Efficient evaluation of material cards for non-reinforced and reinforced thermoplastics

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4a impetus

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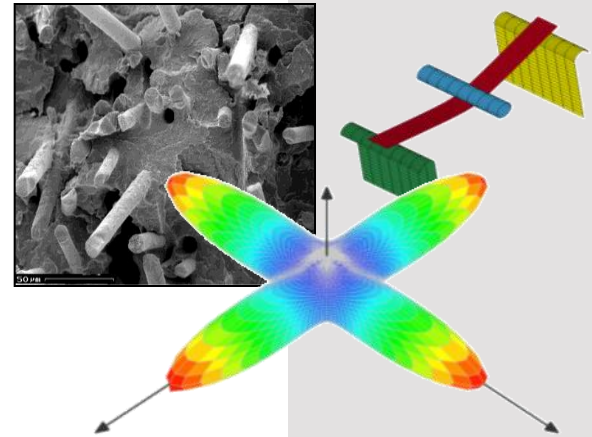
Content

- 4a engineering GmbH
- 4a impetus
- Material models for thermoplastics
  - Material behavior of plastics
  - Simple material models – complex material models
- Material models for composites
  - Coupling to micro-mechanic
  - *ABQ_PLY_FABRIC
- Summary

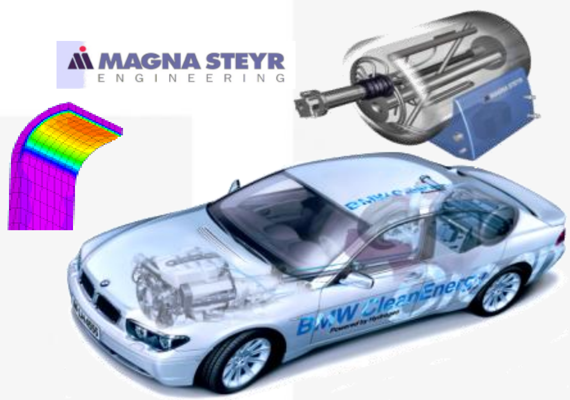
4a engineering GmbH

- polymer and materials science
- numerical simulation methods
- fiber reinforced plastics and composites
- method and software development



- case studies product development:

Alpine touring ski binding



LH_2 – tank mounting

RTM – CFK – strut bar

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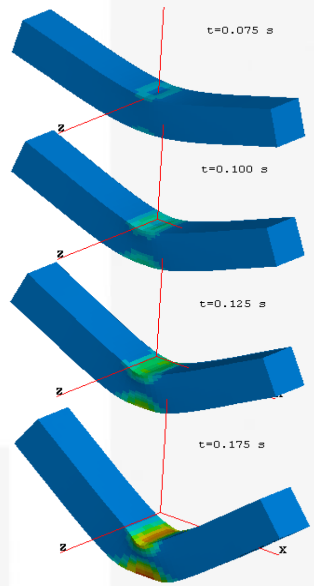
- efficient high-dynamic testing
- crash-behaviour of plastics
- material data for simulation



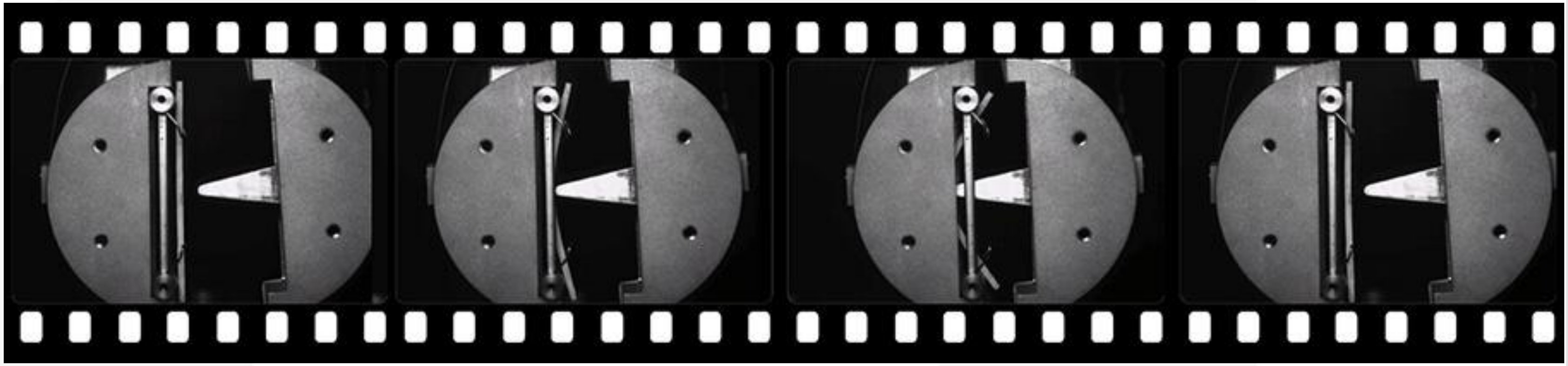
source: http://auto-kaufberatung.at

source: https://www.youtube.com/watch?v=TdtN9UqvZes

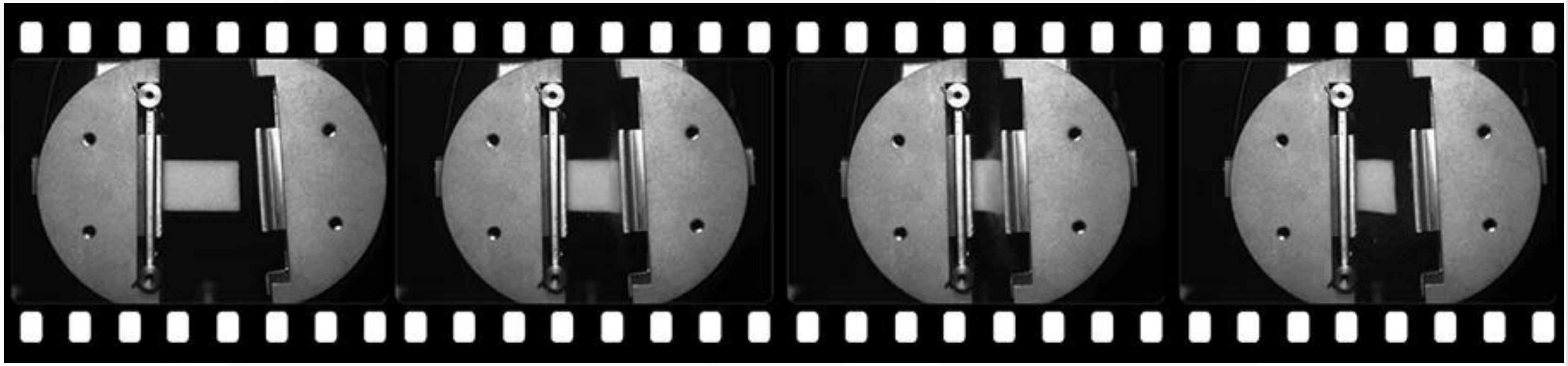
4a impetus - intelligent testing systems
powered by 4a engineering GmbH

4a impetus
dynamic tests up to a velocity of 10 m/s are possible

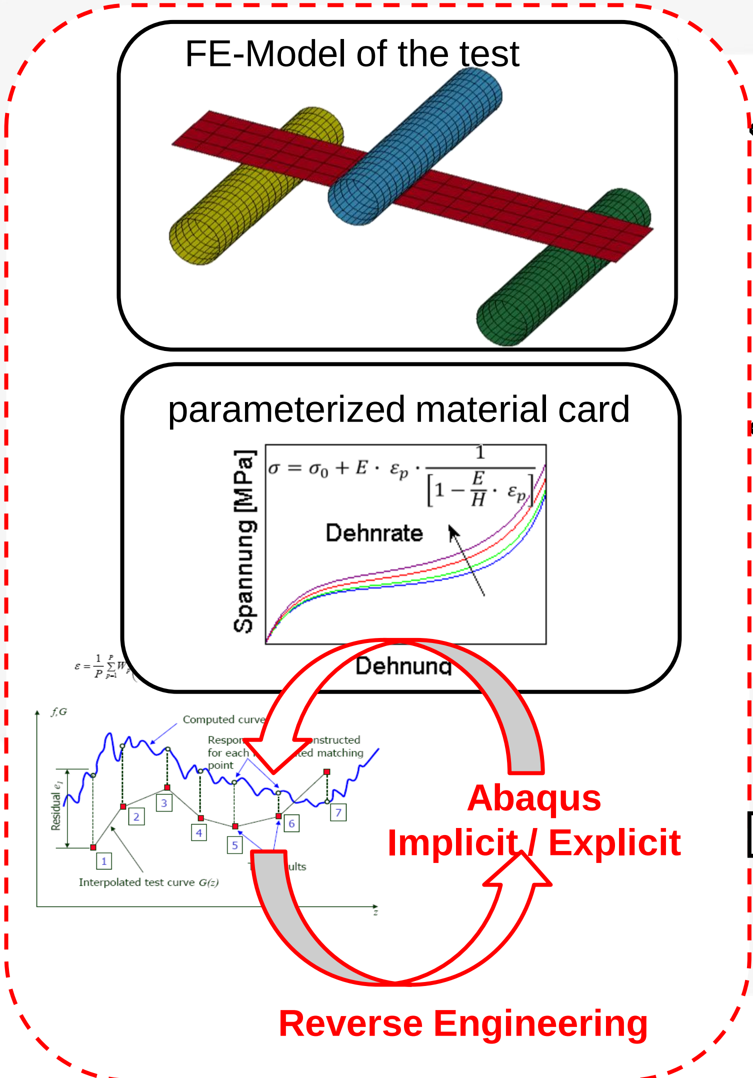
bending test on 4a impetus double pendulum

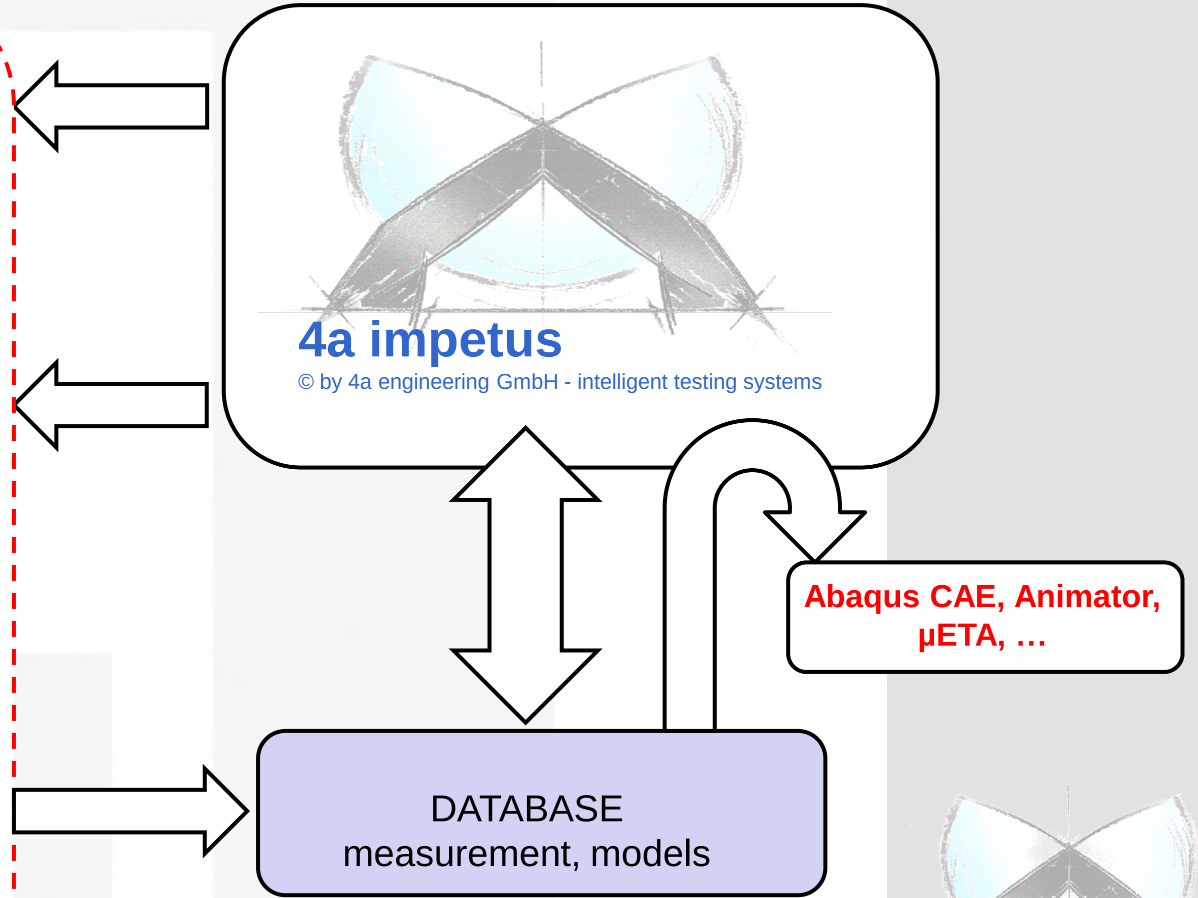


compression test on 4a impetus double pendulum



Material characterization / reverse engineering





Further information:
Deutsche SIMULIA Konferenz 2014 Dresden
Dynamisches Materialverhalten von Kunststoffen und Composites
http:/impetus.4a.co.at

