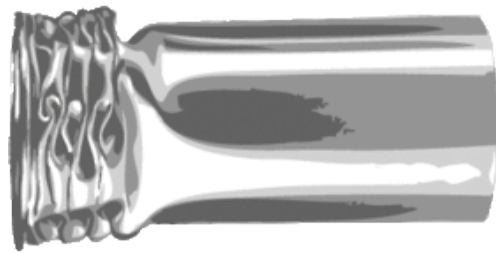


Dynamische Materialcharakterisierung von Composites mit 4a impetus

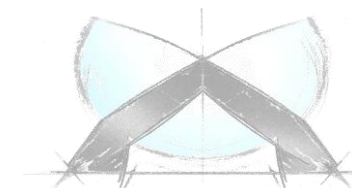
A. Fertschej, B. Jilka, P. Reithofer (4a engineering GmbH)

F. Rudolph, B. Fellner (Magna Steyr Fuel Systems, Magna Steyr Engineering Austria)



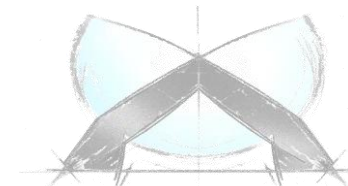
***crash*MAT**
Freiburg

**7. Freiburg Workshop
zum Werkstoff- und Strukturverhalten
bei Crashvorgängen
22. - 23. April 2015**



in physics we trust

- Einleitung
- Faserverbundkompetenz
- Materialcharakterisierung
- Kurzfaserverstärkte Kunststoffe
- Glasfaserverbund + Waben
- Organoblech
- CFK Gelege - Gewebe



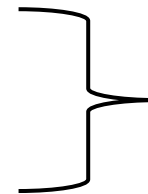
in physics we trust

➤ grobe Einteilung

- Identifizierung von Materialzusammensetzungen
- Bestimmung des „Charakters“ eines Materials
- Chemische / Physikalische / Optische Methoden
- Zerstörungsfreie und **zerstörende Prüfverfahren**

➤ Einsatzgebiete

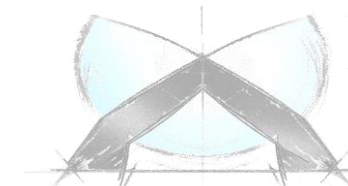
- Materialentwicklung / Vergleich
- Qualitätssicherung
- Entwicklung / Auslegung



Firmenstandards
Normen

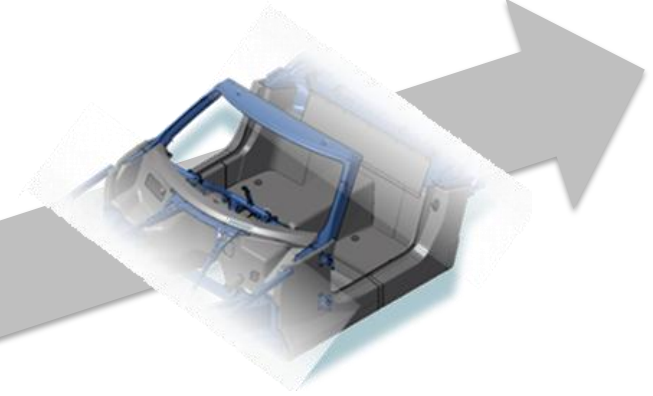
➤ **Simulation**

„Man nimmt was man kriegt !“



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Qualifizierungsprojekte



1970

2004

2010

2015

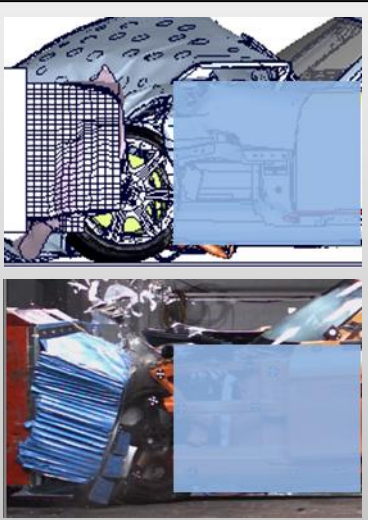
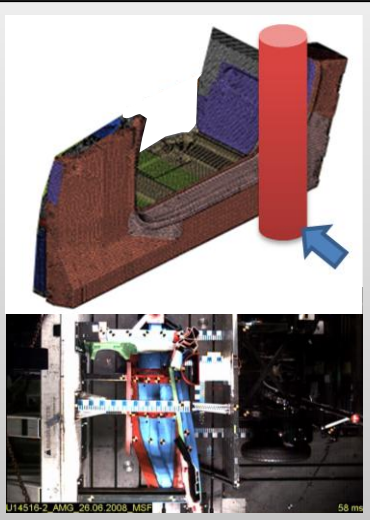
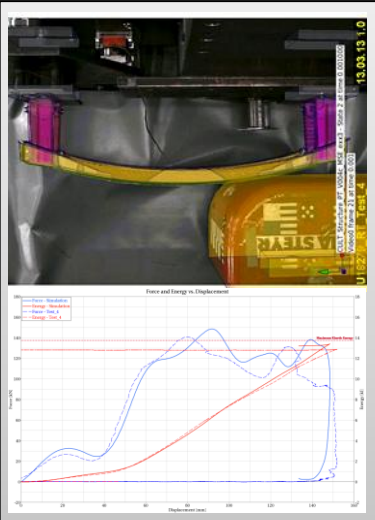
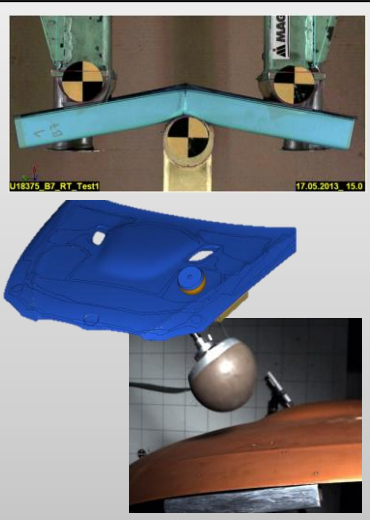
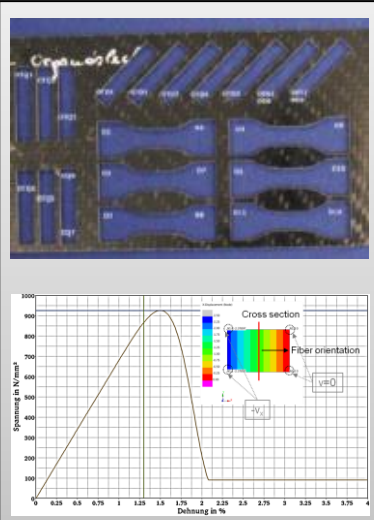
kurzfaser-
verstärkte
Thermoplaste

GFK + Waben

Organoblech

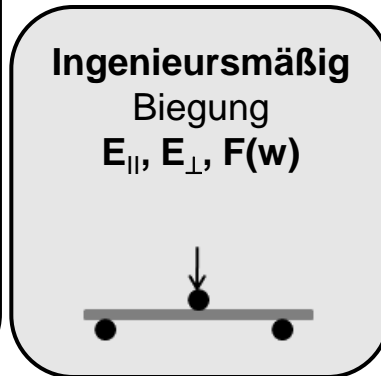
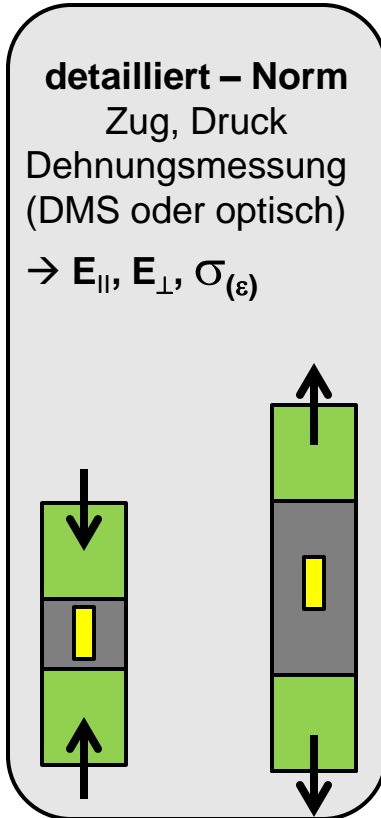
CFK Gelege
+Gewebe

Mehrstufiger Ansatz



Aufwand
Kosten
Zeit

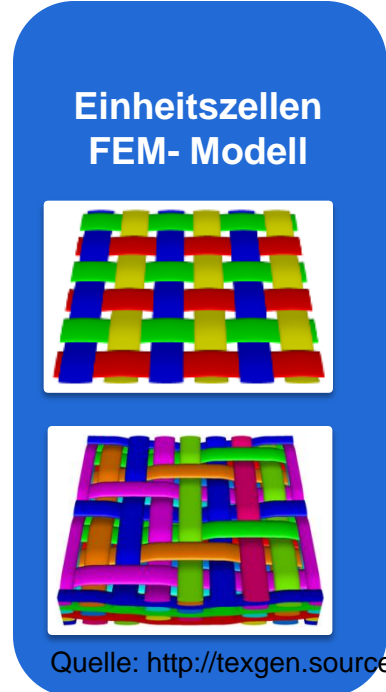
Versuch - zerstörende Prüfung
unterschiedliche Richtungen
 $0^\circ, 45^\circ, 90^\circ$



Virtuelle Methoden
Homogenisierung

$$\underline{\underline{\sigma}}^V = (1 - \varphi) \cdot \underline{\underline{\sigma}}^M + \varphi \cdot \underline{\underline{\sigma}}^F$$

$$\underline{\underline{\sigma}}^F = \underline{\underline{B}}^\sigma \underline{\underline{\sigma}}^M$$



Quelle: <http://texgen.sourceforge.net/>

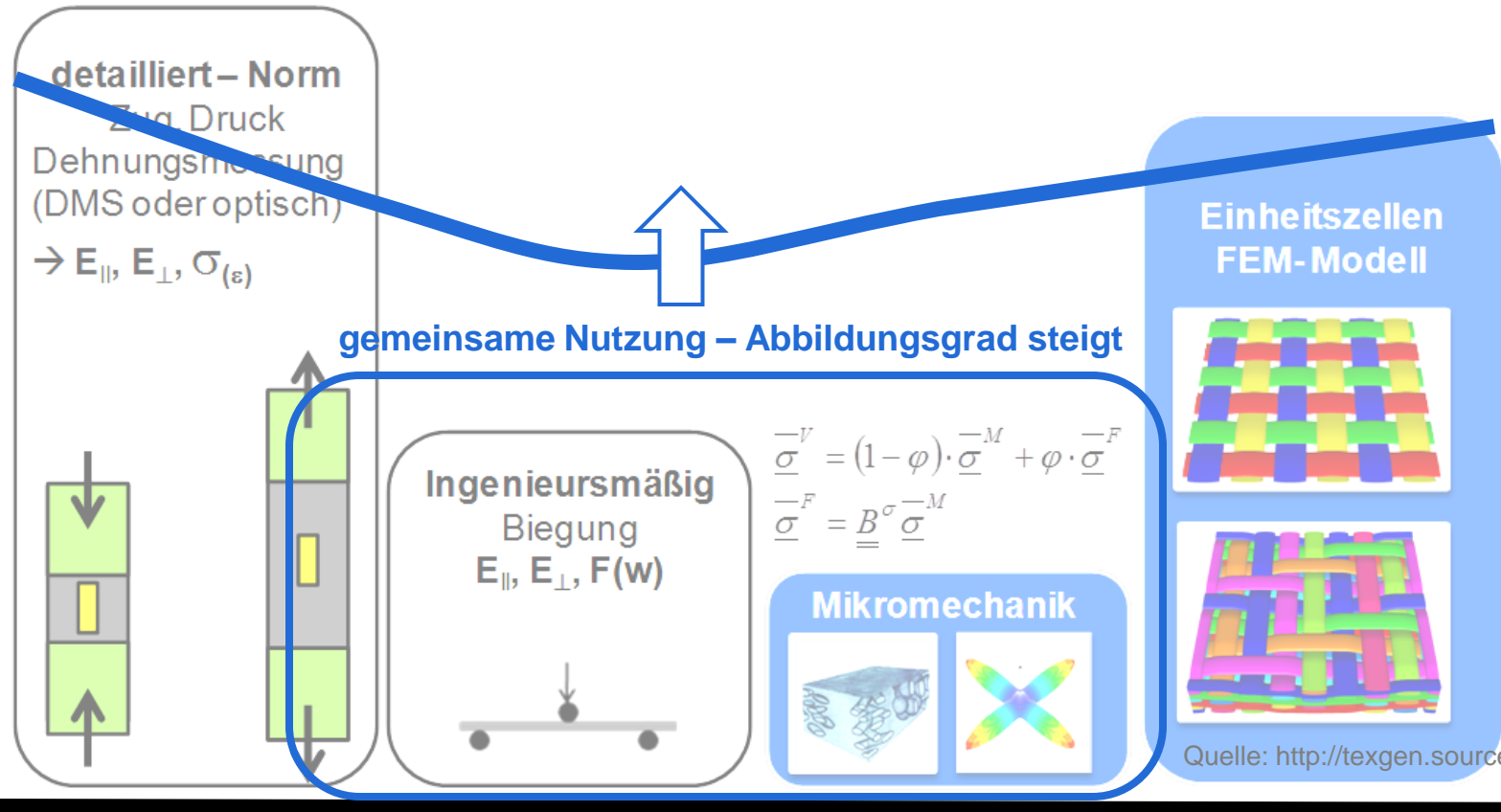
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Abbildung

**Versuch - zerstörende Prüfung
unterschiedliche Richtungen**

**Virtuelle Methoden
Homogenisierung**

100% (Real)



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Input

Kennwerte der
Komponenten (E, α, λ)

