LEICHTBAU BW
Leichtbau-Allianz Baden-Württemberg

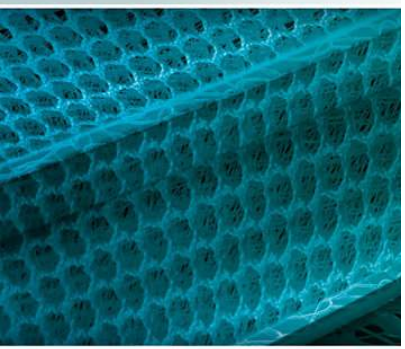
AFBW
Allianz Faserbasierte Werkstoffe Baden-Württemberg e.V.

DITF
DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

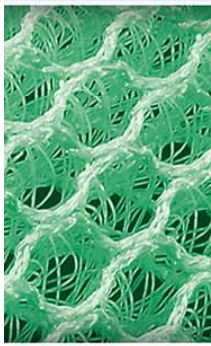
Competence Center Polymers & Fiber Composites

Highlights in Pultrusion

Prof. Dr.-Ing. M. Milwich,



- Deutsche Institute für Textil- und Faserforschung Denkendorf DITF
- Reutlingen University of Applied Science, Faculty TEXOVERSUM Textile
- Scientific Advisory Board Federal Institute of Sport Science (BISp)
- Representative of Leichtbau-Allianz Baden-Württemberg
- Founding member of AFBW, Leichtbau BW, LBZ-e.V., Composite United



Leichtbau-Allianz Baden-Württemberg

- The 3 lightweight associations LBZ e.V., AFBW, Composites United have altogether over 450 Members and provide know-how from material to products to recycling / reuse.

Previous and continuing regular events of the BW lightweight construction associations:

- Member meetings & Workshops
- Carbon-Recycling Congress (6. Congress: Febr.19th 2025, Stuttgart)
- Congress Composite Simulation (CAM / FEA in Architektur/FRP)
- Natural Fiber BW & Crosscluster AFBW/ProHolz

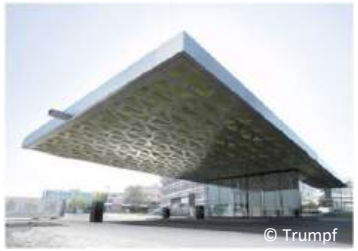
  → Wooden materials / Natural fibers / Bio-FRC

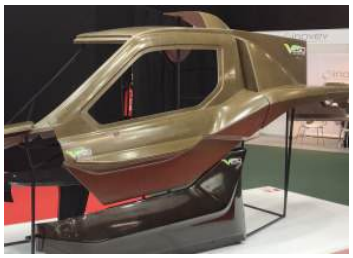
Our tasks and aims

LEICHTBAU BW
Leichtbau-Allianz Baden-Württemberg

Exchange of Information & Networking between different industries with their specific know.how

- Industrial
- Energy
- Building
- Mobility
- Medical
- Sports / Recreation





betrieben von

AFBW Allianz Faserbasierte Werkstoffe Baden-Württemberg e.V.
CU COMPOSITES UNITED
BW
LBZ LEICHTBAUZENTRUM

The economic impact of Light-weight technologies in Germany

Study A study commissioned by the BMWK, presented in July 2024

Authors: Kleissner Anna, Eidenberger Harald, Schöffmann Sabine, Stadlbauer Manfred, Econmove GmbH

- 2019 lightweight technologies produced ca. 5,5 % of Total gross production value of 360 Mrd. €
- Approximately 4% of German economic output, 1.3 million jobs
- Each lightweight construction job creates approximately 1.4 to 1.66 additional jobs in other sectors, i.e. a total employment effect of almost 3.2 million jobs including services.
- Key Lightweight Sectors: Transportation (Auto/Truck/Ship/Aerospace), Mechanical Engineering, Metal Ore
- Highest shares of economic output: Saarland, Lower Saxony, Baden-Württemberg, Bavaria
- Rapid recovery after COVID-19 pandemic

Message to the people: LCA of FRP

LEICHTBAU BW
Leichtbau-Allianz Baden-Württemberg

➢ Longevity as a Key-Asset of FRP:

Life-span…of Wind-Blades: 20-30 years, (Energy-Amortisation only 3..6 Months),
…of Infrastructur, Bridges up to 50…100 years

But even after the 30 years of „official“ life-span, the high fatigue strength of wind blades allows for re-use…re-manufacture…re-sell…after re-pair

➢ Repair / Recycling

- up to now the company „Wings and More“ (Ebersbach/Fils) repaired hundreds of carbon-bicycles
- GRP recycling in cement production has now been standard for years
- CFRP recycling: fibers and matrix: Katack-H, V-Carbon, Mitsubishi Chemical, Toyota,, Holy, IPT Aachen, Swancor/Gigantex, Vestas Chemcycling, Longworth, Uplift360,…and more….

Fa. IPCO:
Shredded EOL GRP for sea container floors, pick-up loading areas

Fa. Acciona:
1500 smaller spanish Wind-blades recyceled into 2400 km Solar-Supports

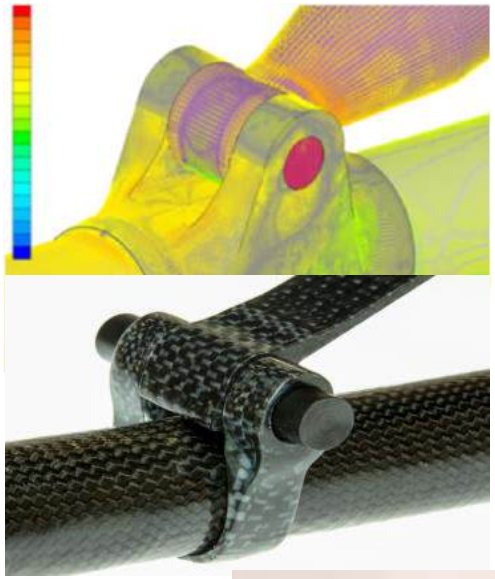
Porsche reC-Tailgate
(V-Carbon, DITF)

reC-Bicycle
(FHNW, V-Carbon, SPIN, CG-TEC, Schmolke, SCRAM, Schwalbe, Carbovation ....)

