Aluminum Plate Inspection Using Phased Array Technology
**PA Basics Applied: Electronic Scanning**

- Spatial scanning by driving an active aperture in a predefined sequence
- Faster inspection as there is no need for mechanical movement
- Replacement of mechanical motion reduces wear and operating costs and increases system reliability
- Combined with electronic focusing
PA Basics Applied: Electronic Focusing

• Electronic focusing permits replacing several single-element probes with different focal distances by one phased array transducer

• Faster inspection of full volume of thick parts by means of dynamic focusing
Advantages of Phased Arrays Technology

- Reduced inspection time by using electronic scanning
- Improved S/N and flaw detection and sizing
- Improved test coverage
- Reduced set-up and inspection time
ScanMaster

Front View
Calibration Table
UT Configuration

- Two probe holders for increased productivity
- Semi-immersion – the probes are mounted in a water box provided with a membrane. Water suction leaves the plate almost dry
- Dual-gimbal configuration allows following the plate curvature
- 128 elements per probe
- 16 elements aperture with electronic scanning of 1 mm index
- Two focusing depths (near surface and mid-depth)
Scanning Head

- Water box for semi-immersion
- Suction of residual water
- Dual-gimbal head
- Safety devices prevent head falling off the plate
ScanMaster

**Operator Station**
Control Cabinet
Conveyor system

- High productivity
- Easy handling
- “Dry” inspection
- Available location for manual inspection
# System Performance

<table>
<thead>
<tr>
<th>Parameter</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motion envelope (inch)</td>
<td>670</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td>Speed range (sec/Inch)</td>
<td>24</td>
<td>24</td>
<td>6</td>
</tr>
<tr>
<td>Repeatability (mm±)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Accuracy mm300/mm±</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>
Example:

- Plate Thickness: 100 mm
- Water path: 25mm
- Maximum linear velocity allowed by the acquisition rate: 150mm/s (with two focusing channels one near the surface and one in the material)

- With one 128 elements (1 mm pitch) probe the productivity is about 18,000 mm²/s
- With two heads the productivity is about 36,000 mm²/s

As a result, a plate of 5 meter x 2 meter can be scanned in 5 min
**System Features**

- A-, B-, C-scan
- Return to defect
- Local scan of suspected area
- Marking of defect area
- Defect evaluation using shear waves
Data Analysis (With A-scan Results)
Set-up Display
**System Advantages**

- High throughput using three conveyors
- High scanning productivity with PA
- Focusing in different depth using one probe
- Better sizing of defects
- Exact location of the defect
- Defect evaluation
- Not sensitive to plate curvature
- Plate remains dry
ADVANCED SOLUTIONS FOR UT OF AIRCRAFT ENGINE RUN
Complexities in UT of Engine Run Hardware
Part Geometry and Surface Conditions

- Difficult access to web entry areas, web areas and bore faces
- Concave sections require contour following
- Limited bore area or I.D.
- Surface condition is rough and may have small holes
Complexities in UT of Engine Run Hardware
Part Geometry and Surface Condition

Spool Stage 3-9

Spool Stage 2-6
Complexities in UT of Engine Run Hardware
Part Geometry and Surface Condition

I.D. Restricts Manipulator Access

Web Diameter is Larger than I.D.
Complexities in UT of Engine Run Hardware
Ultrasonic Complexities

• Stray echoes occur off the probe holding device and the surface of the web

• Restricted water path and shear scan angle results in `ghost echoes`
Complexities in UT of Engine Run Hardware

Ultrasonic Complexities

- Front Surface
- Echoes of Probe Holder
- Ghost Echo
- Front Surface
Complexities in UT of Engine Run Hardware

Type of Inspection

- Multiple scans required in each area
- Incident angles of 0°, 20°, 22°, and 25° are required in the clock wise and counter clock wise directions both axial and circumferential
- Calibration verification must be performed in order to validate results
Complexities in UT of Engine Run Hardware

Type of Inspection

Incident Angles
CW & CCW

- 0 DEG
- 20 DEG
- 22 DEG
Complexities in UT of Engine Run Hardware

Type of Inspection

Incident Angles
Axial Positive and Negative

- 0 DEG
- 20 DEG
- 22 DEG
Complexities in UT of Engine Run Hardware

Multiple Inspection Tools

• Mirrors with various angles
• Elongation devices
• Web following tools
Complexities in UT of Engine Run Hardware

Limited Visibility of Inspected Areas

• Inspection takes place in the I.D.

