Increasing the Sensitivity of Ultrasonic Phased Array Wheel Set Axle Inspection by Using Signal Processing

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Abstract

The geometry and the surface condition of the shaft influence the signal to noise ratio of ultrasonic inspection of wheel set axles significantly. Signal processing algorithms may be applied on the recorded data of in-service inspections to decrease sensitivity to geometry changes by minimizing echos generated by indications of the seats.

Using signal processing methods also enable the reduction of the influence of the individual condition of the wheel set on the sensitivity of the inspection.

The main challenges to overcome by signal processing are on the one hand difficult coupling conditions of the probes attached to the outer surface of the axle due to the complex geometries of the shaft. On the other hand coupling quality can be decreased by a mixture of dust, mud and grease on the shafts.

Therefore signal processing algorithms applied have to be stable against deviations in geometry and as well have to compensate variations in signal amplitude caused by altering coupling conditions.

Different off-line algorithms have been developed and tested against each other on a given number of measured data sets by BAM and BTD at laboratory scale.

Solutions for use in the field will be presented.

BAM
Bundesanstalt für Materialforschung und -prüfung

Sicherheit in Technik und Chemie

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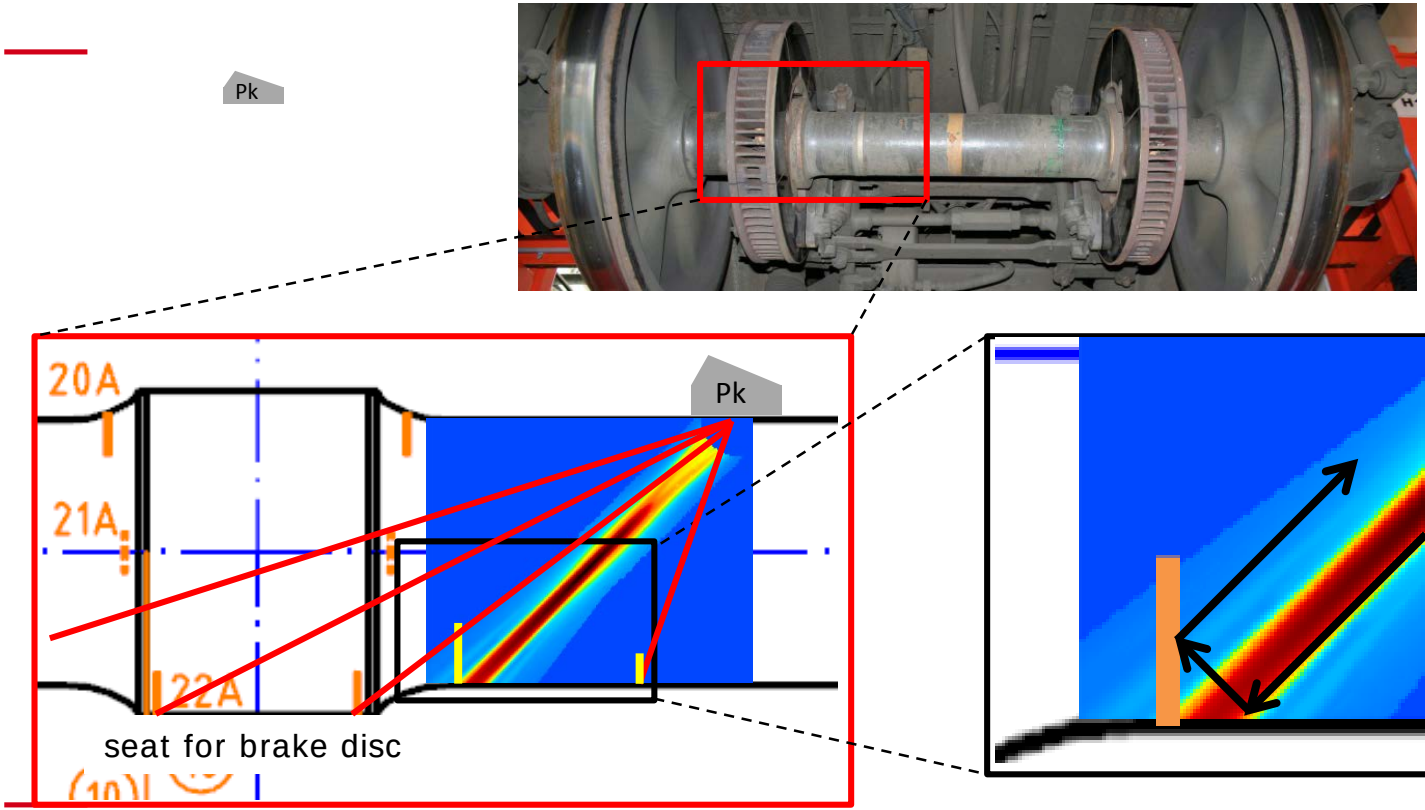
ESIS TC24 Wittenberge 2017, Talk 1.4

In-Service Inspection of Wheelsets

Boogie SBB EC Waggon

SBB Cargo Wheelset

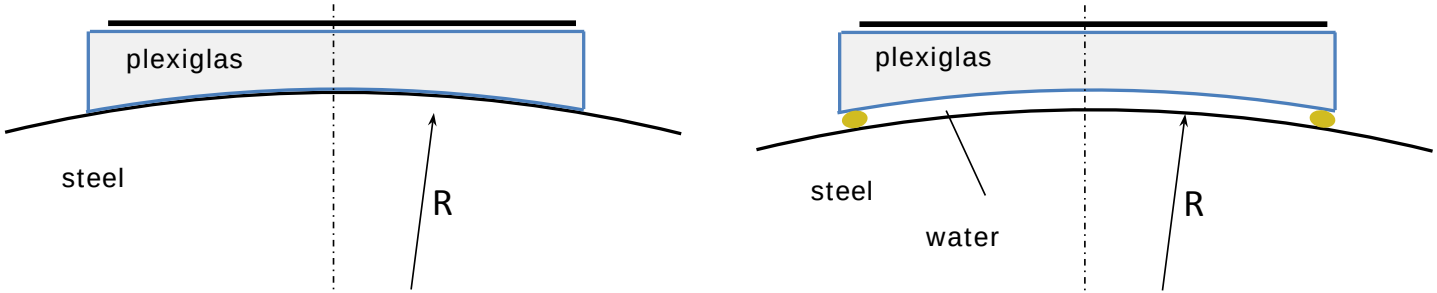
In-Service Inspection Using Angle Beam Probes