Matrix
Verstärkungsstoffe

Datenbank

Faser- und Partikel
Orientierung

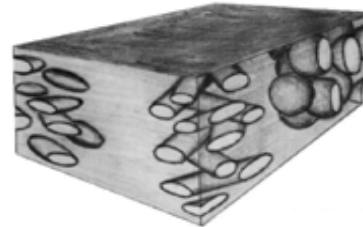
Datenbank

Faser- und Partikel
Gestalt

Datenbank



MicroMec V3.1



MeanField-Theory
3D-Lam-Theory
spezielle Funktionen



Output

3-D Verbundkennwerte

elastischer Tensor

thermischer
Ausdehnungstensor

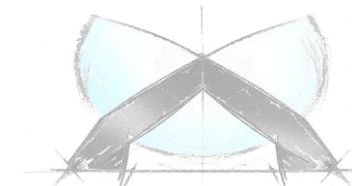
Wärmeleitfähigkeitstensor

Schnittstelle zu
FE-Codes

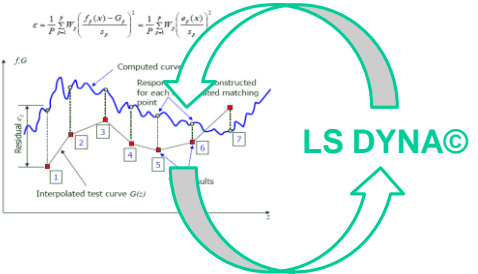
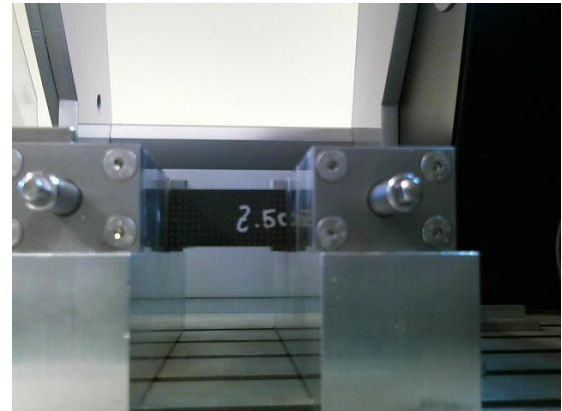
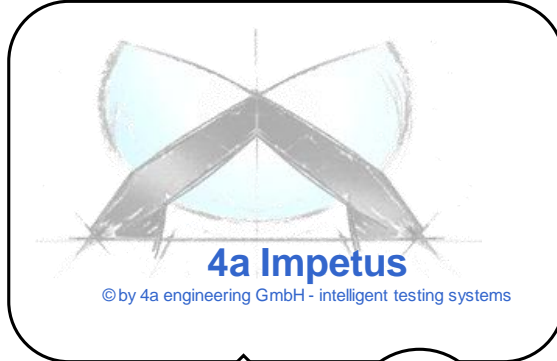
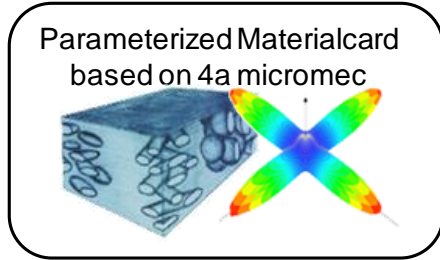
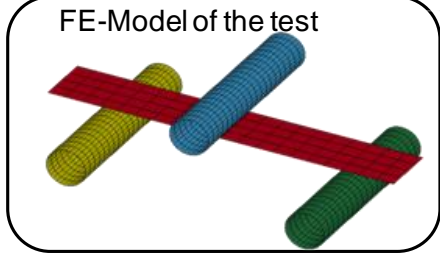
Anwendung im Hause 4a

- Partikel verstärkte Thermoplaste
- kurzglasfaserverstärkte Thermoplaste
- langglasfaserverstärkte Thermoplaste
- endlosfaserverstärkte Kunststoffe

GFK, CFK → UD, Gewebe



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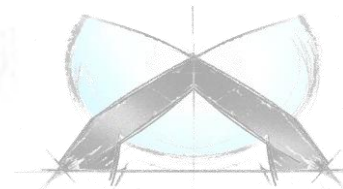
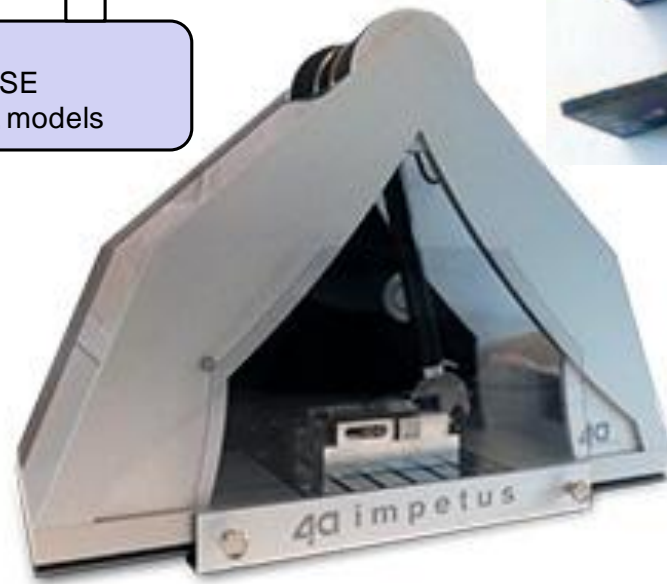


LS DYNA©

Reverse Engineering

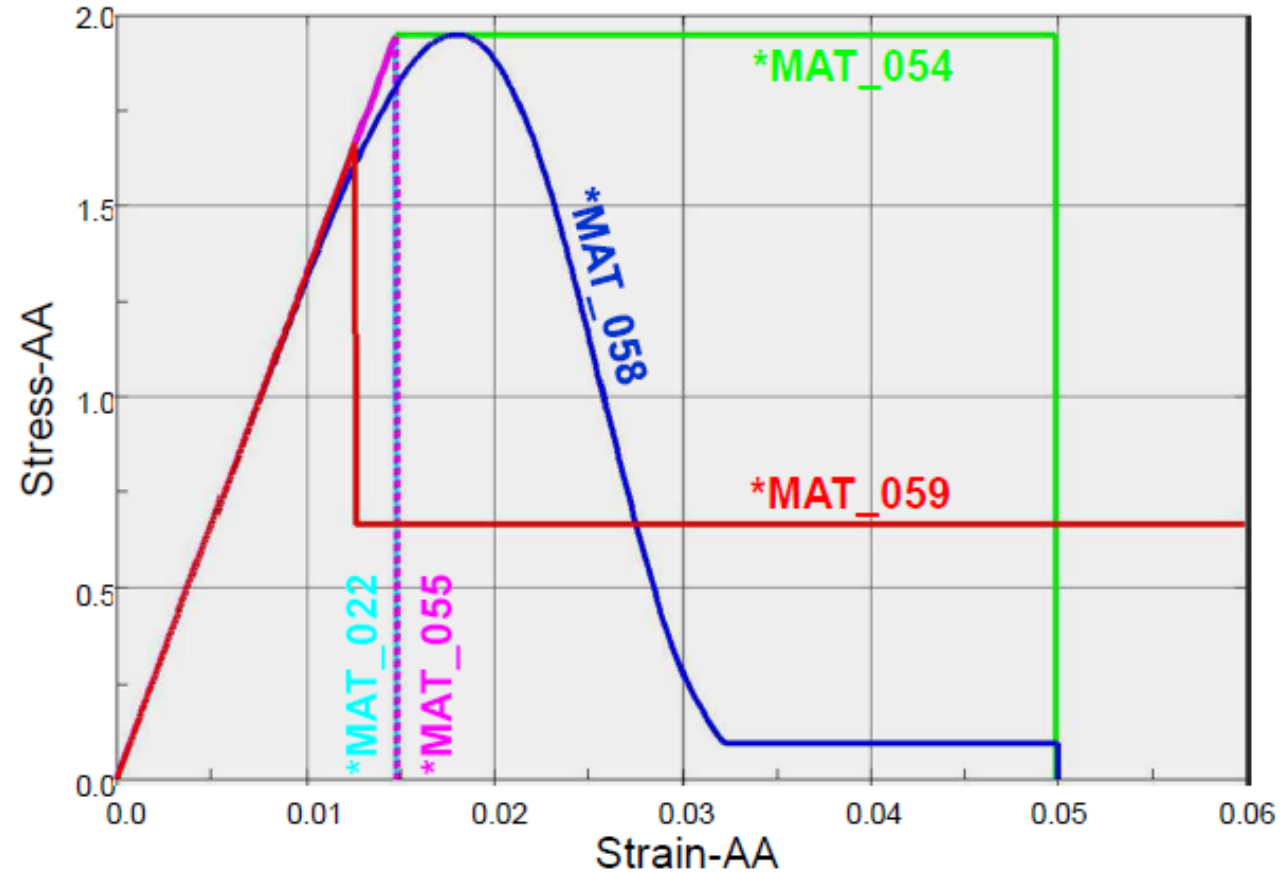
LS PREPOST©

DATABASE
measurement, models

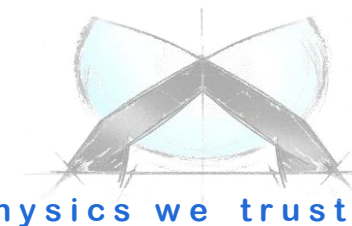


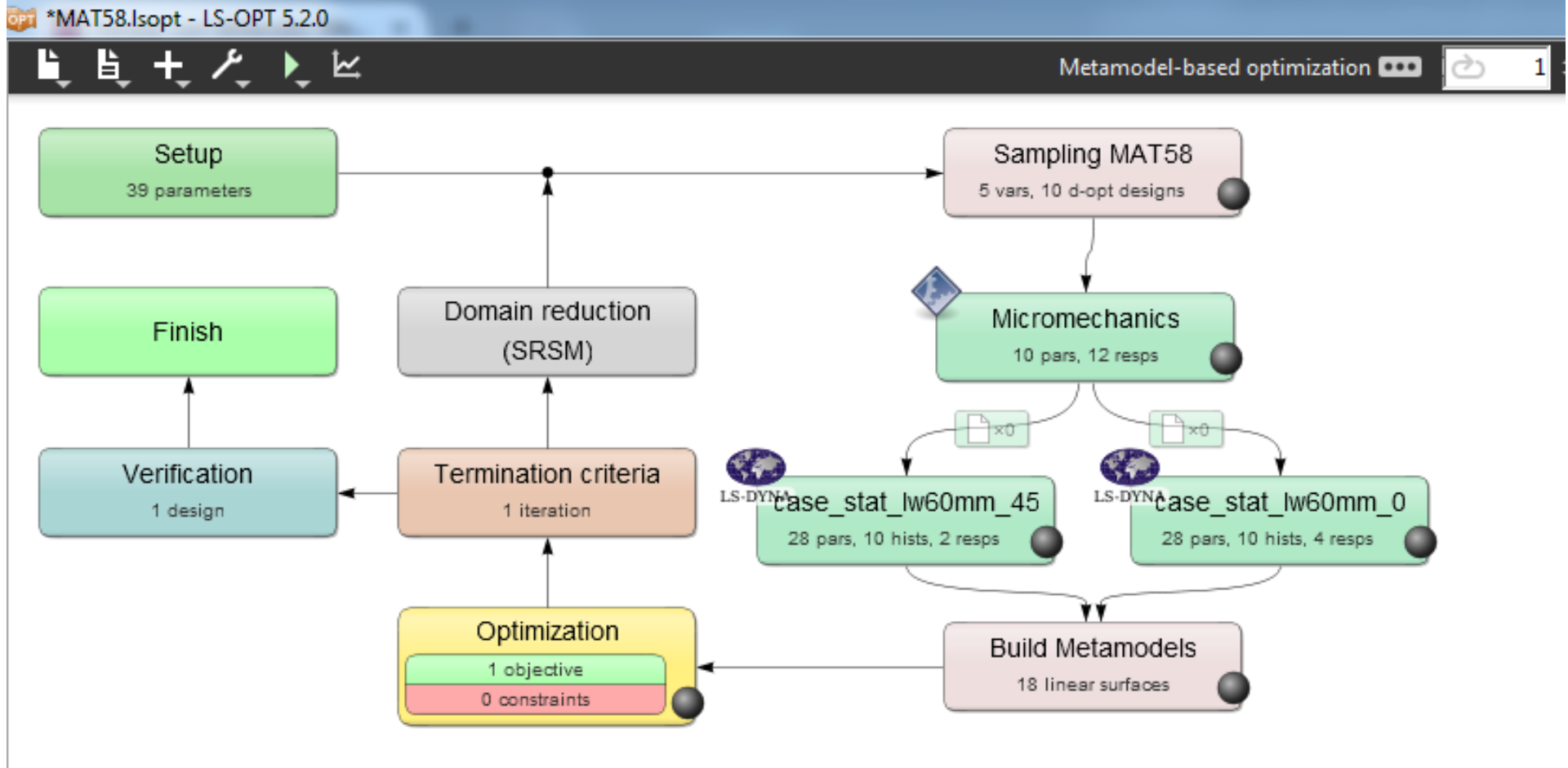
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- Steifigkeit
 - Anisotropie
- Festigkeit
 - Pauschal
 - Hauptrichtung
- Energieaufnahme
 - Fit-Parameter



Quelle: LS-Dyna Manual, <http://www.dynamore.de/>





OPT *MAT58.Isopt - LS-OPT 5.2.0

Problem global setup

Parameter Setup | Stage Matrix | Sampling Matrix | Resources | Features

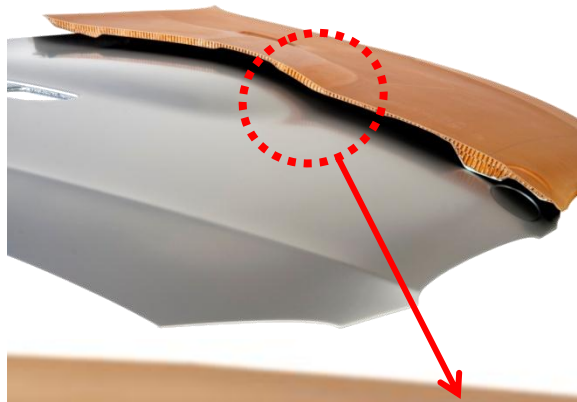
Show advanced options

Type	Name	Starting	Minimum	Maximum
Constant	rohM	0.9		
Constant	EM	1540		
Constant	nueM	0.406		
Constant	rohF	2.6		
Constant	EF	72500		
Constant	nueF	0.22		
Constant	l	0.3		
Constant	d	0.01		
Dependent	aspect	Definition: l/d		
Continuous	PSI	0.4	0.1	0.5
Response Variable	z_E1	Micromechanics_E11		
Response Variable	z_E2	Micromechanics_E22		
Response Variable	z_E3	Micromechanics_E33		
Response Variable	z_G12	Micromechanics_G12		
Response Variable	z_G23	Micromechanics_G23		
Response Variable	z_G31	Micromechanics_E11		
Response Variable	z_nue21	Micromechanics_nue21		
Continuous	z_gamma1	0.035	0.02	0.05
Continuous	z_gms	0.3	0.2	0.5
Continuous	z_sc	61.2	50	110
Continuous	z_tau1	48.2	40	96

