4a impetus – validated material cards in an efficient way

A. Fertschej, P. Reithofer, M. Rollant (4a engineering GmbH)

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  - Considering failure
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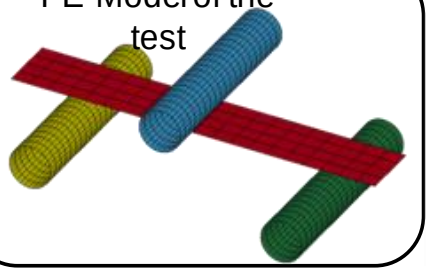
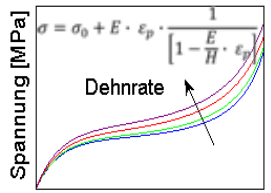
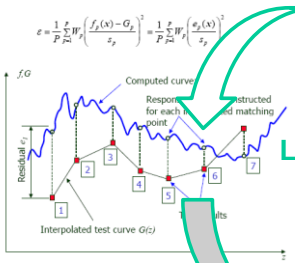
Material characterization / reverse engineering

FE-Model of the test



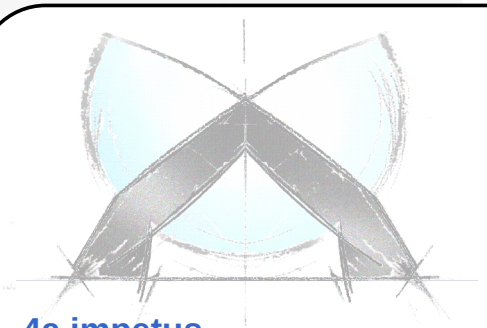
Parameterized





LS DYNA, ABAQUS, PAM CRASH, …

Reverse Engineering

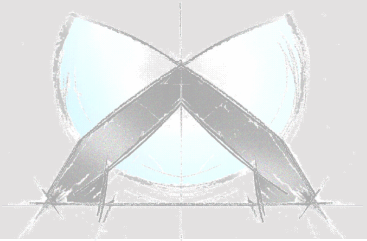


4a impetus

Hyperview, Animator, LS PREPOST, …

DATABASE
measurement, models

Further information:
LS-Dyna Infotage 2013 – Dynamische Kunststoffcharakterisierung
http://www.dynamore.de/de/download/presentation/dokumente/2013-Polymers



4a impetus
How does it work

Test database
- Geometry
- Loading
- Boundary condition
- Orientation
- Measurement results
  Force/Displacement
  Stress/Strain
  …

Model database
- Optimization/Validation
- Solver
  LS Dyna, Abaqus, …
- Material model
  von Mises
  general yield surface
  strain rate dependence
- Idealization
  Shell/Solid
  Meshsize

Directly linked to model build up

Evaluation
Filtering
Averaging

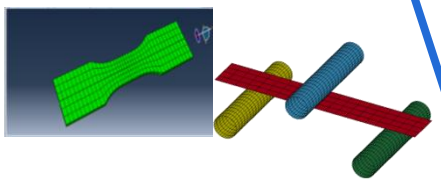
Automatic LS-OPT input-deck

Directly linked to solver run scripts

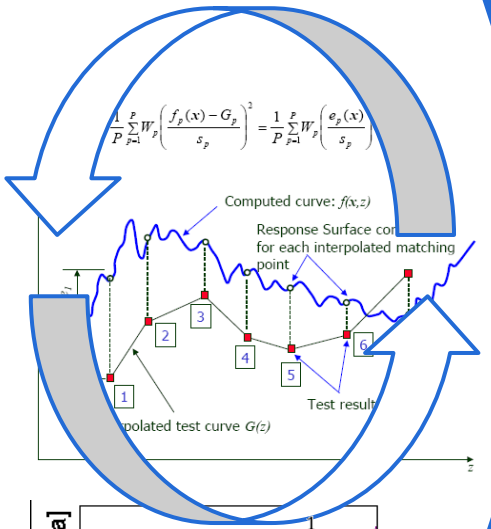
Material optimized parameterized models

Automatic mesh generation

FE-Model of the test



Reverse Engineering

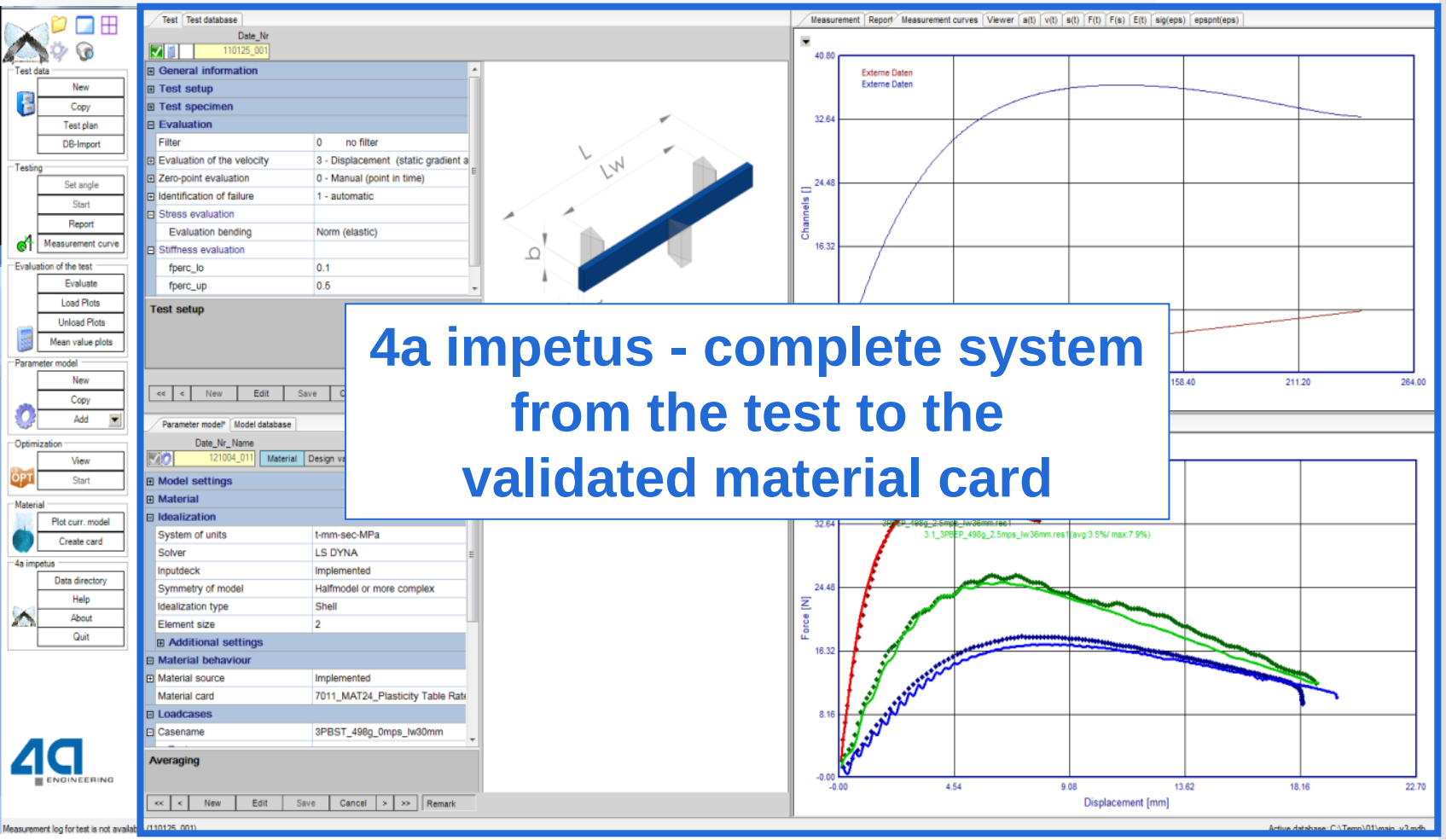


parameterized material card

validated material card

4a impetus
How does it work

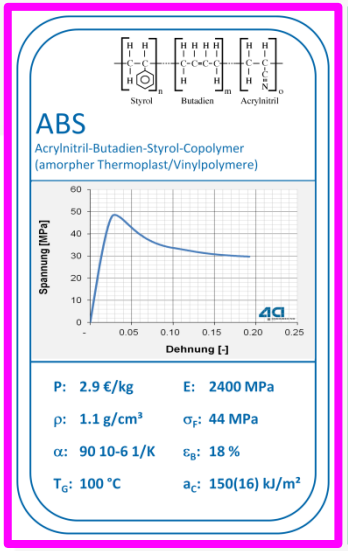
- The tests and simulations models are stored in a data base → easy access and user friendly

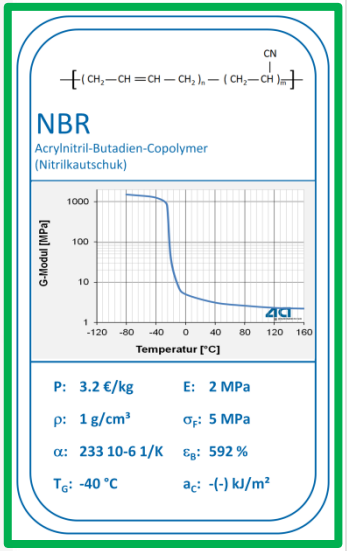


4a impetus - complete system from the test to the validated material card

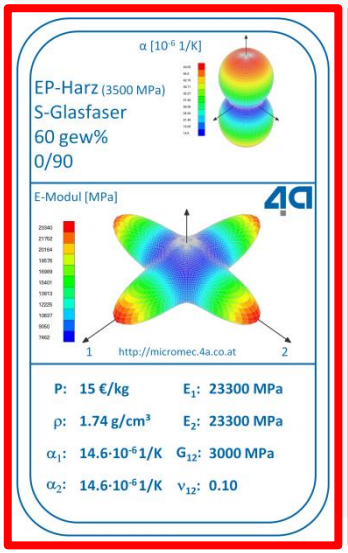
4a impetus
Tested materials

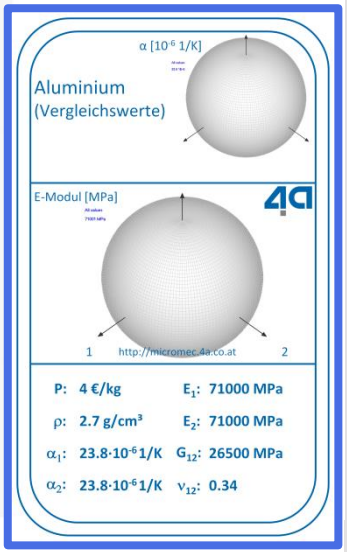
- We have already tested a wide range of
  - thermoplastics (ASA, ABS+PA; ABS+PC; PA6; PA6(6) GF30..50; PA66+P6; PBT GF30; PC; PE; PP; PP+ varnish; PP rubber modified; PP GF20..40; PP Impact modified; PP MX10; PP MX20; PP MX40; PP CF; PP+EPDM; MuCell-materials, …)
  - foams (EPP30..80; PU RG 55, PU RG 65)
  - rubbers (EPDM, SILIKON)
  - thermoset materials (CFK, GFK with epoxy resin)
  - metals (aluminium, DC04, high strength steels (current tests))
  - wood (beech, multiplex, chipboards, MDF)



