ESIS TC24, Politecnico di Milano, 1st - 2nd October 2014

Potential improvements of the presently applied in-service inspection of wheelset axles

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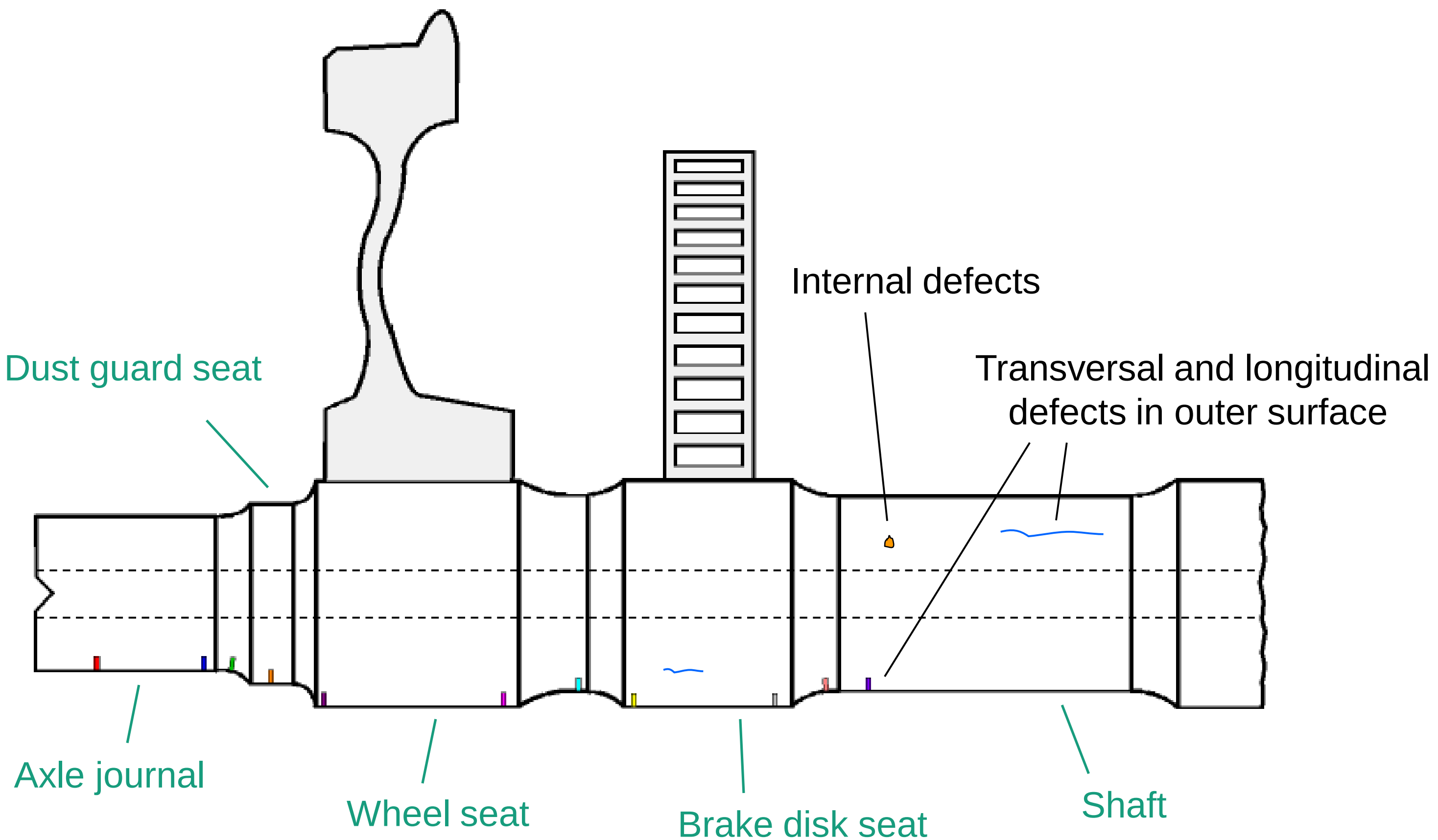
Outline of the Presentation

- State of the art of the presently applied inspection technology for hollow axles and solid axles
- Conclusion from the Gap Analysis related to in-service inspection
- Identification of possible improvements
  - Ultrasonic Phased Array technique
  - Synthetic Aperture Focusing Technique - SAFT
  - POD Simulation for axle testing
  - Induction Thermography for surface crack detection
  - Condition Monitoring

State-of-the-art for the Inspection of Axles in Service

Hollow Axle Testing - Relevant Areas and Defect Types

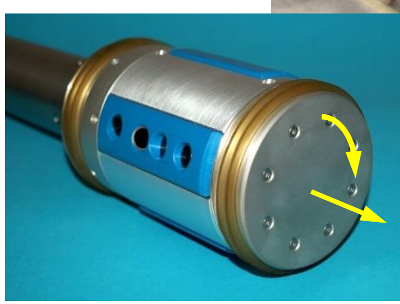


State-of-the-art for the Inspection of Axles in Service

Hollow Axle Testing

Manual testing

Mechanized testing



Mobile

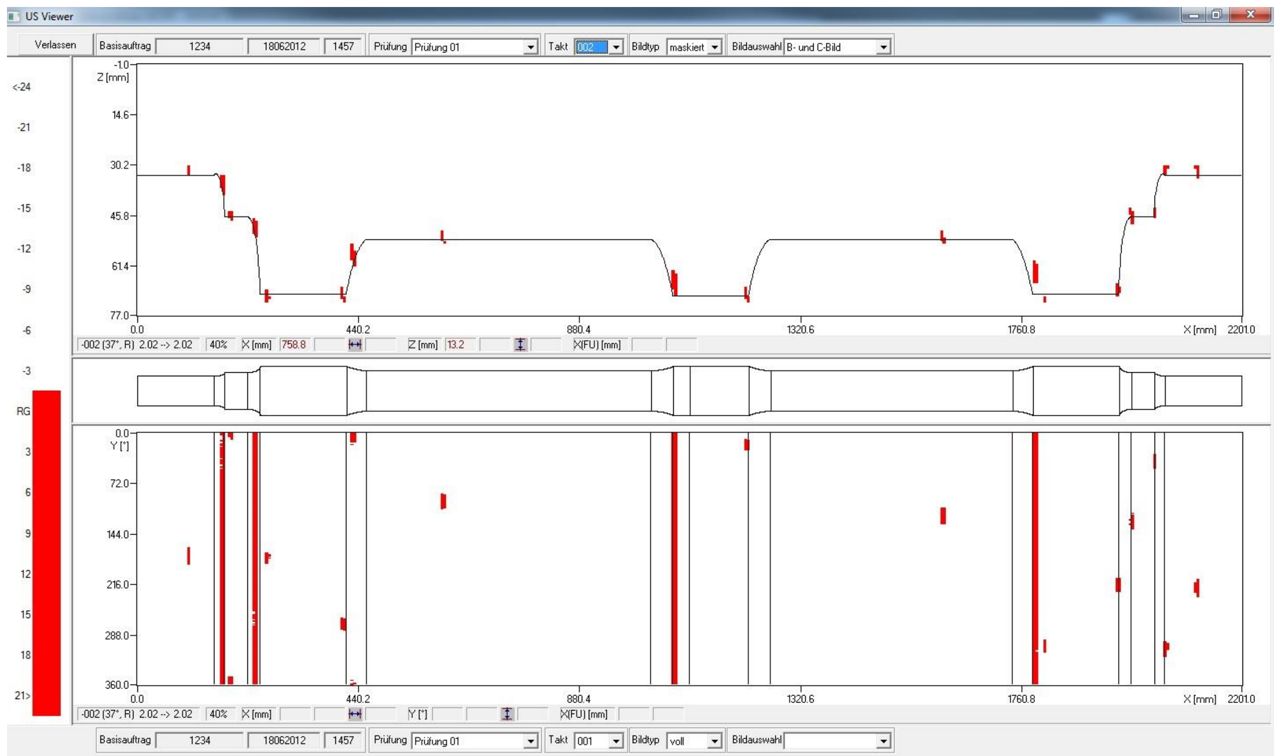
Stationary

State-of-the-art for the Inspection of Axles in Service

Hollow Axle Testing – Result of Automated Inspection

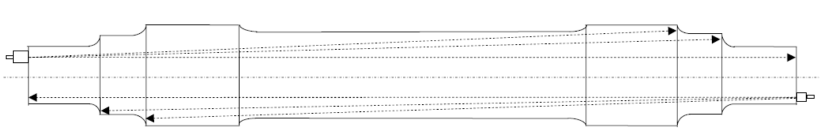
Longitudinal cross-section (B-Scan)

