1. VITCEA Workshop

17th February 2015
BAM Bundesanstalt für Materialforschung und -prüfung

PRODUCTION-INTRODUCED DEFECTS IN CFRP: LIMITS OF NONDESTRUCTIVE TESTING

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HOCHSCHULE MAGDEBURG-STENDAL

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Industrielabor Funktionsoptimierter Leichtbau

zfl ZENTRUM FÜR FASERVERBUNDE UND LEICHTBAU HALDENSLEBEN UG (haftungsbeschränkt)

REGIONAL COMPOSITE NETWORK

Hochschule Magdeburg • Stendal

KAT

ALFA
ALLIANZ FASERVERBUNDE

Wachstumskern ALFA
Maßgeschneiderte Composite für Massenmärkte

Professur Werkstoff und Fügetechnik

Industrielabor
Funktionsoptimierter Leichtbau

Composite · Leichtbau
Kleben

Komplementäre Ausstattung

InnComposites
Innovationszentrum Faserverbunde Haldensleben

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UG (haftungsbeschränkt)

RKW Sachsen-Anhalt

DiCom
Denken in Compositen

Technologienetzwerk für faserverstärkte Kunststoffe

PeCom
Personalentwicklung für Composite

Berufsbegleitende Weiterbildung Composite

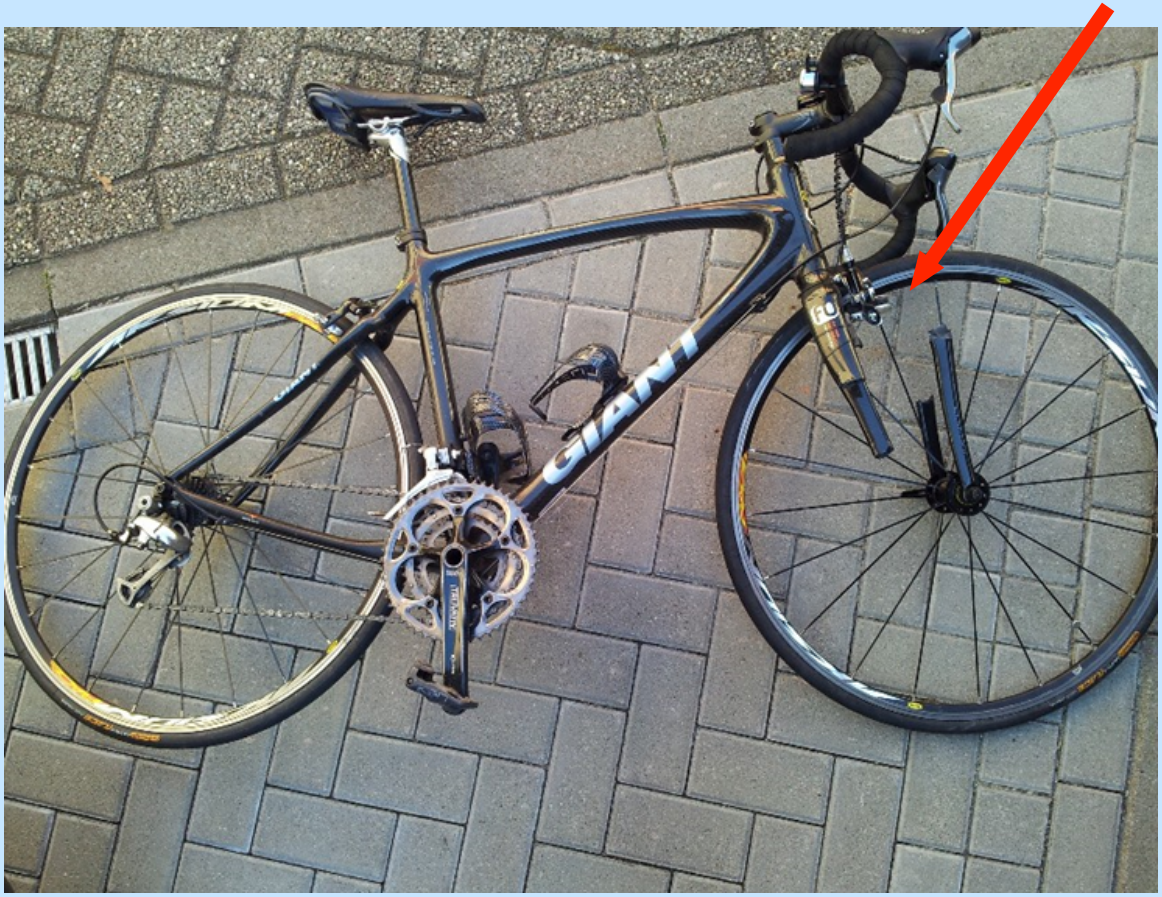
AuCom
Dualer Bachelor-Studiengang
Maschinenbau/Composite-Technologien

Erstausbildung Composite

Wirtschaft

Regionale und überregionale Unternehmen

Evidence base



Near-lethal accident after fracture of a CFRP fork blade of a high-end racing bicycle during „standard cycling“

