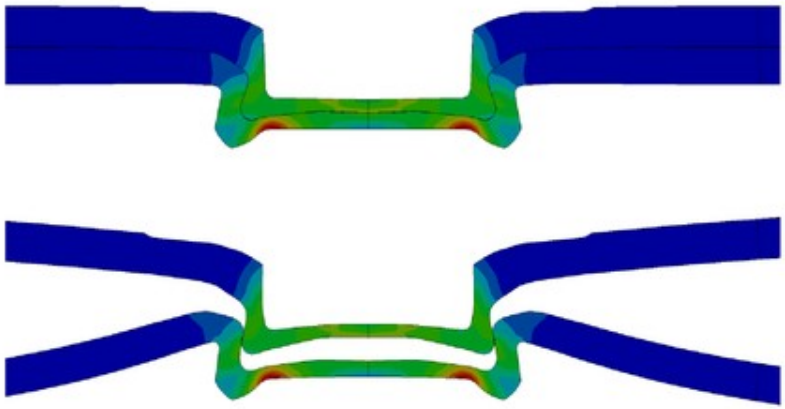
Berücksichtigung der Parameter-Unschärfe

- Ziel:
  - Bestimmung der relevanten Prozessparameter (Reibbeiwerte, Nietfußgeometrie) auf die Eigenschaften einer HSN- bzw. CLN-Verbindung
  - automatisierte Kalibrierung der Prozesssimulation – Bestimmung realitätsnaher Prozessparameter
  - numerische Bestimmung von Zusammenhängen
    - z.B. Hinterschnitt – KS2_90-Tragfähigkeit

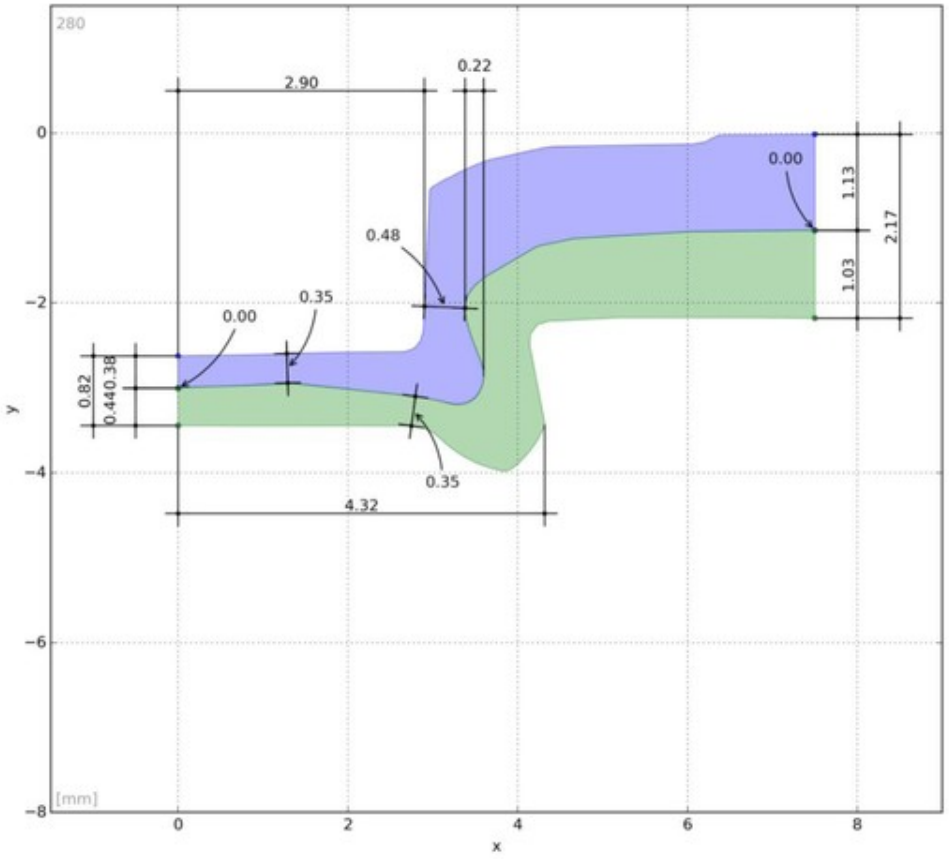
- Exemplarische Sensitivitätsanalyse

Prozess-Simulation Clinchen (CLN)