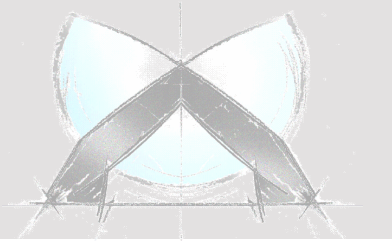


from:
4a Quartet card game "plastics"



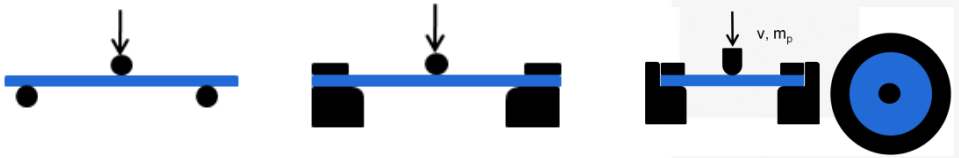


from:
4a Quartet card game "composites"



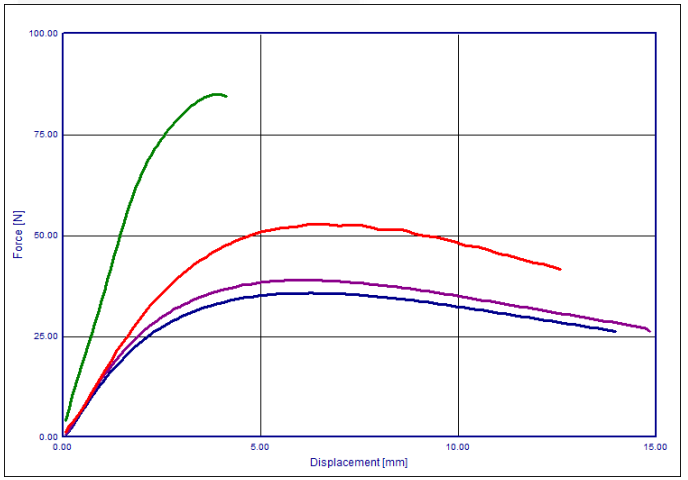
4a impetus
Test methods

- 4a impetus is a pendulum test device to characterize materials by 3-point-bending, compression and puncture tests



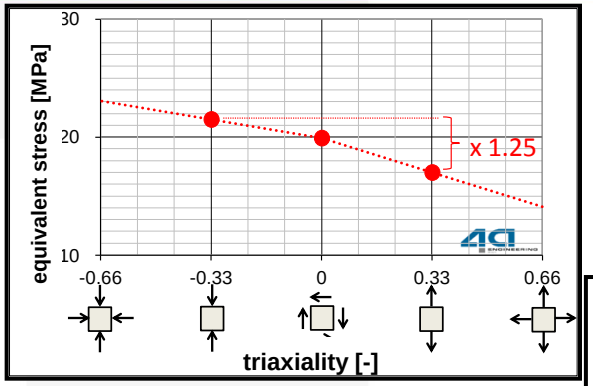
- Capturing different strain rates and the strain rate dependency
  - changing the pendulum speed (up to 4.4 m/s as single pendulum)
  - changing the support distance

velocity [mm/s]	support distance [mm]	strain rate [1/s]
0.1	40	0.002
1	40	0.02
1000	40	11
4000	30	80



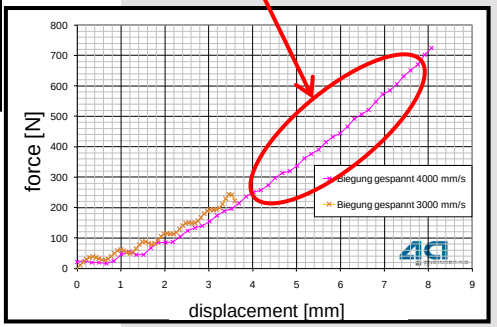
4a impetus
Test methods

- Capturing compression/tension behavior
  - import quasi-static tensile
    (and shear and compression) test
  - clamped bending test
- Capturing loading / unloading → damage
  - 3-point-bending test
  - Multiple loading clamped bending test

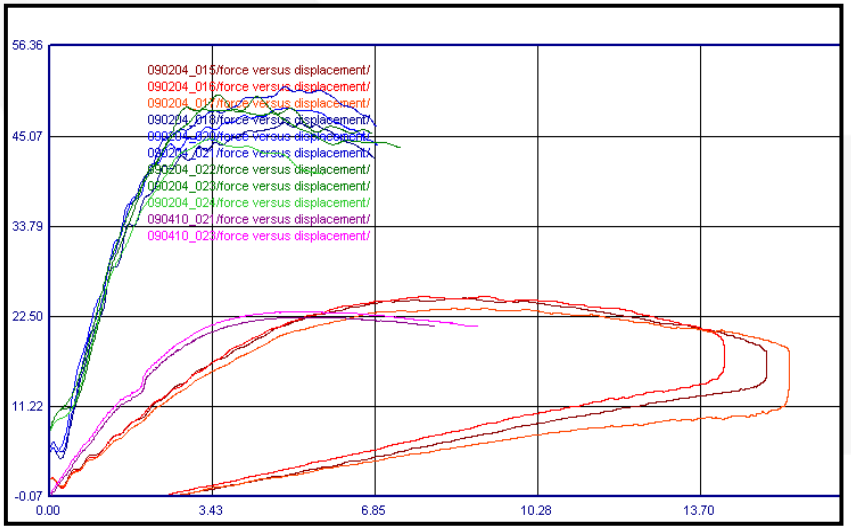


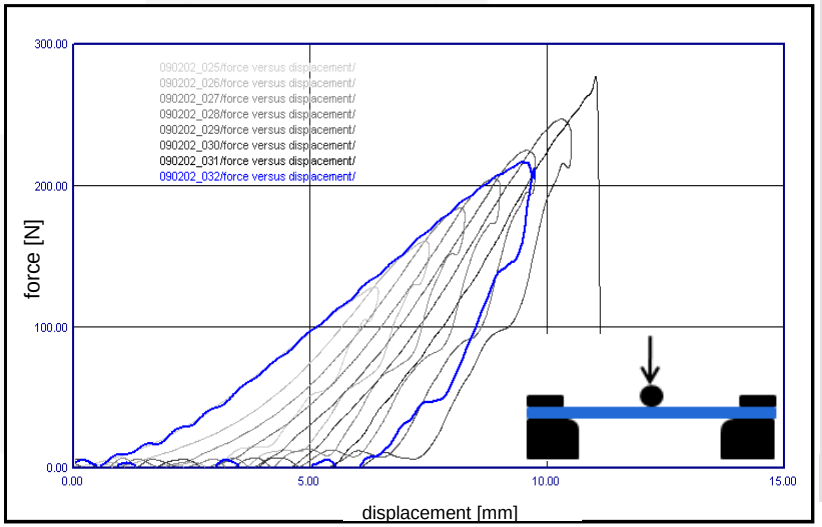
[1]

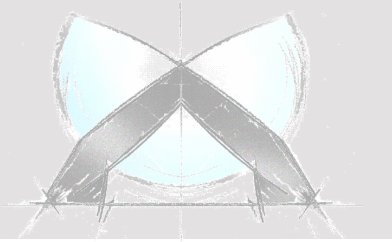
tension dominated



[2]

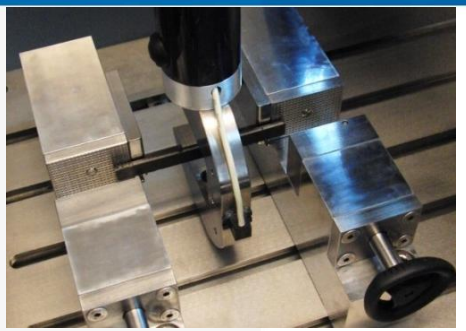


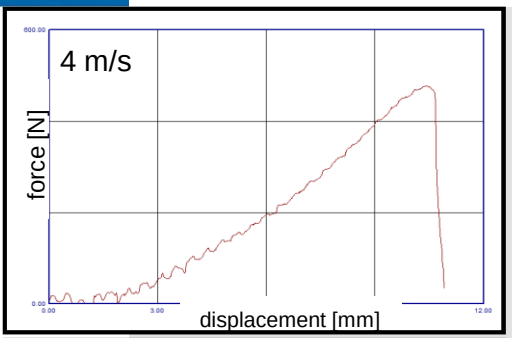


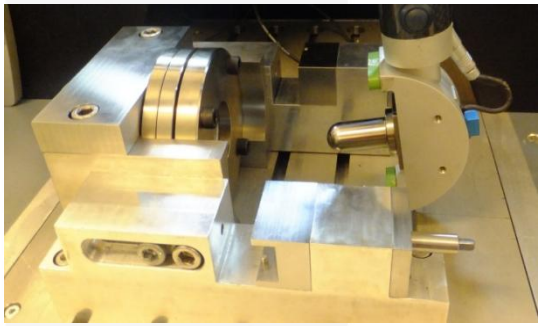


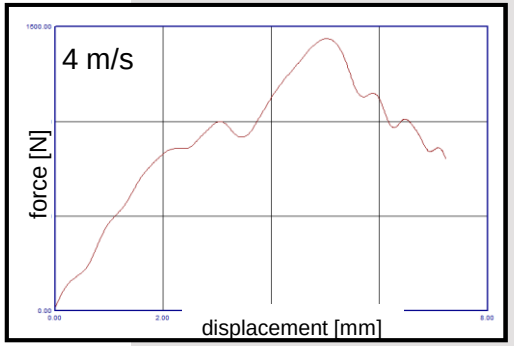
Test methods

- Capturing failure
  - Clamped bending test → uniaxial behavior
  - Puncture test → biaxial behavior