Optimization of probe design

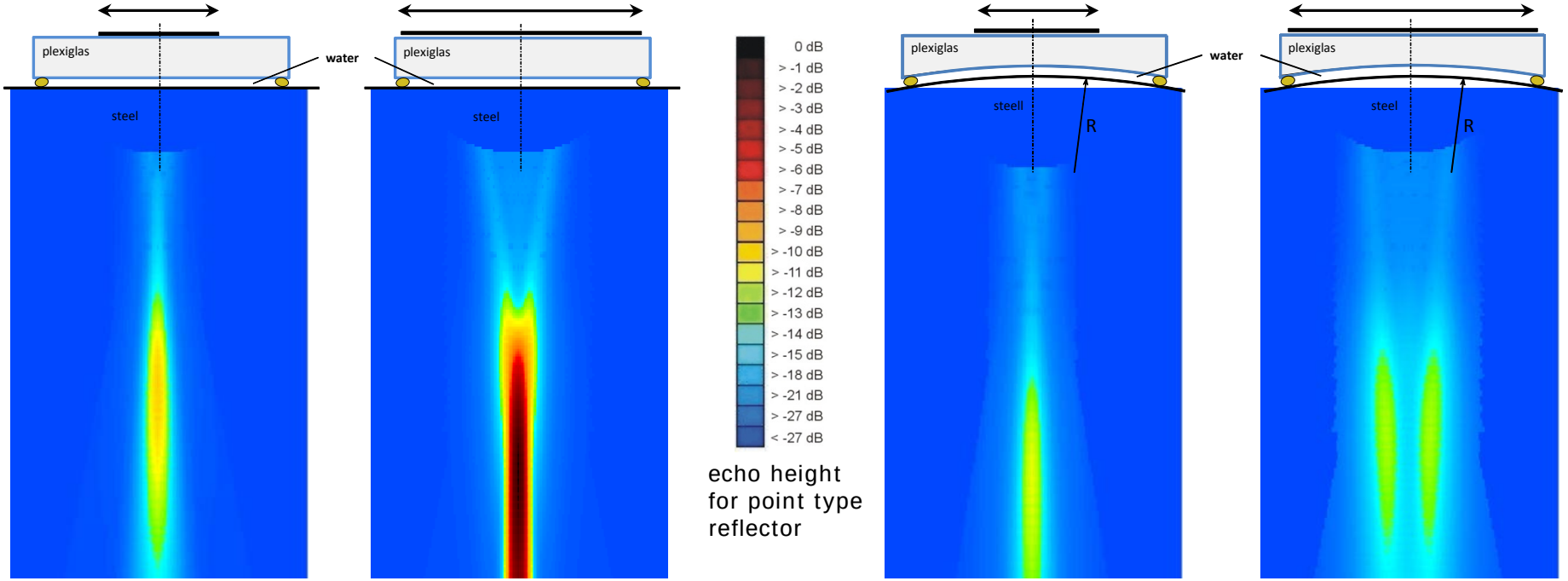
- Change coupling conditions to local immersion testing
- sensor size increased to gain sensititvity
- use of an acoustical lens to optimize soundfield
- angular scan area extended

Change Coupling Conditions to Local Immersion Testing Technique



local „immersion technique“

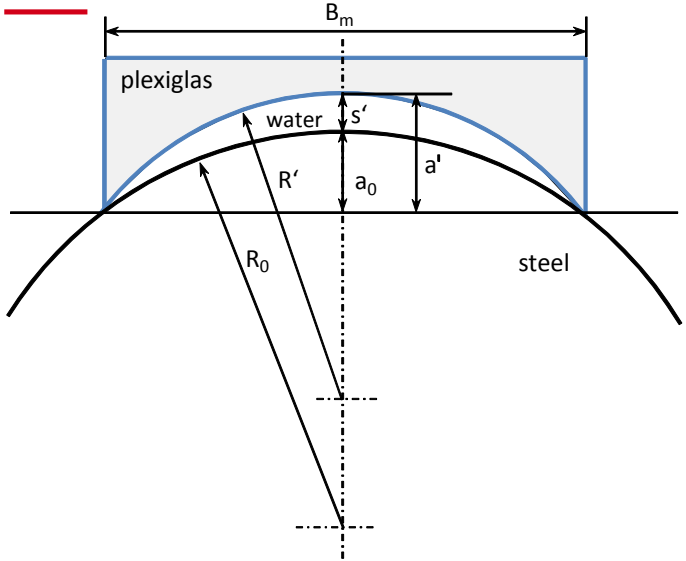
Increase of Sensor Size to Gain Sensititvity

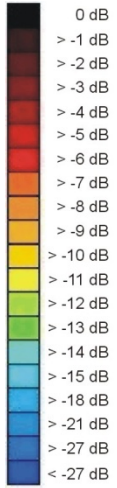


echo height for point type reflector

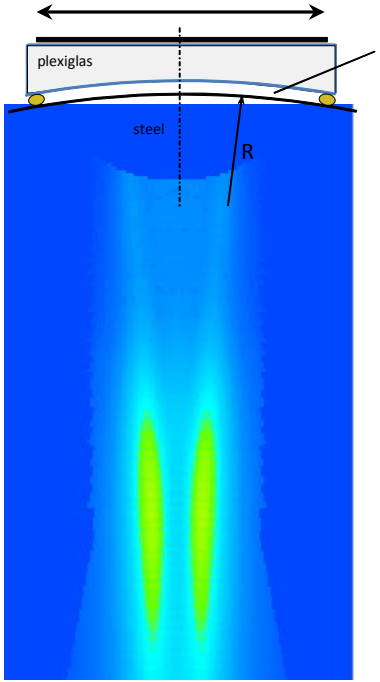
The increase of the sensor area leads to defocussing of the sound beam on curved surfaces.

