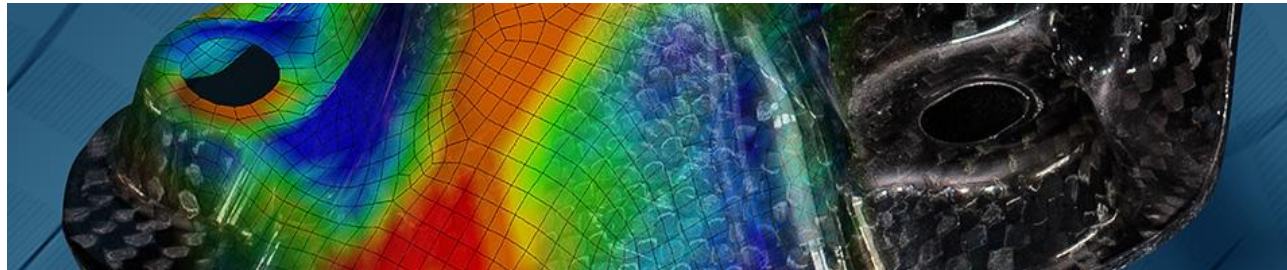


Materialcharakterisierung von Composites

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

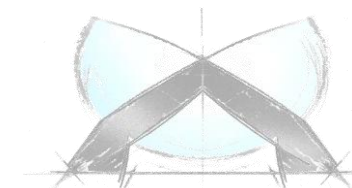
F. Rudolph, B. Fellner (Magna Steyr Fuel Systems, Magna Steyr Engineering Austria)



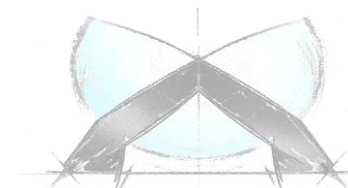
4a Technologietag 2015

Leichtbau und Composites

5. - 6. März 2015



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



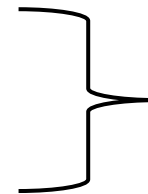
i n p h y s i c s w e t r u s t

➤ grobe Einteilung

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

➤ Einsatzgebiete

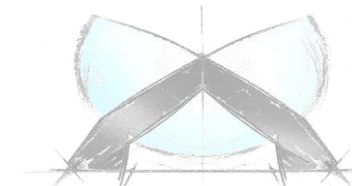
- Materialentwicklung / Vergleich
- Qualitätssicherung
- Entwicklung / Auslegung



Firmenstandards
Normen

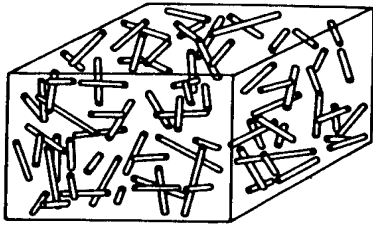
➤ **Simulation**

„Man nimmt was man kriegt !“

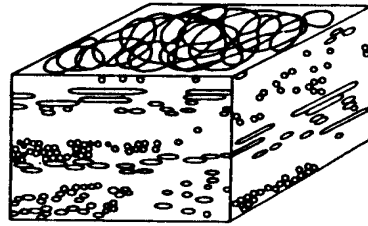


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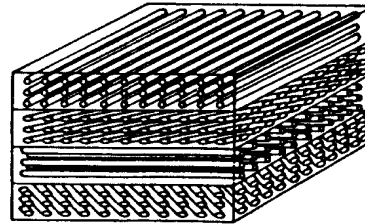
➤ Klassifizierung Composites



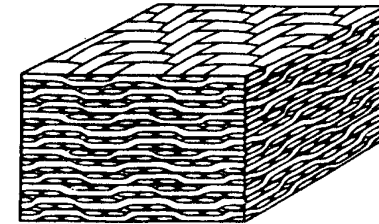
Kurzfaser



Fasermatten



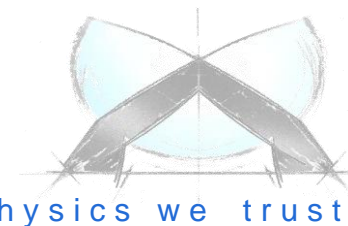
UD Schichten



Gewebe

➤ Skalenebenen

- micro – meso – macro
- Eigenschaften (Faser → Verbund)
- Methoden Messtechnik / Simulation
- Modellierung (Einheitszellenmodell → Strukturmodell)



➤ Beschreibung

➤ Steifigkeit / Festigkeit / Energieaufnahme

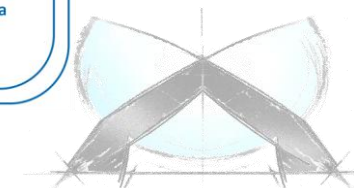
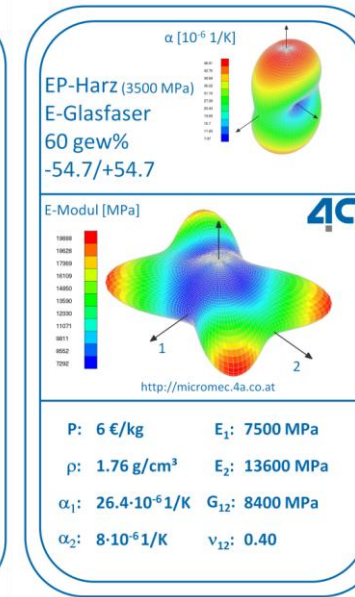
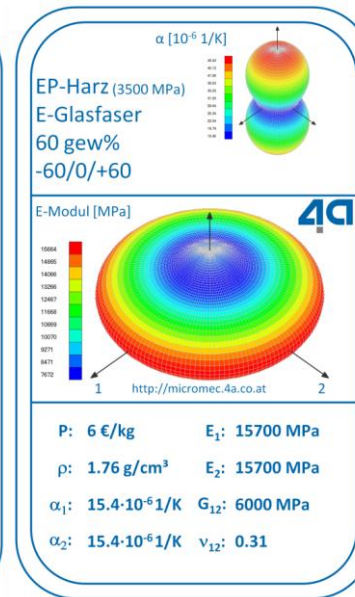
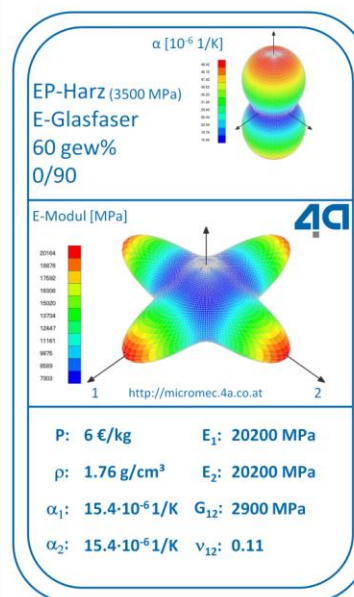
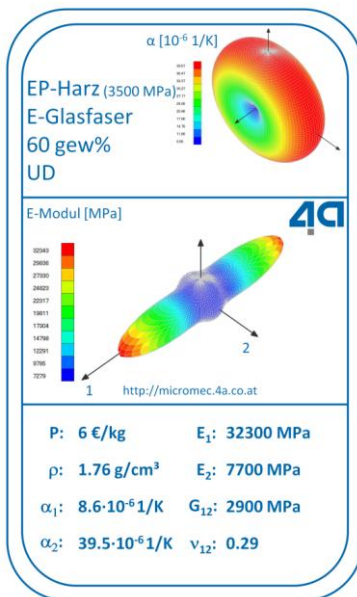
➤ Abhängigkeiten

➤ Geschwindigkeit / Feuchtigkeit / Temperatur

➤ Fasergehalt / -gestalt / -orientierung

Einsatzgebiet

Herstellung

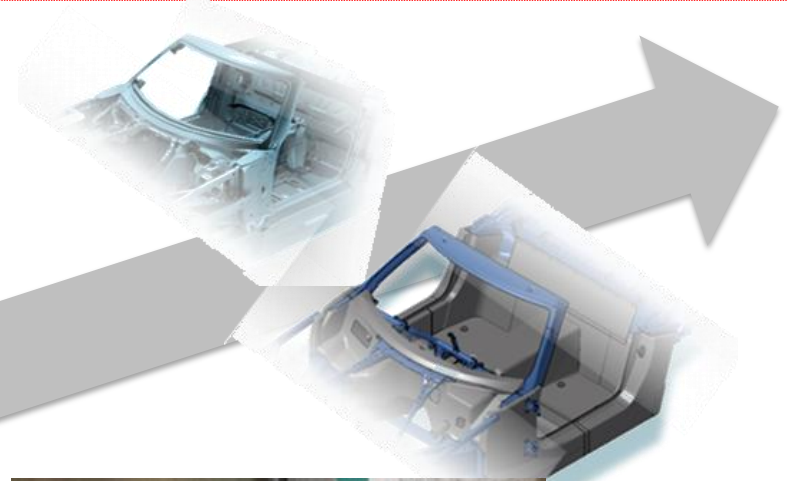


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Faserverbund Kompetenz

Unterschiedlichster Materialien und Herstellverfahren

Qualifizierungsprojekte



1970

2004

2010

2015

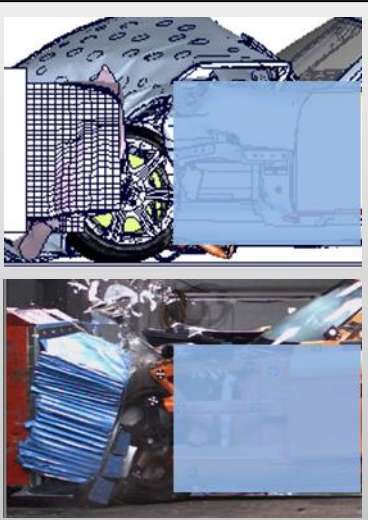
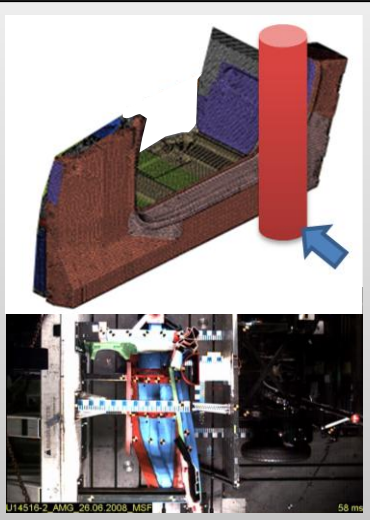
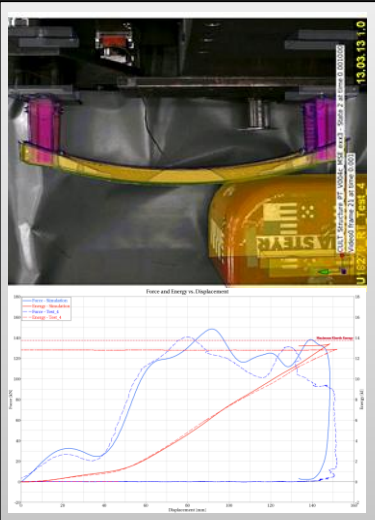
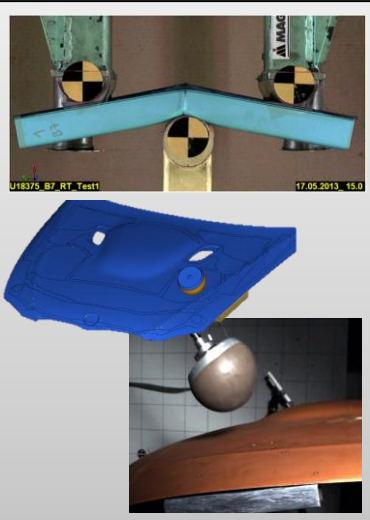
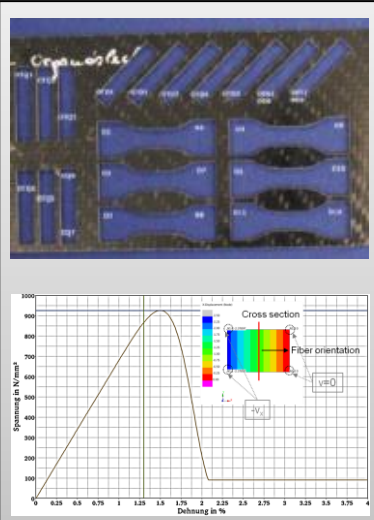
kurzfaser-
verstärkte
Thermoplaste

GFK + Waben

Organoblech

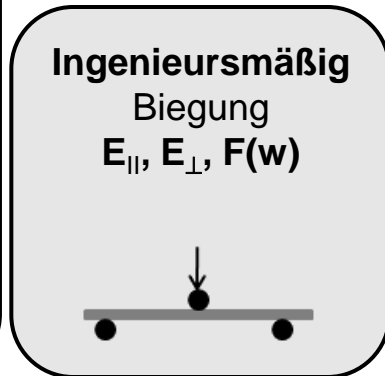
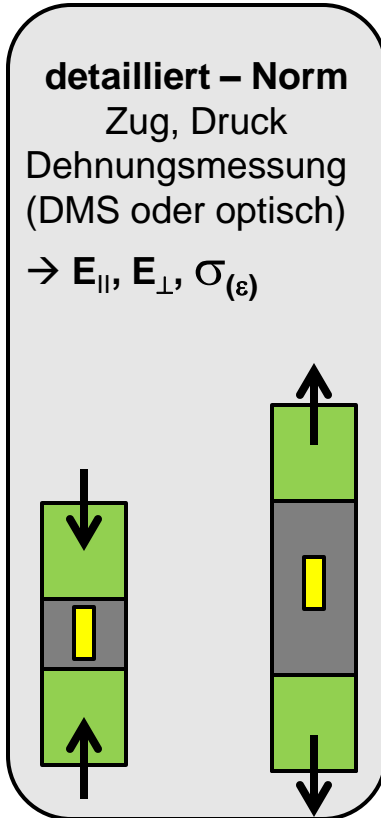
CFK Gelege
+Gewebe

Mehrstufiger Ansatz



Aufwand
Kosten
Zeit

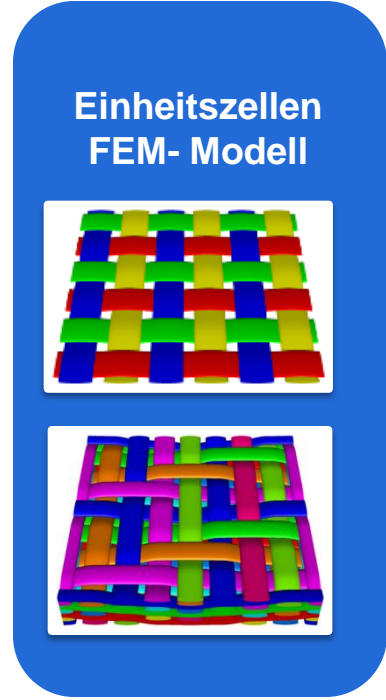
Versuch - zerstörende Prüfung
unterschiedliche Richtungen
 $0^\circ, 45^\circ, 90^\circ$



