Ultrasonic Application Solutions

Bike Eddy Current Array – Robotic Tank Weld Inspections

Application

Integrating an eddy current array for detection of surface cracks on carbon steel welds with a remote-controlled magnetic crawler robot enables tank inspections without personnel having to enter hazardous confined spaces. Pressure vessels used in the Oil & Gas industry require regular inspections to assess the integrity of the asset. Today a lot of this work is still carried out manually by having inspectors enter the asset. The confined space nature of these areas however poses significant safety risks to the personnel.

Eddy current array testing (ECA) was chosen due to its suitability for automaton. Combining this method with a remote-controlled magnetic crawler that can freely maneuver on carbon steel surfaces removes the need for personnel entry into the confined space of the vessel. A sensor carriage engages the eddy current array probe onto the weld with a defined force and angle, removing the usually very operator dependent manual handling of the sensor. With the addition of the crawler being able to move the probe straight and at a constant speed along the weld, results in a very repeatable and robust measurement.

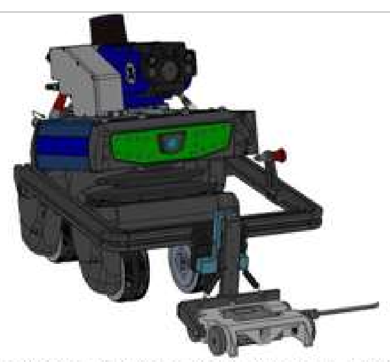

Figure 1: Schematic 3D model of Bike with Probe arm actuator

Customer challenge

For the magnetic crawler, the Waygate Inspection Robotics BIKE platform can freely maneuver on magnetic flat and cylindrical surfaces. Its capability to cross concave and convex corners with angles up to 90° also allows deployments through manholes without man-entry or additional deployment tools. The ECA probe is mounted in a holder that ensures perpendicular alignment to the surface. A spring-loaded linear axis in the holder generates a constant contact force against the weld. An actuated arm allows the probe holder to be retracted above the robot during travelling and corner crossings.

The 3D Loc module with its 2D Lidar sensor and IMU can be mounted in parallel to allow the entire 3-dimensional inspection path to be recorded into a mission database. A high definition tilt-zoom camera can also be added to better monitor the weld crack inspection or carry out visual inspections without having to exit the asset to swap tools.

The robot is remotely controlled from the Integrated Control Station usually placed close to the manhole of the asset. It can generate an incremental encoder signal based on the BIKE movement that can be fed to the Eddy Current Instrument to record continuous C-Scans.

Solution benefits:

- Pressure vessels used in the Oil & Gas industry require regular inspections to assess the integrity of the asset. Butt-welds connecting the plates which make up the shell of a tank are subject to various damage mechanism, many of which appear as surface cracks that can lead to failure of the entire asset.
- Today a lot of this work is still carried out manually by having inspectors enter the asset. The confined space nature of these areas, however poses significant safety risks to the personnel. Any rescue efforts also inevitably expose rescue personnel themselves. The need for internal cleaning and scaffolding before an inspection both further increases the duration of stay in the hazardous area, as well as the outage duration and associated costs. Hence the chief goal of developing this new weld crack inspection tool was to avoid confined space entry and minimize overall time spent inside the asset.
- For the inspection method, eddy current array testing (ECA) was chosen due to its suitability for automaton. Single-pass coverage of both weld and heat affected zone allows unmatched inspection speed at reliable and uniform coverage. The ability of eddy current to inspect through nonmagnetic surface coatings removes most requirements for prior surface treatment. Complete C-Scan can be created by adding just one encoded axis in scan direction. Combining this method with a remote-controlled magnetic crawler that can freely maneuver on carbon steel surfaces removes the need for personnel entry into the confined space of the vessel.
- A sensor carriage contacts the eddy current array probe onto the weld with a defined force and angle, removing the usually very operator dependent manual handling of the sensor. With the addition of the crawler being able to move the probe straight and at a repeatable and robust measurement.