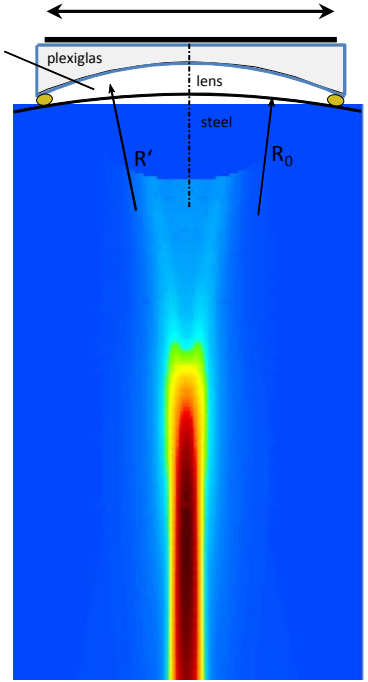
Use of an Acoustical Lens to Optimize Soundfield





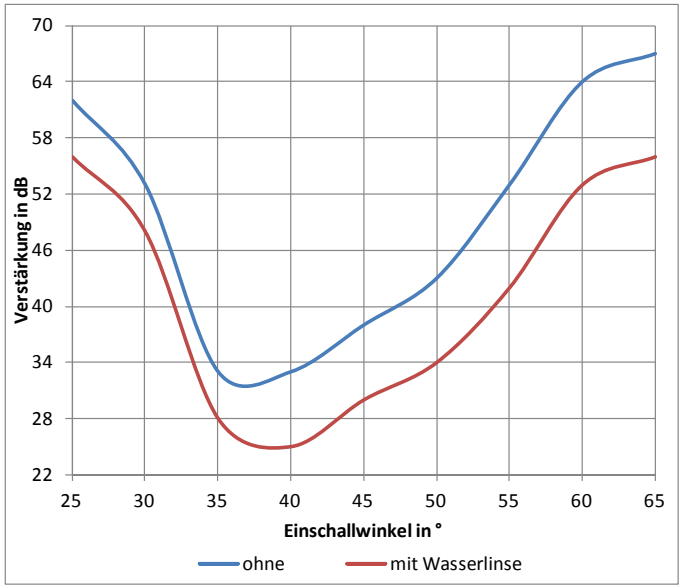
echo height for point type reflector



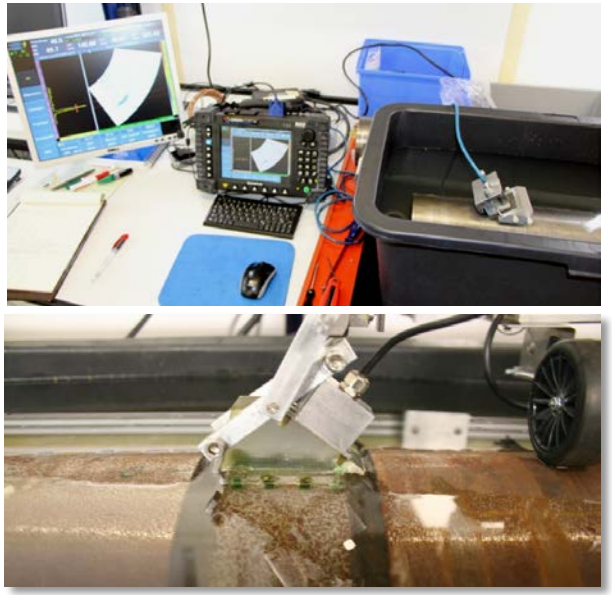


compensation of defocussing by use of acoustical lens

Acoustical Lens – Performance Test

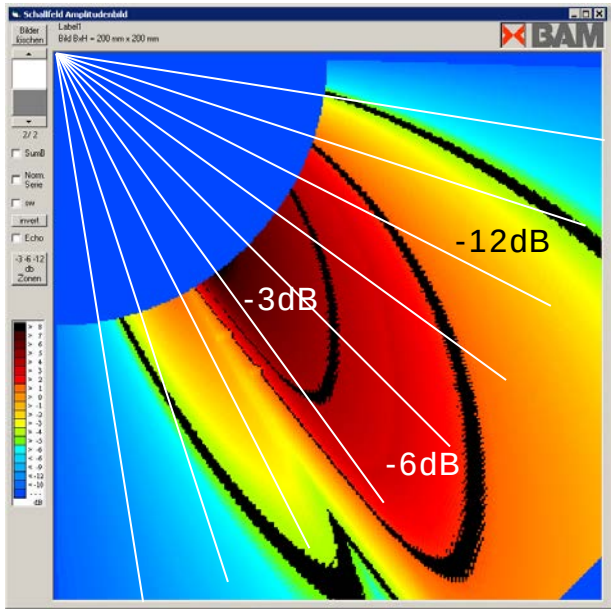


Gain of sensitivity by acoustical lens
on a 2 mm saw cut is +6 dB to +12 dB

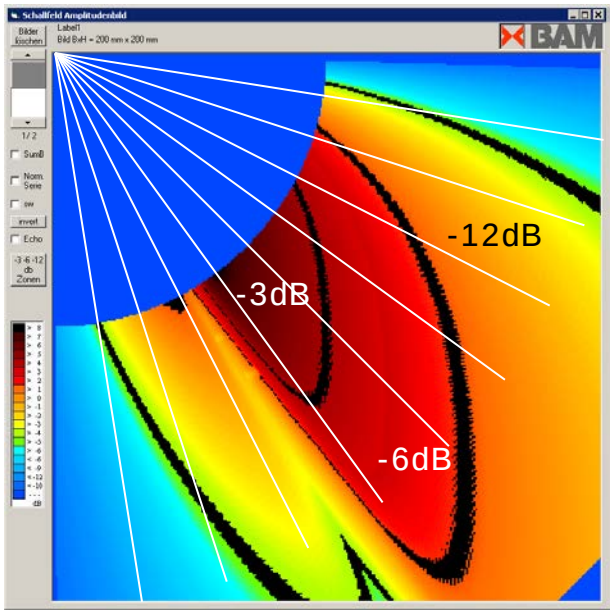


Probe in immersion setup
with a waterpath of 2 mm

Extend of Angular Scanning Area



16 elements, width of element 1.4 mm



32 elements, width of element 0.9 mm