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

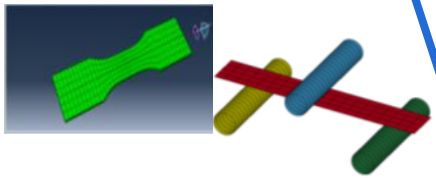
Automatic
LS-OPT input-deck

Directly linked to solver run scripts

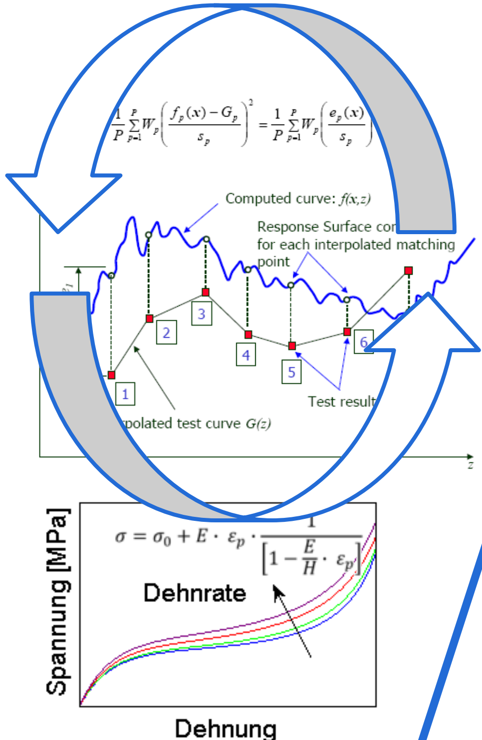
Material optimized parameterized models

Automatic mesh generation

FE-Model of the test



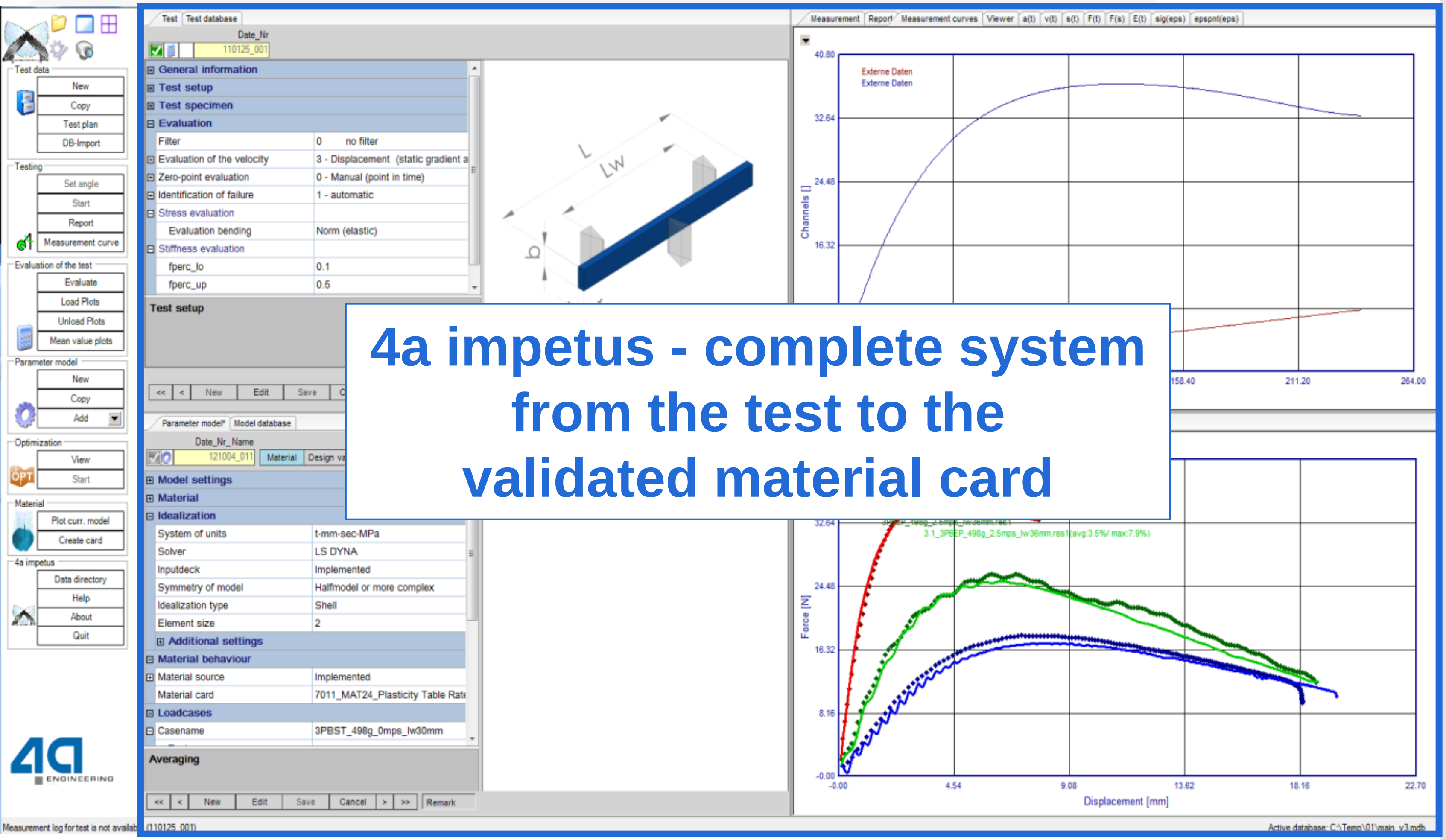
Reverse Engineering



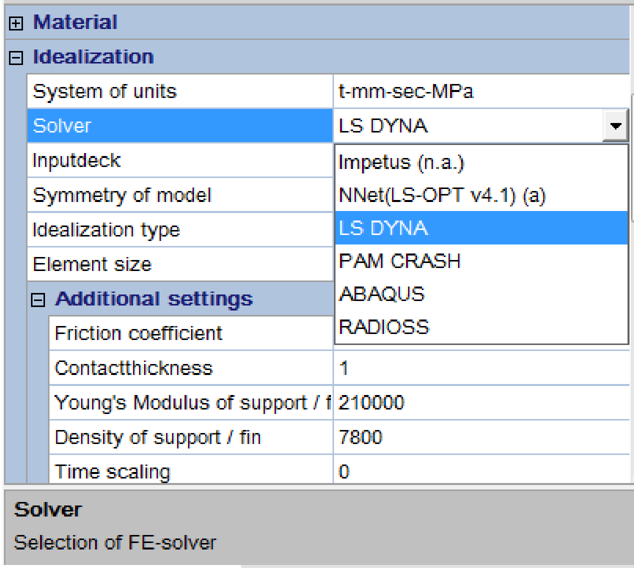
parameterized material card

validated material card

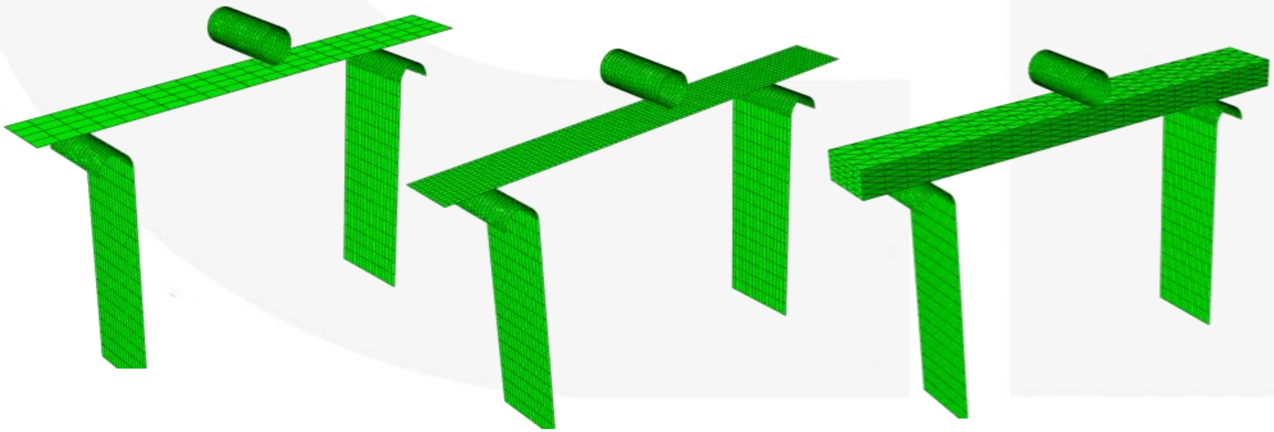
- The tests and simulations models are stored in a data base → easy access and user friendly

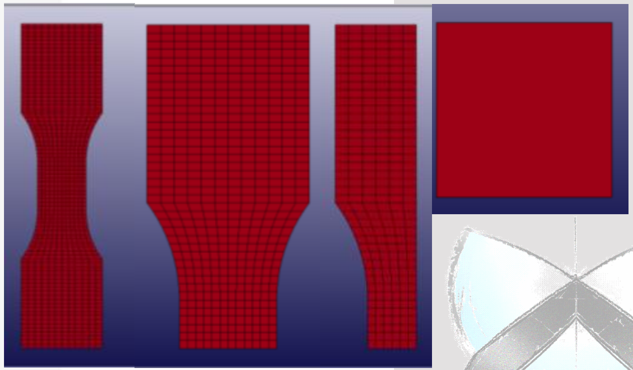


4a impetus
Simulation - Idealization



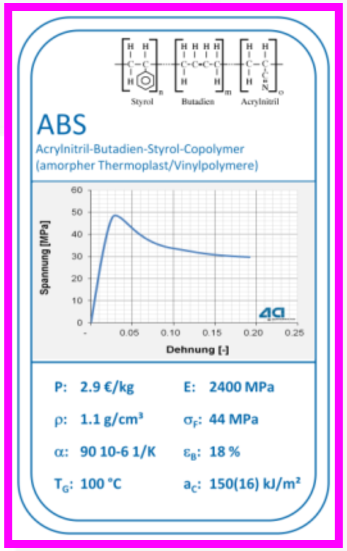
- Can be used local or in network cluster
- Supports Abaqus, LS-Dyna, PAM-Crash
- Allows the idealization in shell or solid using the most popular element types and an arbitrary element size (of course it should be reasonable)
- Can consider symmetries – simplification down to 1-element

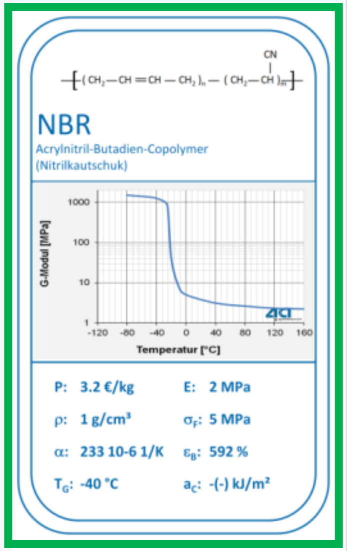




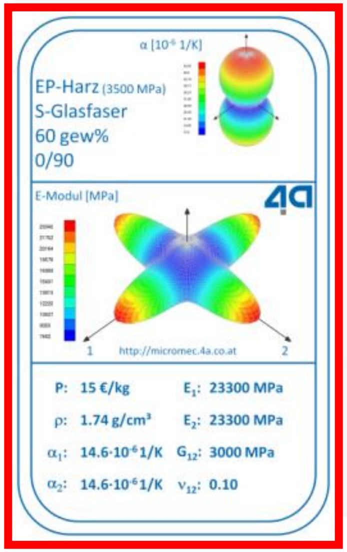
4a impetus
Tested materials

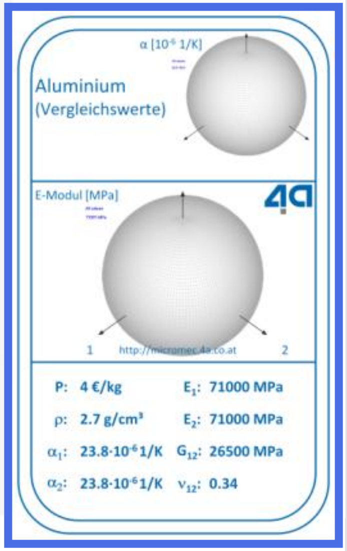
- We have already tested a wide range of
  - thermoplastics (ASA, ABS+PA; ABS+PC; PA6; PA6(6) GF30..50; PA66+P6; PBT GF30; PC; PE; PP; PP+ varnish; PP rubber modified; PP GF20..40; PP Impact modified; PP MX10; PP MX20; PP MX40; PP CF; PP+EPDM; MuCell-materials, …)
  - foams (EPP30..80; PU RG 55, PU RG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





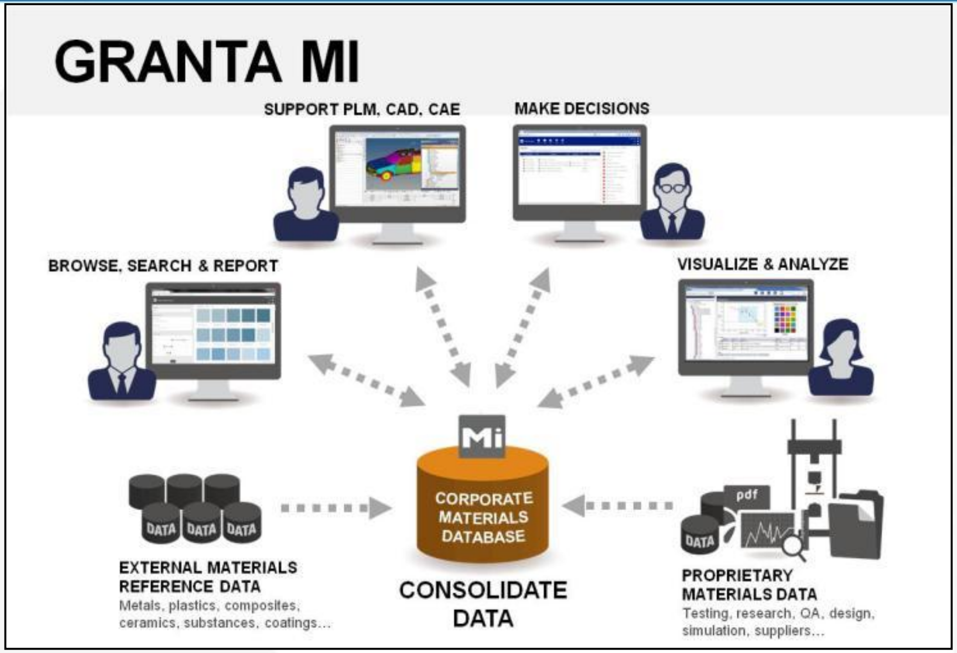
from:
4a Quartet card game "plastics"



