Identification of a GTN damage model parameter set using HyperStudy

Abstract

The damage model based on **G**urson, **T**vergaard and **N**eedleman (**GTN**) is nowadays often used in finite element analysis. There are different possible ways for the identification of the numerous parameters. In this approach, HyperStudy was used to achieve a first experience of the uniqueness and effects of the parameter sets.

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Agenda

- Introduction: Feasibility of deep drawing steel parts
- Problem definition: Parameterisation of complex failure models
- Analysis: Parameter identification by virtual material testing
- Discussion: Uniqueness and usability of a GTN parameter set
- Conclusion: Parameter identification helps to understand the system

Some words about Salzgitter AG and SZMF

Salzgitter AG - Group structure and numbers

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Salzgitter AG Group

External Sales cons.: € 12.5 billion **Employees: 23915**

Steel

Total Sales:
€ 3.0 billion

Employees:
6,949

Tubes

Total Sales:
€ 2.2 billion

Employees:
5,929

Trading

Total Sales:
€ 5.6 billion

Employees:
1,983

Technology

Total Sales:
€ 1.0 billion

Employees:
4,907

Services

Total Sales:
€ 0.5 billion

Employees:
4,003

All data as of: December 12, 2008

Figure 1

Salzgitter AG - Group structure and companies

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Salzgitter AG (Holding)

Salzgitter Mannesmann GmbH – Intermediate holding company

Steel Salzgitter Stahl GmbH	Tubes Mannesmannröhren-Werke GmbH	Trading	Technology	Services
Salzgitter Flachstahl	Europipe (50%)	Salzgitter Mannesmann Handel Gruppe	KHS-Gruppe	DEUMU
Ilsenburger Grobblech	Salzgitter Mannesmann Linepipe	Universal	Klöckner DESMA Elastomertechnik	Salzgitter Service und Technik
Peiner Träger	Salzgitter Mannesmann Precision	Hövelmann&Lueg	Klöckner DESMA Schuhmaschinen	Verkehrsbetriebe Peine-Salzgitter
HSP Hoesch Spundwand und Profil	Salzgitter Mannesmann Stainless Tubes		Klöckner Hansel Processing	SIT: telcat, GESIS
Salzgitter Bauelemente	Salzgitter Mannesmann Großrohre			Hansaport (51%)
Salzgitter Europlatinen	Hüttenwerke Krupp Mannesmann (30%)			Salzgitter Mannesmann Forschung
	Salzgitter Mannesmann Grobblech			Salzgitter Automotive Engineering

As of: December 31, 2008 | simplified structure

Figure 2

SZMF - R&D-activities

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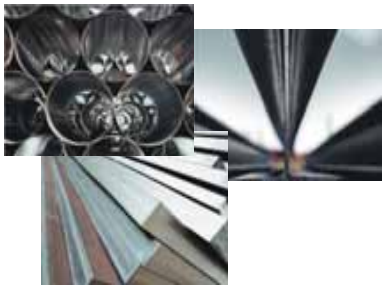
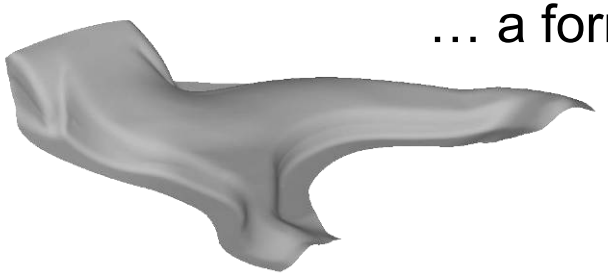
	products / customers	markets
research location: Duisburg 	tubes heavy plates profiles	automotive (power train) machinery and plant construction energy sector construction (sections)
research location: Salzgitter 	hot & cold rolled materials	automotive (body, chassis, …) consumer industry construction (roof, wall, …)

Forming simulation

- SZMF supports the customer to …
  - … chose the right steel grade for
  - … estimate the feasibility of
  - … reduce the weight of
  - … reduce the cost of
  - … optimise the forming processes of

Finite element forming simulation

… a formed steel part!



Sch07

- FE-Tools: **LS-Dyna**, Pam-Stamp, HyperForm, (Ansys)
- Failure criteria: **F**orming **l**imit **c**urve (FLC)

FLC?