Polymers & Fiber Composites at DITF

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

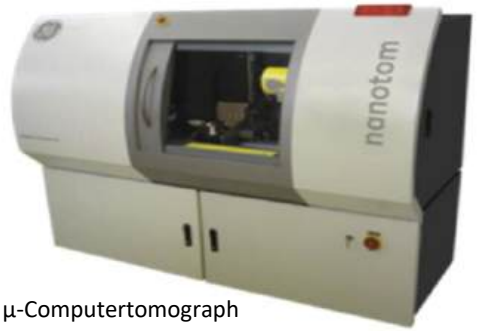
Weaving, Braiding, Pultrusion, Testing, Simulation, Resins, biobased materials……



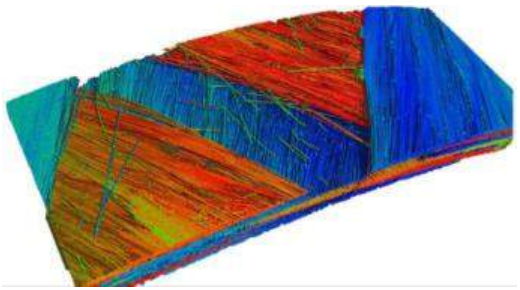
Complex 3D woven and braided composites

Research Campus ARENA 2036

Topology-optimated woven Car floor module with multifunctional integration



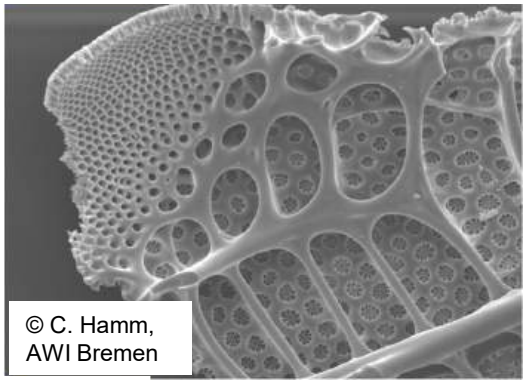
µ-Computertomograph



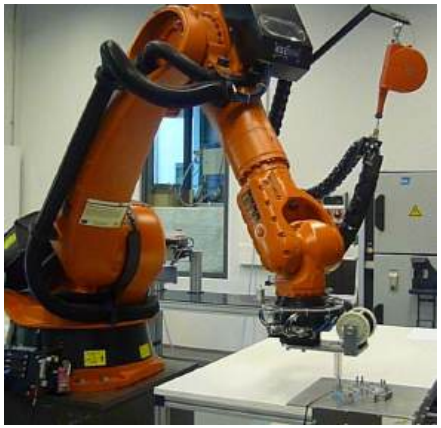
Non-destructive testing and part and process simulation

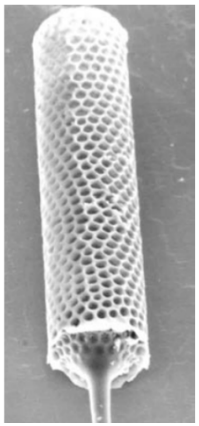
Plankton-Structures & 3D-Fiber Winding

DITF
DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG



© C. Hamm, AWI Bremen



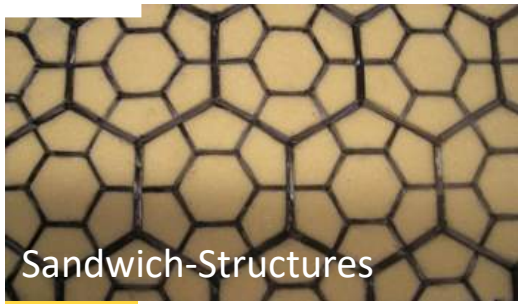


© Harwood & Gersonde

© ICD/ITKE

Coreless Winding of Natural Fibers:
livMatS Pavillon
ITKE/ICD University Stuttgart, Botanical Garden Freib.

DBU



Sandwich-Structures

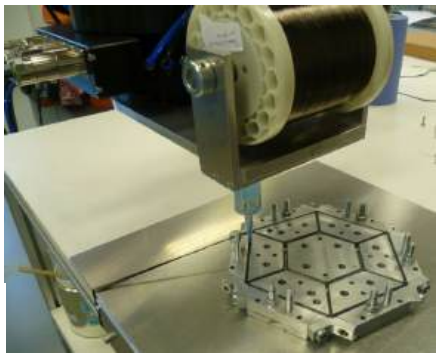
Technologietransfer-Programm Leichtbau

Center-Console of BMW M4 Sportscar, made with Cellulose- / Basaltfibers / Bio-Matrix

Partners: AMC, CSI, BMW-M, DITF

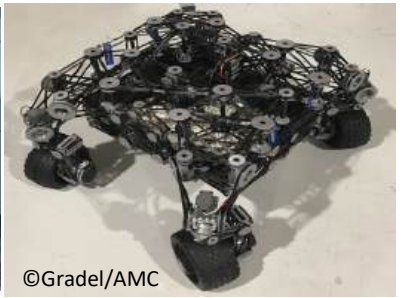
Bundesministerium für Wirtschaft und Klimaschutz

Fassbänder/DITF
Lightweight Motorbike drive sprocket



pentagon / hexagon half-timbering on
3 hierarchical layers

© DITF S. Selvarayan, P. Mindermann



©Gradel/AMC

DFG Deutsche Forschungsgemeinschaft

Project FUPRO: GFRP Seatback : GF/PP

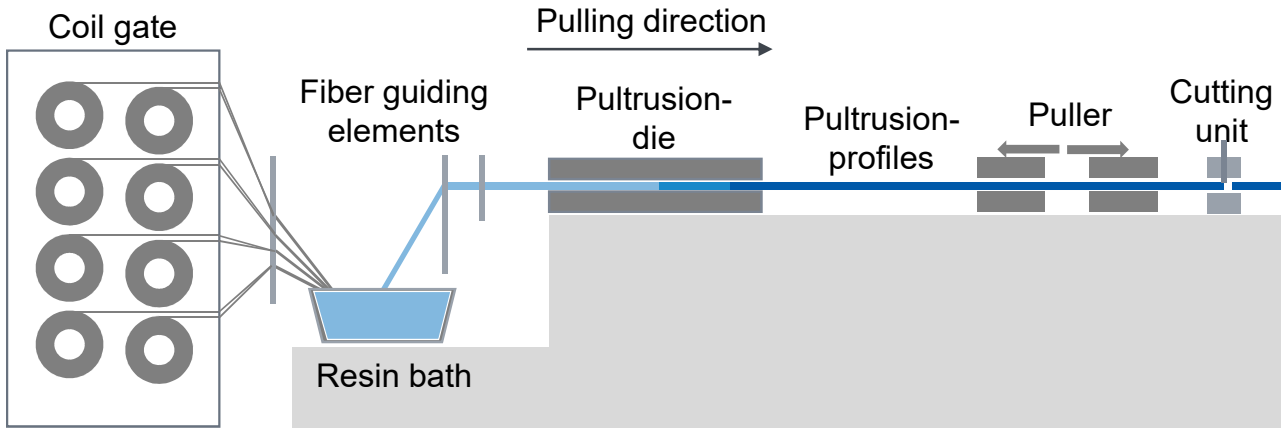
DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

