Ultrasonic Inspection of aluminum components
Conventional to phased array, manual to automatic

Stefan Kierspel
KARL DEUTSCH Prüf- und Messgerätebau GmbH + Co KG
Wuppertal
Contents

- Introduction to KARL DEUTSCH
- Basics of UT inspection
- Distinctiveness of UT testing on aluminum
- Inspection of welds on thin plates with complex geometries
- Inspection of casted aluminum plates
- Integrated precision measurement of wall thickness
- Inspection of spotwelded aluminum plates
- Different types of automatic testing machines
Introduction to
KARL DEUTSCH
Ing. Karl Deutsch & LEPTOSKOP

LEPTOSKOP coating thickness measurement since 1948, founding of company May 13th 1949

Hannover Messe (1951)
• Founded in 1949, family business in 3rd generation
• Two locations in Wuppertal
• 130 employees in Wuppertal +20 more worldwide
KARL DEUTSCH in Wuppertal
Works 1: Portables, R&D, Administration
KARL DEUTSCH Product Range

- Machines, instruments and equipment for PT, MT and UT
- UT probes development and manufacturing
- Portable units for coating- and wall-thickness measurement
- Portable units for measurement of magnetic fields
Application-Laboratory

- Consulting
- Tests on customer specimens
- Instrument-Training
- Application development

Dr. rer. nat. Helge Rast (Laboratory head)
Dr.-Ing. Volker Schuster (QM, Standards)
Stefan Kierspel (Productmanager PA/UT)

Contakt:
kierspel@karldeutsch.de
alab@karldeutsch.de
Basics of UT inspection
Principles of UT inspection

- 1 MHz, 12 mm, Steel
- 2 MHz, 12 mm, Steel
- 2 MHz, 24 mm, Steel
- 2 MHz, 12 mm, Perspex
Principles of UT inspection

- US-signals
- threshold
- flaw gate
- gate
- threshold
Ultrasonic Reflection from Defects
Criteria of Choice:
- frequency (material, penetration depth, sensitivity)
- probe size (intensity)
- incidence angle (application)
- width of sound field, focus
Sound Field Characteristics

Ø = 12 mm  

- f = 2 MHz  

- Steel

Ø = 12 mm  

- f = 1 MHz  

- Steel

Ø = 24 mm  

- f = 2 MHz  

- Steel

Ø = 12 mm  

- f = 2 MHz  

- Plastics

0dB  -6 dB  -12 dB  -18 dB  -24 dB  -30 dB  -36 dB  -42 dB
Reflection and Diffraction

Snells Law Calculations

<table>
<thead>
<tr>
<th>Incident Material</th>
<th>Perspex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity km/s</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>2.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Refracted Material</th>
<th>Mild Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity km/s</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>5.92</td>
</tr>
<tr>
<td>Shear</td>
<td>3.2</td>
</tr>
</tbody>
</table>

\[
\sin \theta_I = \frac{v_I}{v_R}
\]

FOR TRAINING USE ONLY

Created by P. Grosser

Select Material From Drop Down Menu on Teal Square

Karl Deutsch
Reflection and Diffraction

**Snell's Law Calculations**

<table>
<thead>
<tr>
<th>Incident Material</th>
<th>Perspex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity km/s</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>2.68</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Refracted Material</th>
<th>Mild Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity km/s</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>5.92</td>
</tr>
<tr>
<td>Shear</td>
<td>3.2</td>
</tr>
</tbody>
</table>

- Incident: 26
- Refracted Comp: 76
- Refracted Shear: 32

\[
\sin \theta_1 = \frac{V_I}{V_R} = \frac{V_I}{V_R}
\]

Created by P. Grosser

**FOR TRAINING USE ONLY**

Select Material From Drop Down Menu on Title Square

KARL DEUTSCH
Reflection and Diffraction

Snells Law Calculations

Incident Material: Perspex
Velocity km/s
Compression: 2.66

Refracted Material: Mild Steel
Velocity km/s
Compression: 5.92
Shear: 3.2

Incident: 27
Refracted Comp: #ZAHLL
Refracted Shear: 33

\[ \sin \theta_I = \frac{V_I}{VR} \]

FOR TRAINING USE ONLY

Created By P. Grosser

KARL DEUTSCH
Reflection and Diffraction

Snell's Law Calculations

\[
\frac{\sin \theta_I}{\sin \theta_R} = \frac{V_I}{V_R}
\]

Incident Material: Perspex
- Velocity km/s: 2.88
- Compression

Refracted Material: Aluminium
- Velocity km/s:
  - Compression: 6.32
  - Shear: 3.13
- Incident: 26
- Refracted Comp: #ZAHLL
- Refracted Shear: 31

Created by P. Grosser

FOR TRAINING USE ONLY

Select Material From Drop Down Menu or Text Square

KARL DEUTSCH
Phased-Array Probes

- Probe divided into small strips => elements (linear array)
- Every element can be excited individually

- Probes are flexible according:
  - Oscillator size
  - Insonification angle
  - Focussing
Variation of insonification angle
Standard PA-UT methods

Sector-Scan

Linear-Scan
Display of results

PA Probe

Elektronic Scan

Mechanical Scan

Top view (C-/P-scan)

B-Scan

Side View (E-Scan)

Elektronical B-Scans (E-Scan)
Full Matrix Capture (FMC)

- Recording of a complete set of A-scans
- Each element is excited one by one while all elements are receiving
- Result: $n \times n$ Matrix of A-scans
Principle of the Total Focusing Method (TFM)

TFM is a post-processing algorithm for FMC data.