Comment of manufacturer

„Only a previous accident/misuse can have been the cause of the sudden failure…“

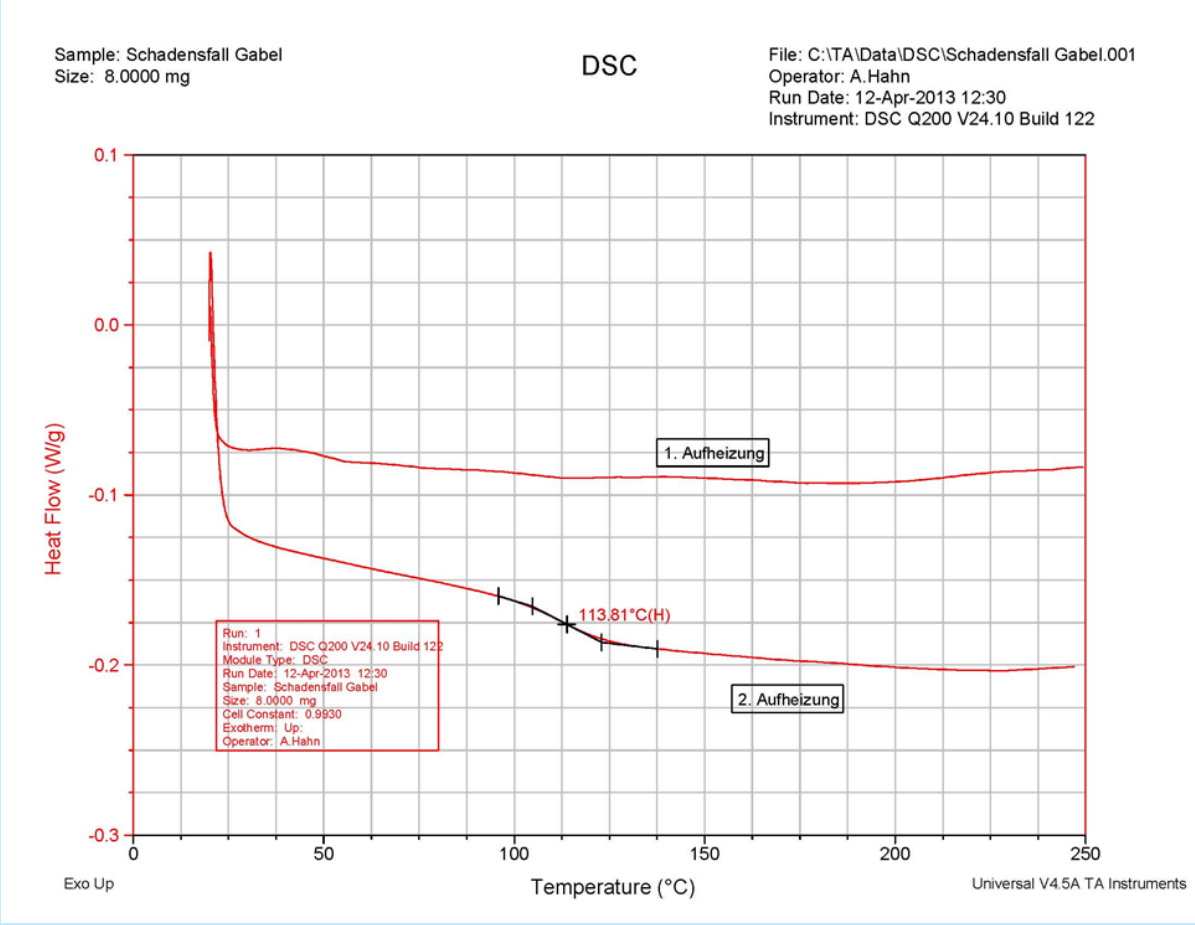
„No responsability/liability will be taken!“

Fractured fork blade

Causes of failure are difficult to detect in CFRP since fracture causes secondary damages

Surprising secondary damage

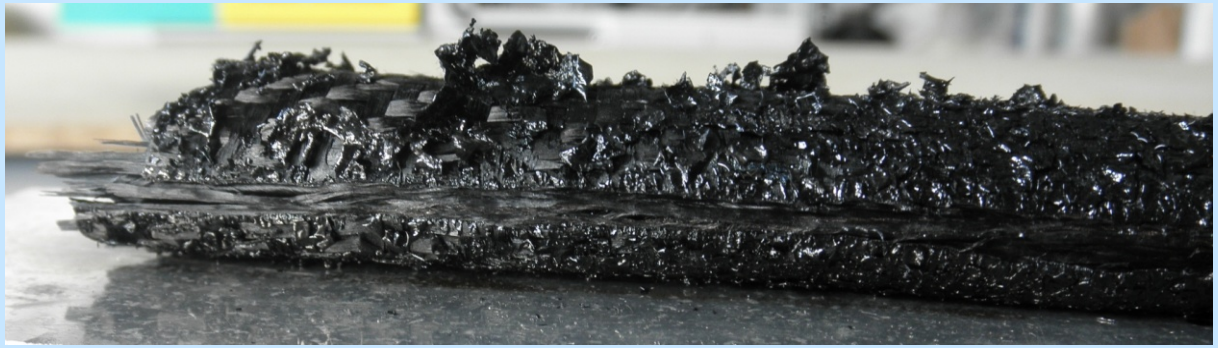
Experimental findings: DSC-Analysis



Perfect DSC-result.