Forming limit curve

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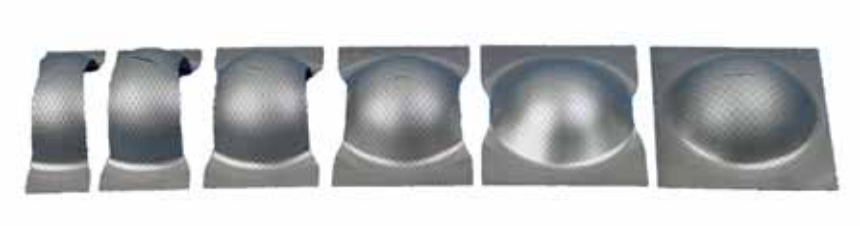
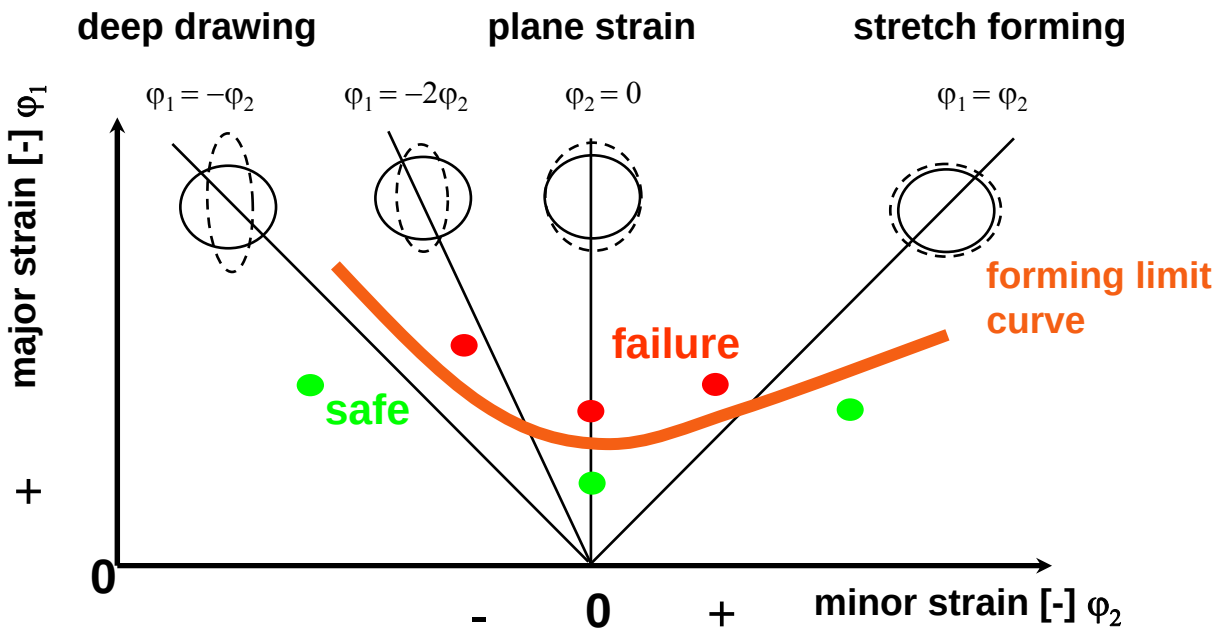
Determination of forming limit curves (FLC)





- ISO 12004
  - Punch Ø 100 mm
  - Thickness < 4.0 mm
  - Quasi-static
  - More than 5 geometries
  - 3 valid tests of each geometry

Alternatives to the FLC?

Problem definition

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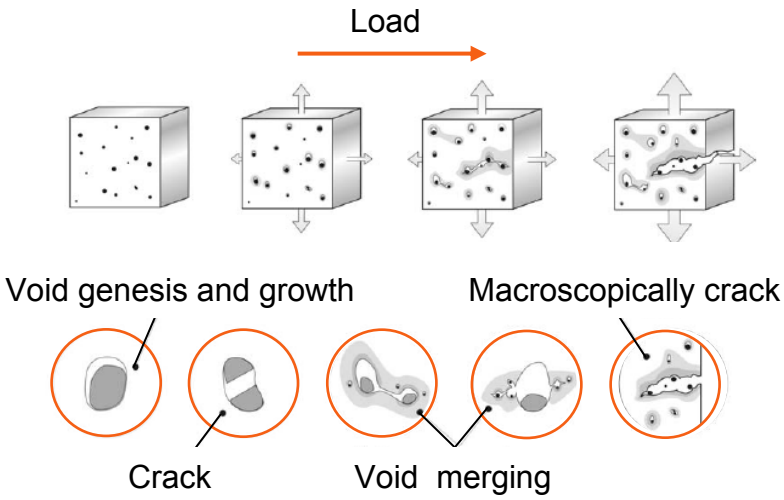
- Alternatives to the FLC:
  - Modifications of Nakajima
  - Similar or additional tests
  - Failure models

Model based on **G**urson, **T**vergaard and **N**eedleman
- Common and often used
- Potentially good to access failure modeling

Gur77, Nee87

- Failure models:
  - Advantages:
    - Strain path independence
    - “Memory” for pre-strains
  - Disadvantages:
    - Complex models
    - Additional testing effort
    - Use of tests without standard



How to feed complex failure models?

