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Weld crack inspection with Eddy Current Array on BIKE Robot

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Abstract

Integrating an eddy current array for detection of surface cracks on carbon steel welds with a remote-controlled magnetic crawler robot enables asset inspections without personnel having to enter hazardous confined spaces. Repeatability is improved by reducing user dependent variability in technique. Complete mission timeline including all inspection results with locations in a digital twin of the asset.

Keywords

Inspection Robotics – Eddy Current Array – BIKE Robot – Weld Inspection – Surface Array Flex Probe – ISO 17643 – ISO 5817 – Digital Twin

Contents

Introduction

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. Non-destructive inspection techniques (NDT) such as magnetic particle testing (MP), Dye penetrant testing (DP) and eddy current testing (EC) are commonly used to identify such surface breaking flaws both during initial manufacturing, as well as over the lifetime of the vessel. 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

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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 non-magnetic 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 constant speed along the weld, results in a very repeatable and robust measurement.

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.

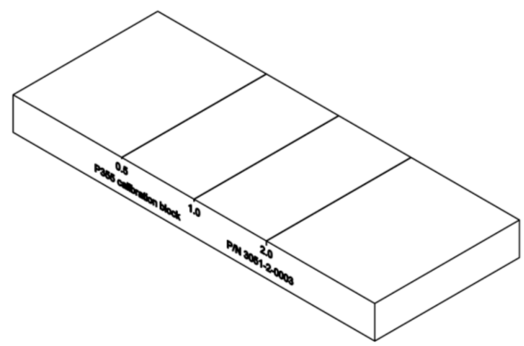

Figure 1: EC calibration block according to ISO 17643

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±0.1 mm long and 0.15±0.1 mm wide. Each location is represented with a set of transverse and axial notches of depths 0.5±0.03 mm, 1.0 ±0.05 mm and 2.0±0.1 mm.

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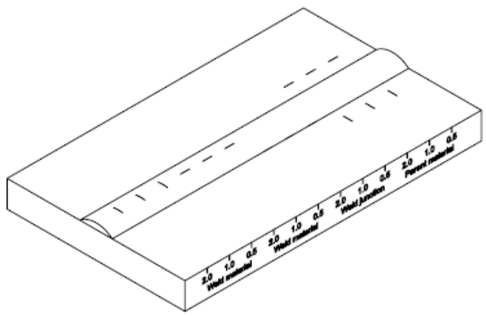

Figure 2: *Weld reference block with EDM notches representing cracks*

The Zetec Surface Array Flex Probe and MIZ-200 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. The surface array probe was further customized with a 30-meter-long cable to cover a large range of asset size. A special wear resistance fabric increases the lifetime of the probe on the rough surfaces encountered during in-service inspections. 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.

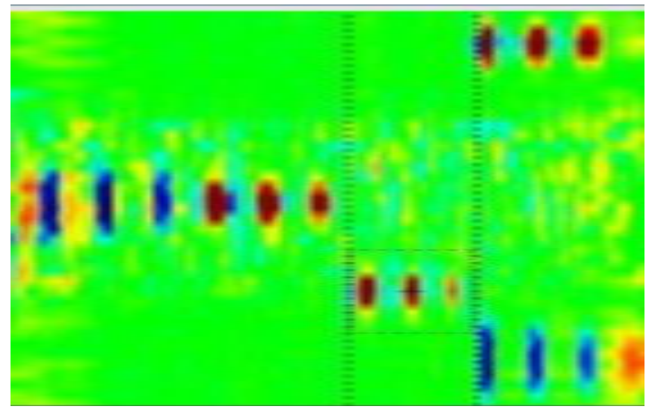

Figure 3: *ECA C-Scan of the weld reference block detecting all EDM notches*

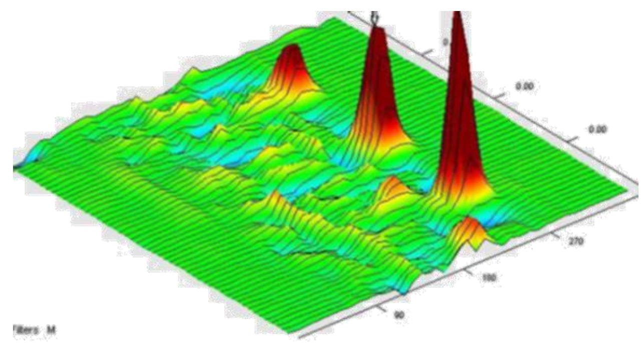

Figure 4: Signal 3D view of the axial notches in the toe of the weld

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.

Robotic Integration

For the magnetic crawler, the Waygate Technologies 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

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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 1-DOF arm allows the probe holder to be retracted above the robot during travelling and corner crossings.

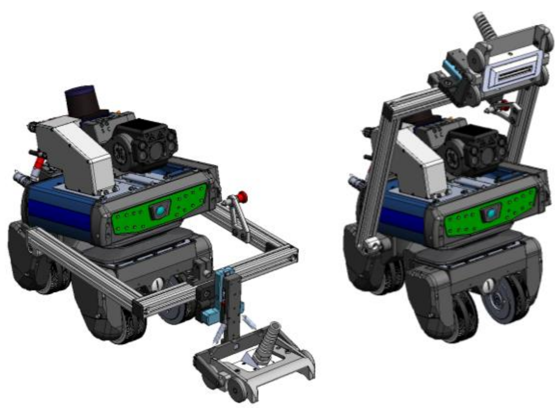

Figure 5: ***BIKE with ECA probe with lowered (left) and raised (right) actuator arm***

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.

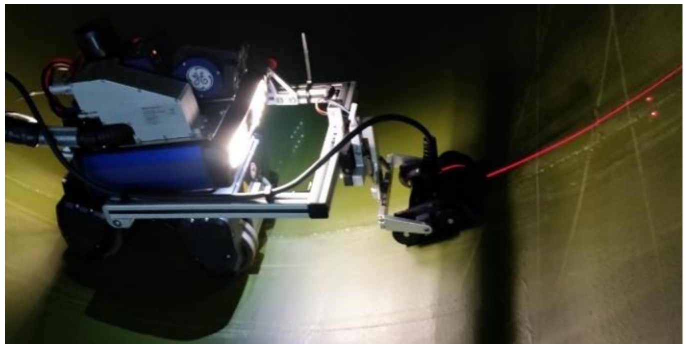

Figure 6: ***ECA inspection system in a representative laboratory environment***

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.

Table 1: ***Major system components***

001	BIKE Platform
002	BIKE Actuator Arm module
003	BIKE 3D Loc module
004	BIKE HDTZ1 inspection camera
005	ICS2 Integrated Control Station
006	3D Loc Robot Control Software
007	Zetec Surface Array Probe
008	Zetec MIZ-200 Eddy Current Test Instrument
009	Zetec Velocity Acquisition / Analysis Software
010	ISO 17643 calibration block
011	Weld reference block

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References

Zetec Surface Array Flex Probe
https://www.zetec.com/products/eddy-current/probes/surface-array-probes/surface-array-flex-probe/

Waygate Technologies Robotics BIKE platform
https://inspection-robotics.com/bike/