Virtuelle Methoden
Homogenisierung

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

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



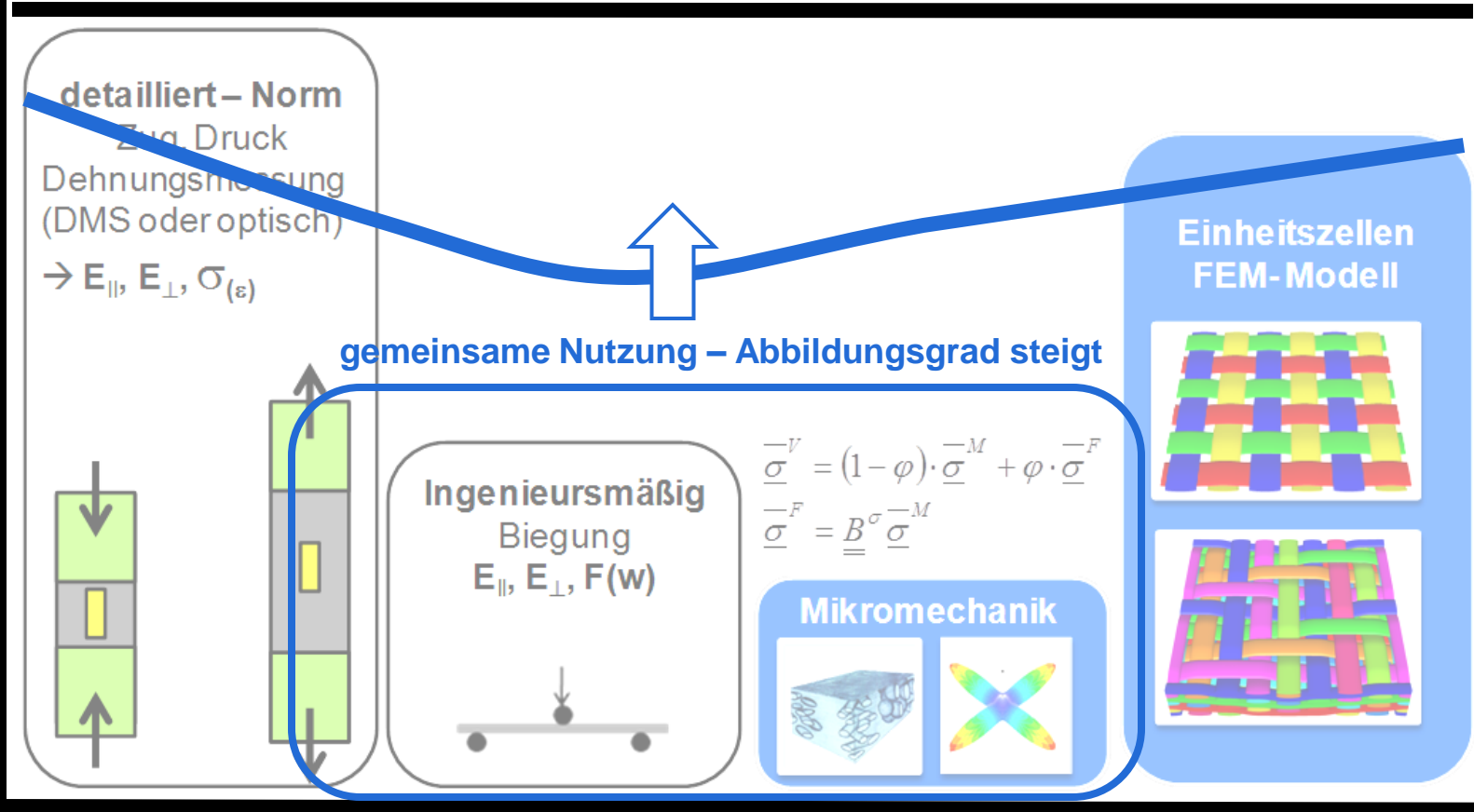
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Abbildung

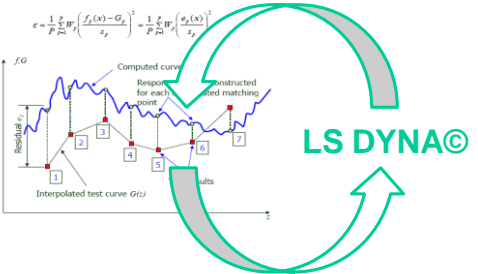
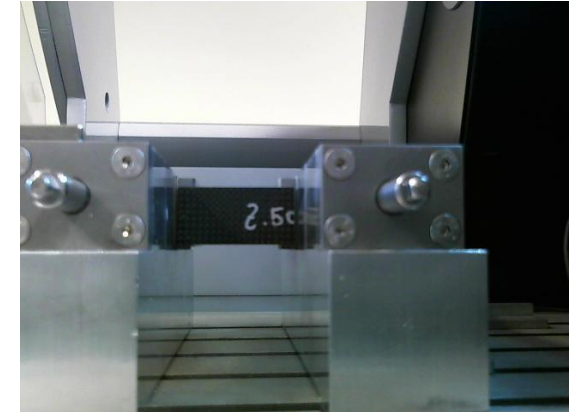
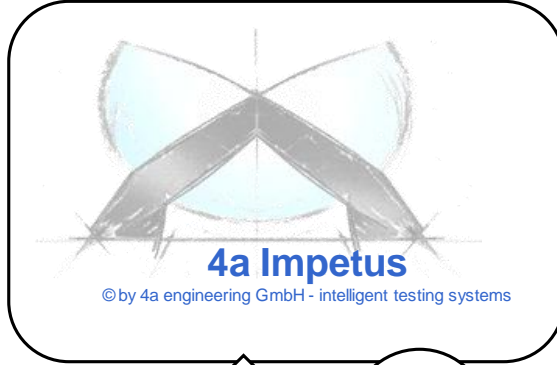
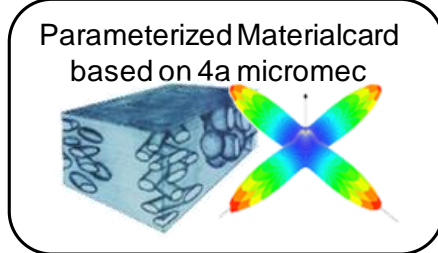
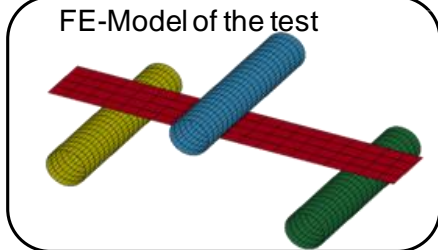
100% (Real)

**Versuch - zerstörende Prüfung
unterschiedliche Richtungen**

**Virtuelle Methoden
Homogenisierung**



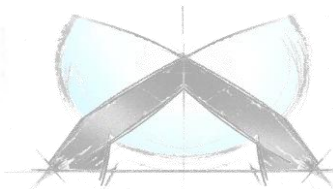
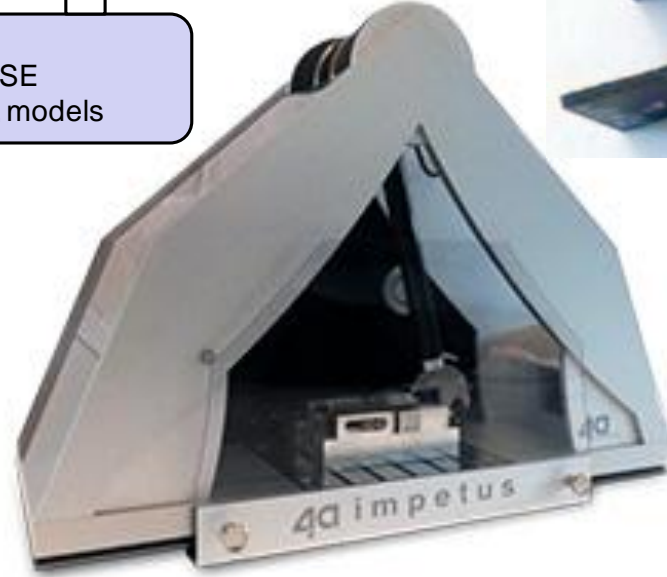
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Reverse Engineering

LS PREPOST©

DATABASE
measurement, models



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Input

Kennwerte der
Komponenten (E, α, λ)