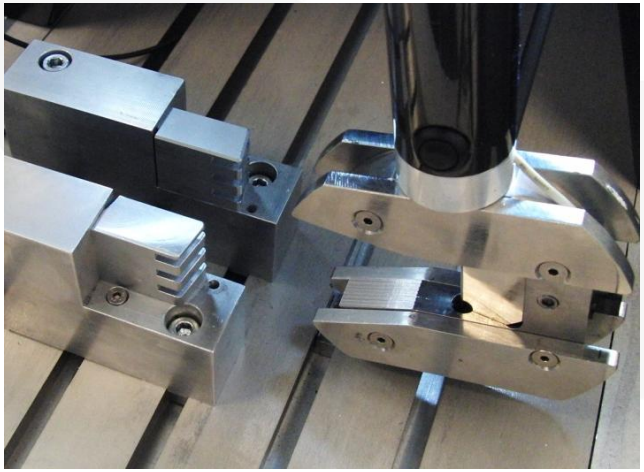


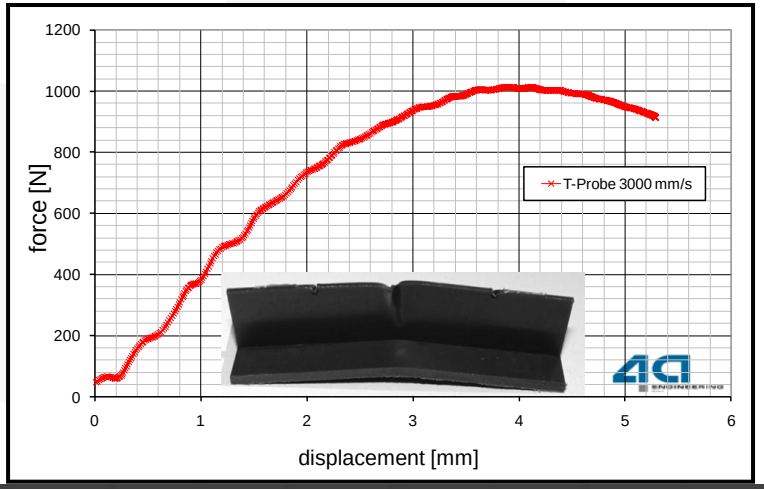






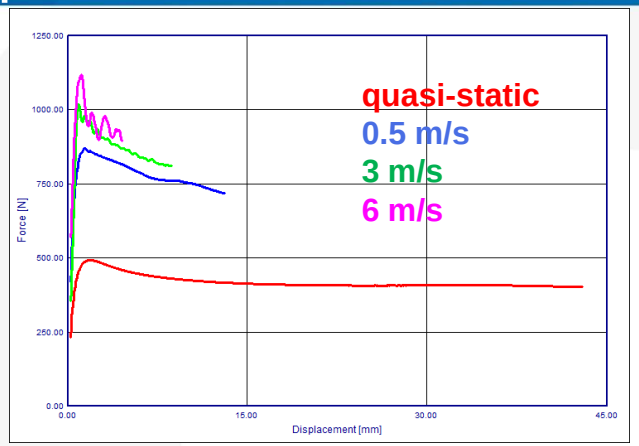
- Capturing component test
  - T-specimen → idealization





[2]

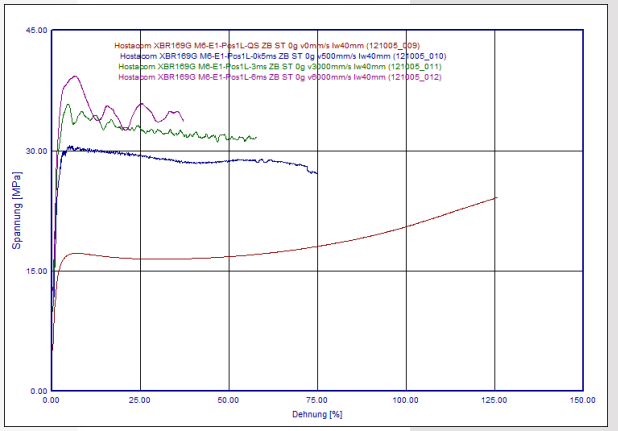
4a impetus
Import test results from different sources



measured force/displacement curves on tensile testing machine

[3]

import



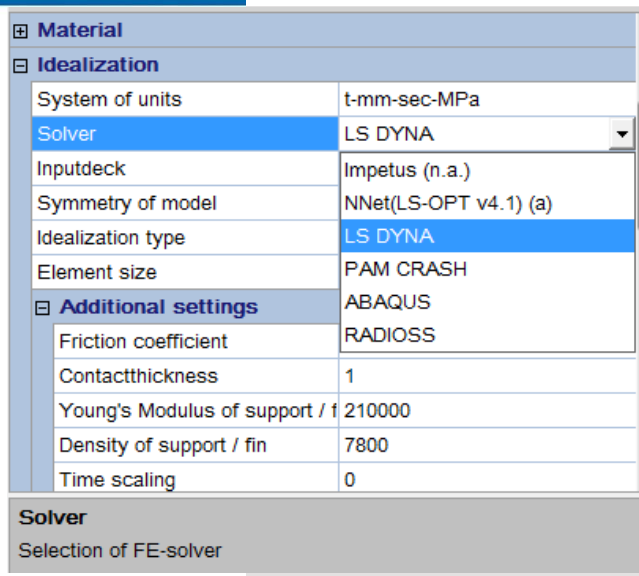
evaluation of stress/strain curves

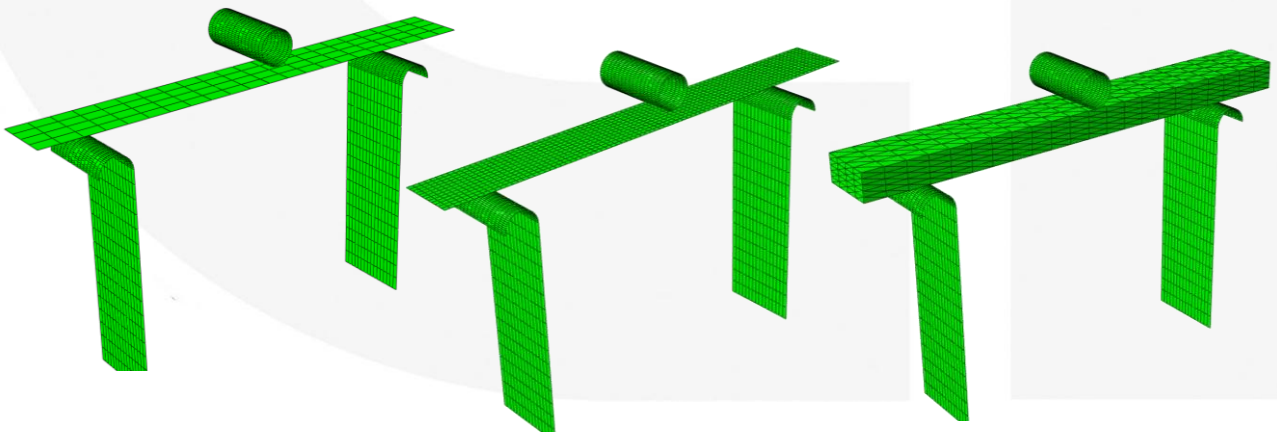
Using the 4a impetus software the user can

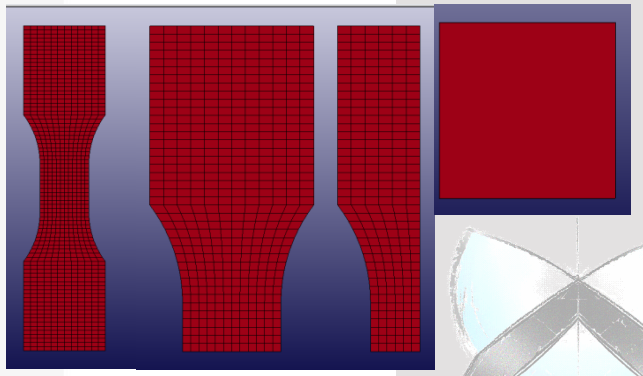
- Import additionally any other tests (e.g. quasi-static bending, tensile or compression test, any supplier) into the test data base (e.g. force/displacement curves),
- Evaluate all the tests (also the imported ones) and use these data only or additional for generating the material card or calculate the test curves using the material card (validation).

4a impetus
Simulation - Idealization

- Can be used local or in network cluster
- Supports LS-Dyna, Abaqus, PAM-Crash, Radioss
- Allows the idealization in shell or solid using the most popular element types and an arbitrary element size (of course it should be reasonable)
- Can consider symmetries – simplification down to 1-element

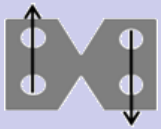
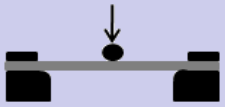
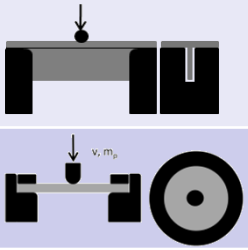






4a impetus

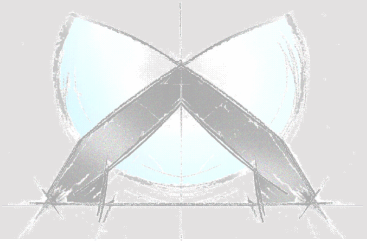
Available test methods - Interfaces in 4a impetus V3.2

	ABAQUS	LS-DYNA	PAMCRASH	RADIOSS
	implicit / explicit	implicit / explicit	explicit	
	implicit / explicit	implicit / explicit	explicit	
	implicit / explicit	implicit / explicit	explicit	
	implicit / explicit	implicit / explicit	explicit	explicit
	implicit / explicit	implicit / explicit	explicit	explicit
	implicit / explicit	implicit / explicit	explicit	explicit
	implicit / explicit	implicit / explicit	explicit	

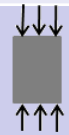
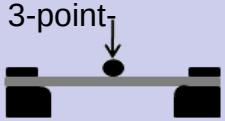
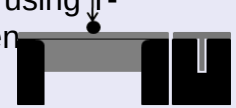
in progress

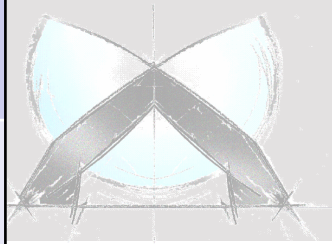
implemented

tested



4a impetus
Generating material cards – different approaches

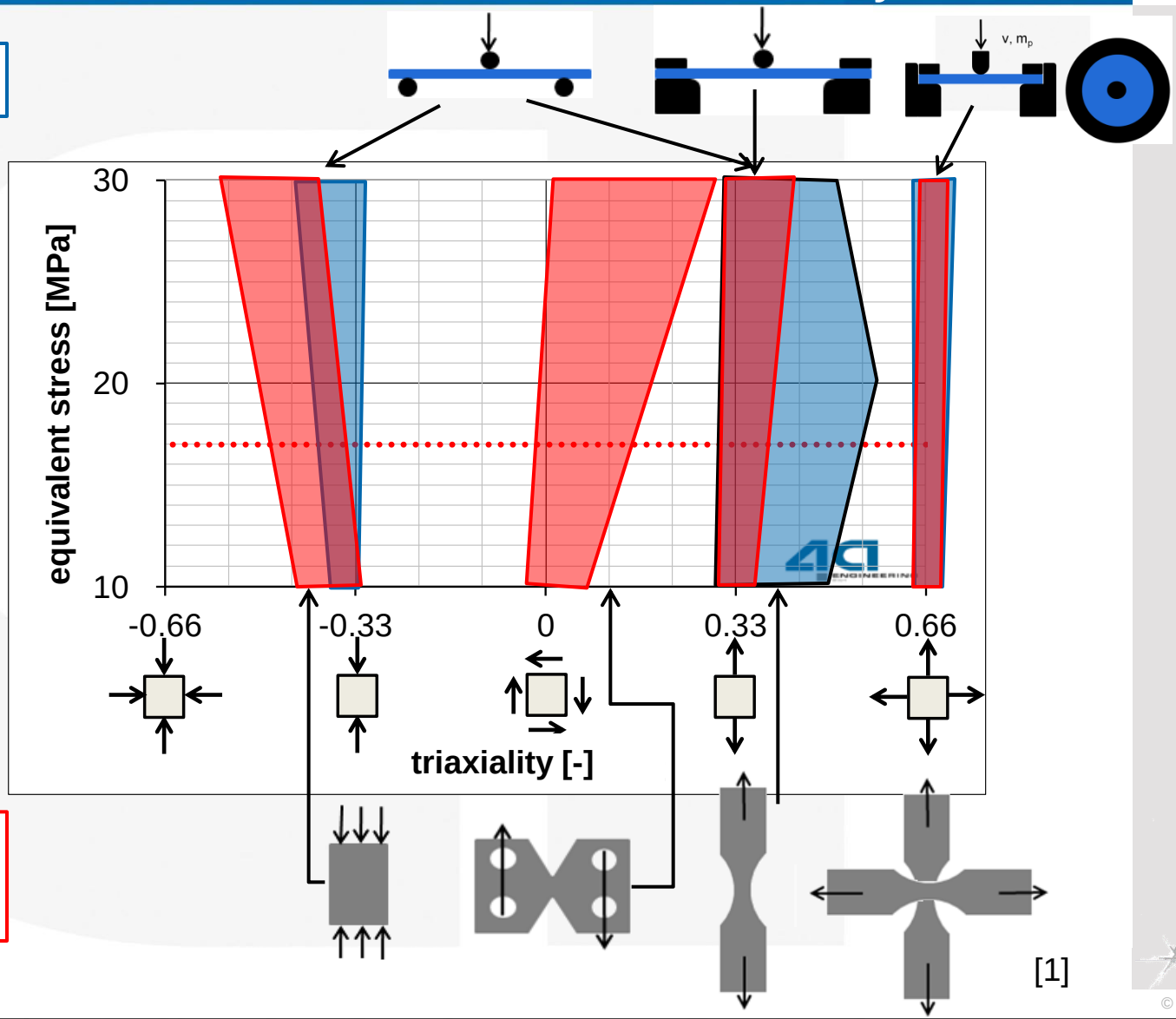
	classic approach		4a impetus		
	*MAT_24	*MAT_187	*MAT_24	*MAT_124	*MAT_187
tensile test 	static and dynamic tests	static and dynamic tests		static tests	static tests
compression 		static tests			
shear 		static tests			
biaxial tension puncture test		static tests			
3-point-bending 			static and dynamic tests	static and dynamic tests	static and dynamic tests
clamped 3-point-bending 				static tests	static tests
bending using T-specimen 	Also possible with 4a impetus software				