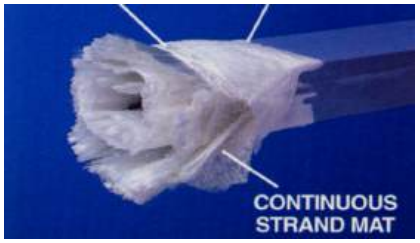
FuPro: Bauweisen- und Prozessentwicklung für funktionalisierte Faserverbund-strukturen mit komplexen Hohlprofilen

- Hybridisation GF/PP
- DITF Woven Fabrics
- DITF Braiding (12 Layers)

(AVK-Award 2019)

Pultrusion





(Fiber Innovations)

Pultrusion at DITF

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

Thermal Pultrusion

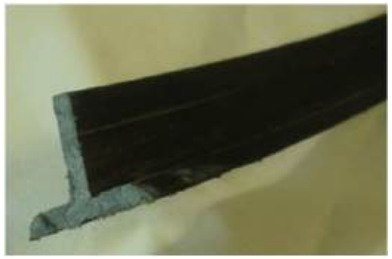
Thermoset

Braidpultrusion

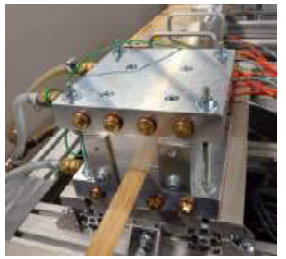
Bio-based materials

Biomimetics

Thermoplast



Curved profiles



Cellulose fibers & matrices

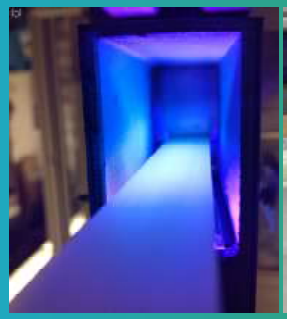
ceramic

Ceramic system

Fast curing

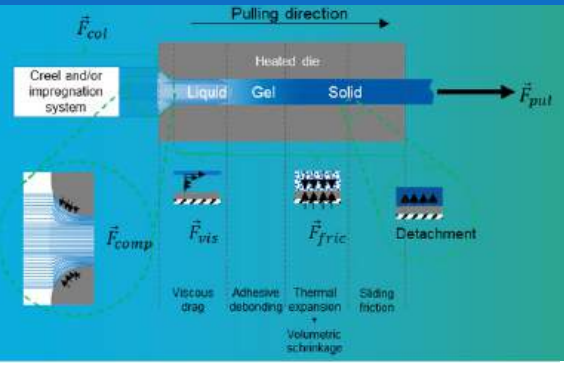
Microwave curing

Ultraviolet light curing

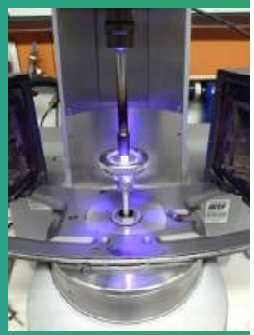


Prozess Optimierung

Pultrusion kinetics

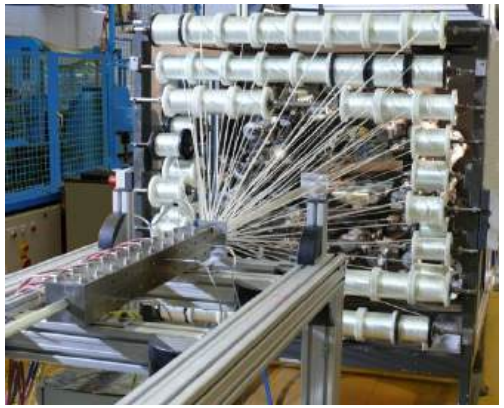


analytiks



(Braid-) Pultrusion, Curved-Profile-Pultrusion

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

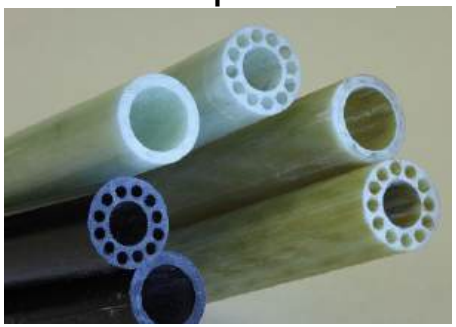


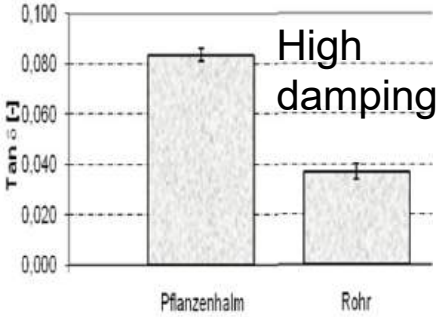
[DLR Fahrzeug-konzepte Stuttgart]

[KraussMaffei]

Overmolding of pultruded Profiles

Technical plant stem





High damping

Biocomposites Research at DITF

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

- DITF Denkendorf was established 1931 to conduct research work on native fiber alternatives to cotton and wool…Viscose, Cellulose
- Natural fibers: Hemp, Hop, Flax Jute, Kenaf, Sisal, Coir, diff. fiber pulping
- Fiber/ Matrix Functionalization: higher tensile strength…
- Flame retardancy
- Cellulose Fibres from Beech wood (…CO_2 Neutrality…) &molecular networking high m. P.
- Viscose is biodegradable in a short time (OECD Test 301 B)
- Post-consumed cellulose can be recycled several times
- European viscose fibers from sustainably managed forests
- New IL-technology for Cellulose Fibres, matrix: Cellulose, Celluloseacetat
- Cellulose-Chitosan-Chitin-Blend-Fibres produced with HighPerCell® Technology (up to 90 wt.-% chitin) and textile coatings (up to 75 wt.-% chitin)
- NF-reinforced Concrete for building and machine beds

