QualiFibre

Qualification and Diagnosis of Carbon and Glass Fibre-Reinforced Composites with Non-Destructive Measurement Technologies

Workpackage 2

28/01/2015, Halle, Germany

Workpackage 2

Title: **Testing, quality parameters and defects acquisition**

Objectives:

a) Relevant defect parameters are identified
b) Reliable methods to insert defined defect structures into glass- and carbon-fibre materials have been implemented
c) Test samples have been designed and produced
d) Testing methods to recognize artificial defect structures have been established
e) Qualification method has been developed to classify defects properly and reliable
f) Concept of experimental set-up for multi sensor analysis has been developed

Task 2.1

- **Title:** Definition of defect analysis, material parameter acquisition and qualification
- **Task Leader:** EMPA
- **Goals:**
  - Analysis of different kinds of defects
  - Categorisation of defects
  - Qualification of defects

Task 2.1

- Analysis of different kinds of defects (examples) ... using ultrasonic

Figure 2: Ultrasonic C-scan of internal echo: Images of delaminations due to a 2 J (left) and 8 J (right) impact damage (image from EMPA).

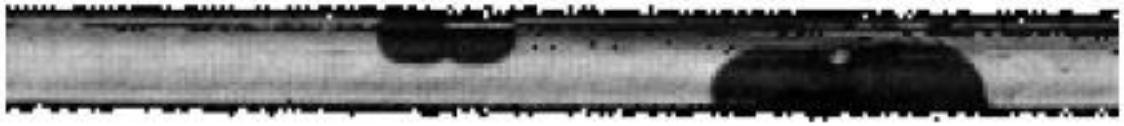


Figure 3: Ultrasonic C-scan of backwall echo: Images of delaminations due to a 2 J (left) and 8 J (right) impact damage (image from EMPA).

Task 2.1

- Analysis of different kinds of defects (examples) ... using thermography

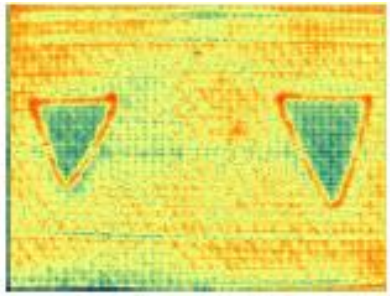


Figure 5: Thermographic image of a FRP part where a double layer of fibres was introduced in a triangular region (image from Fraunhofer IPA).

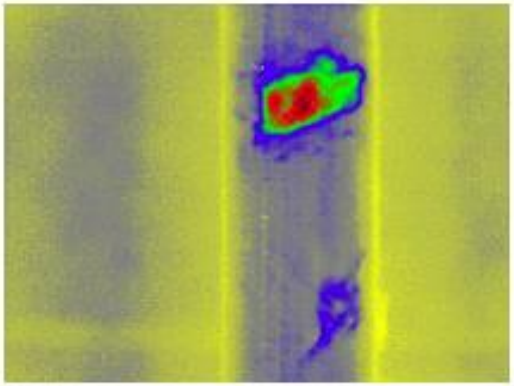


Figure 8: Dry patch in FRP cylinder seen by IR imaging (image from Fraunhofer IPA).

Task 2.1

- Analysis of different kinds of defects (examples) ... using CT

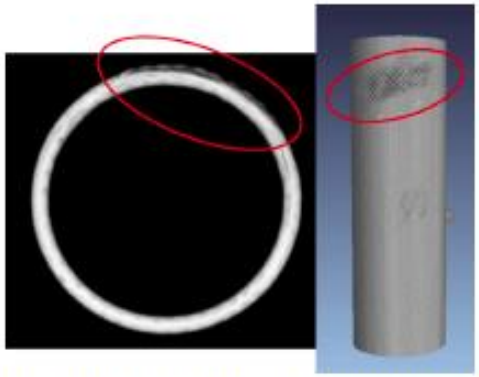


Figure 16: Dry patch as seen in a CT slice image (left) and 3D image (right) of a cylindrical FRP part (image from Fraunhofer IPA).

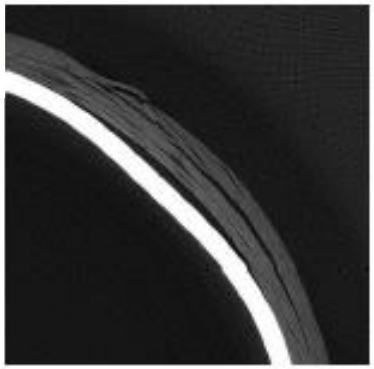


Figure 15: Cracks after an impact on a CFRP bottle with Al liner as seen in a CT slice image (image from EMPA).

Task 2.1

- Analysis of different kinds of defects (examples) ... using dark field

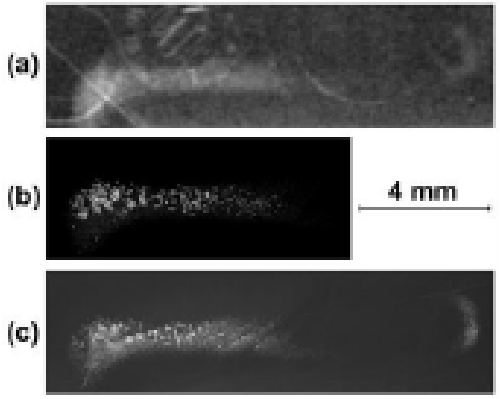


Figure 21: Dark-field image of stress whitening (a) and the comparison with local micro CT scan (b) and microsection microscopic image (c) [1].

