Dynamische Materialcharakterisierung mit 4a impetus - LIVE Messung

M. Rollant
4a engineering GmbH, Traboch, Austria

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    - statischer Zugversuch → Faserorientierung über die Dicke, vgl. Biegung
    - Komponentenbiegung und Durchstoß → Versagen

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Inhalt

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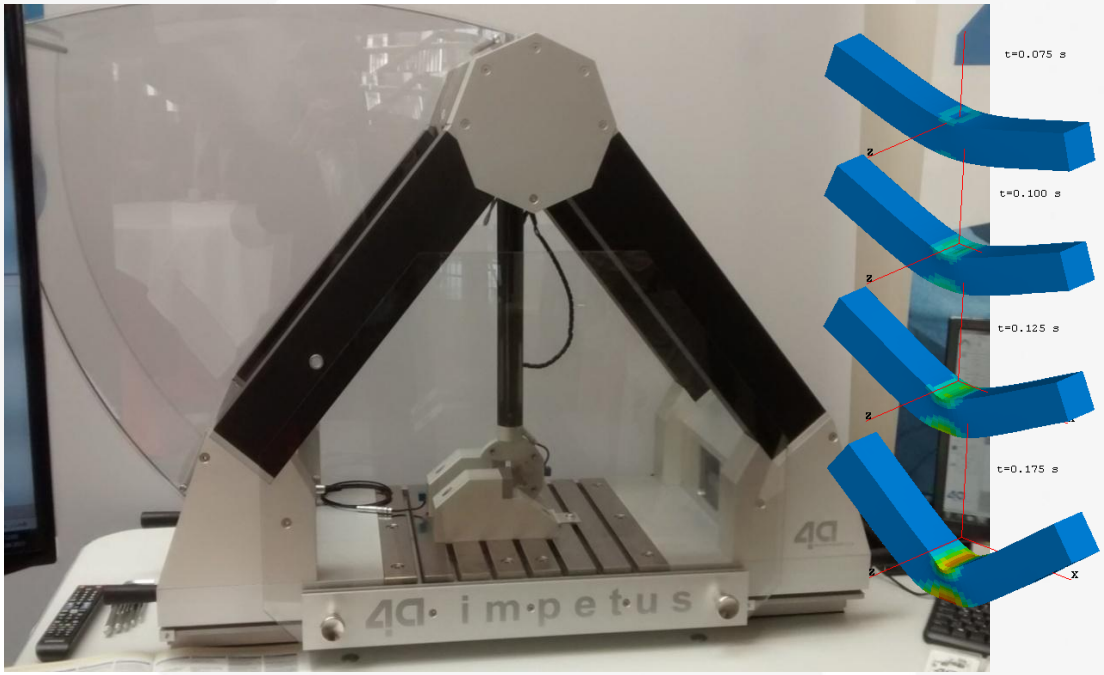
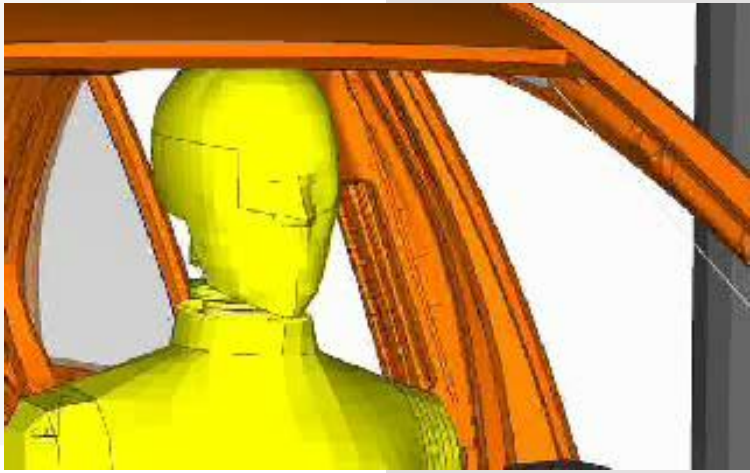
4a impetus dynamische Prüfungen
Prüfystem

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



source: http://gm-volt.com/



source: Dynamore GmbH

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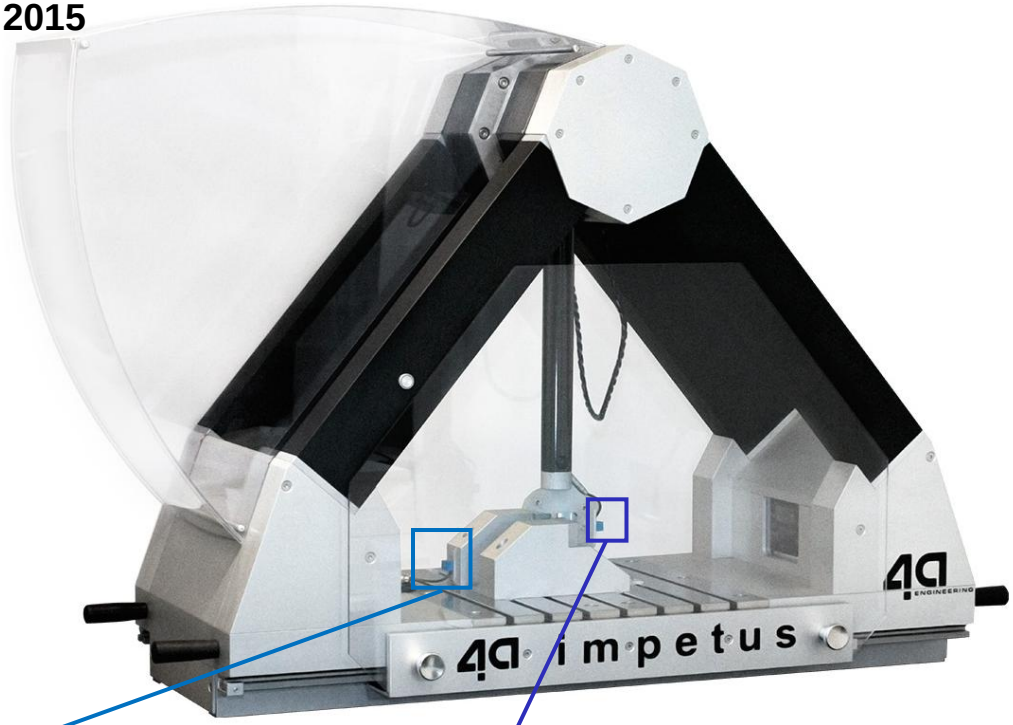
4a impetus dynamische Prüfungen

Prüfsystem

2012

2015



g-Sensor am Widerlager und g-Sensor am Pendelkopf

Pendelkopfmasse: 500 - 2000 g (Zusatzgewichte)

Prüfgeschwindigkeit: 1 – 4.4 m/s

Finnen- und Widerlagerradius: 2 bzw. 5 mm

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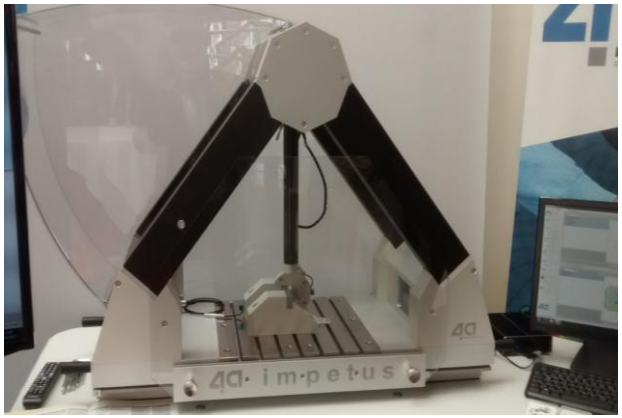
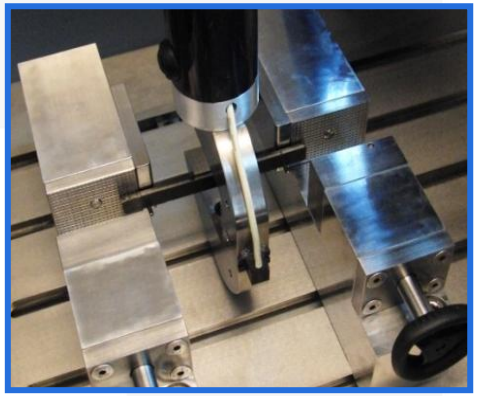
4a impetus dynamische Prüfungen
Prüfsystem

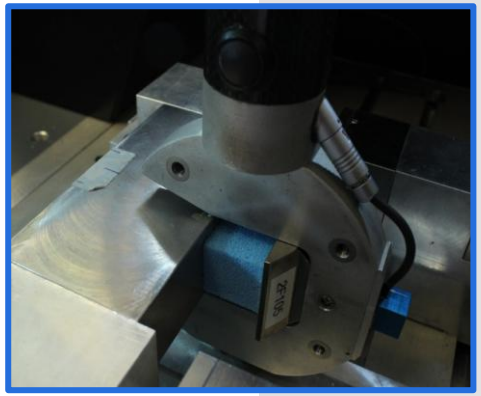
4a impetus Hardware



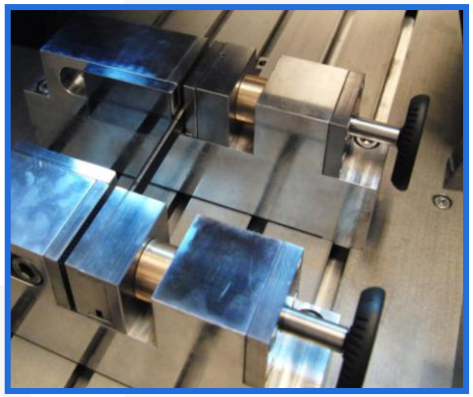
- single pendulum up to 4.5 m/s
- double pendulum up to 8 m/s
- **standard test methods**
- **specialized test methods**



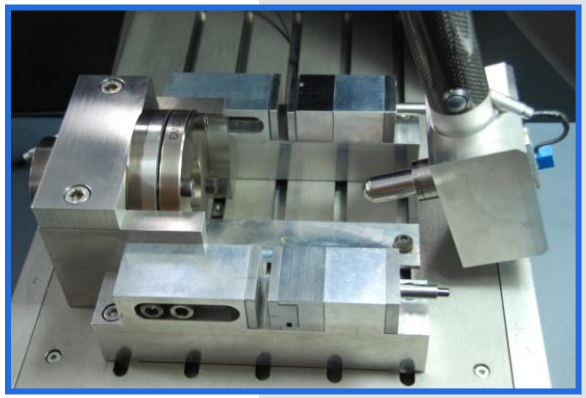
bending test



compression test



Fixed bending test



Puncture test

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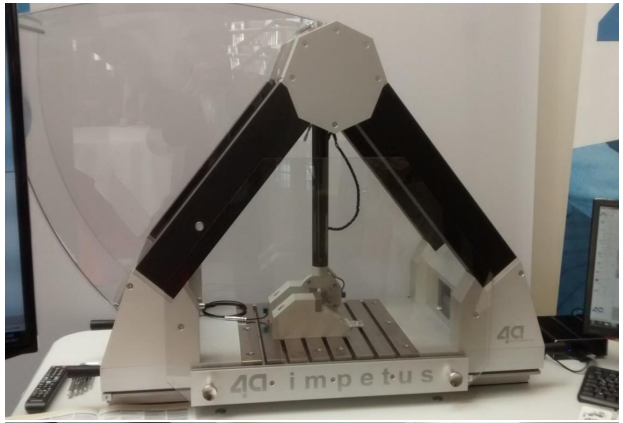
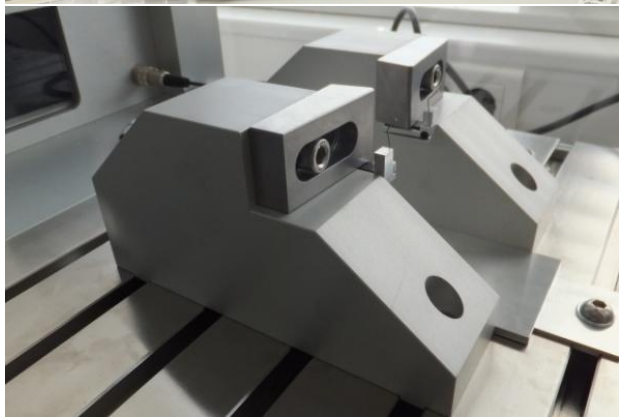
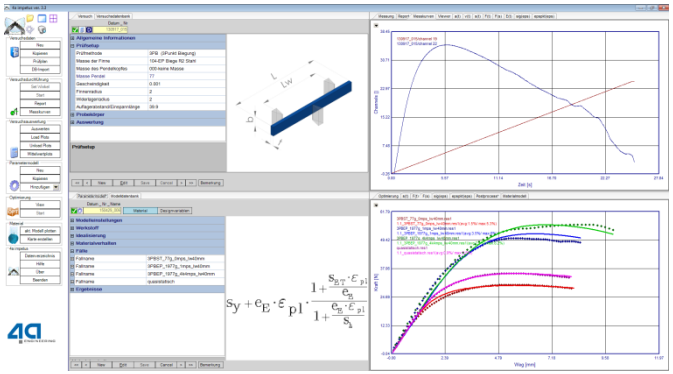
4a impetus dynamische Prüfungen
3-Punkt-Biegung