Matrix
Verstärkungsstoffe

Datenbank

Faser- und Partikel
Orientierung

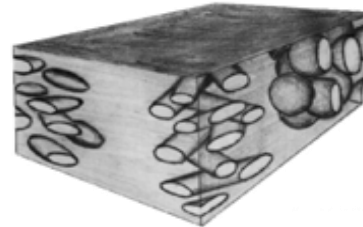
Datenbank

Faser- und Partikel
Gestalt

Datenbank



MicroMec V3.1



MeanField-Theory
3D-Lam-Theory
spezielle Funktionen



Output

3-D Verbundkennwerte

elastischer Tensor

thermischer
Ausdehnungstensor

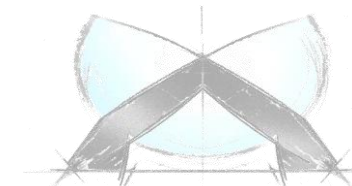
Wärmeleitfähigkeitstensor

Schnittstelle zu
FE-Codes

Anwendung im Hause 4a

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

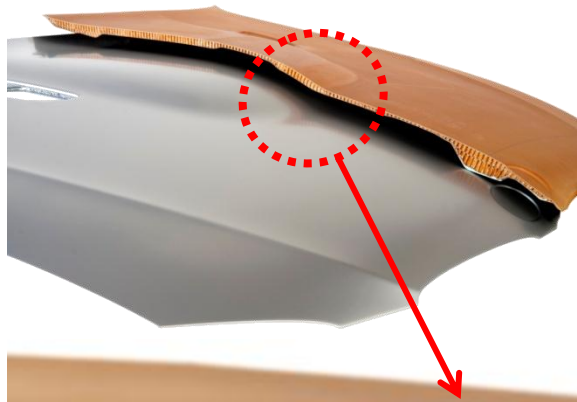
GFK, CFK → UD, Gewebe



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Glasfaserverbund + Waben

Frontklappe schematischer Aufbau



IMC-Schicht

Glas- oder Carbonfaser
Prepreg Komplettlagen

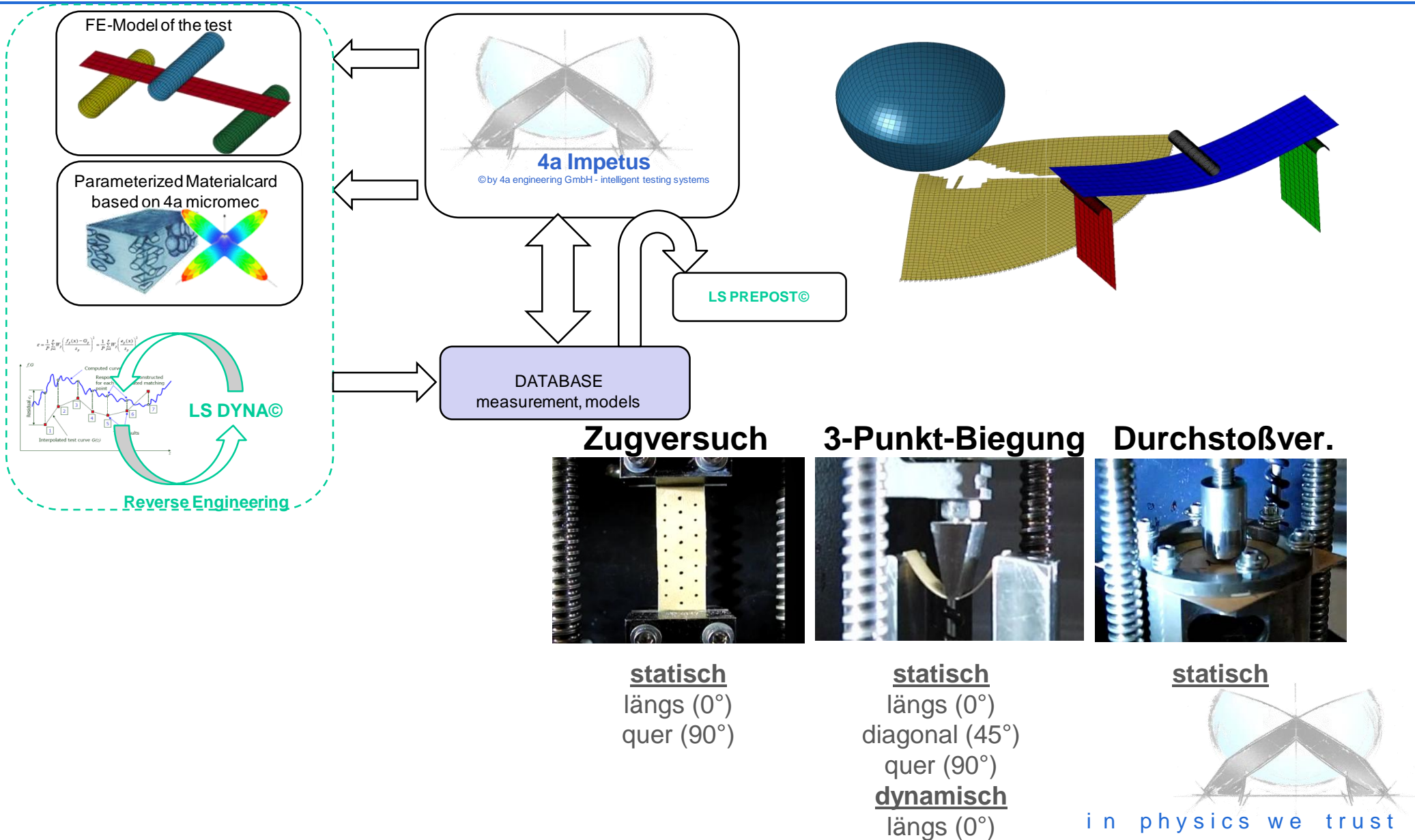
Wabe

Glas- oder Carbonfaser
Prepreg Komplettlagen



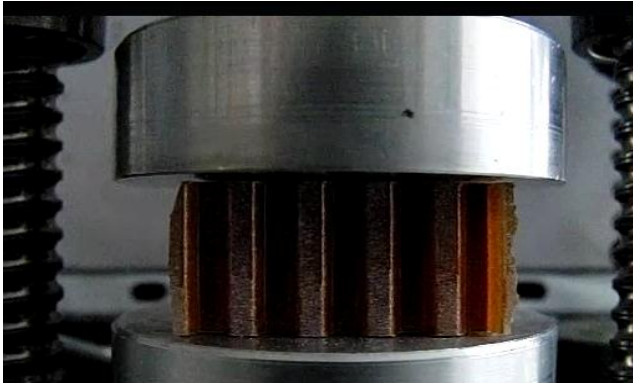
Glasfaserverbund + Waben

Charakterisierung Decklagen

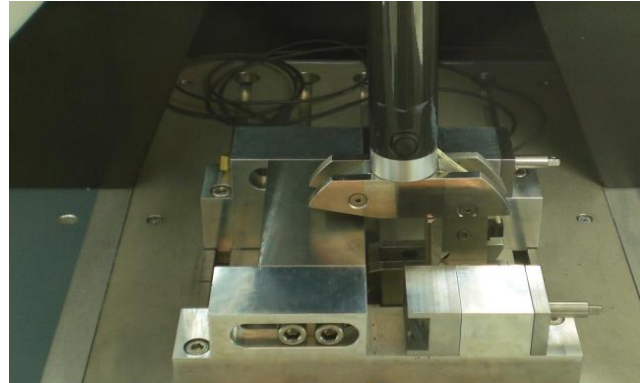


Glasfaserverbund + Waben

Charakterisierung Wabenkern / Gesamtverbund



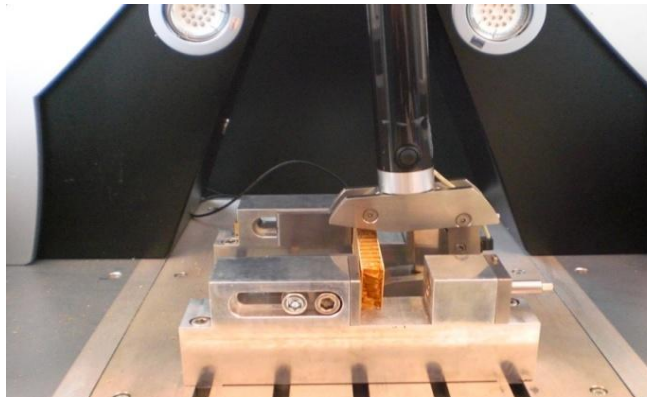
statische Druckversuche



dynamische Druckversuche



statische Biegeversuche



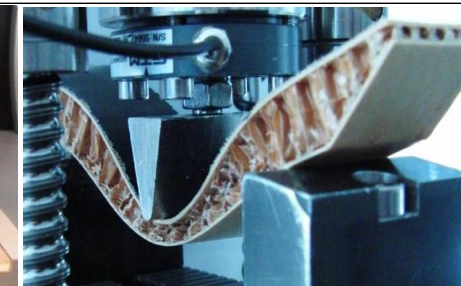
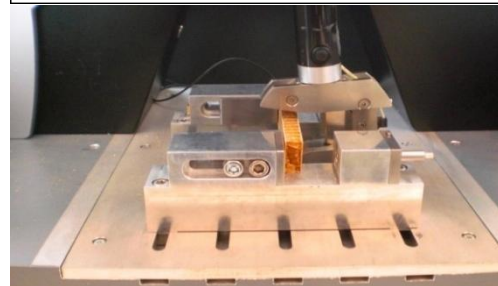
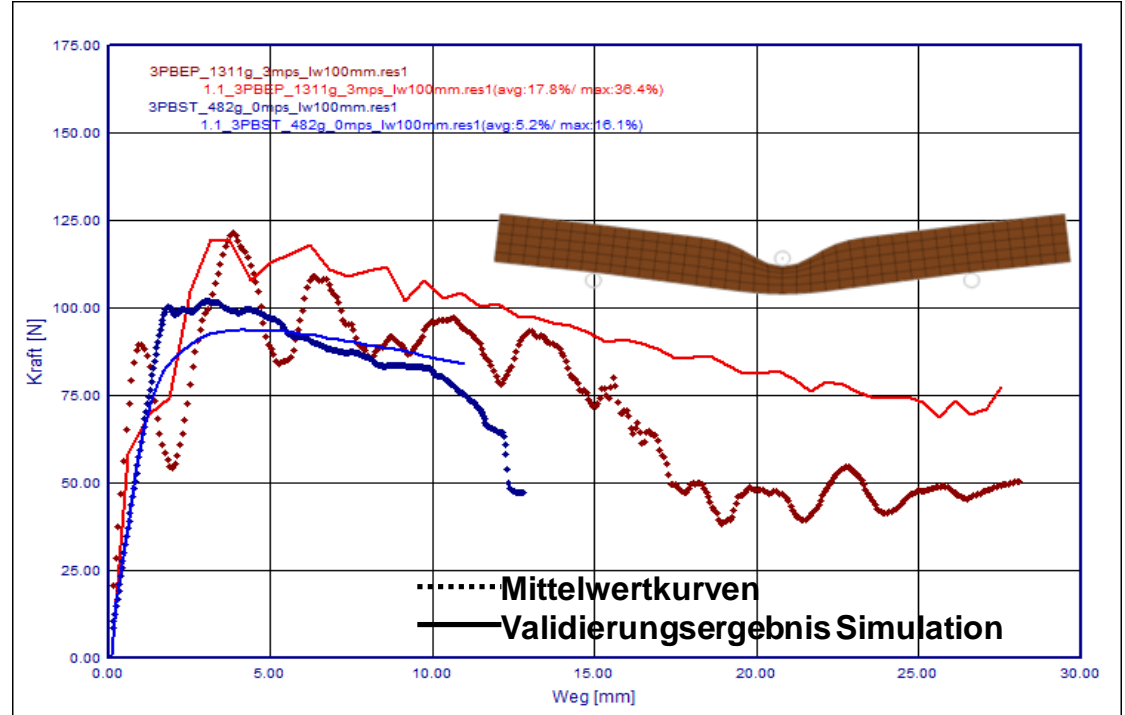
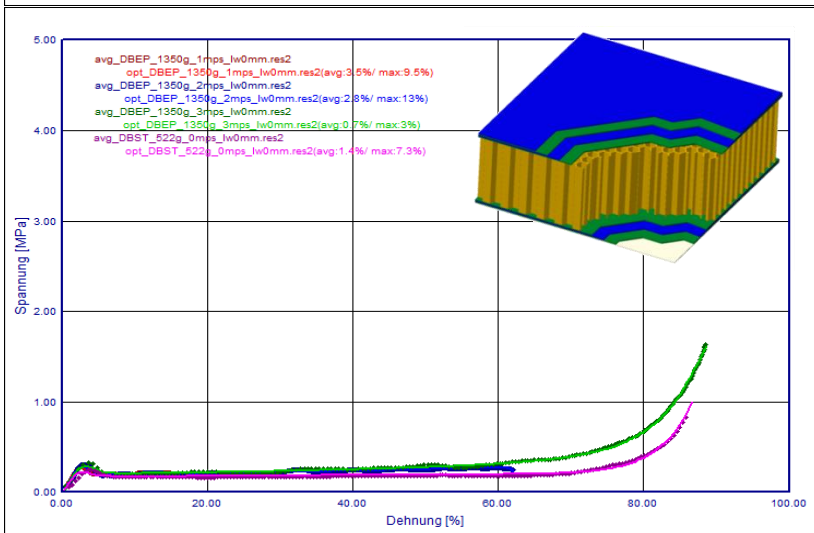
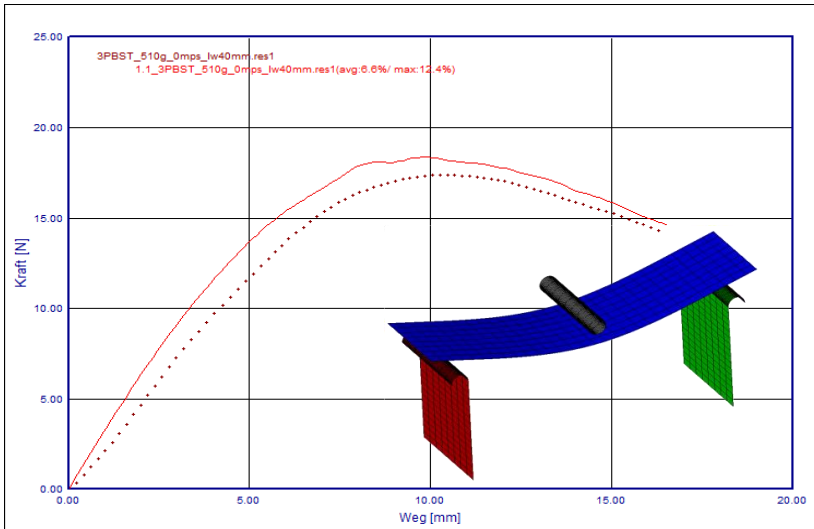
dynamische Biegeversuche



Bauteilversuche

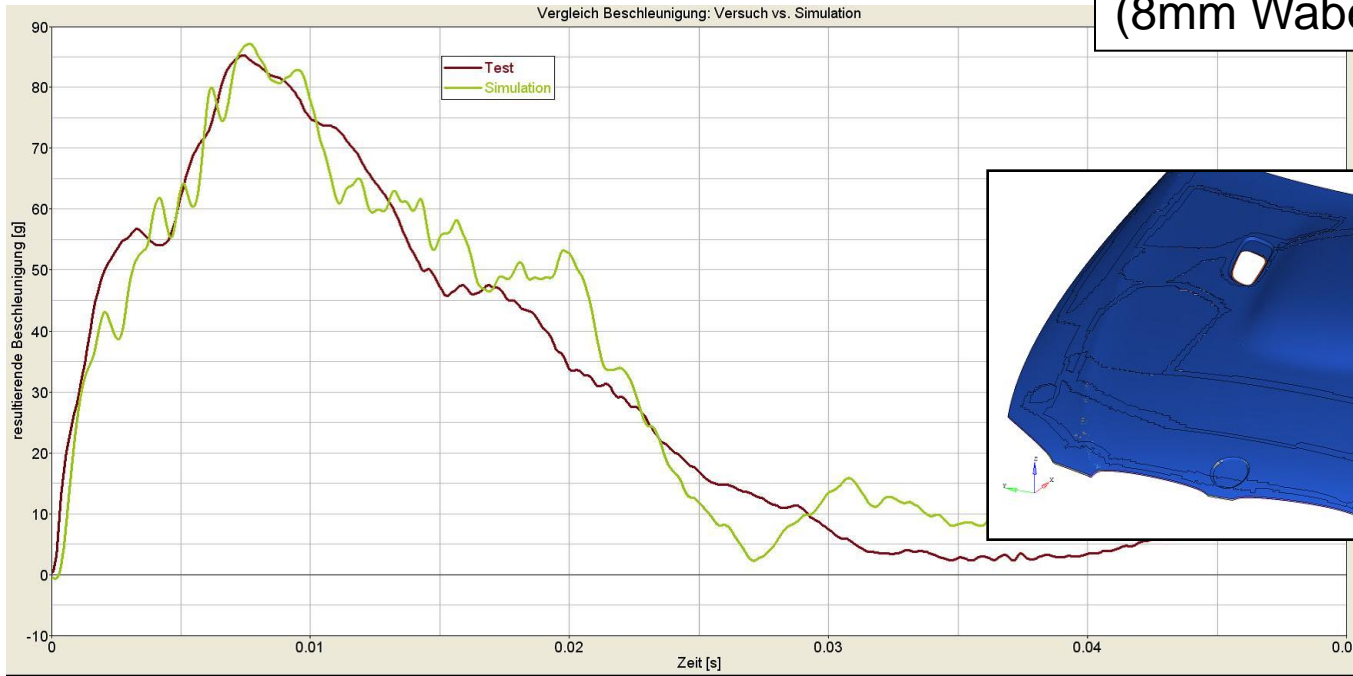
Glasfaserverbund + Waben

Material - Test vs. Simulation

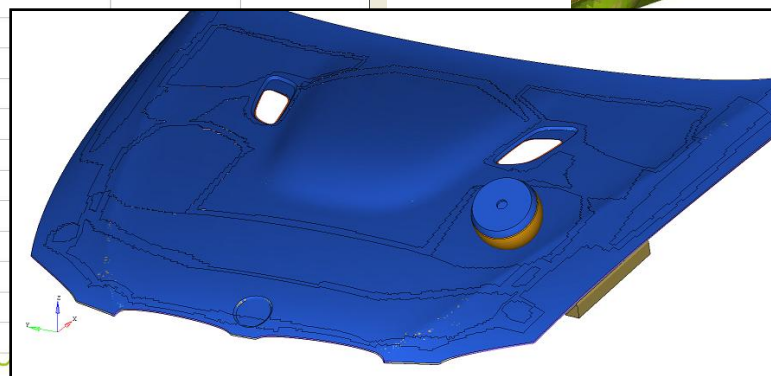
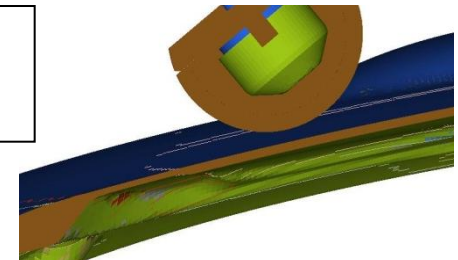


Glasfaserverbund + Waben

Bauteil - Test vs. Simulation



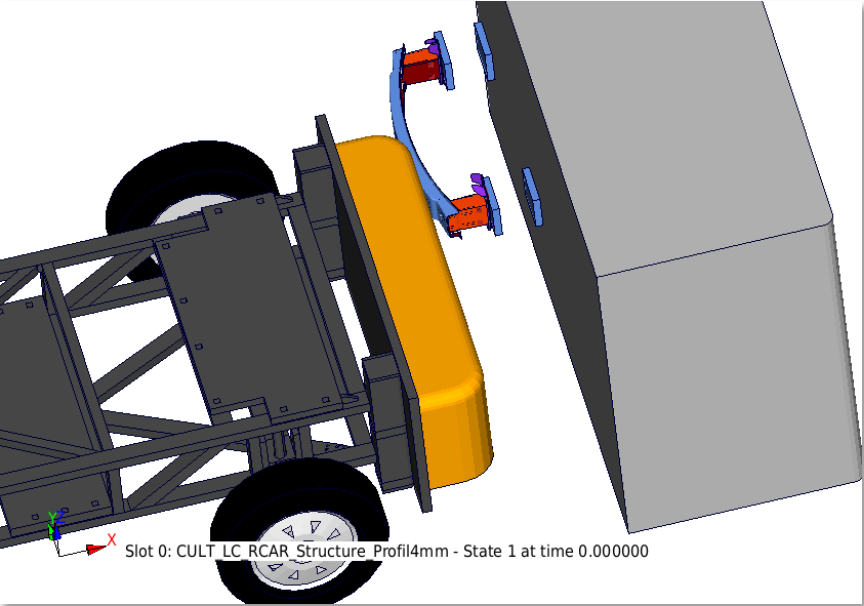
Pkt. in Zone 2
(8mm Wabenkern)



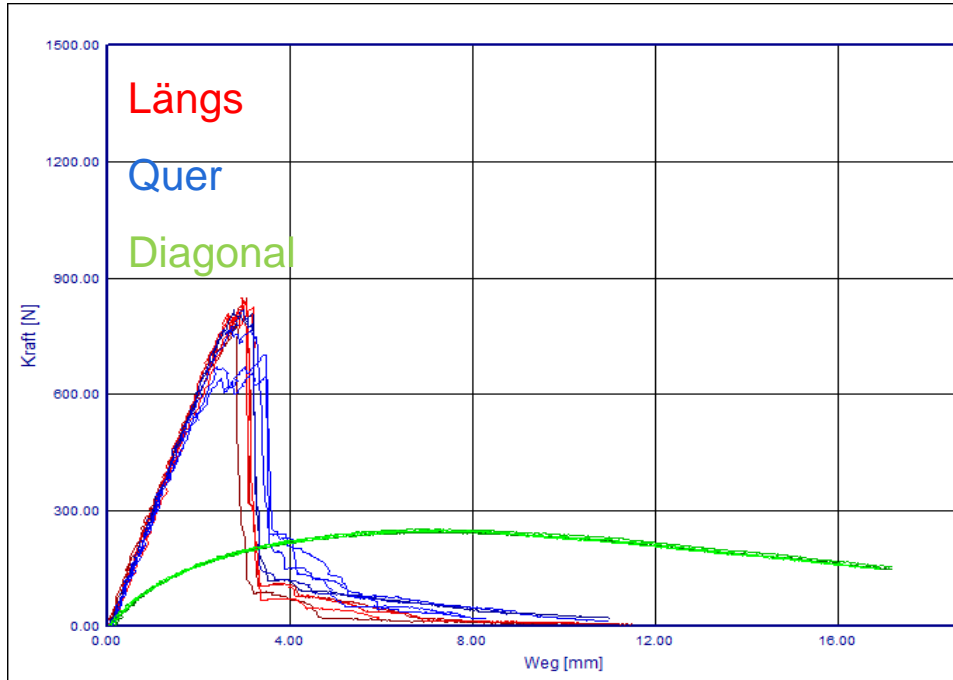
Keine Validierungsmaßnahmen wurden vorgenommen
Gute Übereinstimmung des Beschleunigungsverlaufes
Kurvencharakteristik bildet Bruchbeginn gut ab