Task 2.1

- Defect Structure Qualification and Characterization Method Matrix

type of defect	ultra-sonic	thermo-graphy	X-ray CT	dark-field	produc-tion	in the field	repair
(1) microscopic inclusion			●	●	●		▪
(2) void cluster				●	●	●	▪
(3) broken fibres				?		●	
(4) fibre pull out				●		●	
(5) macroscopic inclusion	●	●	●	●	●		▪
(6) void	●	●	●	●	●		▪
(7) delamination	●	●	●	▪	●	●	●
(8) crack	●	●	●	●		●	
(9) dry patch	▪	●	●	▪	●		▪
(10) fibre density			▪	?	●		▪
(11) fibre orientation		▪	●	?	●		▪
(12) fibre length			▪	?	●		▪
(13) joint	●	●	●	●	●		●

Task 2.1: Did we reach our goals?

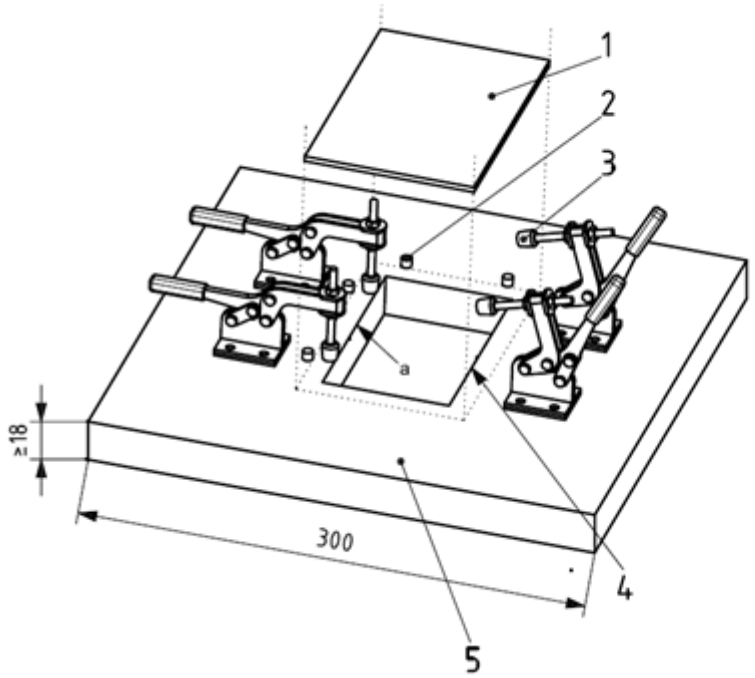
- **Goals:**
  - Analysis of different kinds of defects ✓
  - Categorisation of defects ✓
  - Qualification of defects ✓

Task 2.2

- **Title:** Development of adequate test parts and samples with defined defects. Elaboration of a test plan for specified parameter/data resampling
- **Task Leader:** STW
- **Goals:**
  - Development of test-part mould for production
  - Reproducible production of test-parts with defined defects
  - Elaboration of a test-plan for multi-sensor-data acquisition

Task 2.2

- The Mould for the test parts

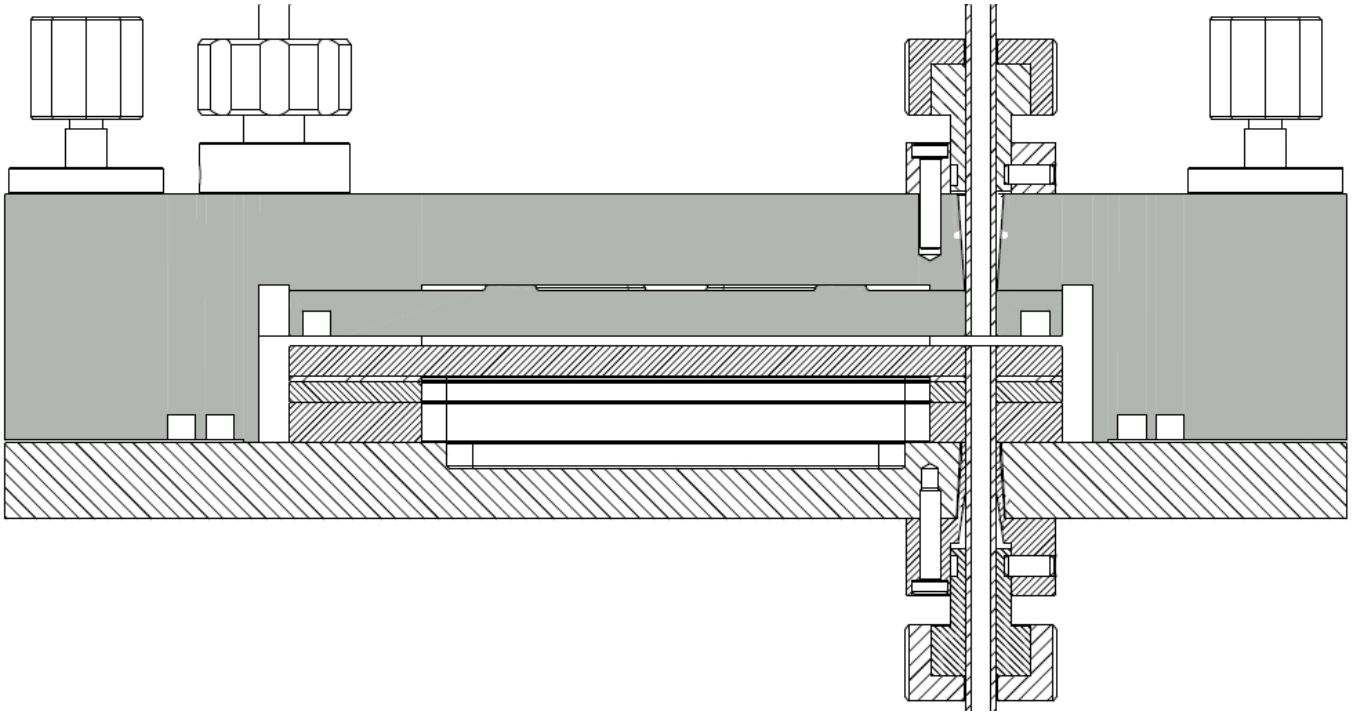


1: Testpart
2: Alignment pin
3: Rubber buffer
4: Cutout
DIN 65561: 76,2mm x 127mm
ISO 18352: 75±1mm x 125±1mm
a: Phase 1mm x 45°
5: Base plate (steel)