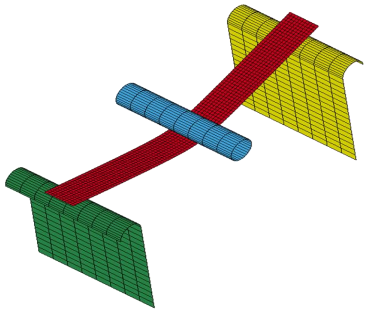
4a impetus Hardware





4a impetus Software





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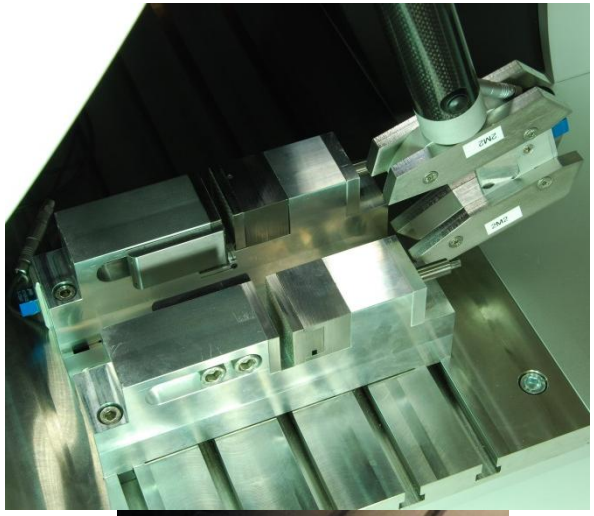
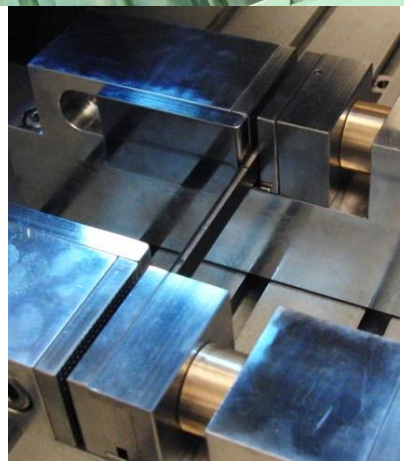
4a impetus dynamische Prüfungen
gespannte 3-Punkt-Biegung

4a impetus Hardware





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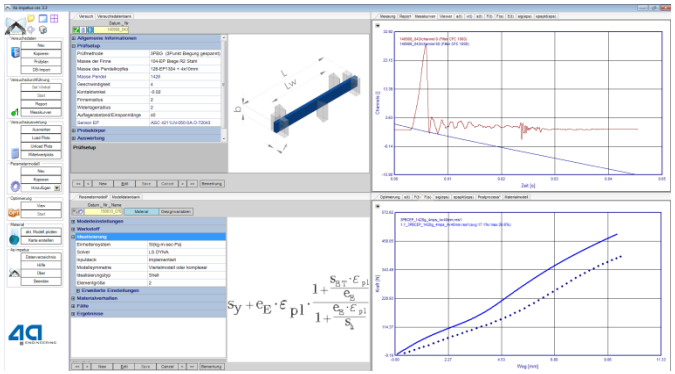

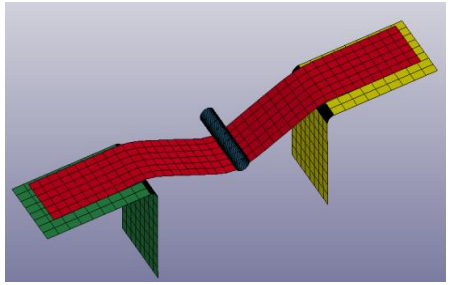

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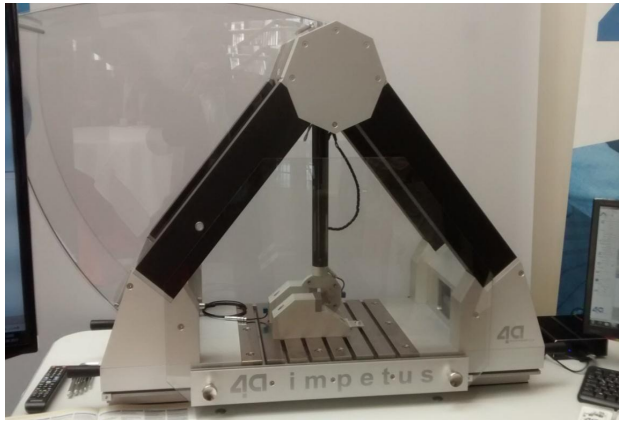
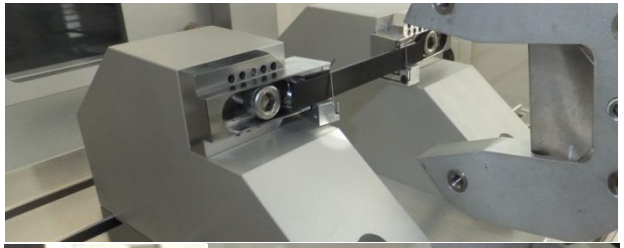
4a impetus dynamische Prüfungen

Komponentenprüfung T-Probe

4a impetus Hardware





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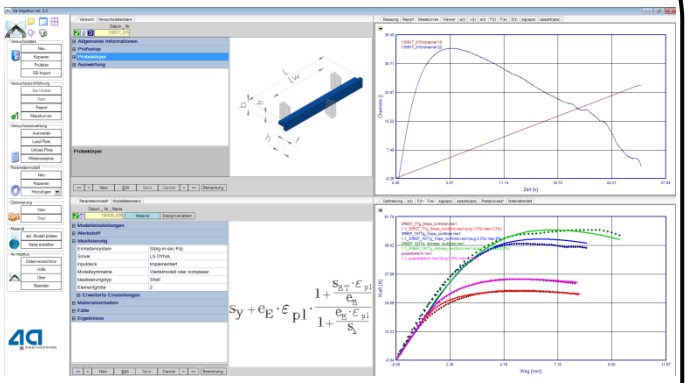

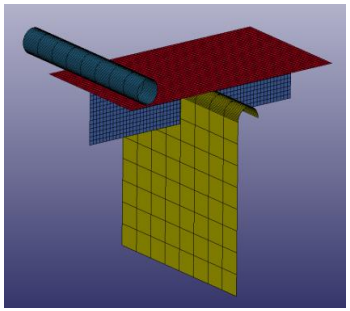

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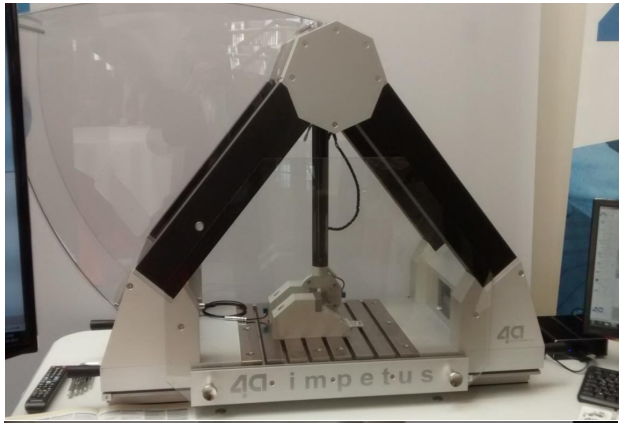
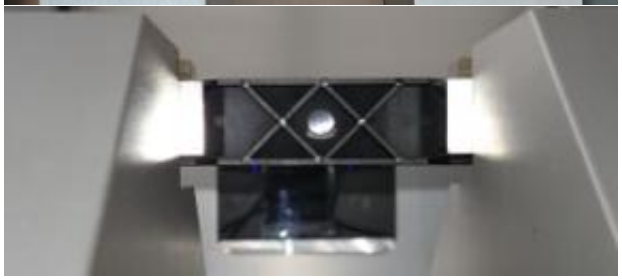
4a impetus dynamische Prüfungen

Komponentenprüfung Doppelrippe

4a impetus Hardware





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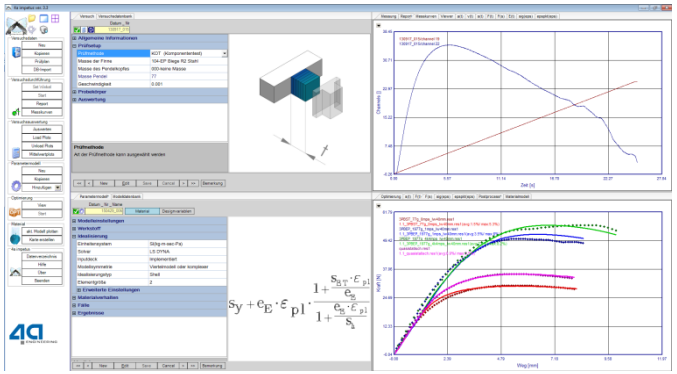

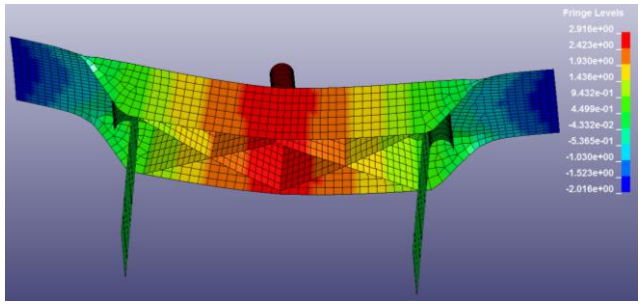

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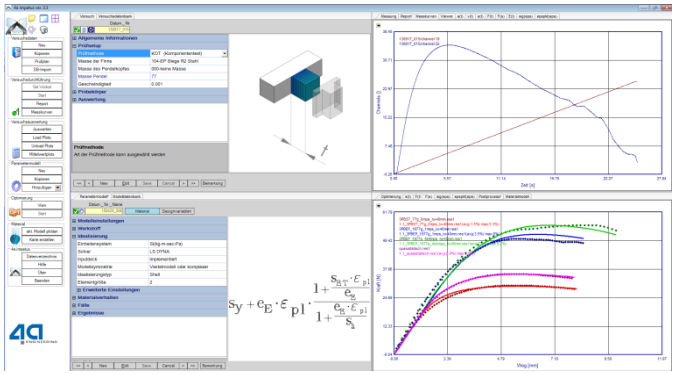
4a impetus dynamische Prüfungen
Komponenten

4a impetus Hardware

4a impetus Software



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4a impetus dynamische Prüfungen

Ausblick Pendelarm

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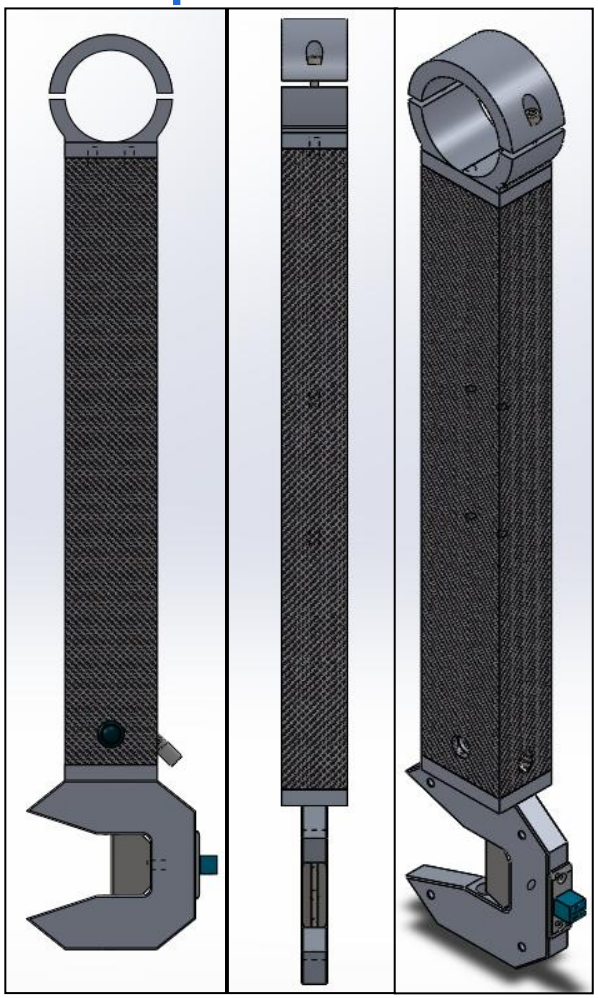

Spezifikationen	
Pendelarmlänge	500 mm
mögliche Prüfgeschwindigkeiten	0,5-4,4 m/s
maximal zulässige Zusatzmassen	4000 g
maximal zulässige Prüfenergie	50J

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4a impetus dynamische Prüfungen
Ausblick Durchstoß