cs we trust

Glasfaserverbund + Waben

Frontklappe schematischer Aufbau



IMC-Schicht

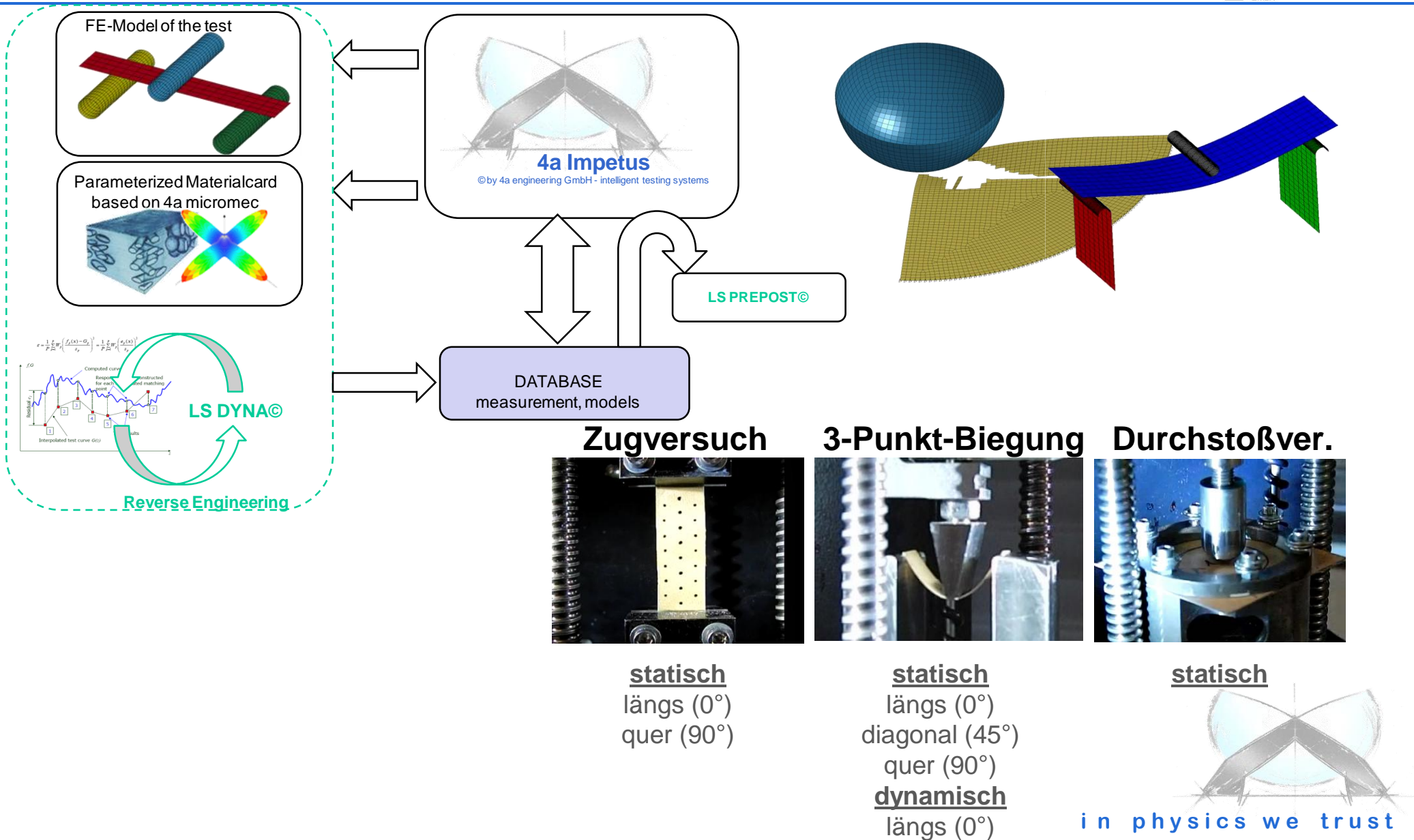
Glas- oder Carbonfaser
Prepreg Komplettlagen

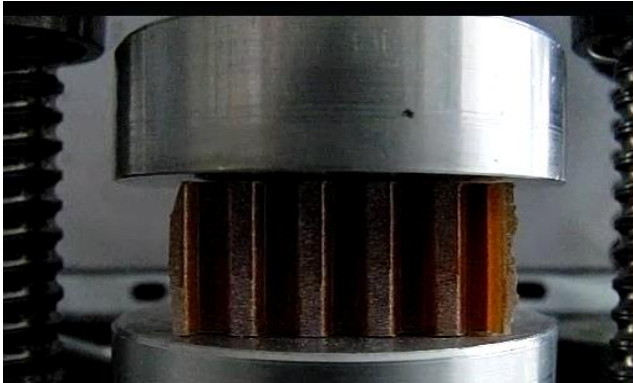
Wabe

Glas- oder Carbonfaser
Prepreg Komplettlagen

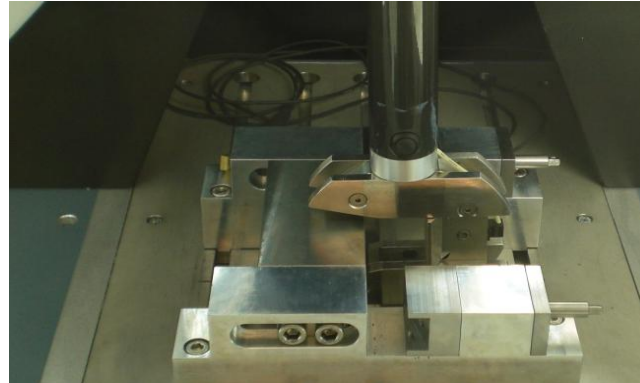
Glasfaserverbund + Waben

Charakterisierung Decklagen





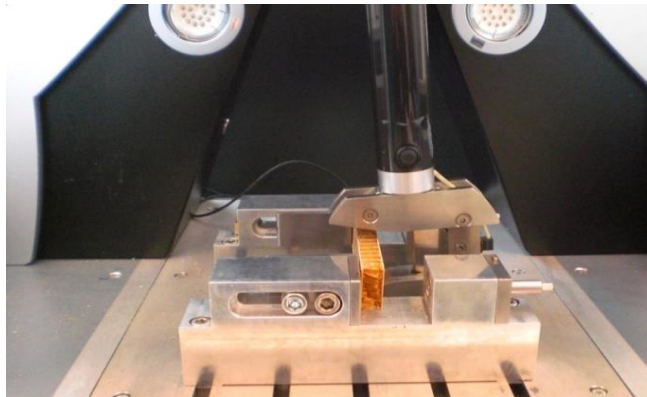
statische Druckversuche



dynamische Druckversuche



statische Biegeversuche



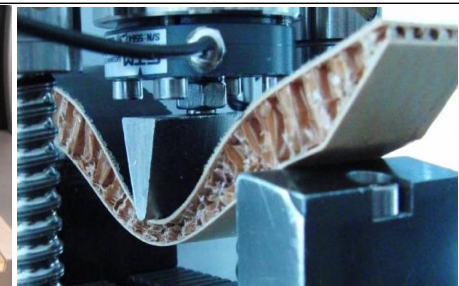
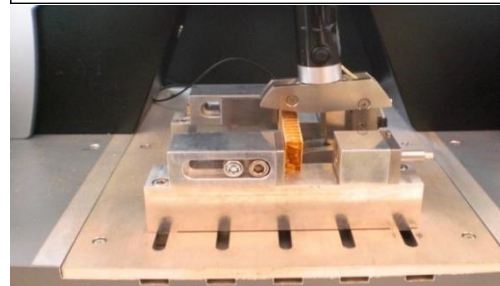
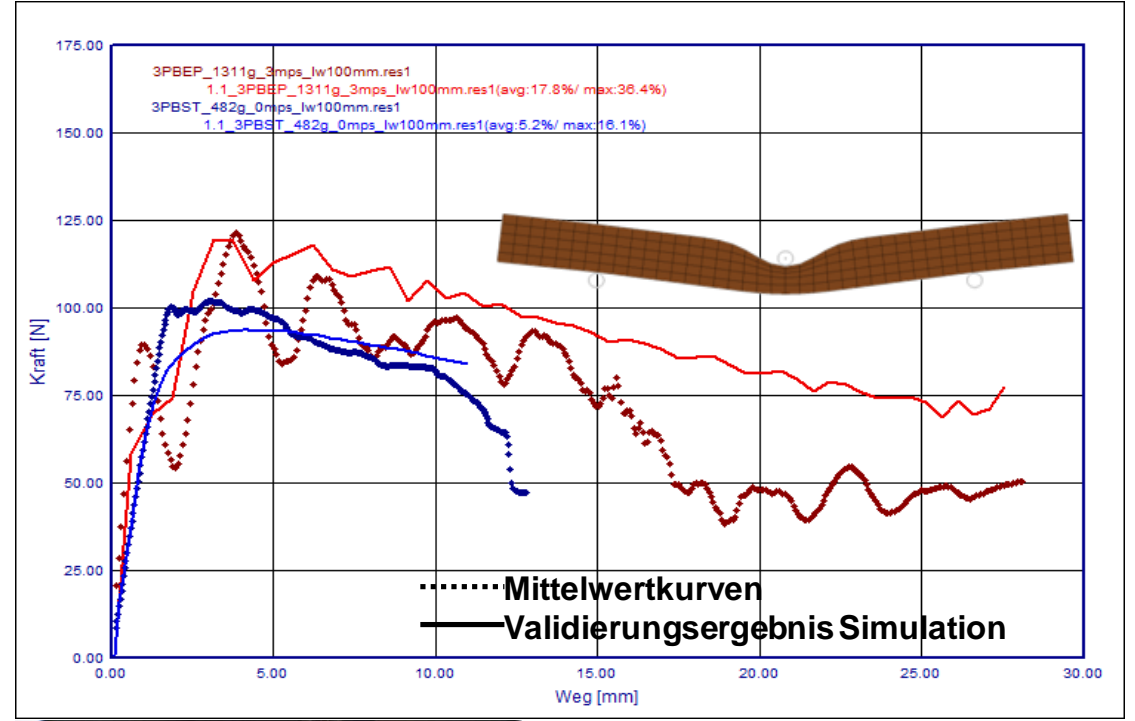
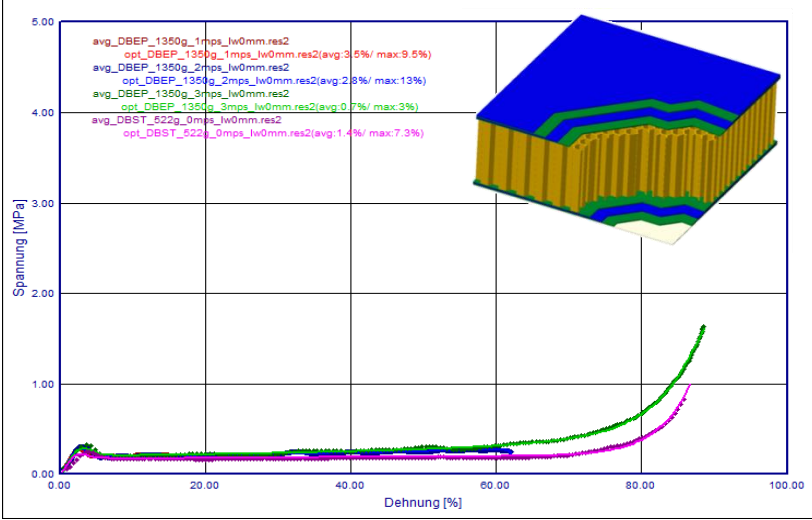
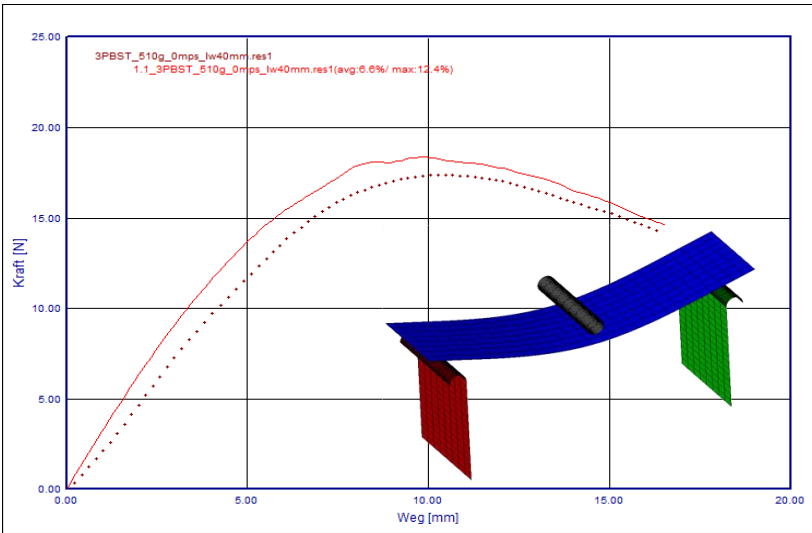
dynamische Biegeversuche



Bauteilversuche

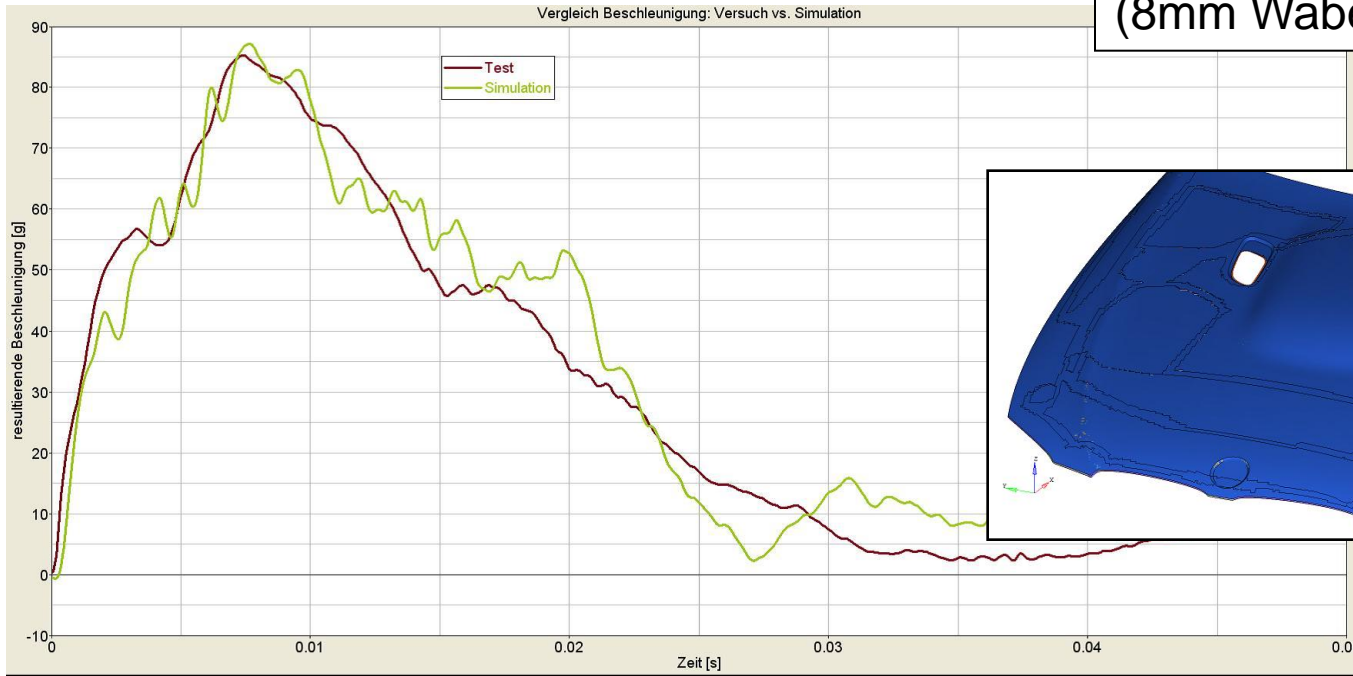
Glasfaserverbund + Waben

Material - Test vs. Simulation

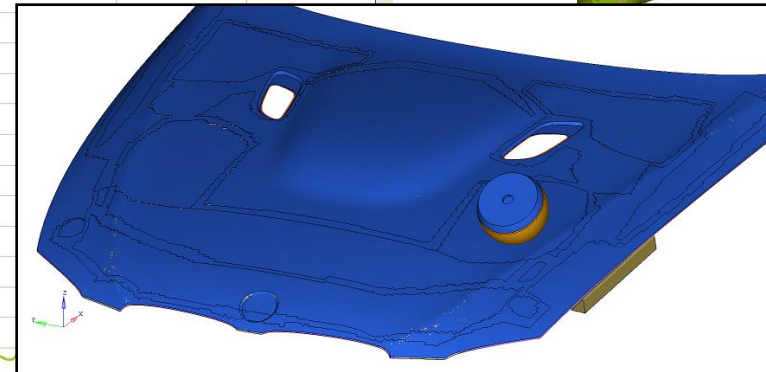
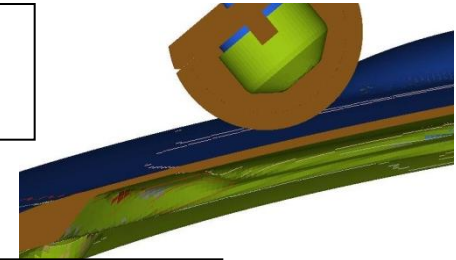


