

Inlineprüfung von multiaxialen Kohlefasergelegen mittels Hochfrequenzwirbelstrom unter Verwendung modularer Sensorarrays

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Kurzfassung

Um multiaxiale Hochleistungskohlefasergelege (sogenannte Non-Crimp-Fabrics) in voller Produktionsbreite zerstörungsfrei und inline zu prüfen, kommen aktuell nur optischen Verfahren unter Verwendung von Zeilenkameras zum Einsatz. Unsichtbare verdeckte Lagen sind mit diesen Methoden nicht inspizierbar, was das Verfahren demnach auf die obere bzw. untere Decklage beschränkt.

Am Fraunhofer IKTS wurde basierend auf der industrieerprobten IKTS EddyCus® Pro-II Wirbelstromplattform ein völlig neuartiges Wirbelstromarraysystem entwickelt, welches es ermöglicht auch verdeckte Kohlefasergelege im Inneren eines multiaxialen Lagenaufbaus zu detektieren und zu bewerten. Das System ermöglicht es durch die modulare Erweiterung von Arrayelementen Produktionsbreiten von bis zu 101“ blindpixelfrei, inline und bei Produktionsgeschwindigkeiten bis zu 5 m/s zu prüfen. Das System kann neben einer automatisierten Gassendetektion- und Fehlergrößenbewertung sowie einer Winkellagenvermessung auch metallische Verunreinigungen und eingenähte Kohlefaserflusen eindeutig klassifizieren.

In diesem Vortrag wird ein theoretischer Einblick in die Hochfrequenzwirbelstromprüfung an Kohlefasergelegen gegeben sowie auf die speziellen Randbedingungen und Herausforderungen bei der Integration in ein industrietaugliches Arraysystem eingegangen. Insbesondere für den Kanalabgleich am anisotropen Kohlefasergelege mussten, über die in der Norm bekannten Abgleichverfahren hinaus, neuartige Methoden entwickelt werden, welche im Vortrag am praktischen Beispiel erörtert werden. Darüber hinaus wird das entwickelte modulare Wirbelstromsensorenarray in einem virtuellen Laborrundgang vorgestellt.

Di.1.C.2

Inlineprüfung von multiaxialen Kohlefasergelegen mittels Hochfrequenzwirbelstrom unter Verwendung modularer Sensorarrays

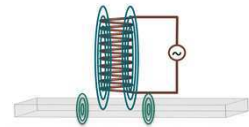
H. Heuer, D. Hofmann, J. Michauk, M. Oemus, C. Pilz, M. Pooch, M. Rake, **M. Schulze**, T. Schulze, N. Wohlgemuth

16.05.2023



Fraunhofer Institute for Ceramic Technologies and Systems IKTS

Group: Eddy-Current Methods



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Content

- Eddy-Current basics on CF-Material
- EddyCus® NDT-Systems at Fraunhofer IKTS
- First Eddy-Current Array sensor prototype at JEC – Exhibition 2019
- Development of a customized multi-channel inspection system
- Overview of full-width 101“ inspection system
 - Lab-Tour and demonstration of Eddy-Current evaluation system
 - Calibration preview
 - Results on NCF
- Conclusion

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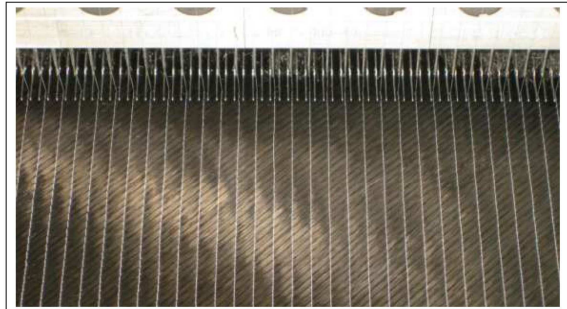
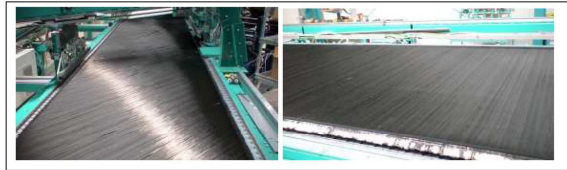
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Production of a Carbon Fiber Non-Crimp Fabric



Malitronic® MULTIAXIAL: modular base platform for machines for the production of multiaxial NCF