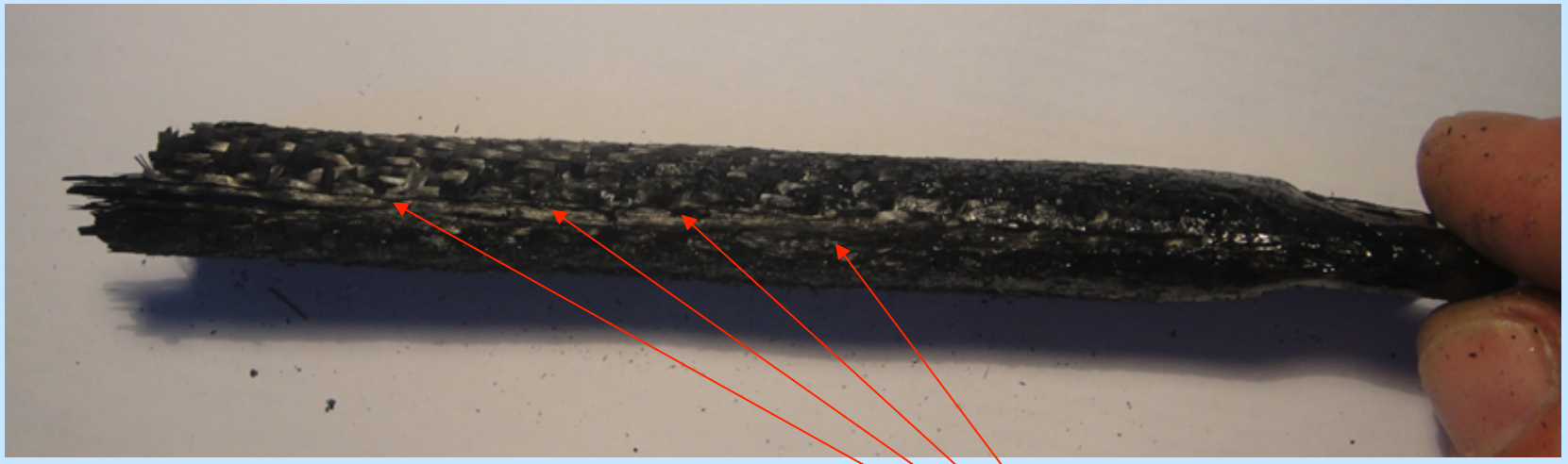
Laminate is fully cured!

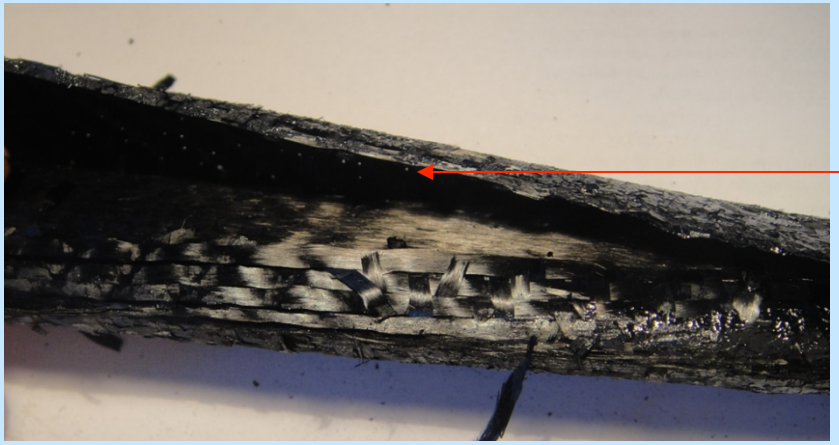
Experimental findings: Ashing/Incineration



Layer# from outside to inside	Orientation (°)	Orientation symbolic	Layer thickness after ashing (mm)*
1	0/90 Fabric (C)	I-	0,24
2	0 (C)	I	0,16
3	+ 45 (C)	/	0,16
4	- 45 (C)	\	0,16
5	0 (C)	I	0,25
6	+45 (C)	/	0,16
7	- 45 (C)	\	0,16
8	0 (C)	I	0,16
9	0/90 (G)	I-	0,22
			Sum 1,67

