Tank inspection using a linear phased array (1/4)

The objective of the NDT procedure in this case is to detect internal cracks from the outside of the tank. For one rotation of the probe around the tank (manual or automated), the procedure must be able to provide real-time defect imaging that allows the inspector to assess the structural health of the tank. As illustrated in the figure below, the optimal diagnostic display shows only those defects that are larger than the specified critical size. The desired configuration is to use a single linear rotation to produce a scaled map that shows the location and size of defects in the area under inspection (see blue map in the figure).

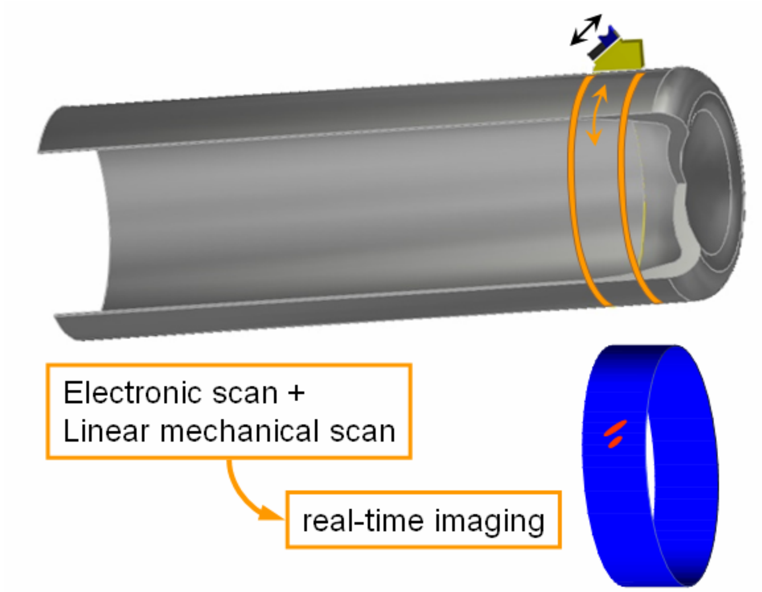

Illustration of customer concept for tank inspection.

Requirements include provision of a real-time scaled map using a single displacement encoder.

Cracks occur most often near the bottom of the tank where there is a change in wall thickness. Simulations using CIVA were performed to determine the optimal probe configuration and inspection strategy. One proposed solution is to use a shear-wave inspection at 45 degrees using a linear array with a wedge (see below), combined with electronic scanning.

As a first step, the beam profile is optimized using CIVA to gain maximum resolution in the area of interest. The number of elements to be fired at the same time and the focusing delay laws are deduced from analysis of the beam calculations.

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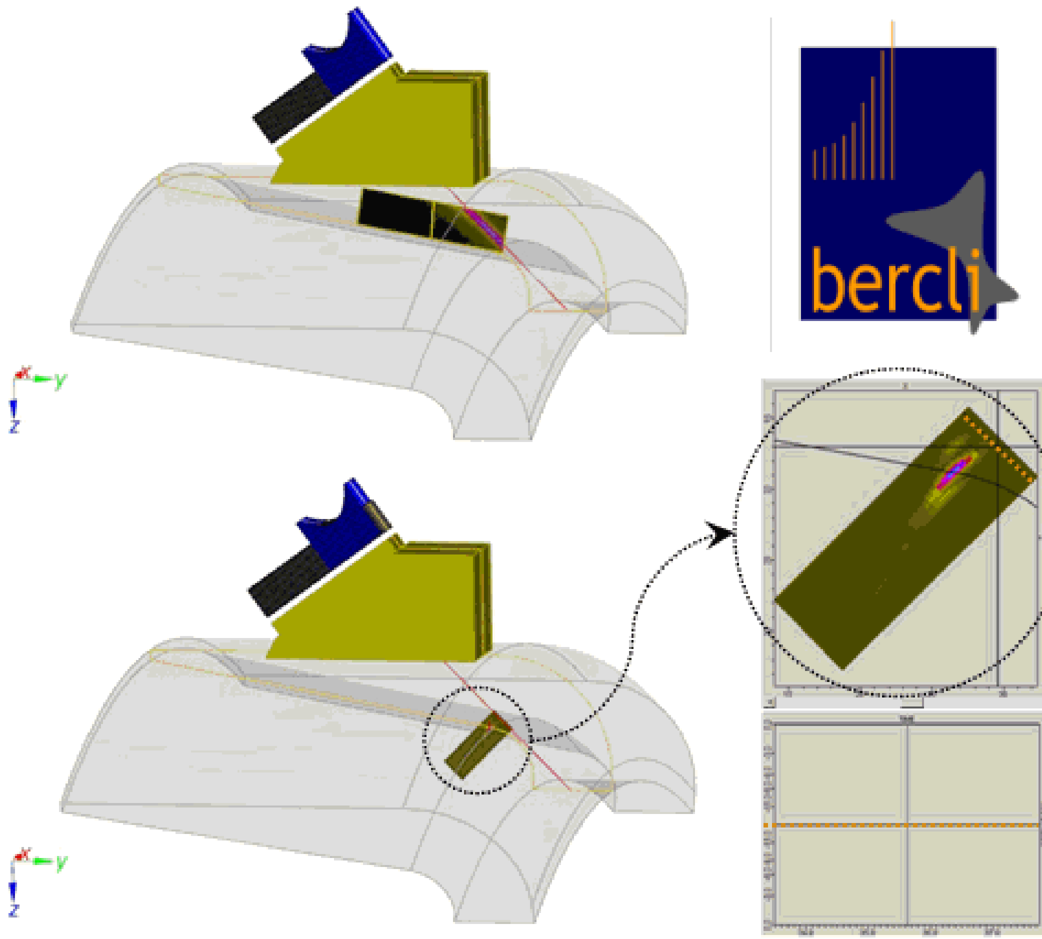
Tank inspection using a linear phased array (2/4)