Development of axle geometry (C-Scan)

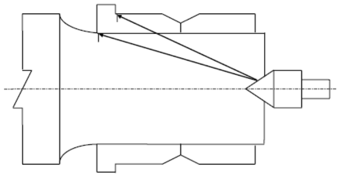


State-of-the-art for the Inspection of Axles in Service

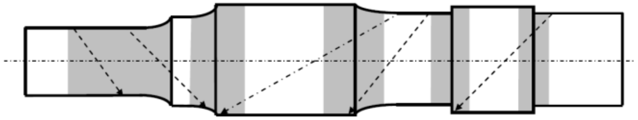
Solid Axle Testing – Scanning Techniques



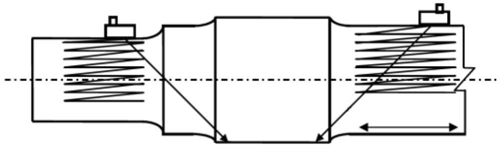
Axial scanning using normal beam probes



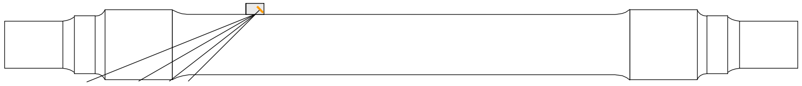
Detection of transversal cracks in axle journal and in the rear bearing inner ring



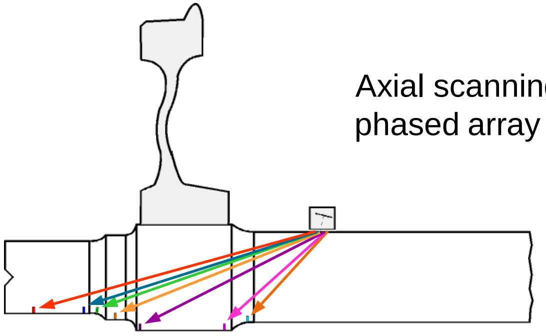
Axle inspection with various fixed angle beam probes



Scanning pattern for the inspection with conventional fixed angle beam probes



Axle inspection with various fixed angle beam probes at the same time without longitudinal scanning



Axial scanning using phased array probes

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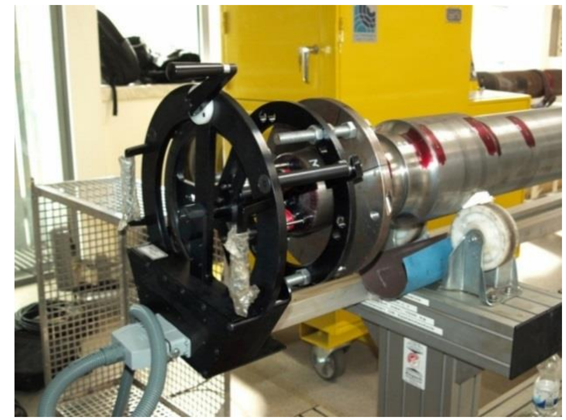
State-of-the-art for the Inspection of Axles in Service

Solid Axle Testing

Manual testing



Mechanized testing

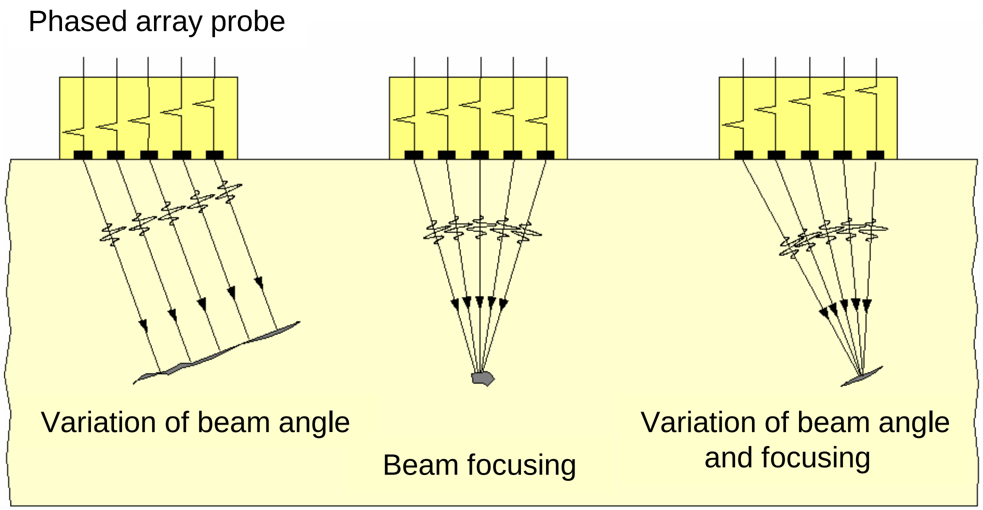
Fully automatic testing

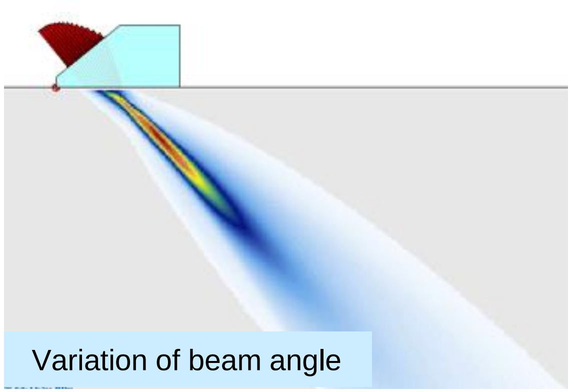
Conclusions from the EURAXLES Gap Analysis

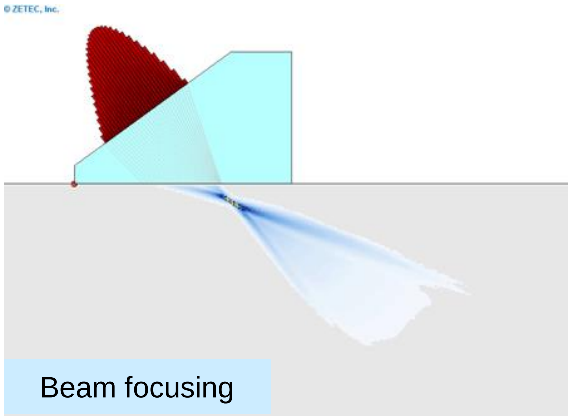
- Replacement of manual testing by automated testing to ensure reliability and repeatability, reduce human errors, improve throughput, allow for automatic documentation and data storage
- Improvement of sensitivity without increasing the false calls rate
- Differentiation between critical and non-critical surface imperfections
- Differentiation between geometrical echoes and defect echoes
- Improvement of the spatial resolution especially in the cross-sectional transition areas where the probability of crack initiation is high
- Defect characterization with respect to size, orientation and type in order to evaluate the consequences on the axle's remaining life time (NDE)
- Establishing methods for condition monitoring of axles as a basis for safety increase and condition-based maintenance