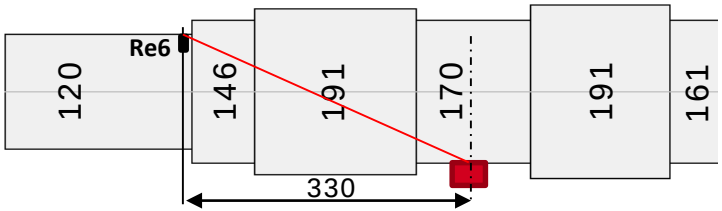
Signal Processing

Optimization of scans/images for evaluation

- suppression of echos induced by geometry
- suppression of noise
- separation of spurious signals

Signal Processing
Suppression of Echos Induced by Geometry (1)

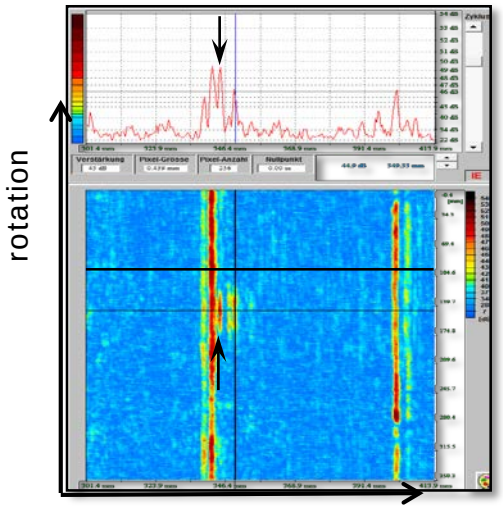
Probe: 3 MHz, 16 elements
α_0 = 45°, α = 10° - 70°



A - Scan

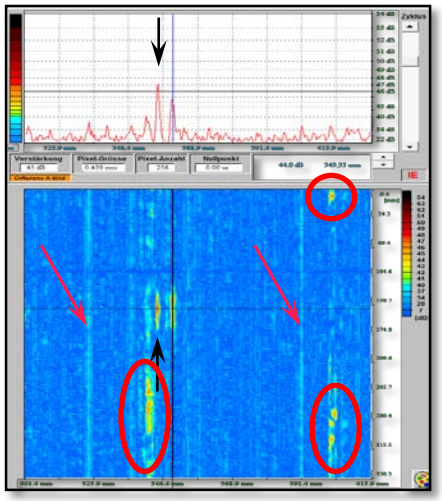
Reflektor 6

TD - Scan



TD-Bild original soundpath

Selected A-scan used for reference



Subtracted TD-Scan

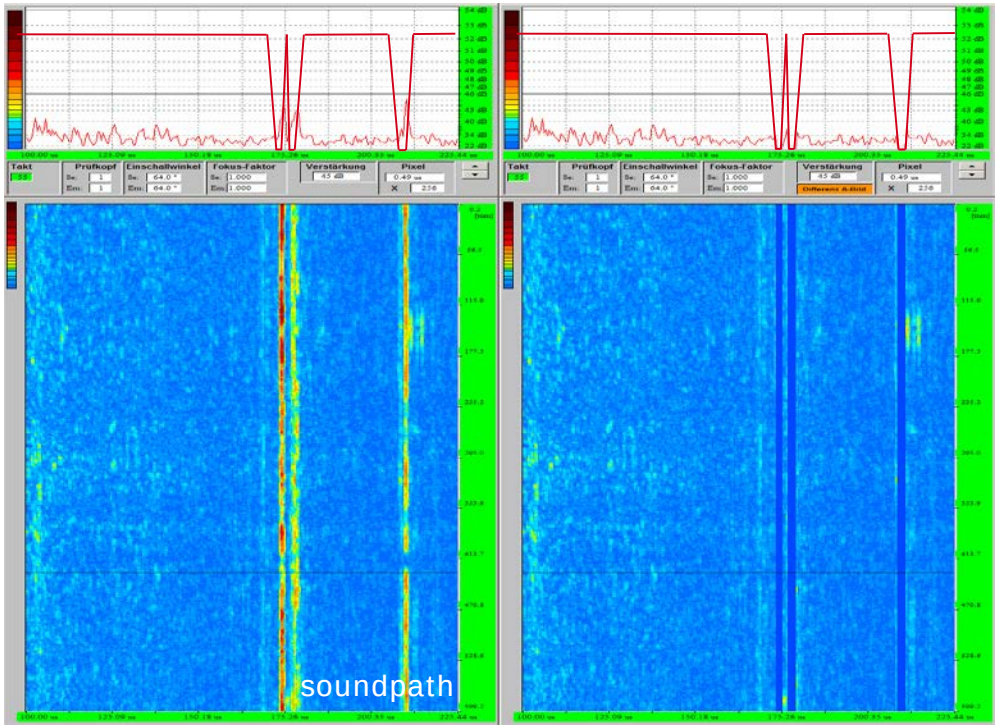
Signal Processing
Suppression of Echos Induced by Geometry (2)