Pultrusion of Bio-Composites

Carbon-, Glasfiber- Tubes, Profiles
Technical Plant Stem
50-K Carbon Bridge reinforcement
Basalt-Fiber/Ceramic-Matrix rods (non combustible)

Pultrusion of Semi-opened Hemp stems:

- High tensile properties
- More original matrix → Less Bio-Resin
- Recovery of Bio-Epoxy possible

FNR

Bundesministerium
für Ernährung
und Landwirtschaft

BioMat.-Pavillon

Dep. Bio based Materials and
Materials Cycles in Architecture

Flax Fibers **+**
....a) Standard Epoxy
....b) Bio-Epoxy: epoxidized Linseed oil

…shown on Biennale 2023

Project Partner: BioMat Group & ITKE Uni Stuttgart, ZenVision, Biomaterials & More GmbH, Steinhuder Werkzeugbau, CG-TEC, DITF

Baden-Württemberg
Ministerium für Ernährung,
Ländlichen Raum und Verbraucherschutz

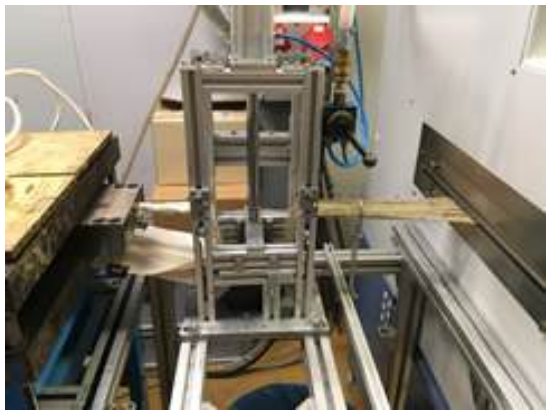
Pultrusion of Bio-Composites in Sports:
Hemp/Bioresin

BIPL-Project Partner:
Leki, CG-TEC, DITF
Bio-Composites and More,
Troi.composite solutions

Leki - Trecking Pole
Hemp Vario one

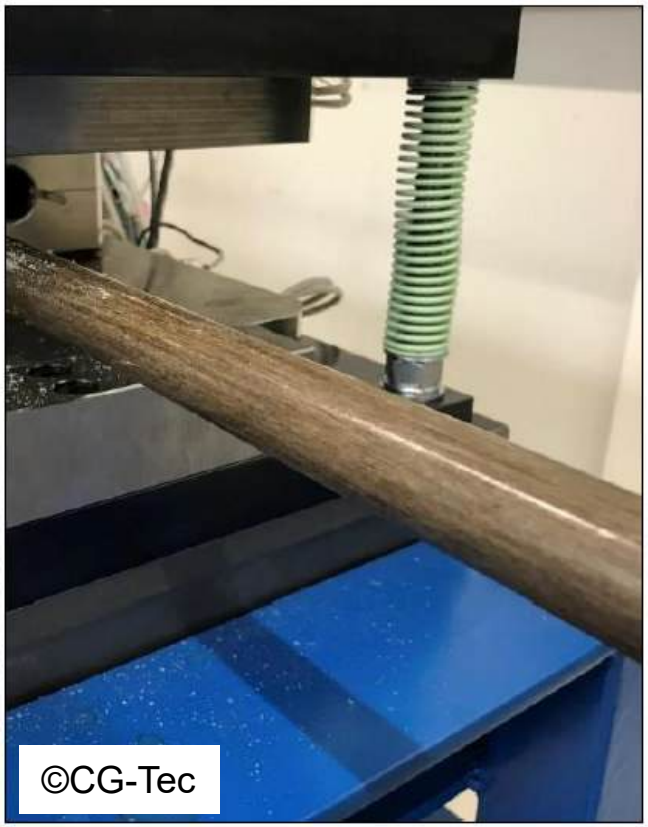
Flax Fiber Pultrusion

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG



DITF

Fibers from Safilin



CG-Tec Premises

Bio-Resin-Formulations (extract)

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

Thermoset
SUPER SAP® (Entropy Resins, von der Linden)
Cardolite PA, GreenPoxy (SICOMIN)
Bio-polyester 3830 (Structol)
PTP (from linseed oil), PFA (polyfurfuryl alcohol)
Bio-Epoxy (Biocomposites & more)

Thermoplastic
PGA, PLA, PHB, PBAT (Ecobio: BASF)
TPS (Thermoplastic starch)…..

NF/PFA-Matrix Ecopreg (Evolution Ltd.)	VALUE
Density	1.450 g/cm³
Flexural Strength	109 MPa
Flexural Modulus	8.5 GPa
Tensile Strength	69 MPa
Tensile Modulus	10.5 GPa

https://renew-able-carbon.eu/ news/bio-resin-for-surfboards-sicomin-and-notox-form-a-sustainable-synergy/

Hardener
Isocyanat Desmodur® eco N 7300 (Covestro (+PPG) 70% Carbon Content from Biomass, 30% Reduction of Carbon Footprint – without reduction of properties
Admeric Acid (Hobum), Citric Acid (Univ. of Leoben), Sebacic Acid

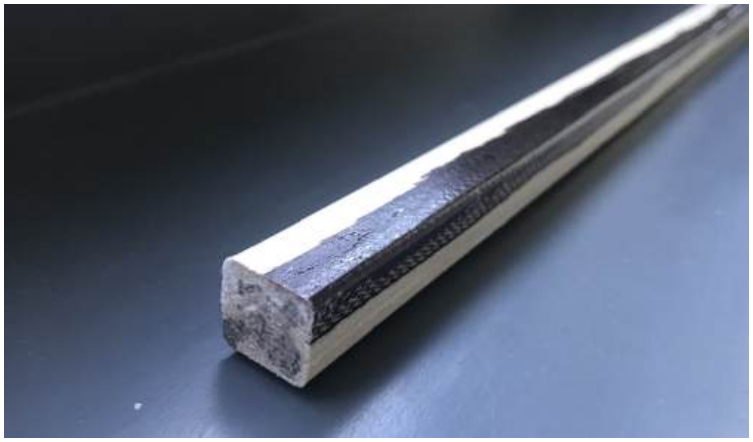
Fibre-Matrix-Interface / Sizing
Silanes, Trialkoxysilane(APTES, GLYMO, etc.)