Glasfaserverbund + Waben

Bauteil - Test vs. Simulation



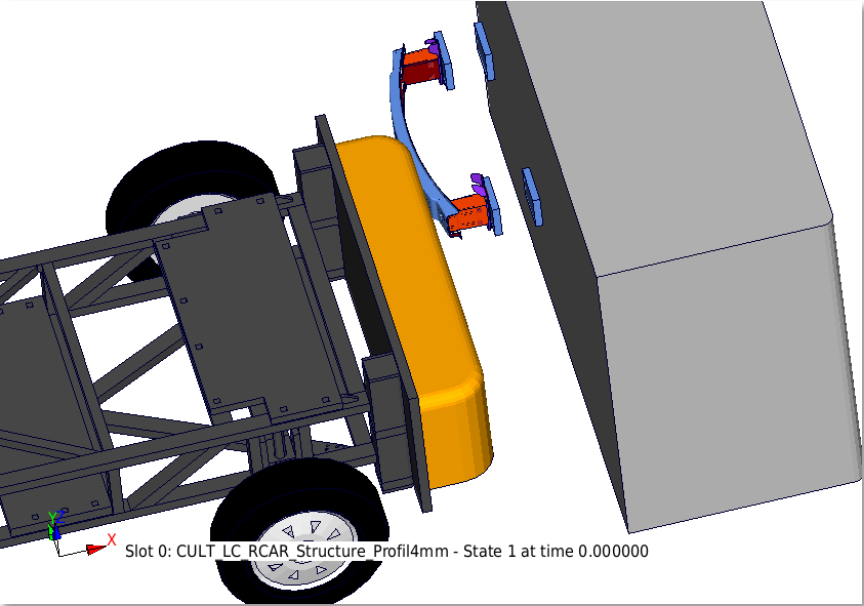
Pkt. in Zone 2
(8mm Wabenkern)



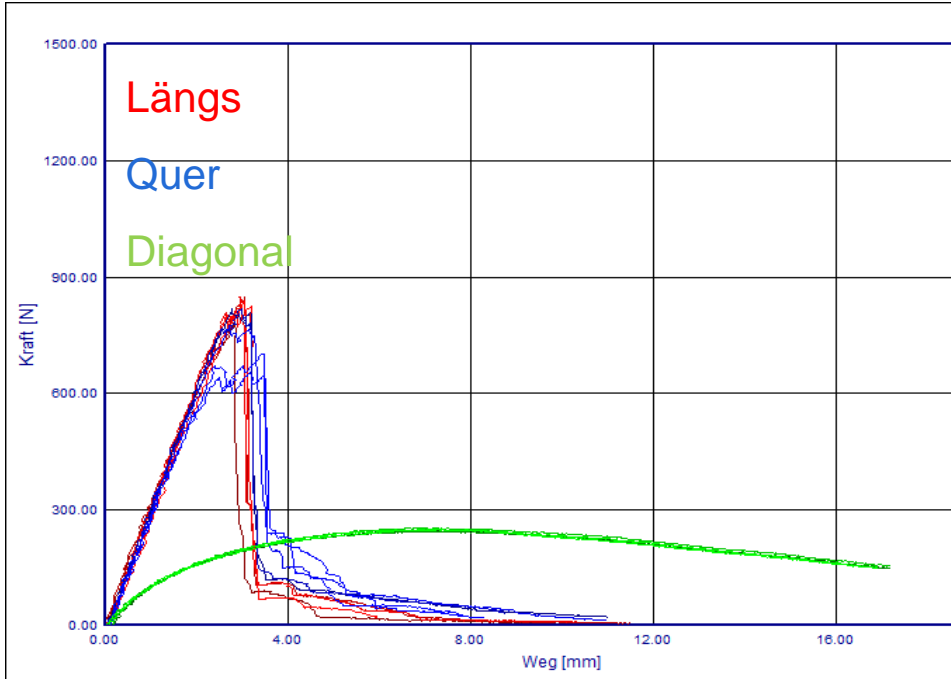
Keine Validierungsmaßnahmen wurden vorgenommen
Gute Übereinstimmung des Beschleunigungsverlaufes
Kurvencharakteristik bildet Bruchbeginn gut ab

Organoblech

Crash Management System

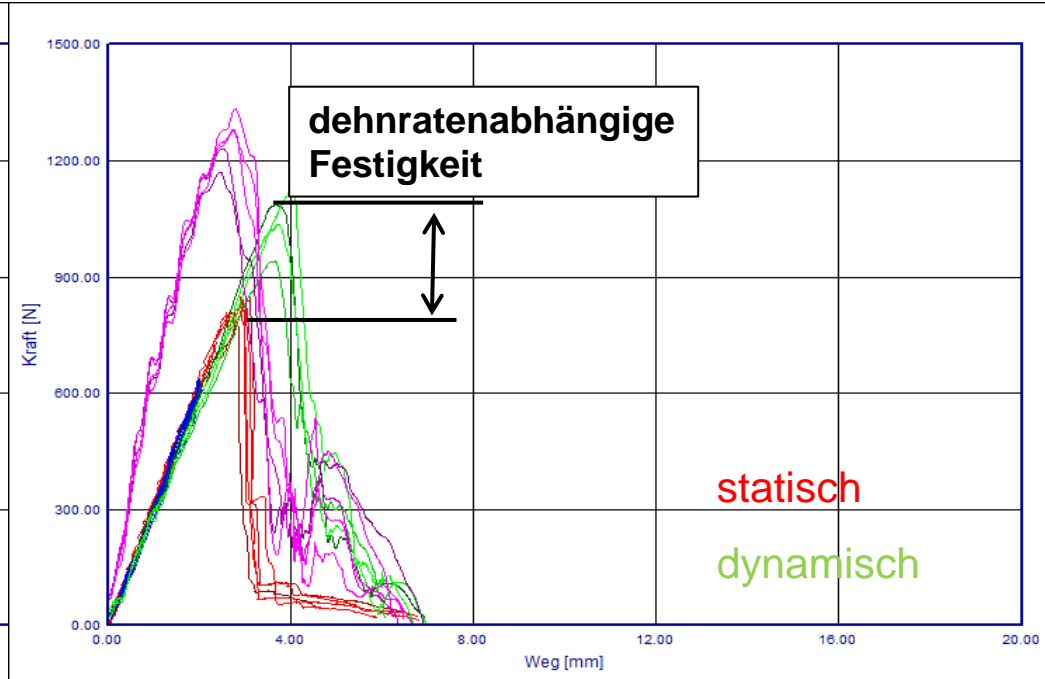


statische 3-Punkt-Biegemessungen

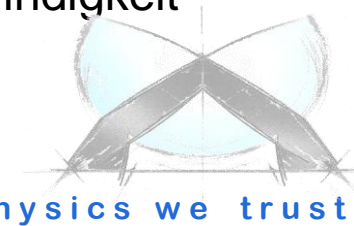


Einfluss Orientierung

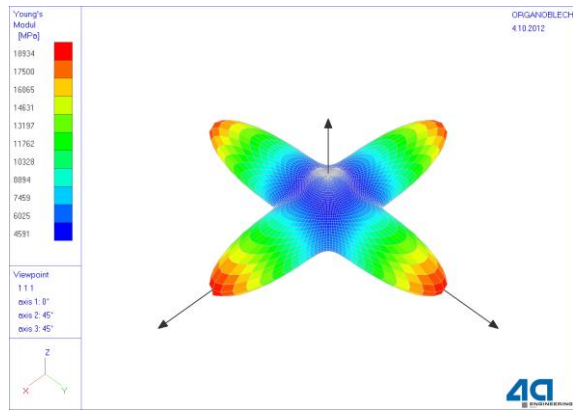
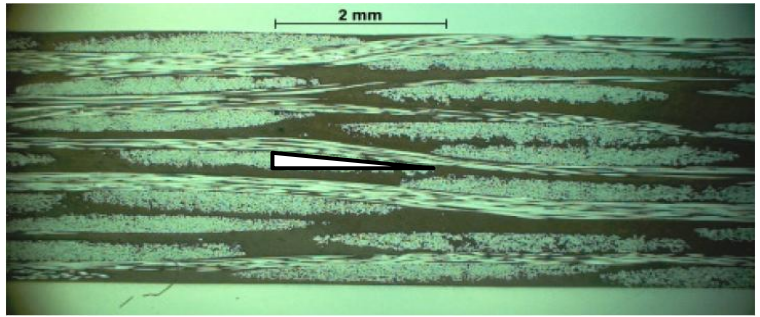
dynamische 3-Punkt-Biegemessungen



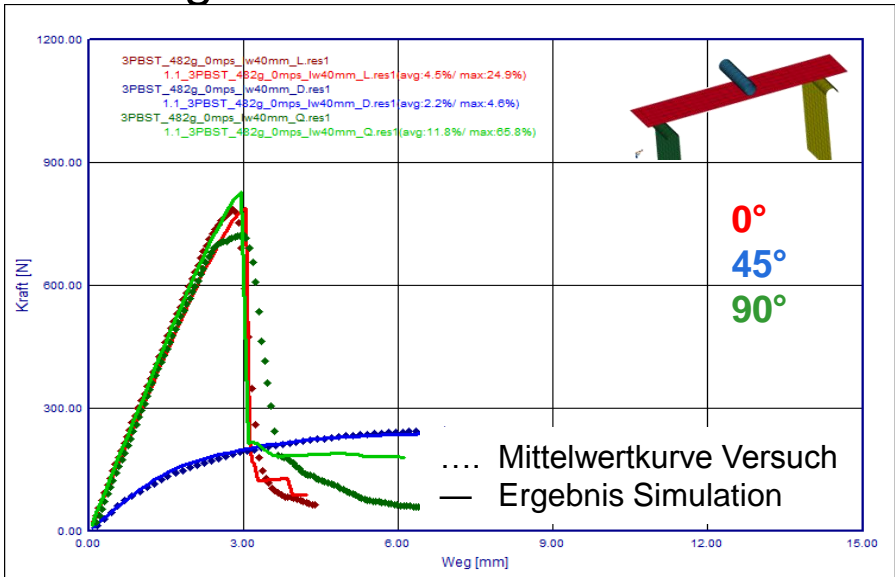
Einfluss Prüfgeschwindigkeit



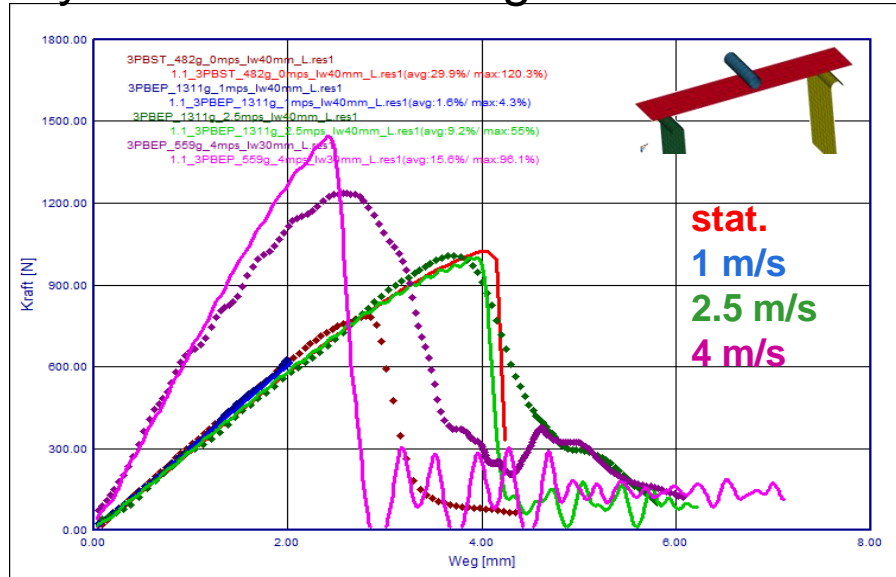
Steifigkeit mit Hilfe der Mikromechanik



Versagensanpassung quasistatische Messergebnisse

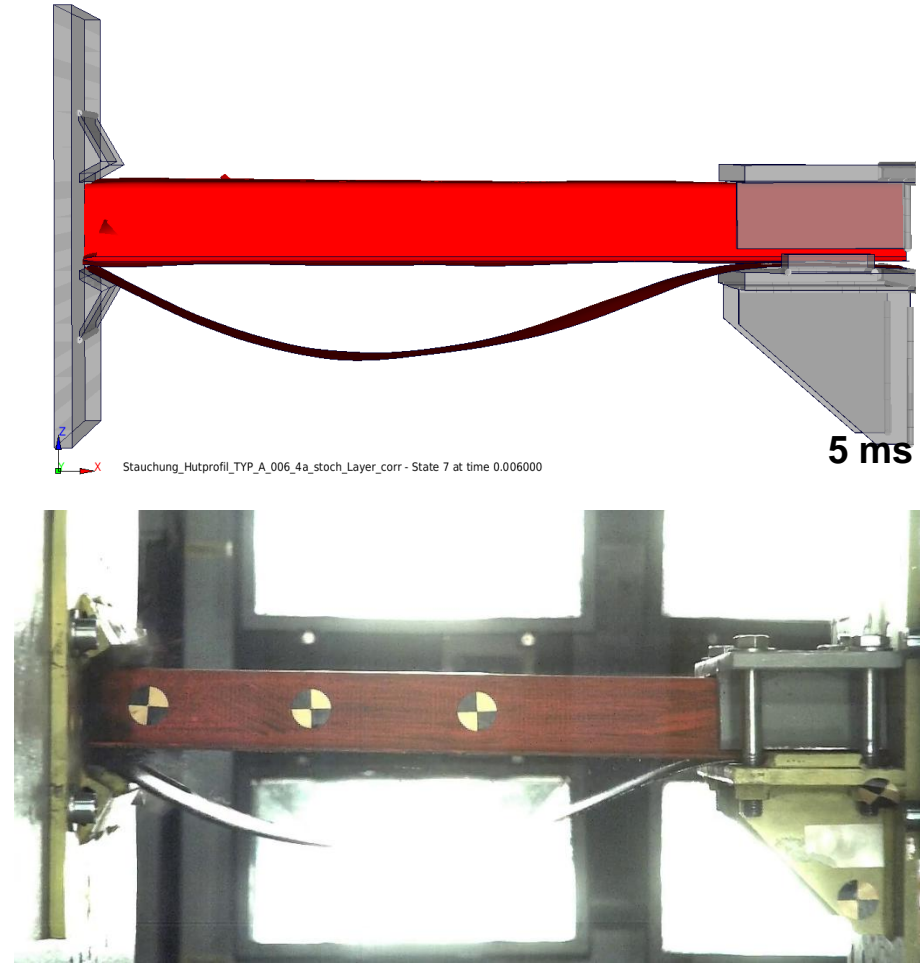
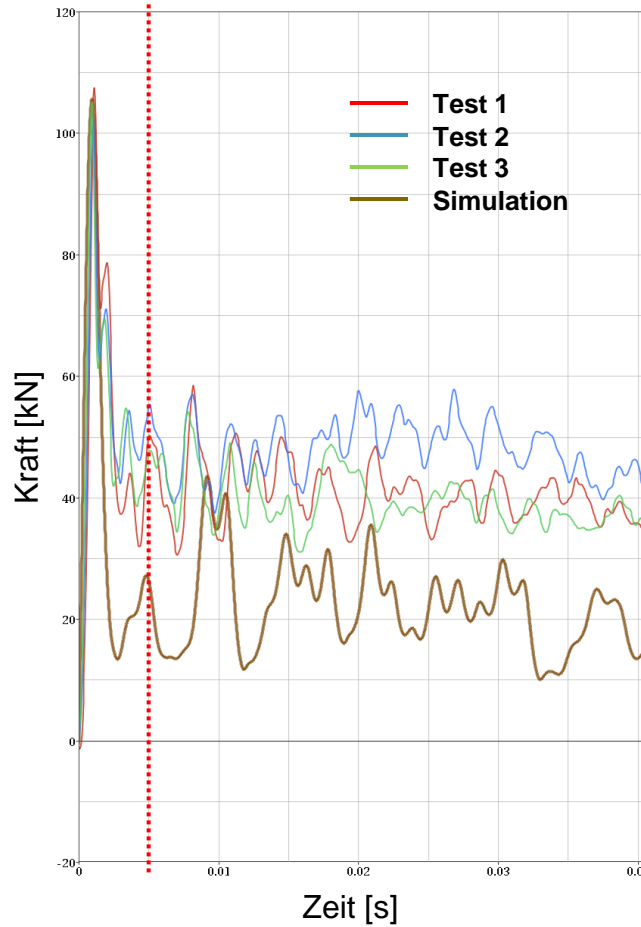