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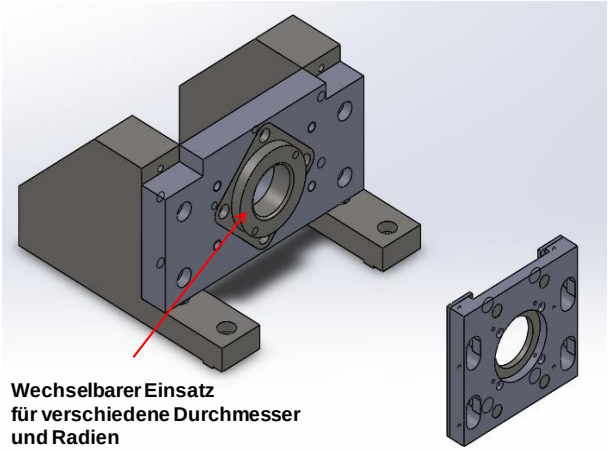
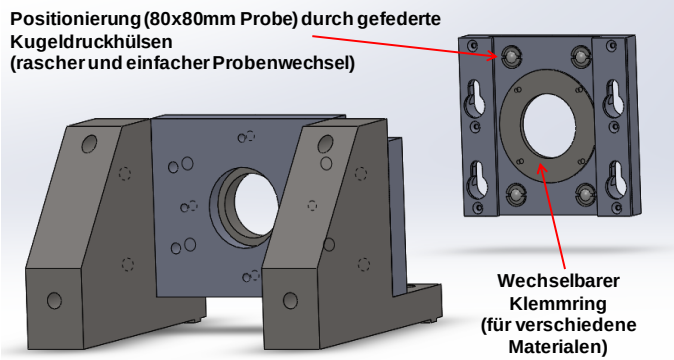
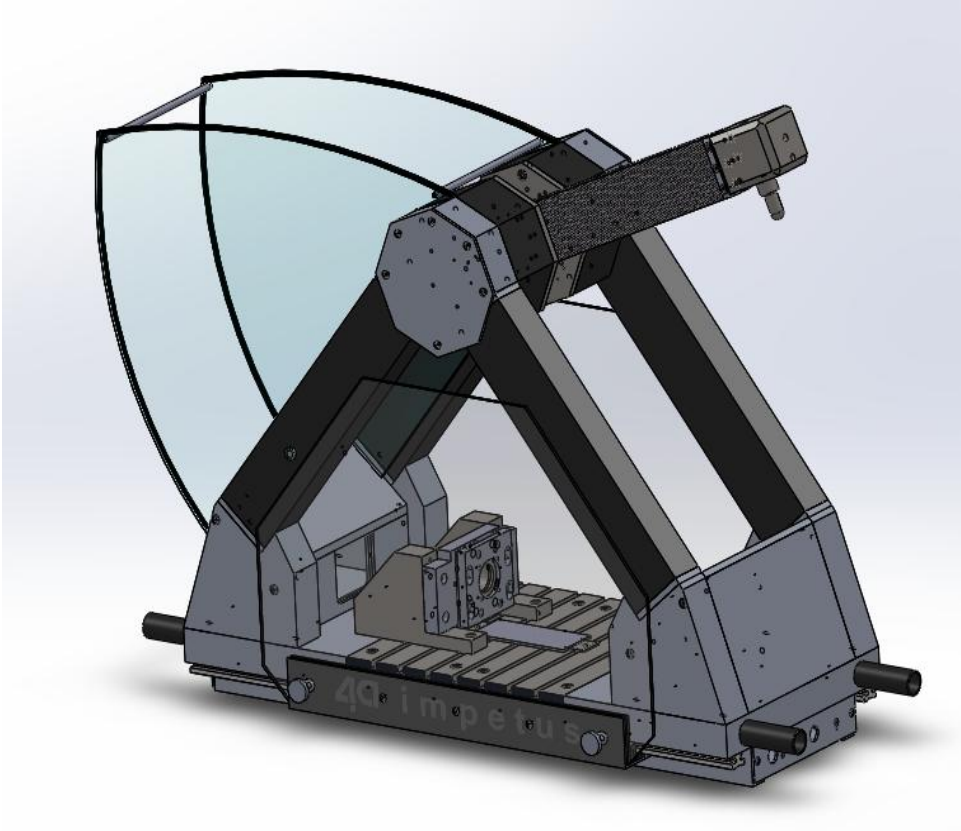




Durchstoßversuch

(Voraussetzung neuer Pendelarm)



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4a impetus Ablaufübersicht

Messung/Auswertung-Simulation-Materialkarte

static

dynamic

External Testing

gom Optical Measuring Techniques

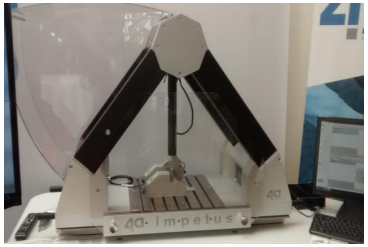
Zwick / Roell

MTS

INSTRON

SHIMADZU

4a impetus Hardware



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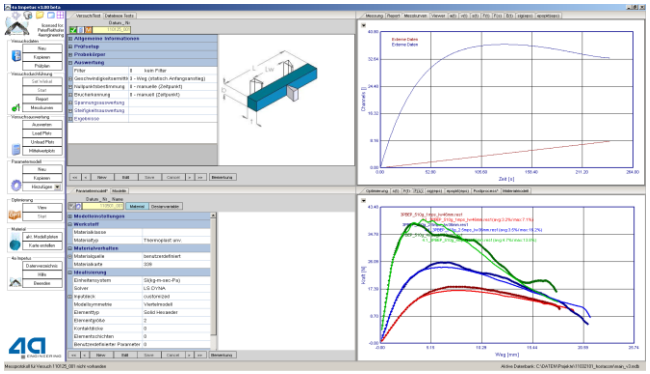
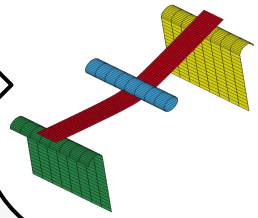




Automatic*

LS-OPT

Optimierer

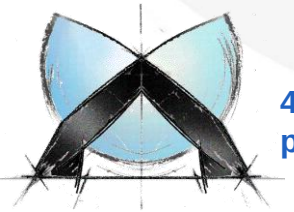
Reverse Engineering

Testresults

Reports

Workflow

Materialcards



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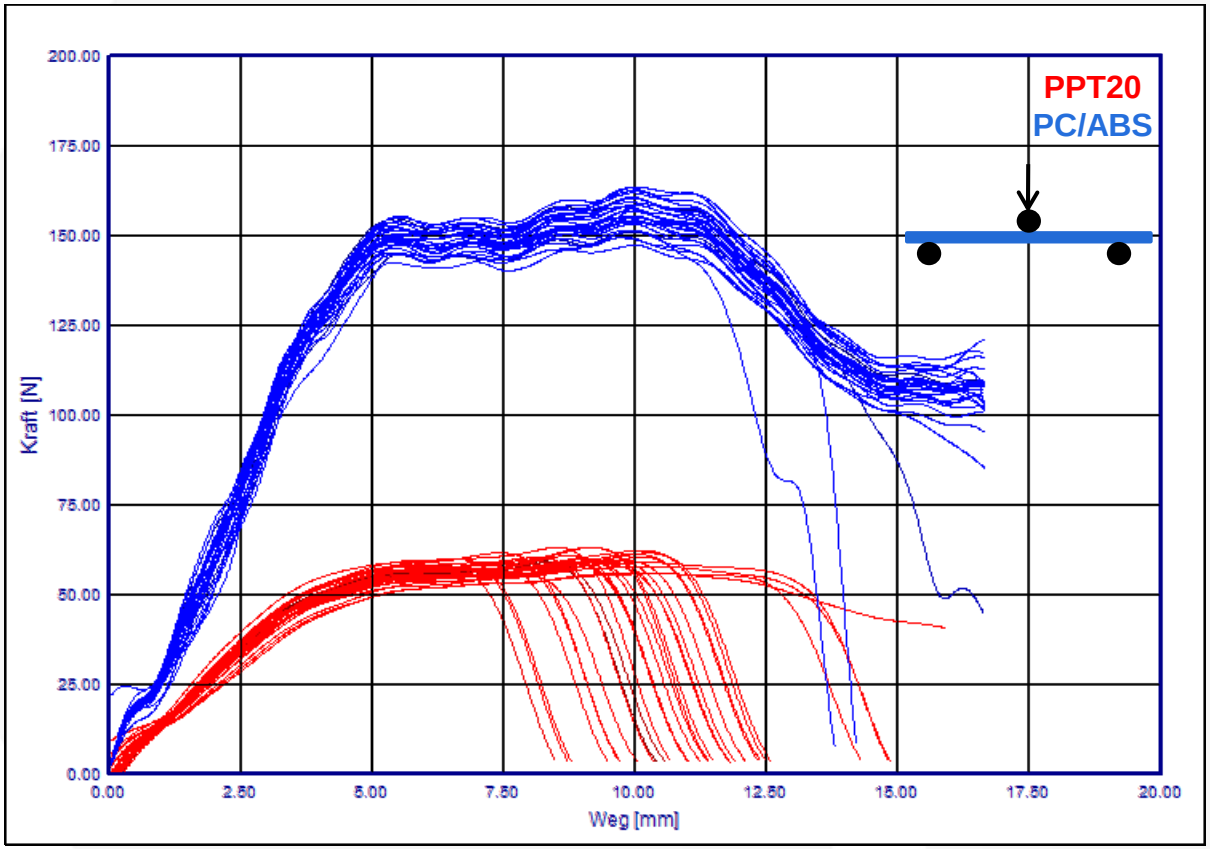
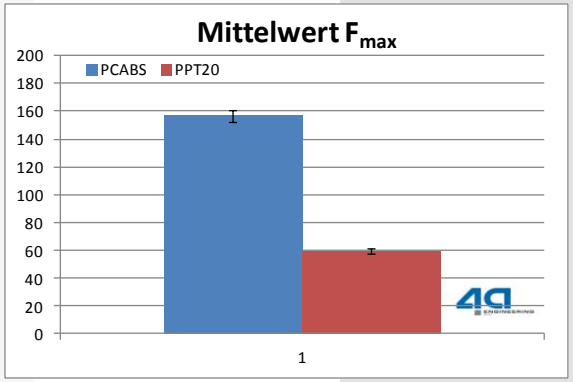
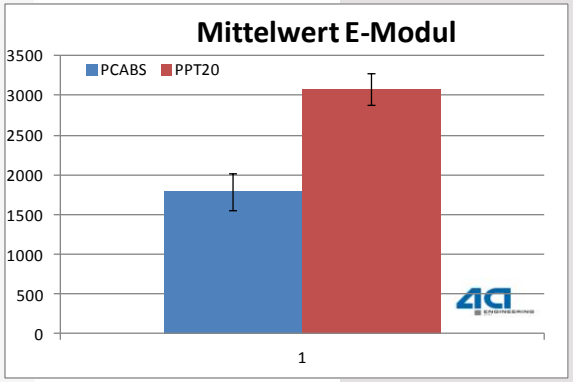
4a impetus Messergebnis

Punktwerte, statistische Auswertung in der Software







Die Messergebnisse der Technologietagteilnehmer aus dem Jahr 2014

(~ 30 Messungen pro Material)

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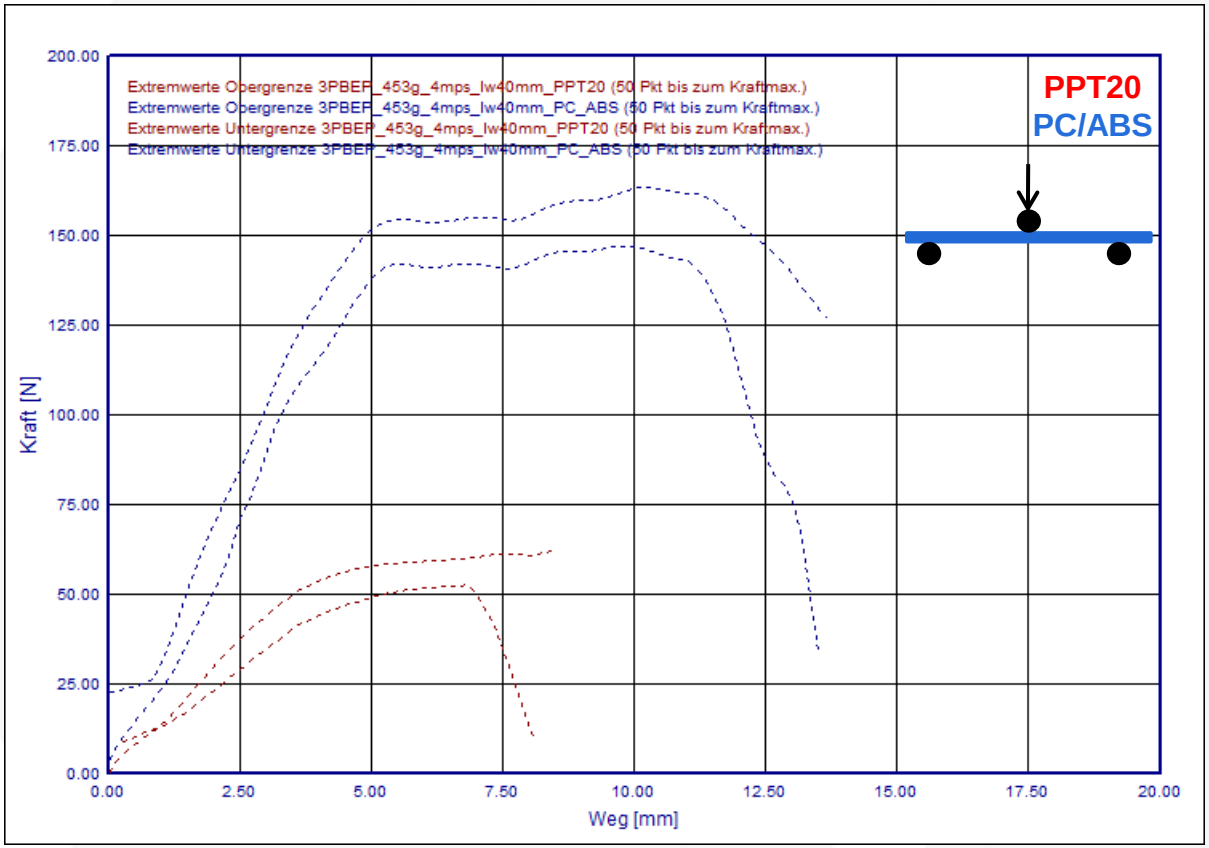
4a impetus Messergebnis