Identification of Possible Improvements

Phased Array Technology - Principle



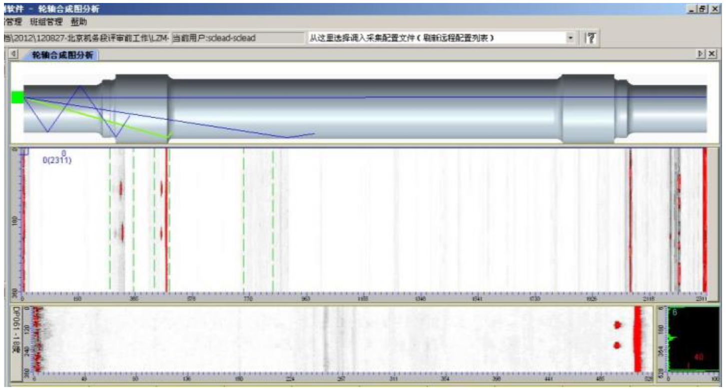




Identification of Possible Improvements

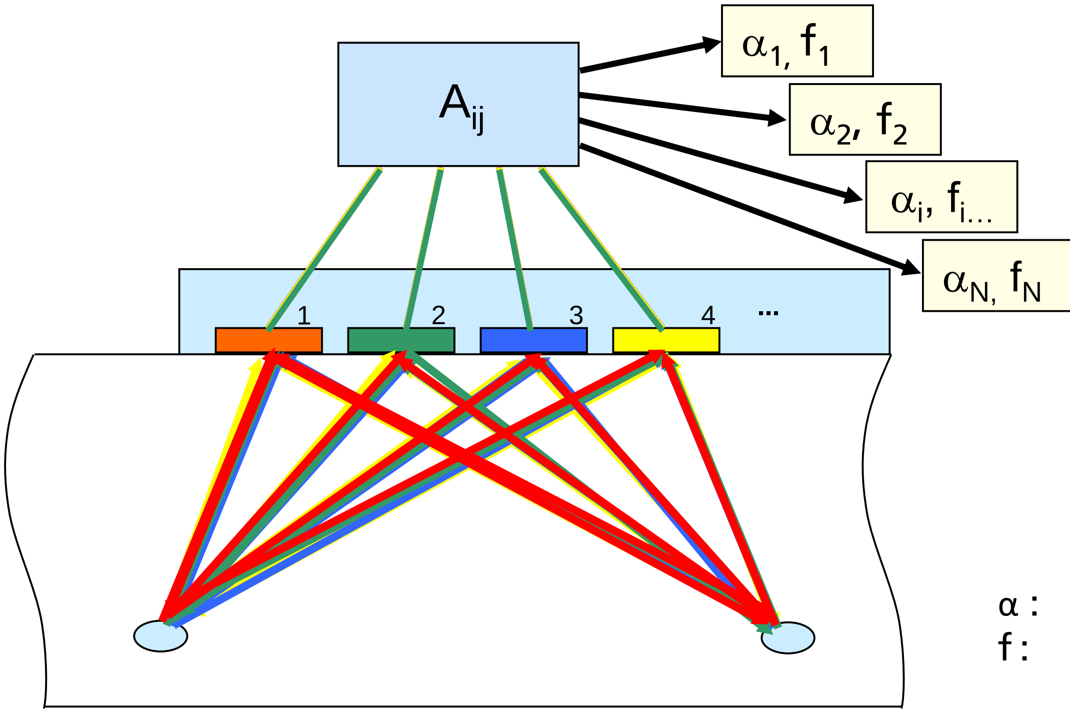
Phased Array Technology – End face Solid Axle Testing System

- Solid axle ultrasonic inspection from the axle's end face
- Fully-automatic mobile inspection system using phased arrays
- Application in light and heavy maintenance
- Suitable for all types of solid axles for rolling stock and metro vehicles
- 2 minutes inspection time excluding bearing cap disassembly



Identification of Possible Improvements

Phased Array Technology – Sampling Phased Array (SPA)

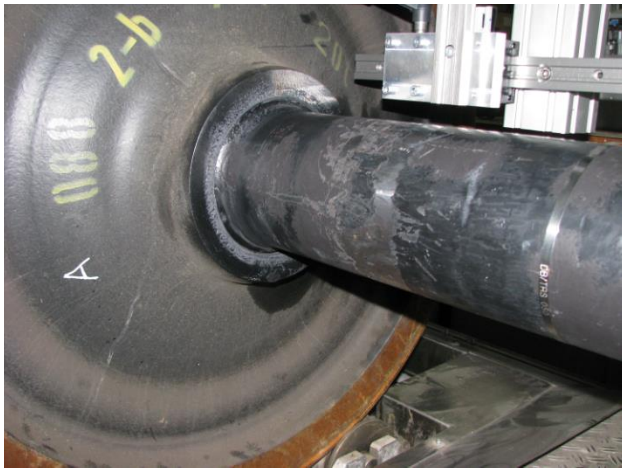


α : beam angle
f : focal depth

- Acquisition and processing of n x n HF-signals in the computer
- Any desired focal law can be calculated
- Application of noise elimination algorithms