Versagensanpassung dynamische Messergebnisse



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Bauteil – Profilsimulation



Werkstoff

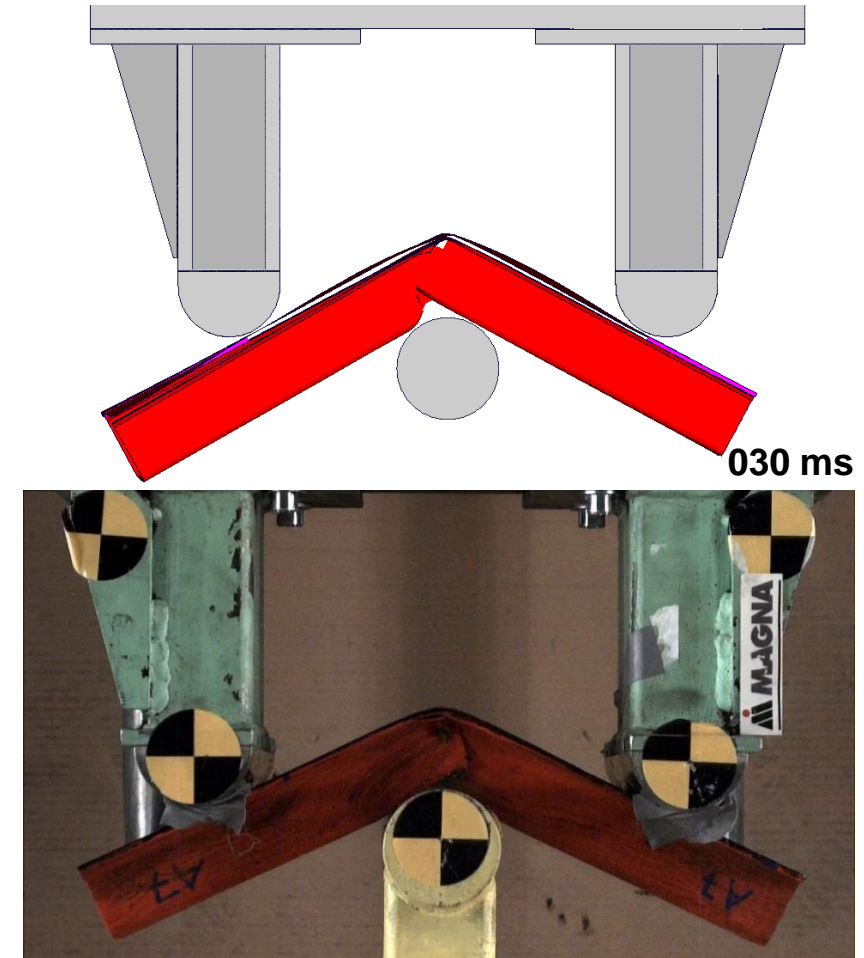
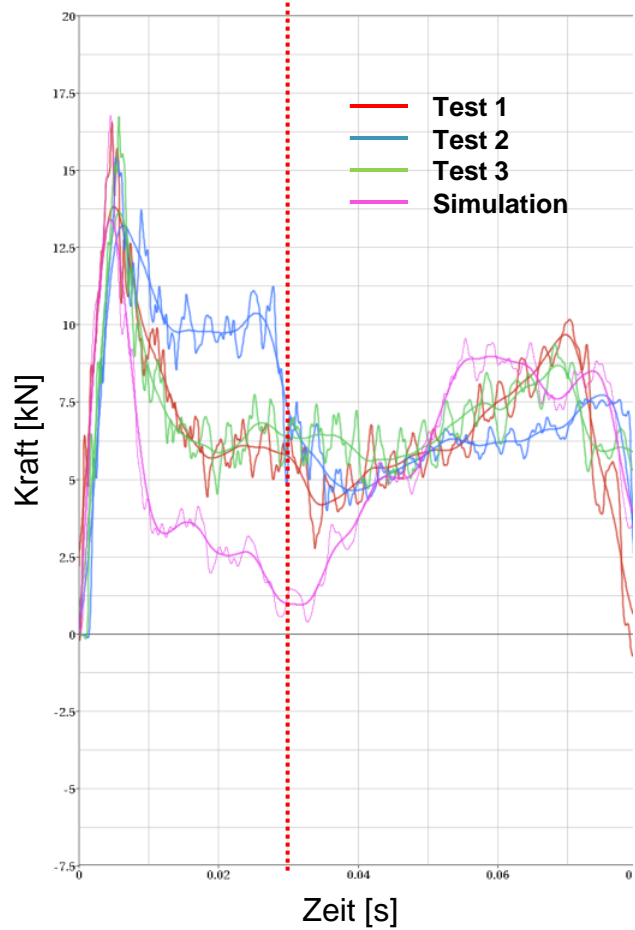
Bauteil

Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

Bauteil – Profilsimulation



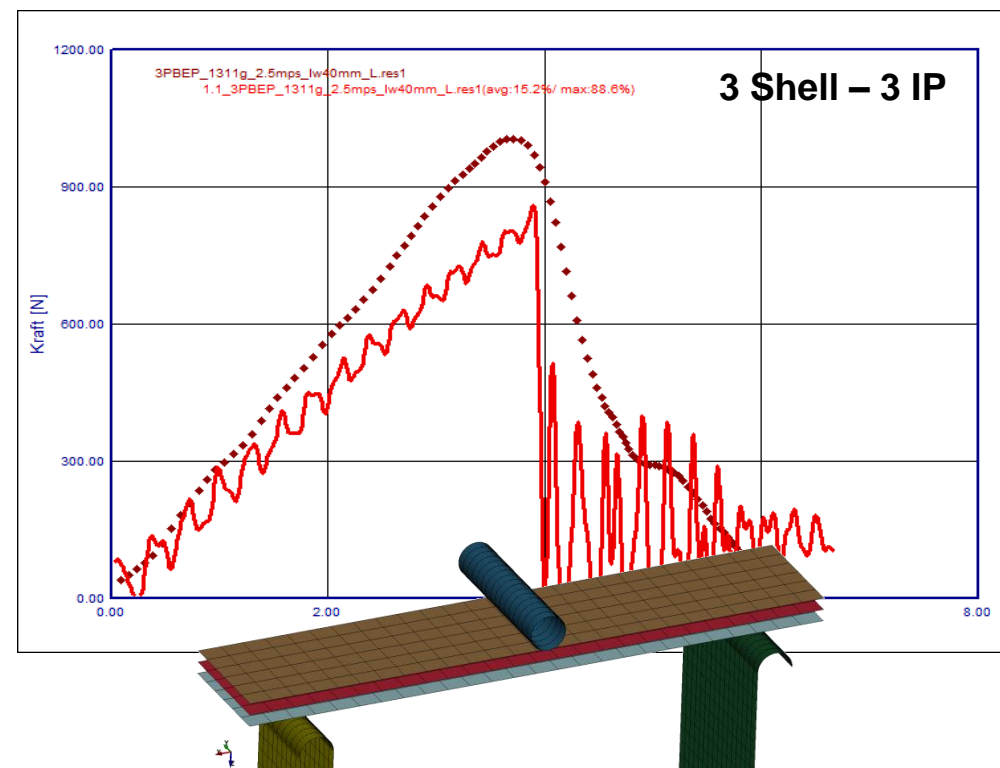
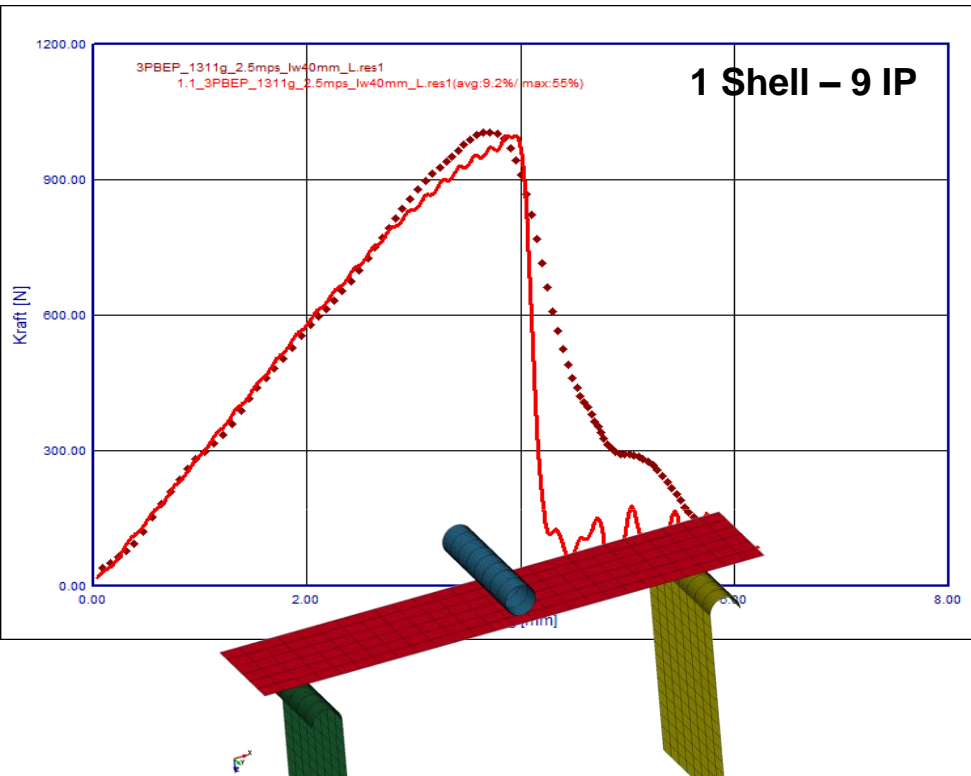
Werkstoff

Bauteil

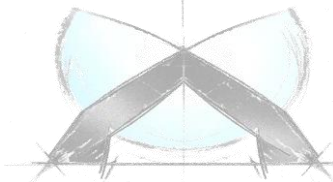
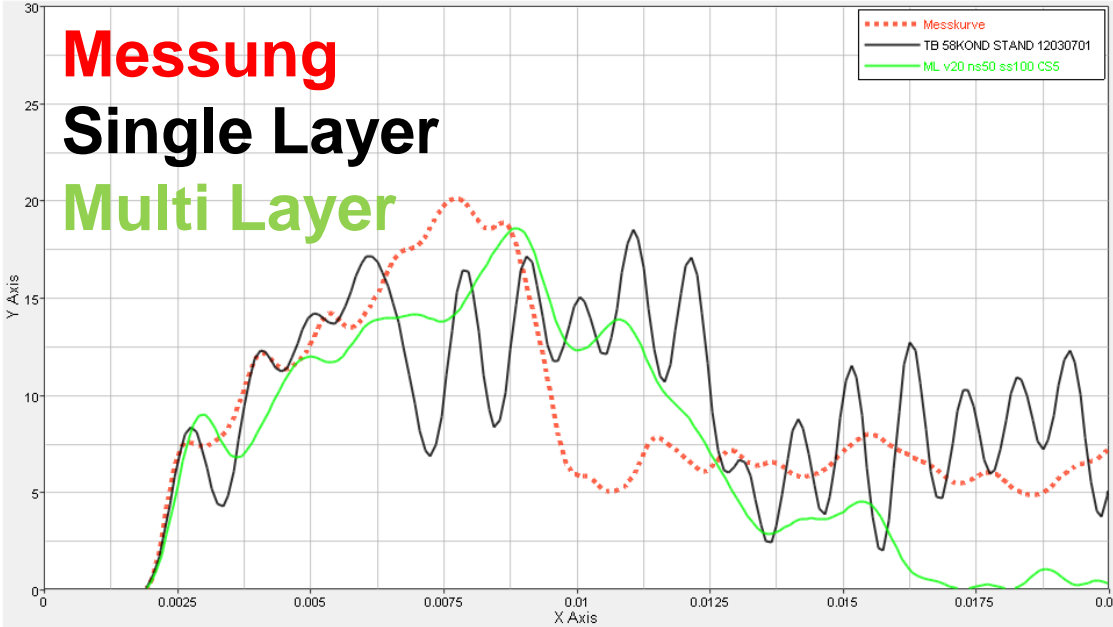
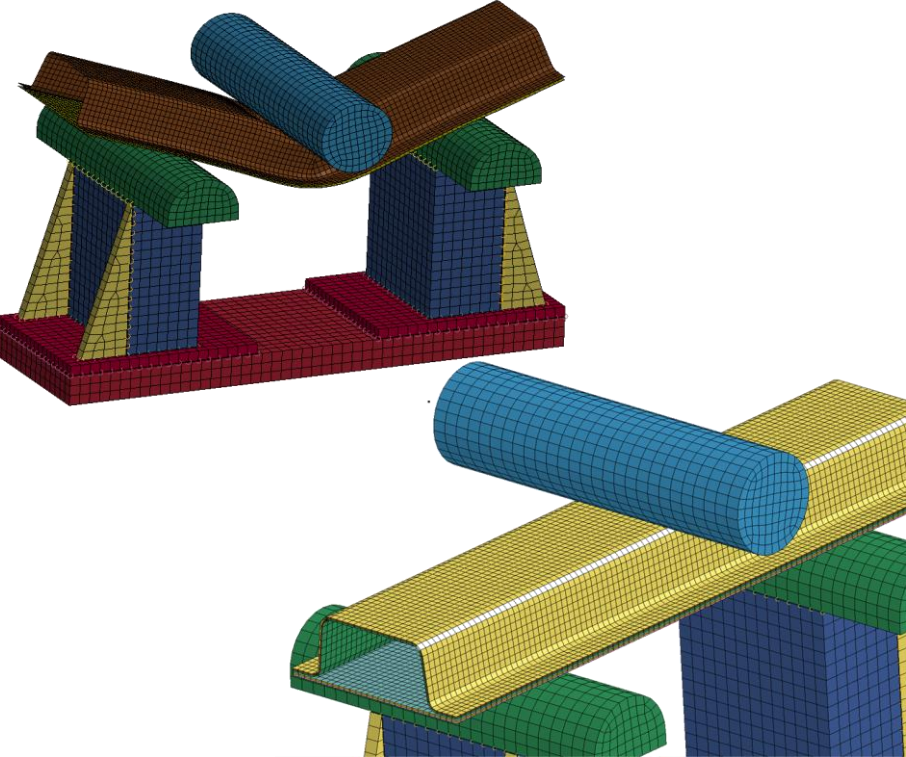
Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