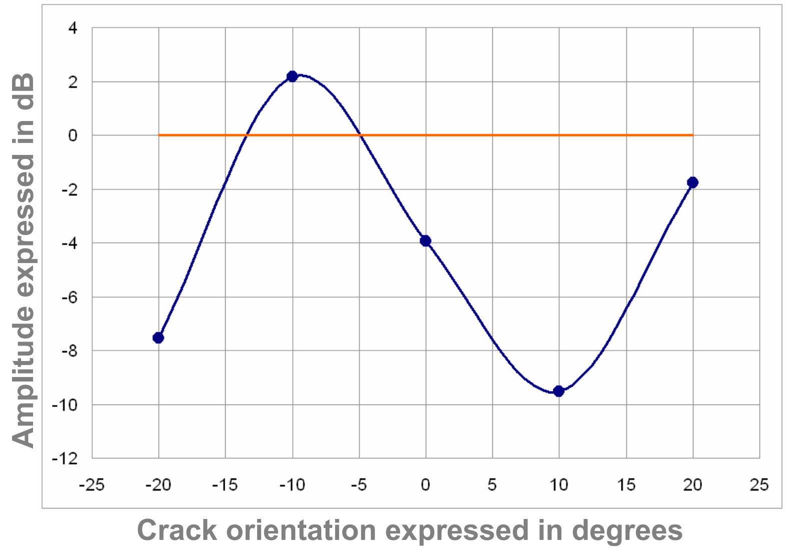


Beam simulation (top figure) and wave-defect interactions (bottom figures).

Tank inspection using a linear phased array (3/4)

Once the beam is optimized, wave-defect interactions are calculated (see animation above). A reference case is simulated (usually a calibrated side-drilled hole) and a parametric study is conducted to determine the effect of crack orientation. Here the crack is rotated from –20 to +20 degrees, with a 10º step. Results are shown in the plot below, which shows echo amplitude versus crack orientation.

The plot illustrates the dependence of the amplitude on the reflected echo on the crack orientation. Amplitude is expressed in dB, i.e., the gain with respect to the reference defect (here a side-drilled hole). Orientation is expressed in degrees. The straight line is the amplitude of the echo reflected off the calibrated side-drilled hole. Note that the maximum occurs at –10º because of the curvature of the inner wall.



By correlating these simulation results to experimental measurements on the calibrated defect, the sensitivity of the procedure can be inferred; i.e., the inclination range that can be detected. Note that similar parametric studies can be performed to determine the smallest resolvable defect, and the coverage zone.

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Tank inspection using a linear phased array (4/4)

Practical example:
For equipment with an 80-dB dynamic range, let's suppose that the calibrated defect is observed experimentally at a 50dB gain with an echo at 100% of the screen height and a noise below 5% of the screen height.
Let's now assume that any full-height echo measurement is acceptable as long as the noise level is below 30% of the screen height.
As a first approach, the remaining dynamic range to keep the measurement acceptable is:
$20x\log(30/5) = 15.5$ dB
Any echo within a 15.5dB range of the side-drilled-hole echo will therefore be accepted. Going back to the simulation results that show that any echo from a rotated crack (within ± 20º) remains within 10 dB of the reference echo (see plot), we can conclude that all defects with rotations within this range will be detected using the proposed inspection strategy.

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