Organoblech

Crash Management System

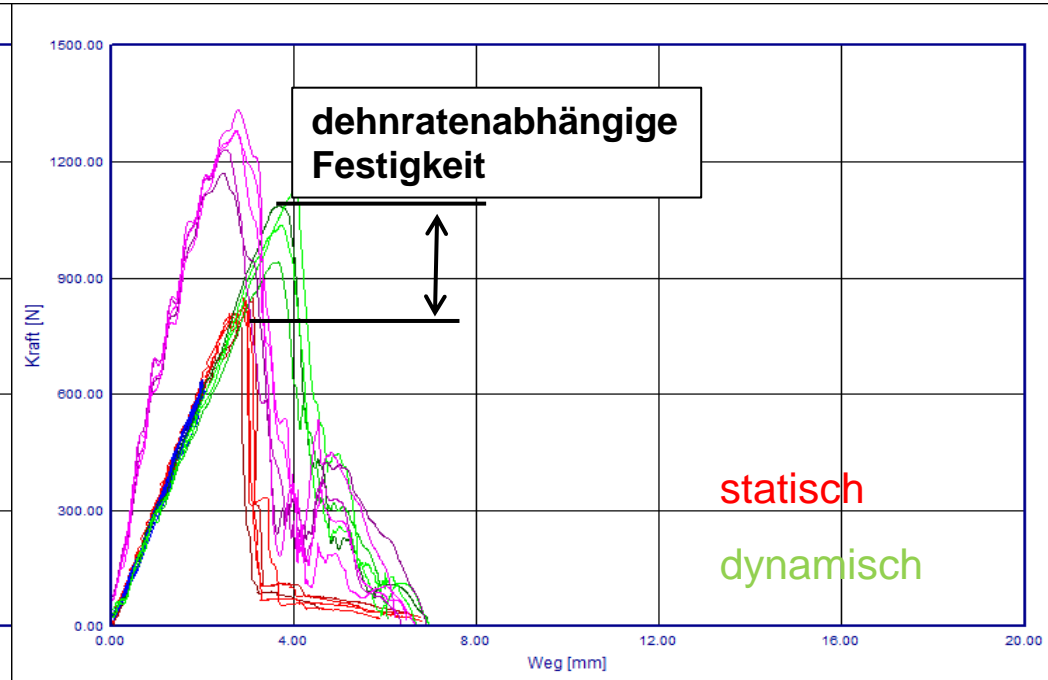


statische 3-Punkt-Biegemessungen



Einfluss Orientierung

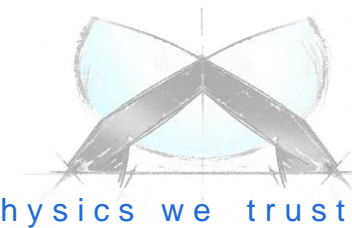
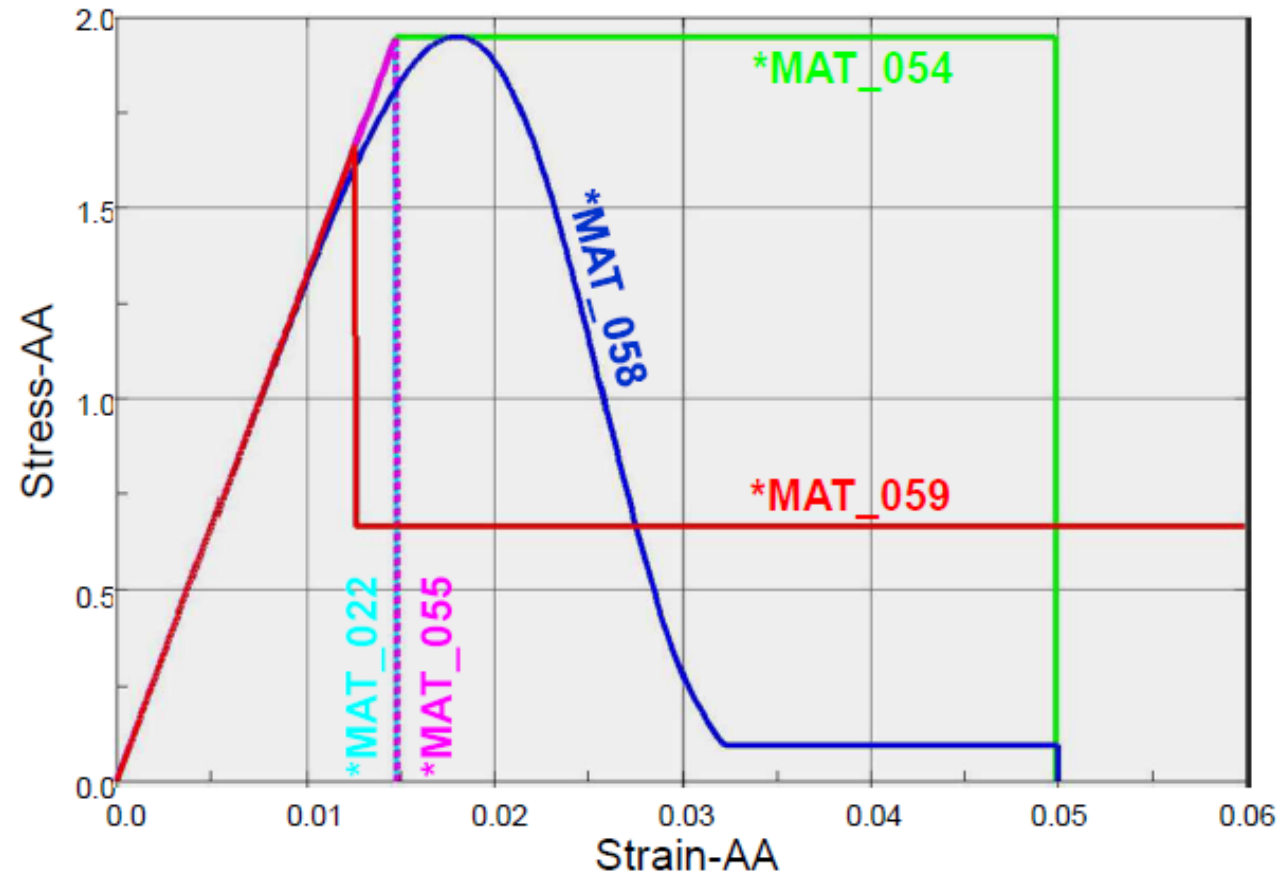
dynamische 3-Punkt-Biegemessungen



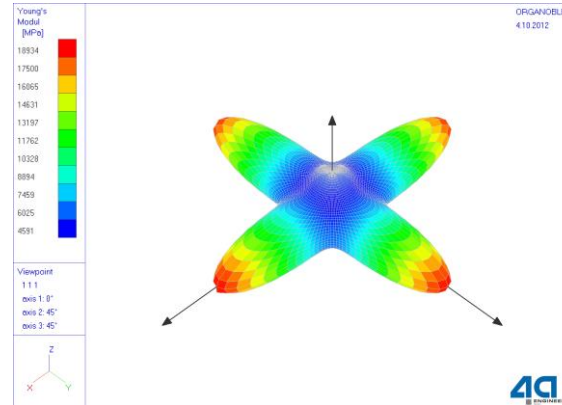
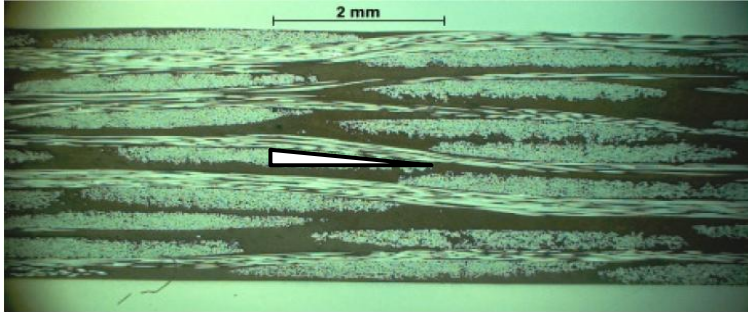
Einfluss Prüfgeschwindigkeit



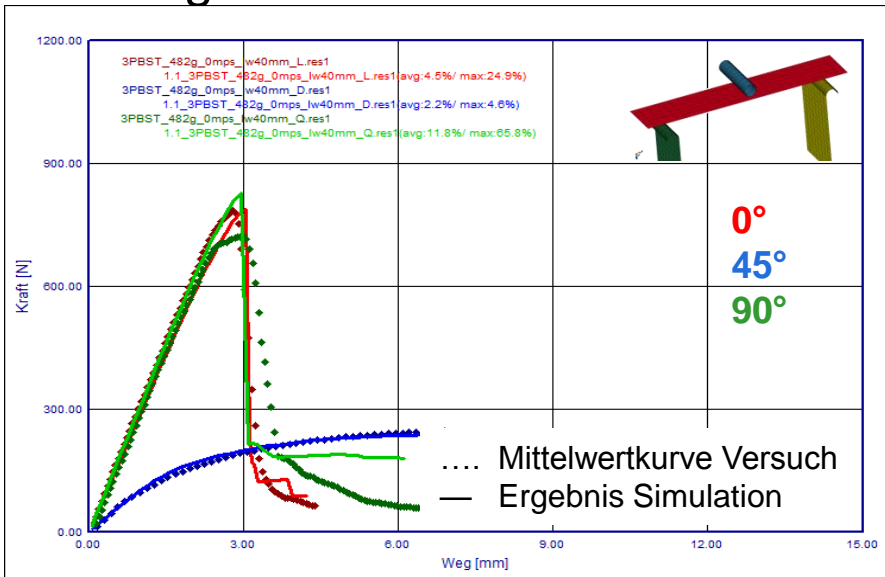
- Steifigkeit
 - Anisotropie
- Festigkeit
 - Pauschal
 - Hauptrichtung
- Energieaufnahme
 - Fit-Parameter



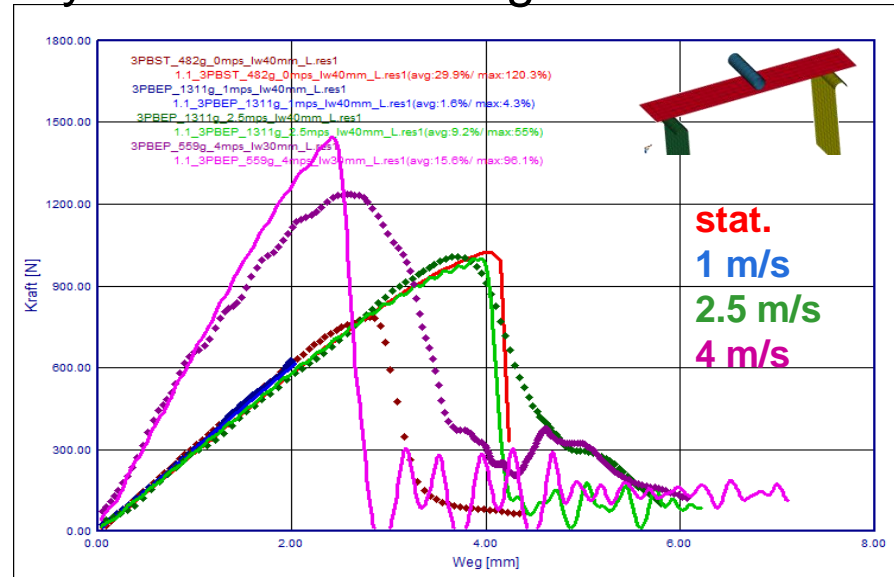
Steifigkeit mit Hilfe der Mikromechanik



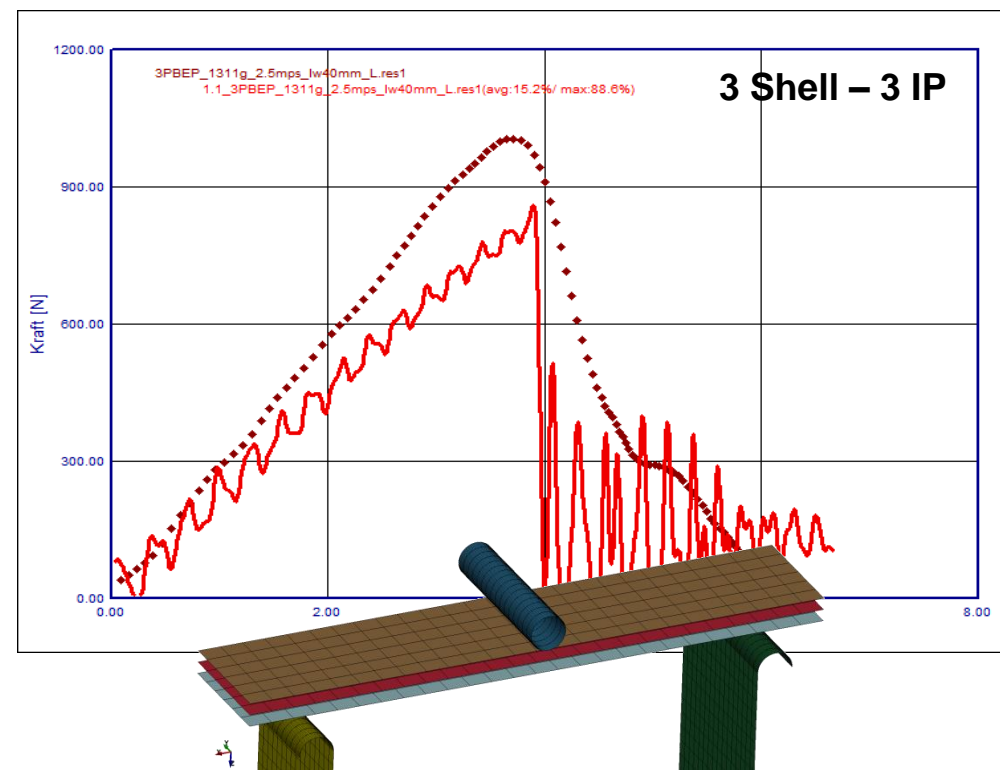
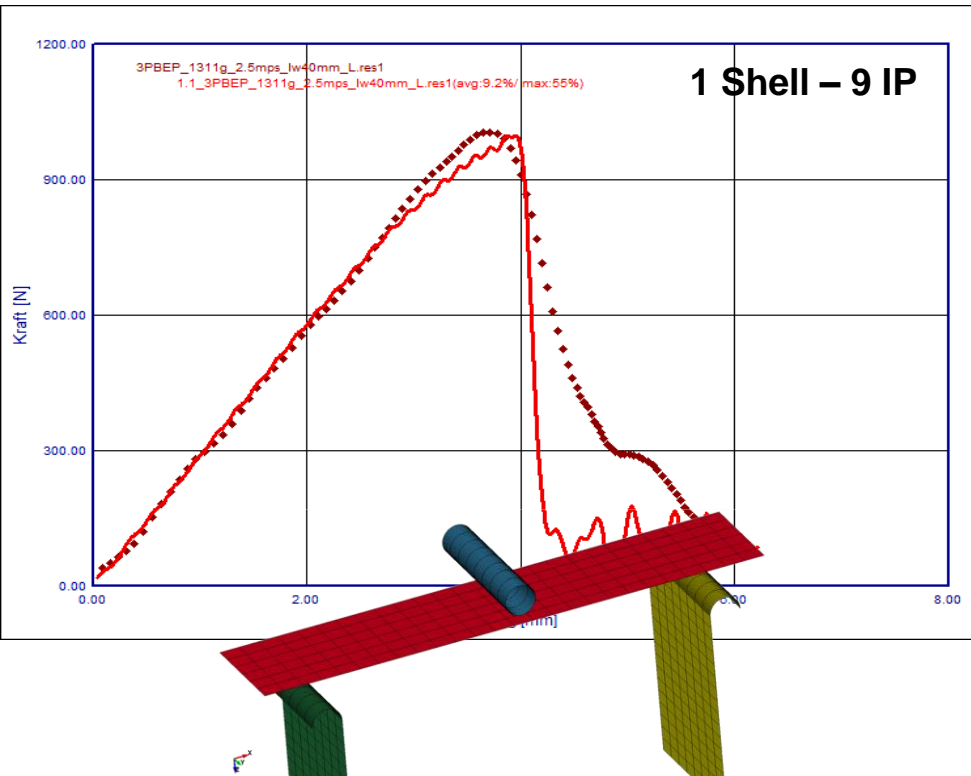
Versagensanpassung quasistatische Messergebnisse