Source: Final Report Project „Multisensorline“



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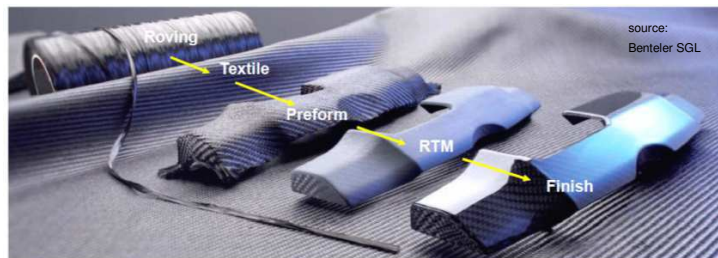
Motivation – reduction of defect material during production

Defects during production

- Gaps, overlapped tows
- foreign objects (Pins, needles)
- Wrong Orientation (Angle, Stacking)
- Fuzz-Balls
- Thickness (density) variations
- Dry spots, voids
- In / Out-of plane undulations
- Matrix imperfections

Defects during usage

- Delamination, Debonding
- reduced strength
- component failure



source:
Benteler SGL

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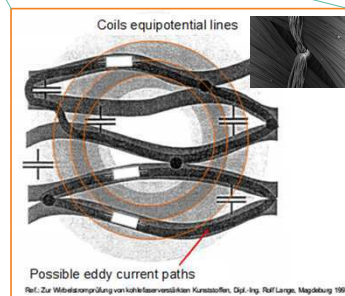
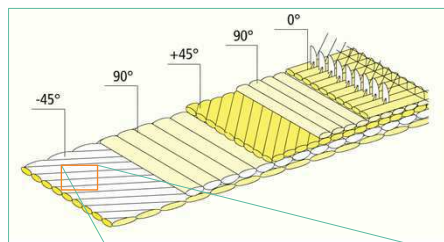
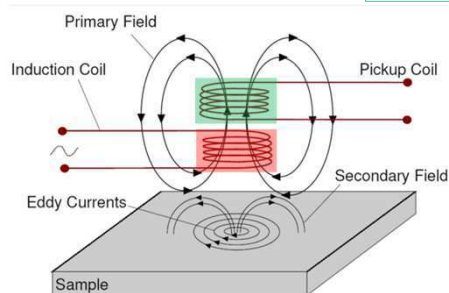
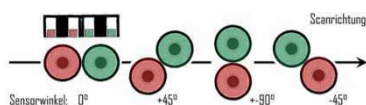
Eddy-Current basics on NCF / CFRP

Conductivity :

- Graphite: $\sigma = 3 \cdot 10^6 \text{ S/m}$
- Aluminum: $\sigma = 37 \cdot 10^6 \text{ S/m}$
- Carbon Fiber: $\sigma = 5 \cdot 10^3 - 5 \cdot 10^4 \text{ S/m}$ (0° to Fiber)
 $\sigma = 10 - 100 \text{ S/m}$ (90° to Fiber)

Electrical Effects :

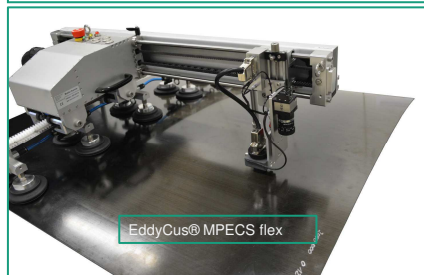
- Fiber / Volume Ratio
- Density
- Capacitive Coupling



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Scanning EddyCus® Systems at IKTS



Sample	Picture (1 st layer)	Picture (3 rd layer)	EC-Image (front)	EC-Image (rear)
#1				

3 layer RCF with small tapered lanes (compare to Fig.1(b)) in the 1st and 3rd layer, four missing fiber bundles in the 3rd and one horizontal in the 2nd layer - Sample Size [mm]: 210*295

#3				
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3 layer RCF with 2 missing bundles and 2 lanes in the 1st layer, visible even in rear C-Scan, the marcel has a good distinguish ability - Sample Size [mm]: 275*275

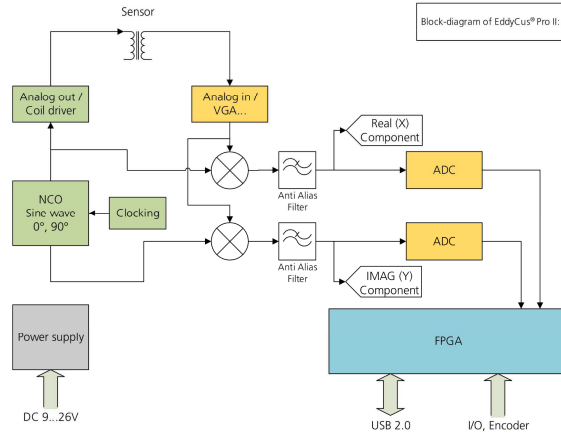
- Inspection of CFRP in 2D (Laboratory) and 2,5D (BMW)
- Inspection of dry RTM-Stacks and components as well