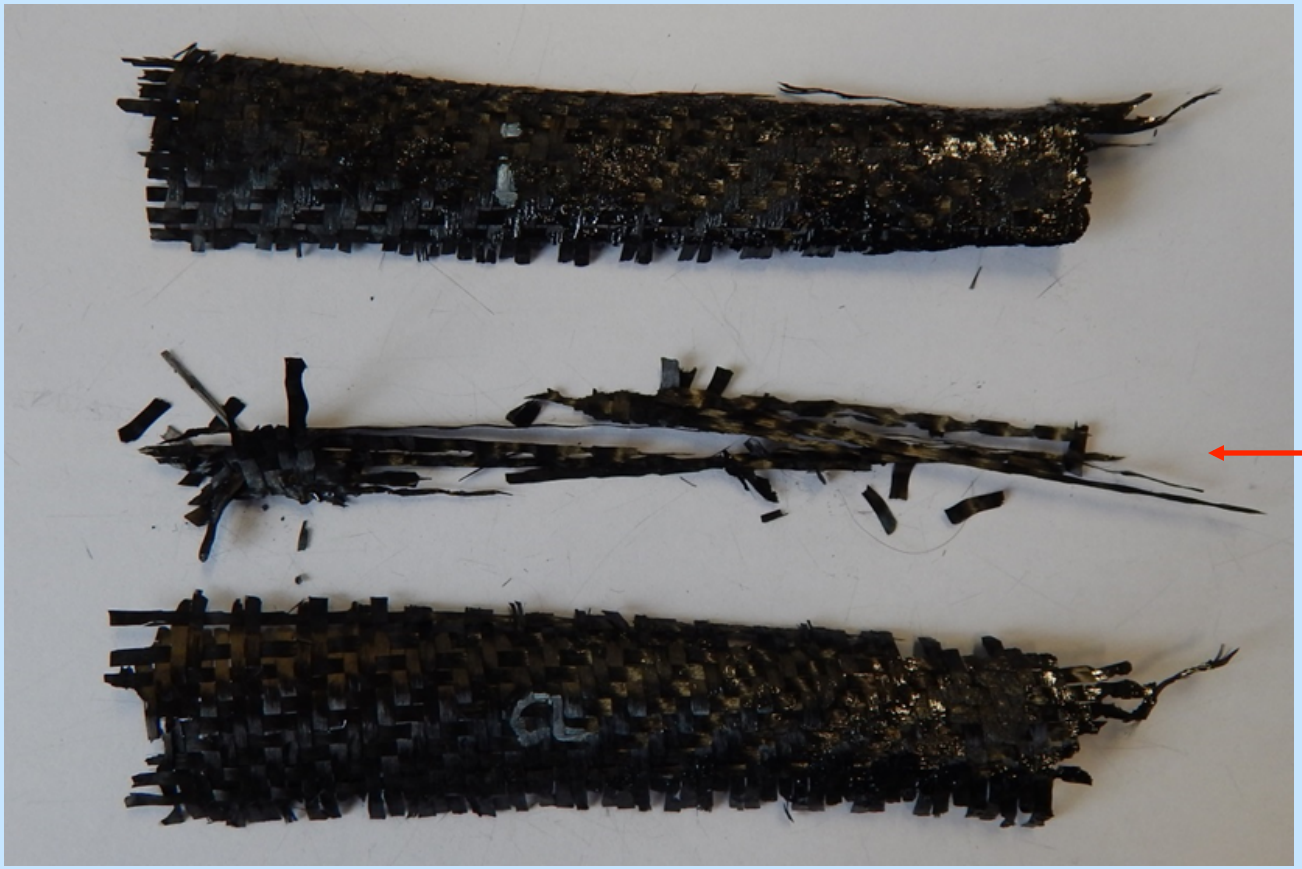
Experimental findings: Production-introduced defects