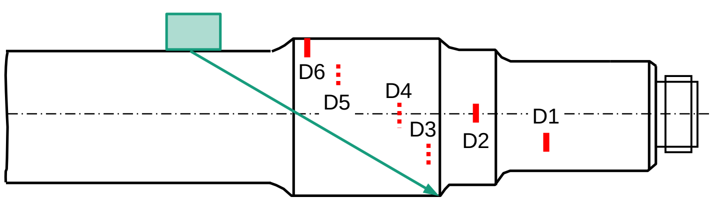
Identification of Possible Improvements

Phased Array Technology – SPA with Noise Elimination

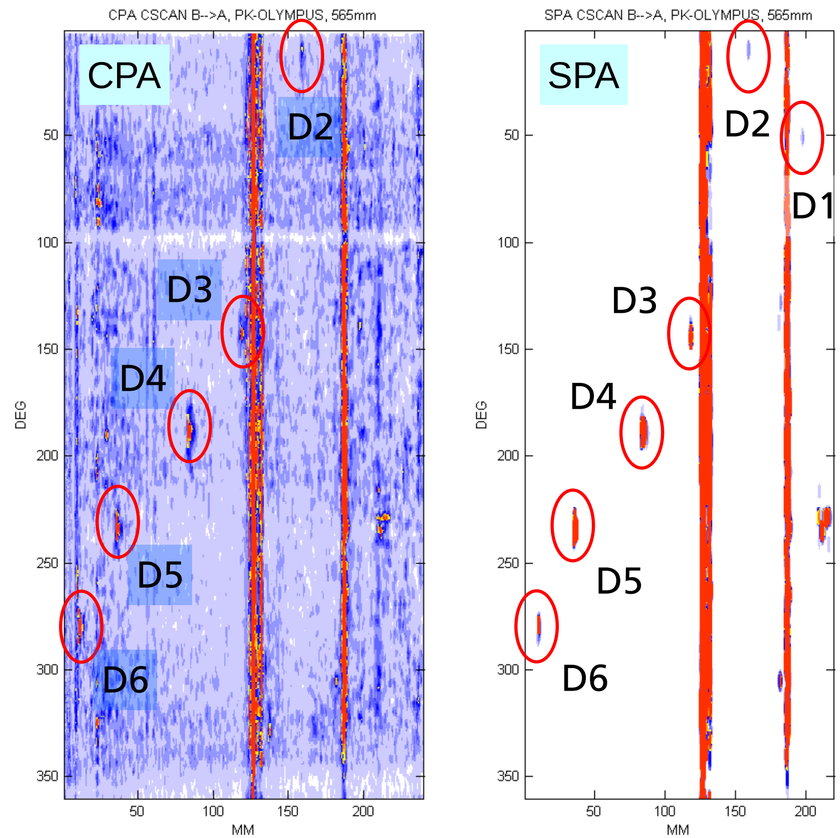


Coated axle

Phased Array probe



Defect locations



Inspection results

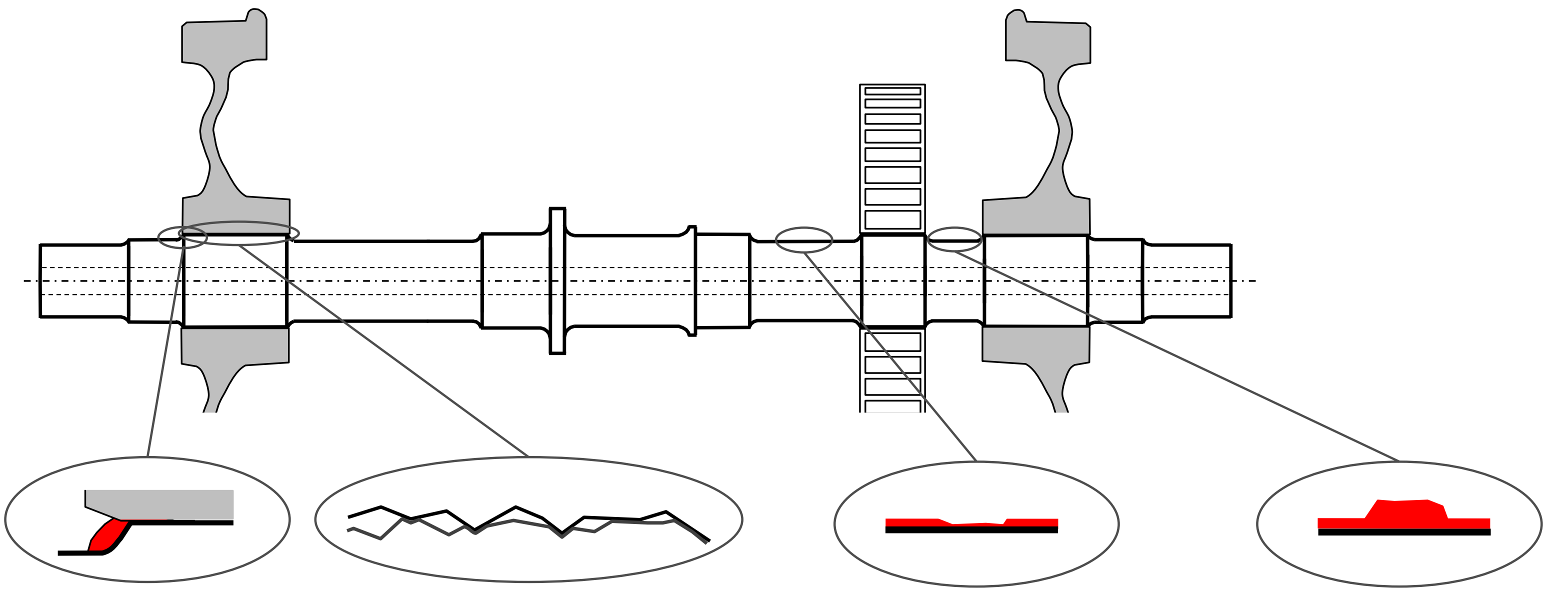
Identification of Possible Improvements

Phased Array Technology – SPA for the Inspection of Coated Axles

- Coating with RELEST® Protect Wheel by BASF
- Coating thickness ~ 2 mm
- No removal of coating for UT inspection
- Sensitivity should not be influenced by the coating
- High-angle scanning on the train with a mobile SPA-based system in combination with visual testing according to EVIC

Identification of Possible Improvements

Synthetic Aperture Focusing Technique – Motivation for implementation



Assembly paste, grease or dirt

Press fit

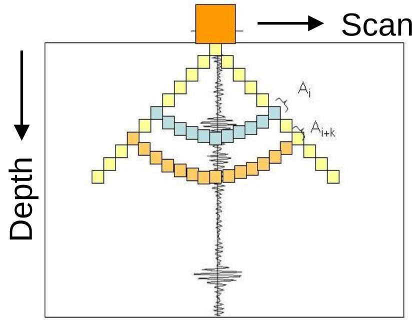
Flaking coating, ballast impact

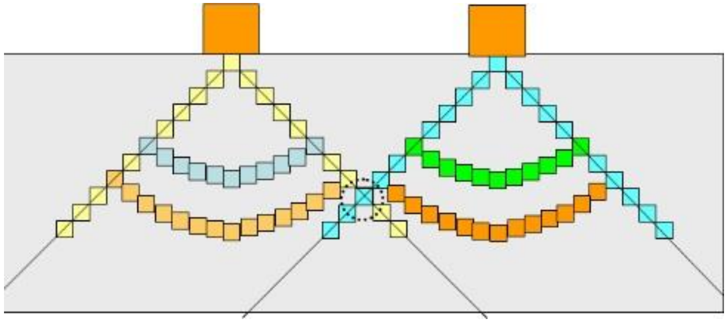
Paint spots

These possible influences for false indications stand out even more when testing sensitivity is increased !

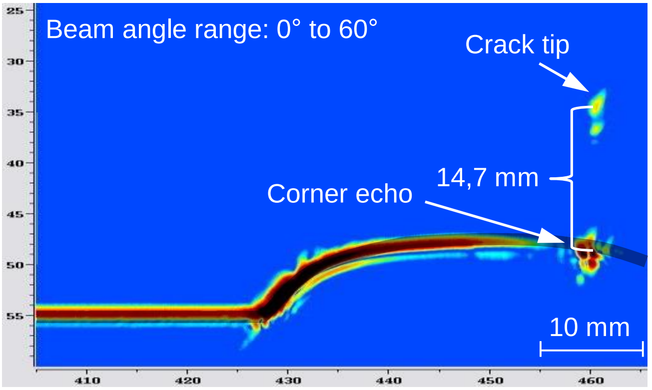
Identification of Possible Improvements

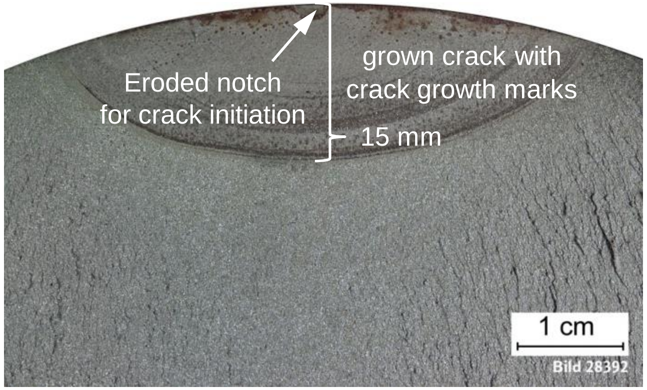
Synthetic Aperture Focusing Technique – Principle





