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.
INCREASING THE SENSITIVITY OF ULTRASONIC PHASED ARRAY WHEEL SET AXLE INSPECTION BY USING SIGNAL PROCESSING

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In-Service Inspection of Wheelsets

Boogie SBB EC Waggon

SBB Cargo Wheelset
In-Service Inspection Using Angle Beam Probes
- Change coupling conditions to local immersion testing
- Sensor size increased to gain sensitivity
- Use of an acoustical lens to optimize soundfield
- Angular scan area extended
Change Coupling Conditions to Local Immersion Testing Technique

local „immersion technique“
The increase of the sensor area leads to defocussing of the sound beam on curved surfaces.
Use of an Acoustical Lens to Optimize Soundfield

compensation of defocussing by use of acoustical lens
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

-12dB
-3dB
-6dB

16 elements, width of element 1.4 mm

-12dB
-3dB
-6dB

32 elements, width of element 0.9 mm
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
$\alpha_0 = 45^\circ$, $\alpha = 10^\circ - 70^\circ$
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
Axle with artificial flaws, software by BTD, overlay of TD-scans for angles 28° - 72°

Filtering without modification of echo height

GOAL:
display of relevant indications only

SOLUTION:
suppression of unwanted "noise"
Signal Processing
No Modification in Amplitude is Allowed

raw data → decision matrix → processed image

statistic based signal processing → classification

Quelle: DB
Quelle: BMVI
Signal Processing
Statistical Evaluation of Raw Data Set

Criterion $AW_1$: $AW_1 < 1$
Recognition of geometry caused circumferential indications

Criterion $AW_2$: $AW_2 > SNR_{\text{min}}$
Recognition of indication caused by flaws
Distinguish between noise, flaws and spurious signals on form and amplitude
Signal Processing
Statistic Evaluation on Test 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°
Axle with artificial flaws, overlay of TD-scans for angles 28° - 72°
Examination Result on Axle with Artificial Flaws
Conclusion - Improvements

- Local immersion technique
- Increase of sensitivity by use of larger transducer
- Optimization of sound field by use of a lens
- Increase in scan area by use of smaller elements
- Identification and suppression of geometry caused indications
- Suppression of noise
- Suppression of spurious signals
Conclusion – What is left to do?

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

Gefördert vom
im Rahmen eines
MNPQ – Projekts
Messen, Normen, Prüfen,
Qualitätssicherung

Fachbereich 8.4

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