https://netcomposites.com/media/1211/biocomposites-guide.pdf

Pultrusion of Furniture parts by Manaomea (& DITF)

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

- textile remnants
- sheep wool selvedges
- organic cotton selvedges
- organic jute yarn (Bangladesh, Nepal)
- Bio-resin from >95% renewable resources
  - -- Formulated by manaomea
  - -- Manufactured by DITF (pilot plant scale)
  - -- Now Commercially available



Bundesministerium für Wirtschaft und Klimaschutz

eXIST

Flame Retardancy of Biocomposites

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

A … non combustible, e.g. mineral material

B1..best in case of organic materials

Flame retardants for Biocomposites	horizontal	vertical
50% ATH Aluminiumhydroxide, most used	B2	B2
50% APP Amm.polyphosphat, halogen free, intumescent	B2	B2
5% DOPO 9,10-Dihydro-9-oxa-10-phospha-phenantren-10-oxid, organic, most used	B2	B2
50% APP + 5% DOPO	B2	B2
Basis starch, turns into a Carbon-Foam-Insulation (Fa. Bio-Composites And More)	**B1**	**B1**
Carbohydrate-paper (Fa. Bio-Composites And More)	**B1**	**B1**

Flame test: UL 94 V (2013-03) / DIN 4102

Berlin-Opera „Unter den Linden“

Non-combustible Composite by using basalt fibers and a Phosphor cement matrix

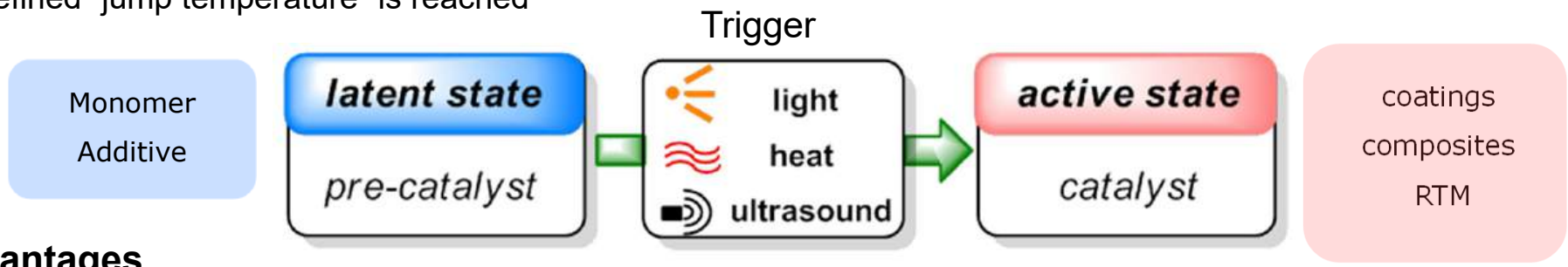
©Knippers

Pultrusion of 1-Component-Caprolactam System or Epoxys

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

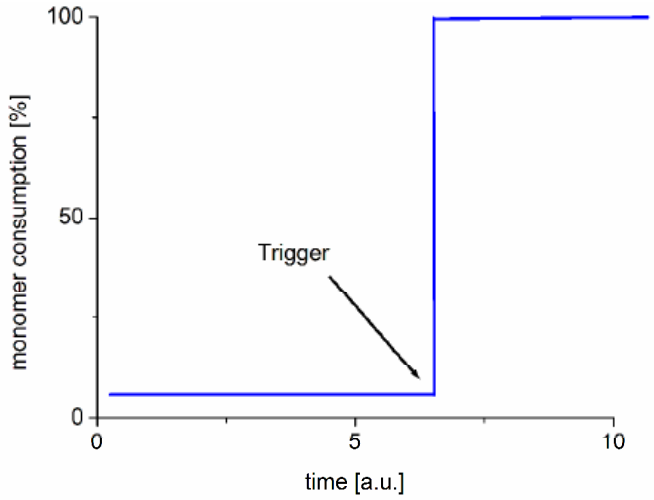
Fast - save - non toxic

- Usually 2K-in situ systems e.g. Fa. Brüggemann.
- 1K-in-situ systems: Prepolymers, resin, additives, hardener, catalyst are already mixed, but only react when a defined “jump temperature” is reached



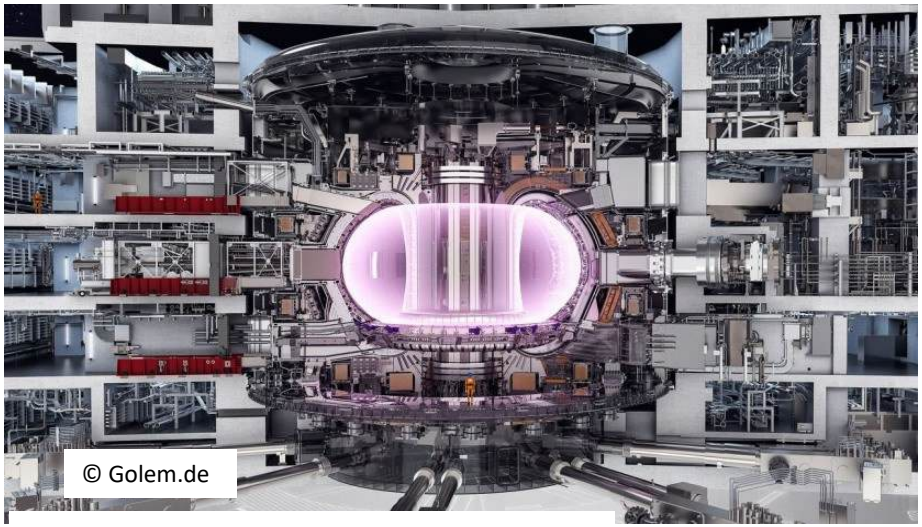
Advantages

- No dependence on mixing technology
- Longer pot life (infiltration)
- Constant viscosity (draping)
- Defined reaction start upon reaching the deprotection temperature (latency)
- Consistent component quality, e.g., fewer air inclusions
- - High process reliability