A - scan

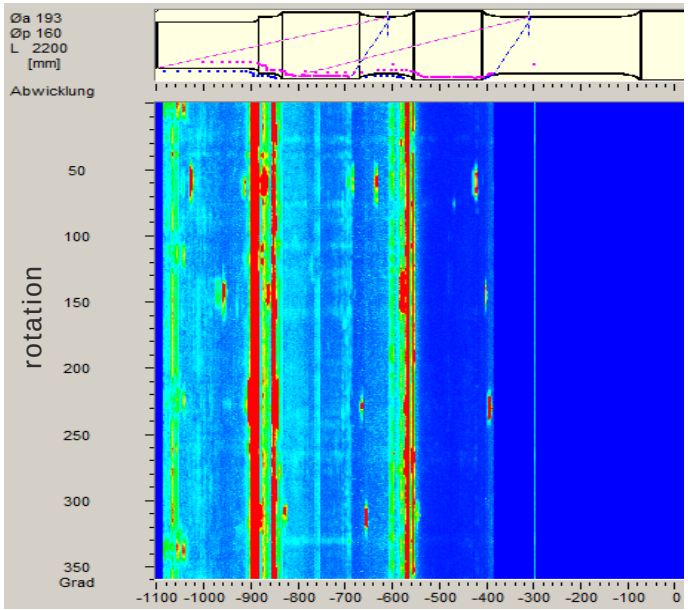
Identification of circumferential indications by means of statistic methods and image processing