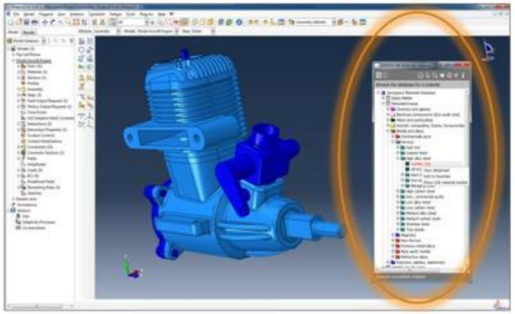


from:
4a Quartet card game "composites"

Granta Design – innovating since 1994
Introduction



Gateways for material import to CAE



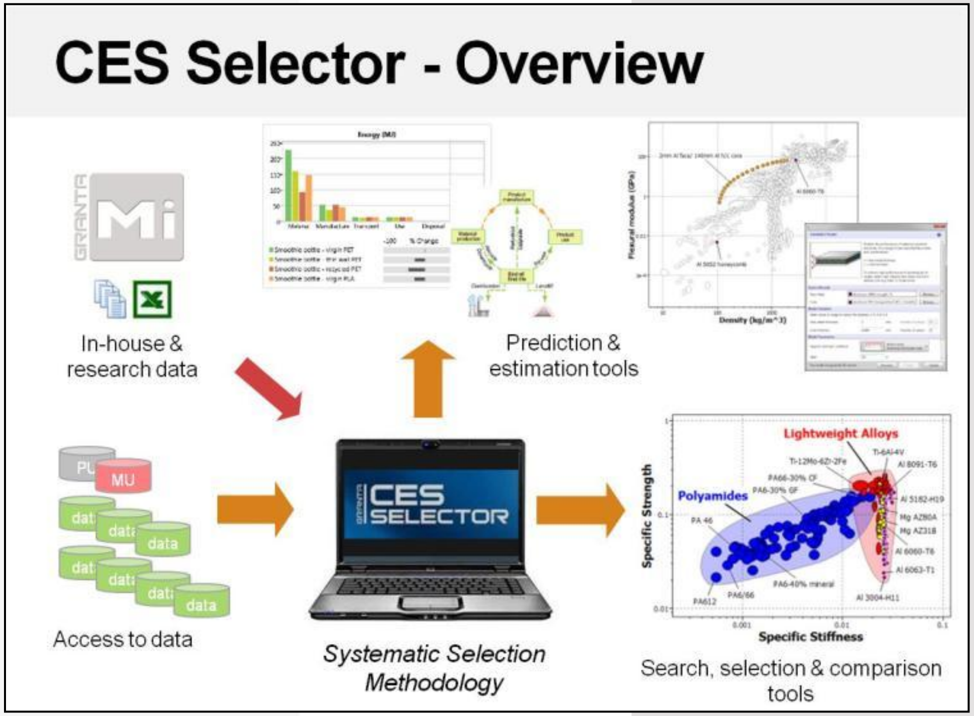
ANSYS Workbench

New! HyperMesh

Abaqus/CAE

MATERIAL INTELLIGENCE

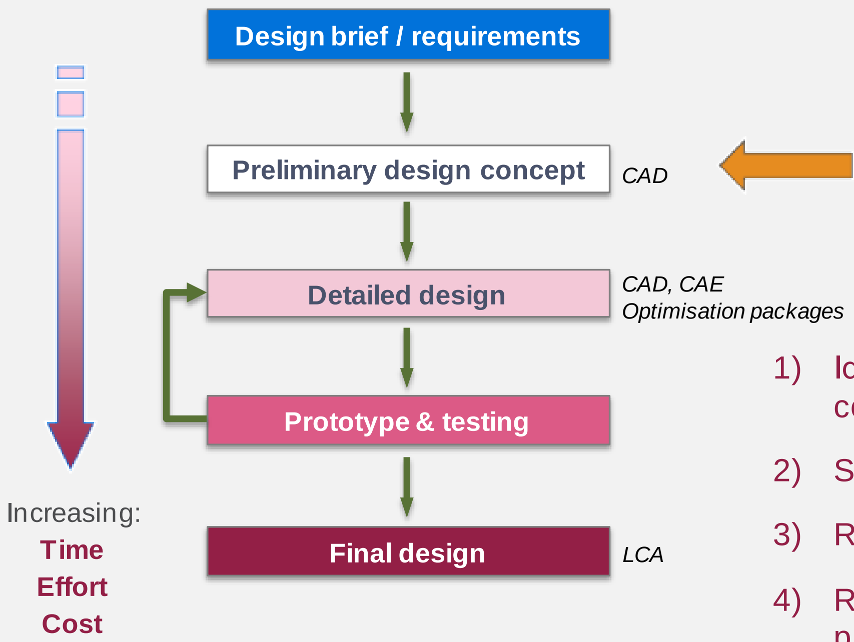
www.grantadesign.com

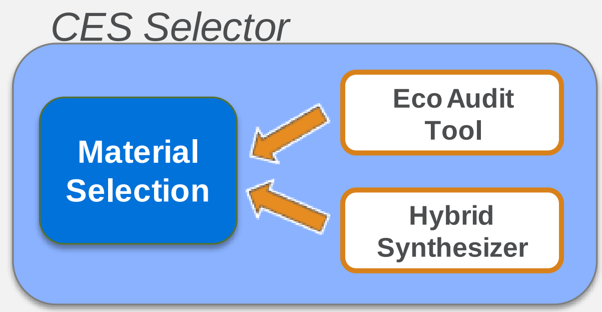


4a ENGINEERING GmbH
GRANTA MATERIAL INTELLIGENCE

Integration into Engineering Workflows

Typical design & development workflow





1) Identify 'best' material options prior to committing to design or material development
2) Supplements existing design tools
3) Reduces design & prototyping cycles
4) Reduce risk of issues arising during pre-production and in-service

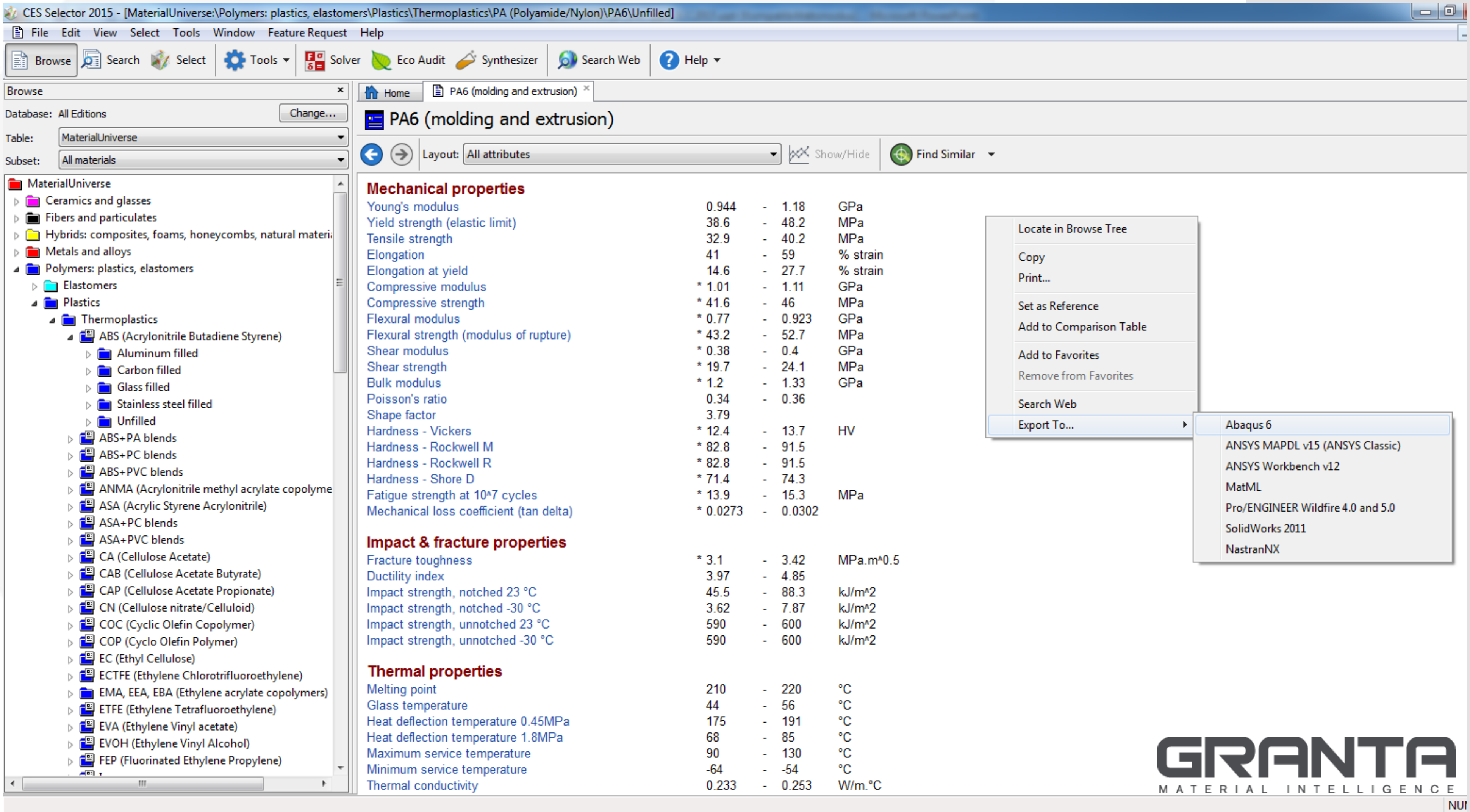
Plastics - Material behavior

Introduction – Design Phase

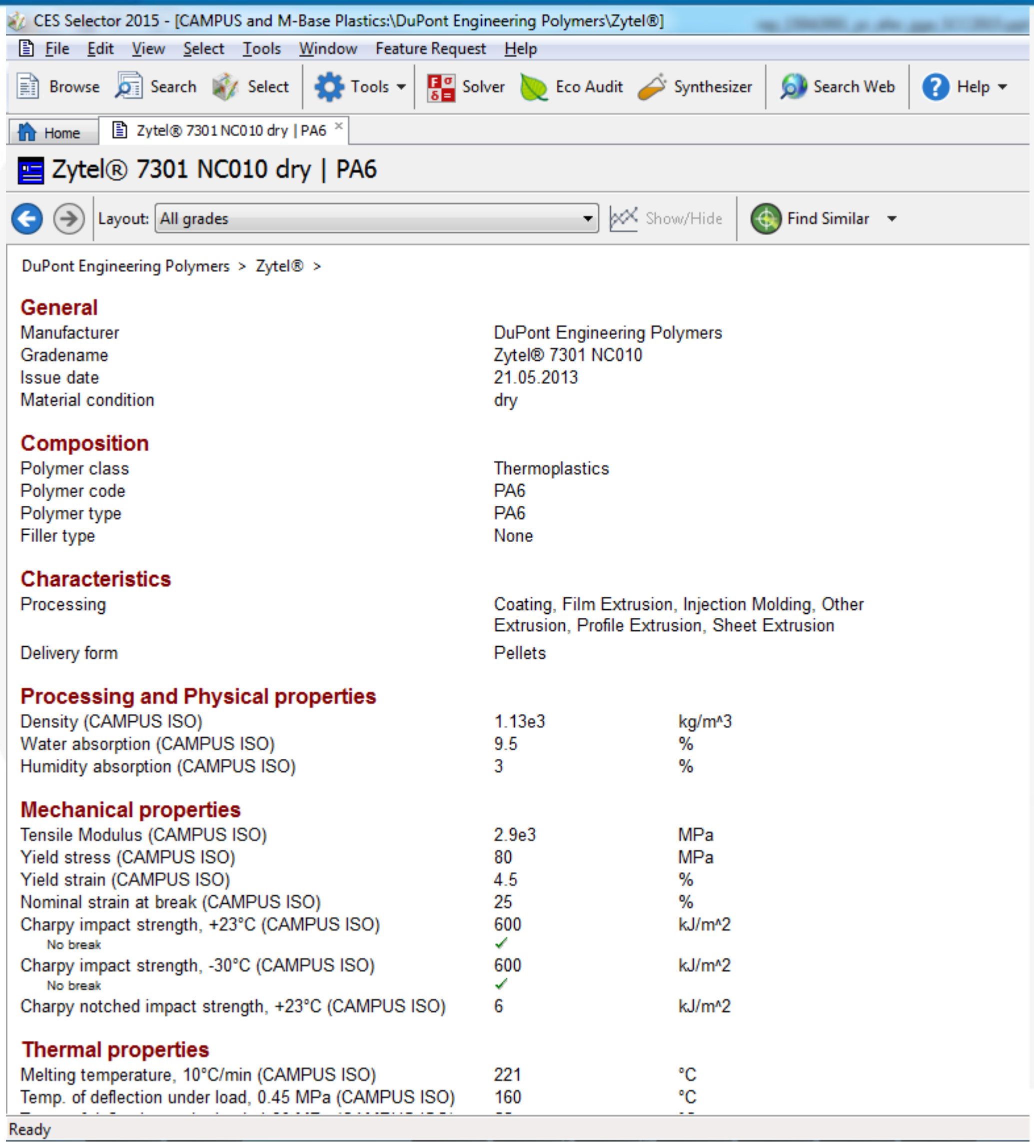
1. **Check your design**
   - Design requirements
   - Preliminary design → first principal simulations
2. **Get as much information as you can**
   - Material supplier / literature / in-house material information
   - Get feeling for the material
     (other supplier – deviation of properties)
   - Material database
     (Campus, IDES, GRANTA MI, CES SELECTOR)
   - Influence on mechanical behavior (glass transient temperature)
   - Medium resistance (oil, chemical, …)