• Precise positioning required at the web entry point

• Impossible to see the current position of the robot manipulator
Solutions for UT of Engine Run Hardware

General

• Large immersion tanks with high precision system mechanics

• Specially designed software

• High resolution UT instrumentation
Solutions for UT of Engine Run Hardware

General

Immersion Tank
Solutions for UT of Engine Run Hardware

Compact Manipulator

Radial Section: INSPECTION SPOOL 2–6
AREA 1–5
Solutions for UT of Engine Run Hardware

Compact Manipulator
Solutions for UT of Engine Run Hardware

Hardware Solutions for Web Areas – Telescopic Device

• Telescopic device attached to a special yoke adapter
• Web contour near I.D. scanned with device in retracted position
• Web contour near O.D. scanned with device in extended position
Solutions for UT of Engine Run Hardware

Hardware Solutions for Web Areas – Telescopic Device

Yoke with Telescopic Device Extended   Yoke with Telescopic Device Retracted
Solutions for UT of Engine Run Hardware

Hardware Solutions for Web Areas – Probe Holder and Surface Following Device

- Rotatable 180° to allow for CW and CCW scans
- Maintains 25° incident angle to generate shear waves
- Maintains 20mm water path as required by transducer focus
- Automatically tracks contours and planar surfaces
Solutions for UT of Engine Run Hardware

Hardware Solutions for Web Areas – Probe Holder and Surface Following Device

Probe holder can be revolved 180 degrees to allow both CCW and CW
Solutions for UT of Engine Run Hardware
Software Solutions for Web Areas

• Import of part geometry from CAD
• Pre-programmed pauses with interactive messaging
• 3D image display of part, robot, yoke and telescopic device
• Real-time display of current robot position
• Future position predictor
Solutions for UT of Engine Run Hardware

Software Solutions for Web Areas - 3D Graphics Display

- Part Profile
- Web Tool Displayed
- Web Area Being Scanned
ScanMaster

Solutions for UT of Engine Run Hardware

Software Solutions for Web Areas - Advanced Movement Prediction

Advanced robot position

Current robot position
Solutions for UT of Engine Run Hardware

Hardware Solutions for Bore Areas – Multi-position Mirror

- Allows for 7 different incident angles
- Adjustable in both radial and axial directions
- Allows for probe to mirror distance adjustment
- Mirror plate has dual gimbal for normalizing beam
- Absorbing shield to prevent stray echoes
Solutions for UT of Engine Run Hardware

Hardware Solutions for Bore Areas – Multi-position Mirror
Solutions for UT of Engine Run Hardware

Hardware Solutions for Bore Areas – Multi-position Mirror
Solutions for UT of Engine Run Hardware

Software Solutions for Bore Areas

• Incident angle and water path verification

• Graphic display of beam exit angle and precise position of inspected surface

• Automatic position update
Solutions for UT of Engine Run Hardware

Advanced Software Solutions

- Automatic return to calibration block for flaw size and depth verification
- Verification data along with flaw data automatic stored in report database
- Validation by operator or supervisor
- Up to 20 custom fields
- Allows for defining sequences which include: auto normalization, auto tool selection, auto scan selection and sequence, auto park tool
- Full or threshold-based A-scan capture, B- and C-scan
Solutions for UT of Engine Run Hardware

Advanced Software Solutions - A-, B- and C-scan