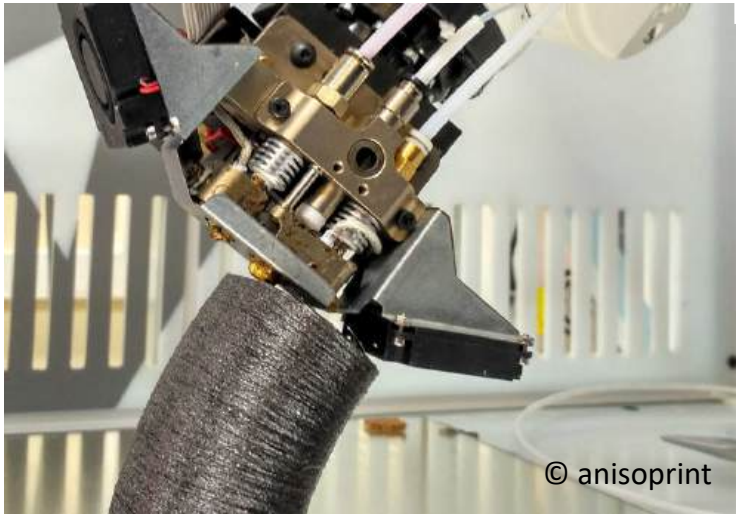
Future Energy Production and More Energy Saving

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG



DITF: Composite Woven Inner Cladding & braided cooling-liones for the Iter-Fusion-Reactor

Fibers: Tungsten
Matrix: Copper, Tungsten, ….