- Discretion of an inspection area to a grid
- Creation of an artificial focus at all points of the grid by summation of the FMC data

Advantage:

- Inspection area may be wider than the probe
- Focussation within the complete inspection zone
Soundfield of a single element

- CIVA simulation of a probe with 10 MHz, 64 elements, 0.3 mm pitch, 0.05 mm gap
- Wide soundfield
- Probe „looks“ into all directions
What TFM can do

- Sample: ASTM E2491 Phased Array Test Block Metric 7075-T6 Aluminum
- Instrument: GEKKO
- Probe: 10 MHz, 64 elements, 0.3 mm pitch, 0.05 mm gap

Image: A close-up of the test block with indications of 1 mm SDH and 0.3 mm distance.
What TFM can do

B-scan
Focussed B-scan
Total Focusing Method

16/64 16/64 32/64 64/64
Distinctiveness of UT testing on aluminum
Special characteristics of aluminum in terms of UT inspection are:

- Relatively high sound velocity of L-waves (6.400 m/sec) and relatively low sound velocity of T-waves (3.100 m/sec) => angle inspection with T-waves can go down to 30° without having an L-wave
- Relatively low sound attenuation => pulser voltage on steel might be ok but leads to over-saturated signals on aluminum
- Inhomogeneous sound velocity on rolled parts
- Grain size influences sound attenuation
Inspection of welds on thin plates with complex geometries
Thin plates
Thin plates
Thin plates

Probe 16 Elements, 10 MHz, 50° wedge Sector-Scan 40-80°
Thin plates
Thin plates
Thin plates
Interpretation
Inspection of casted aluminum plates
Probe with 5 MHz, 0.85 mm pitch, 10 mm elevation, Watergap 1 mm
Without focussation

FBH 2,5 mm at 150 mm unfoussed Sector Scan -10° to +10°
With focussation at 150 mm

FBH 2,5 mm at 150 mm focus at 150 mm Sector Scan -10° to +10°
All area focus with TFM

FBH 2,5 mm at 150 mm TFM scan
Evaluation of the defect size

FBH 2.5 mm at 150 mm TFM scan
Evaluation of the defect size

Testblock with same dimensions, FBH 1,8 mm at 150 mm and 250 mm

Conventional UT with ECHOGRAPH 1095 and probe S 24 HB 4
Without focussation

FBH 1,8 mm at 150 mm unfocused
Sector Scan -10° to +10°
With focussation at 150 mm

FBH 1.8 mm at 150 mm focus at 150 mm
Sector Scan -10° to +10°
All area focus with TFM

FBH 1,8 mm at 150 mm TFM scan
Evaluation of the defect size

FBH 1.8 mm at 150 mm TFM scan
FBH 1,8 mm at 250 mm TFM scan

All area focus with TFM
Evaluation of the defect size

FBH 1,8 mm at 250 mm TFM scan
Integrated precision measurement of wall thickness
Sonic Eye by Starrag

Multi-axis grinding machine for large vertical parts
Sonic Eye as a changing tool
Automatic thickness measurement, measured data directly influence the grinding process
Inside Sonic Eye

Special Version of standard precision wall-thickness gauge ECHOMETER 1077 with probe DS 12 PB 1-7
Inspection of spotwelded aluminum plates
Spot welding is useful as it can produce high quality welds at a relatively low cost.

About 3,000-5,000 spots on a regular car body.
Welding Process

1. Pressure applies to assure full sheet contact
2. Heat melt the steel to form the nugget weld
The Result
The challenge

Weld quality is impossible to predict visually from the outside
Some nugget types

- Good
- No Weld (Loose)
- Undersized
Spotweld inspection with UT/Mate
Spotweld inspection - probes

Probes have to be selected according to the nominal nugget size.
Spotweld inspection – basic principle
Spotweld inspection – basic principle

- Good spot
- Spot too small
- Cladding
- No weld
Spotweld inspection – basic principle

- Good spot
- Spot too small
- Cladding
- No weld

A pore in the spot center may give the same signal but is not critical.

Spot welded aluminum plates often show such pores.
Spotweld inspection with PA UT/X

Phased-Array-Technique is applied in UT/x

- Matrix-Probe with 61 Elements
- Only one probe required
- PA-Electronic MANTIS
- Weld nugget is evaluated
- Welded area is measured