Figure 3 - Reu03

Analysis approach

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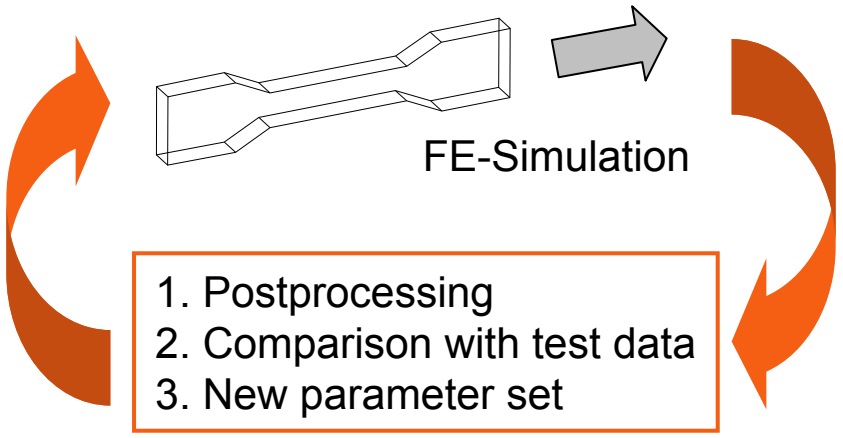
- Parameters of the GTN model: f_0, f_c, f_f, f_N, ε_N, s_N Hal07
- Physical motivated: Additional tests, metallographic analysis
- Mathematical approximation: Use of parameter identification

- Parameter identification:
  - FE-model of testing method
    - Target: parameter set with best match
  - Method should be fixed by standard
  - Results should be part of standard test
  - Automated process
    - HyperStudy



Implementation?

Figure 4

Analysis approach

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- FE-solver: LS-Dyna
- Job management: Platform LSF®
- Post processing:
  - Result read out: LS-Pre-Post controlled by scripts
  - Result comparison and abstraction: Fortran routines
- Parameter optimisation: HyperStudy
  - Design variables: 6
  - Vector sources: 10
  - Responses: 17
  - Constrains: 13
- Optimisation algorithm: Genetic
  - Abort criteria: Minimal 15 generations (1900 runs) and 3 generations without improvement

Altair HyperStudy®

First step: tensile test

Analysis: Tensile test of DP-steel HCT780XD

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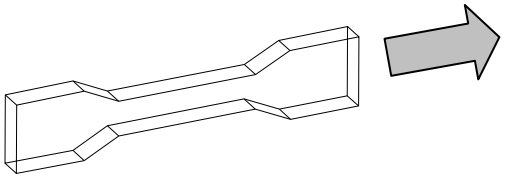
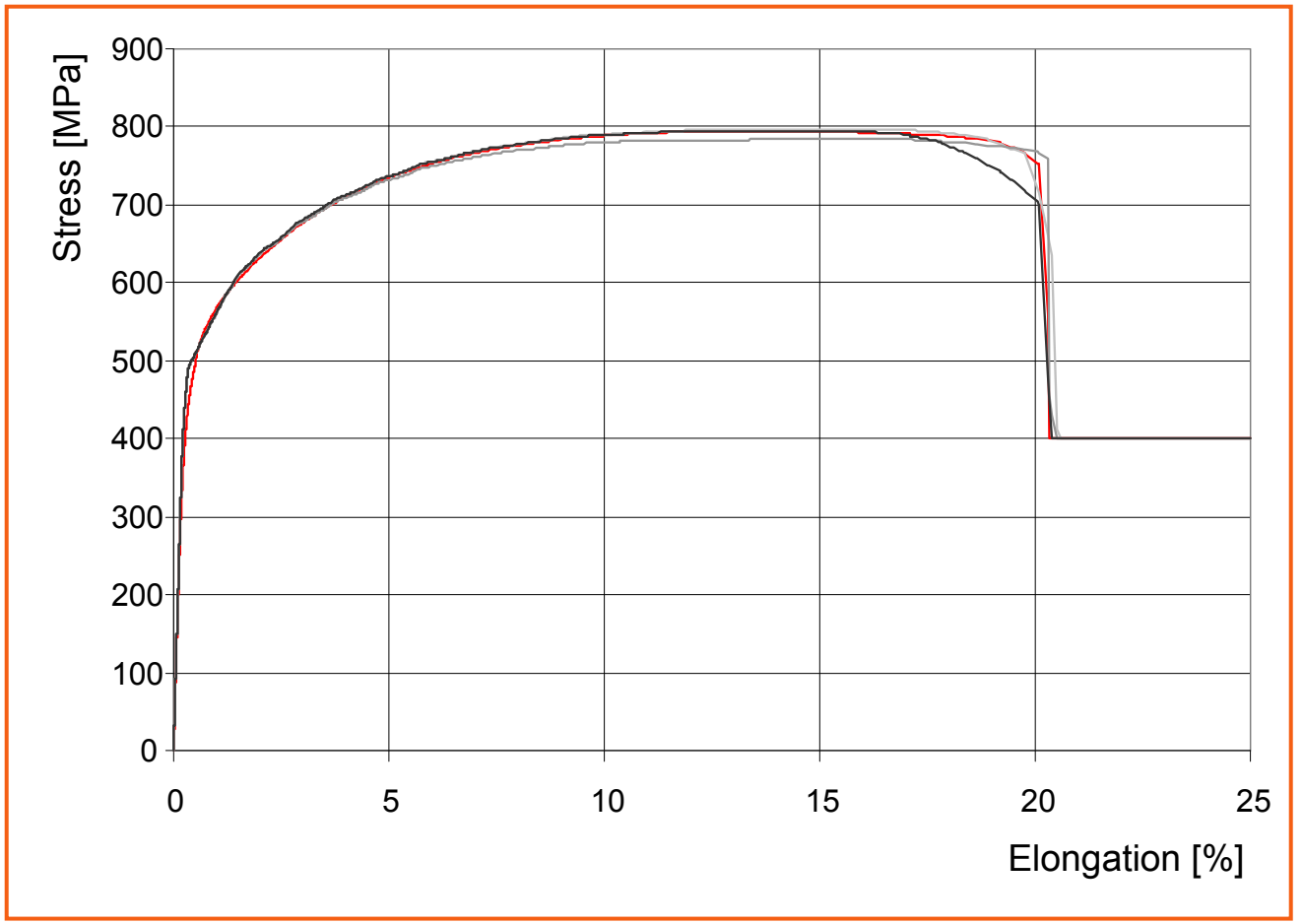
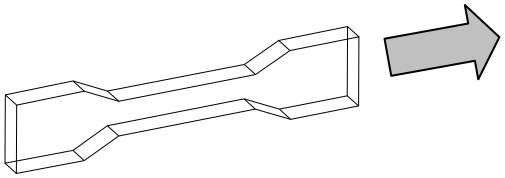