Endless-fiber 3D printing

Ritsumasyl-Bridge (NL) 30to of Bio-Composite instead of 400to steel/concrete

DITF-UV-Pultrusion saves 50% Energy

UV Pult

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

IST metz

Mubea

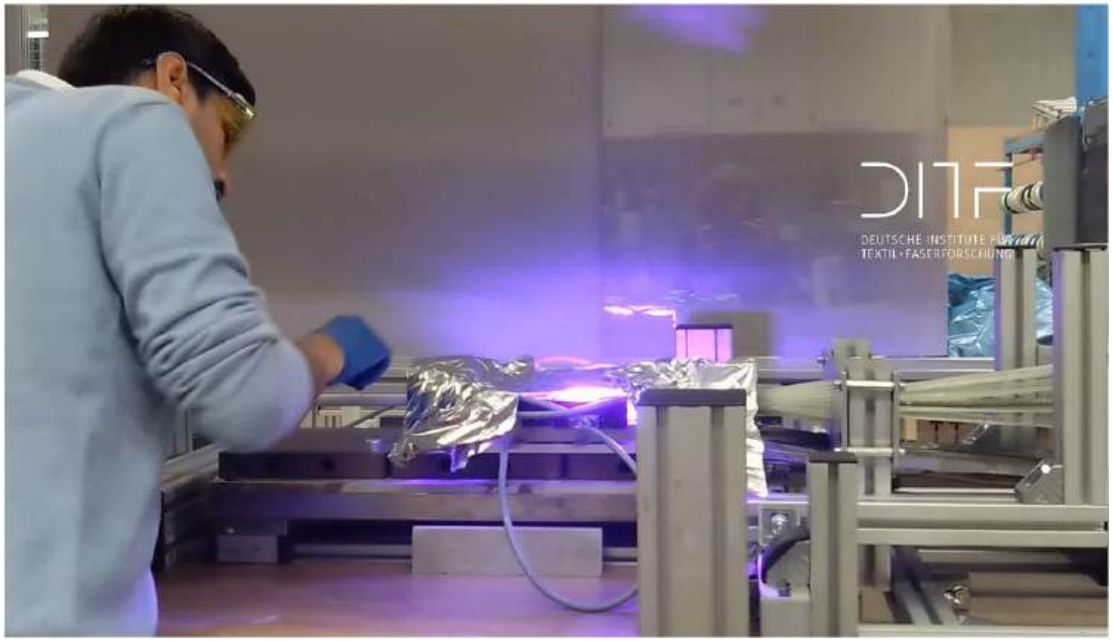
STEINHUDER Werkzeugbau

Assoziierte Partnern

allnex

BYK

Johns Manville



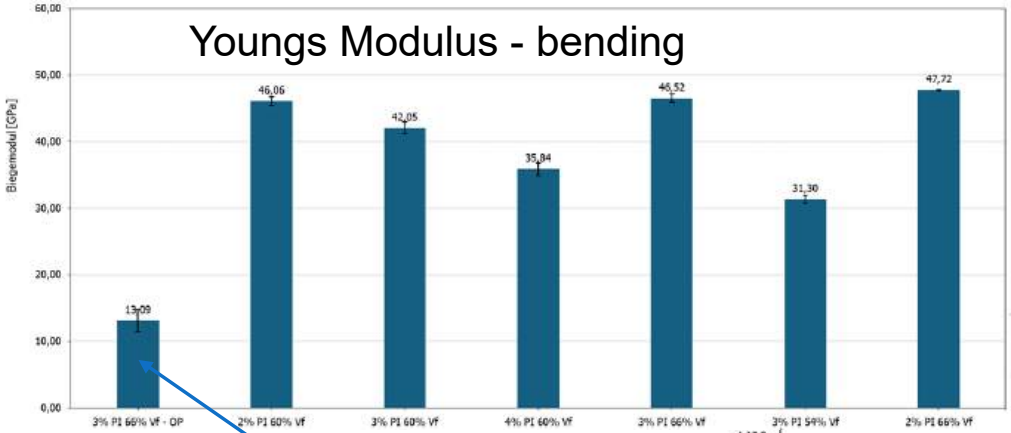
UV Pultrusion

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

patented in-line re-shaping

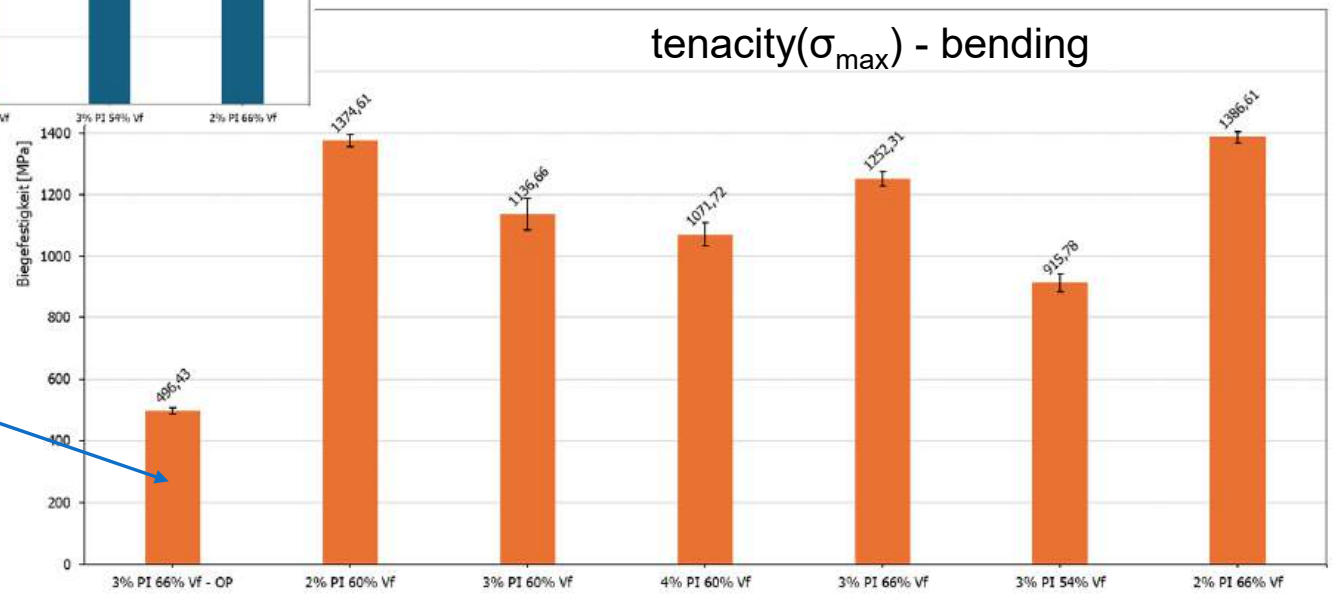
UV-Pultrusion

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

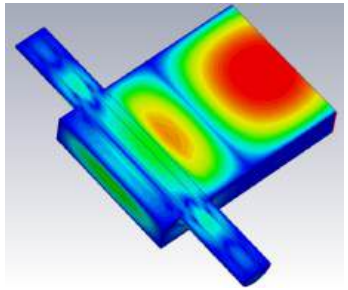


mechanical properties

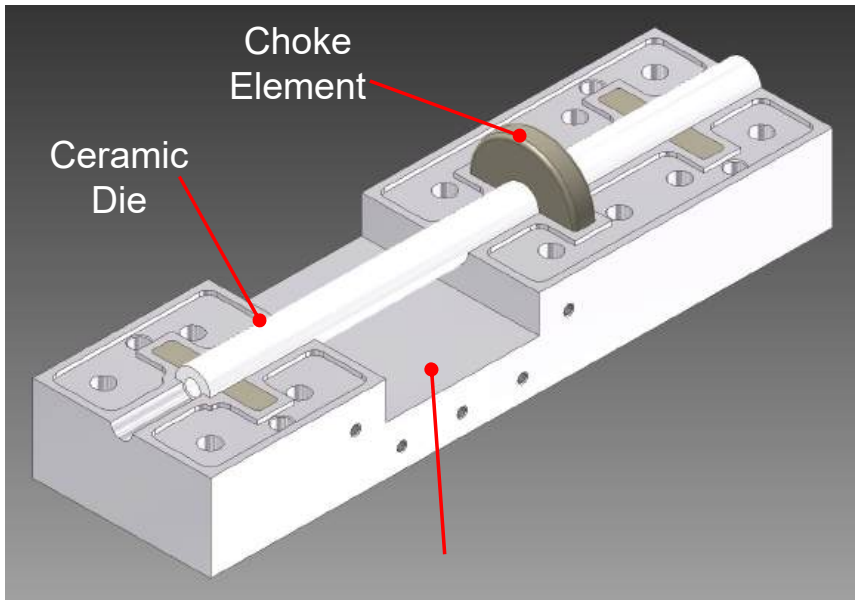
Standard Epoxy,
Heat curing

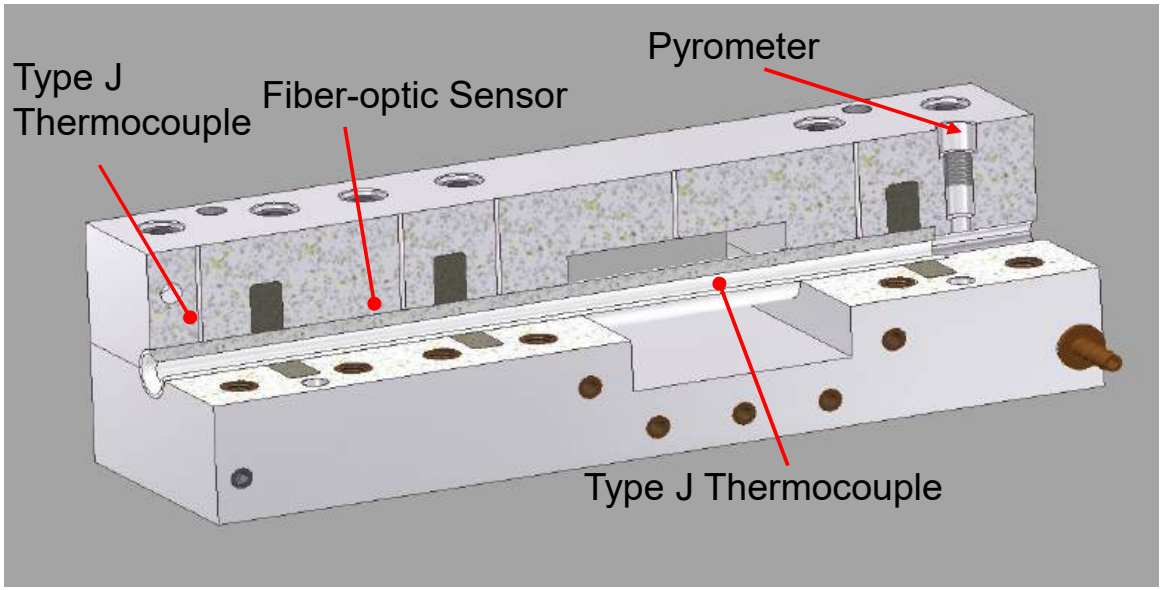