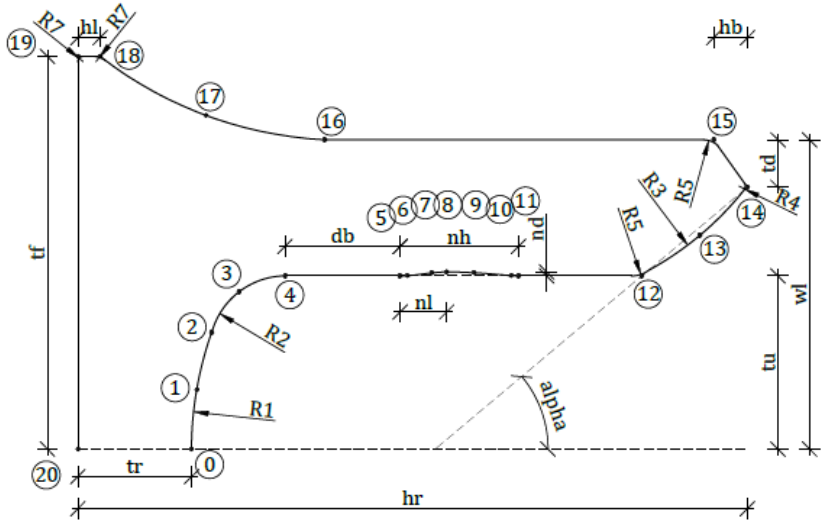
- automatisiertes Aufsetzen von axialsymmetrischen Fügesimulationen
- automatisierte Vermessung der Fügegeometrie nach Entlastung
- automatisierte Zerreis-Simulationen

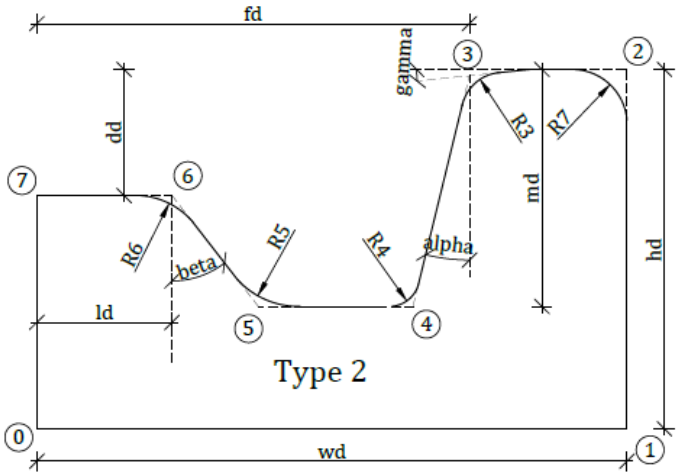


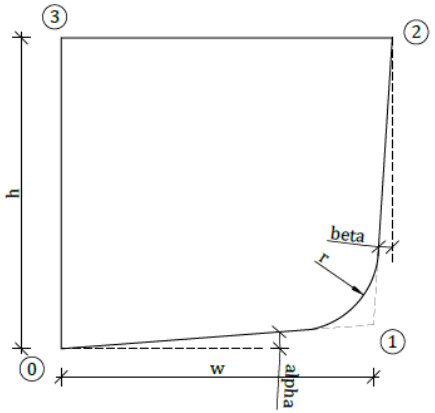
epspl

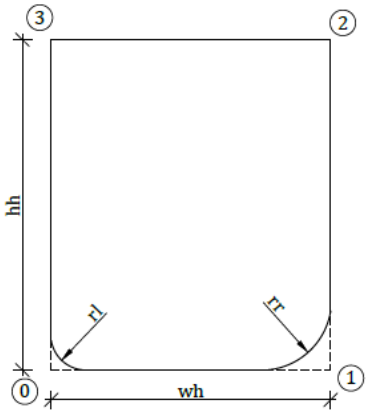


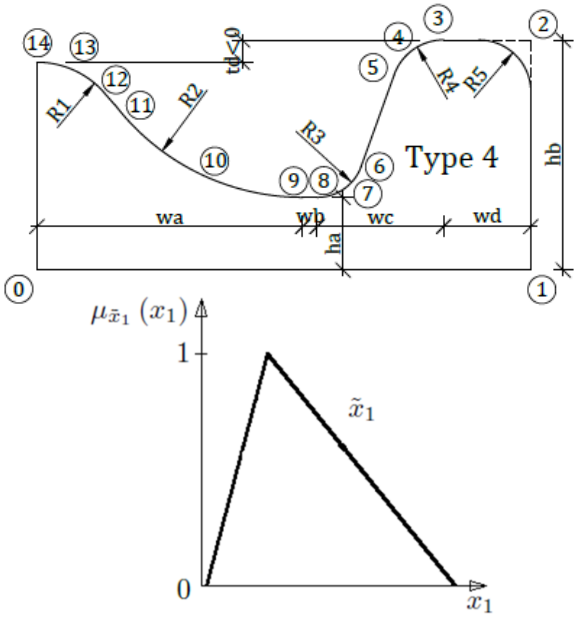
parametrische Nietsystemgeometrien (HSN-Prozess)