- Real tensile test
- GTN - 6 free parameters
- GTN - 2 parameters set by metallographic
- GTN - 2 step approach (before and after uniform elongation ε_u)



Tensile test: Good matching

Analysis: Tensile test of DP-steel HCT780XD



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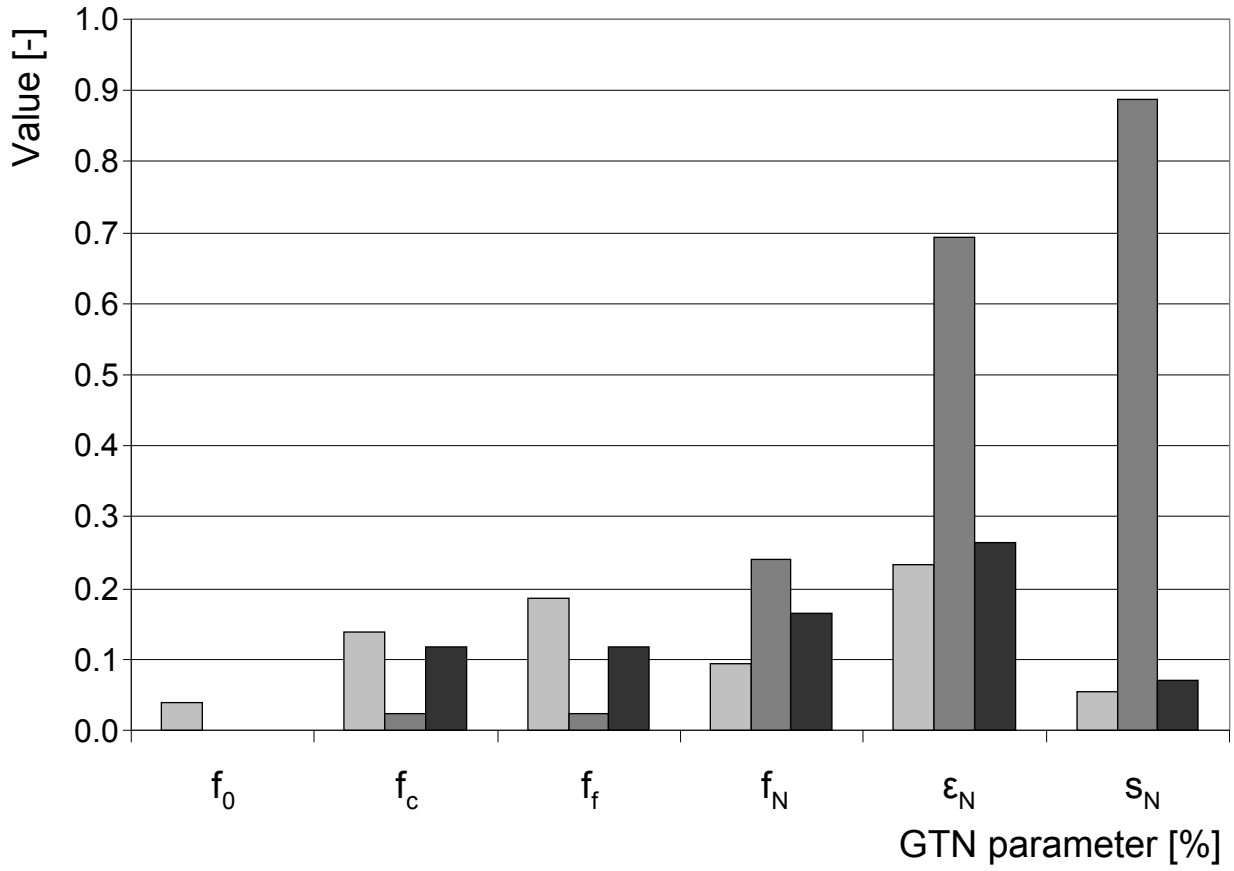

