High Resolution Ultrasonic Measurements Using Immersion Technique

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What are the challenges behind this nice ultrasonic image?
Parameters Having an Influence on the Measurement

**Component:**
- material
- manufacturing process
- outer diameter
- inner diameter
- surface finish

**Probe:**
- transducer frequency
- transducer diameter
- focal point
- aperture
- acoustical axis
- pulse shape
- pulse length

**Manipulator:**
- displacement intervals
- speed
- resolution of position
- accuracy of position
- reproducibility

**Analysis:**
- display of results
- signal processing
- classifiers

**Calibration:**
- material
- geometry
- test reflectors

**Couplant:**
- sound velocity
- temperature
- fluid flow
- mixture ratio

**Ultrasonic device:**
- transmitter stage
- receiver stage
- resolution of amplitude
- resolution of travel time
- signal processing
1 Delay Line
2 A-Scan Monitor
3 Pulser
4 Gate
5 Peak Detector
6 Position Controller
7 Display
8 Probe
9 Ball Shaped Reflector
Soundfield of a Focal Probe, $f = 10$ MHz, $D = 20$ mm, $f_D = 125$ mm

Sound pressure on acoustical axis (amplitude scale is given in dB, soundpath is given in mm)

Start of focal zone

Maximum of focal zone

End of focal zone

Cross section X-Y

Cross section X-Z
3D Visualisation of a Soundfield (Boundary is −6 dB)
Immersion Tank – High Resolution Ultrasonic Inspection
Setup for an Inspection Going Beyond SEP 1927 and ASTM E588
**Probe:**
- Frequency = 10 MHz
- Focal Distance = 200 mm
- Diameter = 20 mm

**Couplant**
- Water \( c = 1480 \text{ m/s} \)

**Specimen:**
- Steel \( c = 5920 \text{ m/s} \)
- Plain Surface

Influence of Geometry – Water/Steel, Plain Surface
**Probe:**
- Frequency = 10 MHz
- Focal Distance = 200 mm
- Diameter = 20 mm

**Couplant**
- Water c = 1480 m/s

**Specimen:**
- Steel c = 5920 m/s
- Curved Surface

**Influence of Geometry – Water/Steel, Cylindrical Geometry**
Influence of Curvature on Sensitivity (1/2)
Influence of Curvature on Sensitivity (2/2)
Optimisation of Sensitivity (e.g. according SEP 1927)

Setup according SEP 1927
- non focal probe
- frequency 10 MHz
- water path 40 mm
- valid for all diameters!

Optimised setup for diameter 60 mm
- focal probe $f_{ak} = 200$ mm
- frequency 10 MHz
- water path 135 mm
- sensitivity $+14$ dB
### Tabelle 1 / Table 1: Empfindlichkeitsklassen / Sensitivity classes

<table>
<thead>
<tr>
<th>Empfindlichkeitsklasse / Sensitivity class</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registrierschwelle / Recording level in % BSH / FSH</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
<td>80</td>
</tr>
<tr>
<td>Flachbodenbohrung / Flat-bottom hole in mm</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
<td>1,0</td>
</tr>
<tr>
<td>Verstärkungszuschlag / additional gain $V_k$ in dB</td>
<td>+6</td>
<td>+12</td>
<td>+15</td>
<td>+18</td>
<td>+21</td>
</tr>
</tbody>
</table>

**Calibration according SEP 1927**

Reflector is flat bottom hole 1 mm
Depth is 2 mm before backwall

Setup valid for all diameters!
Defocal behaviour of setup is not compensated!

**Registration according SEP 1927**

- Automated registration using C-Scan (maximum echo)
- Result is a counted number of indications per volume

Calibration According SEP 1927 Gives no Equivalent Size
Axial step 0.1 mm
Angular step 0.05°
Registration level DSR 0.125 mm

rotation angle [°]

B-Scan Evaluation of Indications
A-, B-, C-Scan view is used for the sizing of defects

3D view is used for displaying the distribution and geometrical structure of indications in the volume
3D View of Segment of a Railway Axle
Linear Array - 128 Elements
- Transducer Frequency 17 MHz
- Element Size 0,4 mm x 6 mm

Matrix Array - 121 Elements
- Transducer Frequency 10 MHz
- Element Size 0,9 mm x 0,9 mm

Linear Curved Array - 128 Elements
- Transducer Frequency 5 MHz
- Element Size 0,84 mm x 10 mm
Thank you for your attention

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