4a impetus

Generating material cards – influence of triaxiality

4a impetus



Classic approach

[1]

Generating material cards - LS-Dyna material models

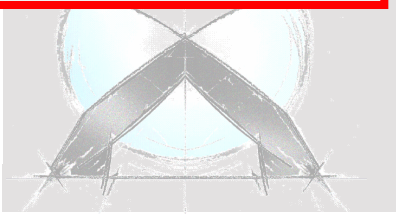
- MAT_19: **MAT_STRAIN_RATE_DEPENDENT_PLASTICITY* — von Mises
- MAT_24: **MAT_PIECEWISE_LINEAR_PLASTICITY* — von Mises
- MAT_124: **MAT_PLASTICITY_COMPRESSION_TENSION* — Drucker Prager
- MAT_187: **MAT_SAMP-1* — general yield surface

Material behaviour	
Material source	Implemented
Density	-1020.83
Poisson's ratio	0.3
Failure strain	0
Elasticity	Linear elastic
Plasticity	vonMises
Curve 1	4a Model A
Strain rate dependency	Table
Strain range upto	0.25
Sampling points	50
Bias factor	10
Material card	7011_MAT24_Plasticity Table Rate log. Table

Material behaviour	
Material source	Implemented
Density	-1020.83
Poisson's ratio	0.3
Failure strain	0
Elasticity	Linear elastic
Plasticity	Drucker-Prager
Curve 1	4a Model A
Curve 2	Kurve 1 skaliert
Strain rate dependency	Table
Strain range upto	0.25
Sampling points	50
Bias factor	10
Material card	7021_MAT124

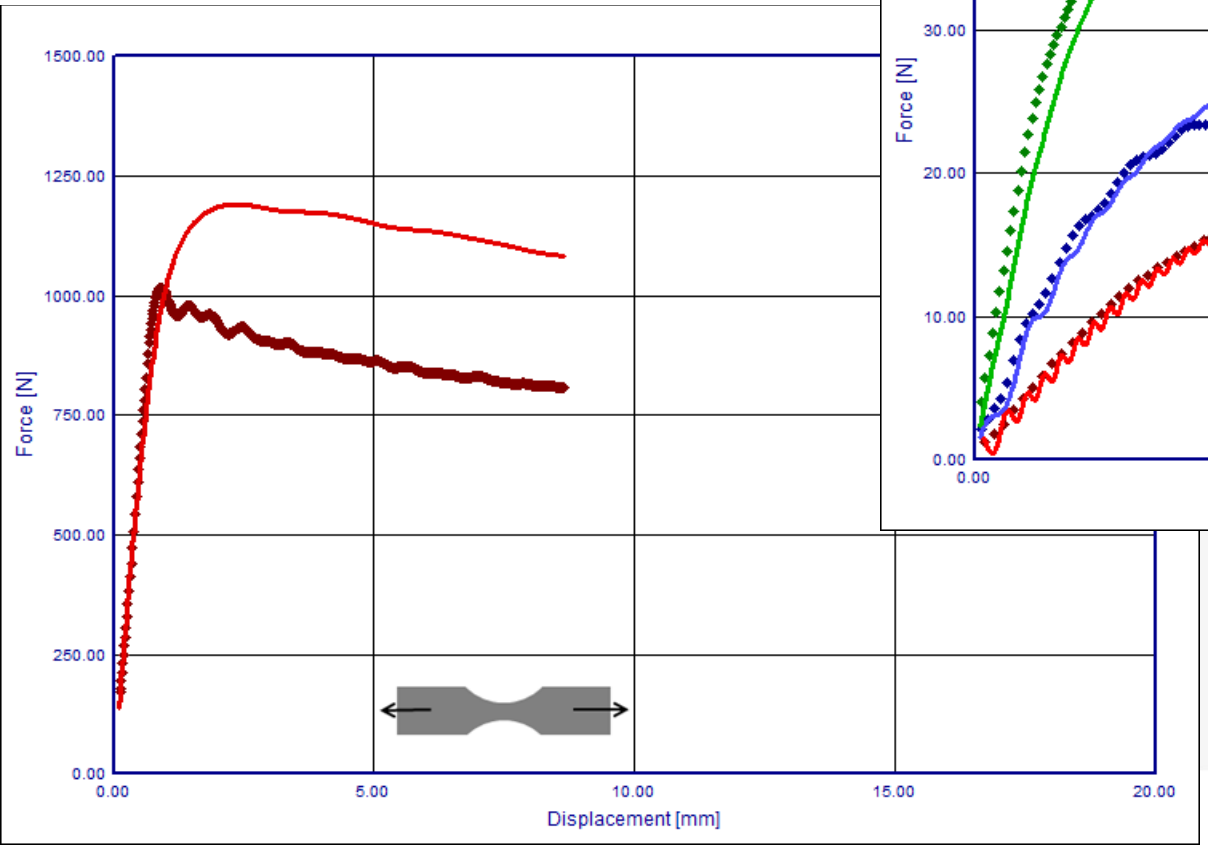
Material behaviour	
Material source	Implemented
Density	-1020.83
Poisson's ratio	0.3
Failure strain	0
Elasticity	Linear elastic
Plasticity	general yield surface (3 curves)
Curve 1	4a Model A
Curve 2	Kurve 1 skaliert
Curve 3	Kurve 1 skaliert
Strain rate dependency	Table
Strain range upto	0.25
Sampling points	50
Bias factor	10
Material card	7031_MAT187

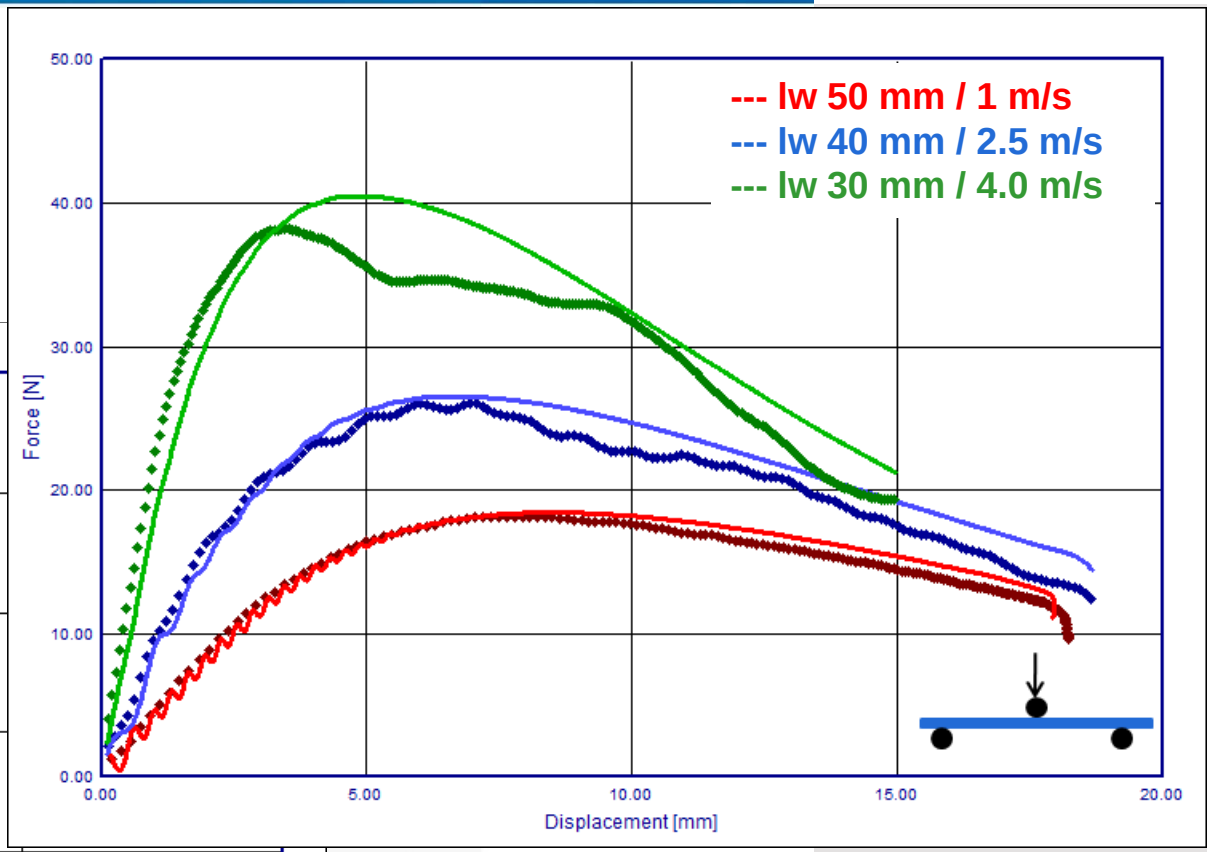
- All LS-DYNA material cards are available using user defined interfaces!
- Same possibilities for the other solvers (e.g. Abaqus, PamCrash,…)