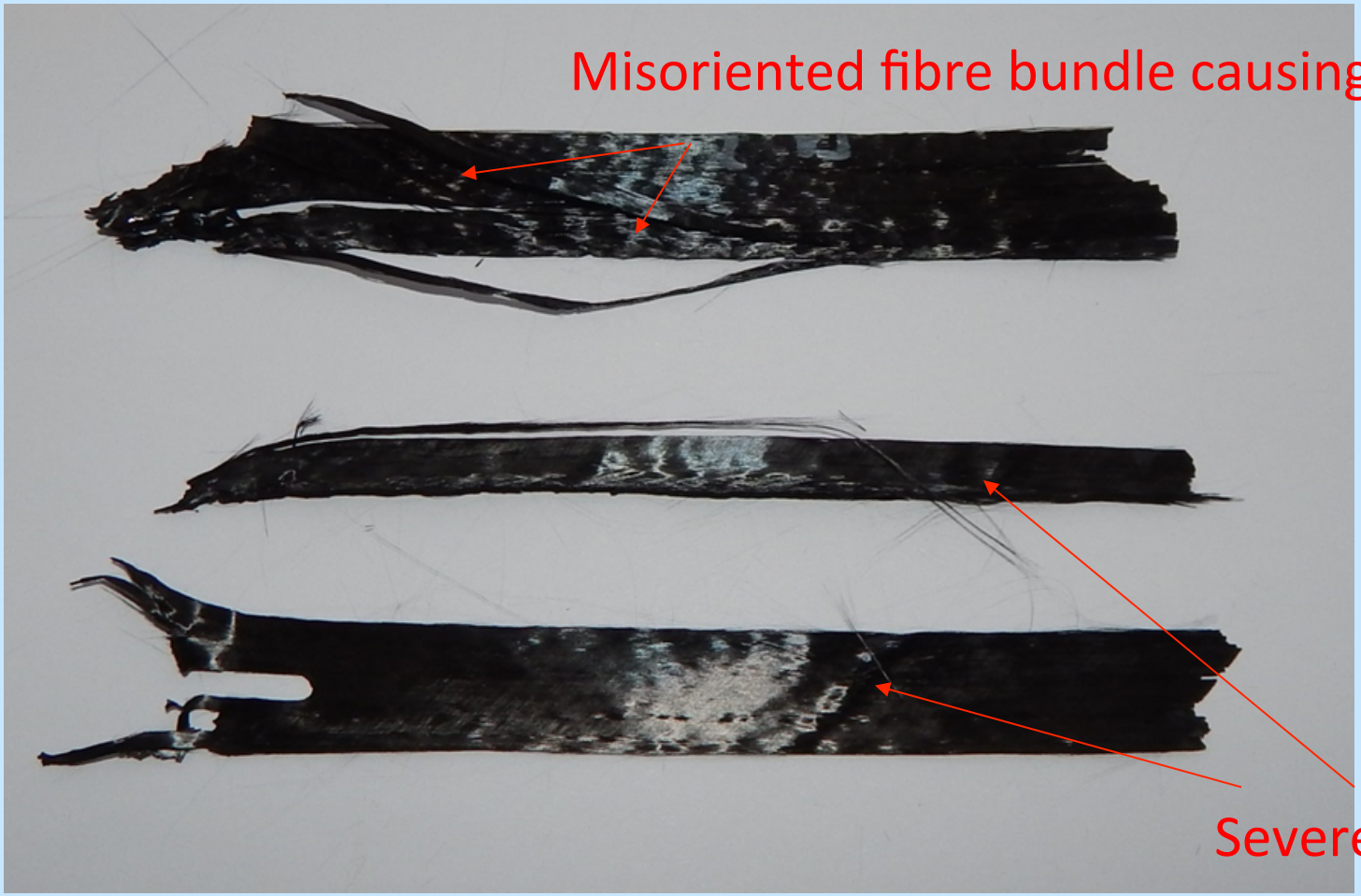


Cut fabric layer# 1

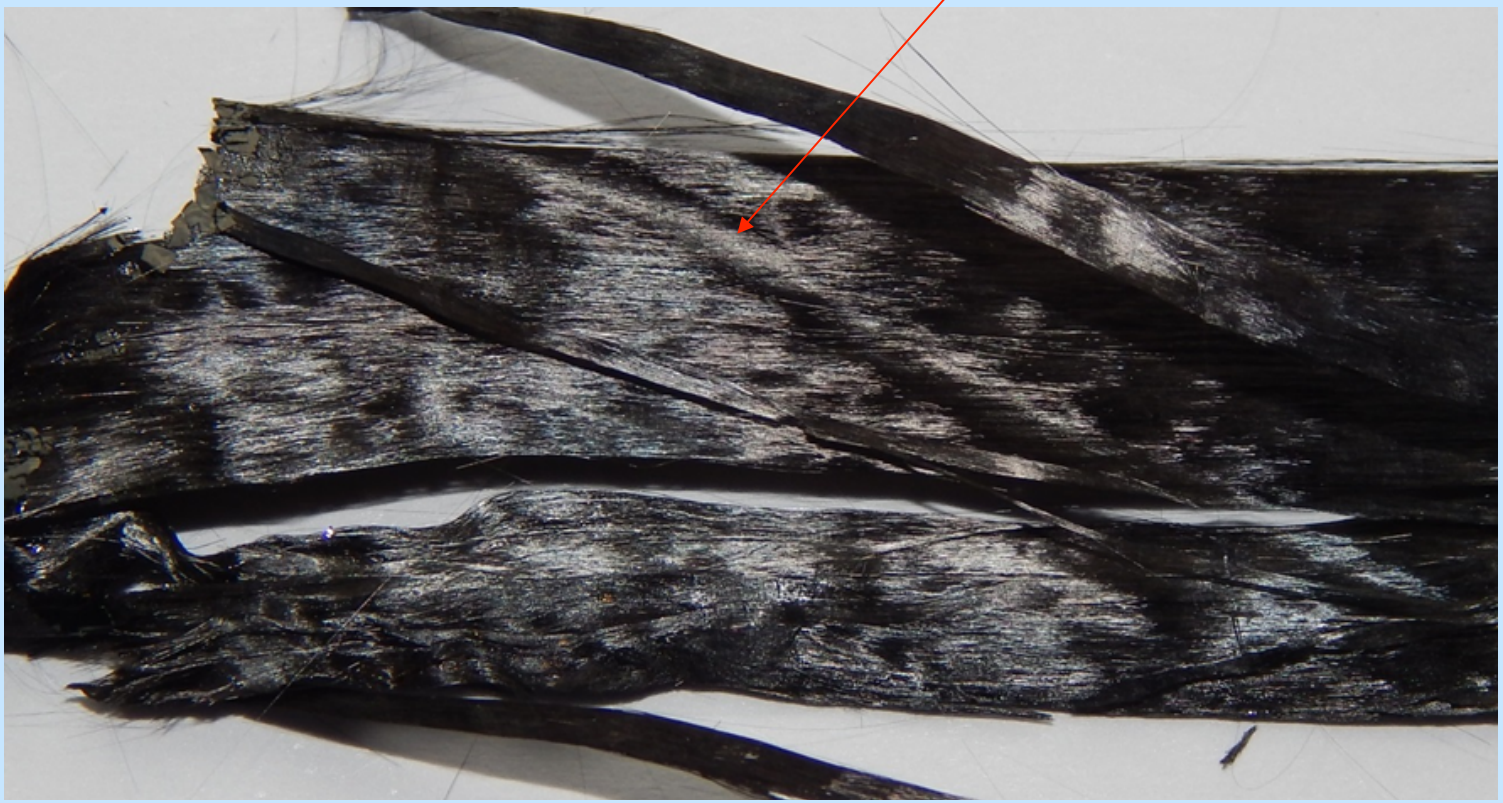
Fabric „layer“ #1 – Victim of grinding



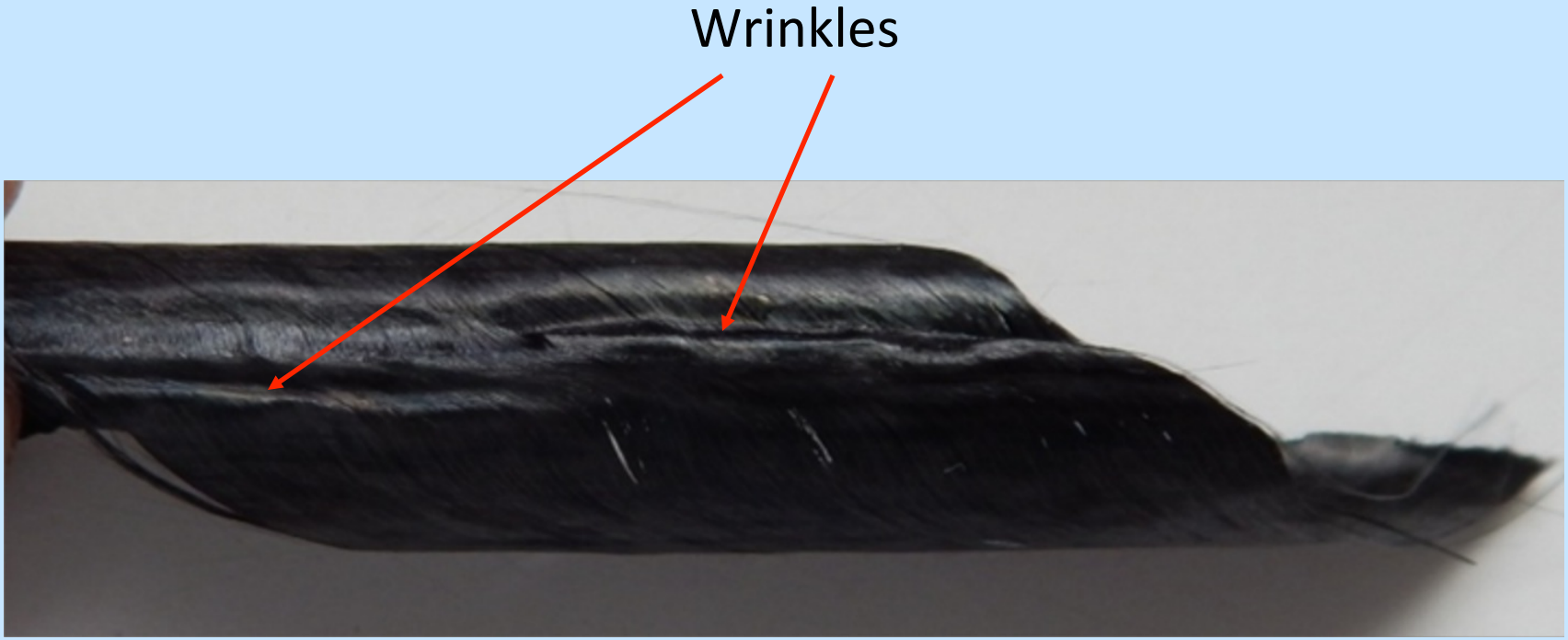