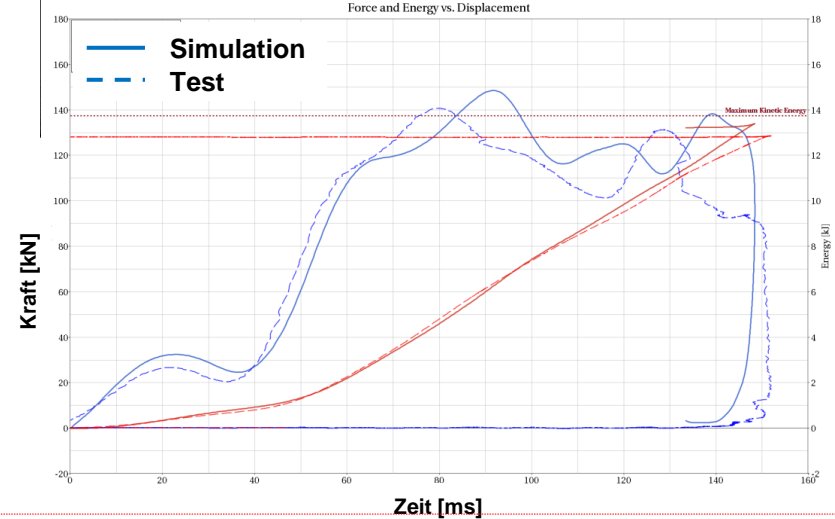
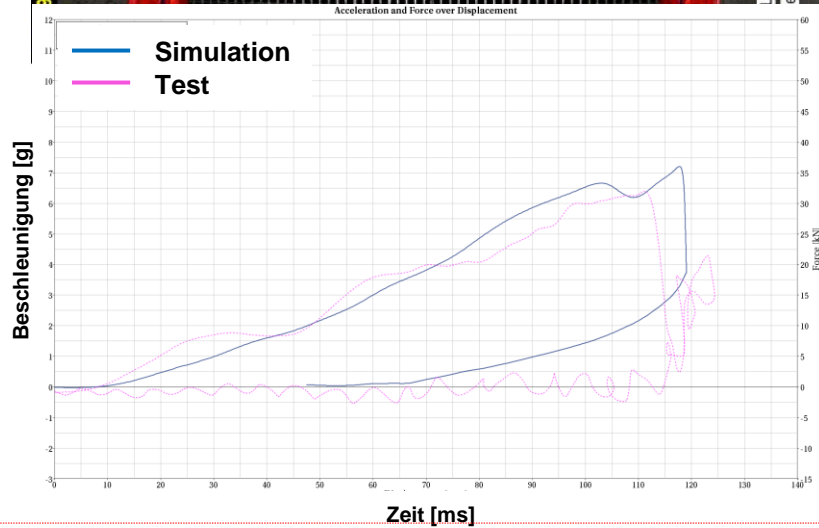
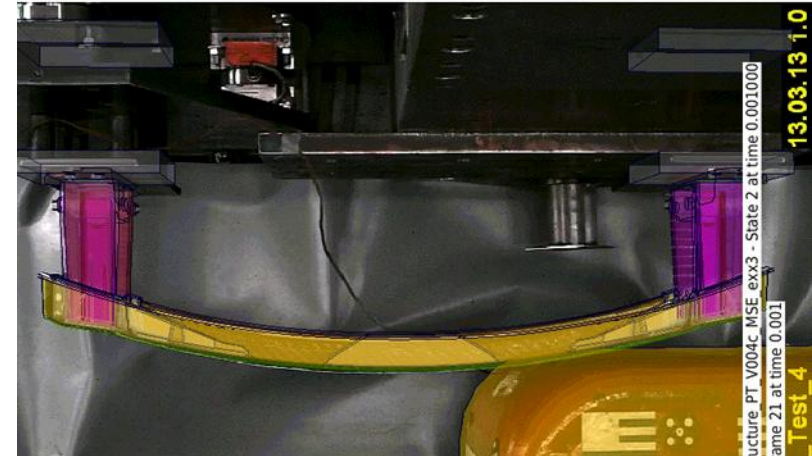
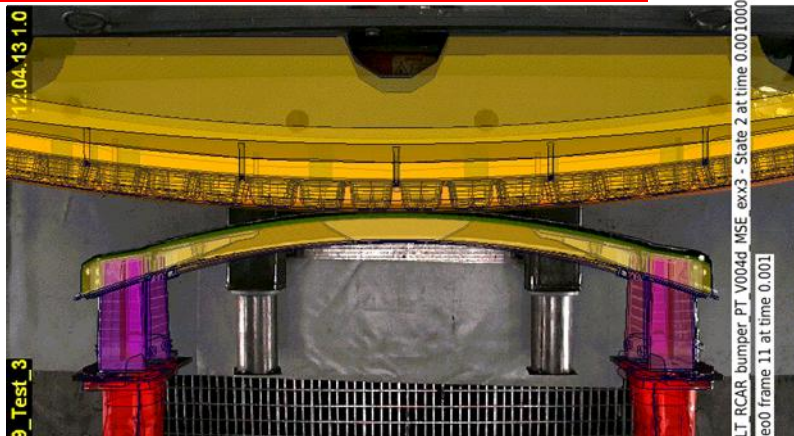


- Ermittelte Materialkarte kann den Versuch bei einer Idealisierung *PART_COMPOSITE mit 9 Integrationspunkten gut abbilden.
- Ein Multi-Layer-Aufbau ohne Modifikation führt zu einer geringeren Steifigkeit, der Bruchzeitpunkt stimmt recht gut mit den Messdaten überein.



in physics we trust

Bauteil – Organo Frontend



Werkstoff

Bauteil

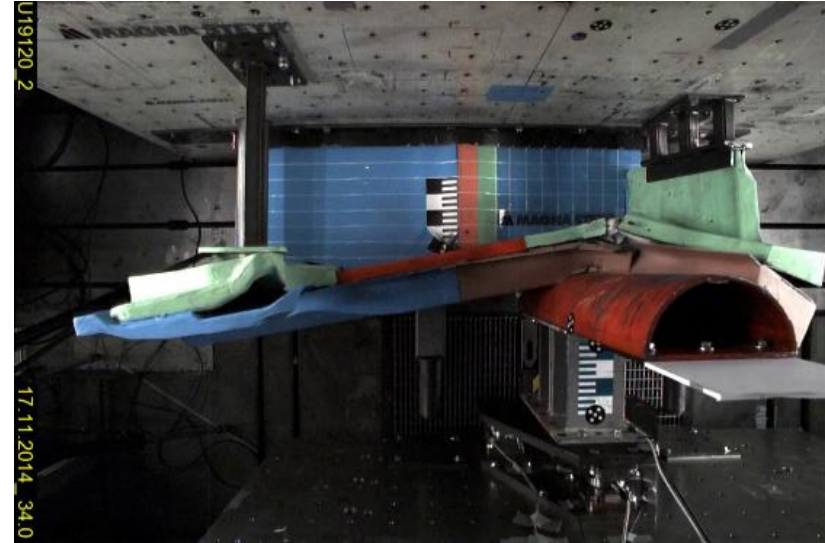
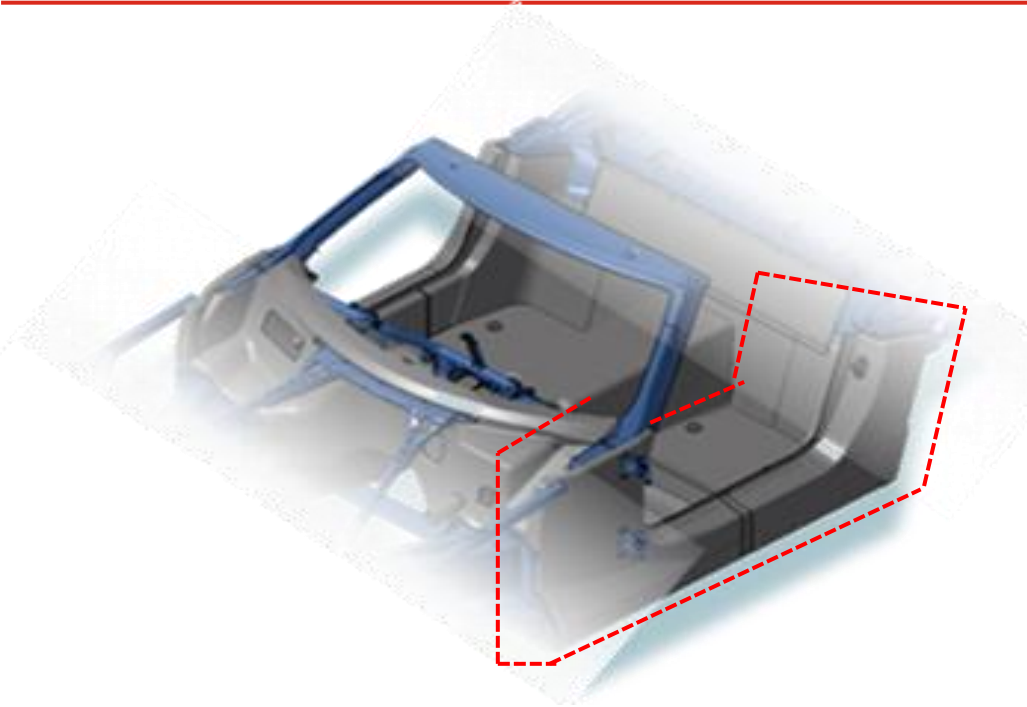
Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

CFK Gelege - Gewebe

Composite Life Cell



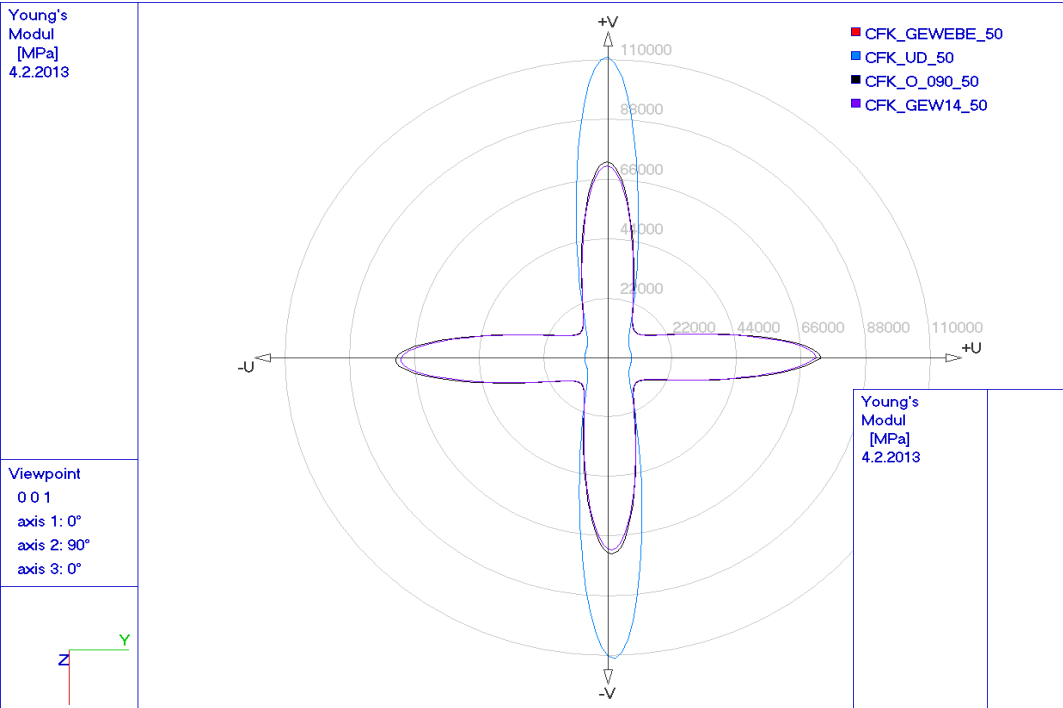
Materialcharakterisierung CFK soll 50%

UD Gelege – Gewebe

Prepreg / Pultrusion / Harzinfusion (Prototypische Fertigung)