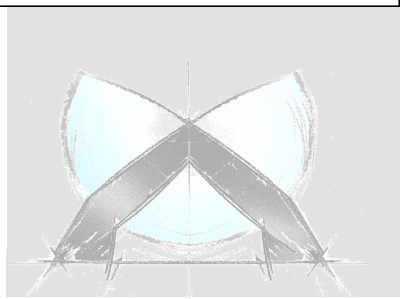


Generating material cards

- LS-Dyna: *MAT24 (von Mises)
- No tension/compression asymmetry
  - → good conformity for bending
  - → poor conformity for tension

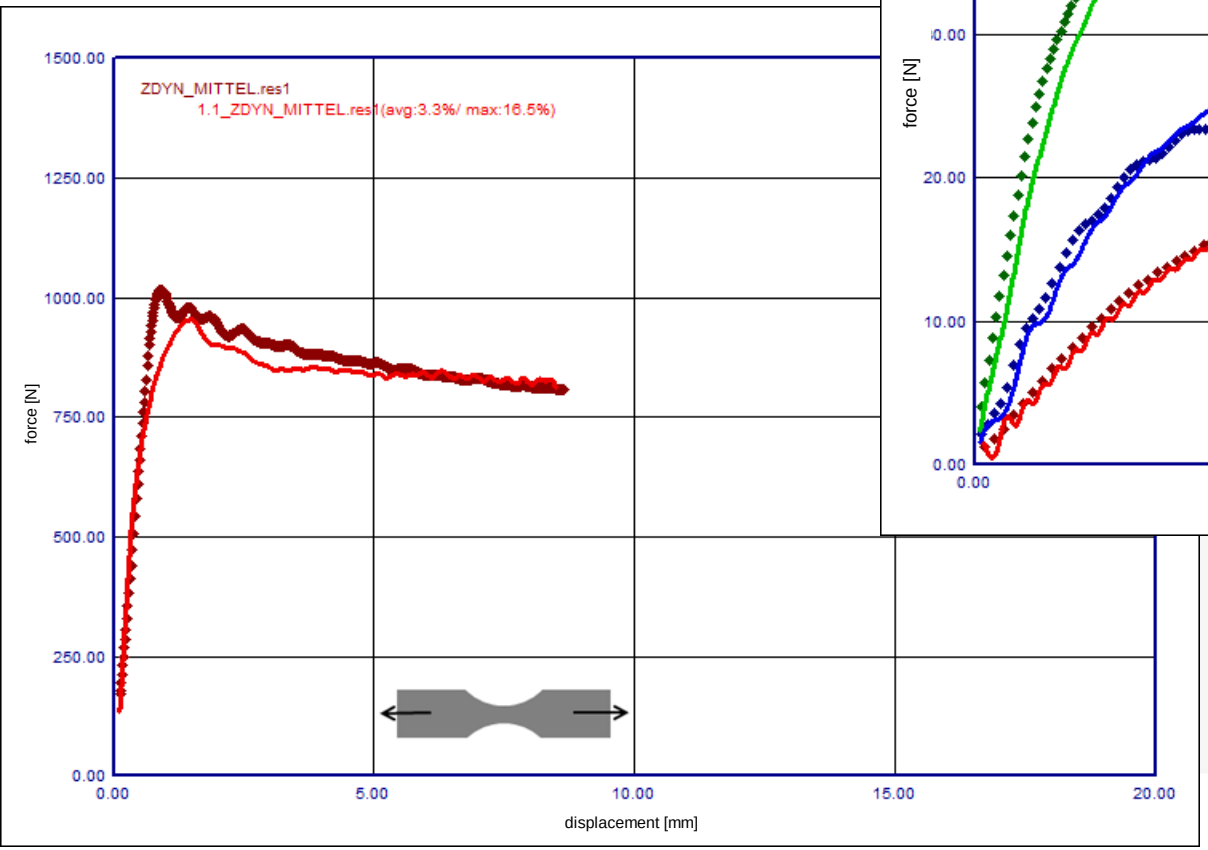


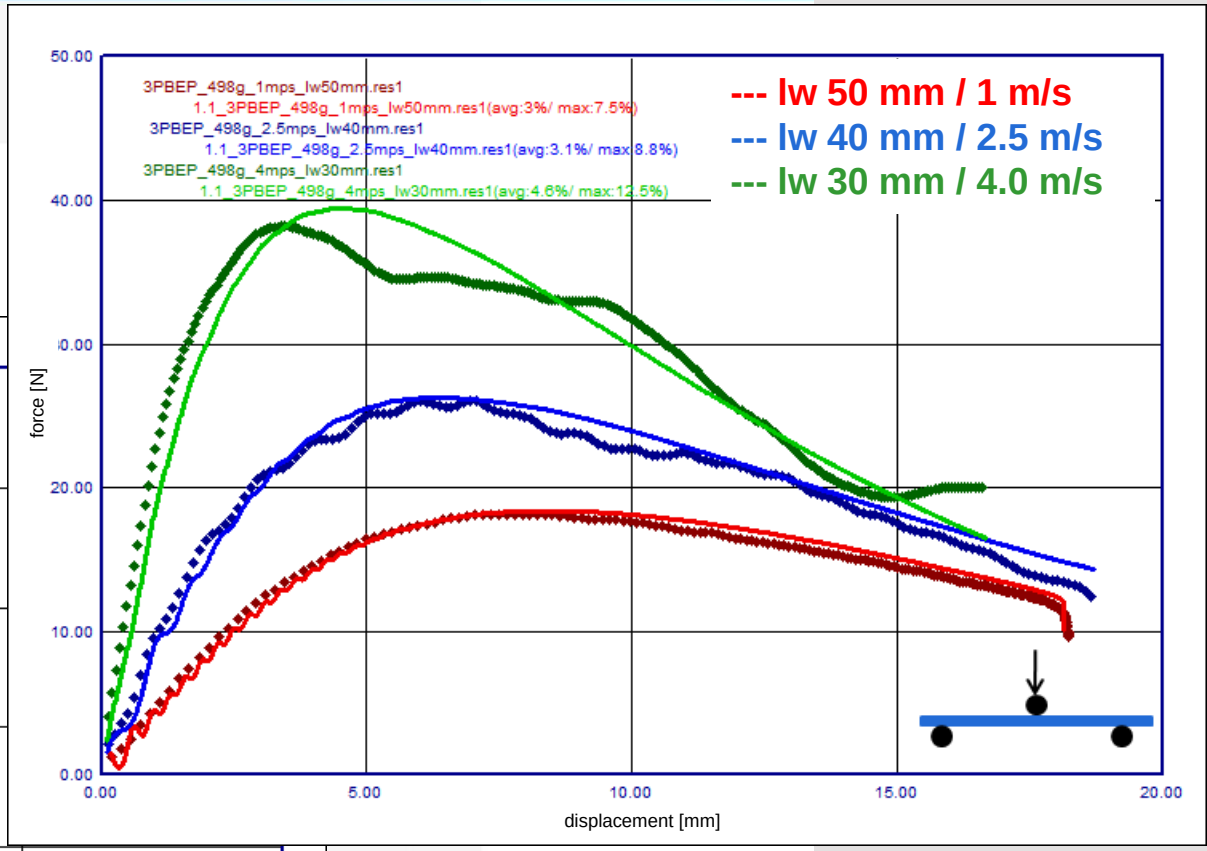


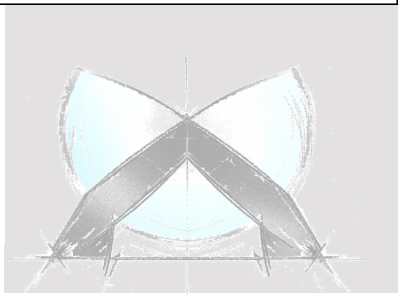


4a impetus
Generating material cards

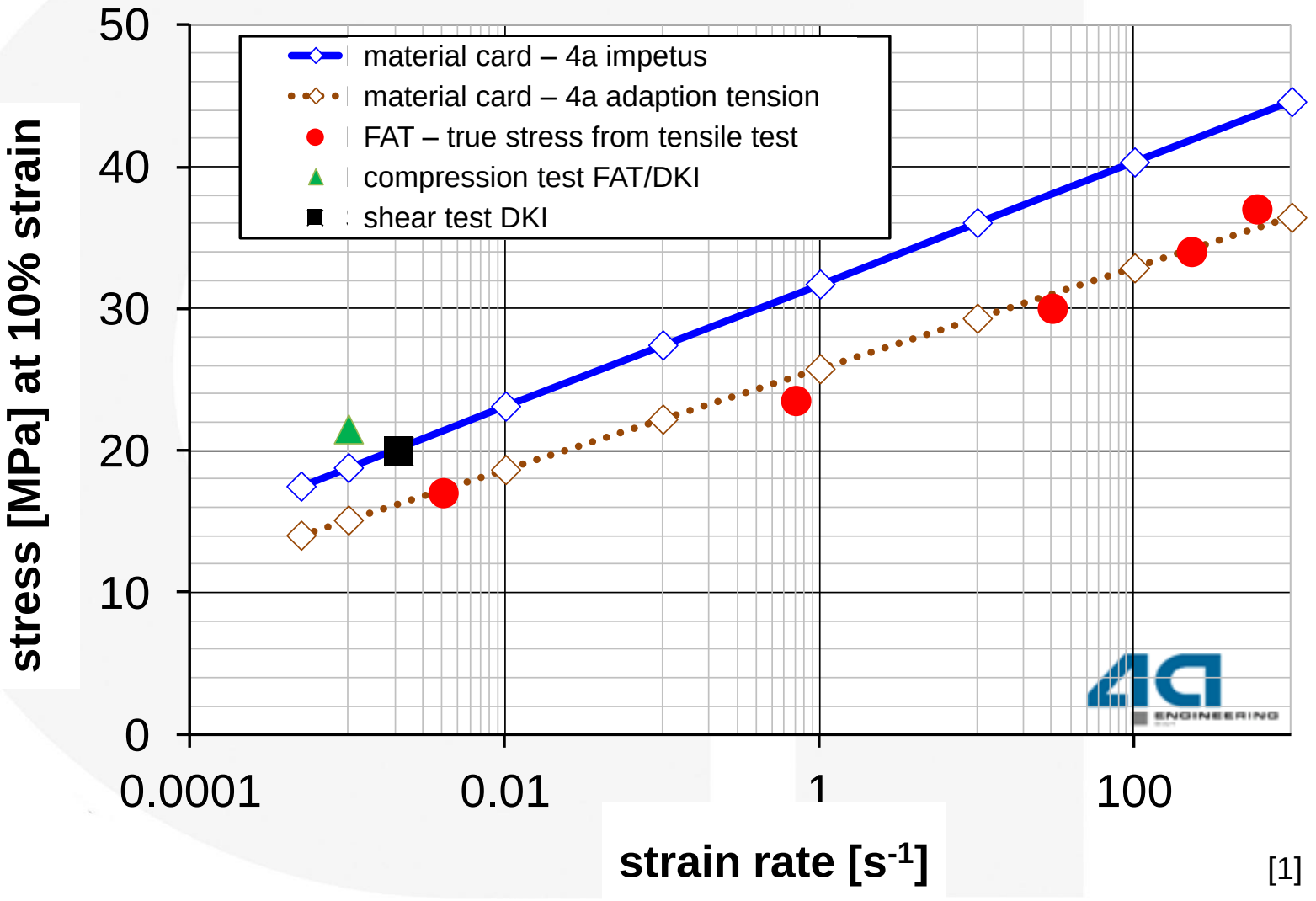
- LS-Dyna: *MAT187 (general yield surface)
- Tension/compression asymmetry
  → good conformity for all load cases