UD-layer #2



Detail of groove UD-layer #2



UD angled layer #3

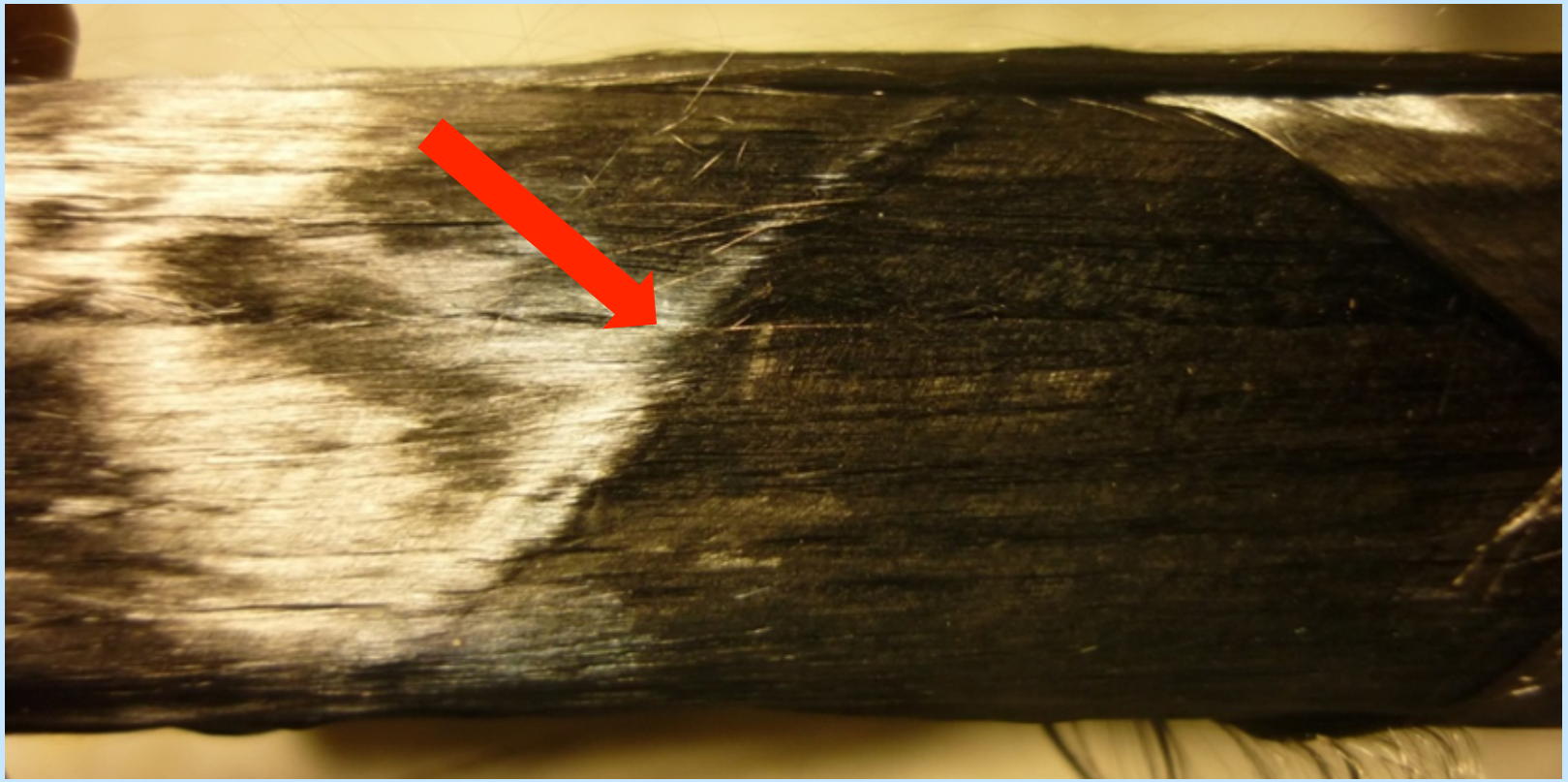


UD angled layer #4

Strong in-plane ondulations and gaps