Mould for test part manufacturing

Task 2.2

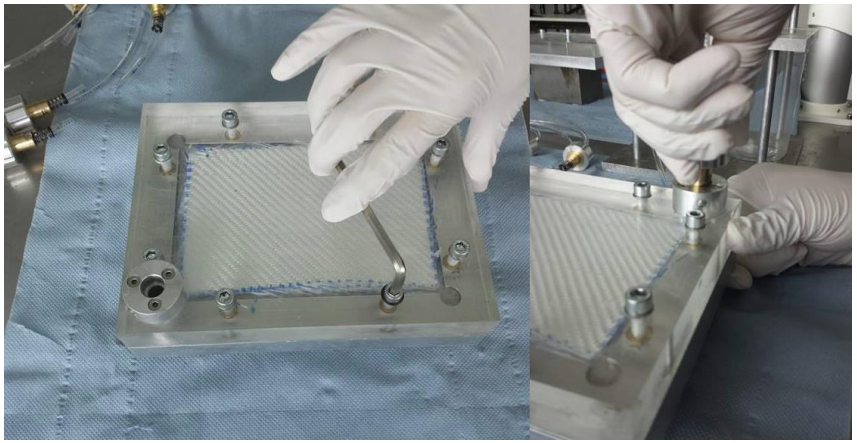
- The Mould for the test parts



Cross section of the mould for flat and 3D-test parts

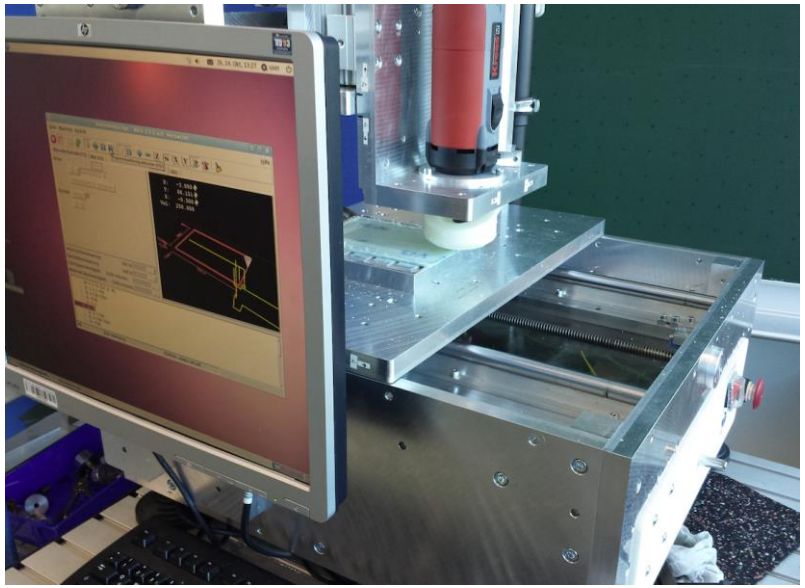
Task 2.2

- The production of the Test parts



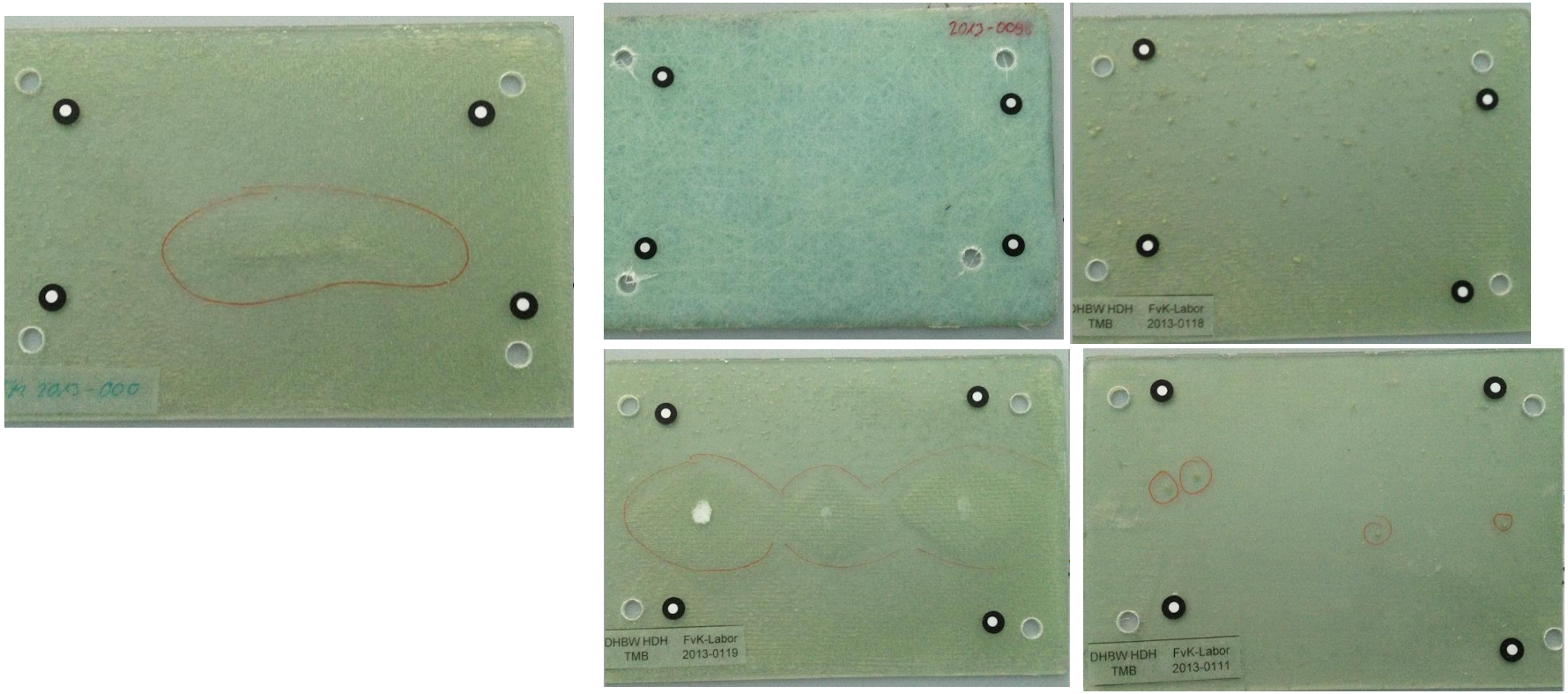
Task 2.2

- The production of the Test parts – post-processing



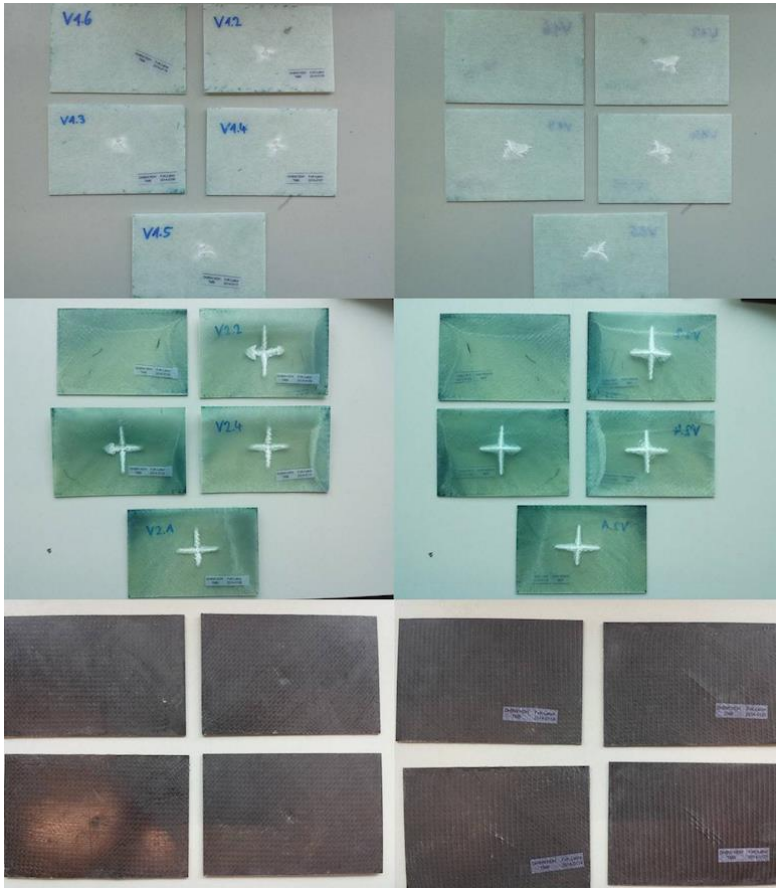
Task 2.2

- Test parts with defined defects



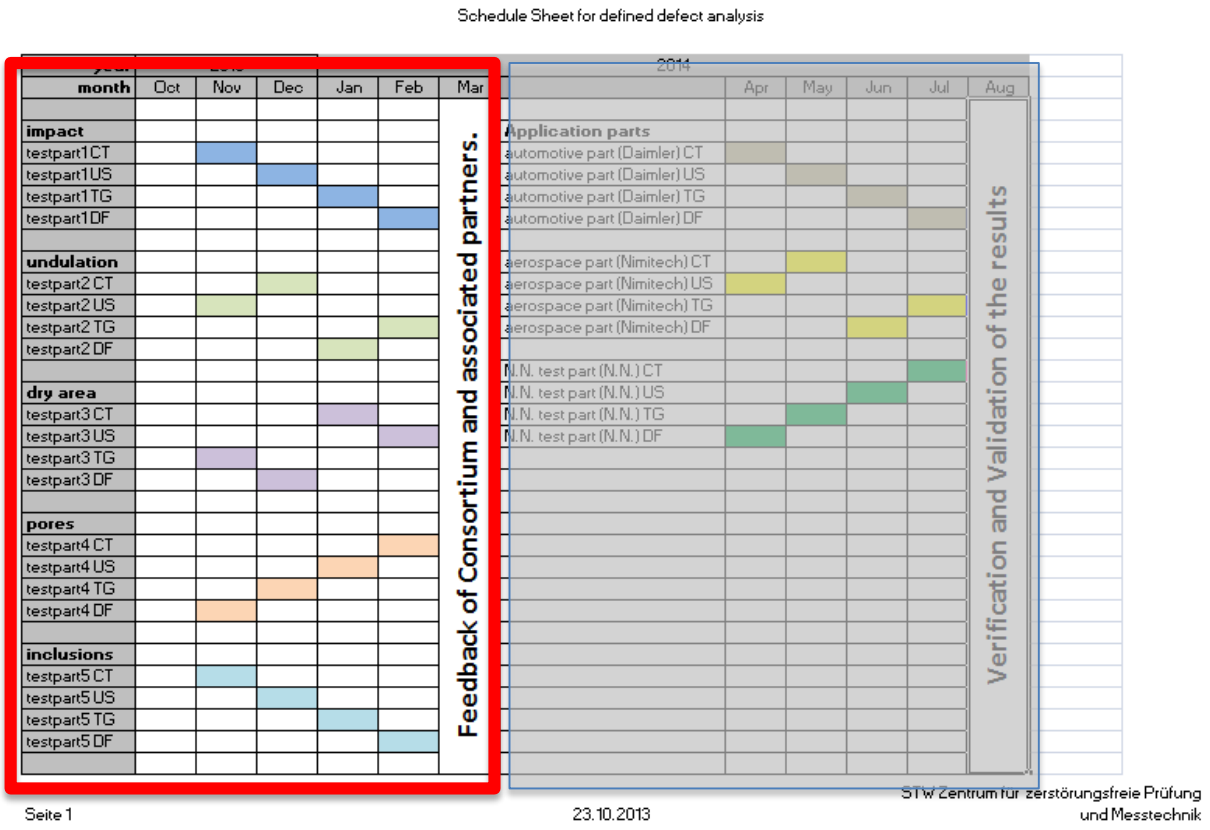
Task 2.2

- Test parts – pre damaging



Task 2.2

- Test plan
  - testparts with defined defects
  - different sensors of one kind (US or TG or CT ...)
  - tests regarding visibility, detectability, resolution, scan-time etc.



Task 2.2: Did we reach our goals?

- **Goals:**
  - Development of test-part mould for production ✓
  - Reproducible production of test-parts with defined defects ✓
  - Elaboration of a test-plan for multi-sensor-data acquisition ✓

Task 2.3

- **Title:** Development of the test plan for sensor type selection considering the different parameter/defect types and specification of the used sensors