Tensile test: Good matching
No uniqueness

Analysis: 1-Element Nakajima of DP-steel HCT780XD

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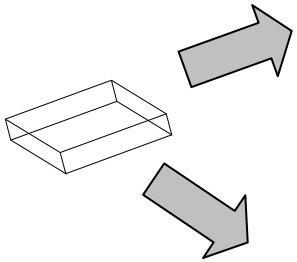
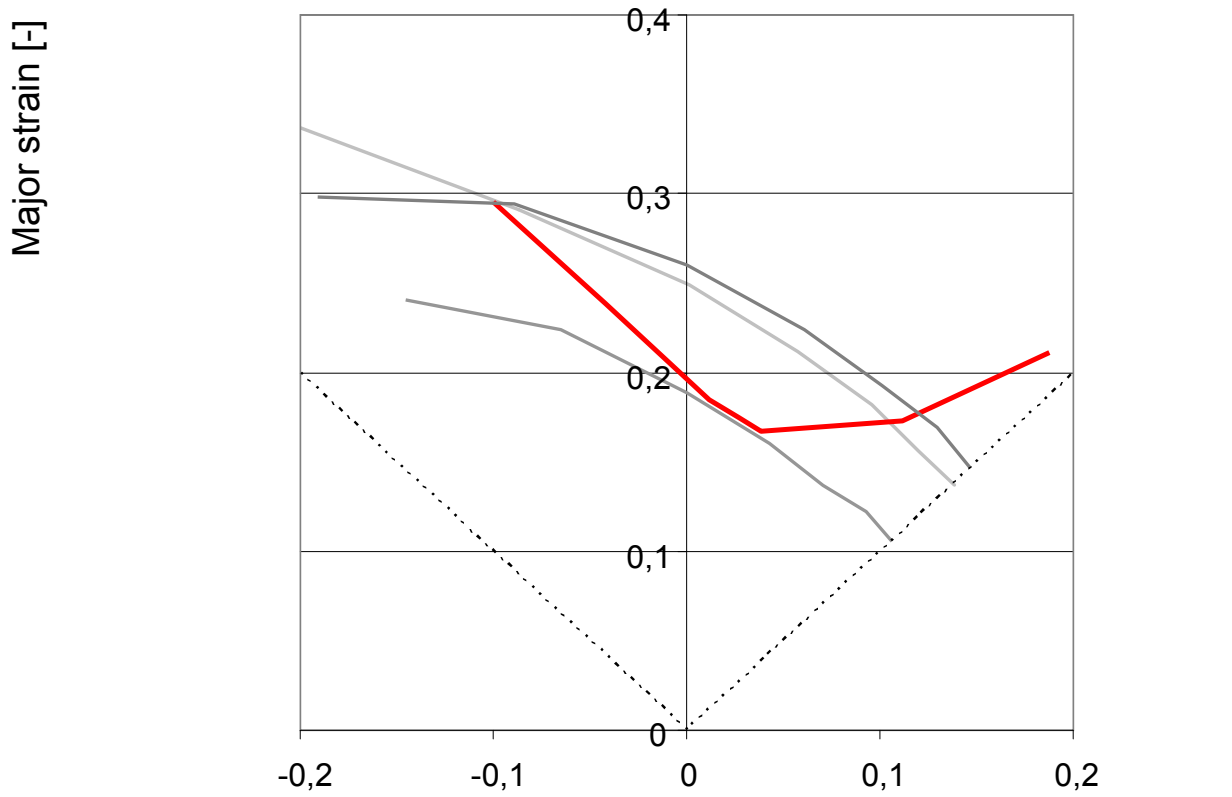


- Real forming limit curve
- GTN parameters optimised for **tensile test**
  - 6 free parameters
  - 2 parameters set by metallographic
  - 2 step approach (before and after uniform elongation ε_u)



1-Element Nakajima: Bad matching with parameter from tensile test
Next step: Optimised FLC parameter set