Calculation of TGC curves to reduce circumferential indications

TD - scan



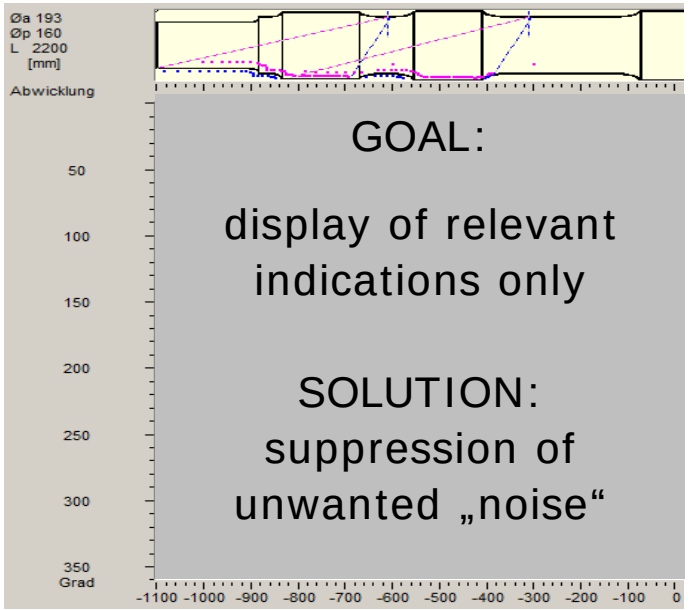
Signal Processing
The New Approach



position on axis

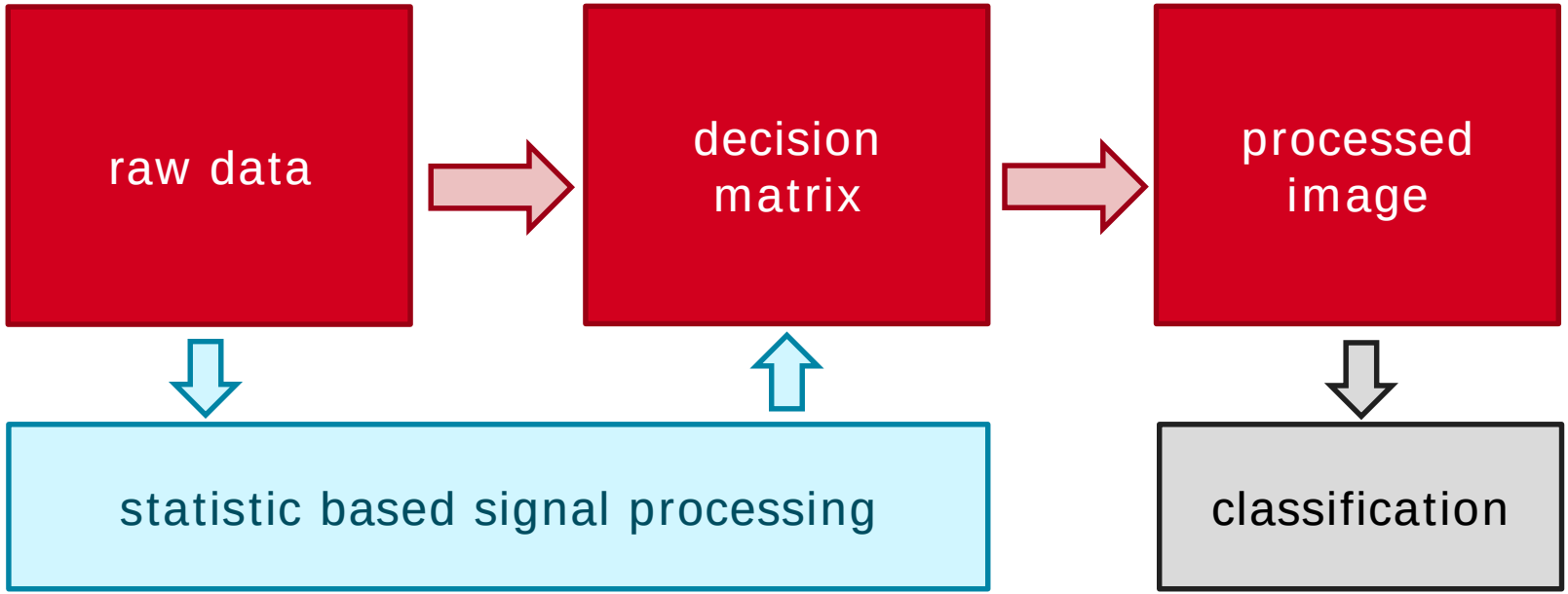
Filtering without

modification of echo height

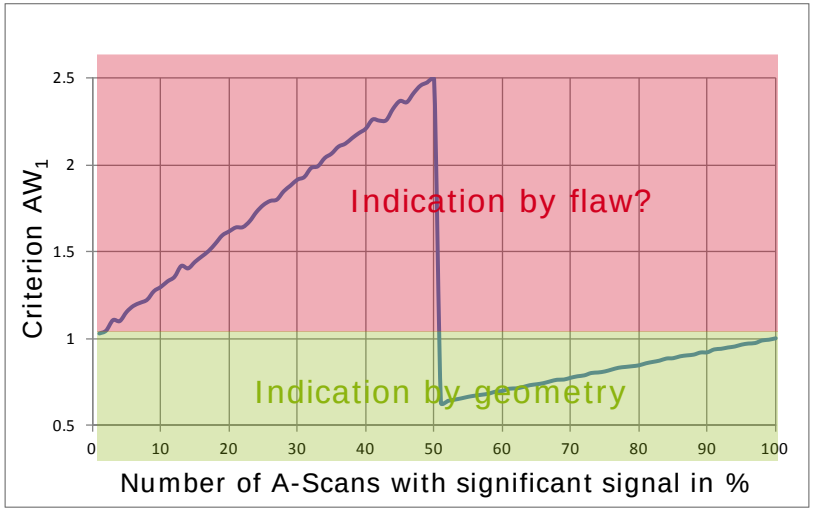


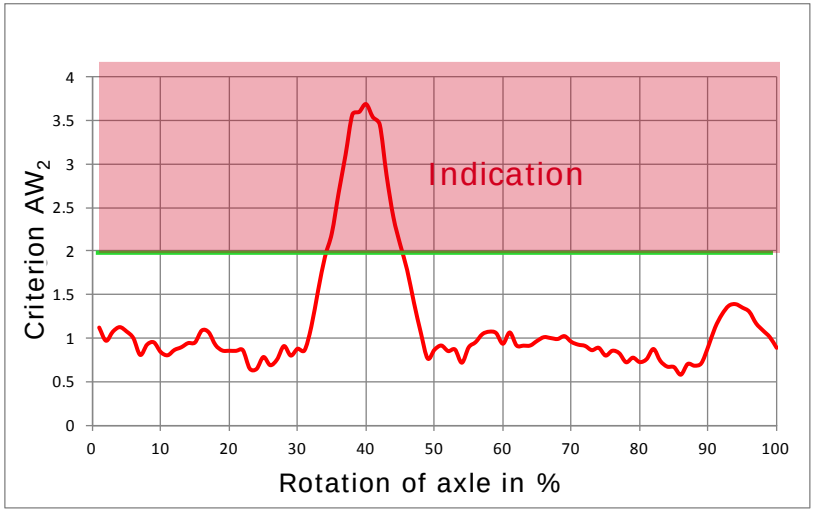
Axle with arteficial flaws, software by BTD, overlay of TD-scans for angles 28° - 72°

Signal Processing
No Modification in Amplitude is Allowed



Signal Processing
Statistical Evaluation of Raw Data Set





Criterion AW_1: $AW_1 < 1$

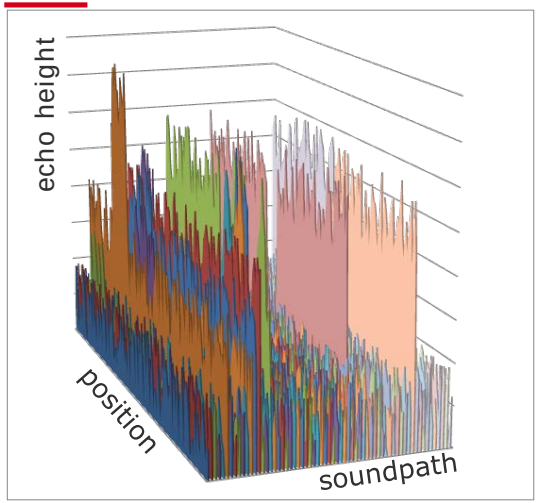
Recognition of geometry caused circumferential indications

Criterion AW_2: $AW_2 > SNR_{min}$

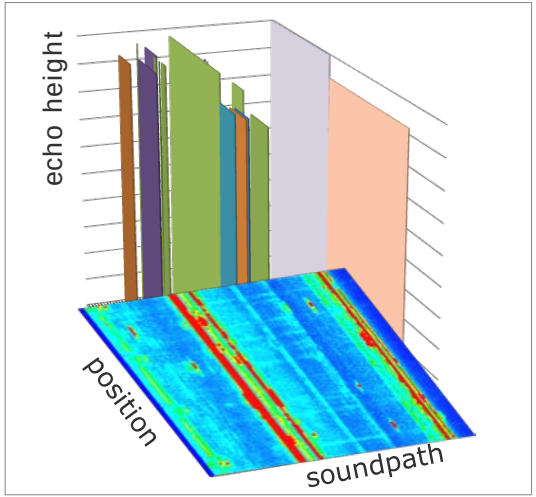
Recognition of indication caused by flaws