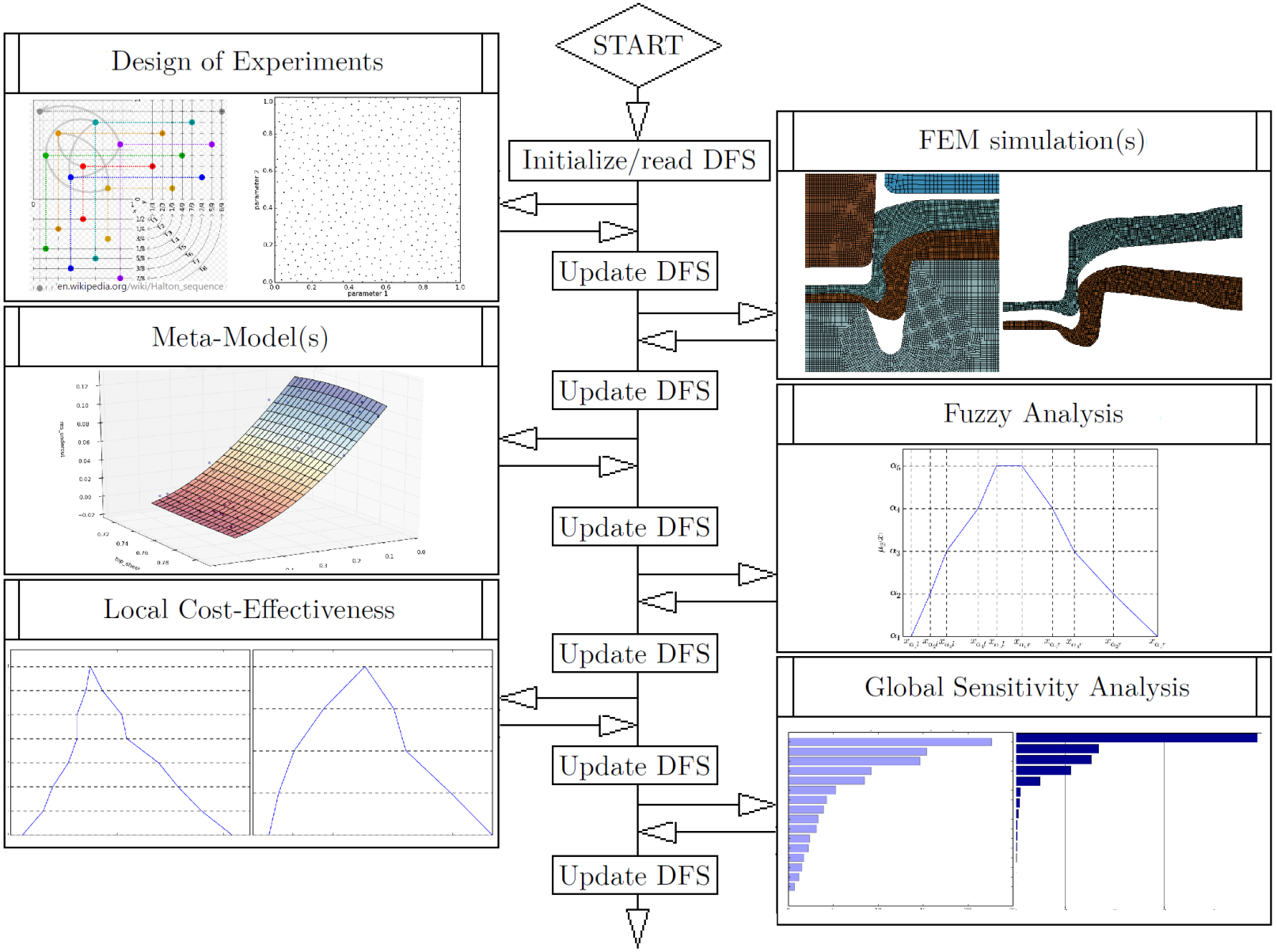






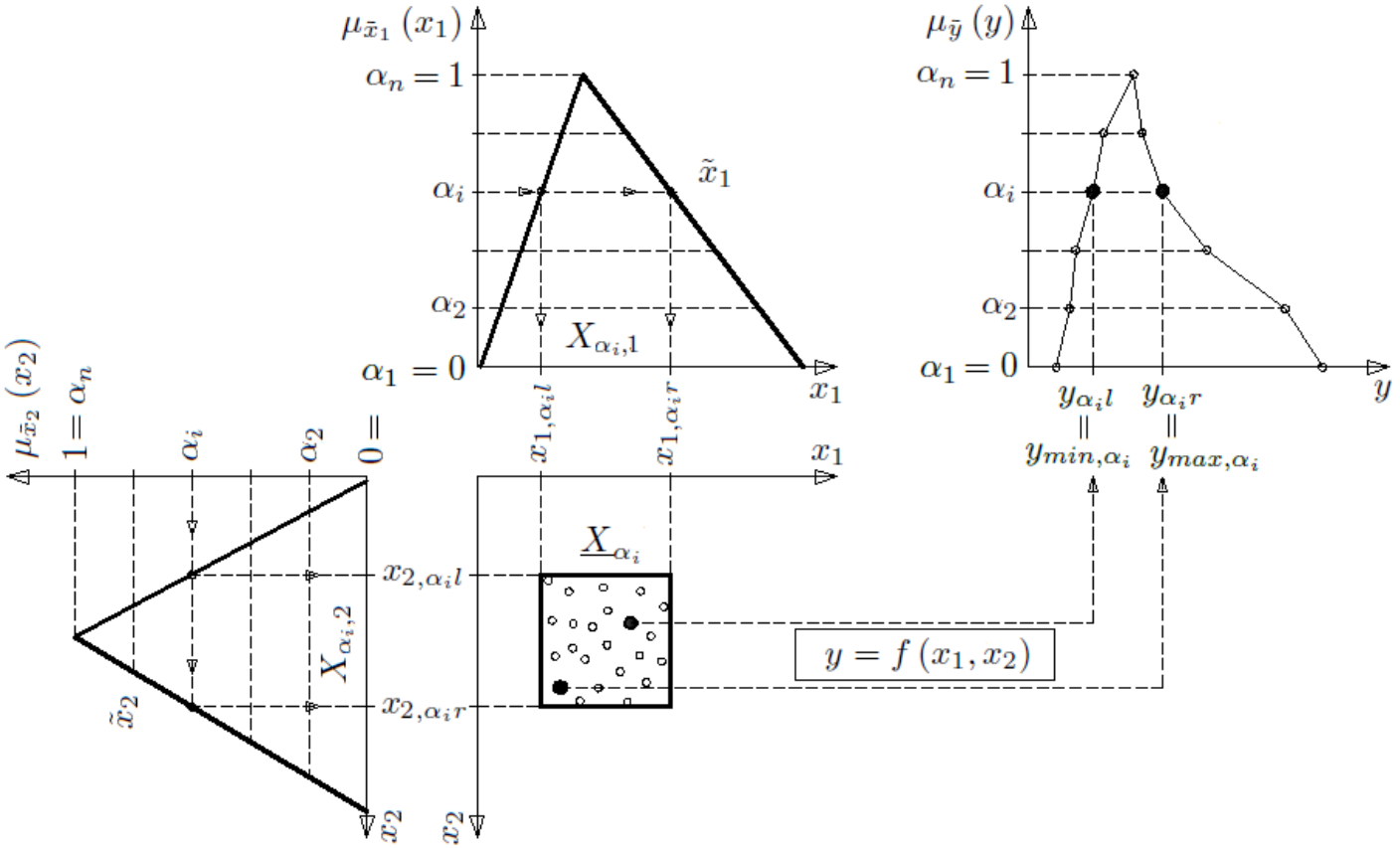


Ablauf einer VBT-Sensititätsanalyse



Fuzzy analysis

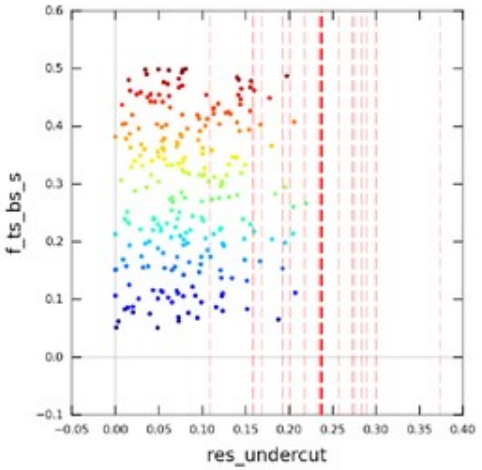
- A fuzzy analysis is performed in order to capture the impreciseness in an output caused by the impreciseness's in the input parameters.