- **Task Leader:** STW
- **Goals:**
  - design of a methodology of multi-sensor measurement equipment
  - development of a test plan, covering all relevant defect structures

Task 2.3

- End users test parts

trunk part from Daimler AG

Task 2.3

- Test plan
  - End users test parts
  - Prove of concept tests
  - Performance tests to locate the optimization potential

Schedule Sheet for defined defect analysis

year	2013					
month	Oct	Nov	Dec	Jan	Feb	Mar
impact						
testpart1 CT						
testpart1 US						
testpart1 TG						
testpart1 DF						
undulation						
testpart2 CT						
testpart2 US						
testpart2 TG						
testpart2 DF						
dry area						
testpart3 CT						
testpart3 US						
testpart3 TG						
testpart3 DF						
pores						
testpart4 CT						
testpart4 US						
testpart4 TG						
testpart4 DF						
inclusions						
testpart5 CT						
testpart5 US						
testpart5 TG						
testpart5 DF						

Feedback of Consortium and associated partners.

2014	Apr	May	Jun	Jul	Aug
Application parts					
automotive part (Daimler) CT					
automotive part (Daimler) US					
automotive part (Daimler) TG					
automotive part (Daimler) DF					
aerospace part (Nimitech) CT					
aerospace part (Nimitech) US					
aerospace part (Nimitech) TG					
aerospace part (Nimitech) DF					
N.N. test part (N.N.) CT					
N.N. test part (N.N.) US					
N.N. test part (N.N.) TG					
N.N. test part (N.N.) DF					

Verification and Validation of the results

Seite 1 23.10.2013 STW Zentrum für zerstörungsfreie Prüfung und Messtechnik

Task 2.3: Did we reach our goals?

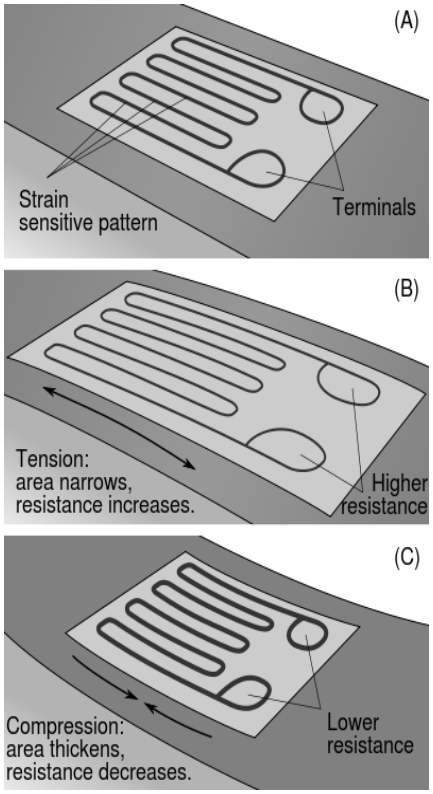
- **Goals:**
  - design of a methodology of multi-sensor measurement equipment ✓
  - development of a test plan, covering all relevant defect structures ✓

Task 2.4

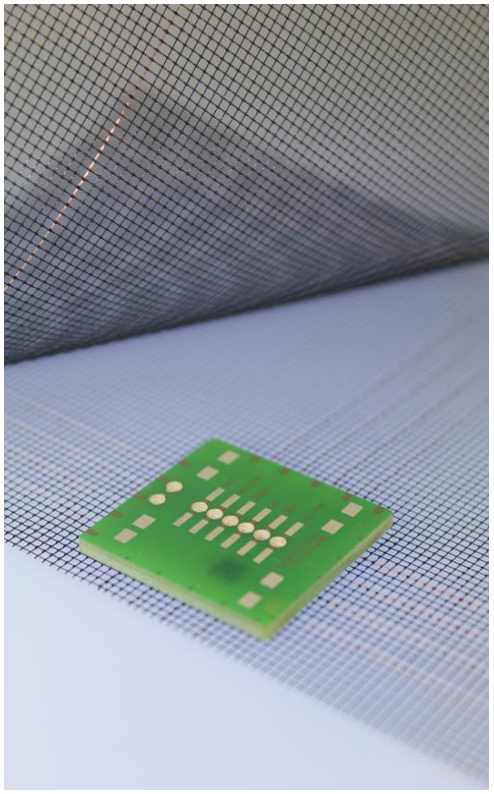
- **Title:** On board overload sensing
- **Task Leader:** STW
- **Goals:**
  - analysis of possible technical solutions with regard of possible usability in field monitoring and status documentation of CRP/GRP objects