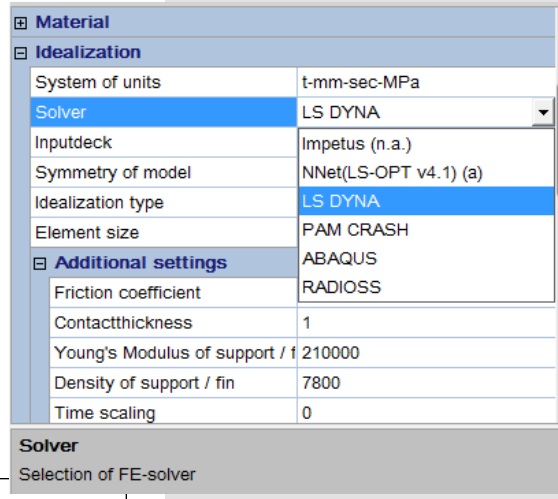
Generating material cards

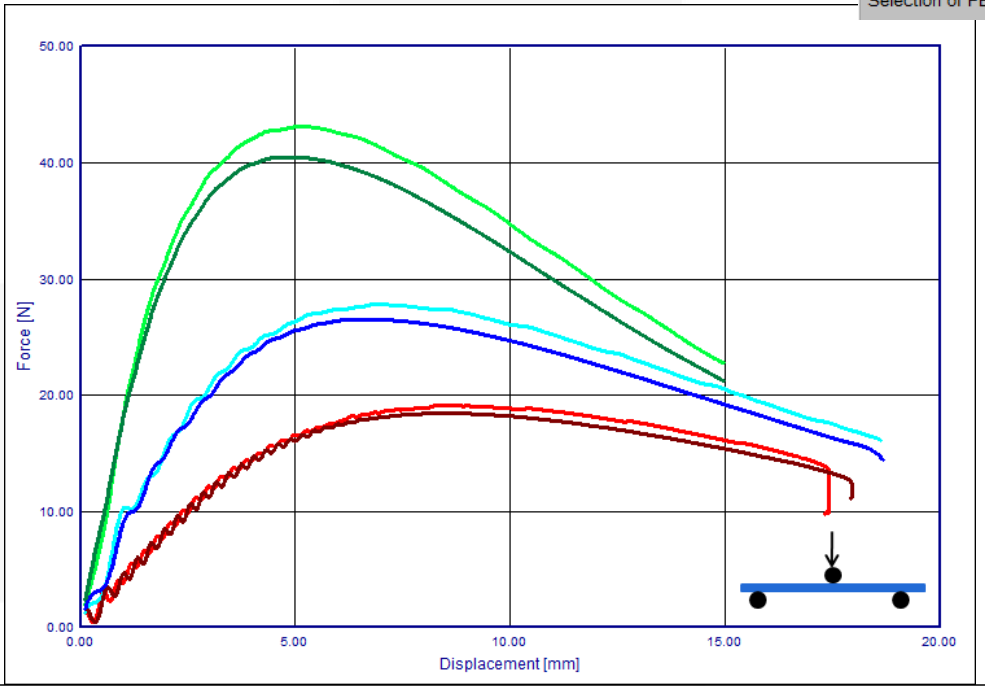


[1]

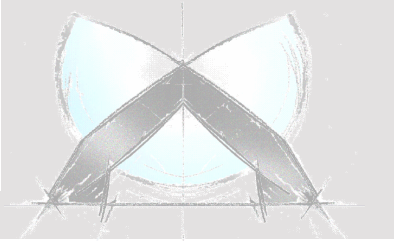
Adaption of material cards - solver transfer

- Material cards can easily be transferred from one solver to another.
- Example: 3-point-bending; von Mises
  Solver LS-Dyna *MAT24 → Solver Abaqus *ELASTIC *PLASTIC;
- By One-Mouse-Click the differences could be researched: the results are very similar, differences occur mainly in the test velocity 4 m/s (green curves).





Hostacom
Dark color: LS-Dyna, Shell type 16
Light color: Abaqus, Shell S4
1 m/s, lw=50 mm
2.5 m/s, lw=40 mm
4 m/s, lw=30 mm

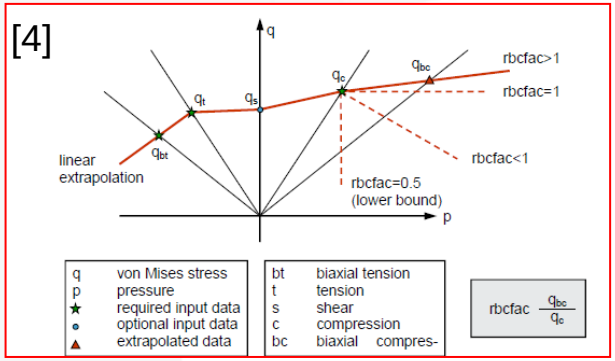


4a impetus
Adaption of material cards - solver transfer

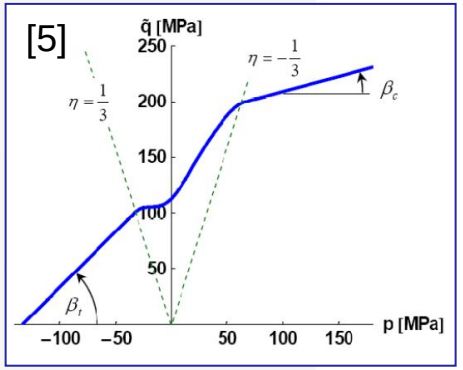
- Another example: 3-point-bending; general yield surface

  Solver LS-Dyna *MAT_SAMP-1 → Solver Abaqus ABQ_MOLDED_PLASTIC;

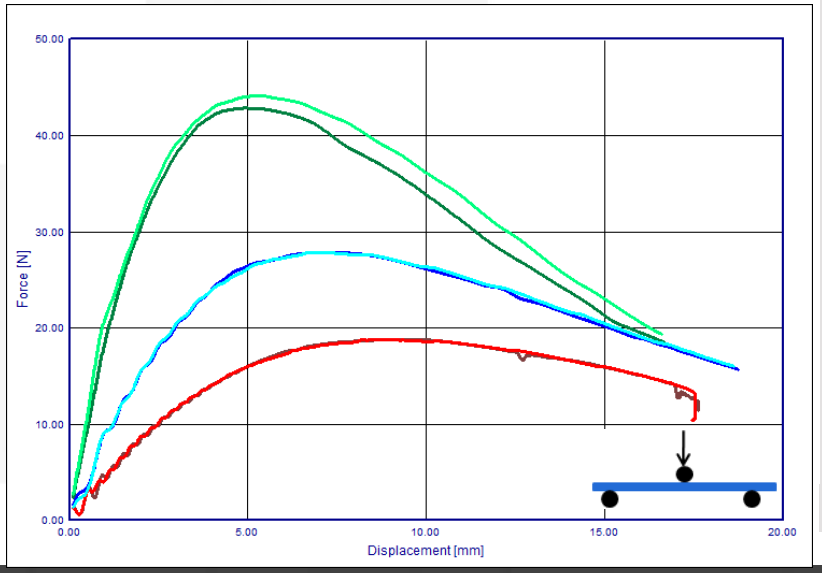
[4]



[5]



- The results are very similar, differences occur mainly in the test velocity 4 m/s.



Hostacom

Dark color: LS-Dyna, Shell type 16

Light color: Abaqus, Shell S4

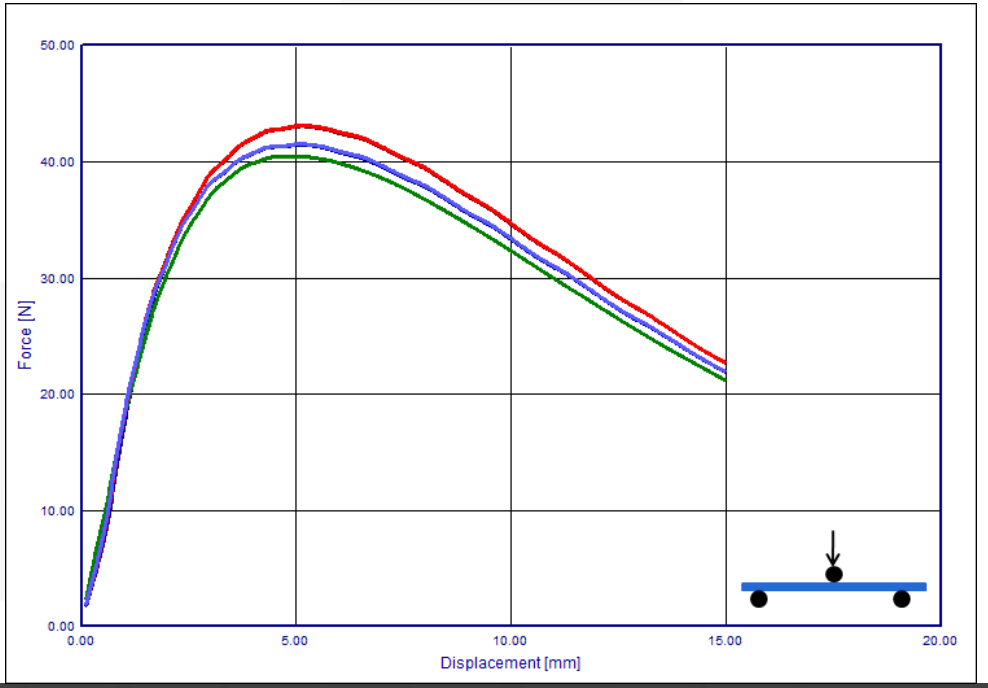
1 m/s, lw=50 mm

2.5 m/s, lw=40 mm

4 m/s, lw=30 mm

4a impetus
Adaption of material cards - influences in the simulation

- The user must have knowledge of the simulation and the influence of different settings (e.g. settings in the control cards of the input decks)
- 4a impetus assists the user in his knowledge
- Example: 3-point-bending; von Mises
  Abaqus Shell S4 Simpson (default) vs. Gauss section integration rule
- The section integration has influence onto the result.