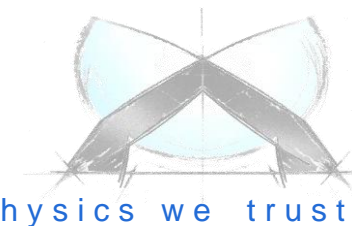
Versagensanpassung dynamische Messergebnisse

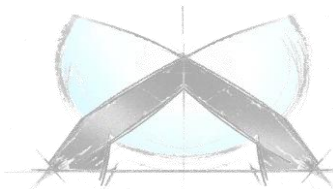
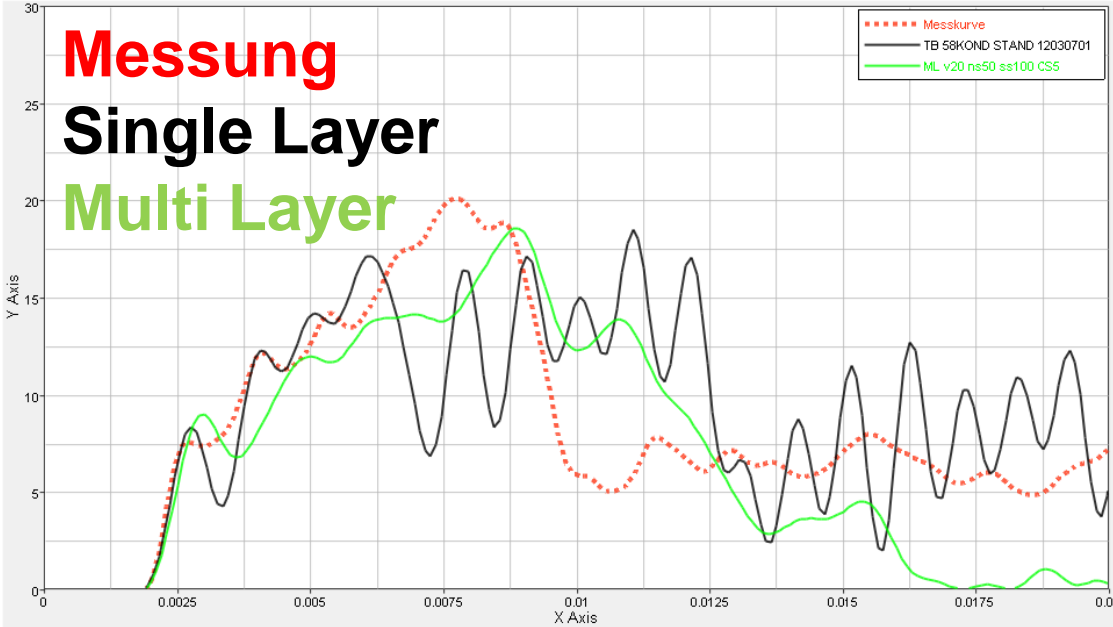
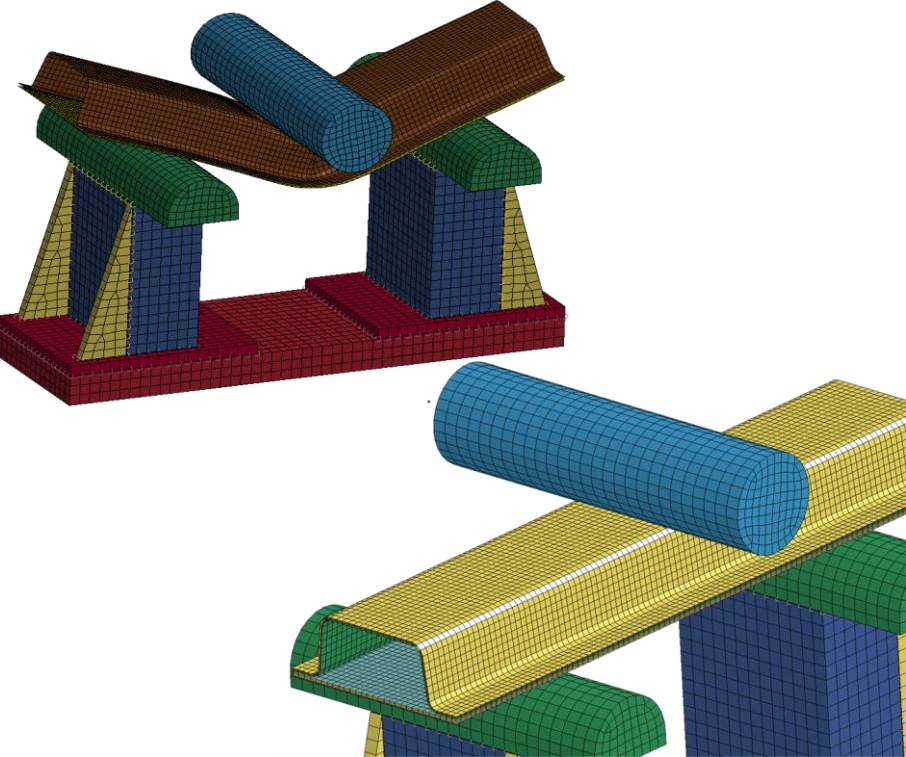


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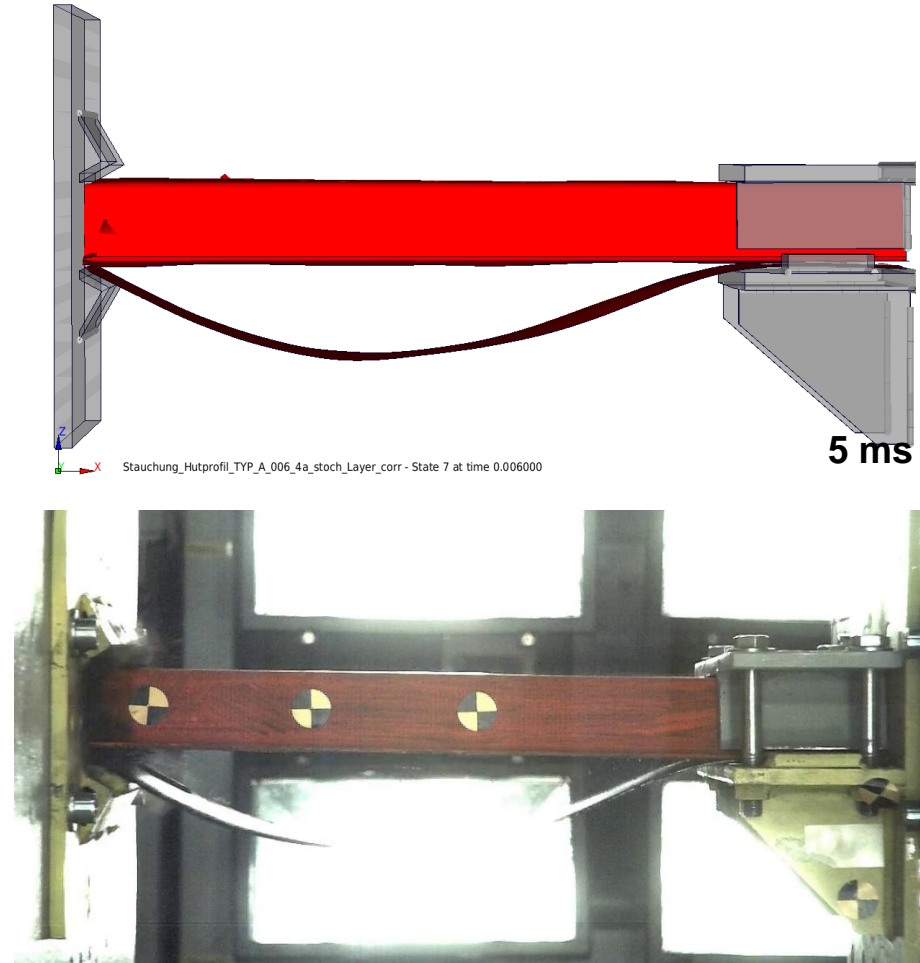
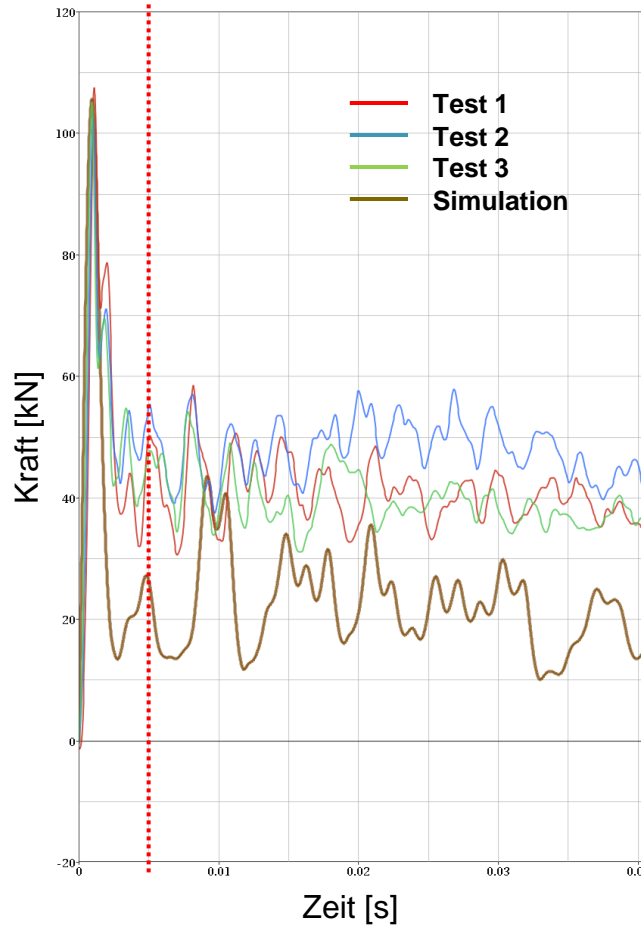
- Ermittelte Materialkarte kann den Versuch bei einer Idealisierung *PART_COMPOSITE mit 9 Integrationspunkten gut abbilden.
- Ein Multi-Layer-Aufbau ohne Modifikation führt zu einer geringeren Steifigkeit, der Bruchzeitpunkt stimmt recht gut mit den Messdaten überein.





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Bauteil – Profilsimulation



Werkstoff

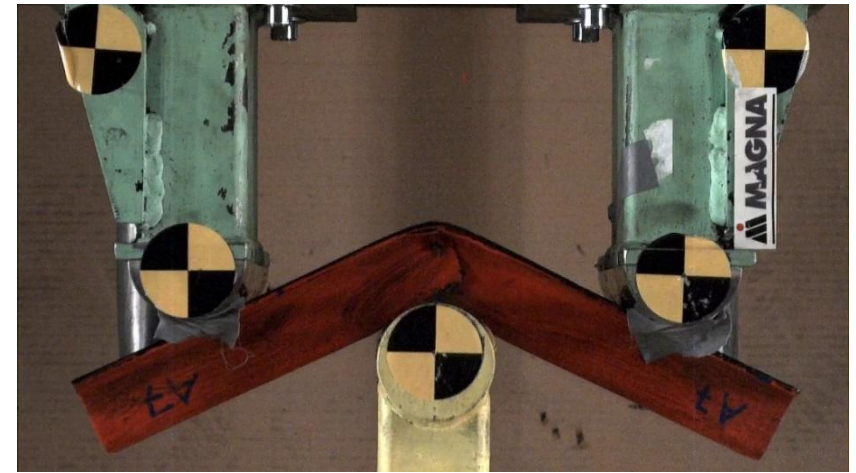
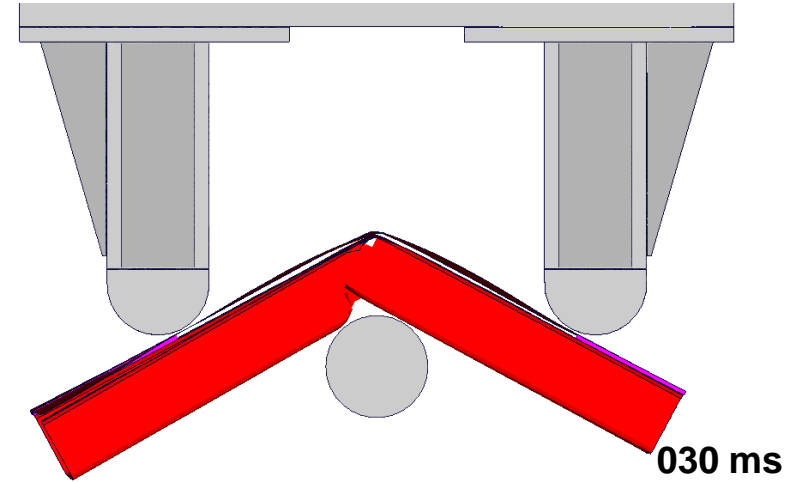
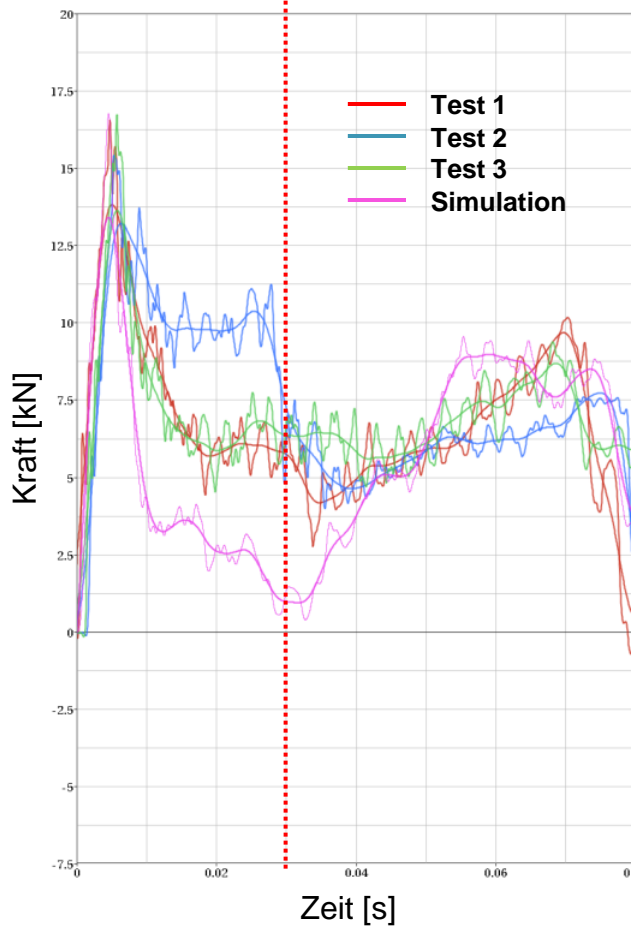
Bauteil

Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

Bauteil – Profilsimulation



Werkstoff

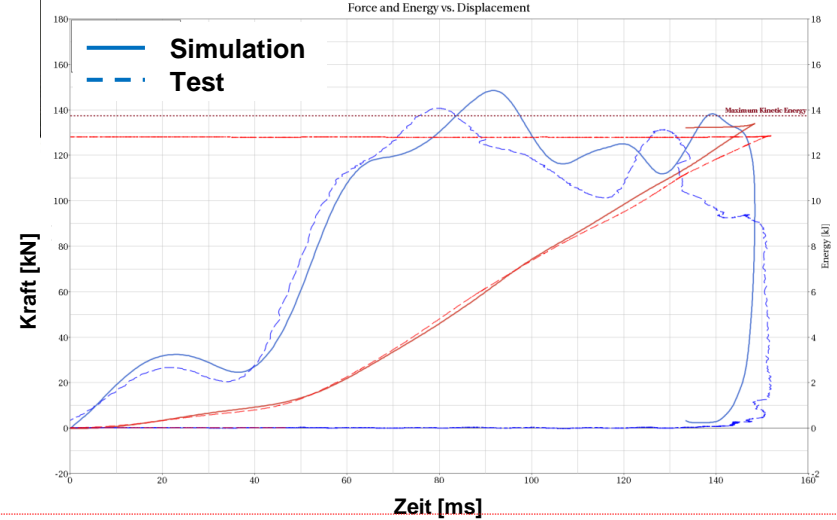
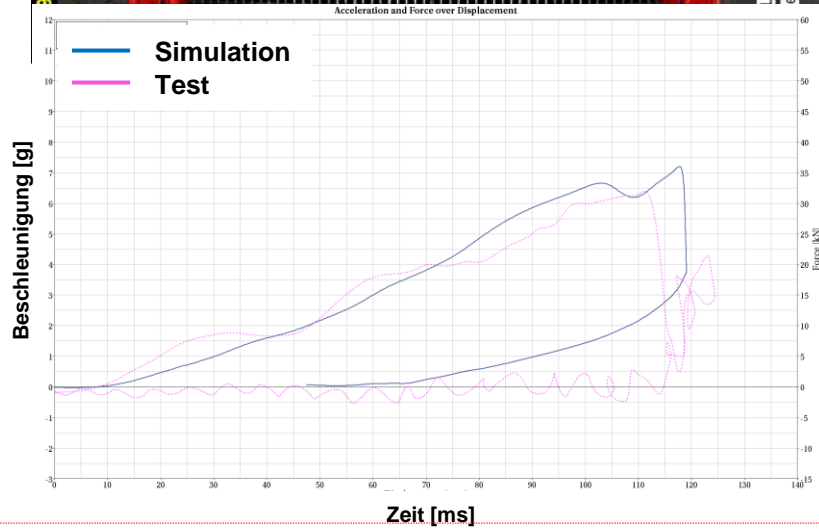
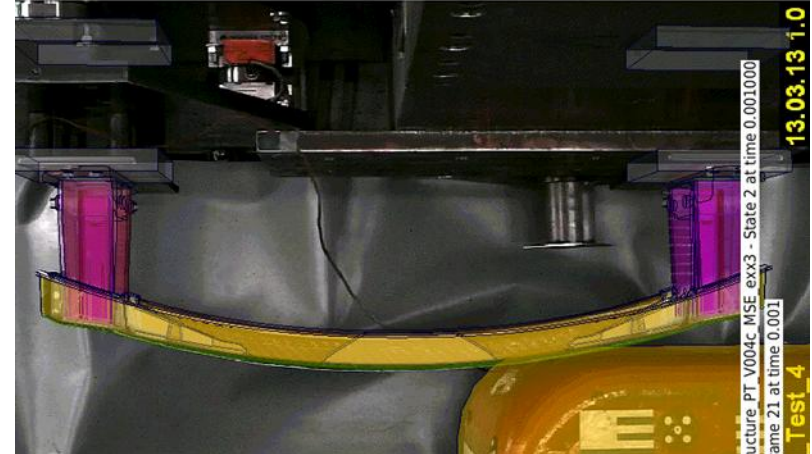
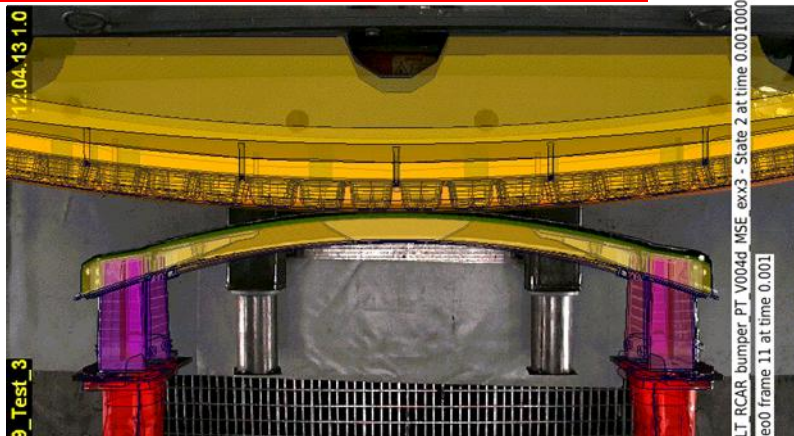
Bauteil

Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

Bauteil – Organo Frontend



Werkstoff

Bauteil

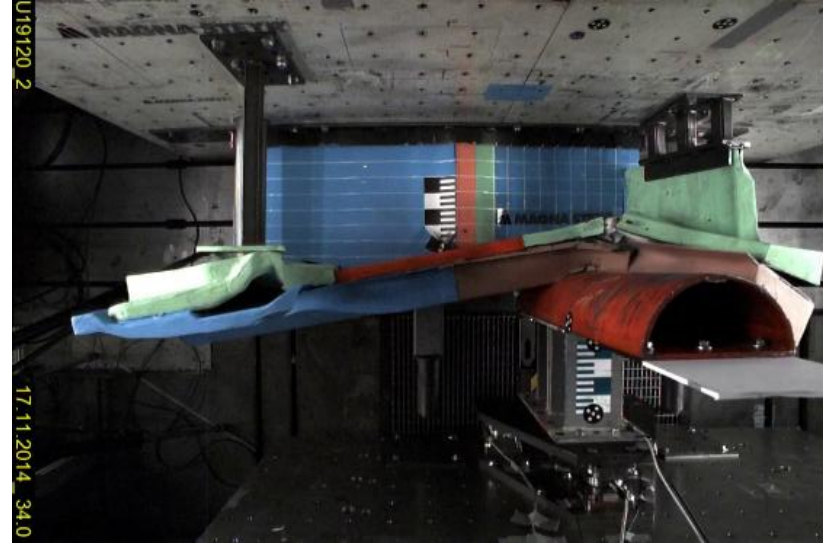
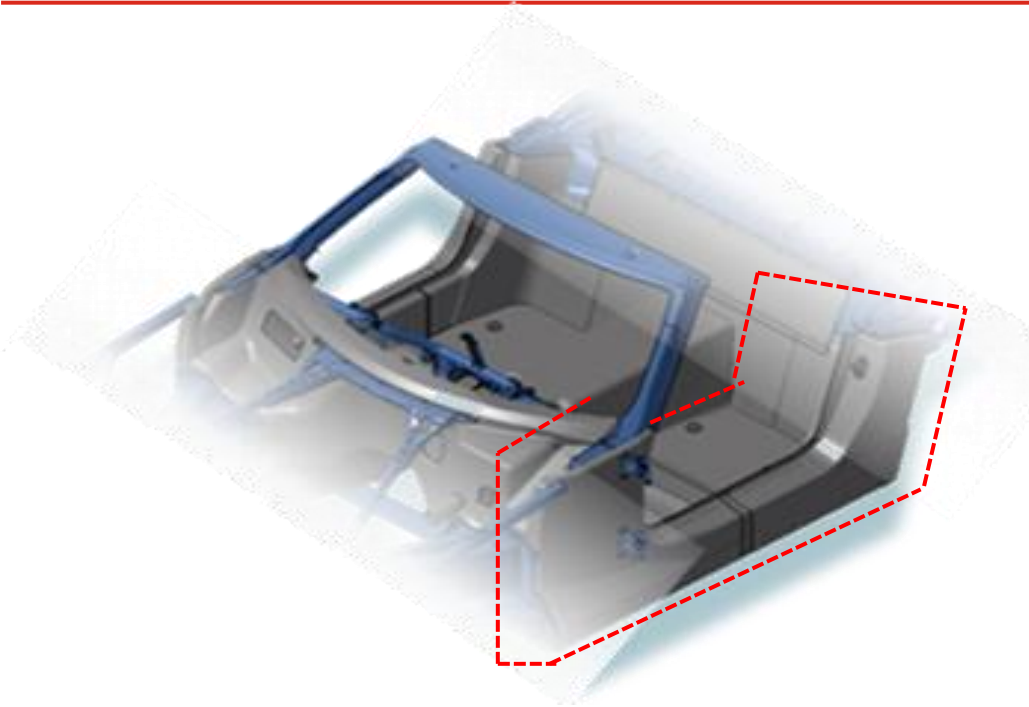
Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

CFK Gelege - Gewebe

Composite Life Cell



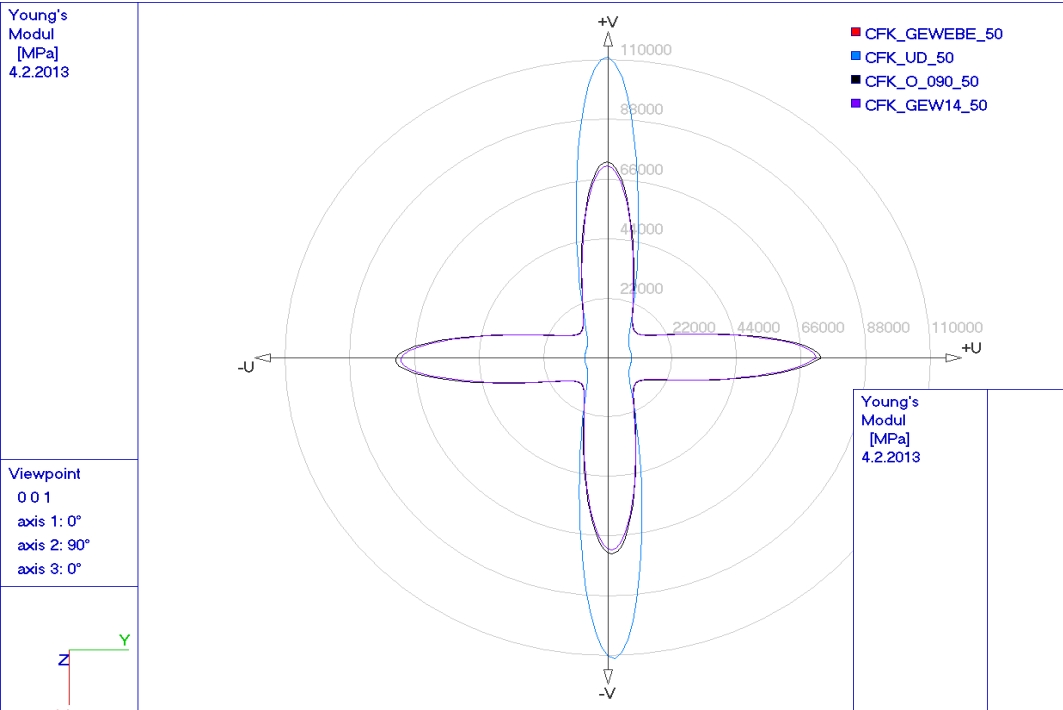
Materialcharakterisierung CFK soll 50%

UD Gelege – Gewebe

Prepreg / Pultrusion / Harzinfusion (Prototypische Fertigung)