Punktwerte, statistische Auswertung in der Software



Extremwertkurven beider Materialien (Einhüllende Grenzwertkurven Minimum und Maximum)

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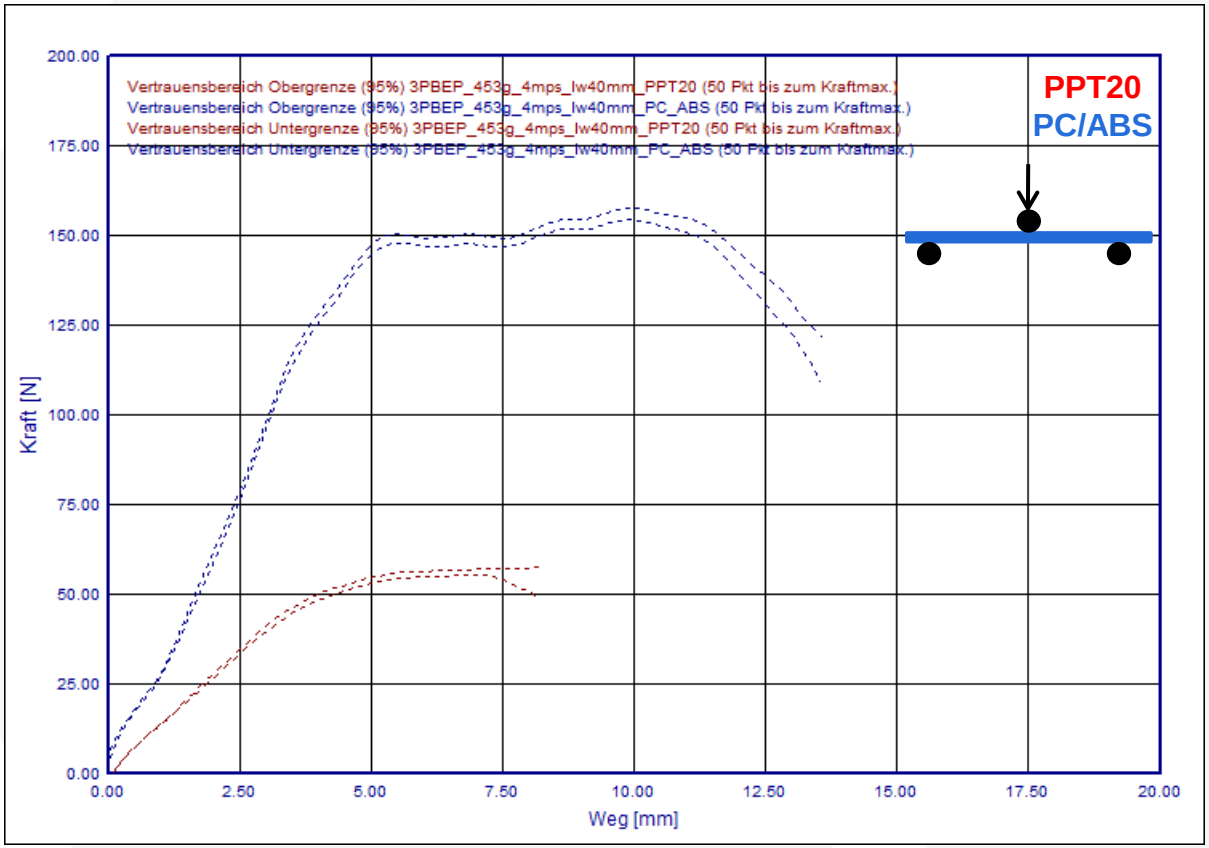
4a impetus Messergebnis

Punktwerte, statistische Auswertung in der Software



- Vertrauensbereich beider Materialien (Konfidenzniveau 95%)
- 95 % aller durchgeführten Messungen, welche im dargestellten Bereich liegen, beinhalten den Mittelwertverlauf.

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4a impetus typisches Prüfprogramm
isotrope Materialien Prüfplanbeispiel

- Die folgende Tabelle zeigt einen beispielhaften Prüfplan für Biegeversuche. Es werden 5 Wiederholungen je Test-Setup bei 23°C durchgeführt.

Test-Setup	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]	έ * [1/s]
3PB_stat_low_velo	**0.0001**	**40**	**-**	**10**	**2**	**50**	**0.00075**
3PB_stat_high_velo	**0.001**	**40**	**-**	**10**	**2**	**50**	**0.0075**
3PB_dyn_low_velo	**1**	**40**	**500 – 2000**	**10**	**2**	**50**	**7.5**
3PB_dyn_med_velo	**2.5**	**40**	**500 – 1000**	**10**	**2**	**50**	**18.75**
3PB_dyn_high_velo	**4**	**30**	**500 – 1000**	**10**	**2**	**40**	**53.3**

* erwartete Anfangsdehnrate

- Zusätzlich können dynamisch gespannte Biegungen, Zug oder T-Proben durchgeführt werden, um eine mögliche Zug/Druckasymmetrie zu erfassen.

Test-Setup	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]	έ * [1/s]
3PBG_dyn_high_velo	**4**	**40**	**1000-2000**	**10**	**2**	**100**	**30**
Zug_stat	**0.00025**	**36**	**-**	**10**	**2**	**120**	**0.007**

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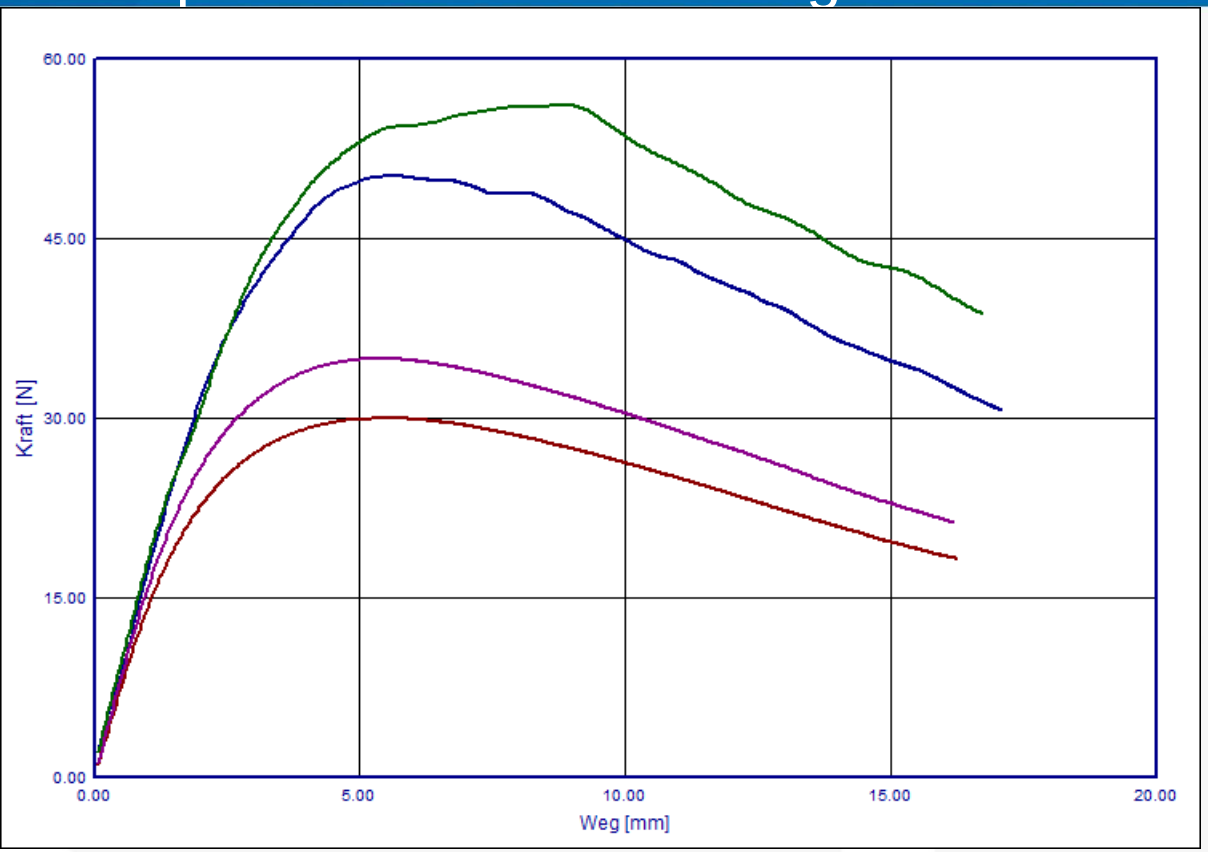
4a impetus typisches Prüfprogramm
isotrope Materialien Messergebnisse



v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
0.0001	40	0	10	2.4	50
0.001	40	0	10	2.4	50
1	40	1977	10	2.4	50
4.4	40	1977	10	2.4	50

- Messergebnis 3-Punkt-Biegung → **Dehnratenabhängigkeit direkt erkennbar bei** Messungen mit **gleichem Auflagerabstand** und unterschiedlicher Prüfgeschwindigkeit

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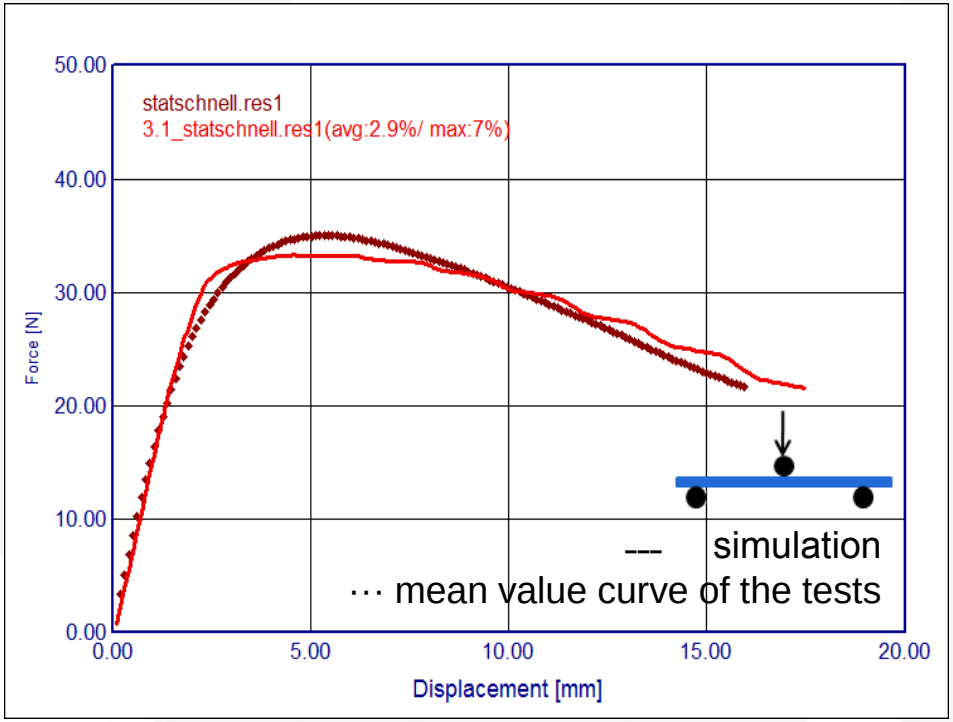
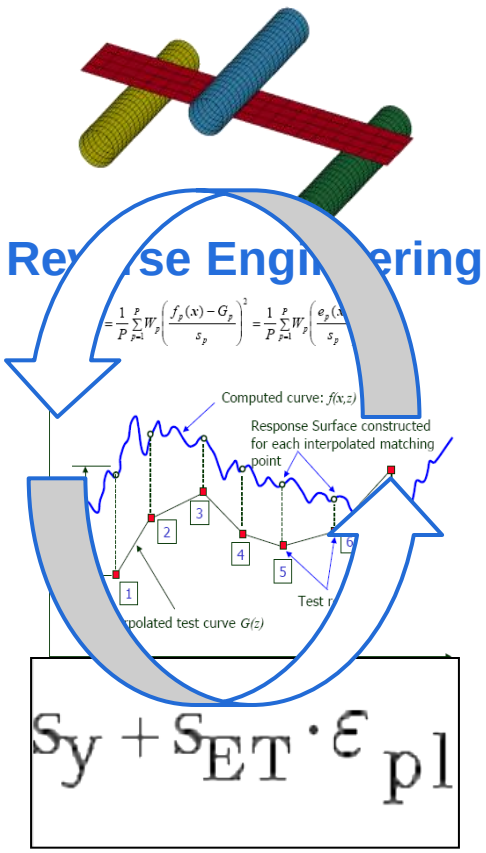
4a impetus typisches Prüfprogramm
isotrope Materialien Reverse Engineering