  - build the membership function for the chosen output

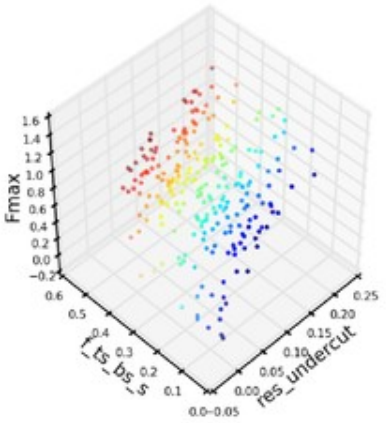


Design of Experiments (DoE): Prozesssimulation Clinchen

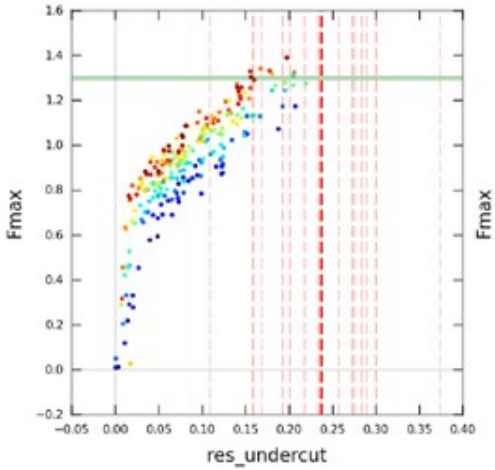
- $F_{max,90}$ – Hinterschnitt – Reibbeiwert zwischen Blechen