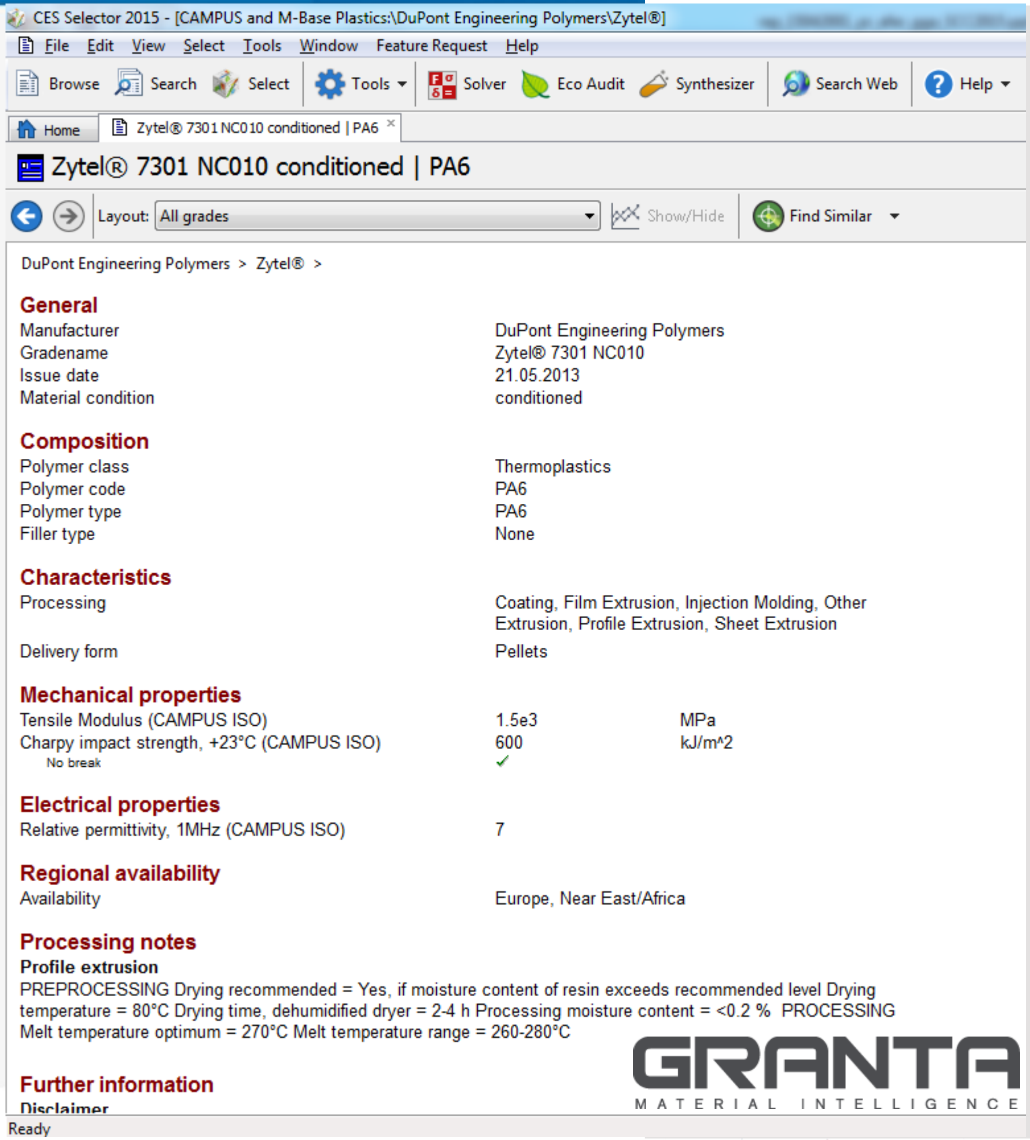
Plastics - Material behavior

Introduction – CES SELECTOR MATERIAL UNIVERSE



Plastics - Material behavior
Introduction – CES SELECTOR CAMPUS



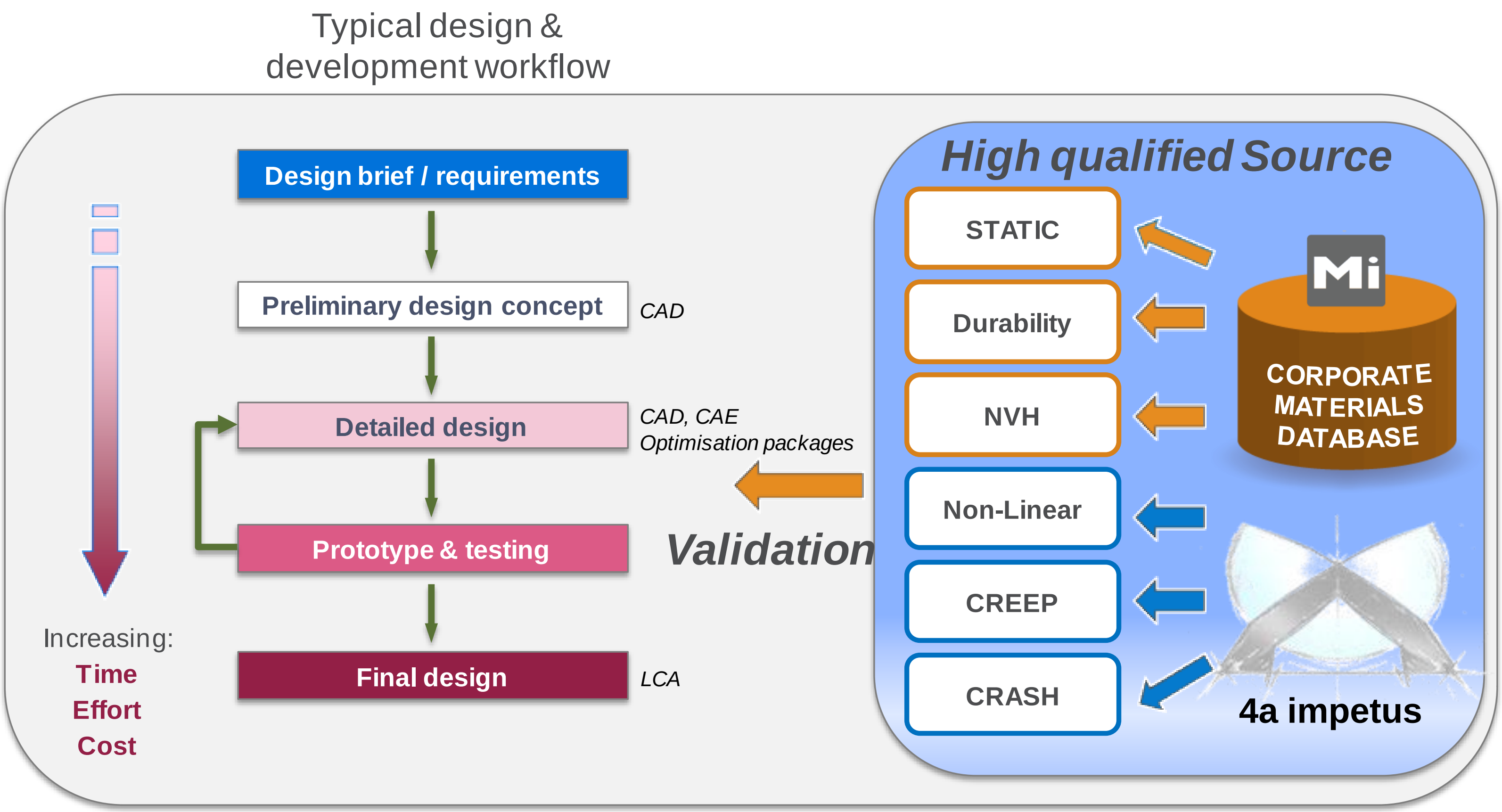


Plastics - Material behavior

Workflow – material card generation / validation

GRANTA
MATERIAL INTELLIGENCE

Integration into Engineering Workflows



Plastics - Material behavior

Introduction – typical influences

- Mechanical behavior could depend on
  - temperature
  - strain rate (loading velocity)
  - moisture content
  - anisotropy (fiber reinforced)
  - loading (tension, compression, shear, bending)

} **ranking through application**

- Engineer's choice between
  - Simple robust material model
  - Complex expensive (costs + cpu) material model

→ **Application driven**

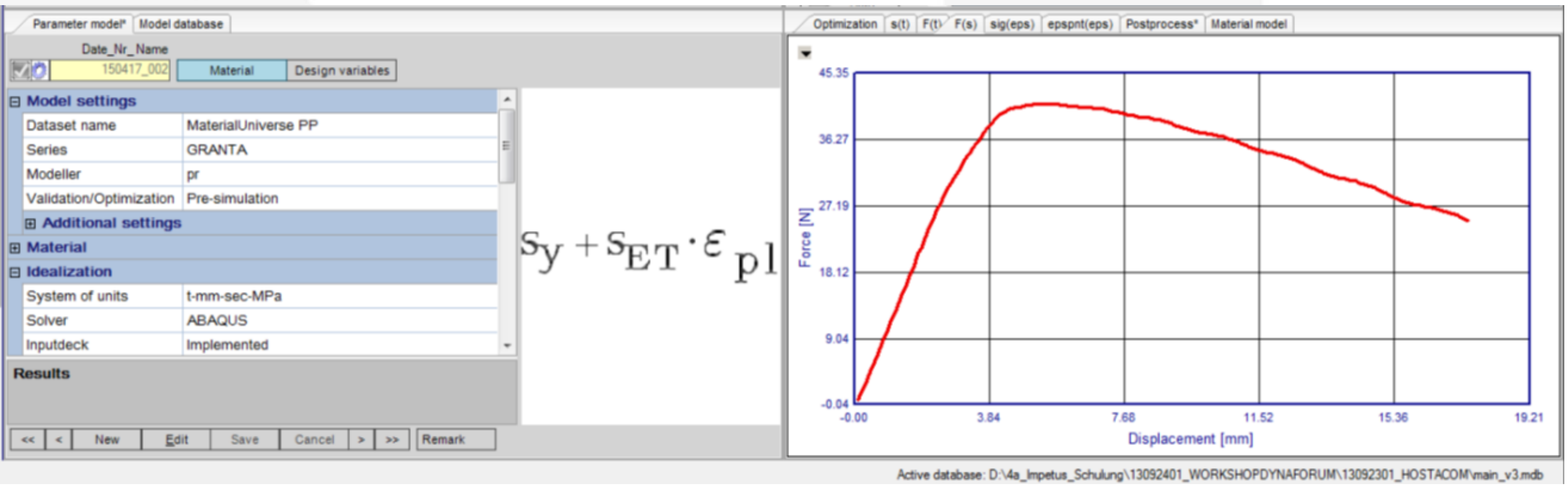
→ **Simulation task driven**

} **different requirements**

2. Get as much information as you can

→ e.g. could be done with CES Selector, Granta MI, Campus, …

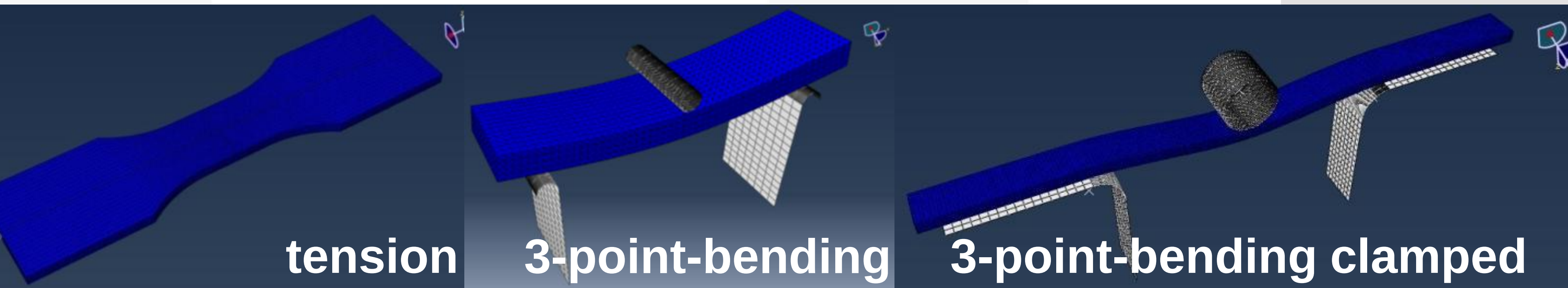
- To prepare specimens (moisture, temperature, chemical resistance, …)
- To define test setup based on application and material requirements
- To do pre-simulations for checking expected load conditions (acceleration, velocity, forces) to define sensors, shown in the image below



Plastics - Material behavior
Workflow – material card generation

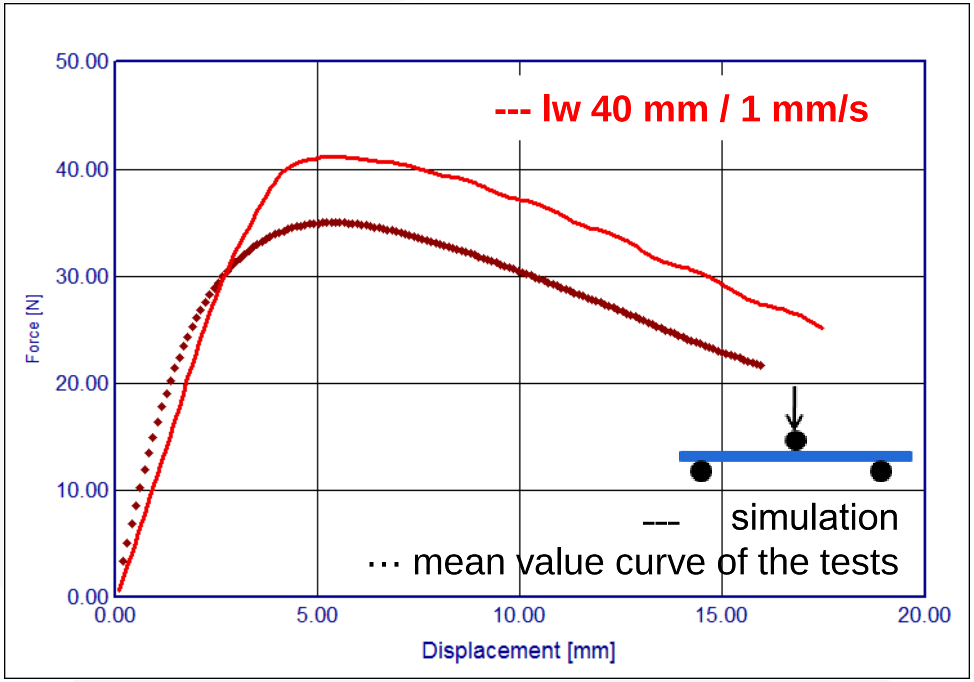
3. Testing with 4a impetus (CRASH)

- static bending and tension (standard universal testing machine)
- dynamic bending and clamped bending (4a impetus)
- dynamic puncture test, T-Specimen (4a impetus)
- ….