Reverse Engineering 4a impetus

(*PLASTIC)



FE-Model of the test



parameterized material card

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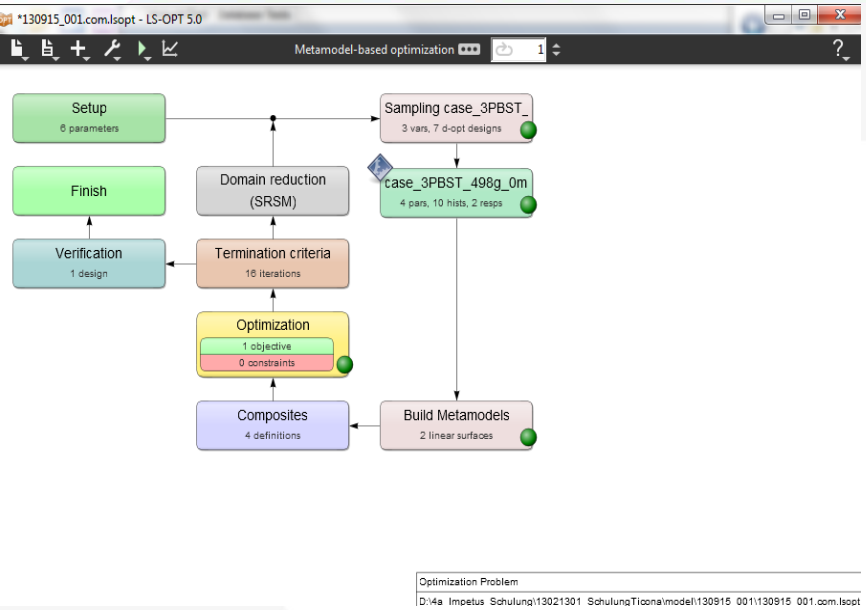
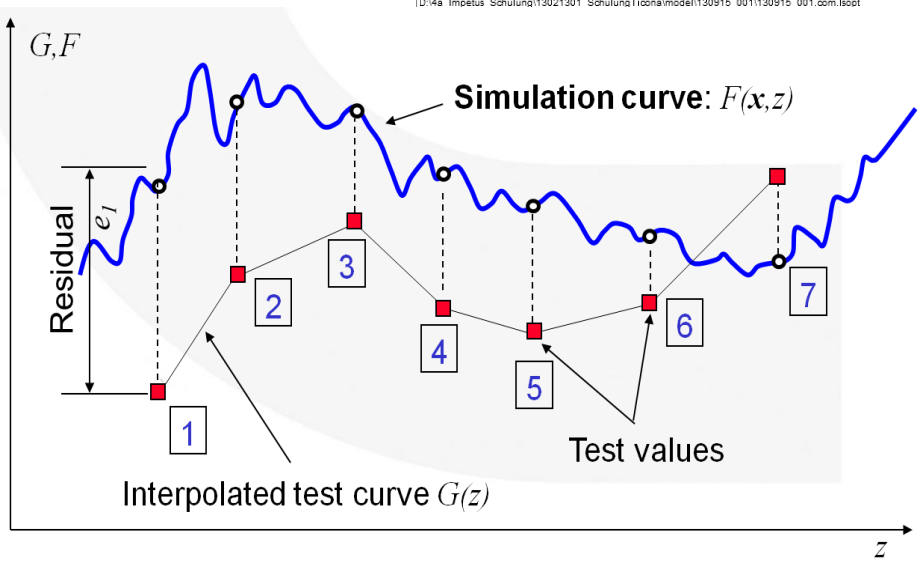
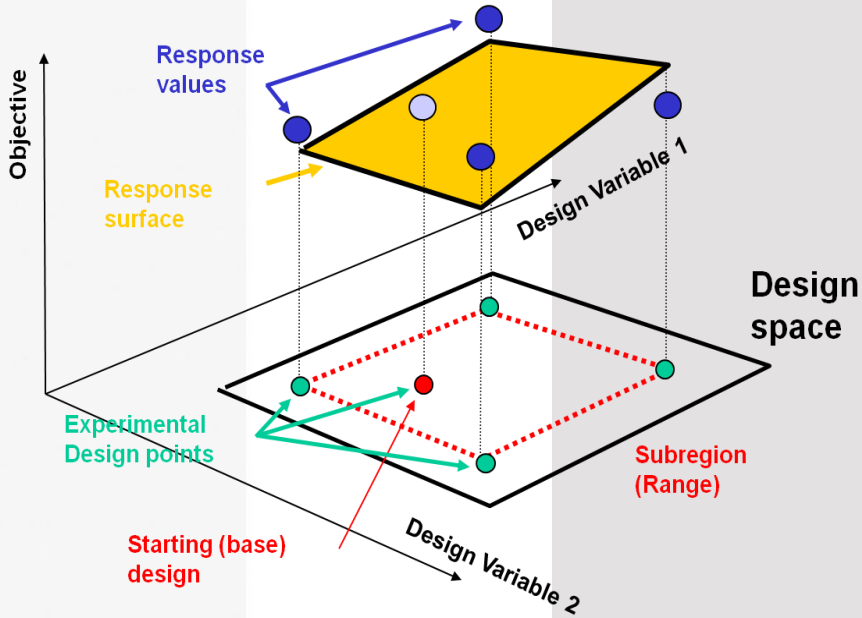
4a impetus typisches Prüfprogramm
isotrope Materialien LS-OPT Prozess





Sequential Response Surface Method



Mean Squared Error

$$MSE(\mathbf{x}) = \frac{1}{P}\sum_{i=1}^{P} W_i \left(\frac{F_i(\mathbf{x}) - G_i}{S_i} \right)^2 \rightarrow \min$$

Bildquelle: CAE Companion 2015/2016

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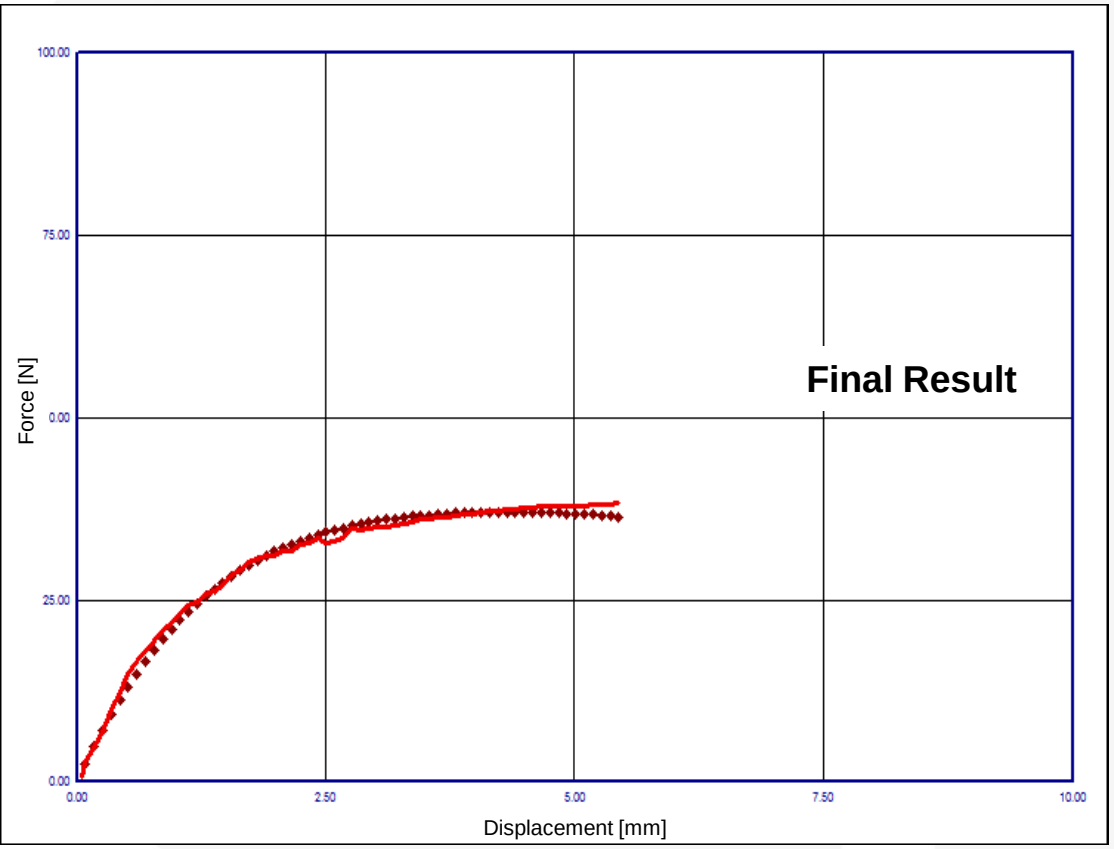
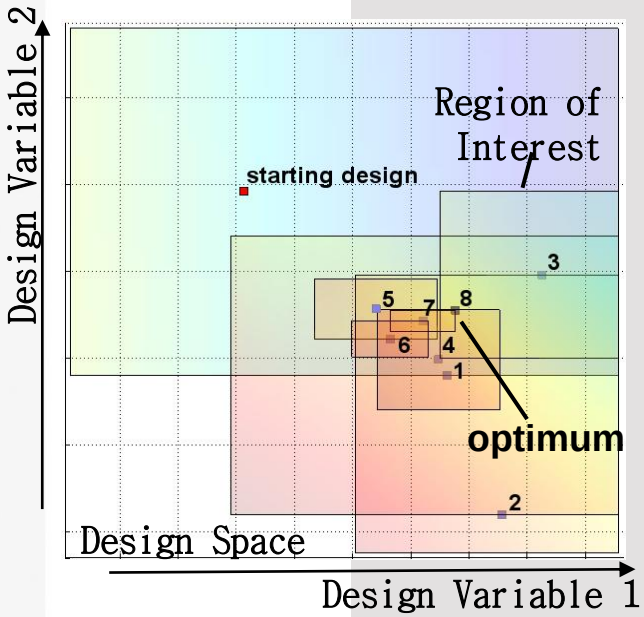
4a impetus typisches Prüfprogramm
isotrope Materialien Fließkurve

- Parameter Identifikation





Bildquelle: CAE Companion 2015/2016

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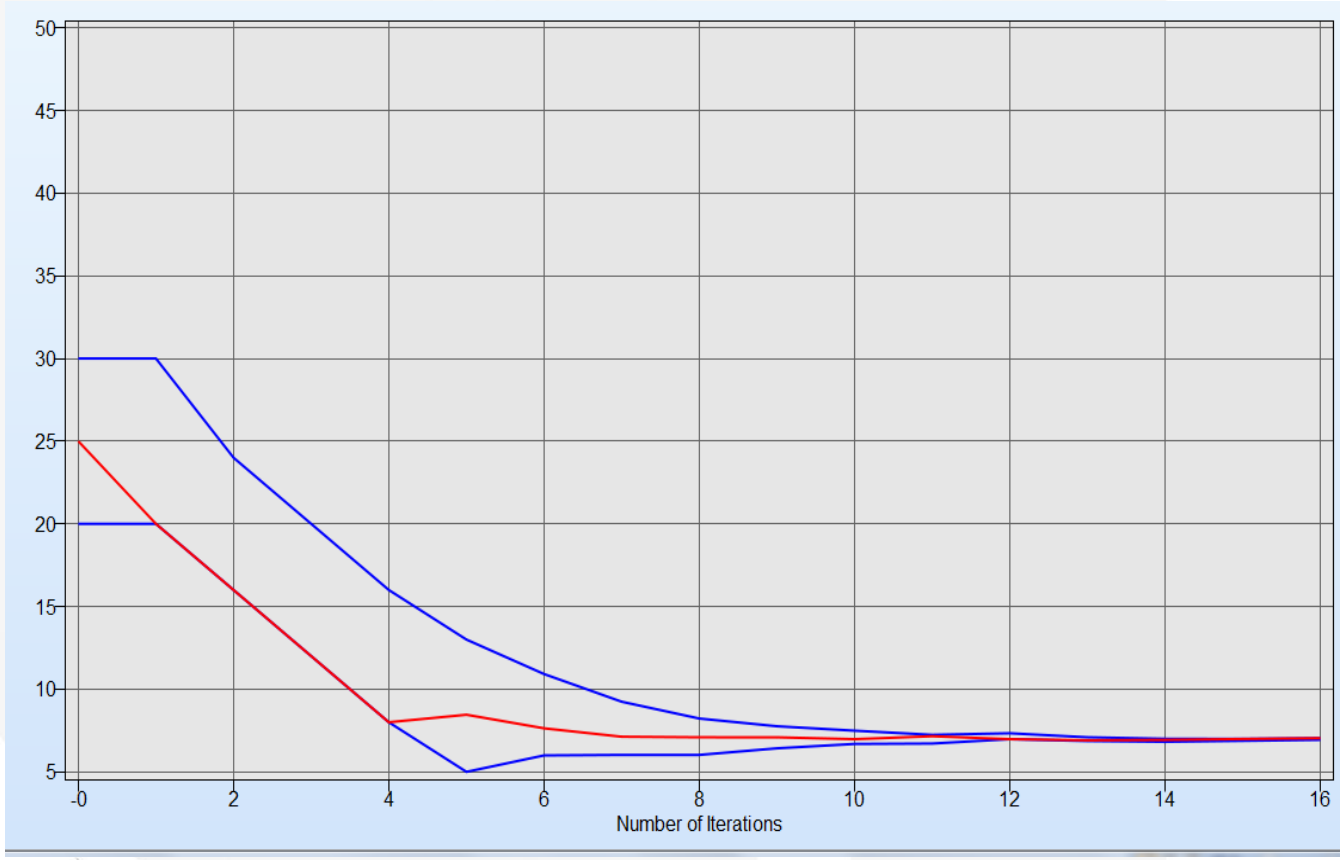
4a impetus typisches Prüfprogramm
isotrope Materialien Fließkurve