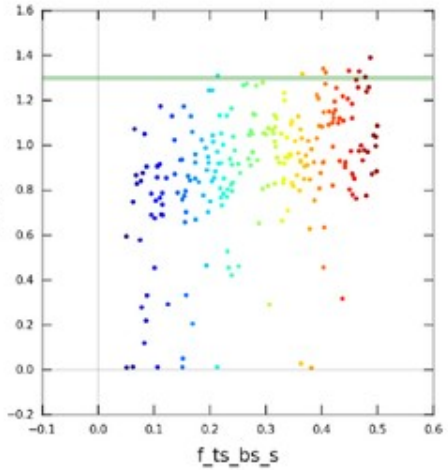
Reibbeiwert Oberblech-Unterblech

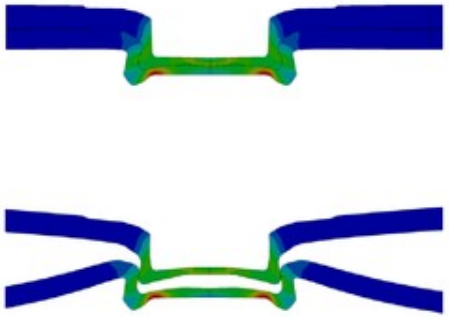




F_{max}







Hinterschnitt

Reibbeiwert zwischen Blechen

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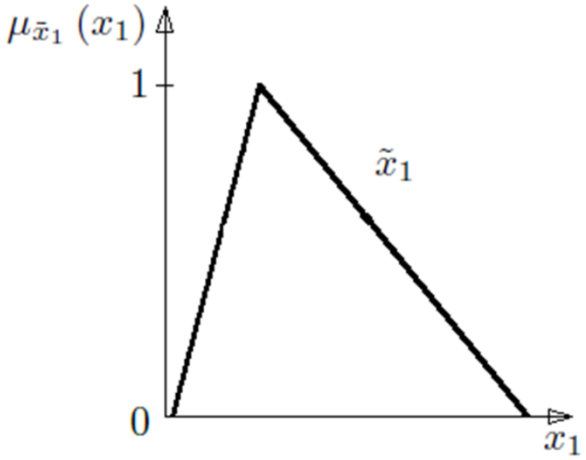
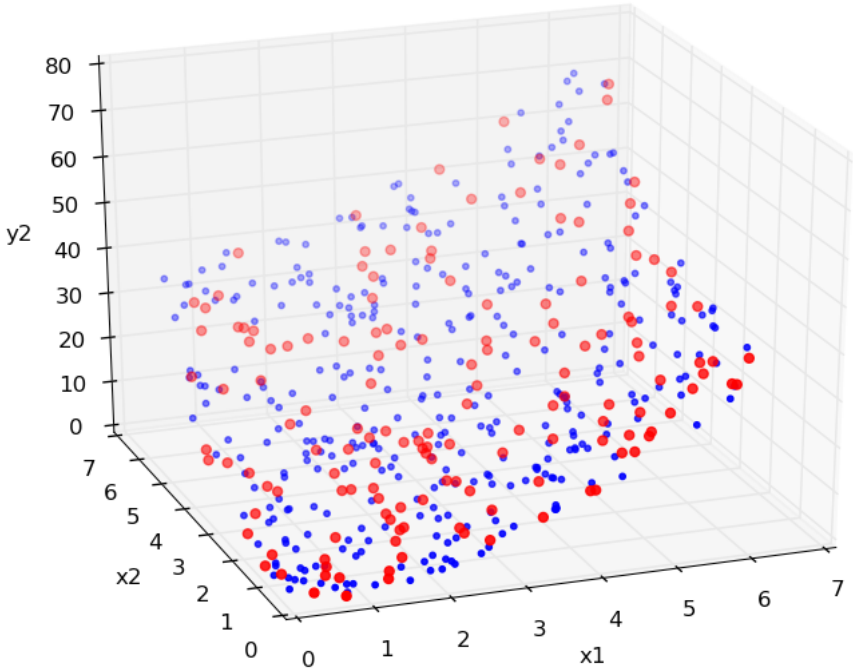
Meta-models

- Since FEM simulations are computationally expensive, meta-models are trained with the aid of LS-OPT for further usage (Fuzzy analysis, Cost-effectiveness fuzzy analysis).

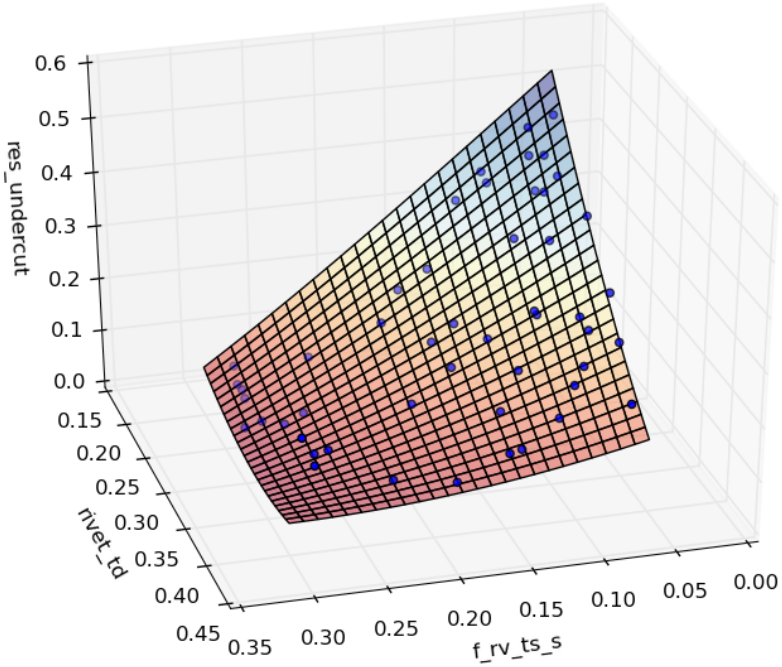
- Workflow:
  - extract points with results
  - divide them into training and testing sets