Distinguish between noise, flaws and spourious signals on form and amplitude

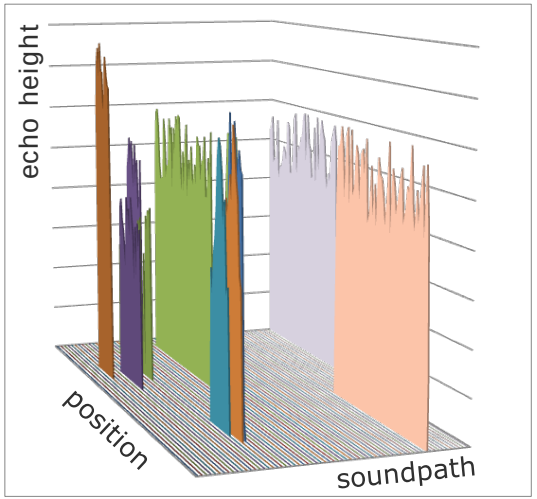
Signal Processing
Statistic Evaluation on Test Data Set



raw data set



decision matrix

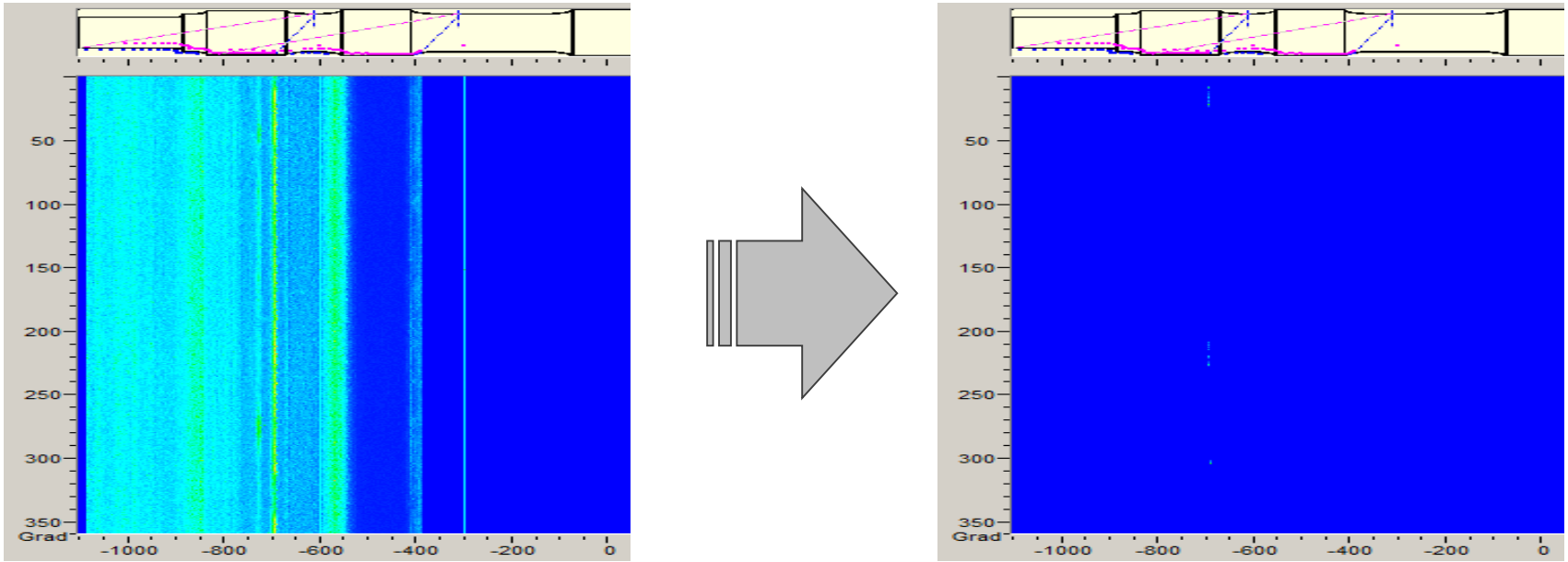


processed data set

Based on the raw data set the algorithm computes a decision matrix.

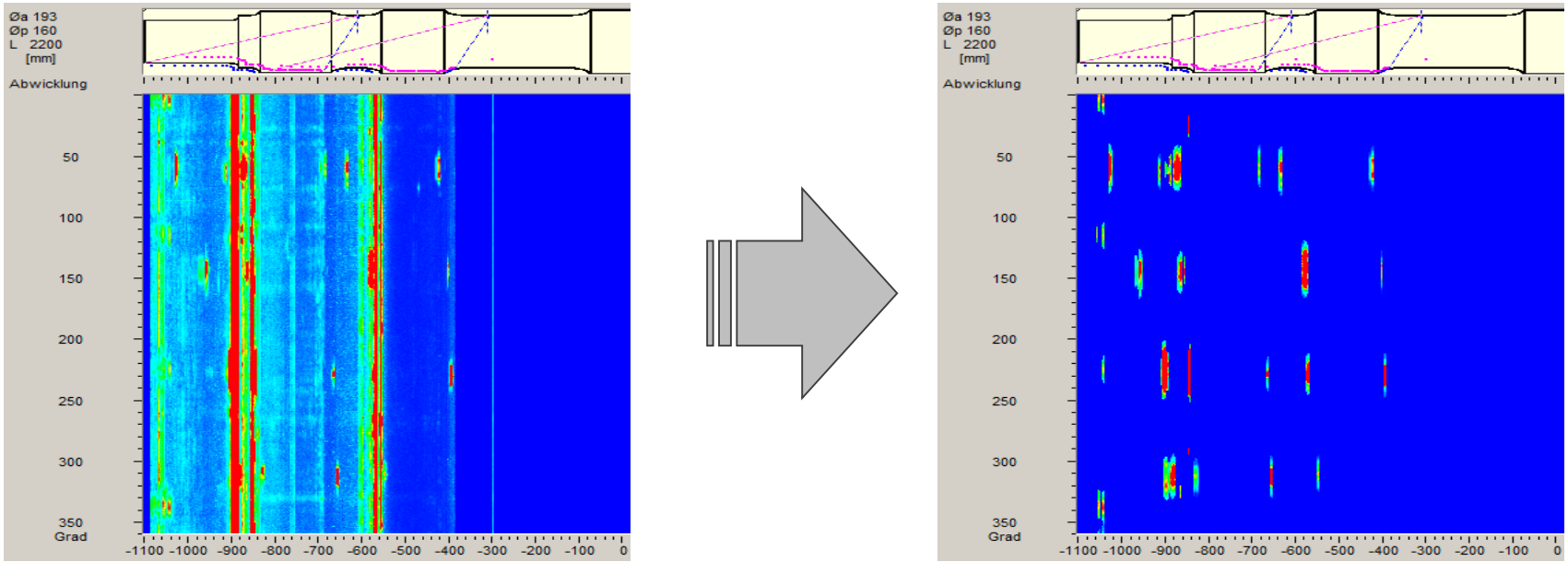
Where relevant information has been detected, the information from the raw data is copied to the processed data set.