Analysis: 1-Element Nakajima of DP-steel HCT780XD

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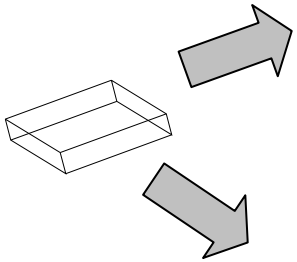
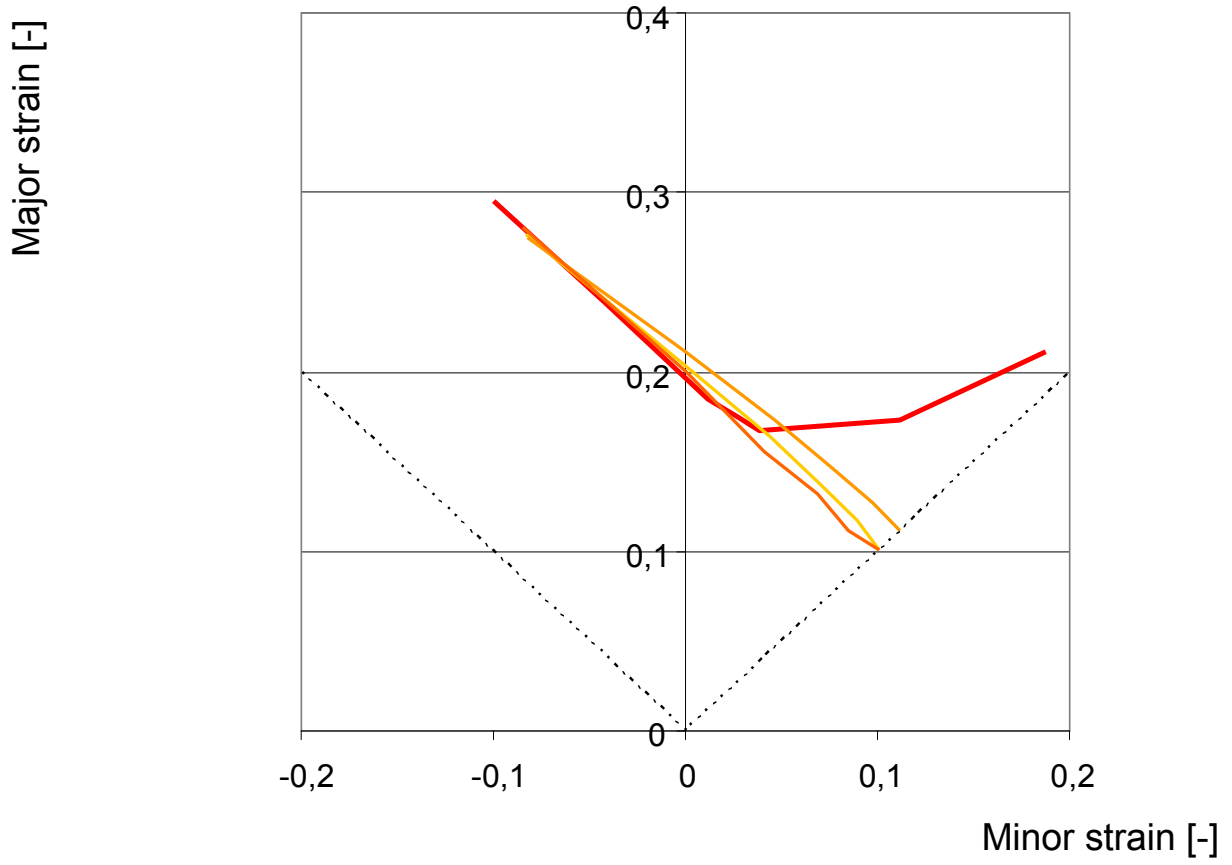
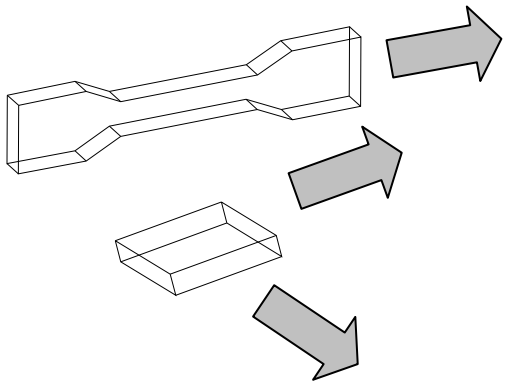