Task 2.4

- **Strain gauges**



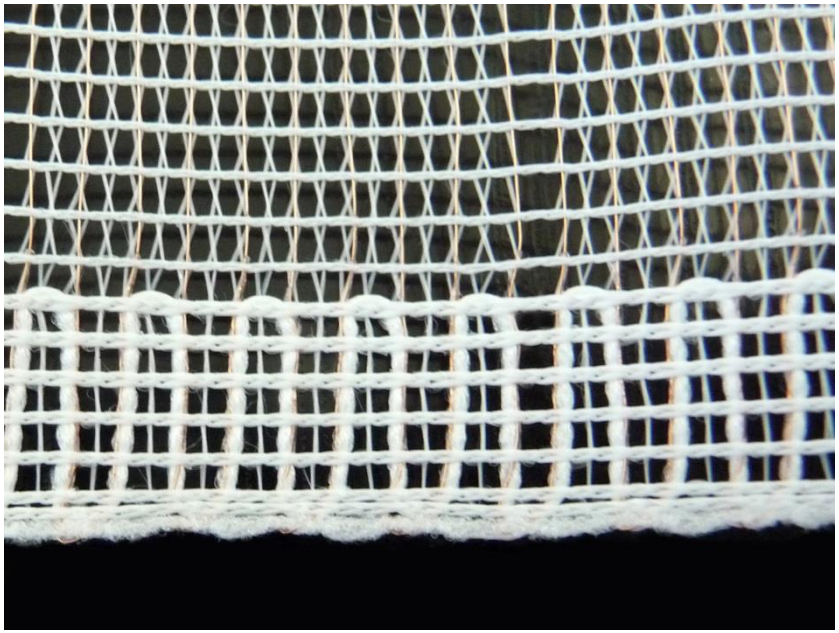
Quelle: http://upload.wikimedia.org/wikipedia/commons/thumb/c/c3/StrainGaugeVisualization.svg/400px-StrainGaugeVisualization.svg.png



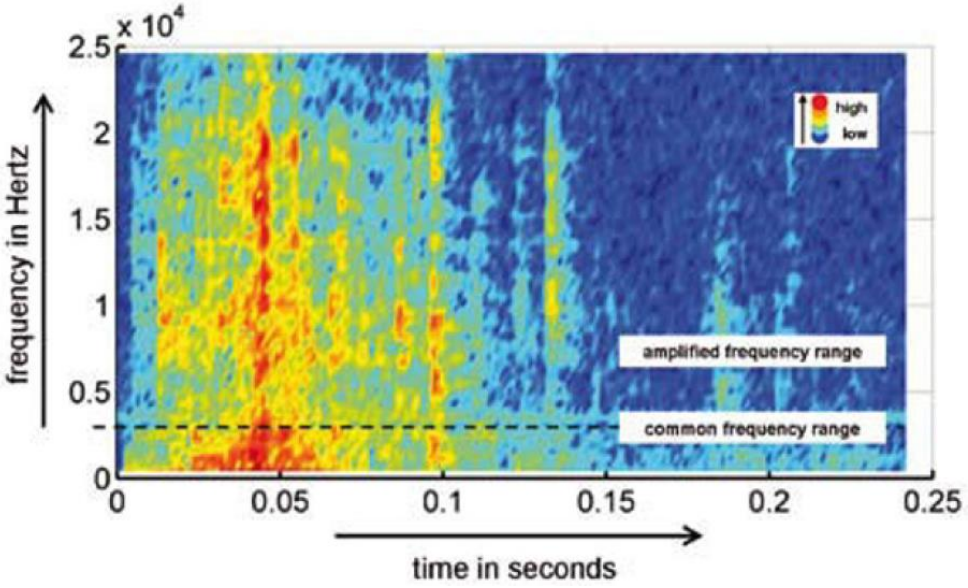
Quelle: Fraunhofer IZM (idw) http://www.extremnews.com/berichte/wissenschaft/2ea51411dfa71ee/d2ed1411dfa7221/

Task 2.4

- **Powersense and structure-borne-noise-/impact-noise-analysis**



Quelle: SEFAR PowerSense, Quelle: Sefar AG, CH
http://www.sefar.com/data/docs/en/7281/SF-Smart-Fabrics-PowerSens-07.jpg?variant=44253



Quelle:
ATZ - Automobiltechnische Zeitschrift Ausgabe 02/2008 Seite 160-165, Autor(en): Dipl.-Ing. (FH) Marinus Luegmair, Dipl.-Ing. (FH) Lucas Oestreicher

Task 2.4: Did we reach our goals?

- **Goals:**
  - analysis of possible technical solutions with regard of possible usability in field monitoring and status documentation of CRP/GRP objects ✓
  - BUT: further investigation an d research necessary!

→ Especially: Production of test parts.

→ And also: Systematic analysis of usability during complete lifetime of a product.

To be continued!

Task 2.5

- **Title:** Conceptual development of experimental set-up for all sensors and application requirements
- **Task Leader:** STW
- **Goals:**
  - conceptual definition of multi-sensor equipment