SAFT reconstruction principle





SAFT B-scan of a fatigue crack and fracture area

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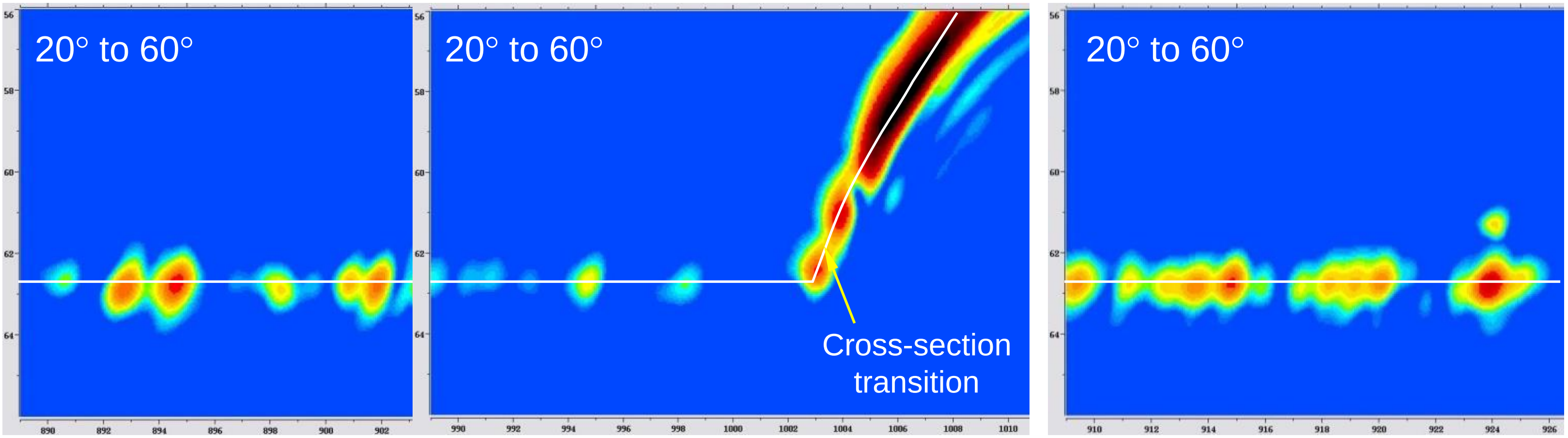
Identification of Possible Improvements

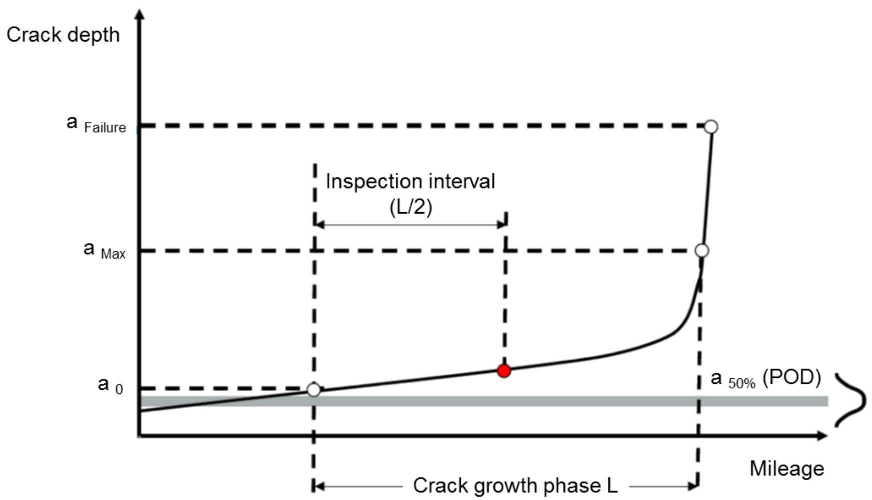
Synthetic Aperture Focusing Technique – Example



SAFT B-scan of false indications and of an artificial crack of 1,6 mm depth in the press-fit area

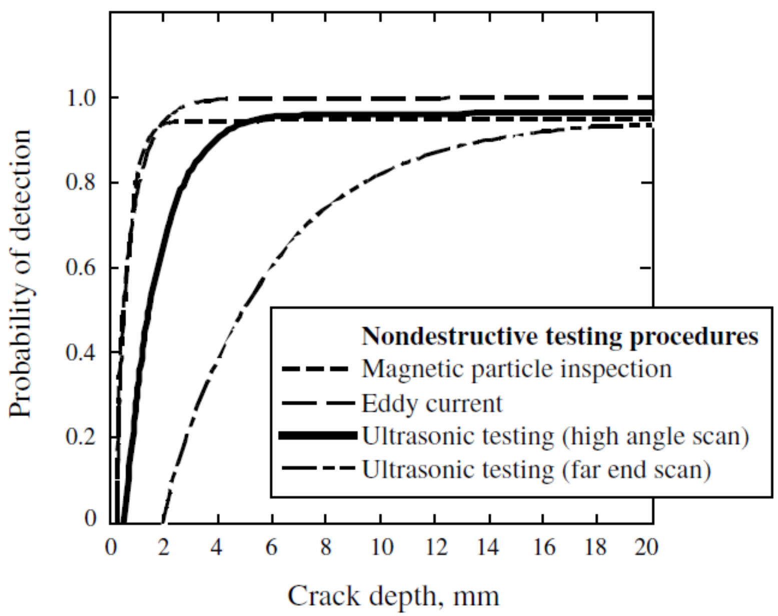
Identification of Possible Improvements

POD Simulation for Axle Testing – Replacing Experiments by Simulation



Definition of inspection intervals

POD for various testing procedure applied at solid axles

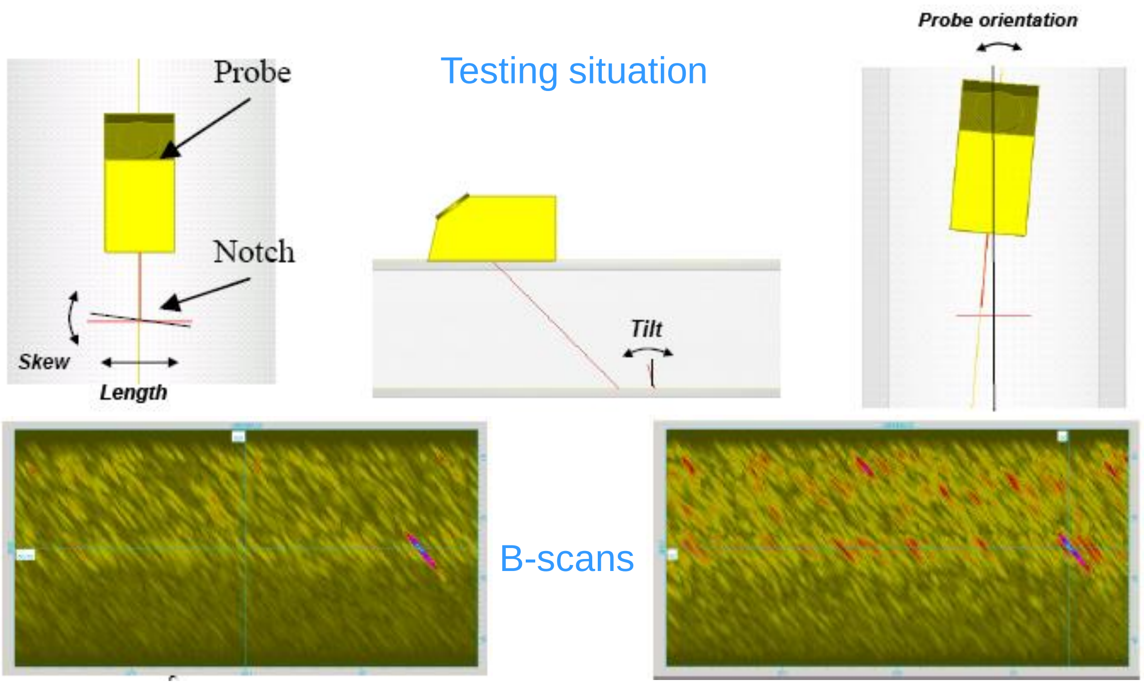


Identification of Possible Improvements

POD Simulation for Axle Testing – The CIVA POD Module

Replacing complex POD experiments by simulation

- Taking into account uncertainties which influence the US signal
- Deterministic or statistical description of the uncertainties