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EddyCus® Pro-II OEM

- EddyCus® Pro-II OEM Eddy-Current device
(Certified according to DIN EN ISO 15548-1)



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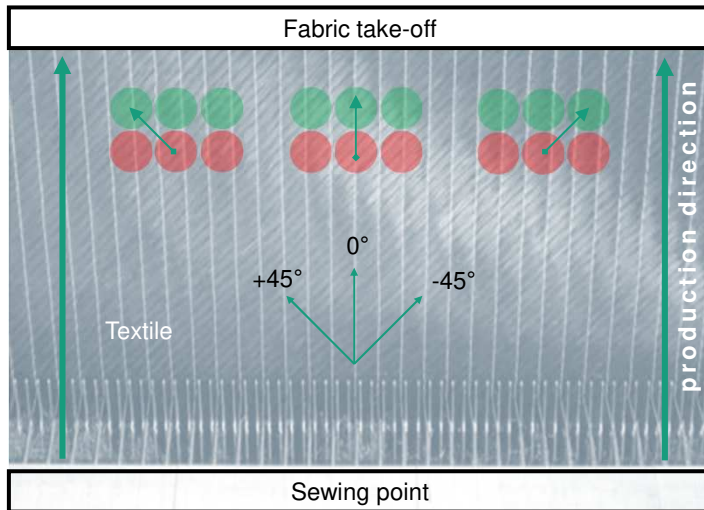
Sensorrotation – Example



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First Inline Sensor Prototype



- Sensor orientations were defined in accordance with textile definition

● Transmitter
● Receiver

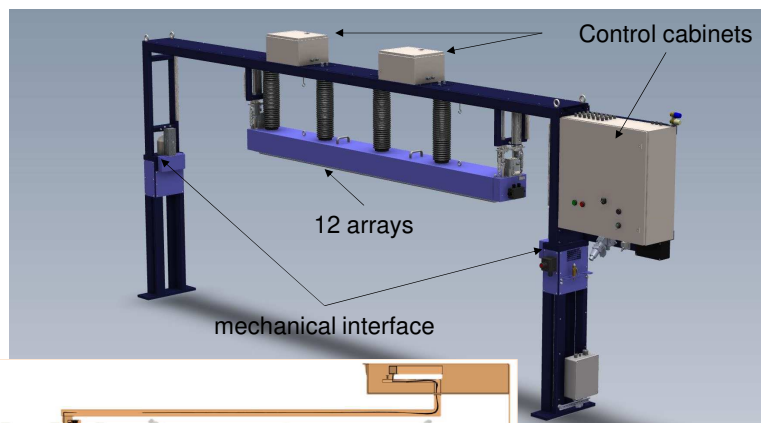


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Inspection system overview

- The system will be installed in two different zones
- The whole System is ATEX Zone 21 certified
- Ingress Protection of IP6x
- Temperature Classification Rating < 300C°
- Most components are commercial certificated products
- Eddy-Current array has a separate ATEX-certificate



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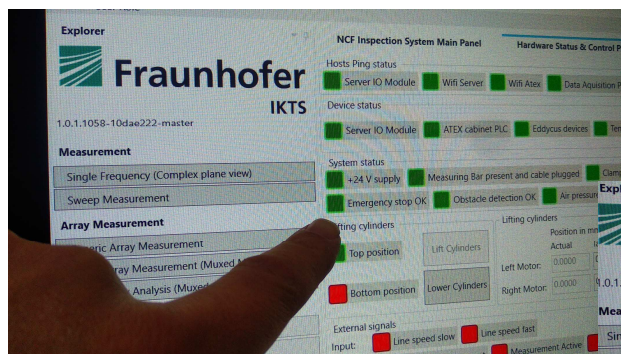
Inspection system overview



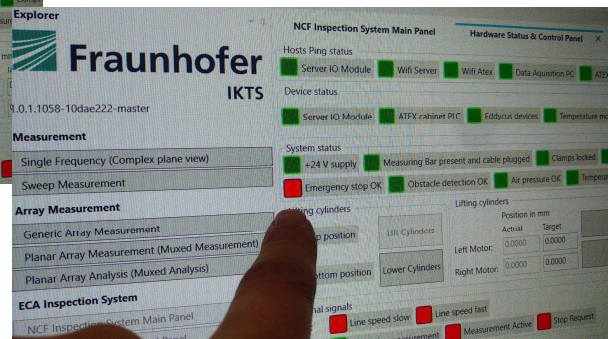
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Software integration