- Entwicklung der design variable σ_y



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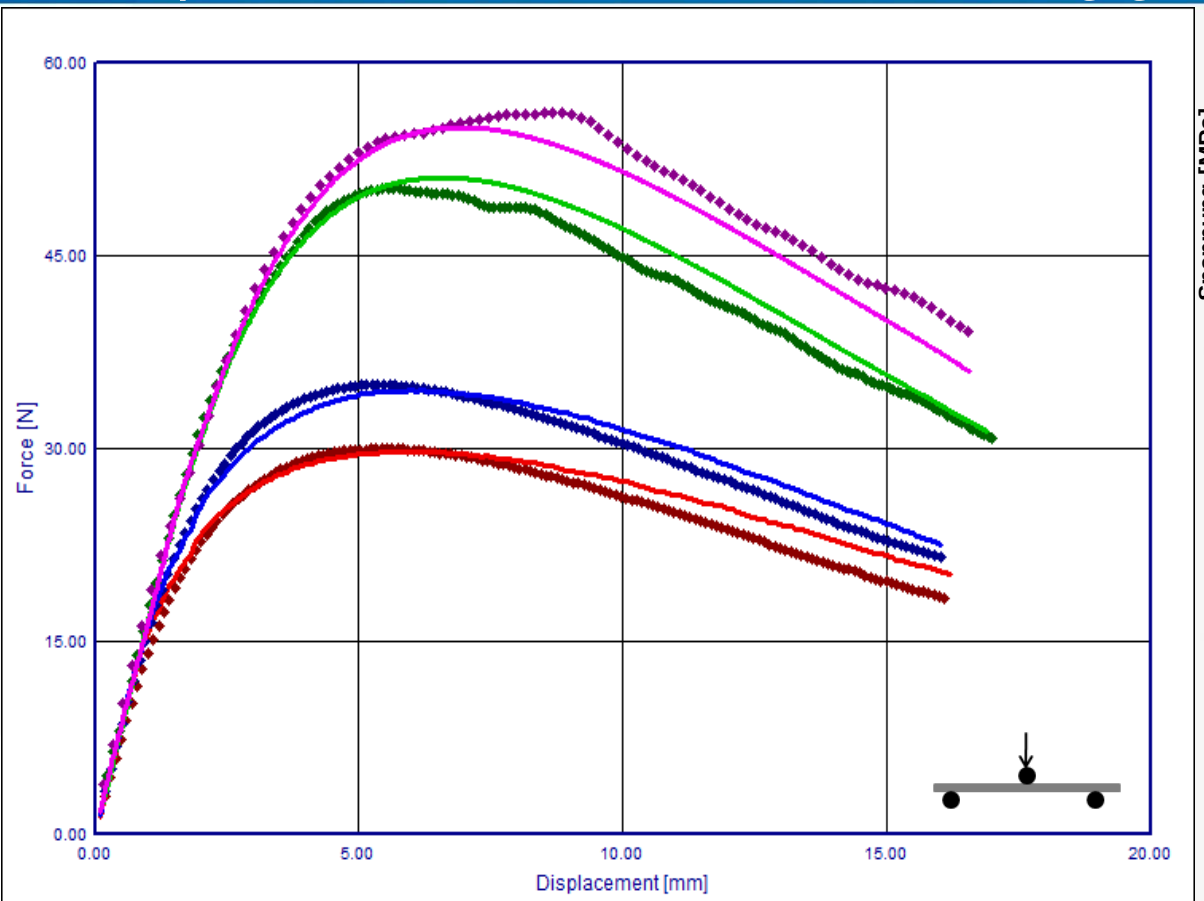
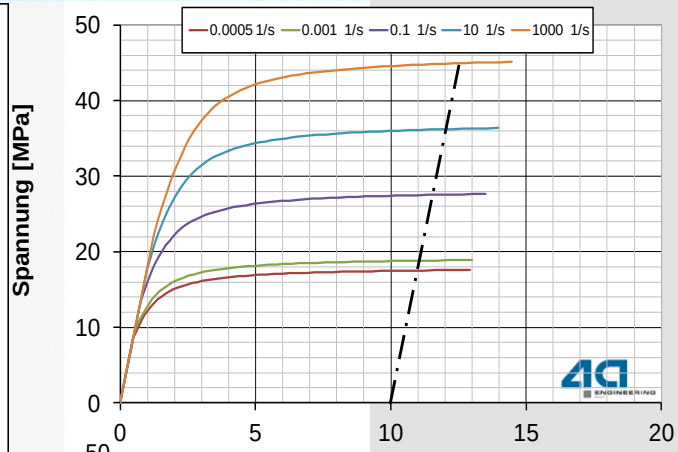
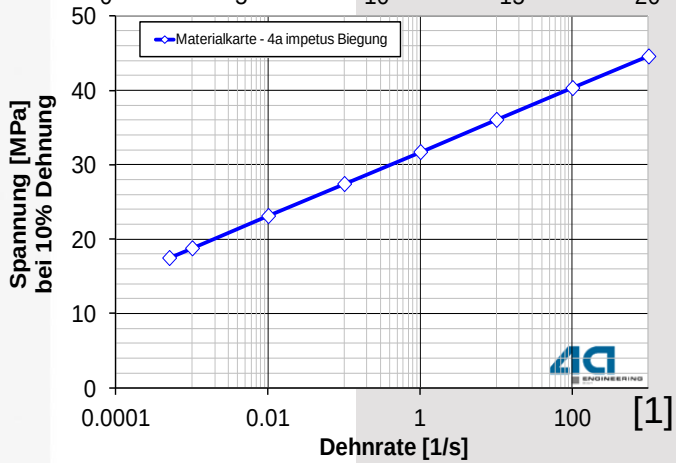
4a impetus typisches Prüfprogramm
isotrope Materialien Dehnratenabhängigkeit







[1]

Geschw. [mm/s]	Auflagerabstand [mm]	Dehnrate [1/s]
0.1	40	0.002
1	40	0.02
1000	40	11
3000	40	80

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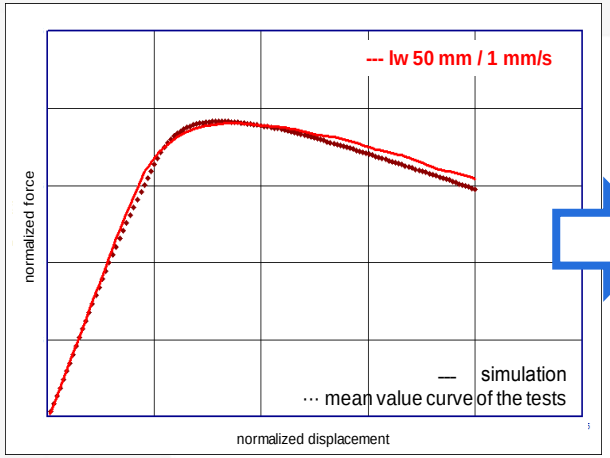
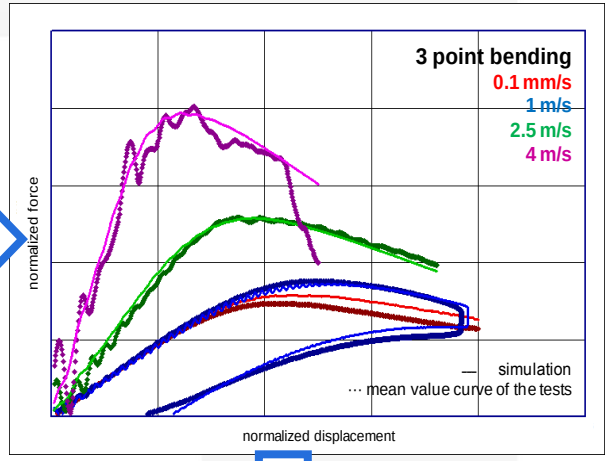
4a impetus typisches Prüfprogramm
isotrope Materialien Workflow

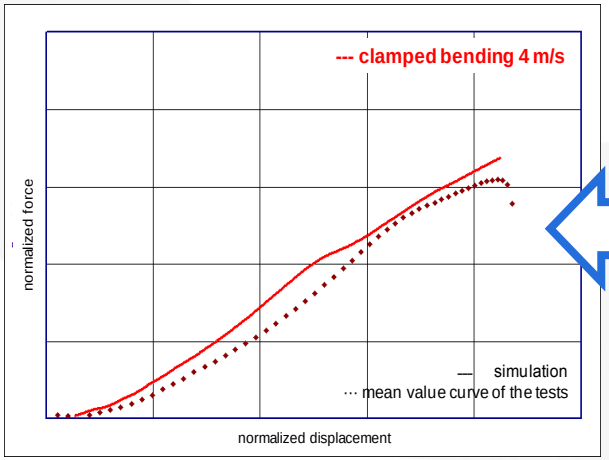
Reverse Engineering 4a impetus



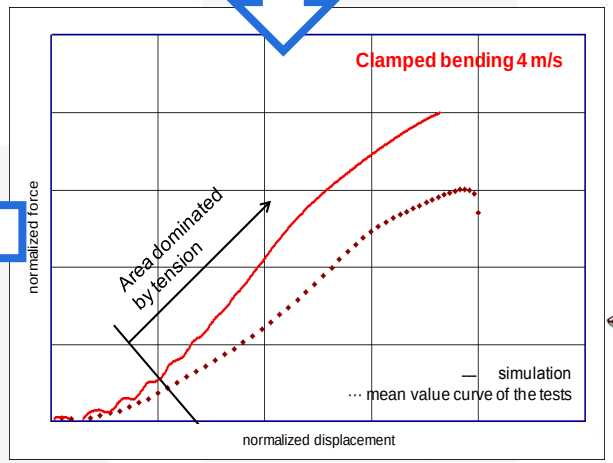
static behavior - yield



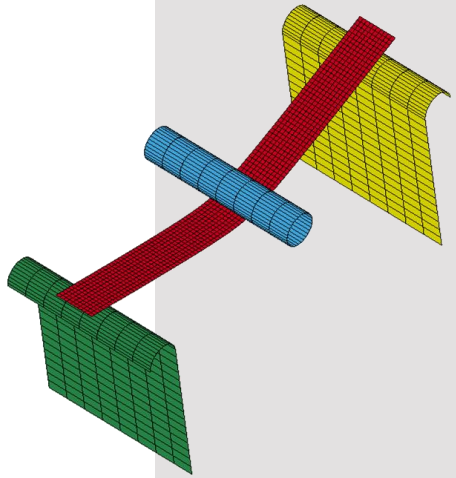
dynamic behavior – strain rate

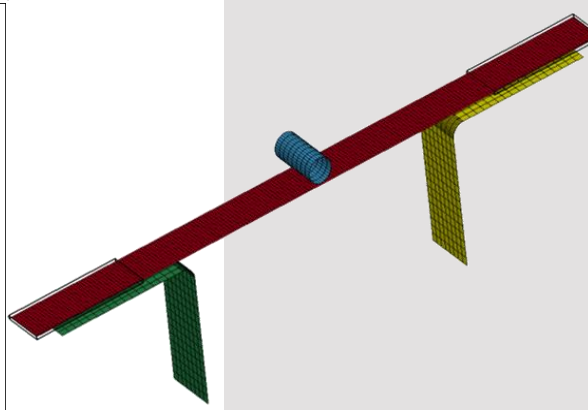


fit compression/tension behavior



check compression/tension behavior





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4a impetus typisches Prüfprogramm
verstärkte Materialien - Prüfplanbeispiel

- Die folgende Tabelle zeigt einen beispielhaften Prüfplan für Biegeversuche. Es werden 5 Wiederholungen je Test-Setup bei 23°C durchgeführt.