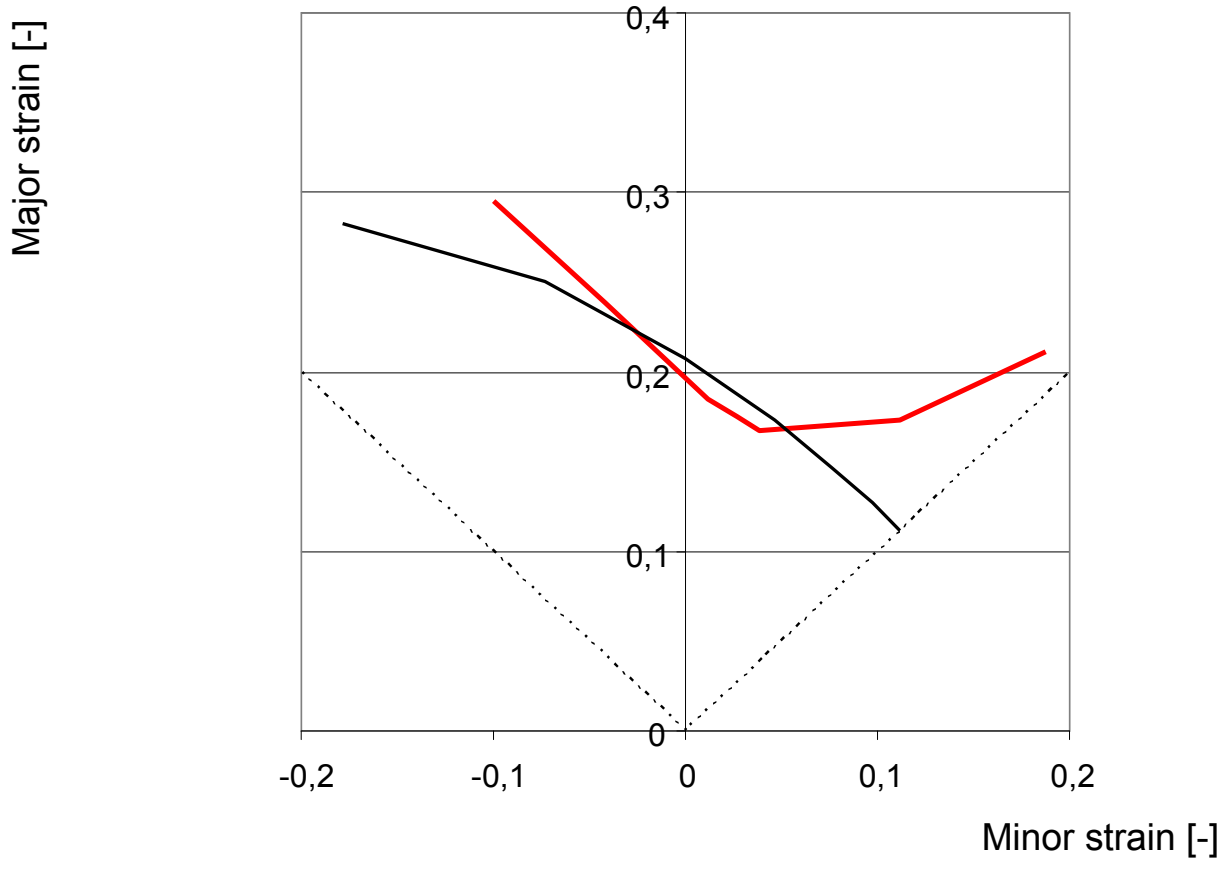
- Real forming limit curve
- GTN parameters optimised for **forming limit curve**
  - 6 free parameters
  - 4 free, 2 parameters set by metallographic
  - 6 free parameters focused on deep drawing and plane strain



1-Element Nakajima: Bad matching in stretch forming zone
Next step: Combined optimisation

Analysis: Combined tensile test & 1-element Nakajima



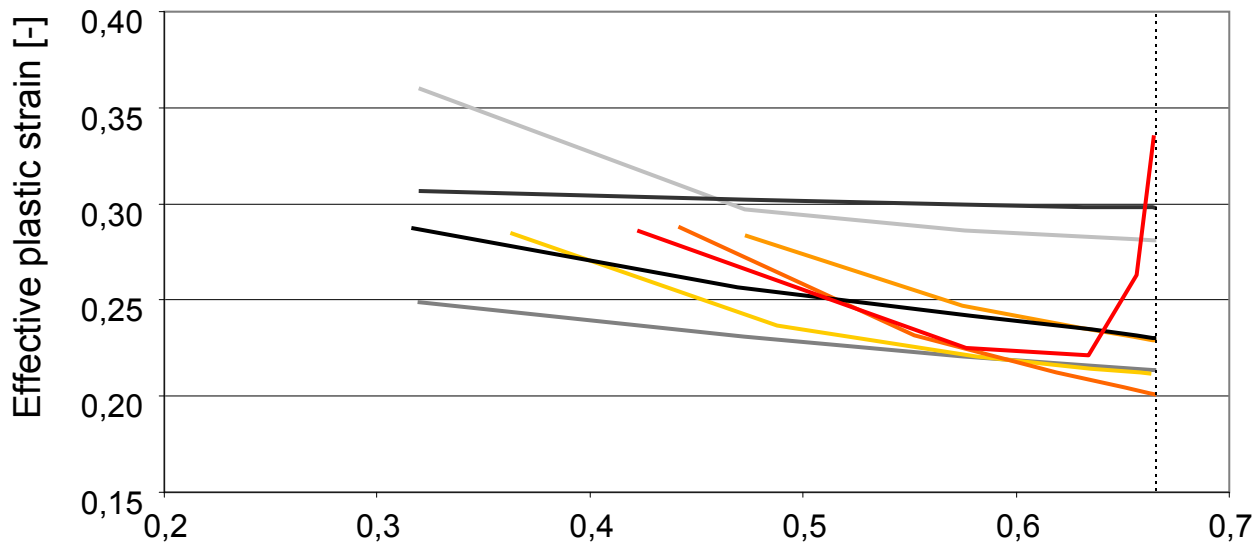


- Real forming limit curve
- GTN parameters optimised for **tensile test** and **forming limit curve**
  - Tensile test deviation:
    - Uniform elongation = 1,6 %
    - Elongation = 0,2 %
    - Tensile stress = 19 MPa