Microwave-Pultrusion



CST Microwave Studio



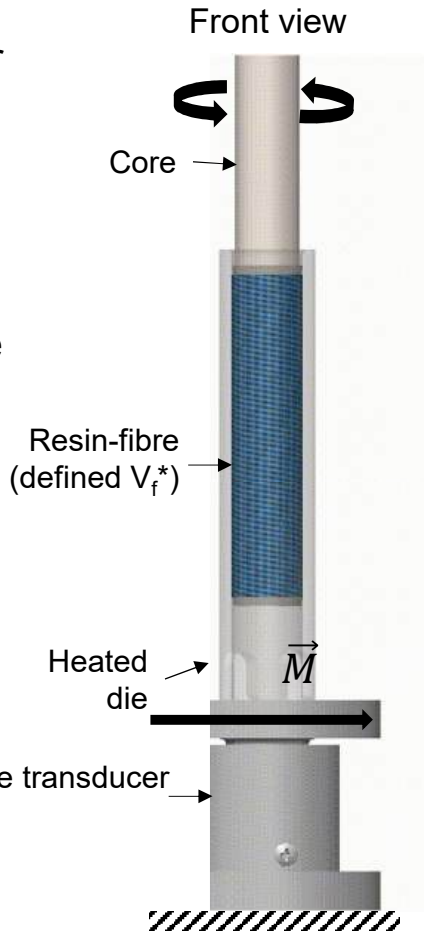


WR 340 rectangular Waveguide: Frequency Range: 2.0 – 3.30 GHz, Power Rating: 5.40 to 7.60 MW

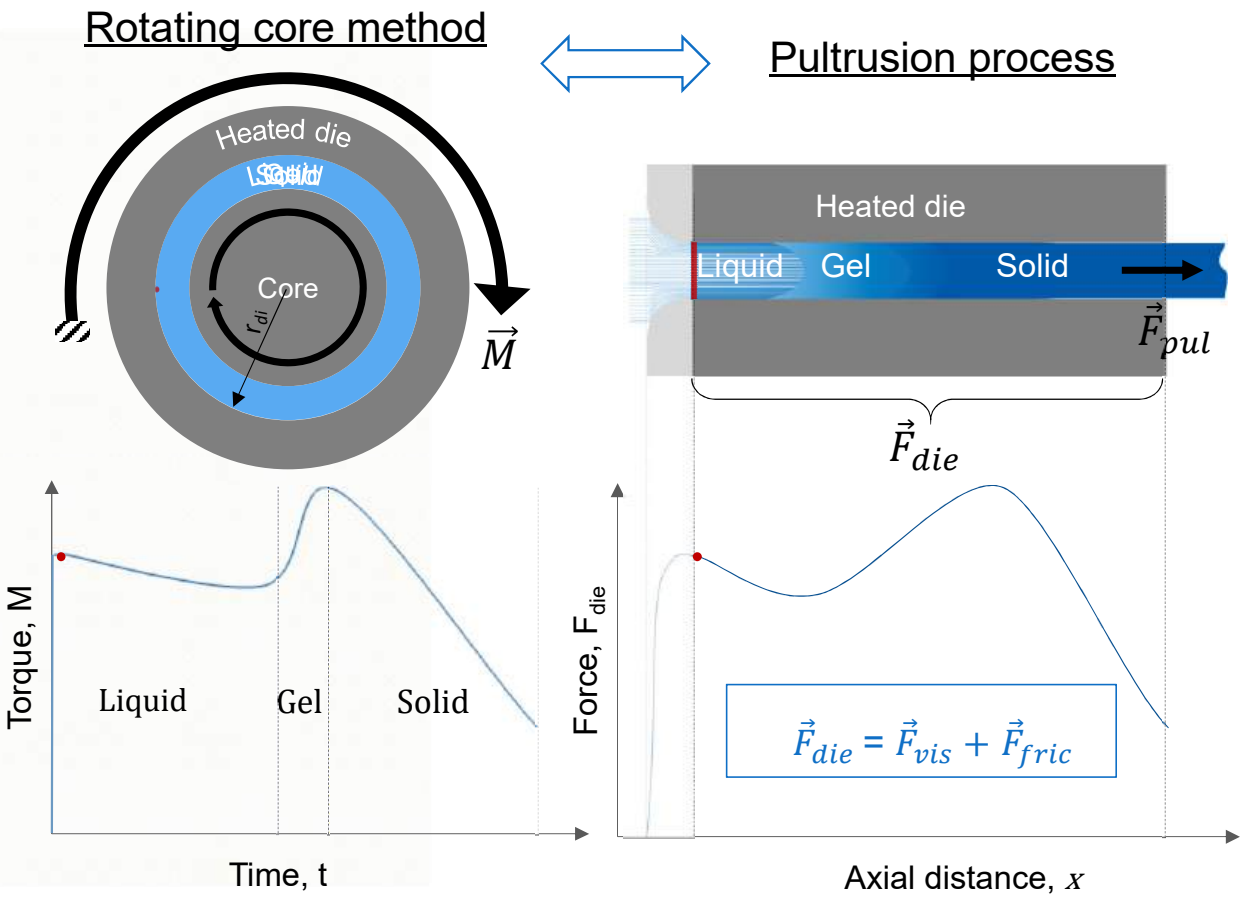
Offline Pultrusion Measurement: rotating-core

DEUTSCHE INSTITUTE FÜR TEXTIL+FASERFORSCHUNG

- Transformation of linear online pultrusion to rotational offline process
- A rod wound with resin wet fibres rotates inside a heated cylindrical die analogous to UD pultrusion
- Resistive forces measured in terms of torque/time
- Possibility to pre-determine $\vec{F}_{vis}$ and $\vec{F}_{fric}$ and map them to pultrusion..”



*V_f – Fibre volume fraction



at steady state: $\vec{F}_{die} = \frac{1}{C.r_{di}} \sum_0^t \vec{M}_t, for \equiv S_A$