Test-Setup	v_0 [m/s]	l_w [mm]	$m_{Pendulum}$ [g]	b [mm]	t [mm]	l [mm]	ε̇ * [1/s]
3PB_stat_low_velo (0°,90°)	0.0001	40	-	10	2.8	50	0.00105
3PB_stat_high_velo (0°, 45°, 90°)	0.001	40	-	10	2.8	50	0.01050
3PB_dyn_low_velo (0°, 90°)	1	40	500 – 2000	10	2.8	50	10.50
3PB_dyn_med_velo (0°, 45°, 90°)	2	40	500 – 1000	10	2.8	50	21.00
3PB_dyn_high_velo (0°, 90°)	4	30	500 – 1000	10	2.8	40	74.67
3PBG_dyn_ high_velo (90°)	4	40	1000-2000	10	2.8	75	42.00
DST_stat_high_velo	0.001	40	-	80	2.8	80	-
DST_dyn_high_velo	3	40	4300	80	2.8	80	-

* erwartete Anfangsdehnrate

- Hinsichtlich der Anisotropie werden zusätzliche statische Versuche in Faserrichtung und unter 45° zur Faserrichtung durchgeführt.

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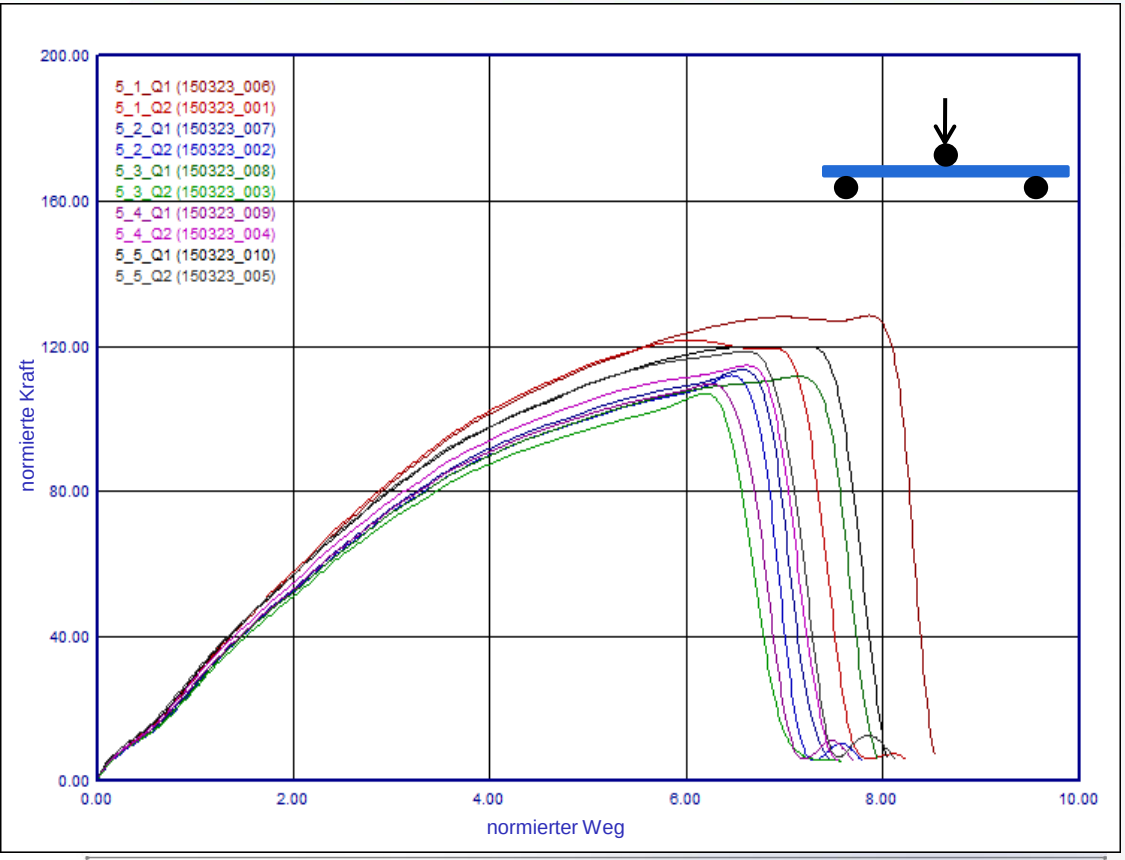
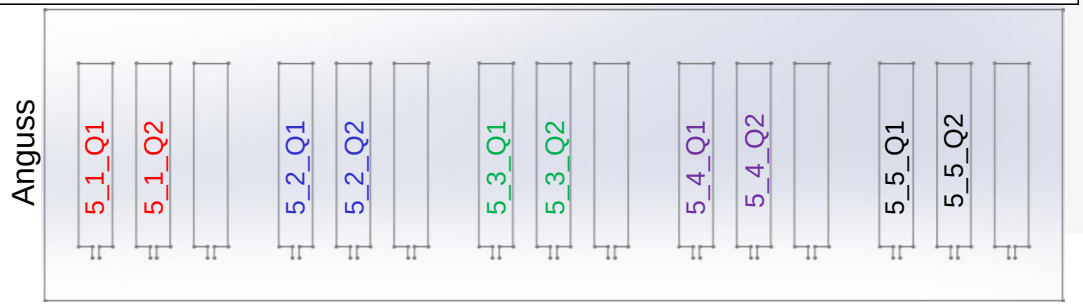
4a impetus typisches Prüfprogramm
verstärkte Materialien Probenposition





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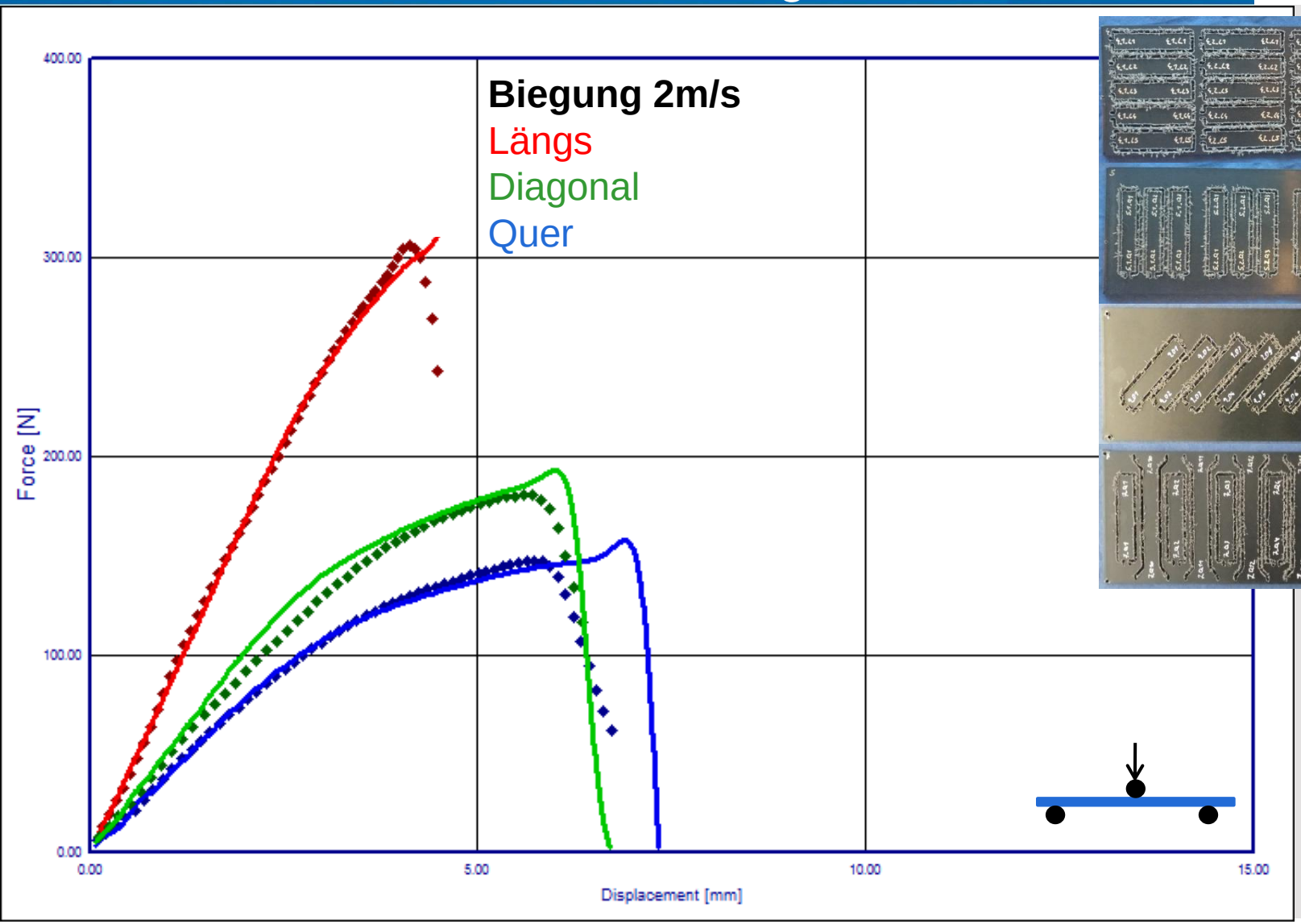
4a impetus typisches Prüfprogramm

verstärkte Materialien Orientierung



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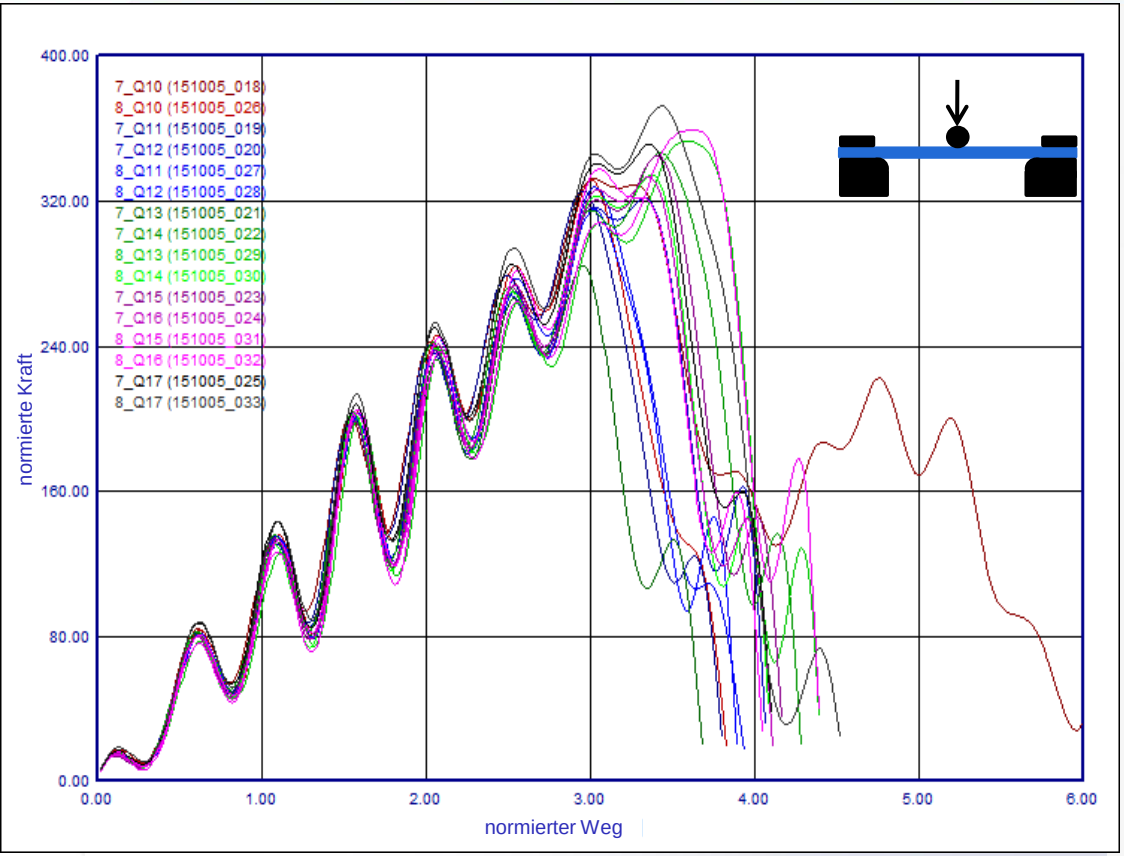
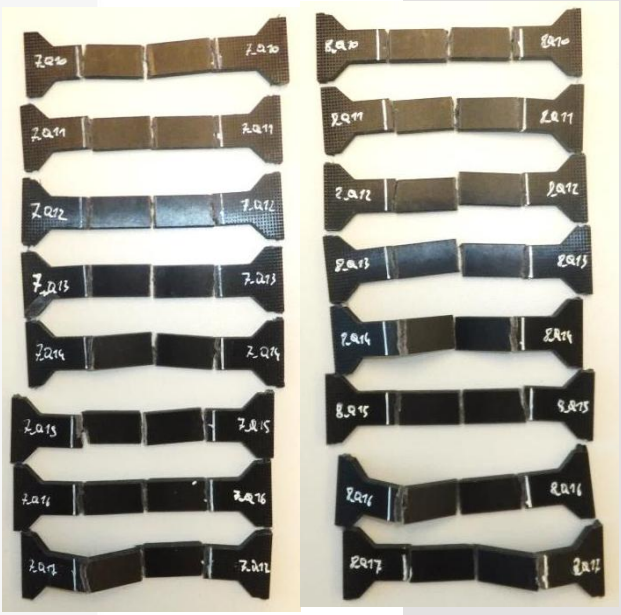
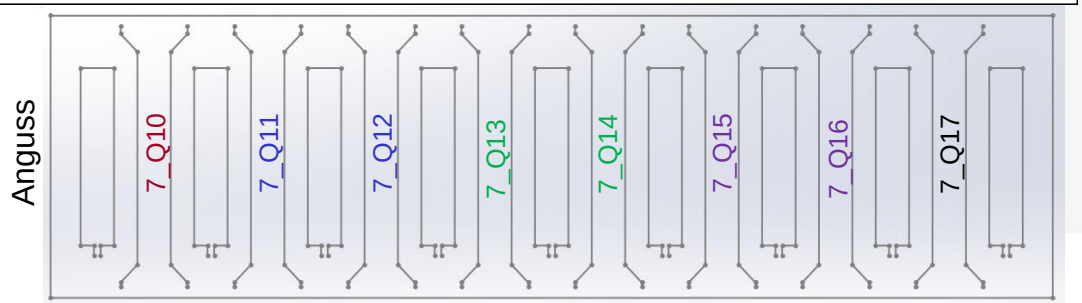
4a impetus typisches Prüfprogramm
verstärkte Materialien



v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
4	**40**	**956**	**10**	**2.8**	**75**