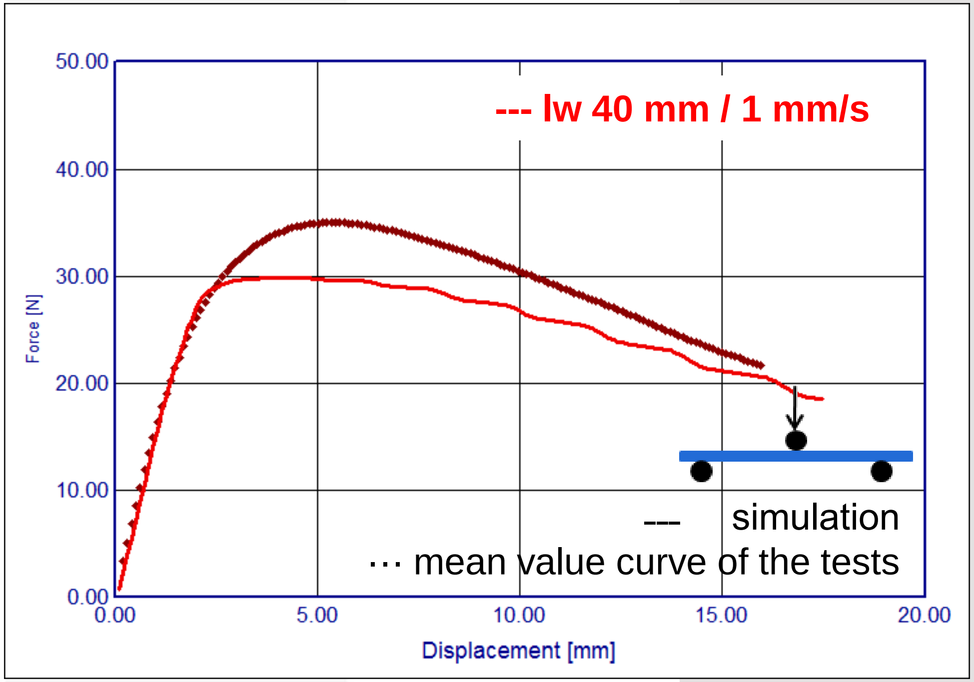


4. Check with existing material card (CES Selector)

Material Universe (PP impact, UV)

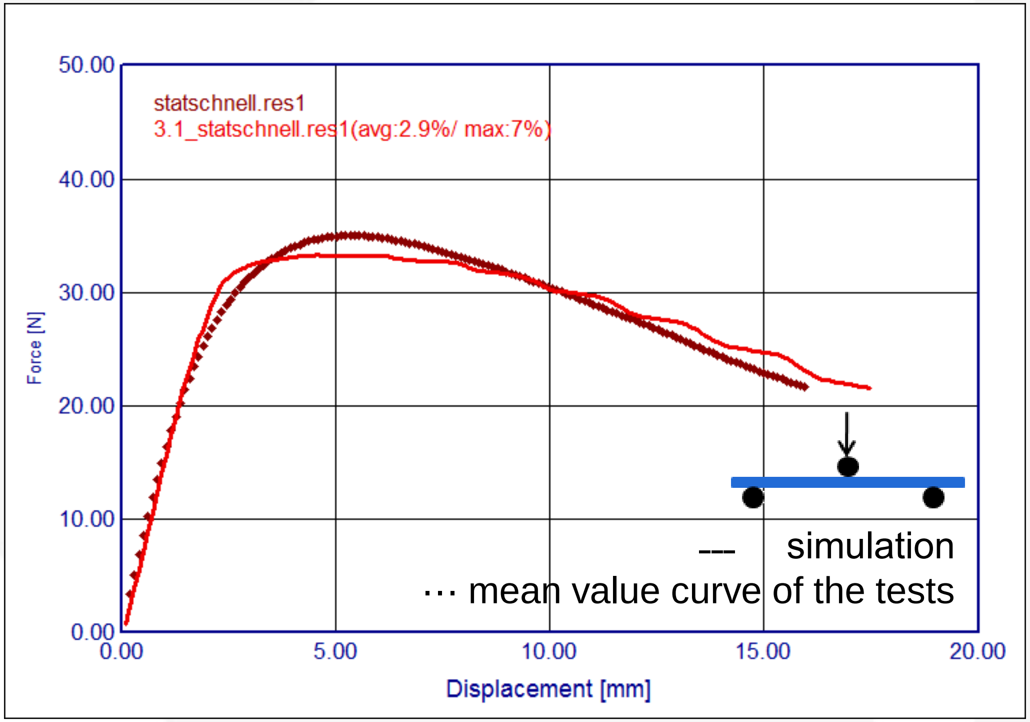


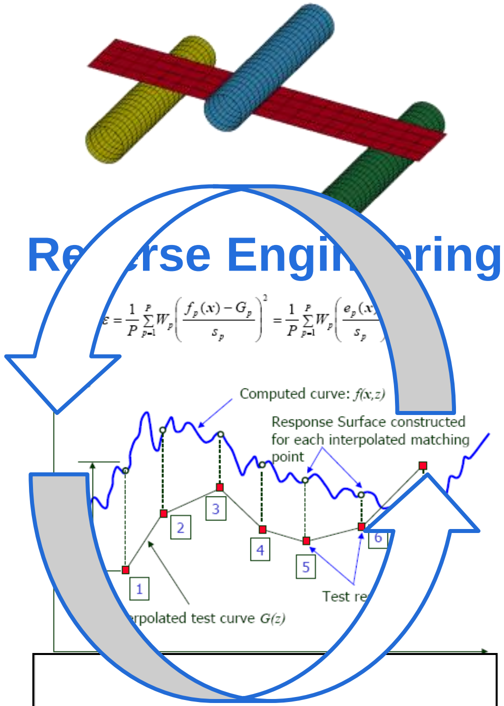
Campus Hostacom XBR 169G



Plastics - Material behavior
Workflow – material card generation

5. Reverse Engineering 4a impetus (*PLASTIC)





$$S_y + S_{ET} \cdot \varepsilon_{pl}$$

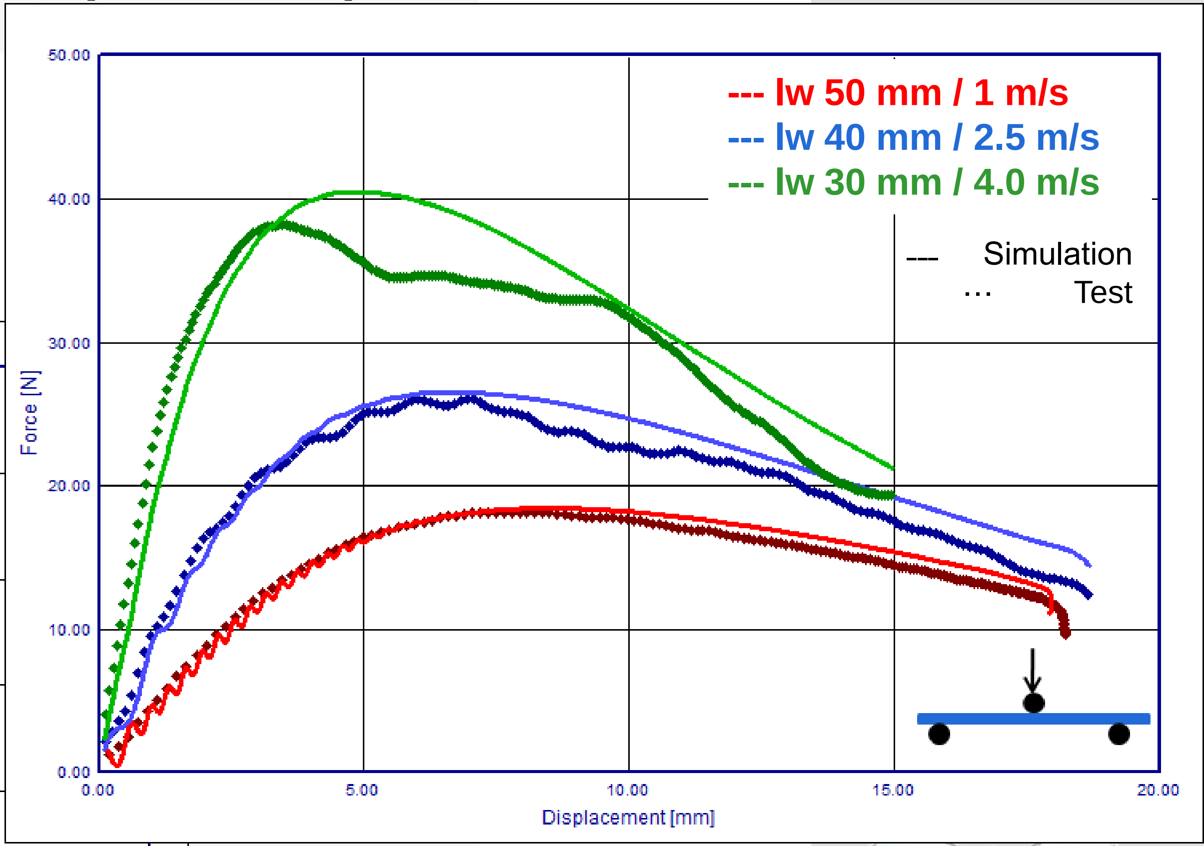
parameterized material card

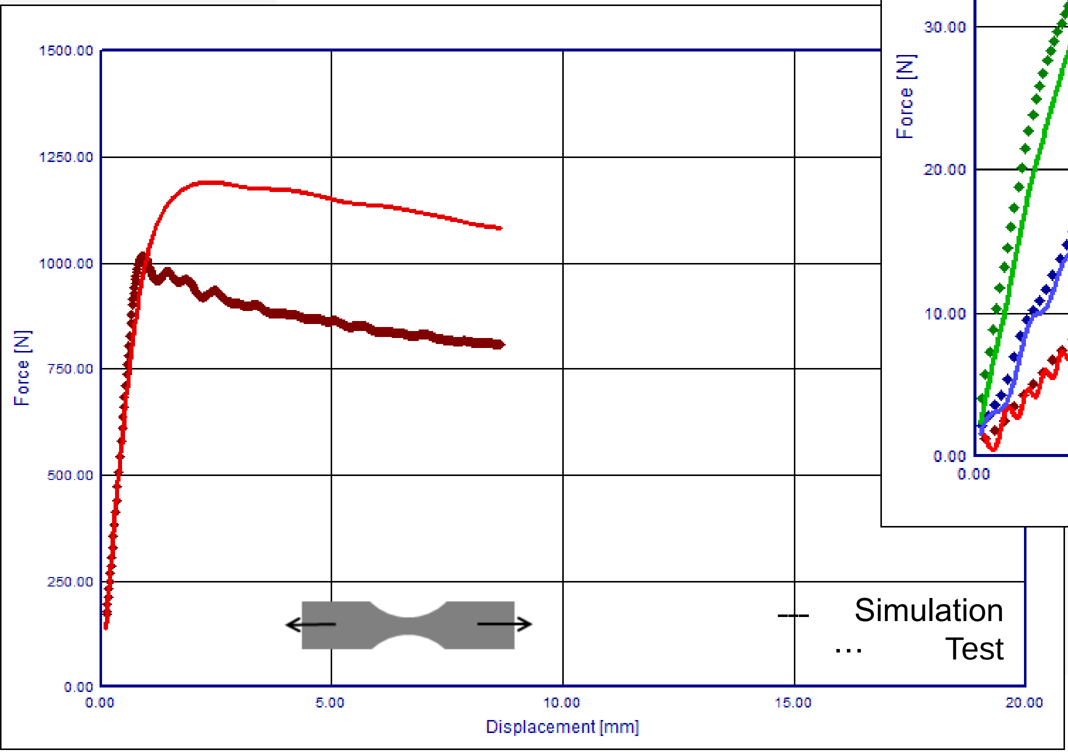
5. Reverse Engineering 4a impetus (*PLASTIC)