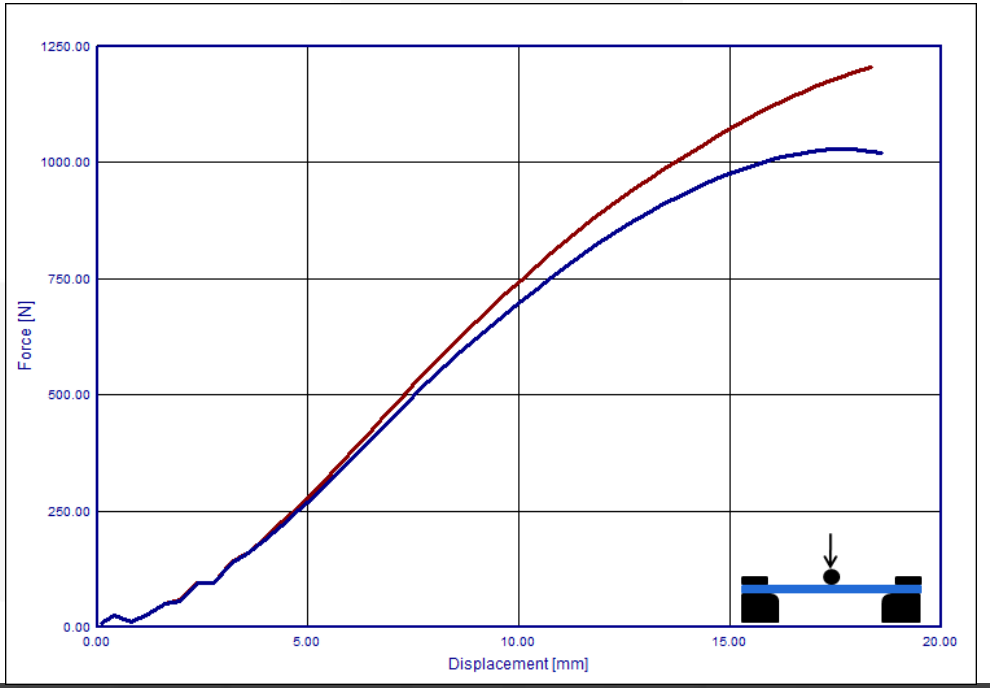


Hostacom; 4 m/s, lw=30 mm
LS-Dyna, Shell type 16
Abaqus, Shell S4, Simpson
Abaqus, Shell S4, Gauss

Adaption of material cards - influences in the simulation

- Example: clamped 3-point-bending; von Mises
  Solver LS-Dyna; *MAT24;
  Flag ISTUPD in control card *CONTROL_SHELL;
- In the area where the tensile yielding is dominating shell thickness will change based on isochoric behavior, if the option ISTUPD=1 (blue curve). is activated. Compared to ISTUPD=0 (red curve) this gives a lower force.

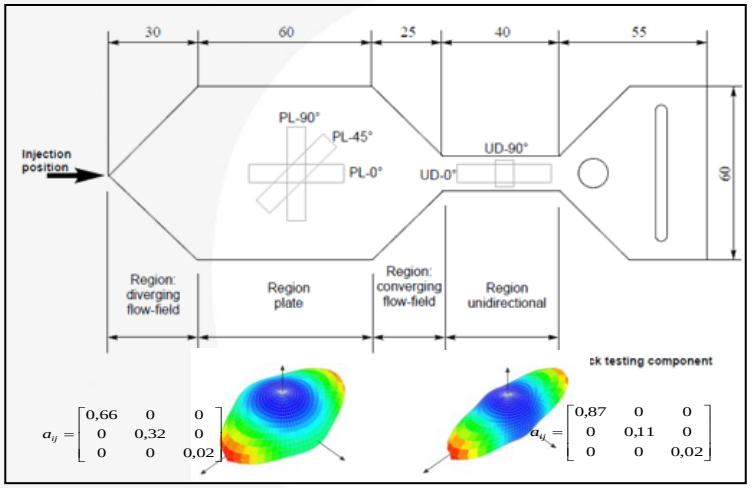
Hostacom, 4 m/s, lw=50mm:
ISTUPD=0
ISTUPD=1

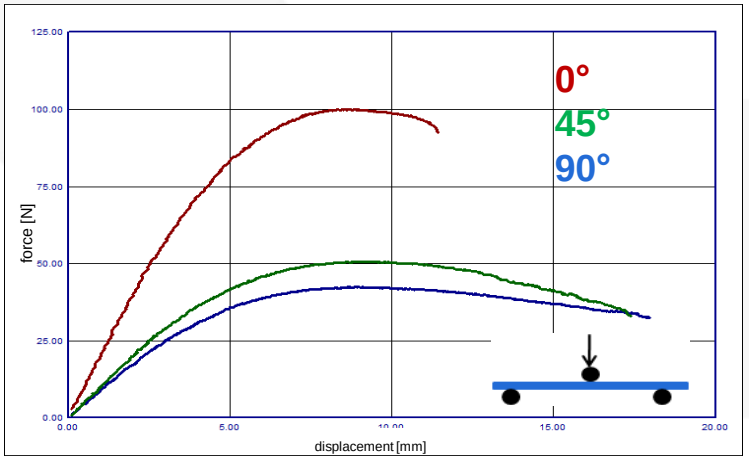


Adaption of material cards - influences of orientation

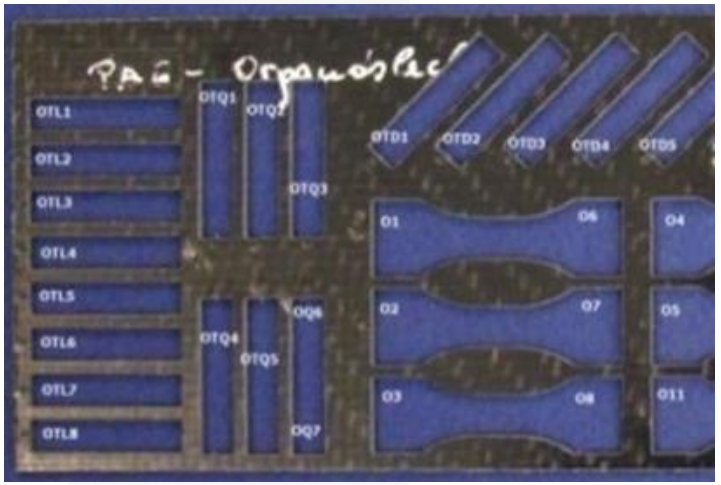
- E.g. sample preparation for different orientation

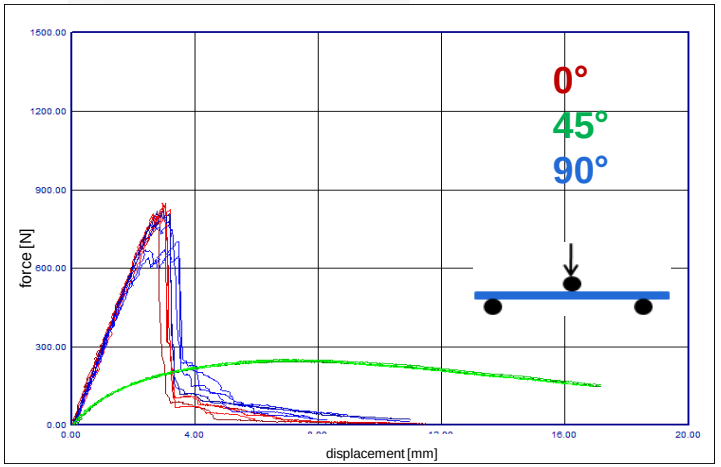
short fiber reinforced thermoplastic [6]





Composite – “Organoblech” [7]





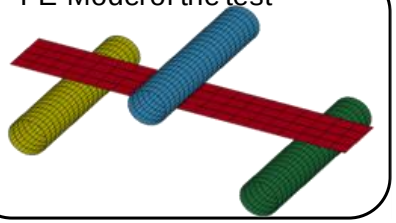
Adaption of material cards - influences of orientation

- The influence of the manufacturing process on the material behavior (fiber orientation) is in the process chain included.

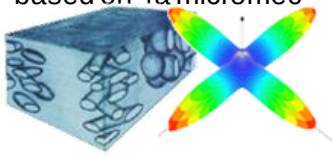
Element orientation e.g.
***ELEMENT_SHELL_BETA**

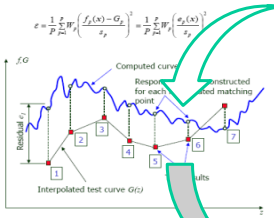
Material angle

FE-Model of the test



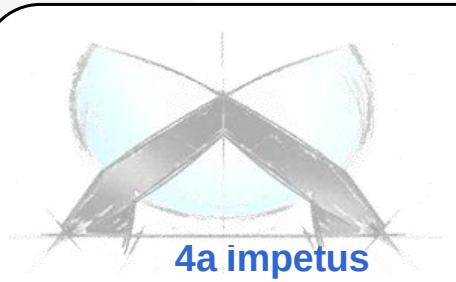
Parameterized Materialcard based on 4a micromec