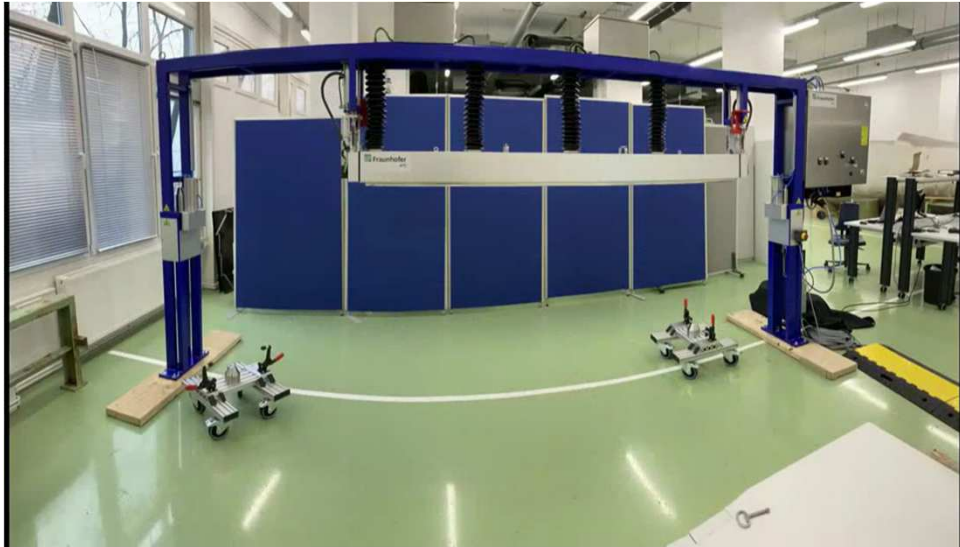
- System is fully integrated into Karl-Mayer PLC
- Highly customizable touch screen interface



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Final system before installation at customer side



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JEC – Exhibition March 2019 / 2023



Full Lab-tour:



<https://s.fhg.de/eddycus>

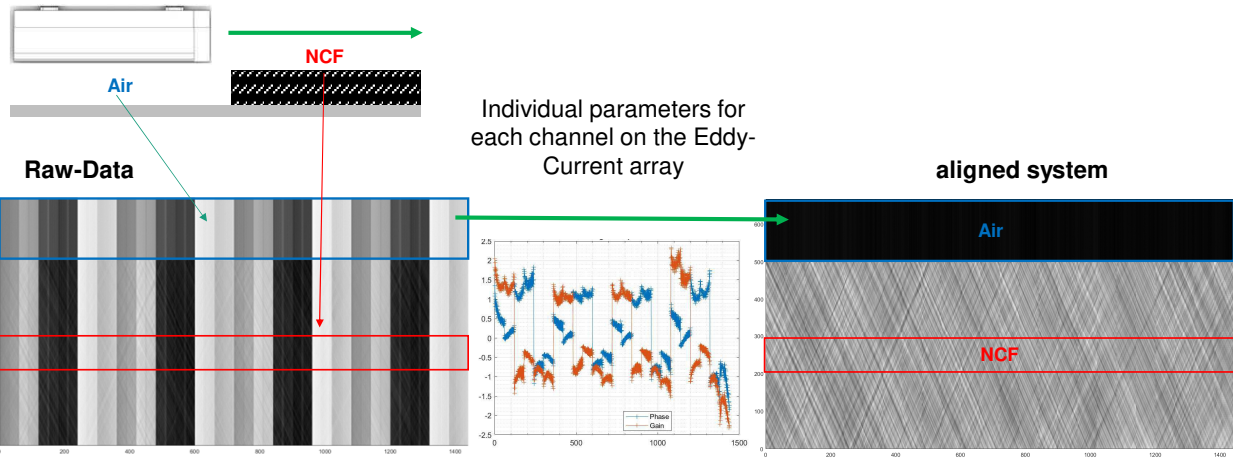


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Calibration – Presentation: Mi.3.A.4 – Maren Rake 13:30 Uhr

- Considering raw data, channels have individual characteristics and need to be aligned
- Existing methods on isotropic material don't work on NCF --> new methods were investigated