Figure 2: Spherical above ground storage tank farm – example of components that can be inspected on inside with remote control Bike platform

Test Equipment:

- Eddy Current Array Probe with Tester
  - Probe cable – 30 meters (~100 feet)
  - 40 Probe coils – 2 mm diameter each
  - Array coverage – 52 mm (2 inches)
  - Maximum weld bead height: 0.197 in. (5 mm)
  - Minimum detectable crack (L x W x D): 0.020 in. x 0.004 in. x 0.020 in. (0.5 mm x 0.1 mm x 0.5 mm)
  - Maximum penetration depth: 0.039 in. (1 mm) (Stainless Steel)

Figure 3: 3D schematic of arm actuator

Figure 4: Bike with EC array probe rolling up the inside of cylindrical tank

Figure 5: Bike with EC array probe inspecting the inside of a tank

Inspection Technique

The system was designed to inspect welds manufactured to the quality standard ISO 5817 for surface imperfections. Hence the eddy current equipment and procedure follows the requirements for eddy current testing techniques according to ISO 17643. For calibration, a block as described in ISO 17643 with three continuous cuts of 0.15±0.03 mm width and depths of 0.5±0.03 mm, 1.0±0.05 mm and 2.0±0.10 mm is used. Plastic shims allow for consideration of surface coatings.

A weld reference block has been designed to validate the performance of the system. EDM notches represent surface breaking weld flaw locations and sizes as described in the ISO 5817 weld quality standard. Notches are placed on the weld bead, weld toe and parent material.

Each notch is 6.0 mm long and 0.15 mm wide. Each location is represented with a set of transverse and axial notches of depths 0.5 mm, 1.0 mm and 2.0 mm.

The Surface Array Probe and Eddy Current instrument was chosen to meet these requirements. Two arrays of 20 coils at a pitch of 2 mm enables detection of longitudinal, transverse and off-axis cracks as short and deep as 0.5 mm. The array width of 52 mm (2 inches) allows single-pass coverage of weld widths up to 22 mm and 10 mm parent material to each side while leaving another 12 mm margin for following the weld. The flexible face of probe carrying the coils can contour to weld bead heights of up to 5 mm. This system can detect all artificial flaws on the weld reference block, including the most critical 0.5 mm deep notch at the weld toe. Lift-off tolerance is very high with the system still being able to detect every artificial flaw at an additional epoxy coating of 0.5 mm thickness.

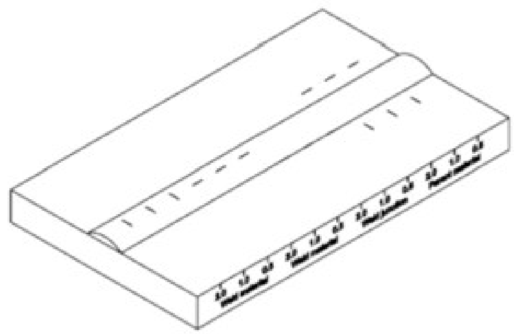

Figure 6: Schematic of Calibration plate with weld and notches

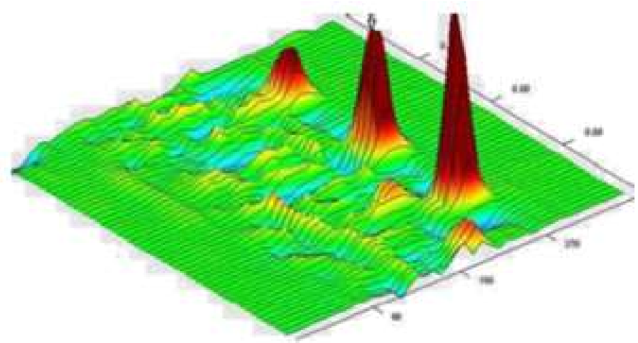

Figure 7: Resulting 3D C-scan display of array data from Calibration plate

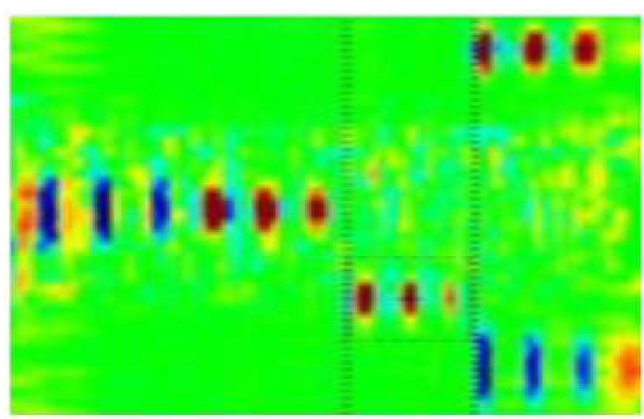

Figure 8: Array data results from Cal plate shown with 2D top-down display