Task 2.5

- Conceptual hardware set-up dark field / CT at **EMPA**

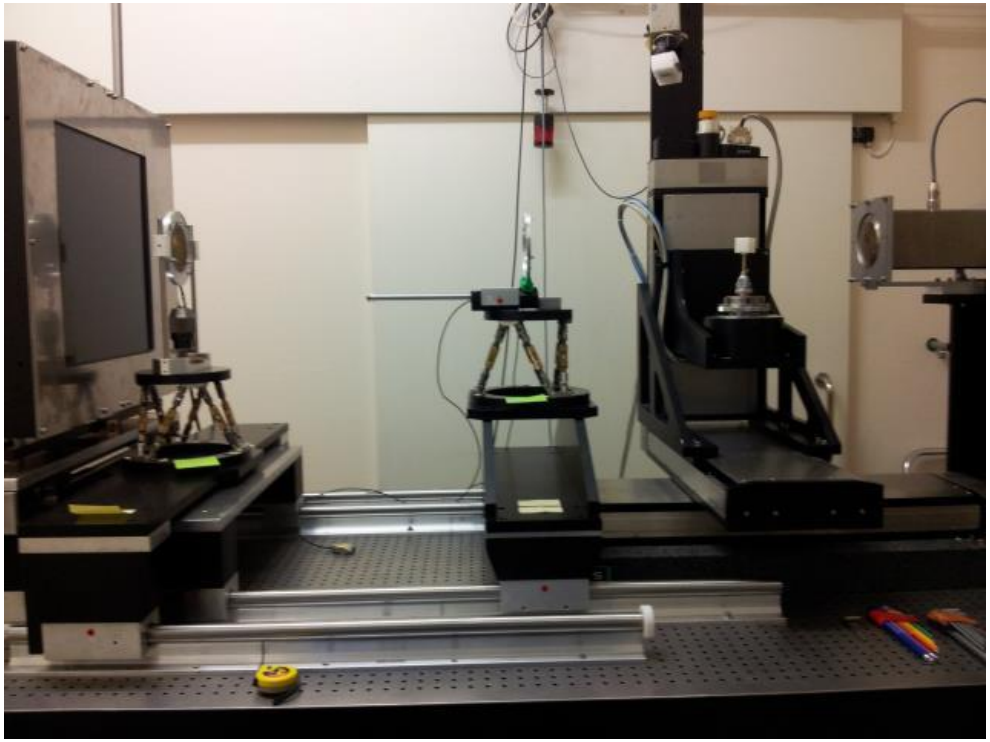


Figure 1: µCT setup at EMPA upgraded to dark field imaging consists of (from right side to left side): X-ray source, sample holder stage, phase grid stage, analyser grid stage and flat panel detector.

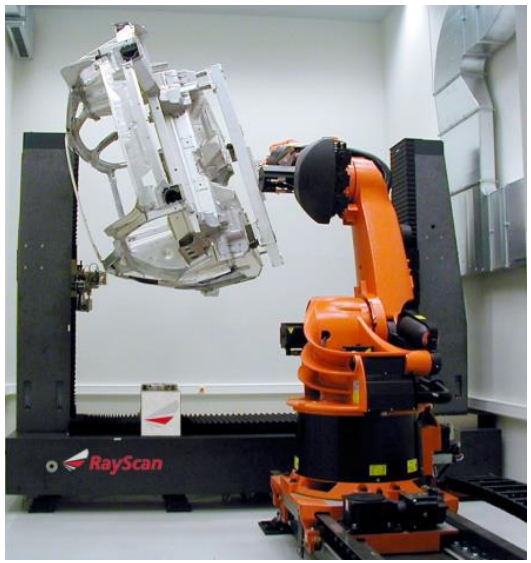
Task 2.5

- Conceptual hardware set-up thermography at **Winterthur Instruments**

Figure 4: Winterthur Instruments Tracer Thermography Lock-In System in a field test.