LS DYNA©

Reverse Engineering

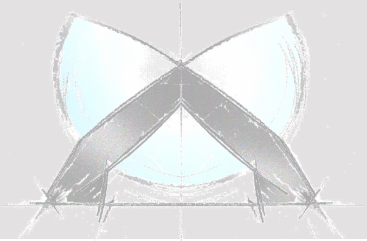


4a impetus

LS PREPOST©

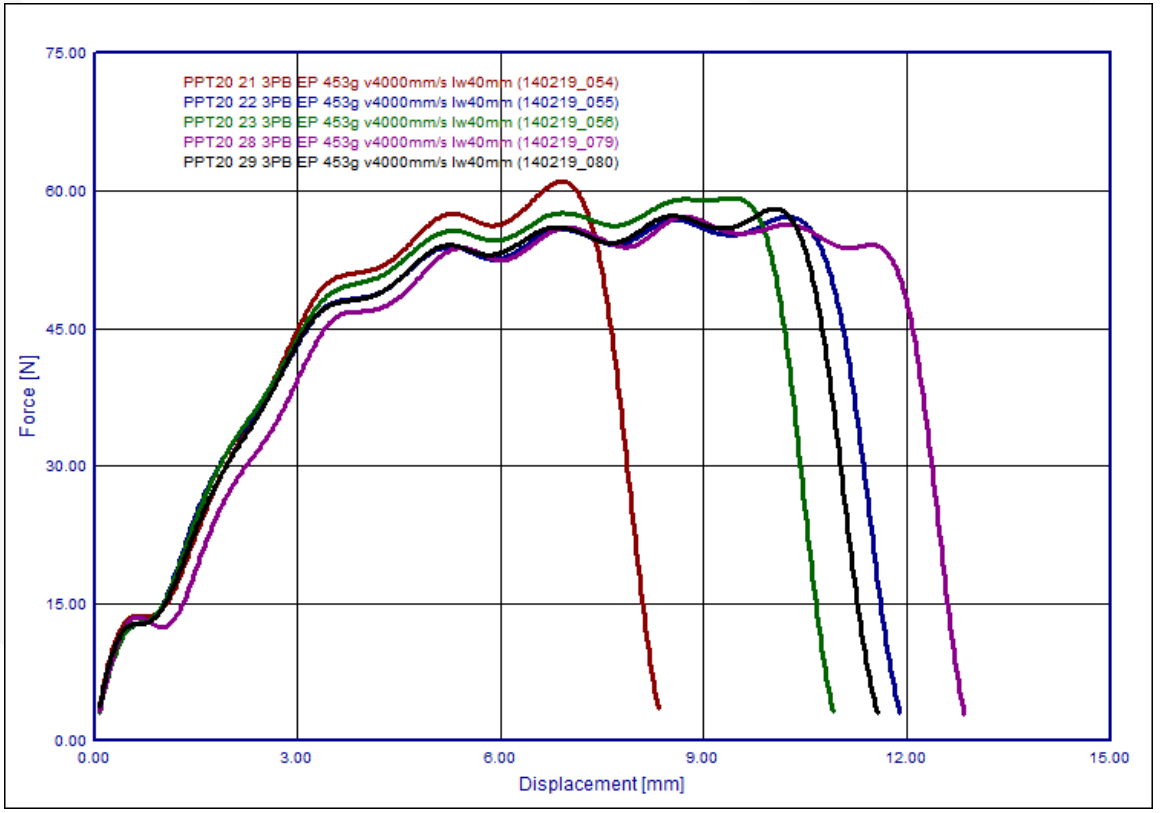
DATABASE
measurement, models

ORIENTATION
e.g. 0°, 45°, 90°



Considering failure

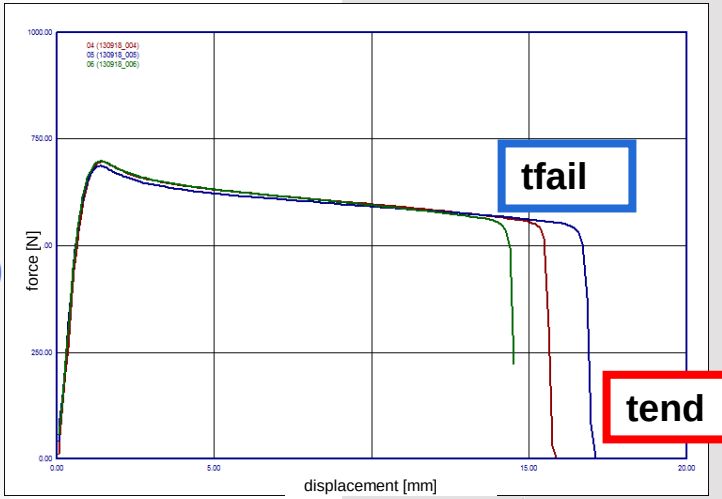
- Failure depends in principle on triaxiality and strain rate.
- Additional imperfections in the test specimens are important (→ scatter range, image: 3-point-bending at 4 m/s, PP T20).



Considering failure - demands for 4a impetus

- Test methods
  - Handling of different test methods (triaxiality)
  - Implementing of additional information in the data base (e.g. orientation,…)
- Preparation of the test data
  - Filtering
  - Occurrence/time for failure begin and complete failure
- Generating models / reverse engineering
  - Using of different idealizations (element type, meshsize…)
  - Implementing complex models
    - user defined material model
    - more user friendly
  - Statistic evaluation of single results
  - Simulation considering element deletion

Evaluation	
Filter	0 no filter
Evaluation of the velocity	3 - Displacement (static gradient at the beginning)
Zero-point evaluation	7 - Extrapolation force-displacement gradient
Identification of failure	0 - Manual (point in time)
tend	1.8
tfail	1.78
alphamax_ep	-5



already implemented
in progress

4a impetus
Available models for failure resp. damage in LS-DYNA

- plastic effective strain

  e.g. **MAT_24:** ***MAT_PIECEWISE_LINEAR_PLASTICITY***
- plastic effective strain considering damage

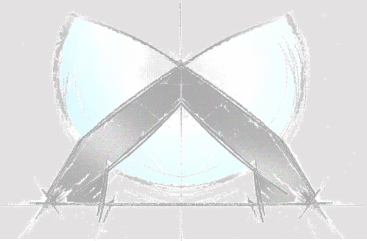
  e.g. **MAT_81:** ***MAT_PLASTICITY_WITH_DAMAGE***
- strain rate dependent equivalent criterion

  e.g. **MAT_19:** ***MAT_STRAIN_RATE_DEPENDENT_PLASTICITY***

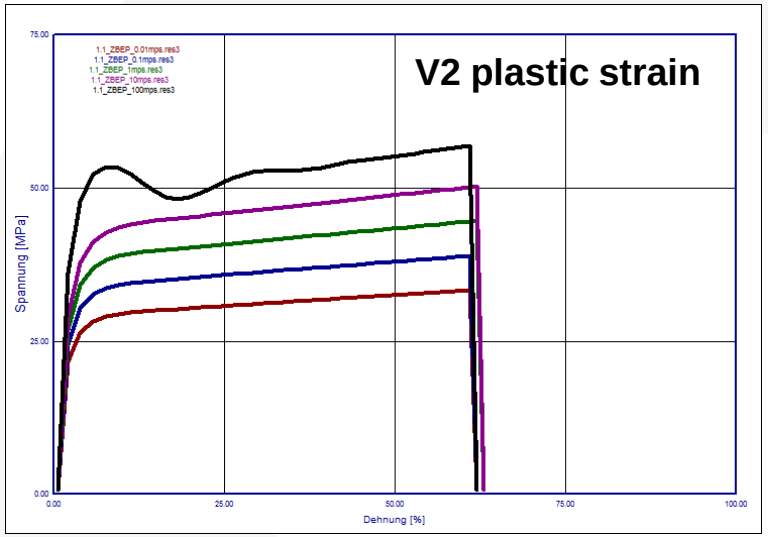
  oder **MAT_124:** ***MAT_PLASTICITY_COMPRESSION_TENSION***
- equivalent criterion in dependence of triaxiality, …

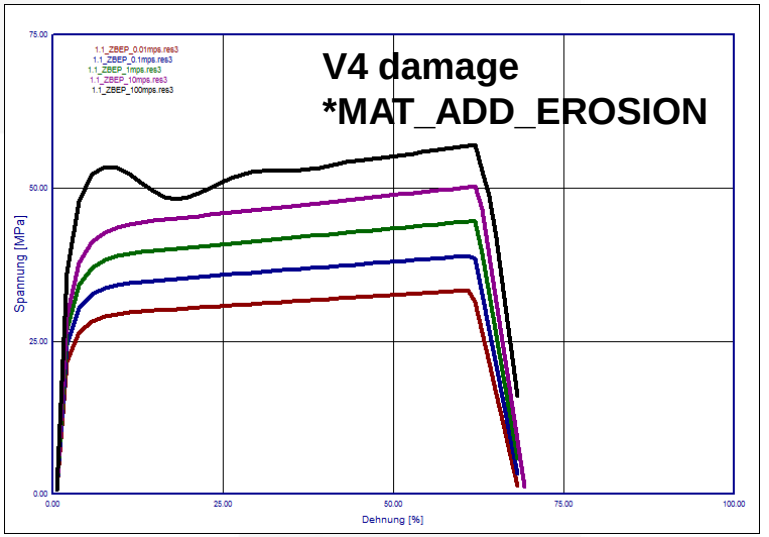
  e.g. **MAT_187:** ***MAT_SAMP-1***

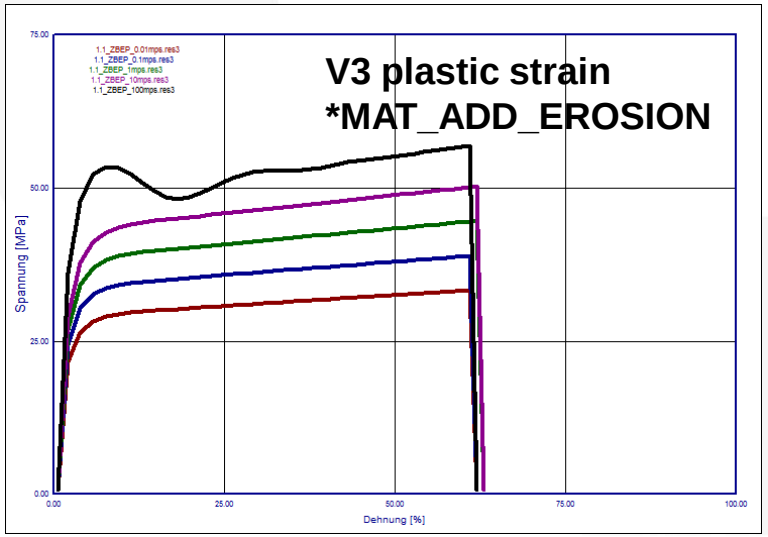
As alternative the additional option ***MAT_ADD_EROSION*** in combination with a material card offers many capabilities for damage and failure modeling.

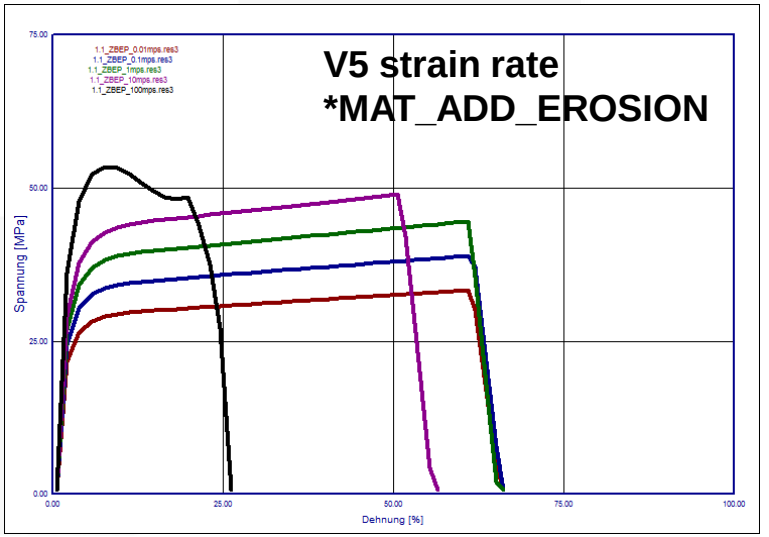


Considering failure - 1-element tests





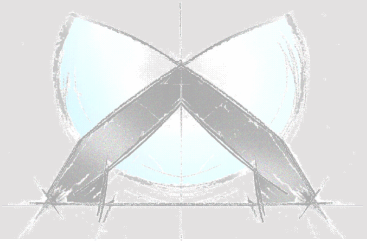




Stress-strain-curves considering various failure models

Summary

- The functionality of 4a impetus was shown which fulfills for the most part the industry requirements.
- 3-point bending, clamped bending and puncture tests can be performed using 4a impetus. In addition other tests (e.g. quasi-static bending tests or tensile, compression or shear tests) can easily be imported.
- Using these tests simple or complex material cards can be generated very quickly. Popular material models are included in the software directly but all other material models are available by user defined interfaces.
- Different solvers and idealizations are set with just some mouse-clicks.
- First possibilities to model failure are already implemented in 4a impetus. Further upgrades, especially a better integration of failure and damage models, are planned.
- Enhancements in this topic will be affected by the variety of customer requests.



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4a Technologietag 2014

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M. Fritz, P. Reithofer, M. Rollant (4a engineering GmbH)

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DKI Deutsches Kunststoff-Institut, Frauenhofer IWM,

KIT Karlsruhe Institute of Technology

Abschlussbericht 15826 N, 2011

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[5] Abaqus Manual – VUMAT for Molded Plastics, Simulia - Dassault Systèmes

[6] 4a micromec für die integrative Simulation faserverstärkter Kunststoffe

A. Fertschej, B. Jilka, P. Reithofer (4a engineering GmbH)

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[7] Dynamische Materialcharakterisierung von Composites mit 4a impetus

A. Dietrich, M. Fritz, B. Jilka, P. Reithofer (4a engineering GmbH)

B. Hofer, B. Fellner (MAGNA STEYR Fahrzeugtechnik AG & Co KG)

11. LS-DYNA Forum 2012, Ulm

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