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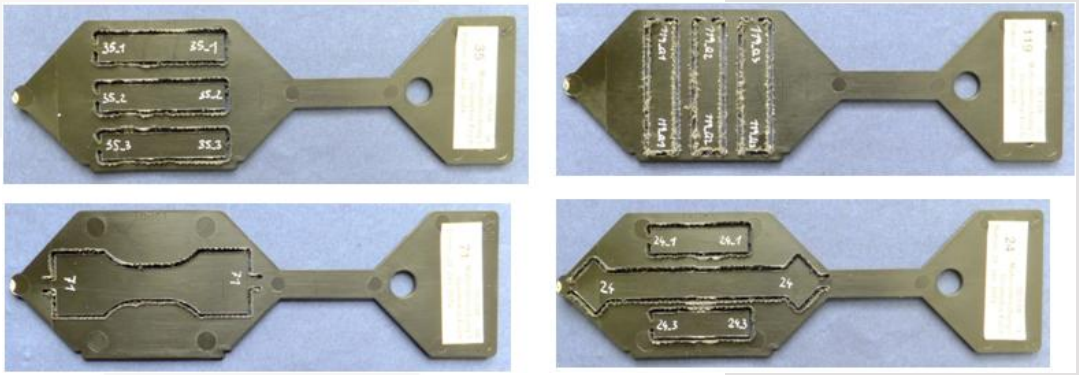
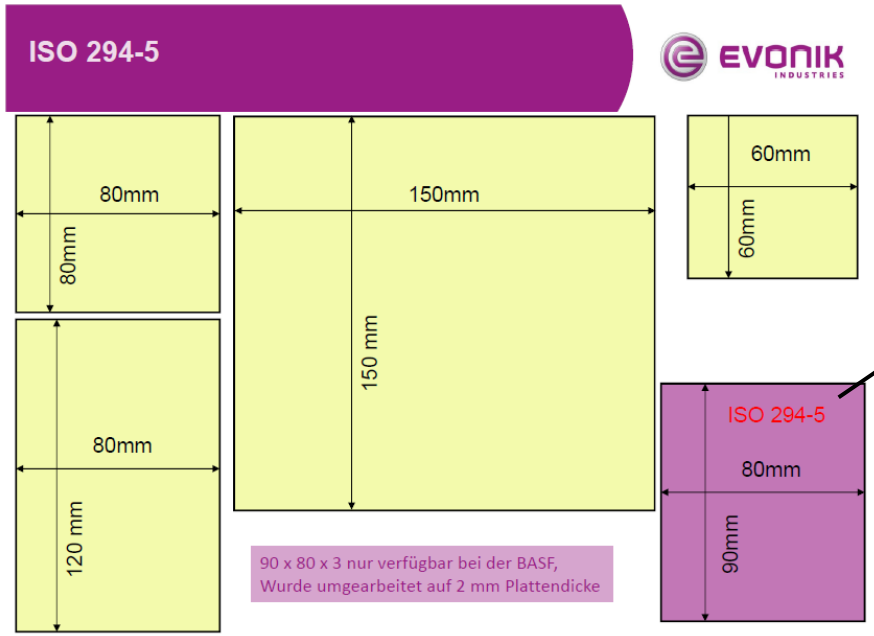
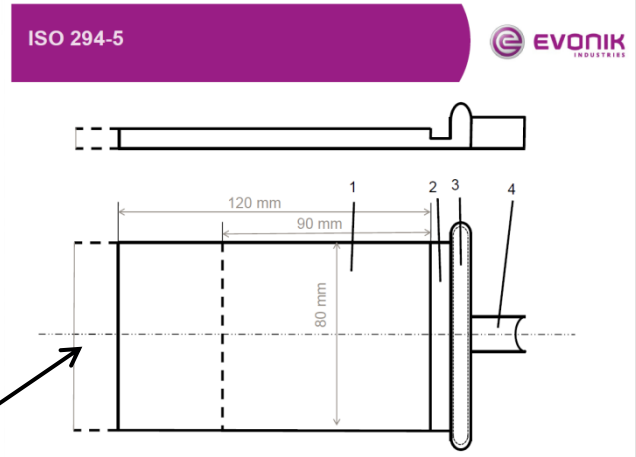
Probenherstellung und Probenentnahme
Probenherstellung

- Spritzguss Probenherstellung
  - Fisch



  - quadratische vs. rechteckige Platte (ISO 294-5)





Revision ISO 294-5
CAMPUS Anisotropiekennwerte auf
Basis 120 x 80 x 2 mm

Quelle: Symposium Zwick/Ulm, R. Tuellmann: Anisotropie in ISO und CAMPUS

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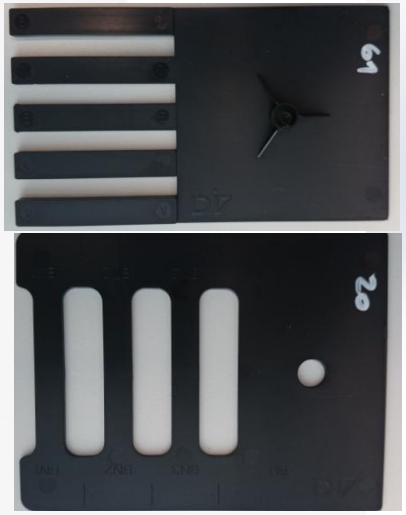
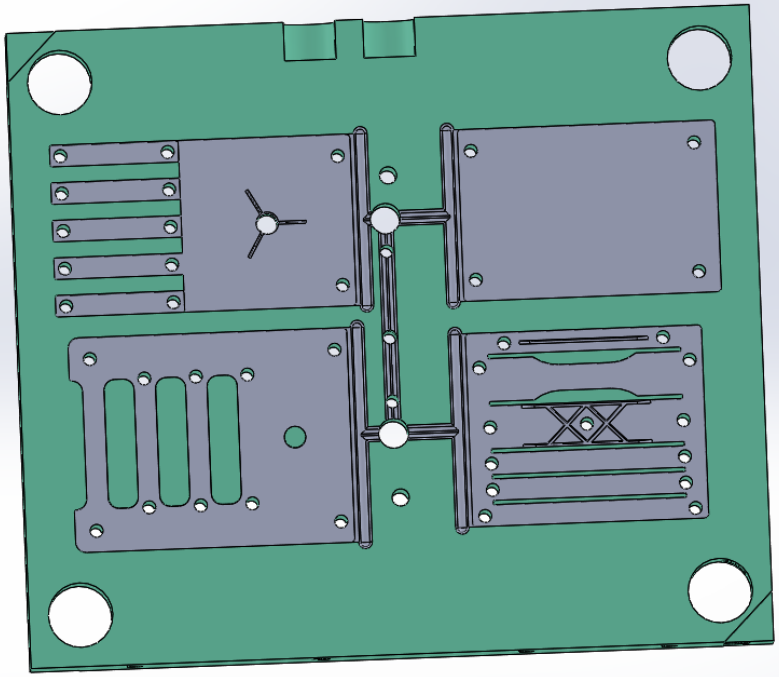
Probenherstellung und Probenentnahme
Probenherstellung

- Spritzguss Probenherstellung
  - 4a Plattenwerkzeug





Platte 120 x 80 x 2 mm

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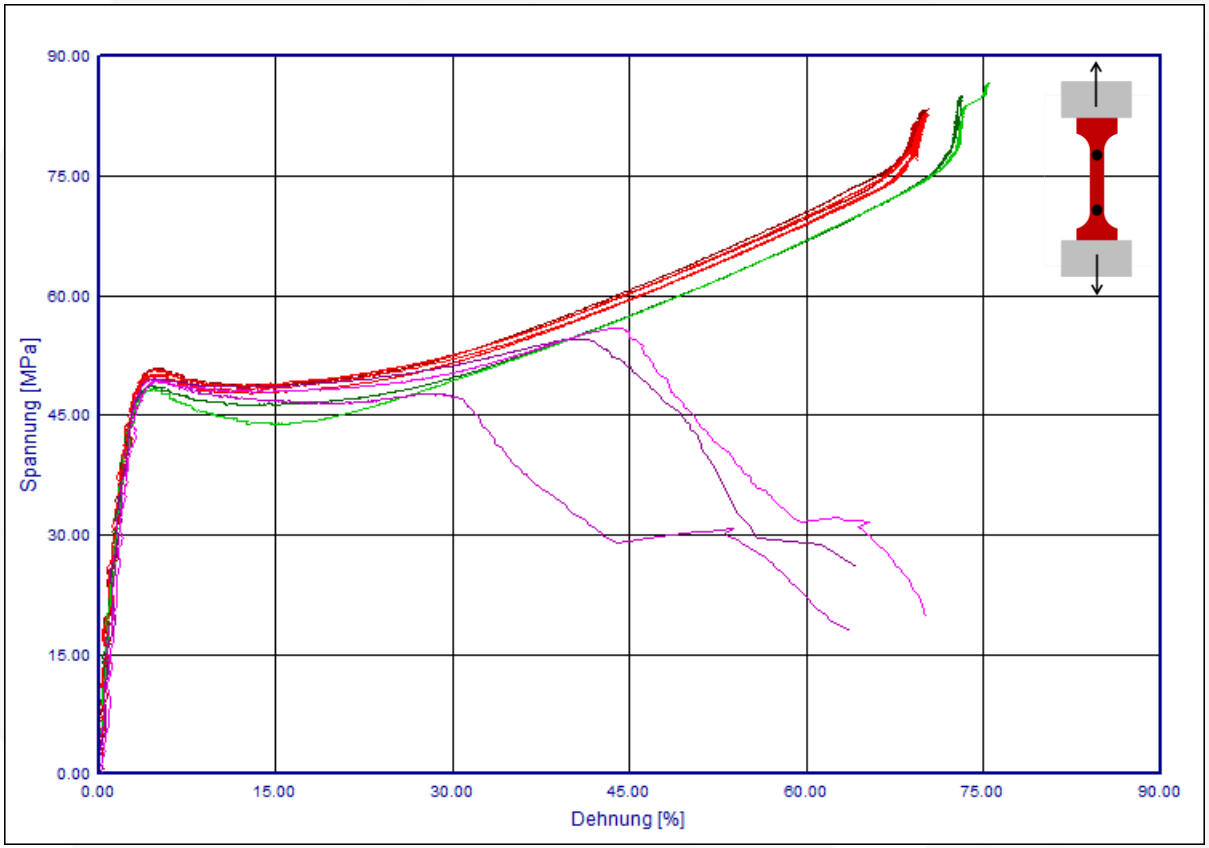
Probenherstellung und Probenentnahme

Probenentnahme



v_0 [m/s]	l_w [mm]	$m_{Pendular}$ [g]	b [mm]	t [mm]	l [mm]
0.0002	50	-	12	2,13	90
0.0002	40	-	10	1,9	75
0.0002	40	-	10	1,9	75

Zugprobe gespritzt

Originalplatte gefräst

Originalplatte Wasserstrahl

- Dargestellt ist der Einfluss der Probenentnahmeart für ein unverstärktes Material.
- Bei der Probenentnahme aus Platten bzw. Bauteilen soll eine möglichst glatte Oberfläche erzielt werden (nachträgliche Schleif- oder Poliertätigkeiten unbedingt in Probenlängsrichtung ausführen).

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Live-Messungen

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