Combined test: Good matching of tensile test
Acceptable matching on left half of FLC

Discussion

- Matching tensile test: In the range of test scattering
- Matching forming limit curve:
  - GTN is not able to “rise” under stretch forming load
  - Focus on “left side”



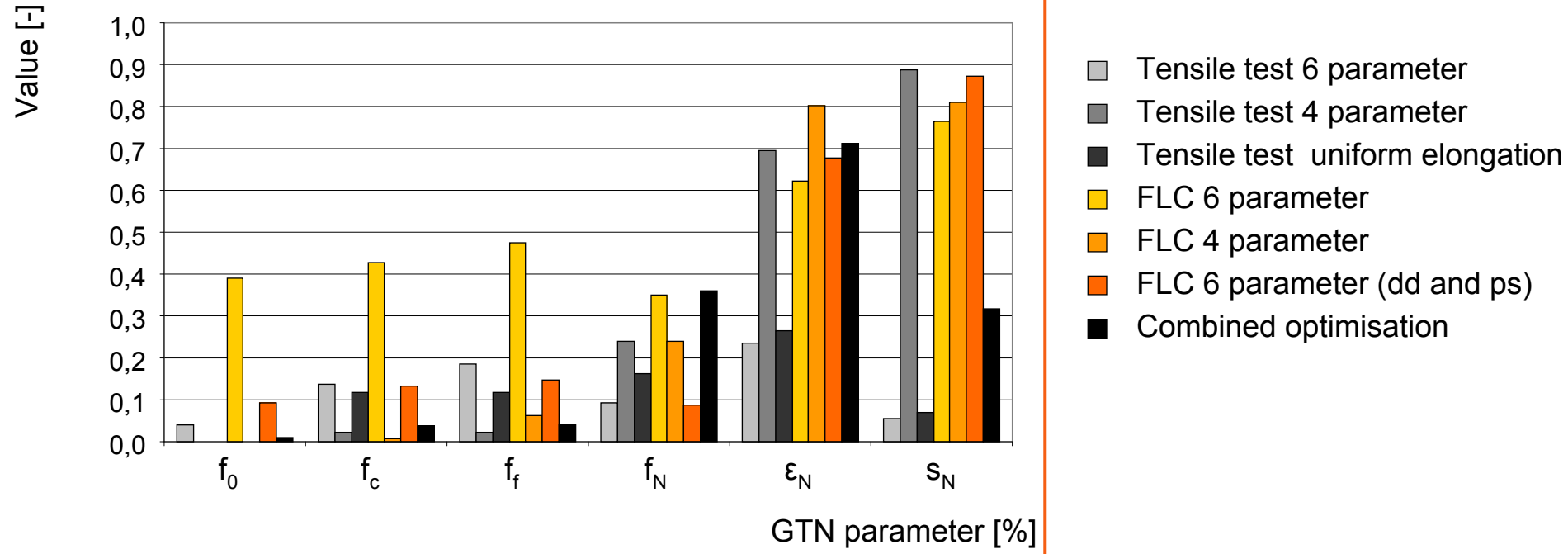
- Real FLC
- Tensile test 6 parameter
- Tensile test 4 parameter
- Tensile test uniform elongation
- FLC 6 parameter
- FLC 4 parameter
- FLC 6 parameter (dd and ps)
- Combined optimisation

Plot 6

Ebe08, Feu09, Neu08

Discussion

- Matching tensile test: In the range of test scattering
- Matching forming limit curve: Focus on “left side”
- Uniqueness: Further investigations necessary
- Element size dependence: More complex optimisation necessary



Plot 7

Conclusions

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- Importance of failure models increases with launch of new more complex materials
- Adequate amount of tests for material and failure models makes them suited for daily use
- Parameter identification helps to reduce test amount and to get first impressions of the options of a system
- GTN failure model shows pros and cons
- There is a need for easy to use failure models with complex capabilities!


Everything is possible.
www.salzgitter-ag.de
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Stahl und Technologie

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Figures and plots

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Figures

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2. Salzgitter AG - companies
3. Schematic picture of GTN failure model
4. Identification routine

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2. GTN parameter optimised for tensile test
3. Forming limit diagram of parameter sets optimised for tensile test
4. Forming limit diagram of parameter sets optimised for FLD
5. Forming limit diagram of parameter set optimised for tensile test and FLD
6. Triaxiality diagram of all used parameter sets
7. GTN parameter of all used sets