UD-layer #5

Wrinkle in thickest UD-layer #5



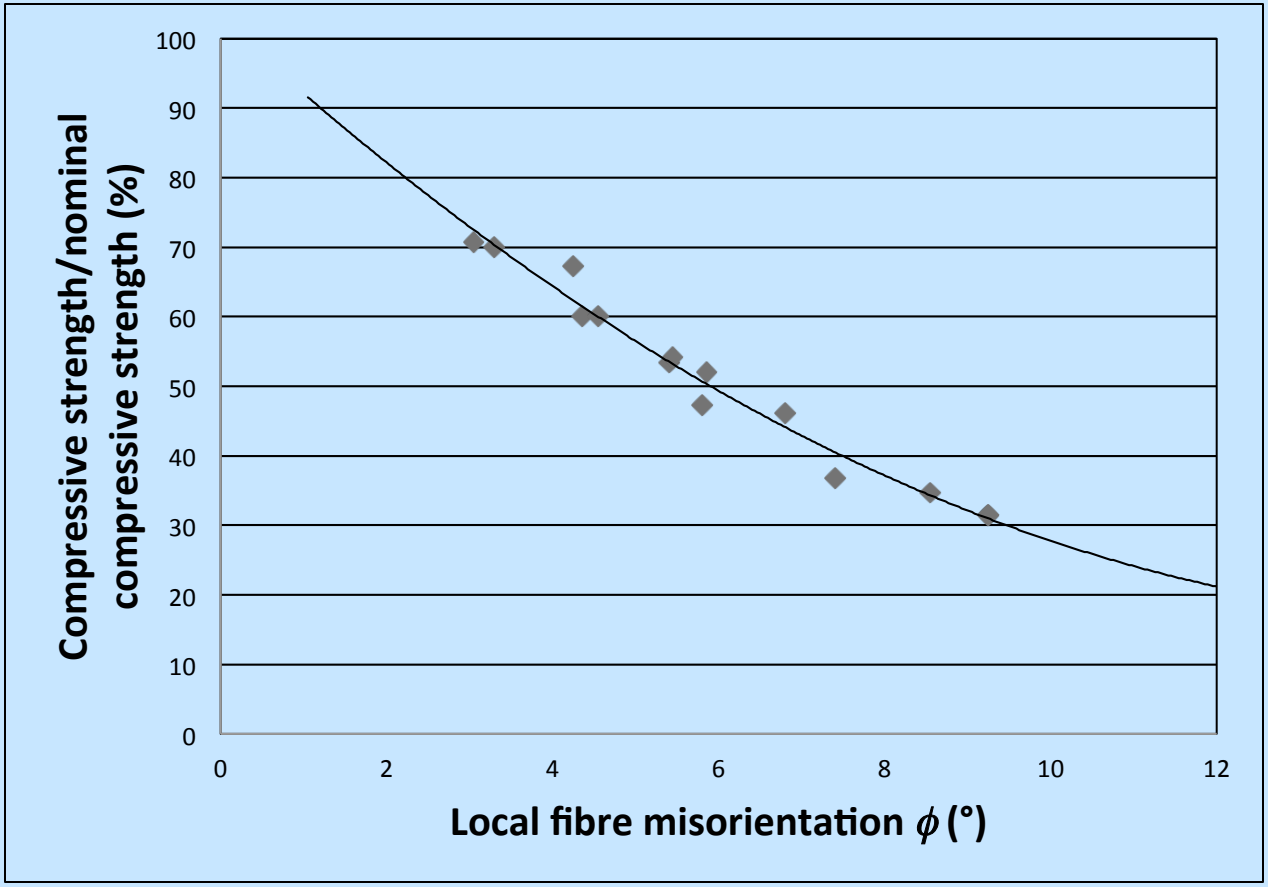
UD angled layer #6/#7

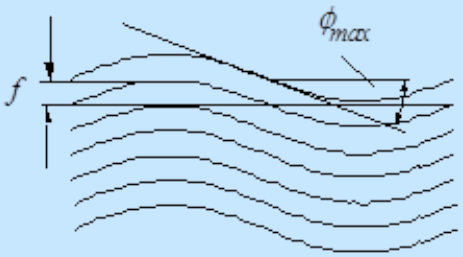
No anomalies in these layers (!)