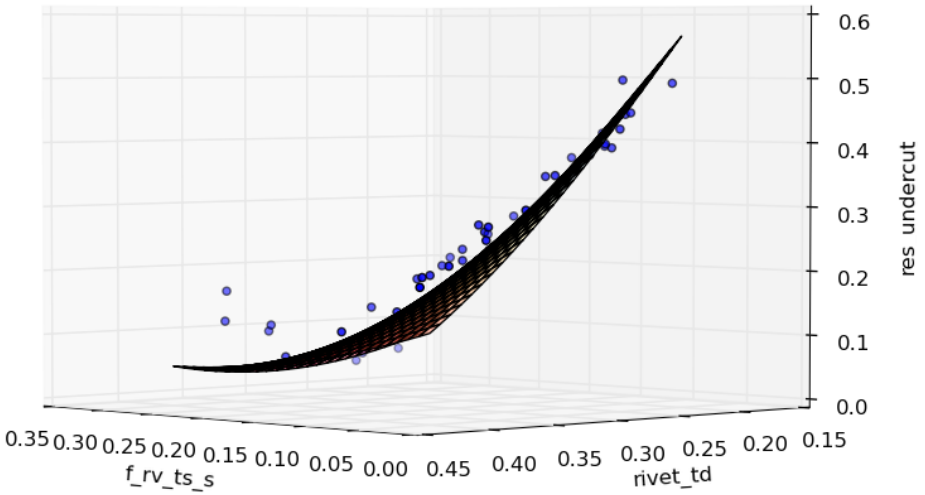




Meta-Model

- ”rbf” meta-model 2D “cut” for the “**res_undercut**” output





Training (700 points) mean error: 8.90%
Testing (300 points) mean error: 18.8%

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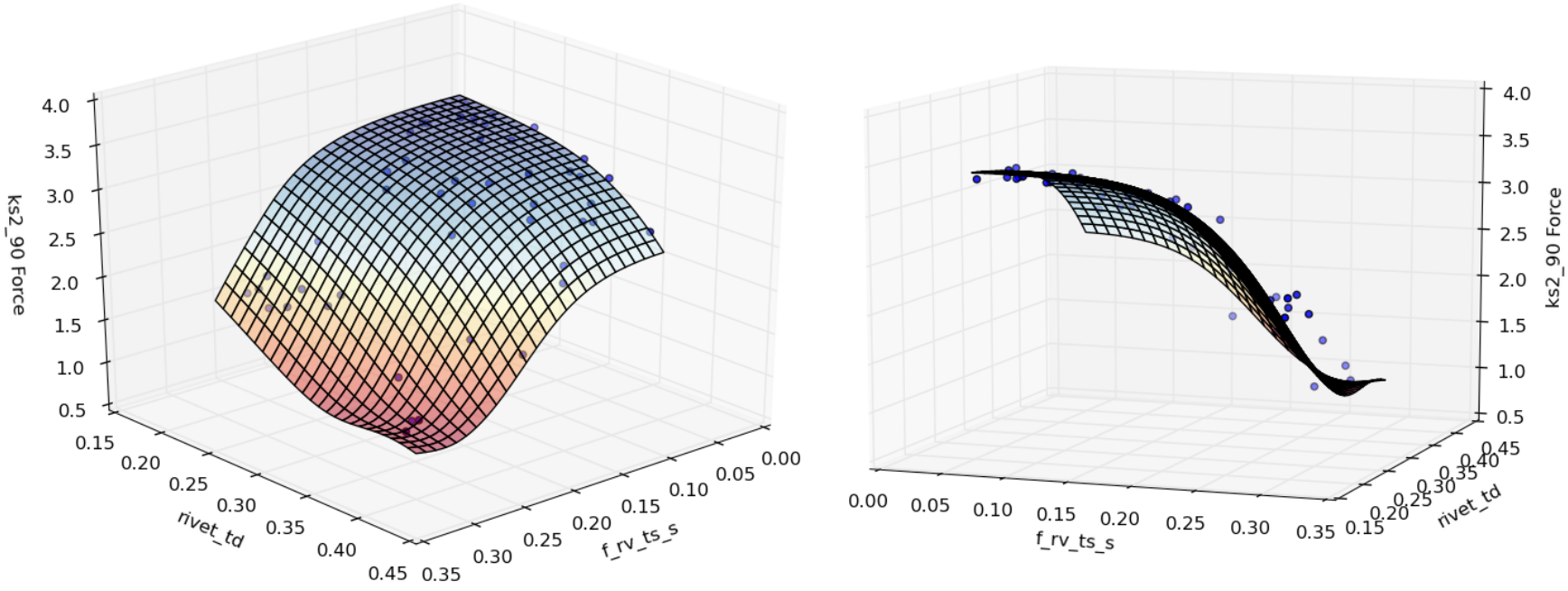
Meta-Model