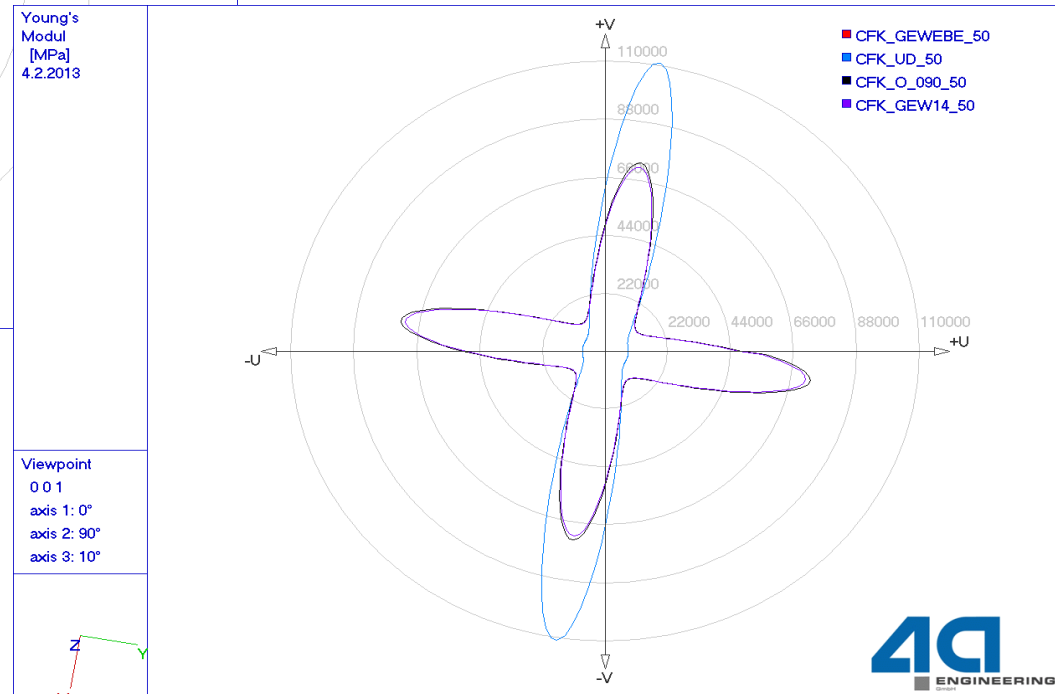
CFK Gelege - Gewebe

Steifigkeit in der Laminatenebene



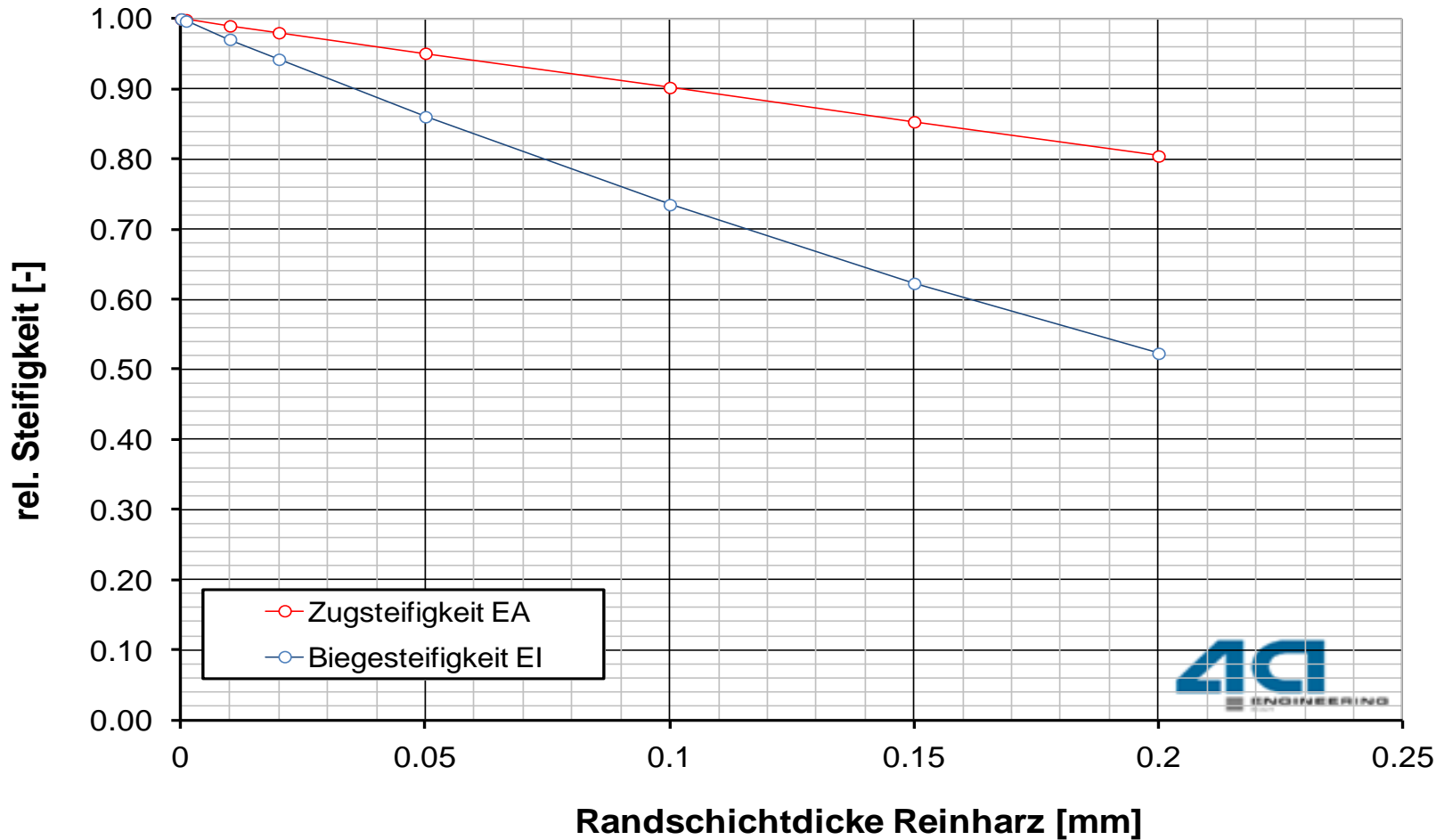
Verdrehung um 10° (Probenentnahme)

- UD starker Einfluss
- Gewebe geringerer rel. Einfluss

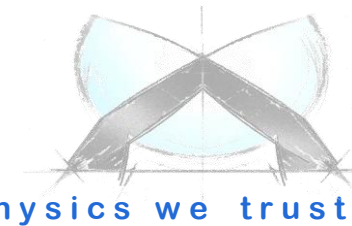


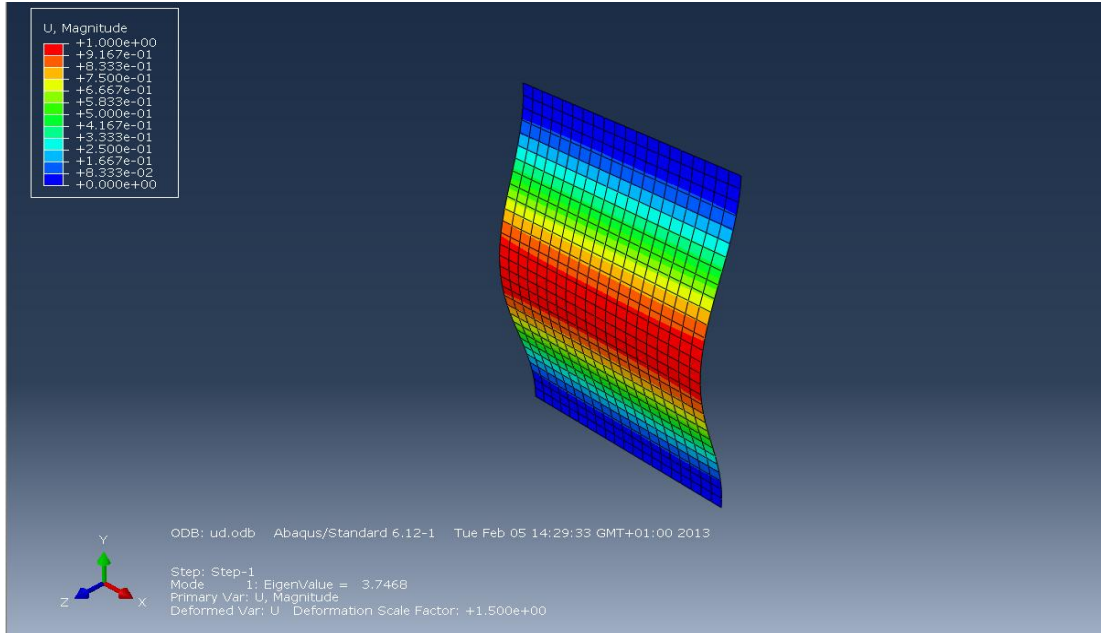
Ermittelt mit 4a MicroMec für

- UD CFK ϕ 50%
- 0/90 CFK ϕ 50%
- 0/90 CFK ϕ 50% (Ondulation 2% in Z)
- 0/90 CFK ϕ 50% (Ondulation 14% in Z)

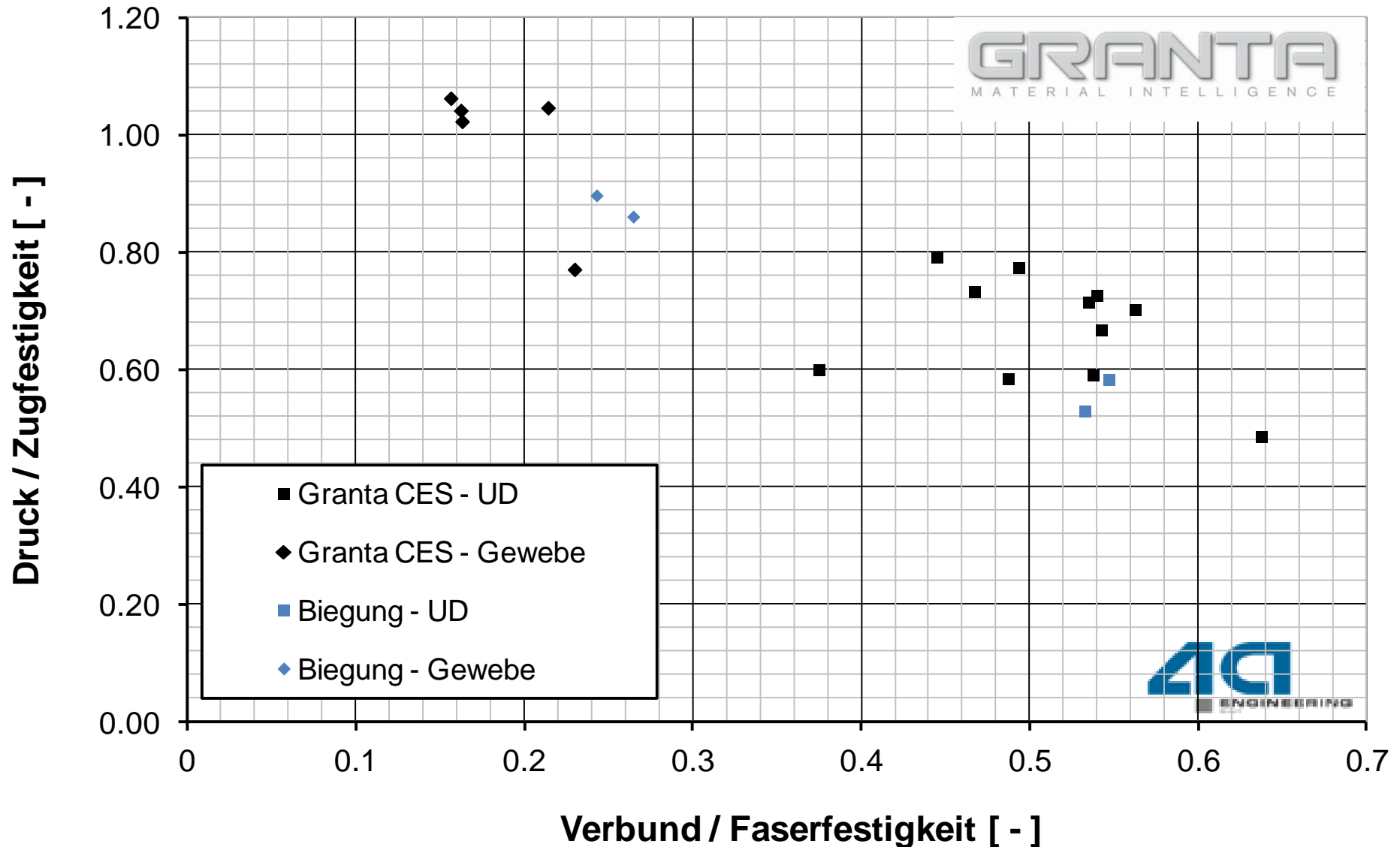


Ermittelt mit 4a Lam2D unter Annahme eines CFK HT 60% UD Laminates mit einer Gesamtdicke von 2 mm.

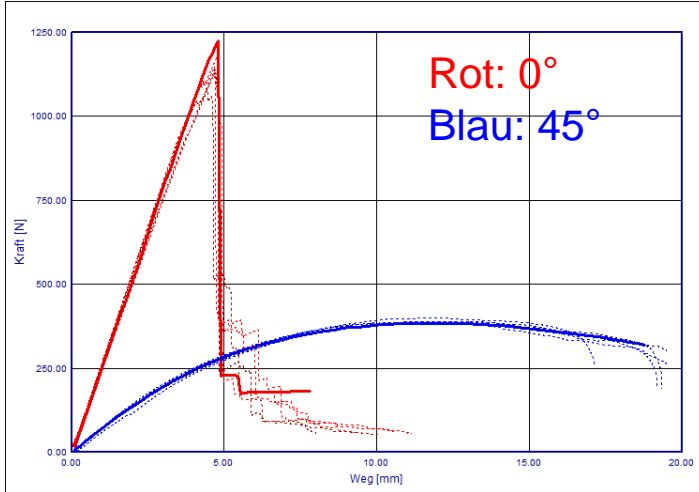




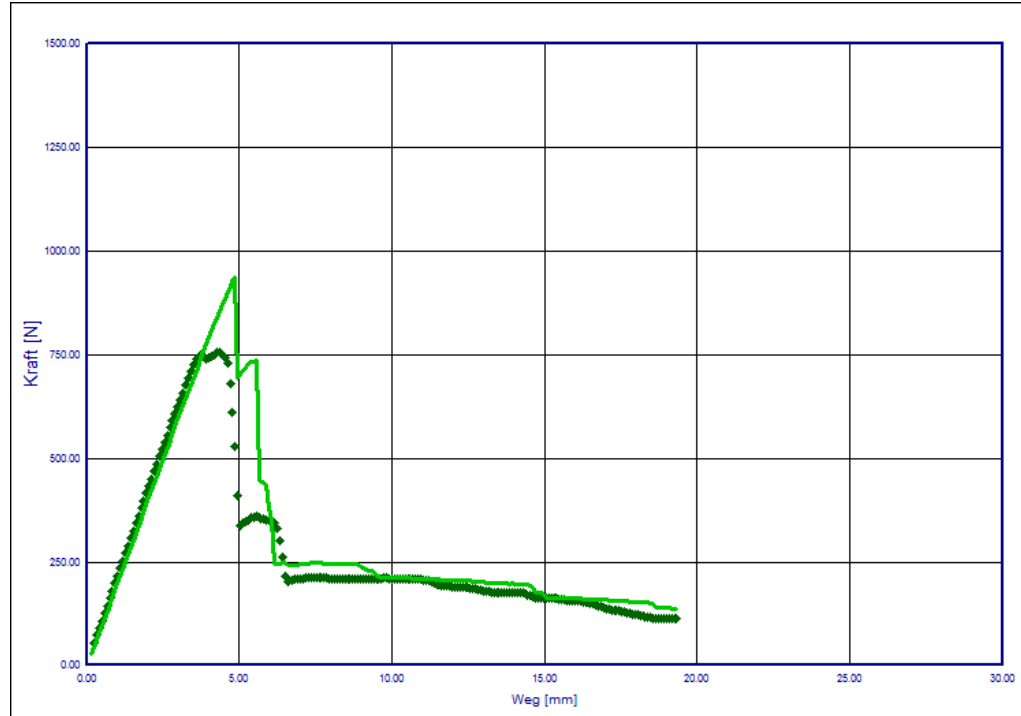
	lw mm	A mm ²	KRAFT [KN]		Spannung [MPa]		theor. Festigkeit Zug[MPa]	
			Längs	Quer	Längs	Quer		
Prepreg Gewebe	15	20	2.59	2.59	129.7	129.7	971.0	13%
Prepreg UD	15	20	3.75	0.68	187.3	33.9	2188.0	9%
Prepreg Gewebe	10	20	3.32	3.32	165.8	165.8	971.0	17%
Prepreg UD	10	20	4.43	1.26	221.5	63.1	2188.0	10%