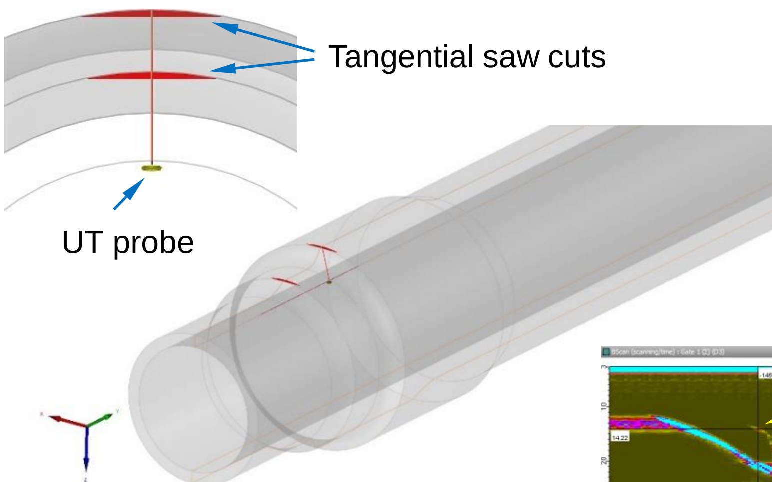


Uncertainties

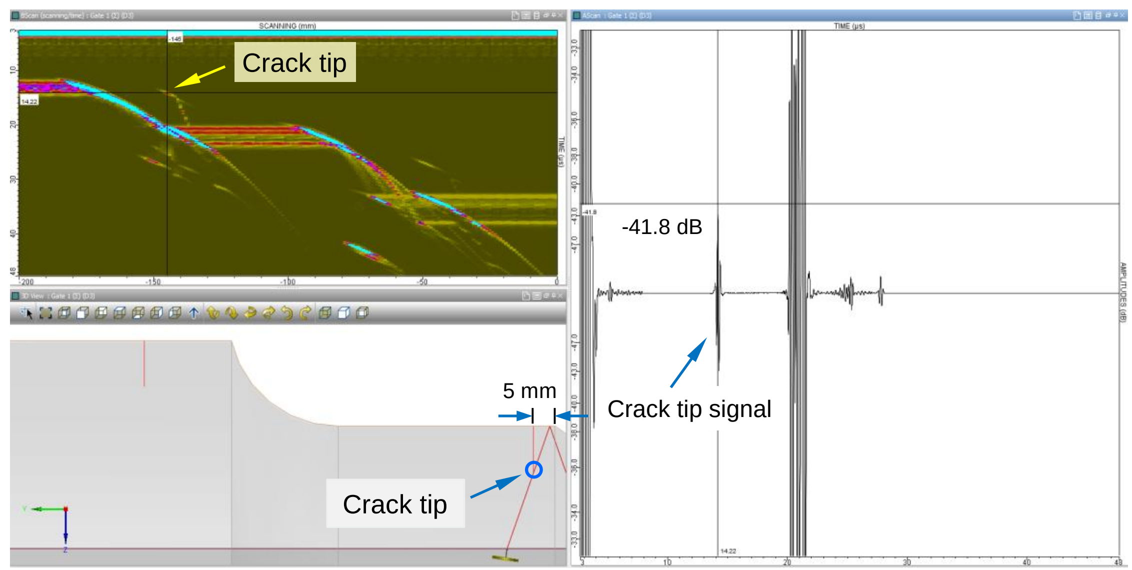
- Defect position
- Defect length
- Probe orientation
- Grain size in the material

Identification of Possible Improvements

POD Simulation for Axle Testing – CIVA Simulation for UT of Hollow Axles



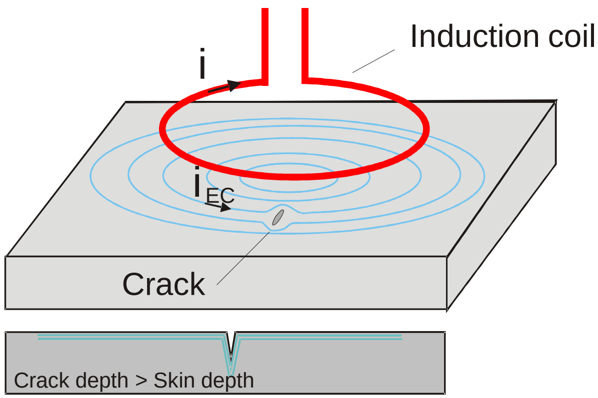
- POD calculations are based on simulation results
- The user defines the uncertain input parameters and their variation ranges



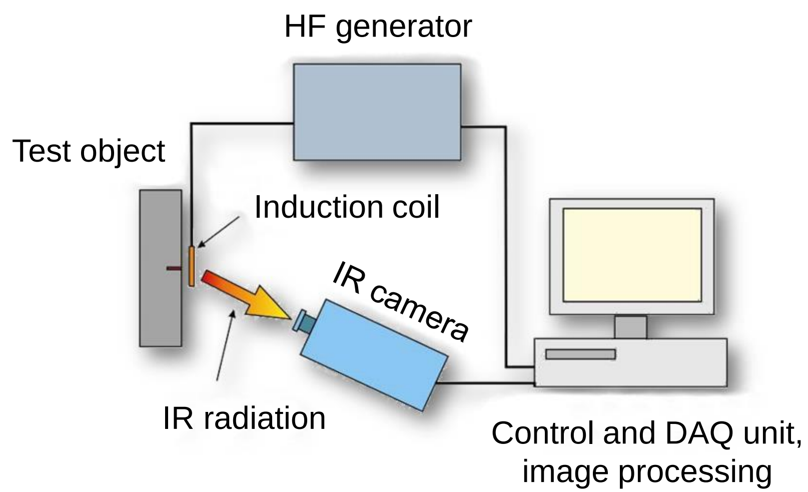
CIVA simulation of C-scan and A-scan

Identification of Possible Improvements

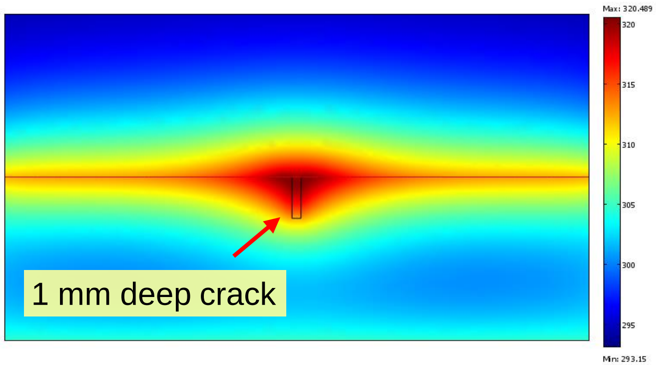
Induction Thermography for Surface Crack Detection