- ”ffnn” meta-model 2D “cut” for the “**ks2_90 Force**” output



Training (700 points) mean error: 4.80%
Testing (300 points) mean error: 12.1%

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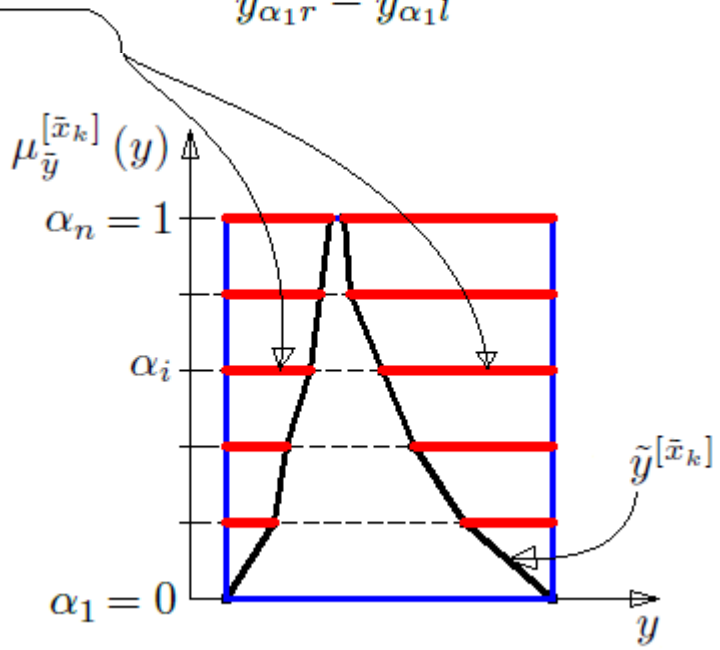
Sensitivity analysis

- Use Local cost-effectiveness fuzzy analysis results to get sensitivity measures/coefficients.
- Procedure:
  - compute the impreciseness reduction effectiveness for each α-level and each output membership function

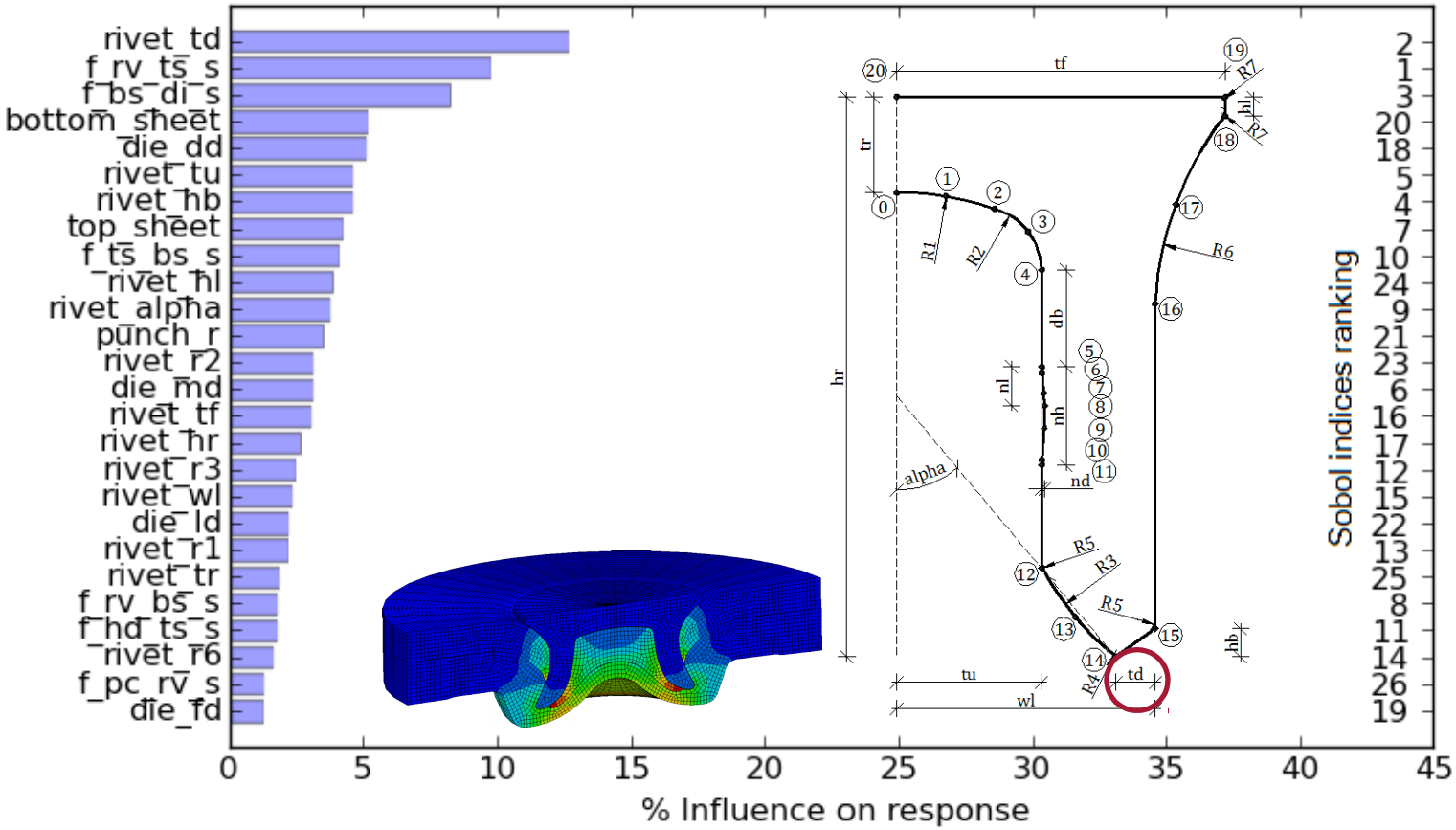
$$E^{[k]}(\alpha_i) = 1 - \frac{y_{\alpha_i r} - y_{\alpha_i l}}{y_{\alpha_1 r} - y_{\alpha_1 l}},\ i = 2, \ldots, n_\alpha$$