Signal Processing on Test Wheel Set
Significant Decrease of Noise



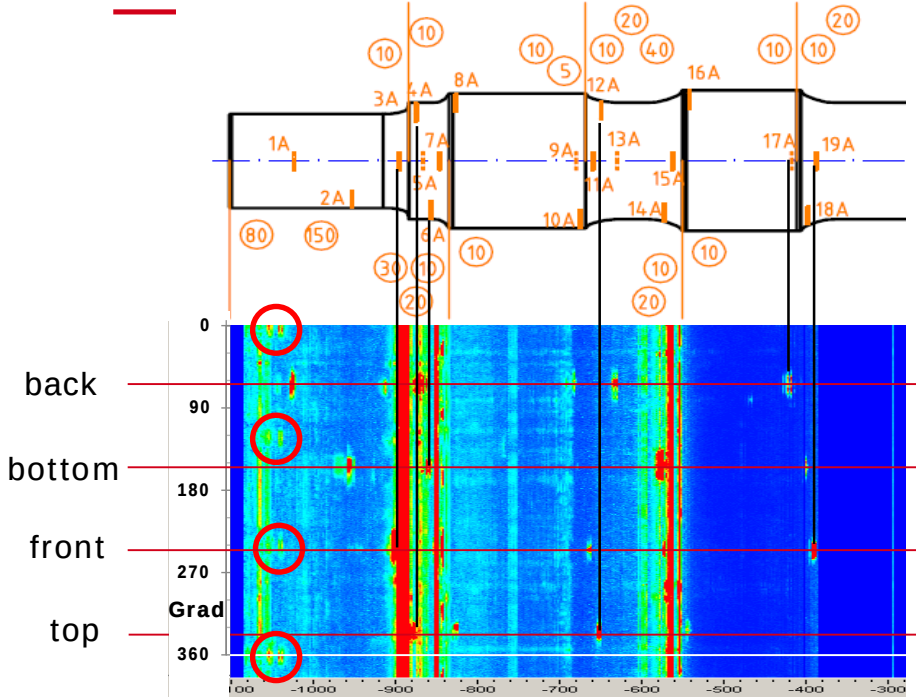
Axle without arteficial flaws, overlay of TD-scans for angles 28° - 72°

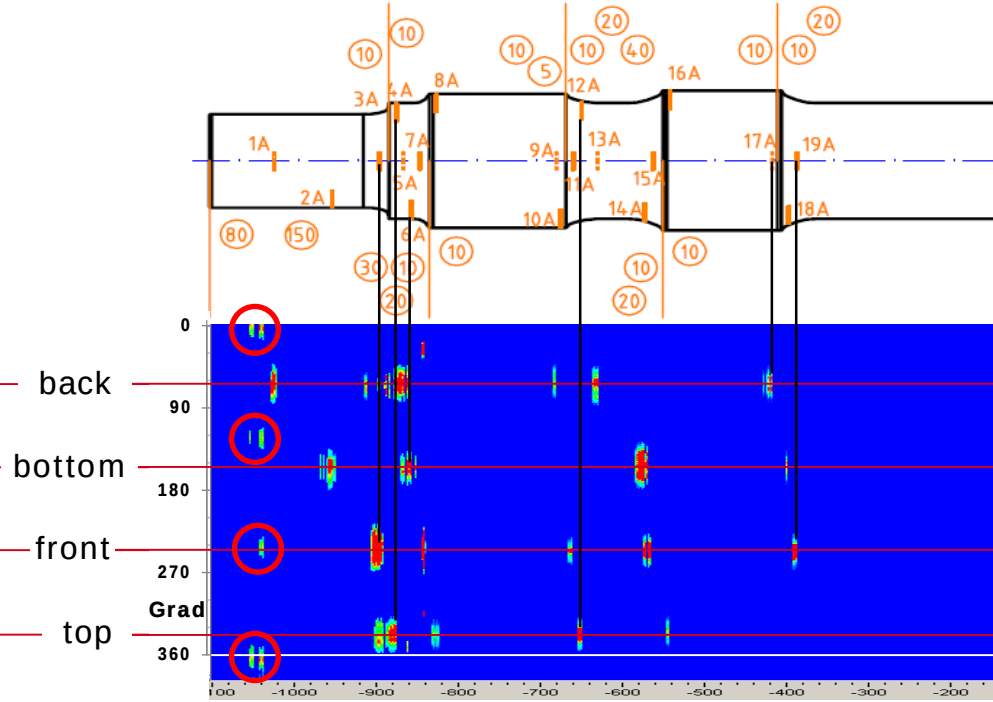
Signal Processing on Test Wheel Set



Axle with arteficial flaws, overlay of TD-scans for angles 28° - 72°

Examination Result on Axle with Arteficial Flaws





Conclusion - Improvements

BAM

Fachbereich 8.4

- Local immersion technique
- Increase of sensitivity by use of lager transducer
- Optimization of sound field by use of a lens
- Increase in scan area by use of smaller elemtens
- Identification and suppression of geometry caused indications
- Suppression of noise
- Suppression of spourios signals

Conclusion – What is left to do?

BAM

Fachbereich 8.4

- Test algorithms in the field
- collect data sets from different types of axles
- Make thresholds adaptive to signal quality

Gefördert vom

Bundesministerium
für Wirtschaft
und Energie

im Rahmen eines
MNPQ – Projekts
Messen, **N**ormen, **P**rüfen,
Qualitätssicherung