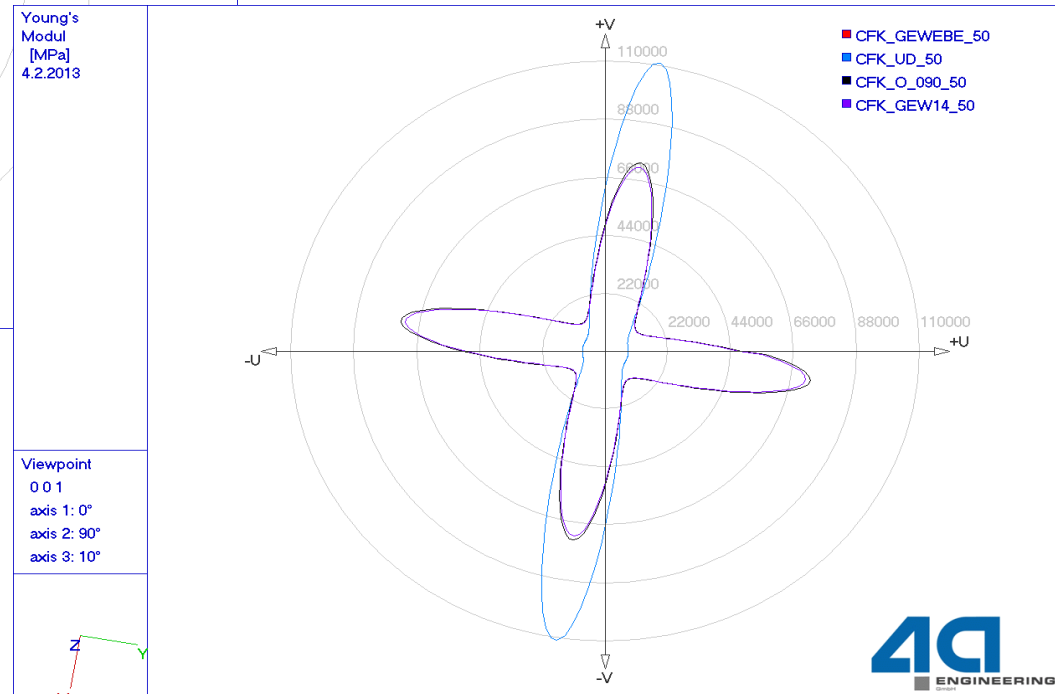
CFK Gelege - Gewebe

Steifigkeit in der Laminatenebene



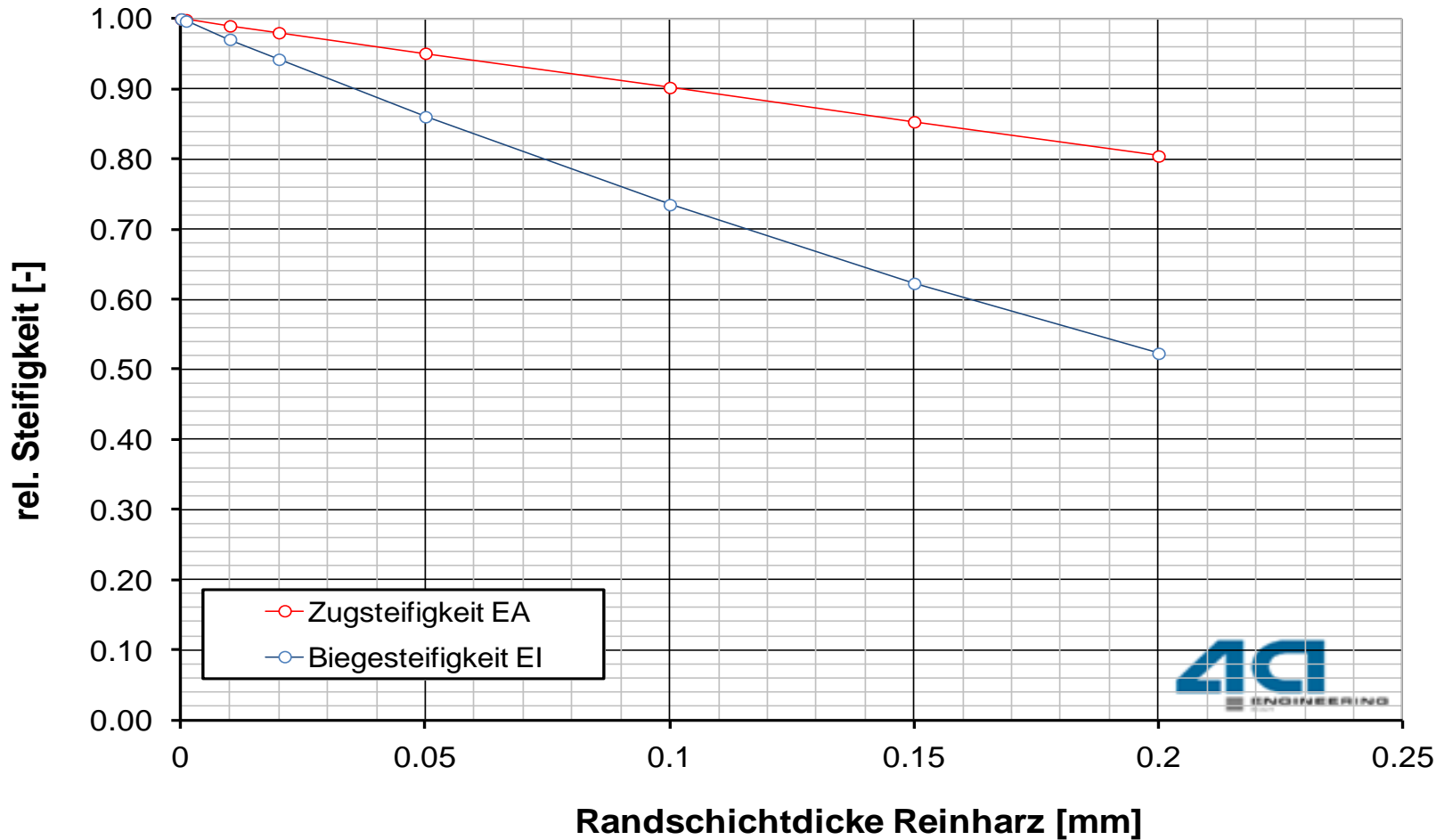
Verdrehung um 10° (Probenentnahme)

- UD starker Einfluss
- Gewebe geringerer rel. Einfluss

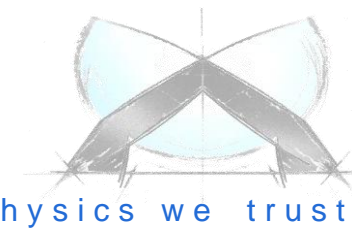


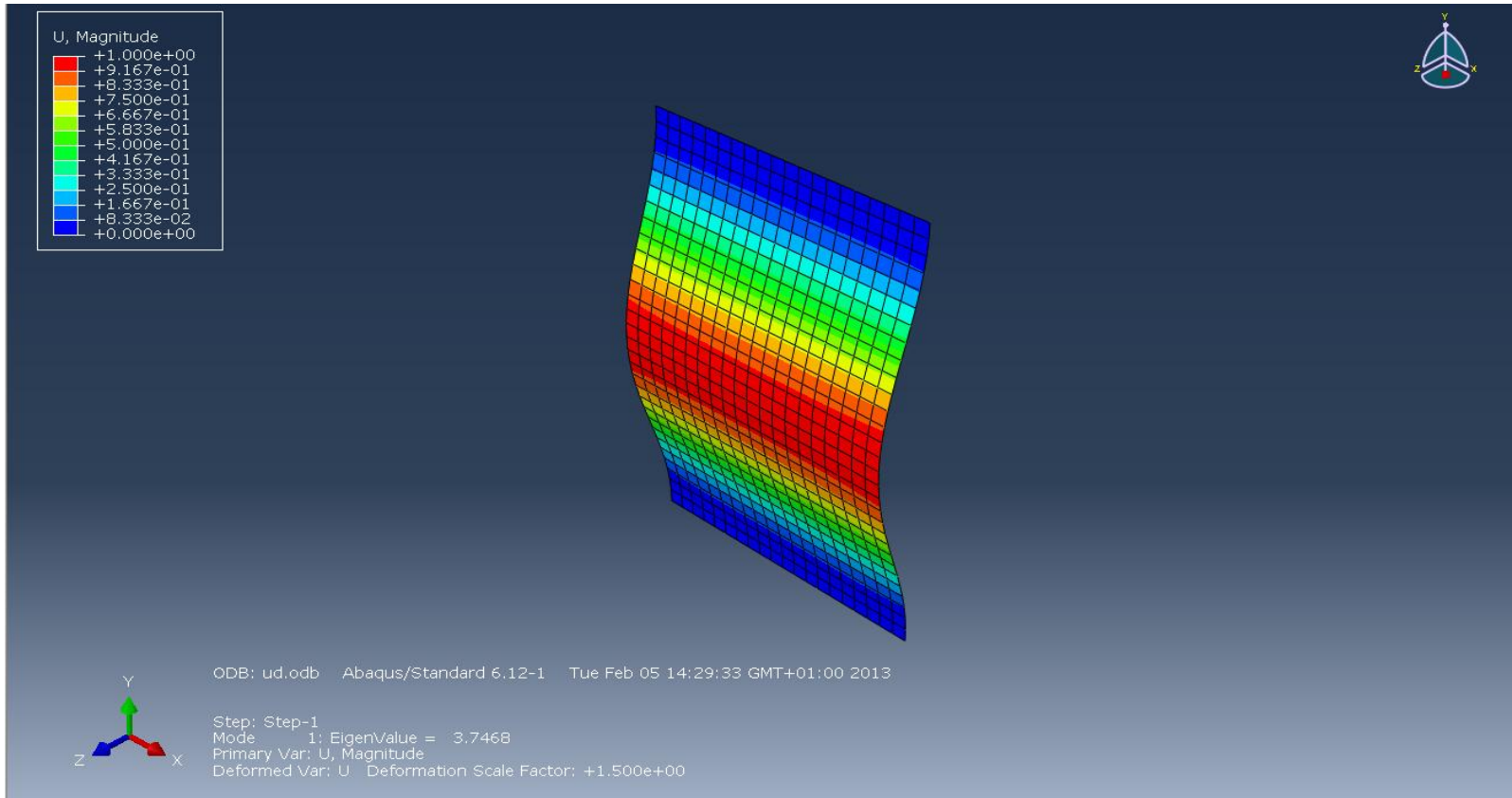
Ermittelt mit 4a MicroMec für

- 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)

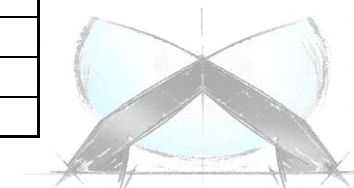


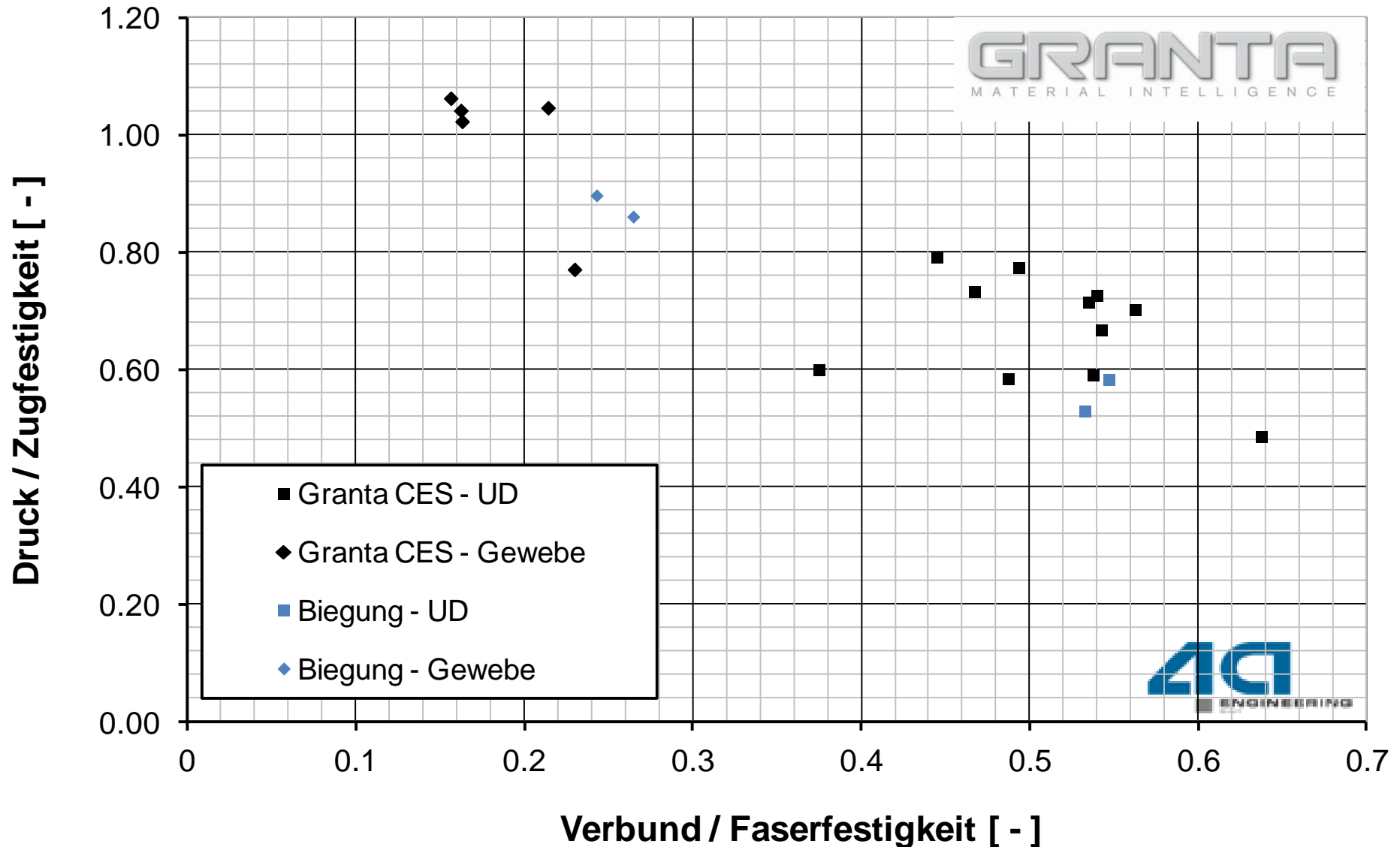
Ermittelt mit 4a Lam2D unter Annahme eines CFK HT 60% UD Laminates mit einer Gesamtdicke von 2 mm.



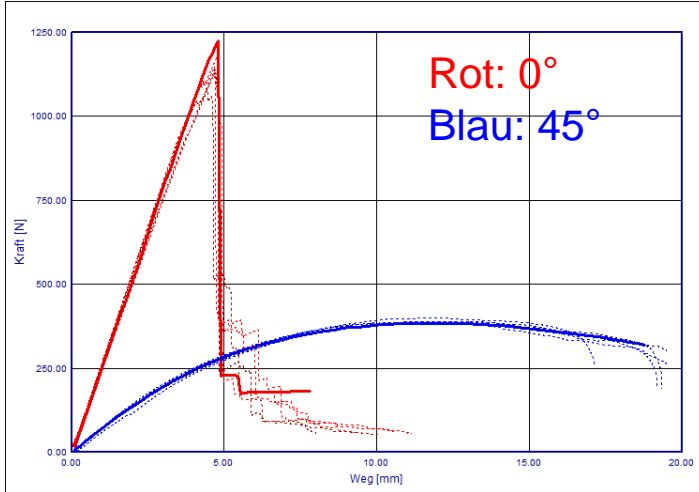


	lw mm	A mm ²	KRAFT [KN]		Spannung [MPa]		theor. Festigkeit Zug[MPa]	
			Längs	Quer	Längs	Quer		
Prepreg Gewebe	15	20	2.59	2.59	129.7	129.7	971.0	13%
Prepreg UD	15	20	3.75	0.68	187.3	33.9	2188.0	9%
Prepreg Gewebe	10	20	3.32	3.32	165.8	165.8	971.0	17%
Prepreg UD	10	20	4.43	1.26	221.5	63.1	2188.0	10%