$$s^{[k]} = \sum_{i=1}^{n_\alpha} E^{[k]}(\alpha_i)$$

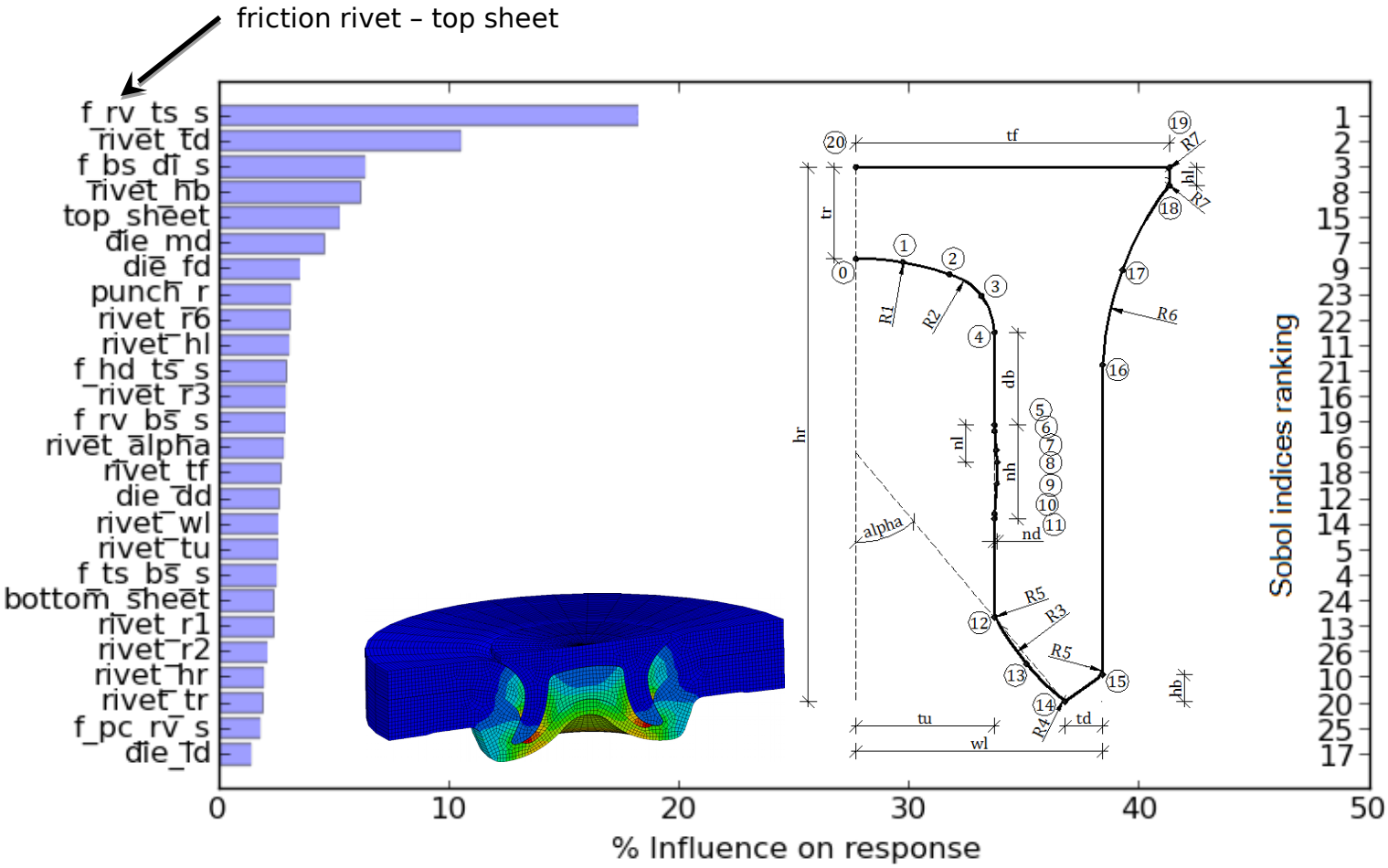
Sensitivity analysis

- obtained sensitivity coefficients for the "**res_undercut**" output from the local cost-effectiveness and with a simple sum:



Sensitivity analysis

- obtained sensitivity coefficients for the "**ks2_90 Force**" output from the local cost-effectiveness and with a simple sum:



Vielen Dank!

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