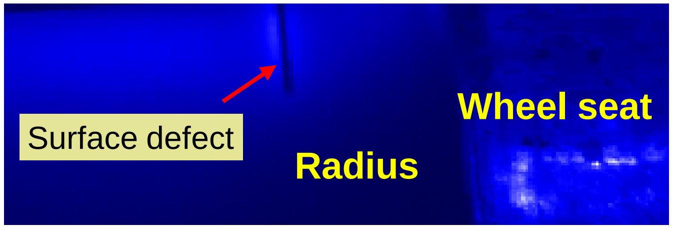
Principle of heat induction



Instrumentation for induction thermography



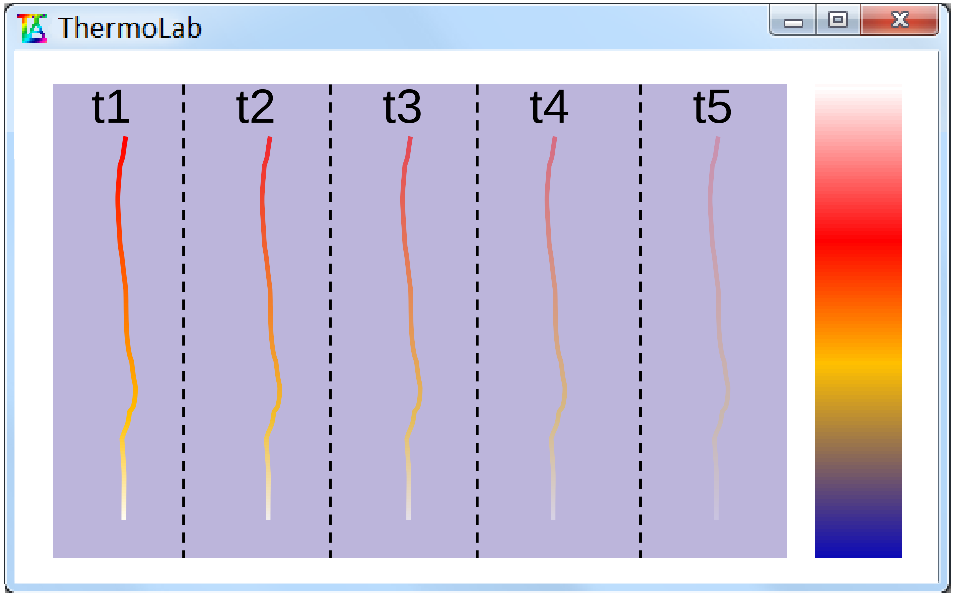
Temperature distribution near a crack



Thermography image of a solid axle

Identification of Possible Improvements

Induction Thermography for Surface Crack Detection



Result of data acquisition:

Crack image at several moments during or after heating

➡ Image reconstruction by transformation from time domain to spatial domain

Identification of Possible Improvements

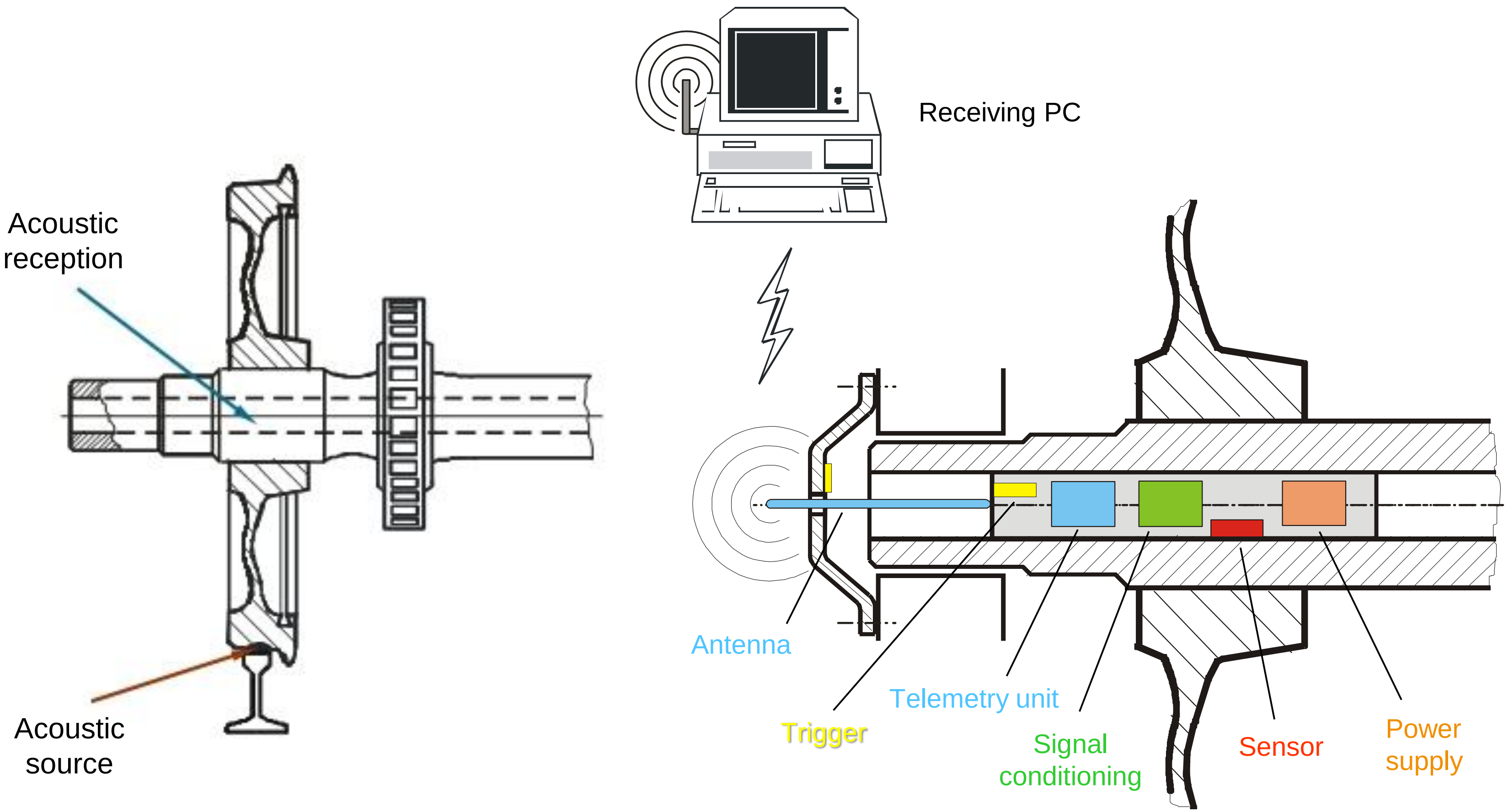
Condition Monitoring – Motivation for its Implementation

- Calculation of the failure probability of an axle cannot consider real loads which act on the axle during its operational life
- Consideration of specific dynamic loads dependent on axle application, railway line characteristics, environmental conditions is only partly possible
- Non-predictable events like impacts from ballast, corrosion, obstacles on the rail, etc. cannot be considered in the life-time calculation models

Condition Monitoring can be an important tool for condition-based maintenance and increase of safety!