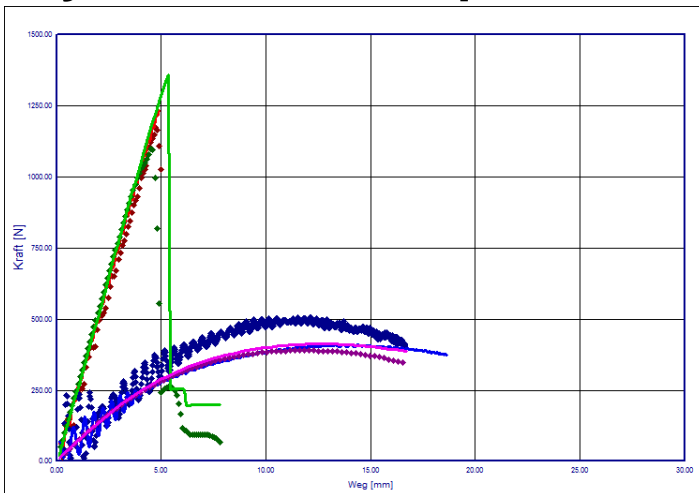
Orientierung



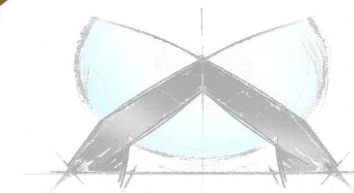
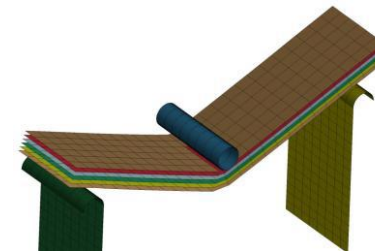
Aufbau - Mehrschichtversagen



Dynamisch 4a impetus

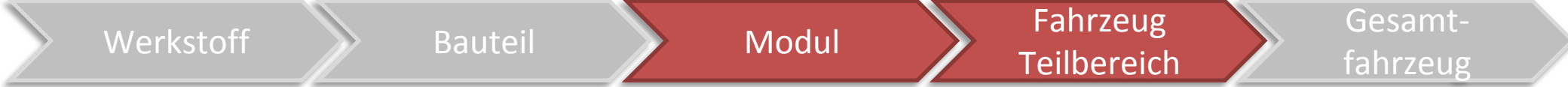
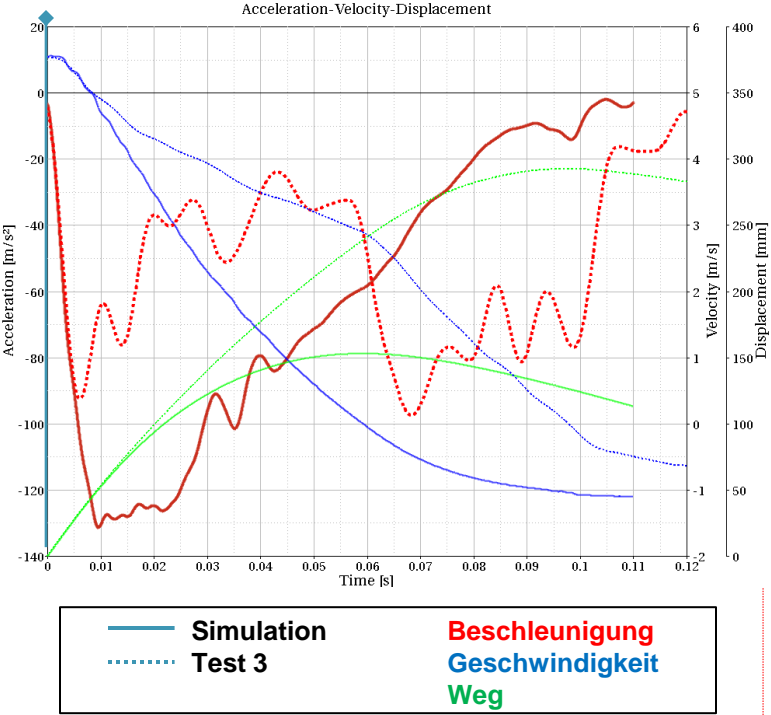
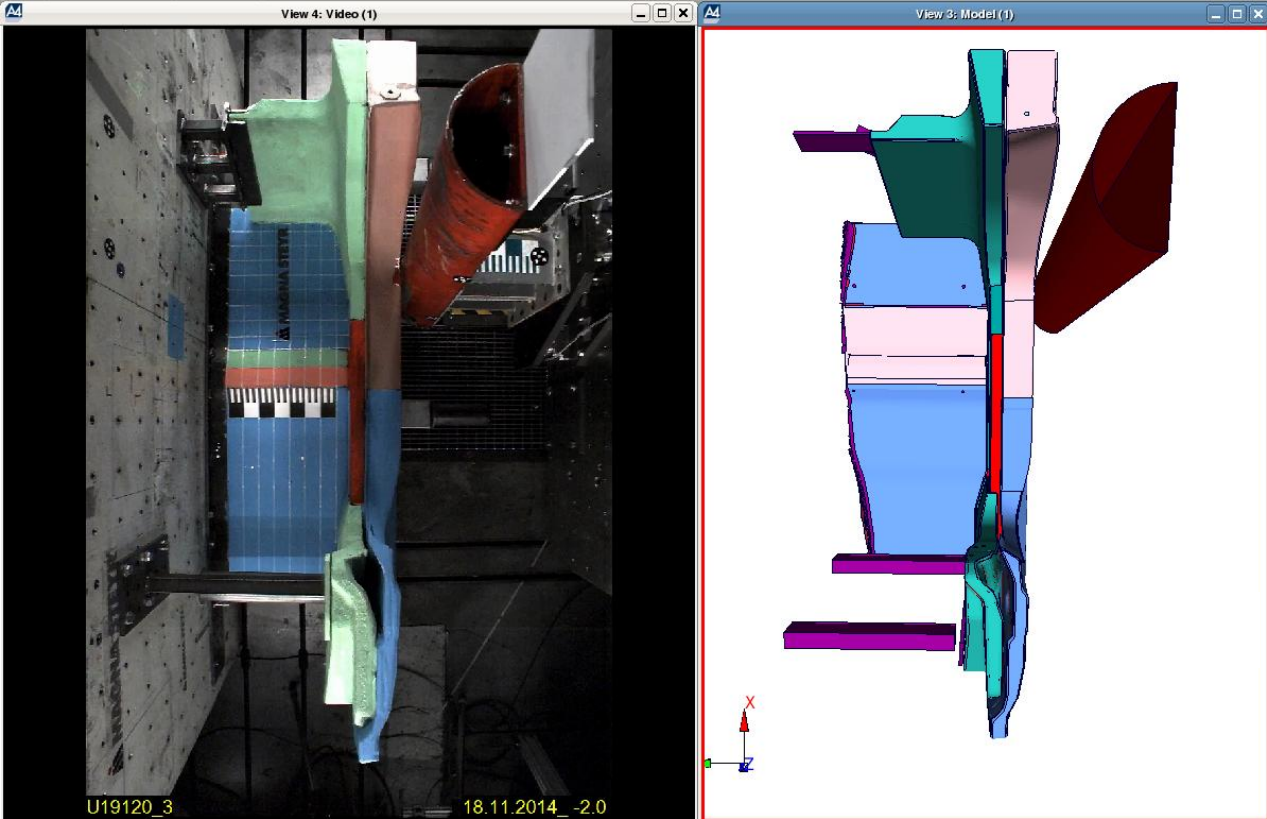


.... Einzelkurven Versuch
— Ergebnis Optimierung

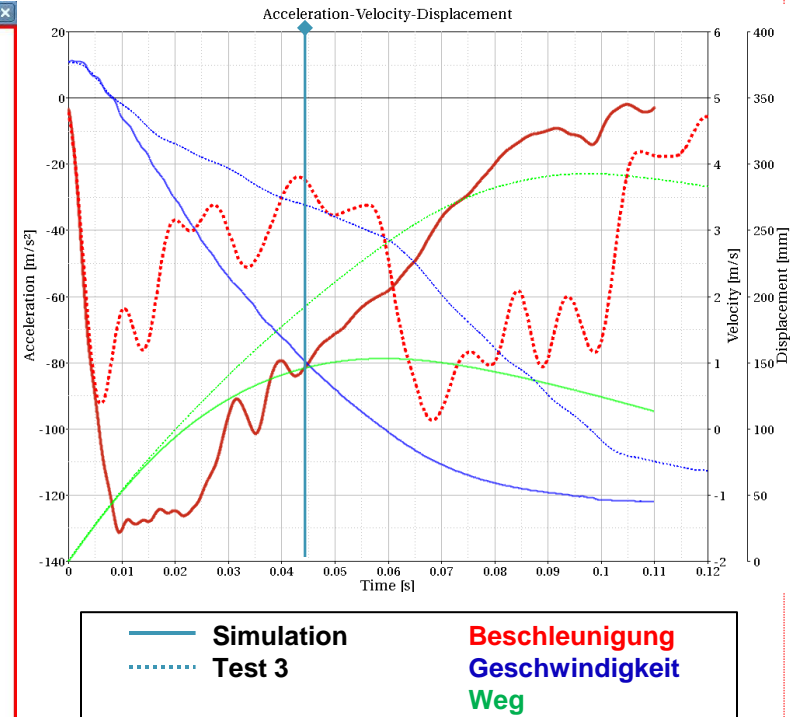
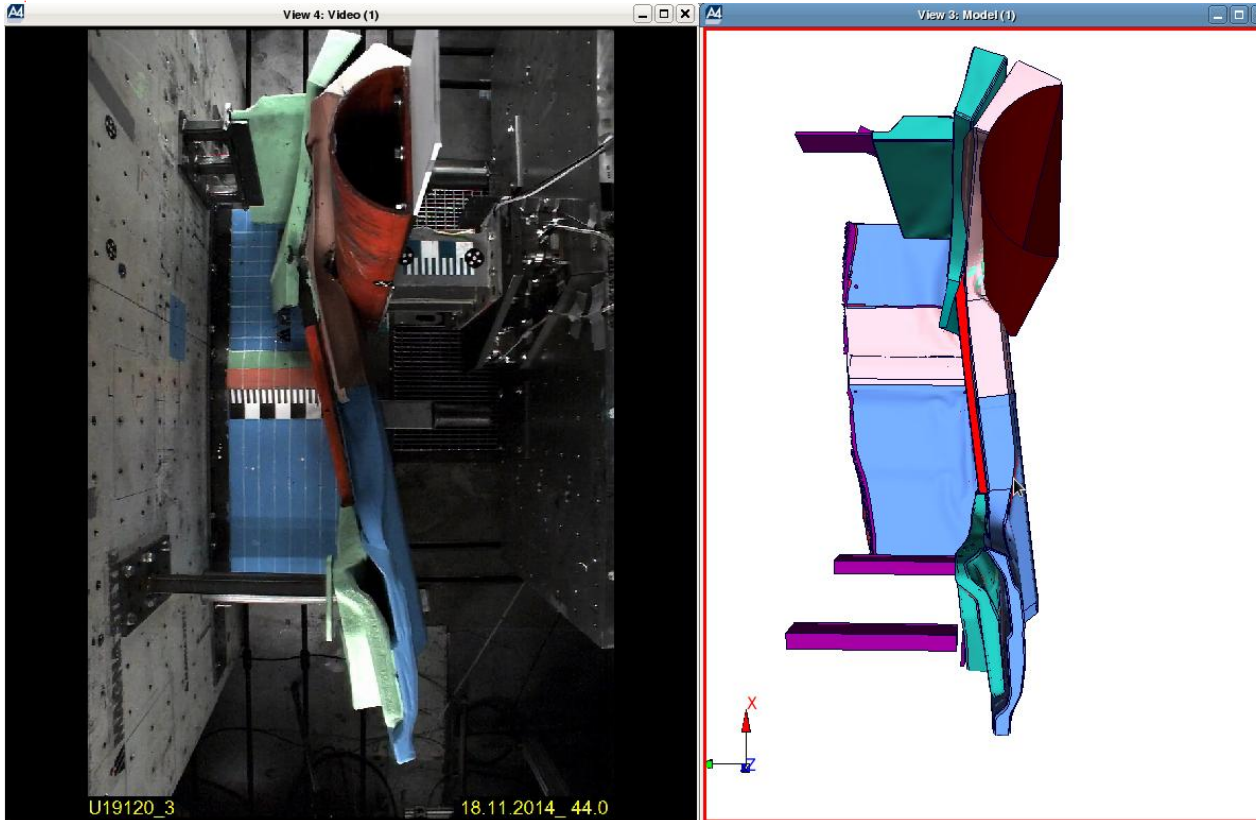


in physics we trust

Fahrzeugteilbereich – Crash



Fahrzeugteilbereich – Crash



Werkstoff

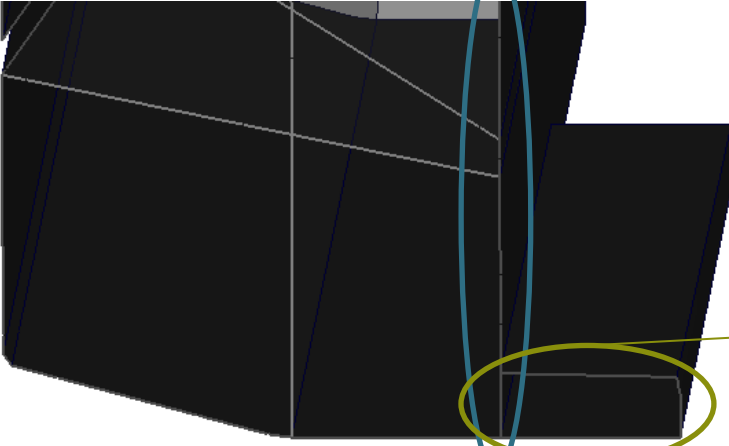
Bauteil

Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

Detail Analyse



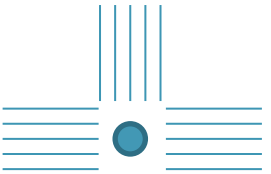
Schwellerprofil - Schnitt



Schwellerprofil deformiert



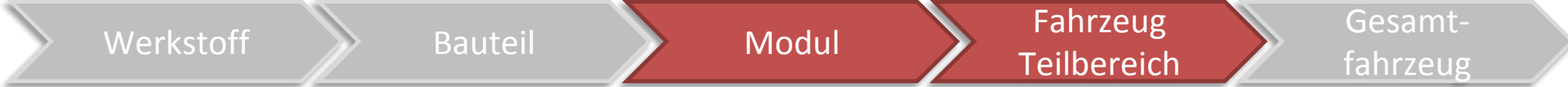
Real fiber structure



FE-model

Fiktives Beispiel:

Layered thin shell element
reicht nicht aus.
Stacked Shell Modell
lokal wieder notwendig



- Charakterisierung mit Fokus auf die Anwendung
 - Modelle (z.B. Mikromechanik) nutzen um
 - Ergebnisse zu plausibilisieren (Fertigung / Prüfaufbau)
 - Materialkarten zu erstellen
 - Prozesse im CAE Umfeld notwendig
 - Materialcharakterisierung
 - Mehrstufenansatz (Werkstoff → Bauteil → Modul → Teilbereich)
 - Delamination / Energieaufnahme und Verbindungstechnik
- zukünftige Themen