Task 2.5

- Conceptual hardware set-up CT at **Rayscan**



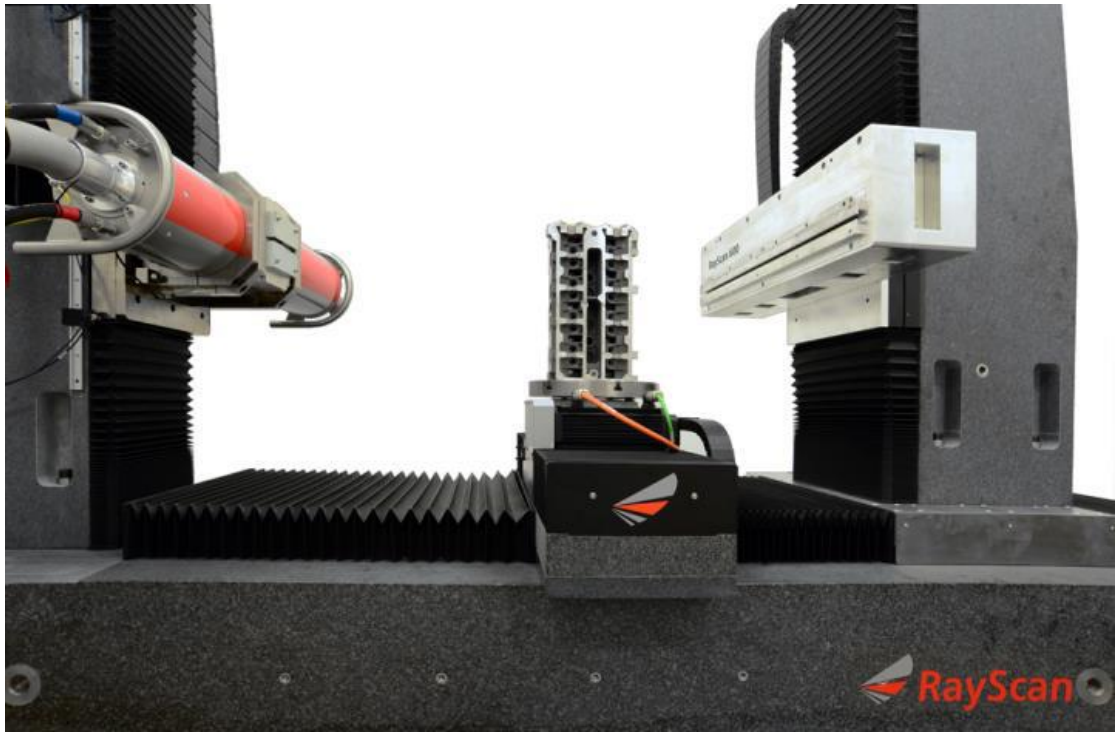


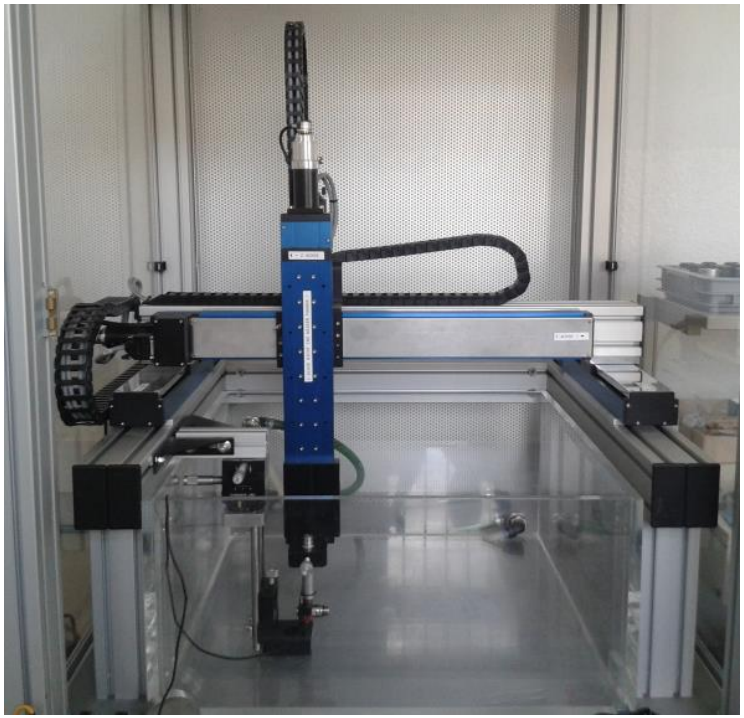
Figure 6: RayScan 200 XE (left) and RayScan 600 (right) X-ray computed tomography system

Task 2.5

- Conceptual hardware set-up ultrasonic at **Sonotec**

Figure 10: Left: New developed A-scan Ultrasonic testing device developed and produced by SONOTEC, test of probes for air-coupling with the SONOSCREEN ST10

Figure 7: The Stationary Ultrasonic testing stand at SONOTEC: HYSCAN (producer FHG IZFP)



Task 2.5

- Conceptual software set-up

→ Details will be presented in WP3

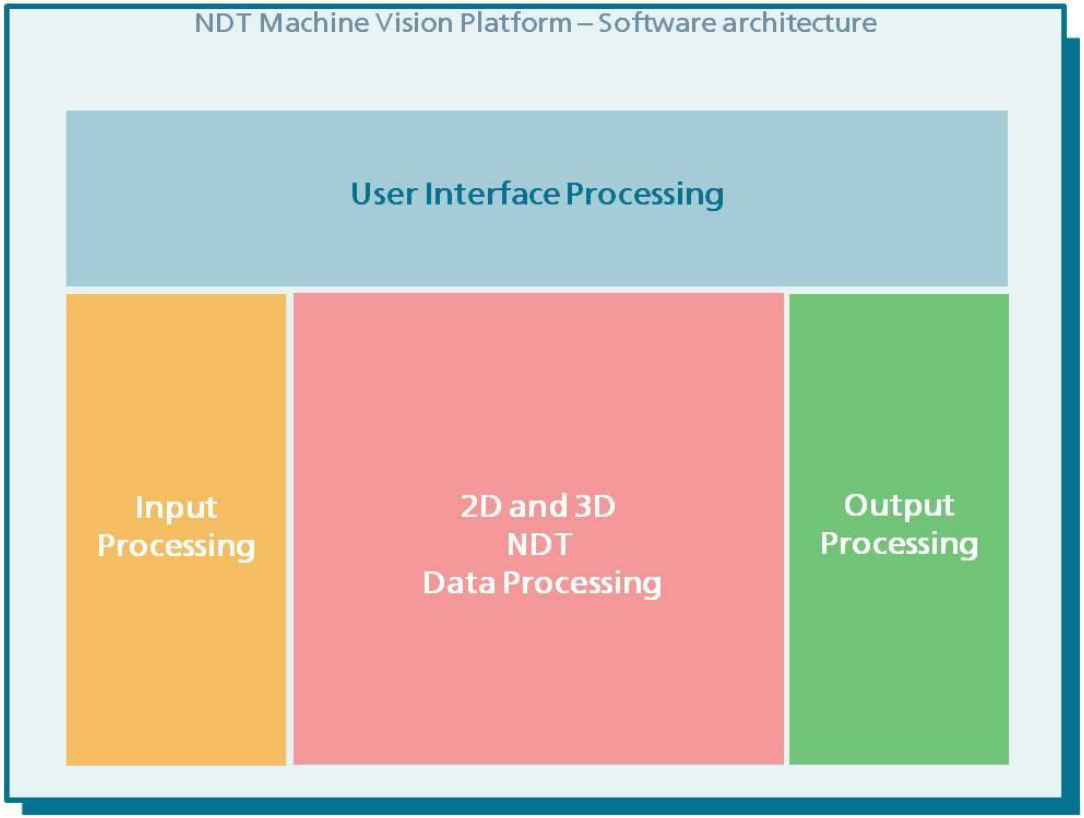


Figure 15: NDT-MVP: general software architecture

WP 2: Conclusion

- **Did we reach the objectives of our Workpackage?**

a) Relevant defect parameters are identified ✓

b) Reliable methods to insert defined defect structures into glass- and carbon-fibre materials have been implemented ✓

c) Test samples have been designed and produced ✓

d) Testing methods to recognize artificial defect structures have been established ✓

e) Qualification method has been developed to classify defects properly and reliable ✓

f) Concept of experimental set-up for multi sensor analysis has been developed ✓