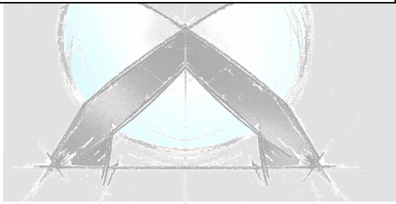
No tension/compression asymmetry

→ good conformity for bending

→ poor conformity for tension

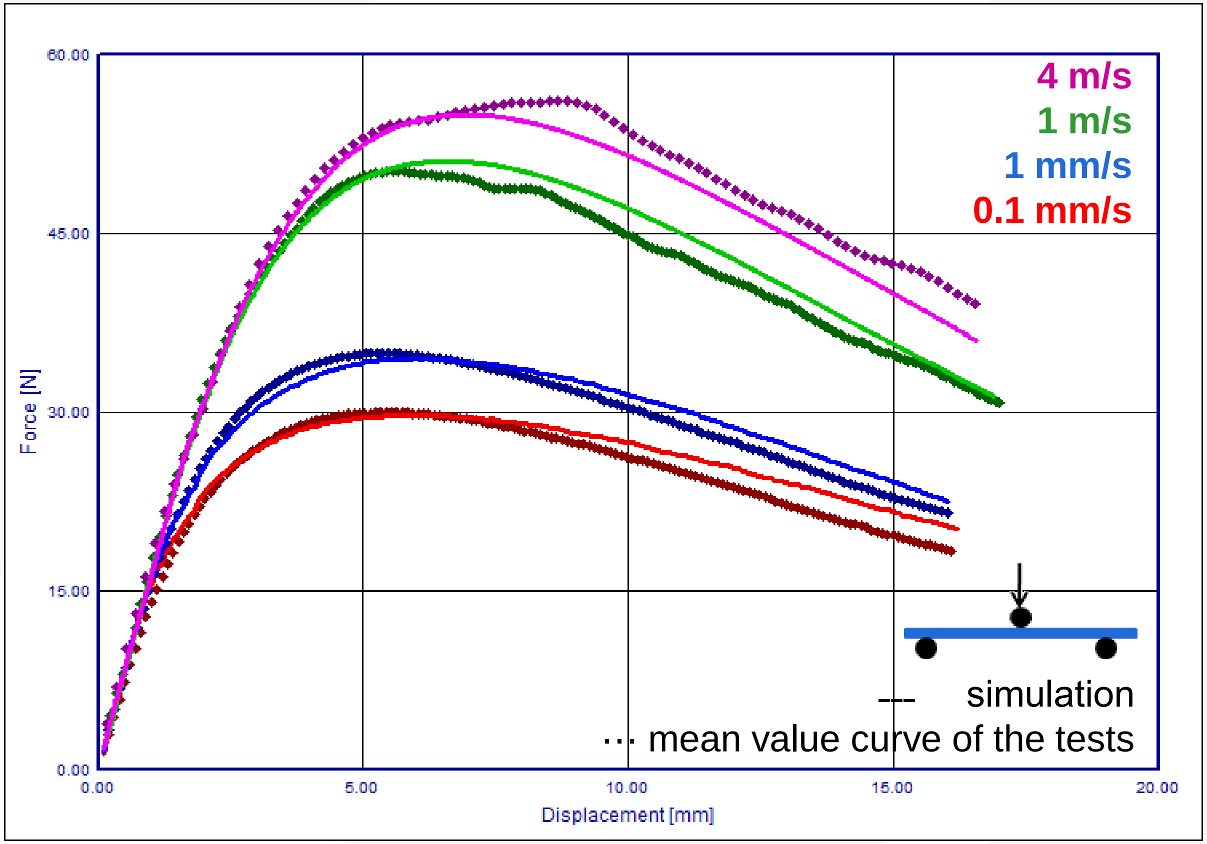






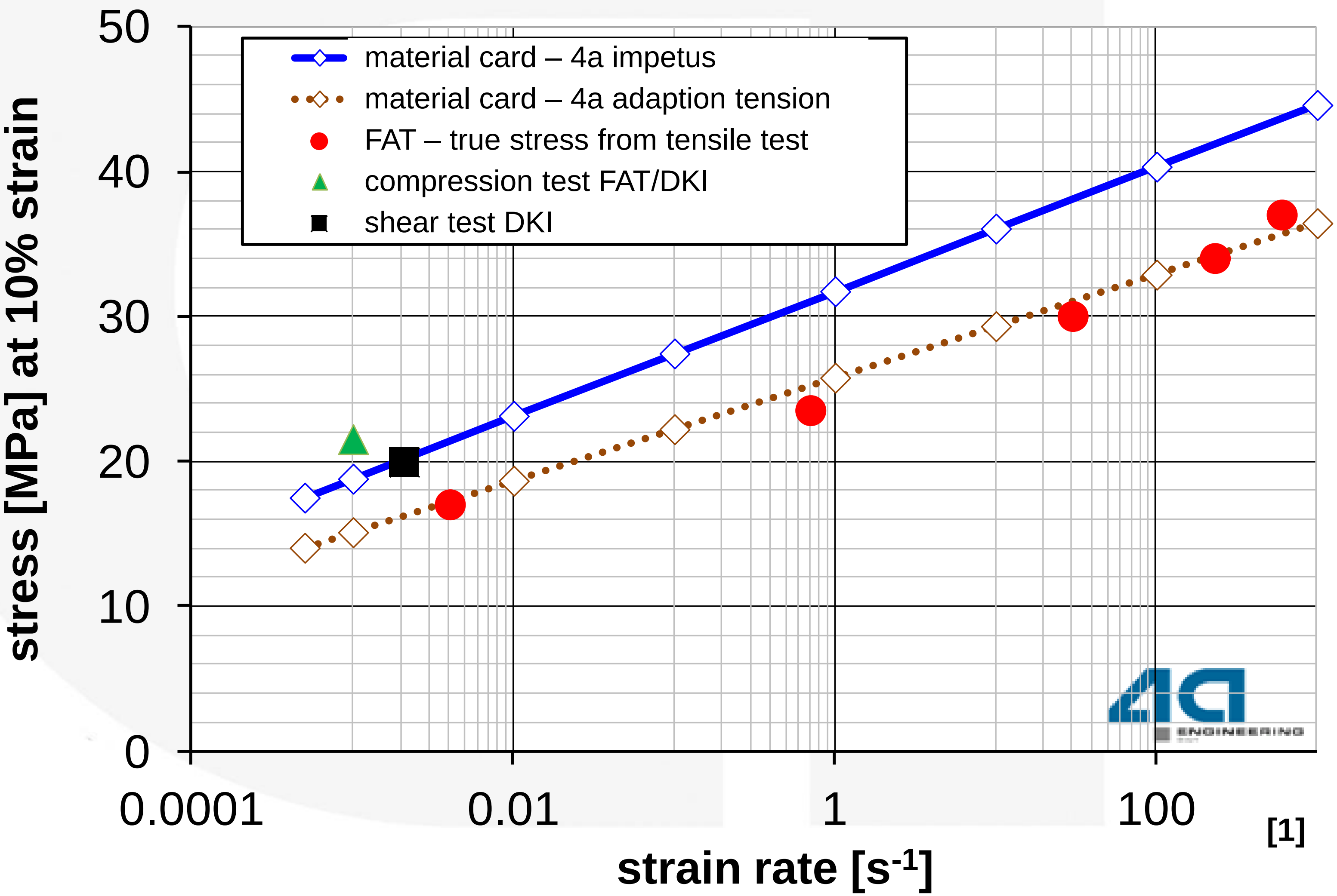
5. Reverse Engineering 4a impetus (*PLASTIC)

Dynamic loadcases



Plastics - Material behavior
Workflow – material card generation

Comparison classical approach vs. 4a impetus



[1]

Supported Abaqus models for isotropic materials

- **PLASTIC* — von Mises
- **DRUCKER PRAGER* — Drucker Prager
- **USERMATERIAL, name=ABQ_MOLDED_PLASTIC [2]* — 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

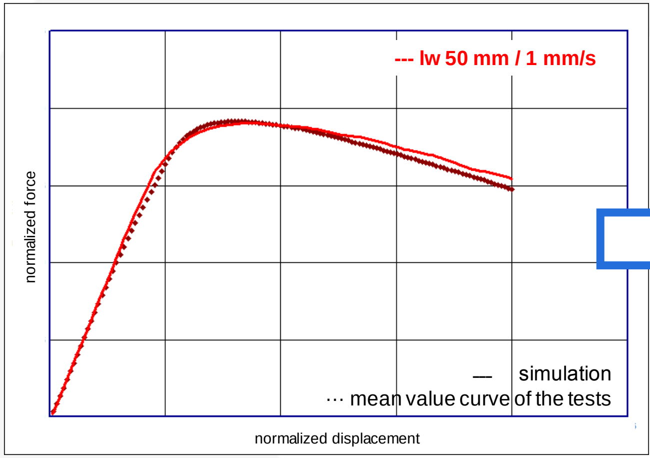
Material behaviour	
Material source	Implemented
Density	-1020.83
Poisson's ratio	0.3
Failure strain	0
Elasticity	Linear elastic
Plasticity	Drucker-Prager
Curve 1	4a Model A
Curve 2	Kurve 1 skaliert
Strain rate dependency	Table
Strain range upto	0.25
Sampling points	50
Bias factor	10

Material 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

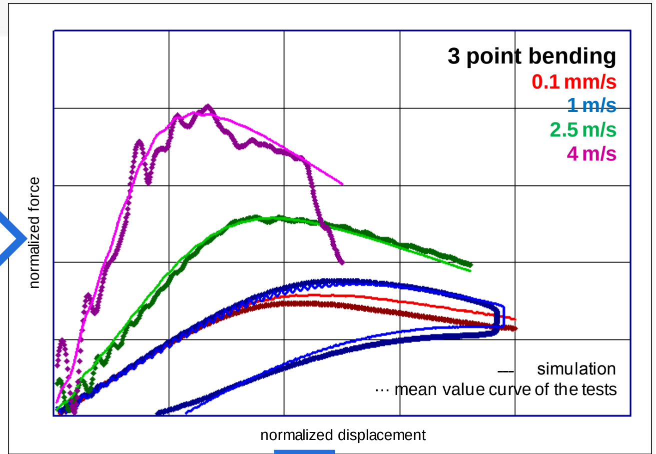
- All ABAQUS material cards are available ***using user defined interfaces***!
- Same possibilities for the ***other solvers*** (e.g. LS-DYNA, Pam-Crash,…)

Plastics - Material behavior
Workflow – material card generation

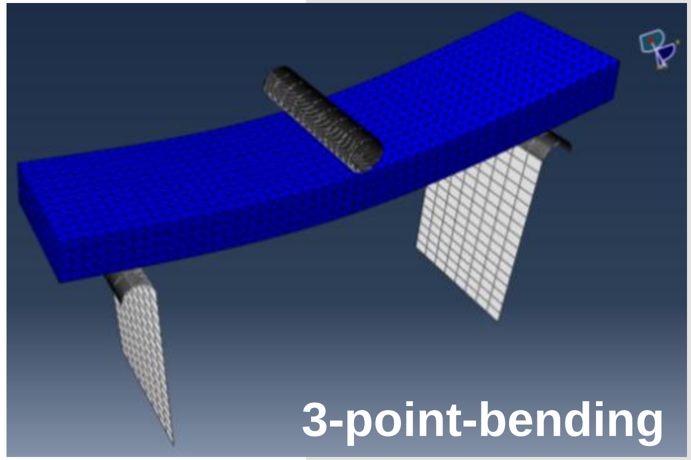
Reverse Engineering 4a impetus (*ABQ_MOLDED_PLASTIC)