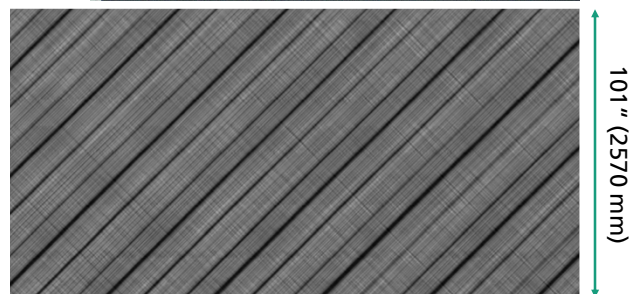
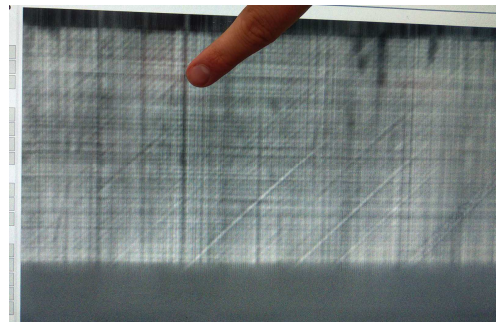


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„Live results“ of real data

- Some small gaps in 0°-orientation are visible
- All three NCF orientations are visible and can be quantified
- System is able to work at speeds up to 5 m /min
- 2976 Eddy-Current sensor elements over 2570 mm (0,85 mm Hardware resolution)
- All defect-detection routines are running inline without any delay
- PDF protocol of NCF roll is beeing created after each roll to ensure traceability

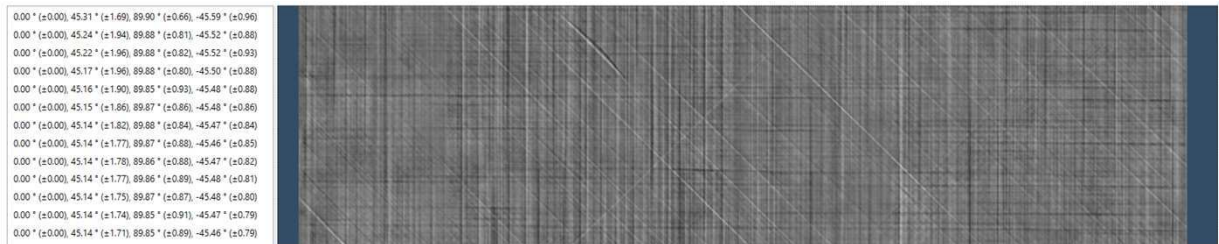
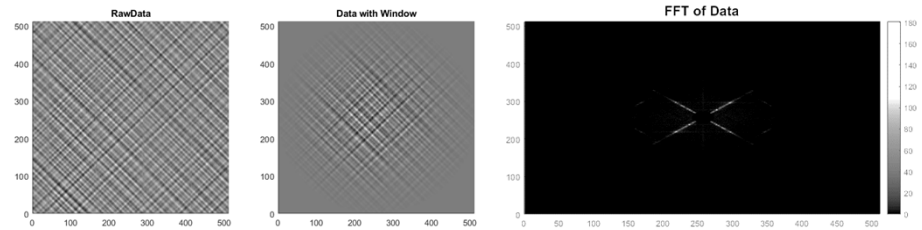


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Fiber orientation measurement - preview

- Determination of orientation with Fast 2D Fourier Transformation



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Conclusion

- World's probably longest Eddy-Current array system was presented
- EddyCus® Pro-II OEM allows a wide range of parametrization and customization
- The system is able to inspect up to 101" width and also hidden carbon fiber layers can be inspected
 - Gap- and overlap detection in all parametrized sensor directions and measurement of the size
 - Fiber angle measurement
 - Foreign objects (metallic pins, needles), Fuzzball detection and quantification
- The system has full ATEX – Zone 21 rating
- Online inspection with live visualization and defect detection was realized
- The system is fully integrated into existent PLC-unit of Karl-Mayer NCF-Machine
- Other actual ongoing applications:
 - Inspection of recycled carbon fiber veils (homogeneity)
 - Inspection of calendared battery foils



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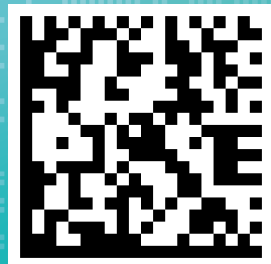
Vielen Dank für Ihre Aufmerksamkeit

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