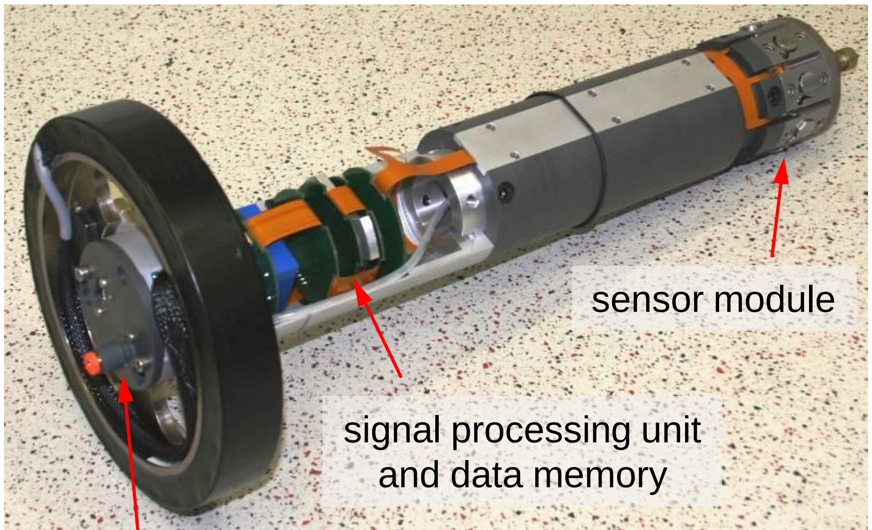
Identification of Possible Improvements

Condition Monitoring – Principle of a Wheel Set Monitoring System



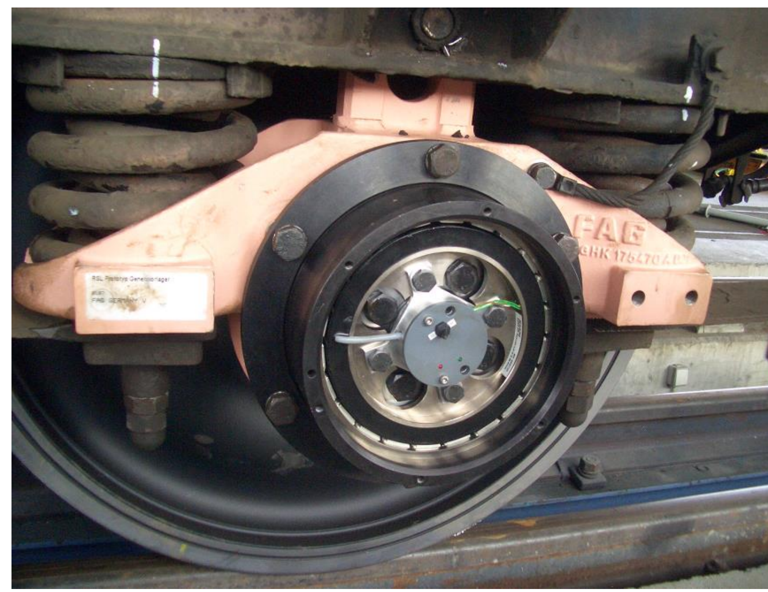
Condition Monitoring of Wheel Sets

Monitoring system in test vehicle



TX/RX radio interface

Hollow axle sensor system

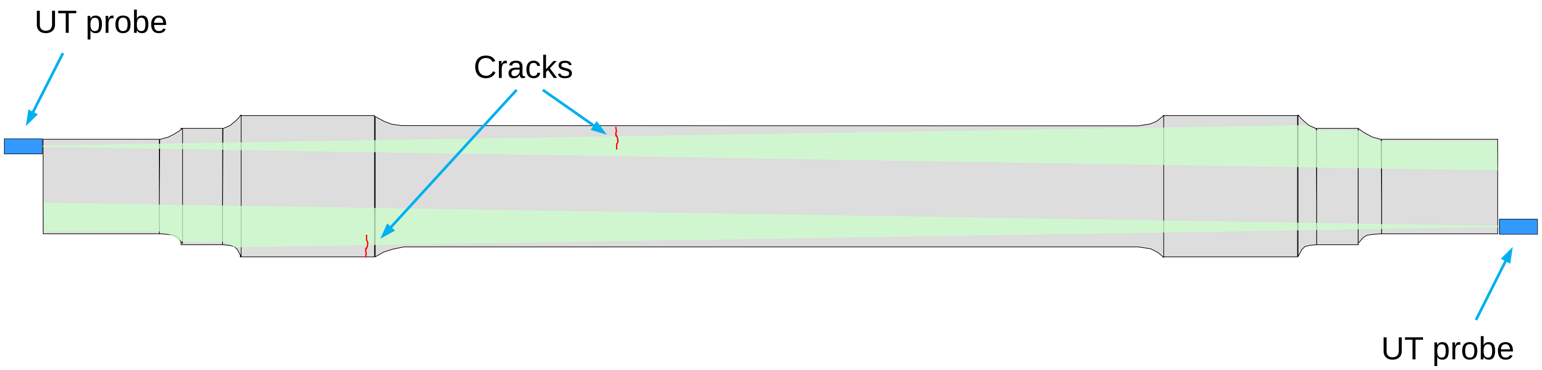


Sensor system inside the hollow shaft with removed bearing cap

Identification of Possible Improvements

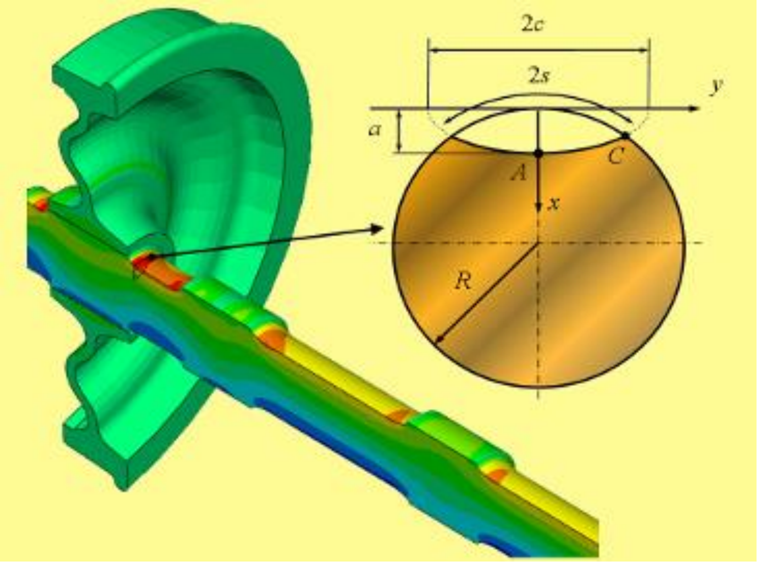
Condition Monitoring – Detection of Transversal Cracks

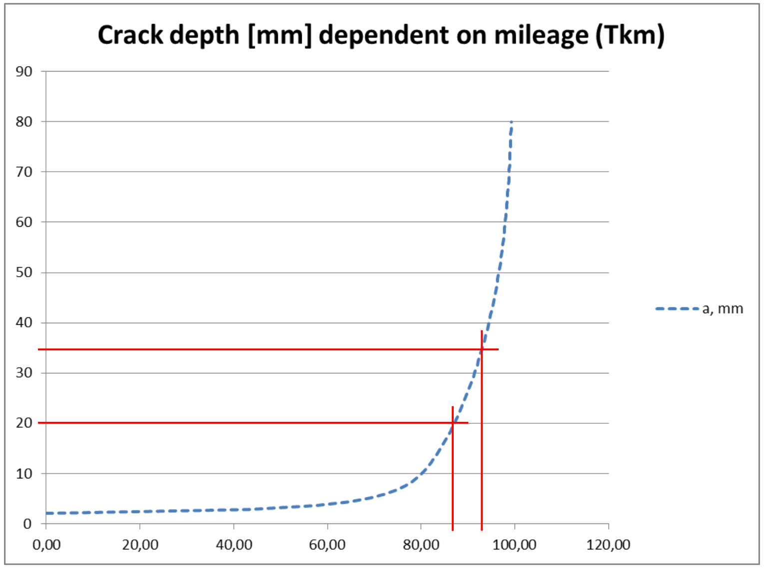
- Detection sensitivity for periodic inspection ~ 2 mm deep crack
- Requirements regarding detection sensitivity for a condition monitoring system?



Identification of Possible Improvements

Condition Monitoring – Crack Growth Rate





Crack location in the diameter transition area and crack propagation curve

Crack growth from 20 to 35 mm within ~ 6,000 km