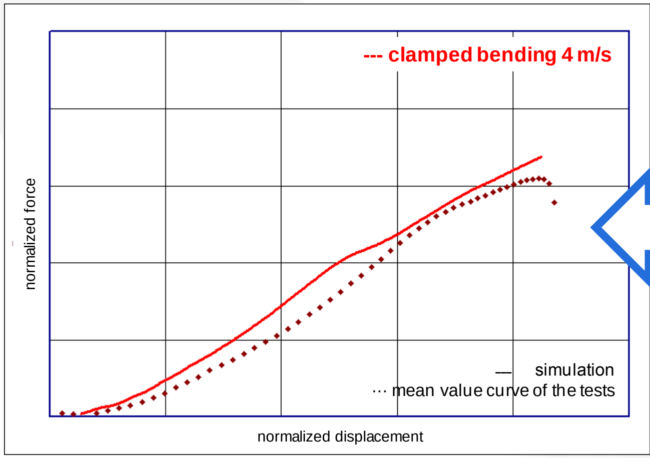


static behavior - yield

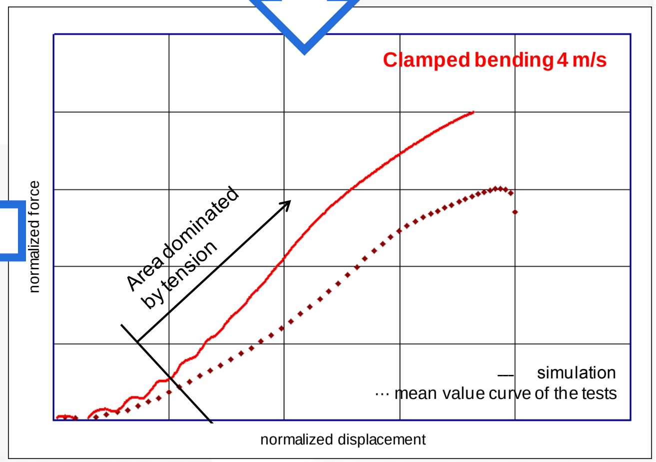


dynamic b vior – strain rate

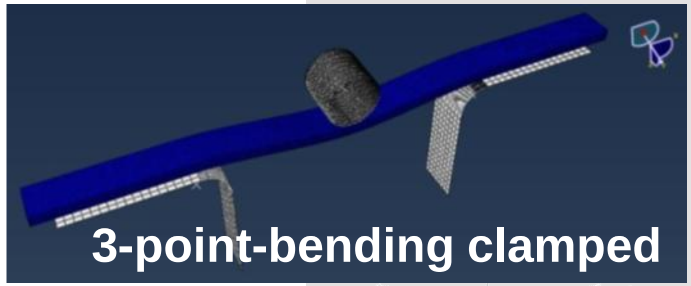




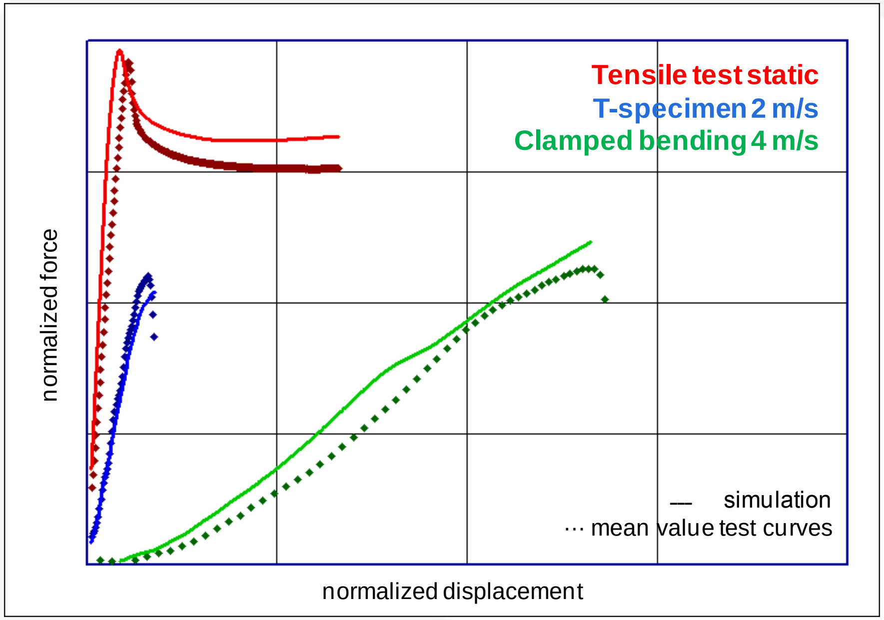
fit compression/tension behavior

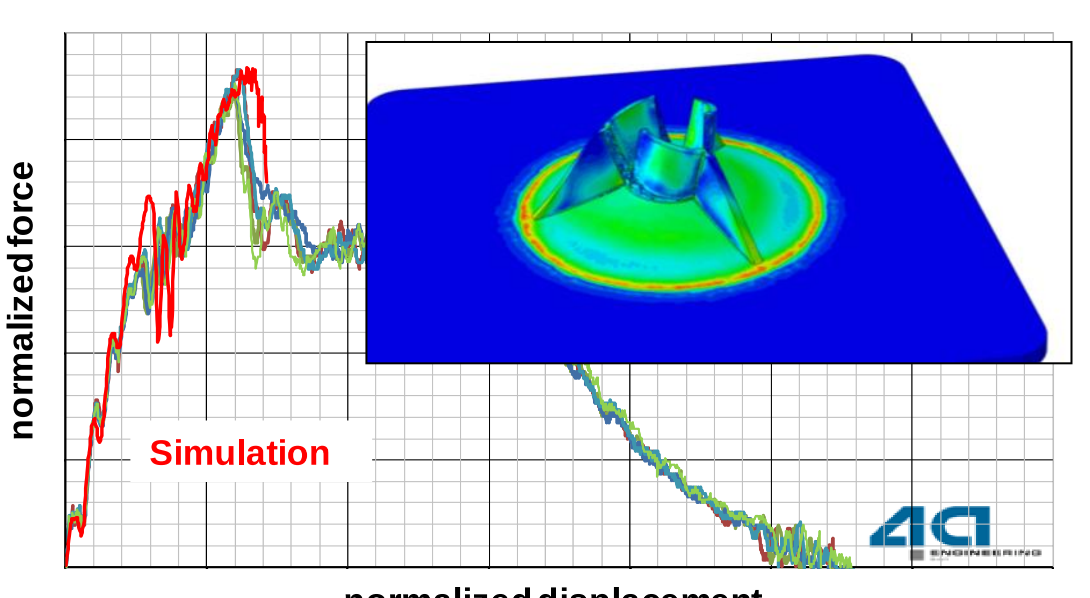


check compression/tension behavior

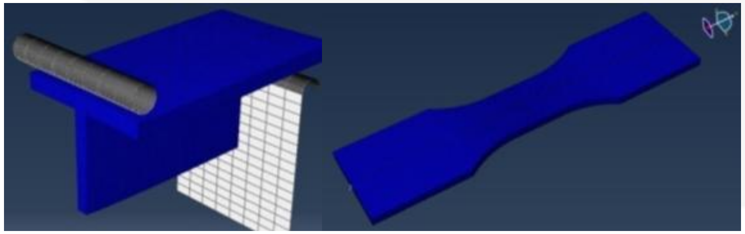


Validation 4a impetus (*ABQ_MOLDED_PLASTIC)





Static tension test
dynamic T-specimen



Dynamic puncture test with the part
The test curves are matched very well

Plastics - Material behavior
Workflow – material card generation

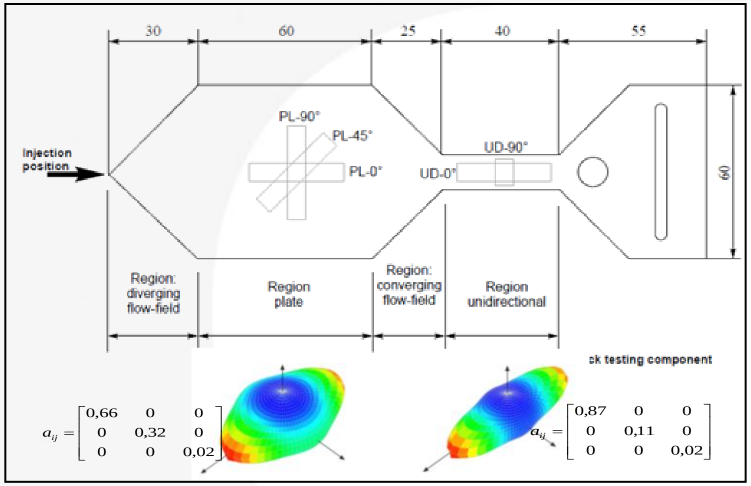
7. Delivery / Storage

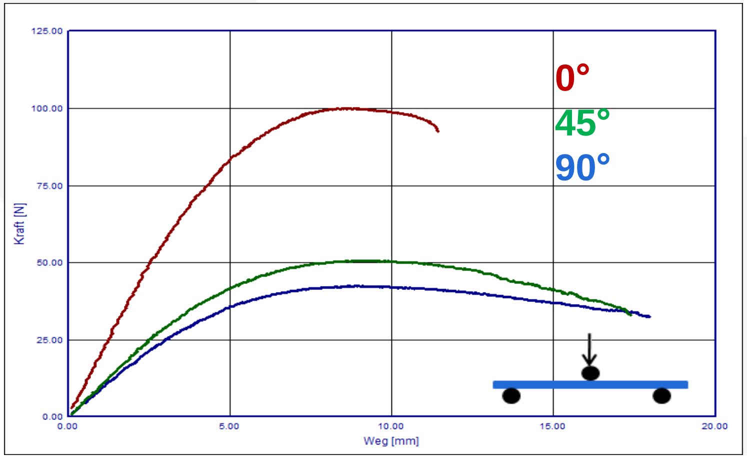
“Too expensive to throw it into the waste basket”

- **Delivery to customer**
  - ASCII File
  - Loss of information (measurement results)
- **Store in Material Information Database**
  - Link between material card and tests → 4a impetus
  - Workgroup solution → 4a impetus
  - Company wide solution (security) → e.g. Granta MI
- **Further usage (4a impetus)**
  - other solvers
  - mesh type / mesh size / solver settings
  - ….

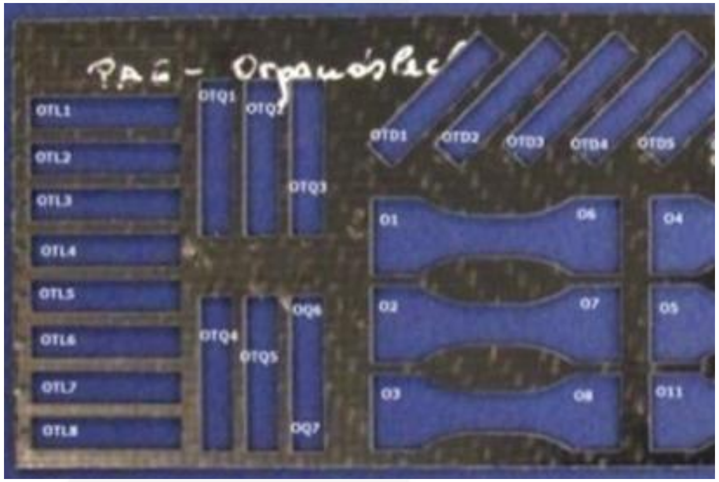
Composites
Influence of the orientation

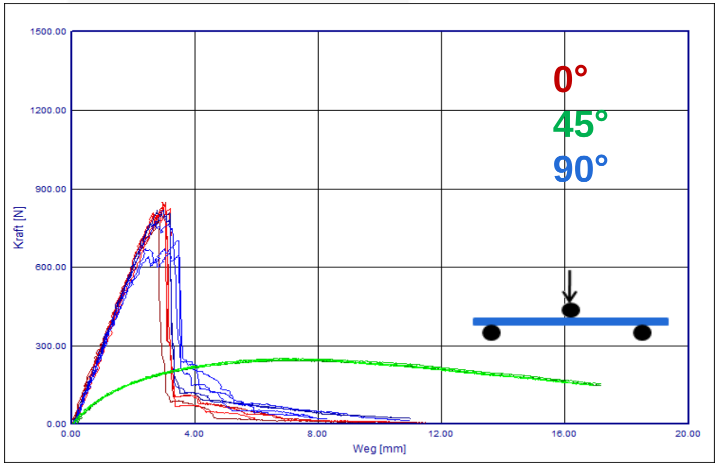
Short fiber reinforced thermoplastic [3]





Composite – organic sheet [4]





Composites

Material model for composites

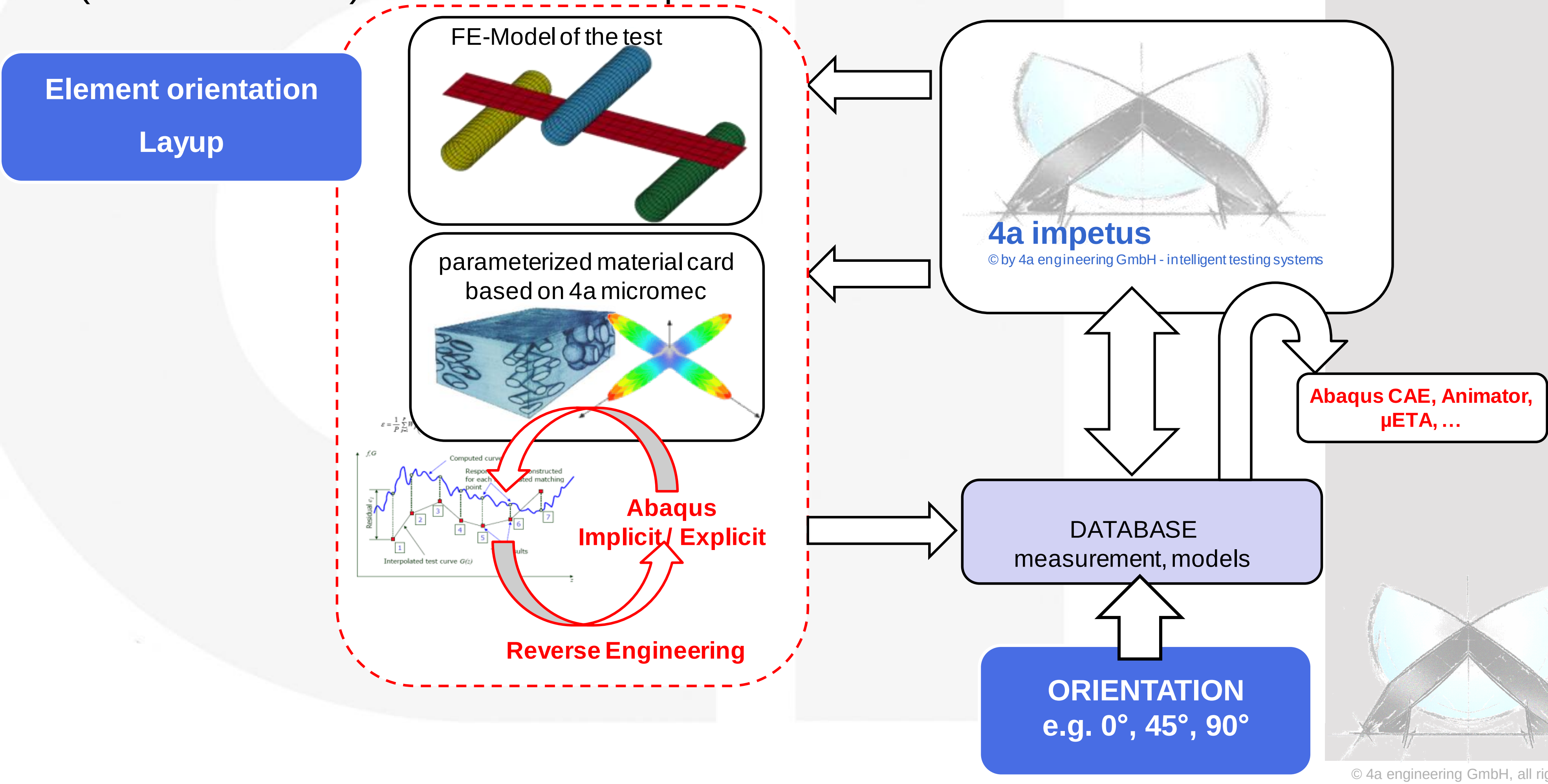
- * VUMAT ABQ_PLY_FABRIC: typical input [5]