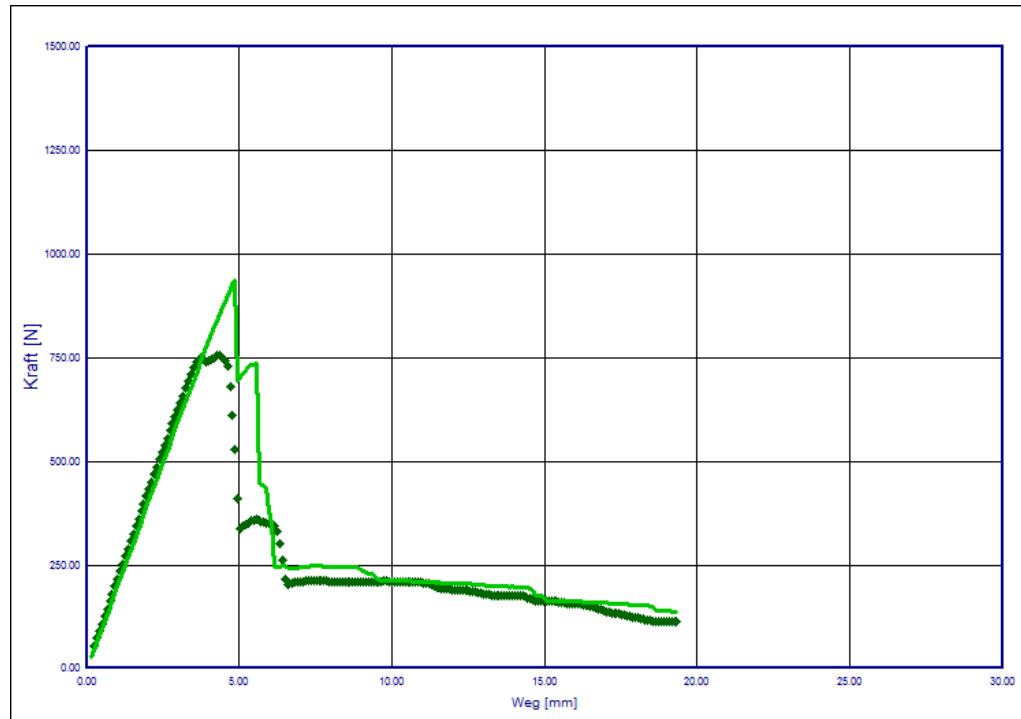




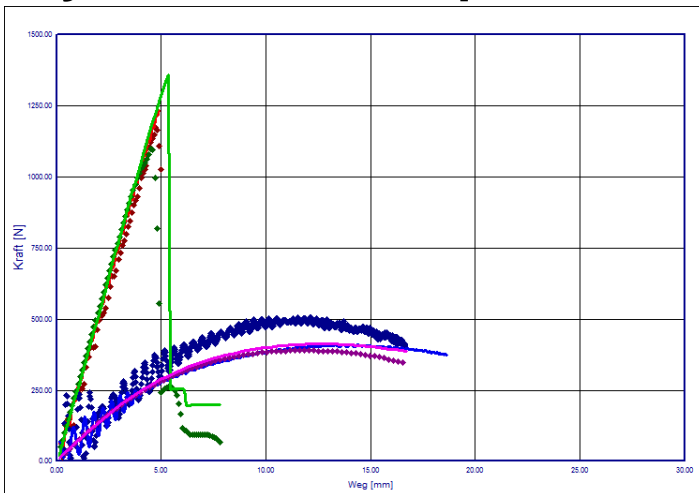
Orientierung



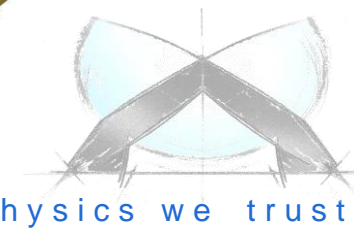
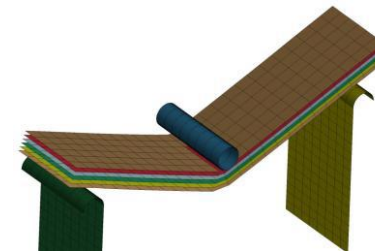
Aufbau - Mehrschichtversagen



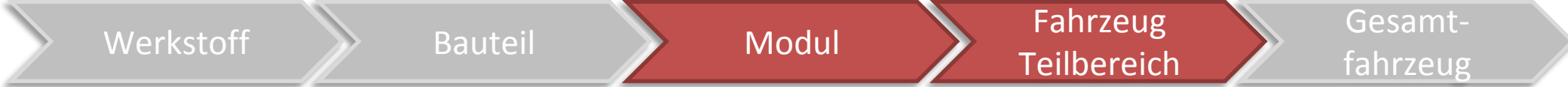
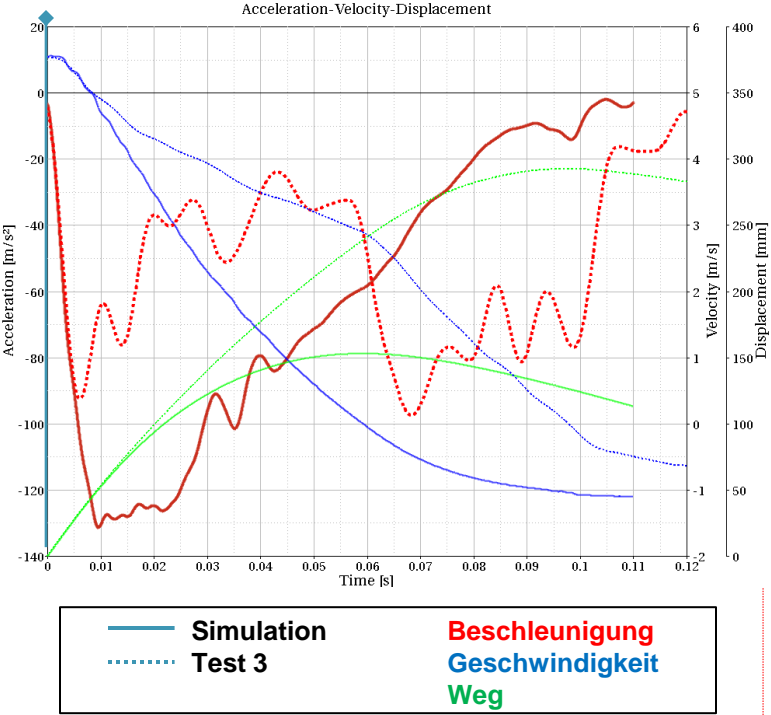
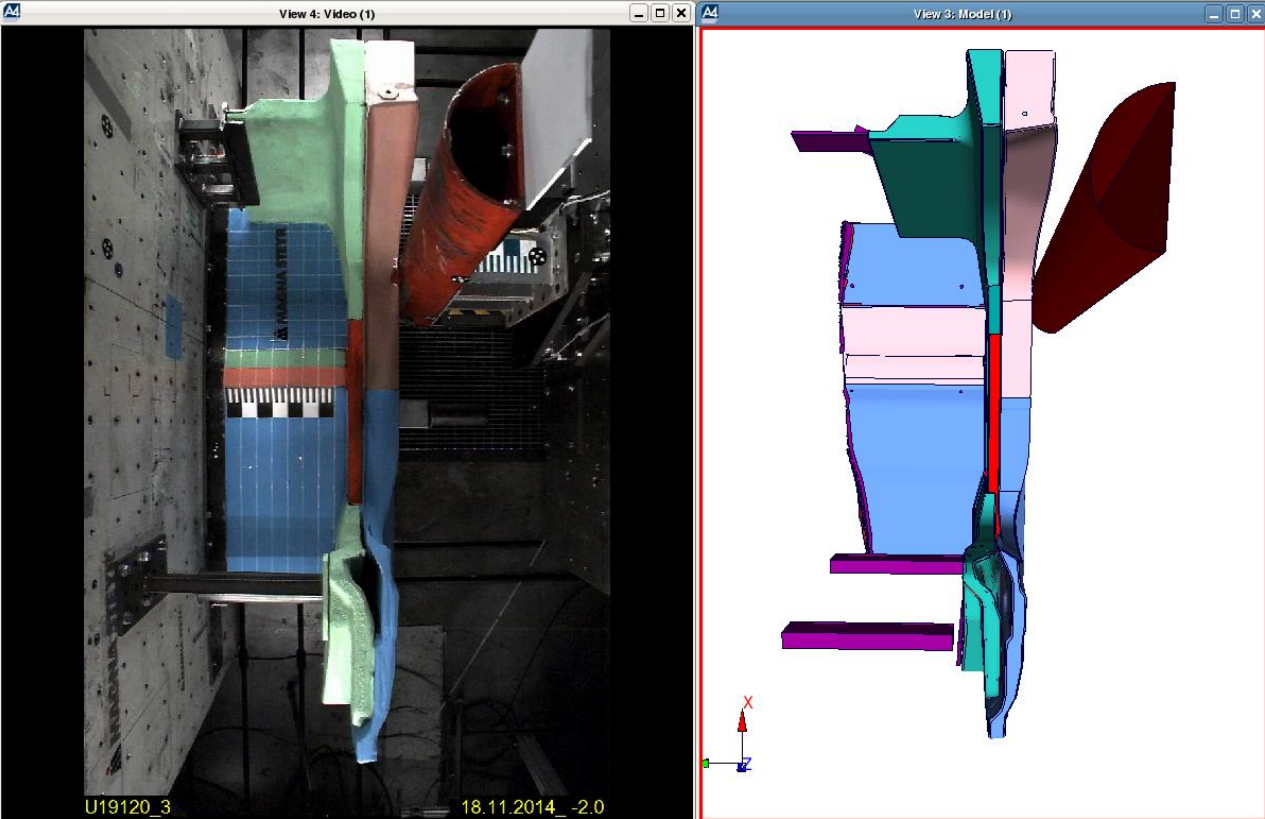
Dynamisch 4a impetus



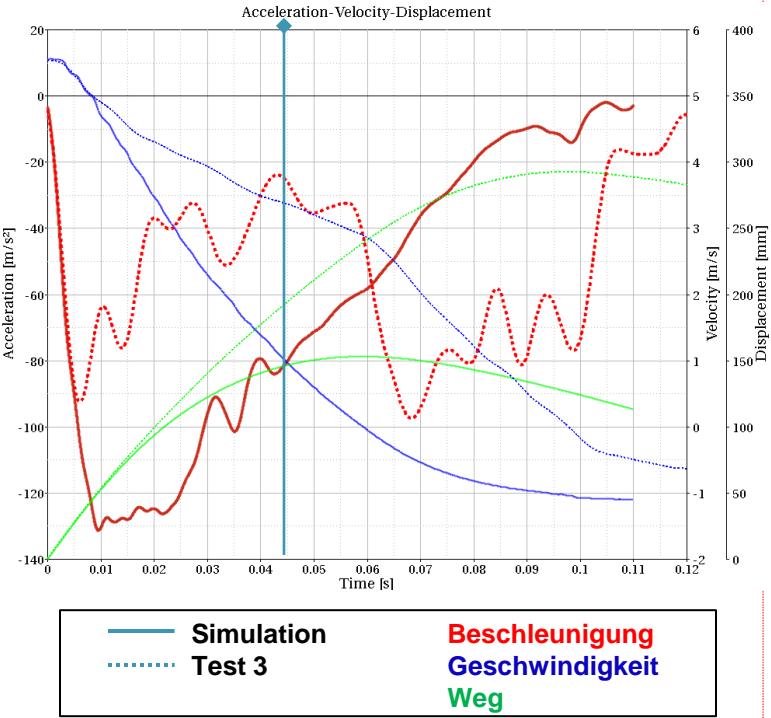
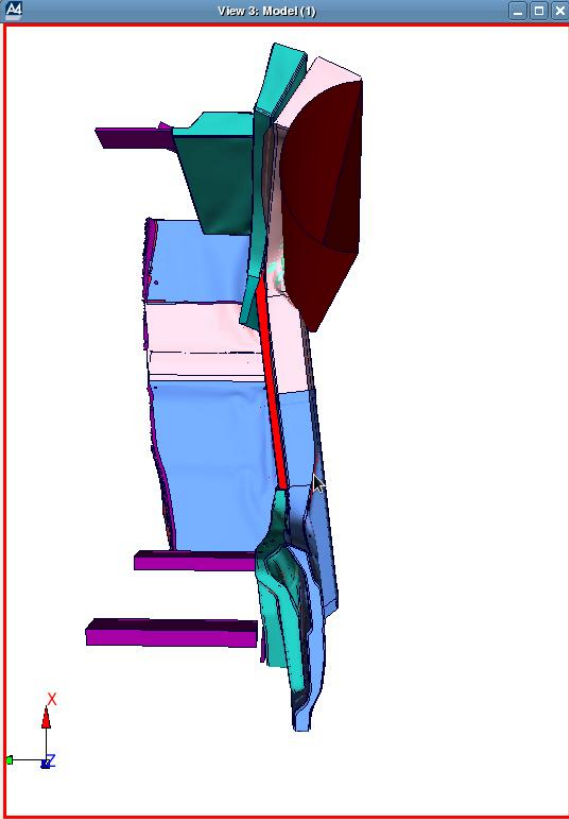
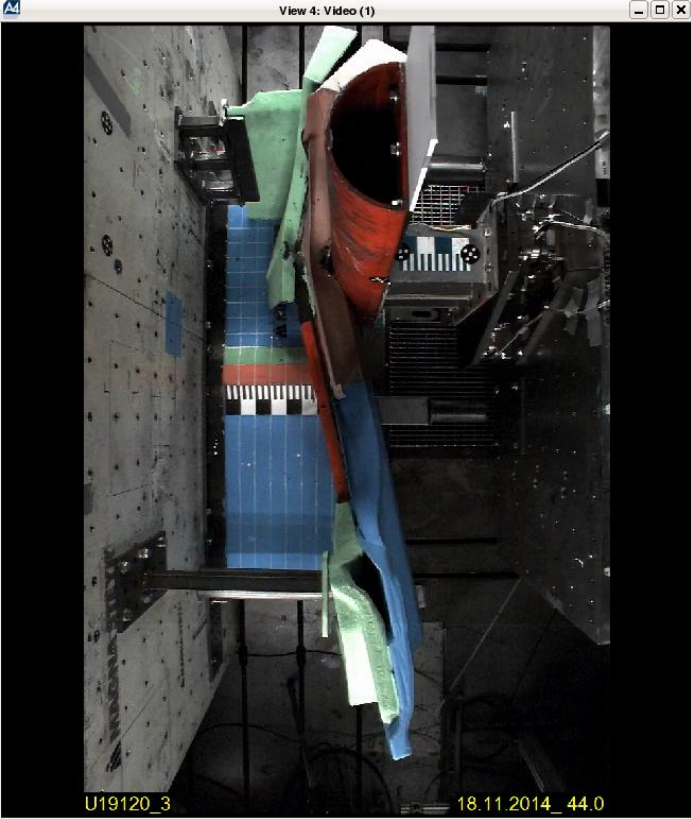
.... Einzelkurven Versuch
— Ergebnis Optimierung



Fahrzeugteilbereich – Crash



Fahrzeugteilbereich – Crash



Werkstoff

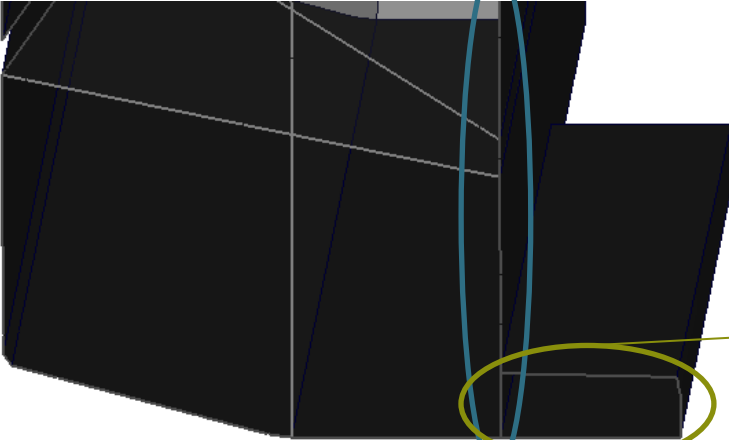
Bauteil

Modul

Fahrzeug
Teilbereich

Gesamt-
fahrzeug

Detail Analyse



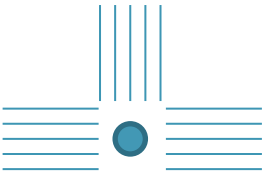
Schwellerprofil - Schnitt



Schwellerprofil deformiert



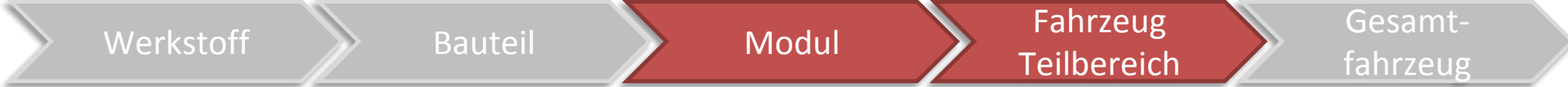
Real fiber structure



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