UD layer #8

Again:
In-plane fibre ondulation in this 0°-layer

Compressive strength vs local fibre misorientation

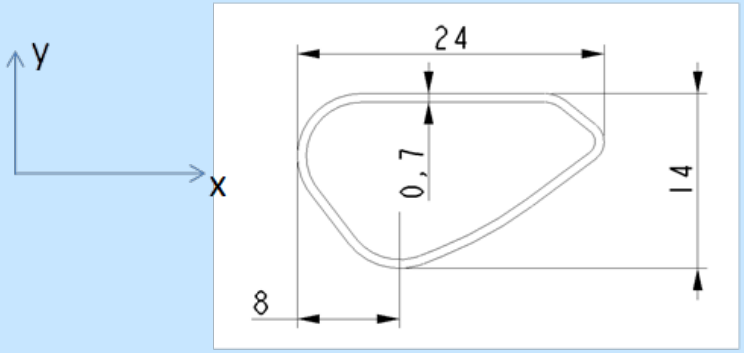




$$\phi_{max} = \pi \frac{f}{l}$$

Test results:
ZFL Haldensleben

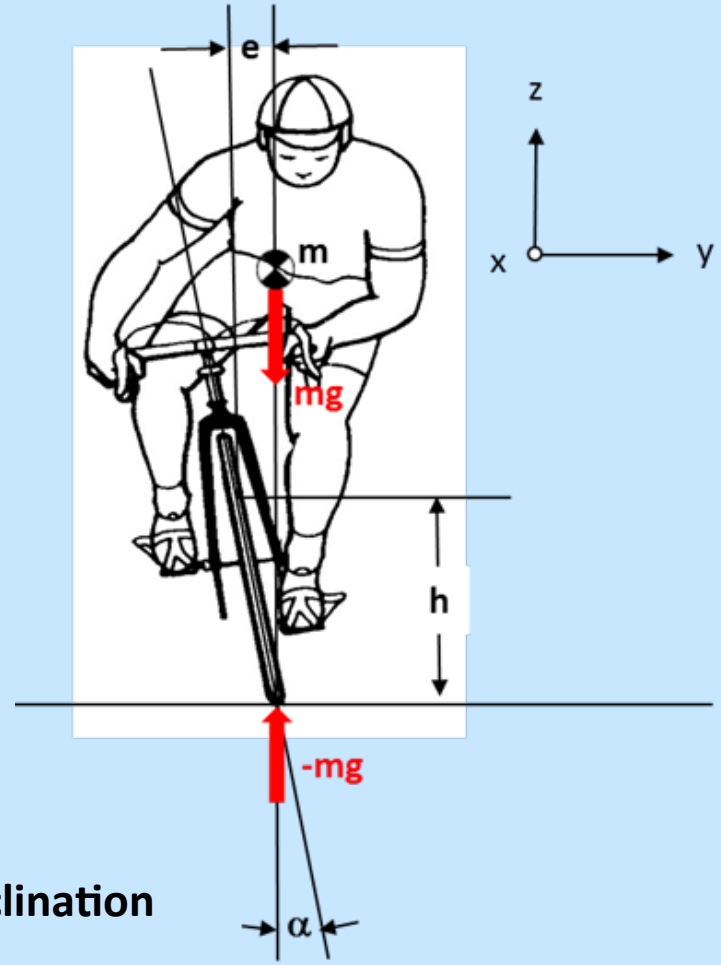
Static analysis



I_x= 9.7022296e+02 mm^4
I_y= 2.2886428e+03 mm^4

Schwerpunkt in Bezug auf den Koordinatenrahmen PRT_CSYS_DEF:
X Y 3.377e+00 -1.6e-00
Im Bezug auf den geraden Teil des Profils (oben) 5,71 mm
y: maximaler Abstand Schwerpunkt/Außenfläche 8,29 mm
x: Maximaler Abstand Schwerpunkt Außenfläche in x-Richtung: 12,62 mm

damit: **W_x=117,04 mm³, W_y=181,31 mm³**



α: cyclist's declination

Result of static analysis

Maximum angle of cyclist‘s declination which would cause fork blade fracture:

$$\alpha_{max} = \arctan\left(4\frac{\sigma_D W_x}{mgh}\right)$$

Experimental values yield a maximum angle of **14,6°**!

Assuming a slight (reasonable) load factor of 1,5 the maximum declination angle reduces to **9,8°**!

… which is easily achieved in ambitious cycling!

Summary

Wrinkles/local fibre ondulations are often introduced during various manufacturing processes. They usually can not be detected from the surface.

Fibre ondulations can lead (and they do) to catastrophic failure in brittle CFRP!

In particular in-plane ondulations are difficult (if at all) to detect with NDT!

Last but not least

Comment of the manufacturer‘s lawer to the experimental findings:

„Ok… what are your damage claims?“