*MATERIAL, NAME= ABQ_PLY_FABRIC
*DENSITY
ρ
*USER MATERIAL, CONSTANTS=40
** Line 1:
E_{1+}, E_{2+}, ν_{12+}, G_{12}, E_{1-}, E_{2-}, ν_{12-} ← Young‘s Modulus in 0° (tension), Young‘s Modulus in 90° (tension), Poisson‘s ratio ν_{12} (tension), Shear Modulus, Young‘s Modulus in 0° (compression), Young‘s Modulus in 90° (compression), Poisson‘s ratio ν_{12} (compression),
** Line 2:
X_{1+}, X_{1-}, X_{2+}, X_{2-}, S ← strength in 0° (tension), strength in 0° (compression), strength in 90° (tension), strength in 90° (compression), shear strength
** Line 3:
G_f^{1+}, G_f^{1-}, G_f^{2+}, G_f^{2-}, α_{12}, d_{12}^{max} ← damage parameter
** Line 4:
$\tilde{\sigma}_{y0}$, C, p ← shear hardening data
** Line 5:
lDelFlag, d_{max}, $\bar{\varepsilon}_{max}^{pl}$, $\hat{\varepsilon}_{max}$, $\hat{\varepsilon}_{min}$ ← data for element erosion
*DEPVAR, DELETE=16
16

Composites

Adaption of material cards - influences of orientation

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



4a micromec: Calculating the elastic values

Input

Material Data of Components (E,α,λ)

Matrix
Reinforcements
Fillers

Data-Base

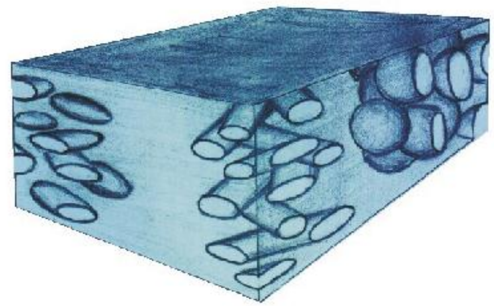
Fibre and Particle Orientation

Data-Base

Fibre and Particle Shape

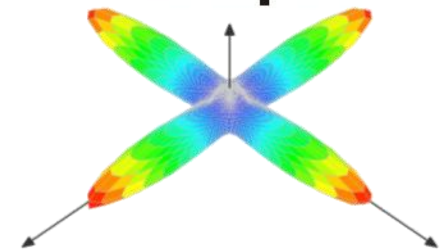
Data-Base

4a micromec



Virtual Material Design

Output



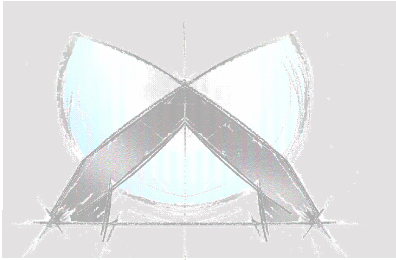
3D Composite Data

elastic properties
thermal expansion
thermal conductivity

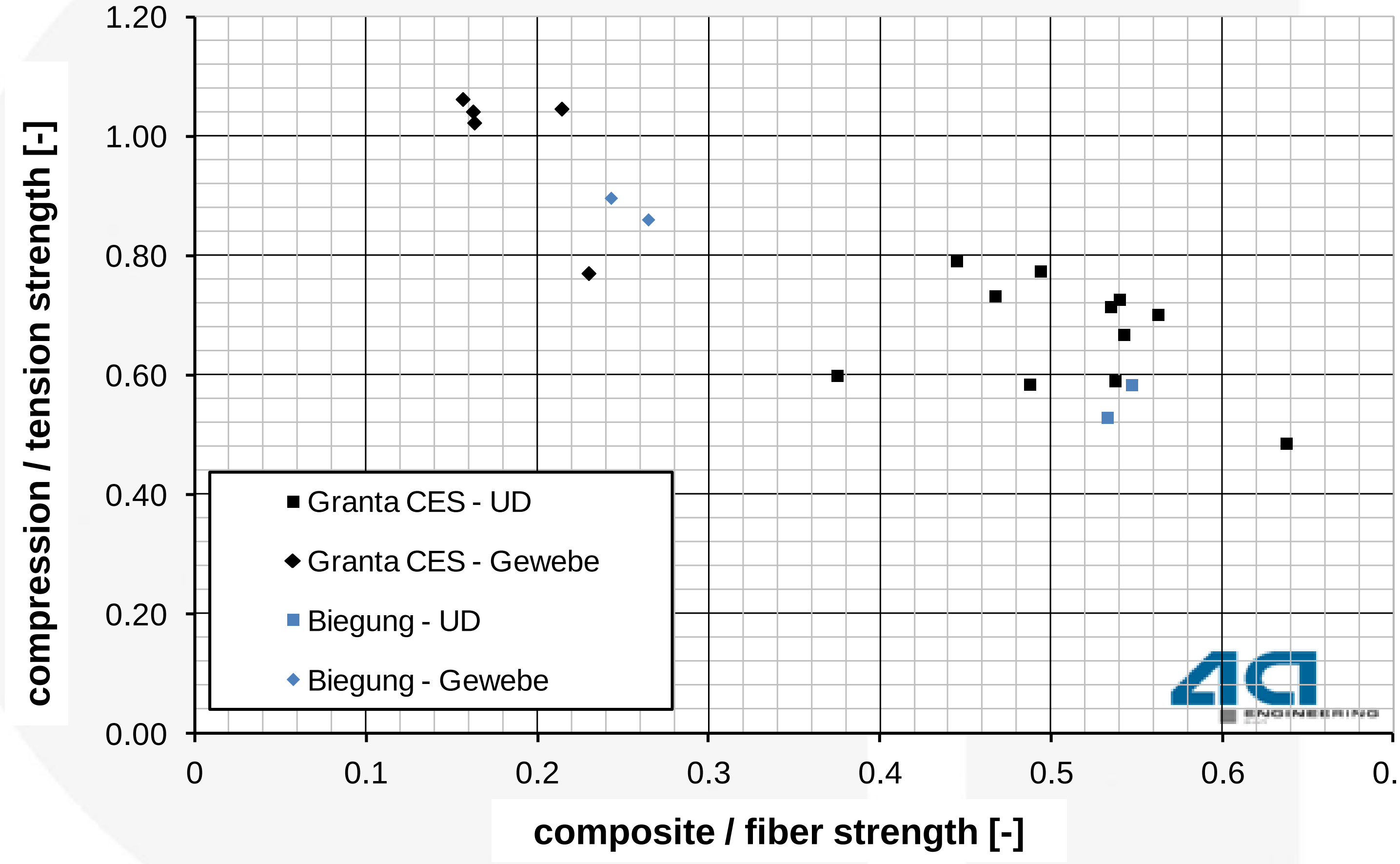
2D&3D graphics

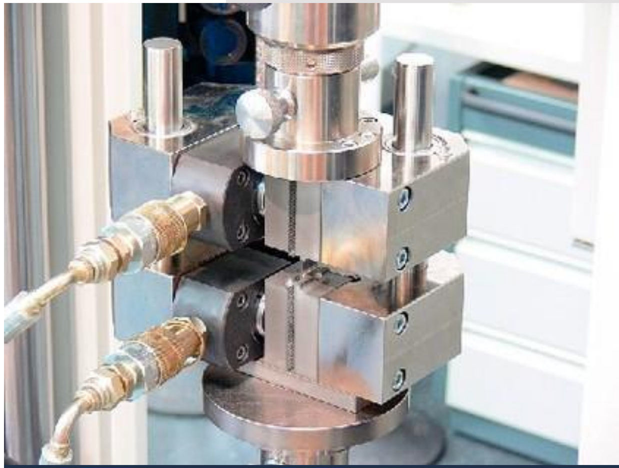
Interphase to MSC.Nastran 4 Windows

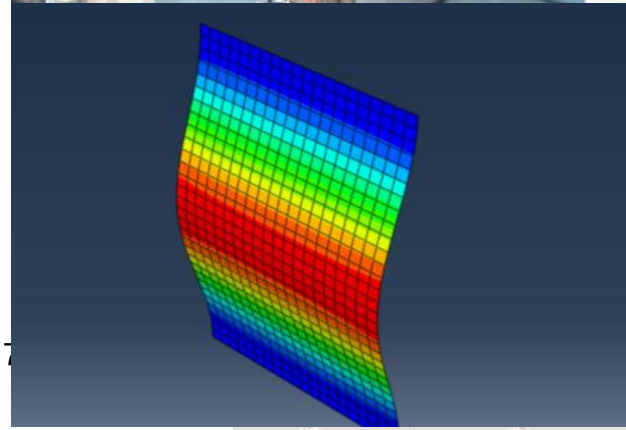
- Usage for SFRT, LFRT, CFRP, GFRP, ….
- Stand-Alone-Solution available (3D thermo-elastic properties)
- User Material (orthotropic elastic visco-plastic including failure)



Composites
Verification of measurements - Compression





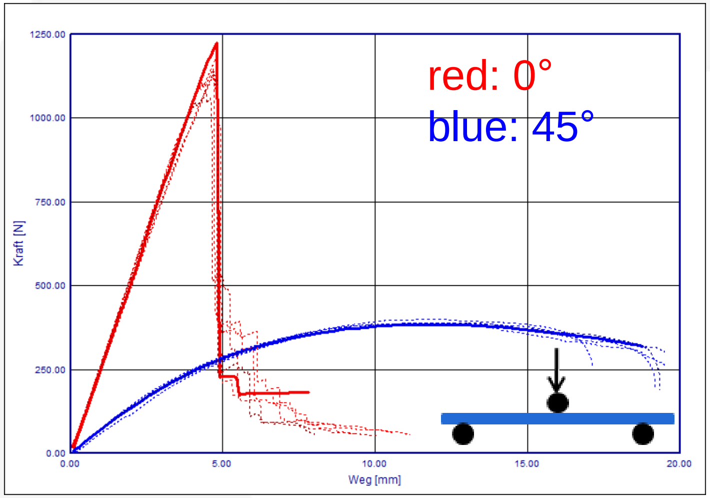


Results with kindly permission of
MAGNA STEYR Fahrzeugtechnik AG & Co KG [6]

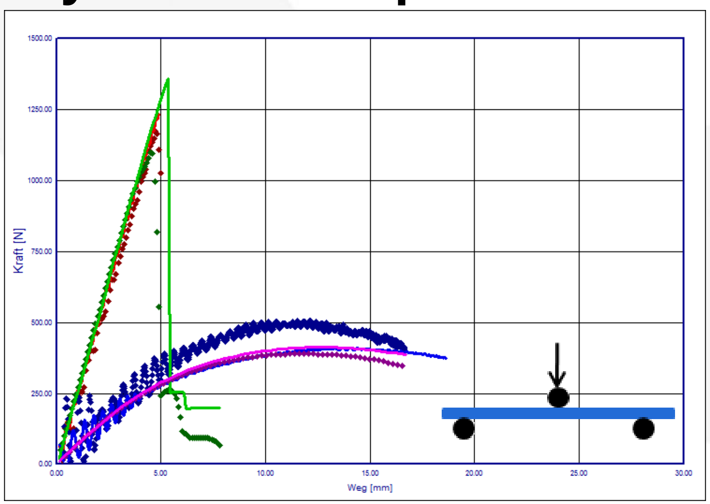
Composites

Verification of measurements - Compression

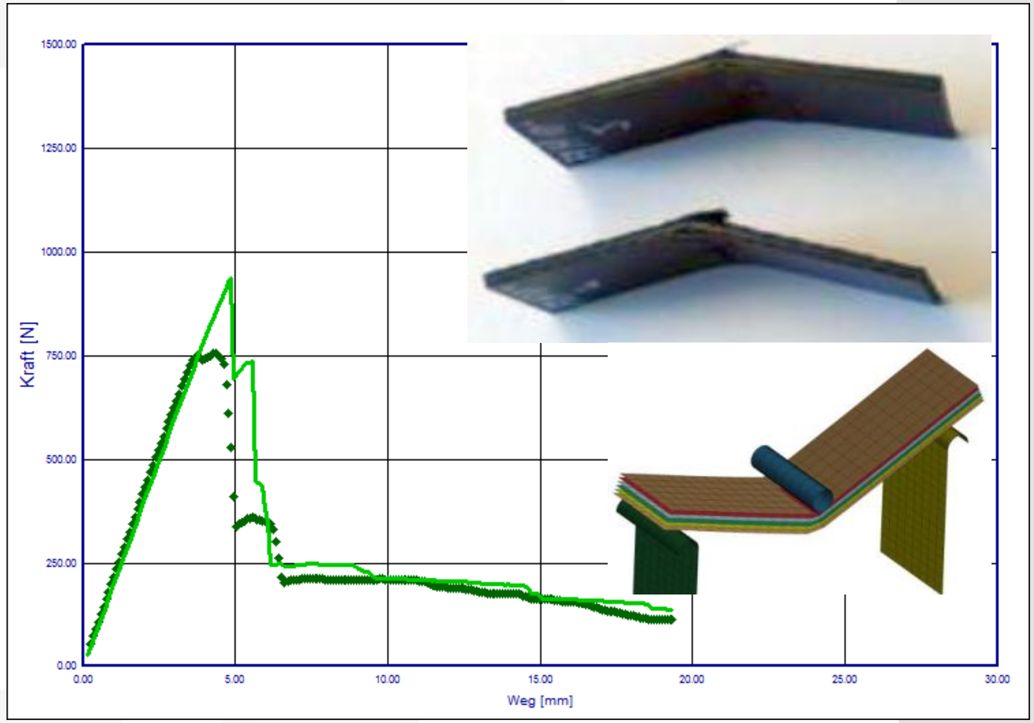
Orientation



Dynamic 4a impetus



Multilayer Setup



…. test
— simulation

Results with kindly permission of
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Summary

- **Abaqus** offers a multitude of material models to describe the dynamic material behavior of **plastics and composites** very well.
- With **increasing complexity** the accurateness of the characterization as well as the effort to adapt the material models rises. Therefore it is essential to **stay focused** on the **significant influences**.
- **Material information systems** (like CES Selector™, GRANTA MI™) are a helpful extension in the material card generation process, to enable full traceability and management of the information especially **at the start** and **end of the process**.
- Tools like **4a impetus** or **4a micromec** ensure **quality and reproducibility** in the **process of generating material cards**, especially as the material card is linked to the chosen idealization (solver, element type, element size, …).
- As plastics will be used much more for mechanical loaded parts, **modeling of failure** will be the **next challenge in future**.

.. in physics we trust

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