ASK THE EXPERT: 'WALKING THE CUP'

Question:

Is the technique walking the cup' in TIG welding purely for visual appearance and are the welds as good as they should be?

Answer:

"Walking the cup" (or "cup walking") is a technique commonly seen in pipe welding activities as well as other applications, where the welder will manipulate the welding torch by resting the ceramic cup on the joint to produce a weld that is very high quality visually, coupled with achieving a high production rate.

A typical application of walking the cup in the GTAW/TIG welding of piping.

High quality and high productivity

The productivity increase is because the welding power (volts x amps) that is used for WTC is much higher than normal, but the welding travel speed is also very fast which, in theory at least, provides a unique combination of high quality and high productivity. This raises a question: does it meet the welding procedure specification (WPS)?

The aesthetics

Visually, welds look very smart and often show various colours from the different cooling rates seen with welding. Weld ripples are even and uniform which makes for good weld aesthetics, but

Good regular cap profile by the use of the 'walking the cup' technique.

what about weld integrity? Does this technique provide a good combination, or does it give a false indication of weld quality with good visual appearance but with low weld mechanical performance?

Summary

The "walking the cup technique" is clearly a favoured technique specifically in a number of industry sectors. In particular, the technique is perhaps best suited for highly skilled welders who can make the welds look excellent in their visual appearance, but is there a need for some research and development of the technique to ensure the resultant welds have the correct weld integrity, such as chemistry, metallurgical properties, as well as the necessary mechanical properties to ensure long term service life of welded components?

Rather than giving a definitive answer to the question raised, perhaps readers could give their views on whether "walking the cup" is a proven technique where welding procedure qualification tests have used the technique, and the subsequent weld testing meets all the test standard requirements for destructive and non-destructive testing? Or are welding procedures often qualified with conventional lower welding currents and moderate travel speeds, but fabricators then look for a significant productivity gain?

Let us know your thoughts and views, which could be published in the "Ask the Expert" column in future editions. Contact, theweldinginstitute@twi.co.uk

PROPOSED BRITISH STANDARD ON QUALIFICATION OF WELDING PROCEDURE SPECIFICATIONS FOR PLASTICS – COMMENTS REQUESTED

For the welding of metals, EN ISO 15614 specifies how to qualify welding procedures. However, there is no equivalent standard for welds in plastic components. The BSI Standards Committee WEE/3 (Welding and thermal joining of plastics) is proposing to develop a new standard that will fill that gap and will help plastics companies to improve the quality of their welded products.

The proposed standard will cover the following plastics welding processes: ultrasonic welding, hot plate welding, vibration welding, spin welding, laser welding, infrared welding, orbital vibration welding and hot gas convection welding, as well as ultrasonic, hot air, electrical and infrared staking.

It will define how to assess the welded joints and how to determine test acceptance levels in order to qualify welding/thermal joining procedures for plastic components.

Before the development of this standard can go ahead, BSI would like to find out from the plastics industry whether they believe this will be a useful document. Comments need to be submitted to BSI using the following link: **https://standardsdevelopment.bsigroup.com/projects/9022-07351#/section**

Please note that, in order to comment, you must first register on the BSI website using the following link: **https://standardsdevelopment.bsigroup.com/ and click on 'Register/login'.**

PIPELINE NDT – STATE OF THE ART USING AUTOMATED ULTRASONIC TESTING (AUT) ON PIPELINE GIRTH WELDS

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Radiographic Testing (RT) has been in use on pipeline girth welds since 1928 and codified acceptance criteria were first introduced by API in 1953. [1] In the late 1970s, there was the gradual introduction of Gas Metal Arc Welding employing mechanised systems, (m-GMAW). The narrow gaps and steep bevel angles used with m-GMAW exposed limitations with radiography, since it was not reliably detecting lack of fusion and other planar flaws common to the welding process. This led to the introduction of Automated Ultrasonic Testing (AUT) which enhanced detection and sizing capabilities. Due to AUT's height sizing capability it also opened the door for fitness for service acceptance criteria, (i.e. based on Engineering Critical Assessment). This with improvements in safety and reduced cycle times added impetus to the use of AUT and as a result RT was gradually displaced by AUT as the primary NDT method for pipeline girth welds. The original AUT systems were based on the zone discrimination technique and comprised conventional pulse-echo, shear wave probes either singly, (for the root, cap and weld volume), or in tandem, (for the steep bevel angles at the fusion line). Mounted on a scanner, fixed probes were configured to inspect discrete portions of the weld in vertical increments (zones). For each zone a B-scan was generated showing amplitude and timing within a gated region. Arranged as a strip chart, the B-scan strips on either side of the weld lent themselves to easy interpretation by appropriately trained operators. Lead in times and preparation activities for fixed probe systems could be protracted (manufacture of special angle probes, system set up. etc.), and in the 1990s phased array probes were introduced. These probes took advantage of improved signal processing and computing power to allow an array of elements to be fired with timings adjusted to emulate various probe angles and beam profiles (focal laws). These offered much more versatility when setting up and evaluating proposed probe configurations and even allowed very quick modification if needed for change of bevel angle, thickness or acoustic properties of pipe. At the same time, we saw the introduction of Time-of-Flight Diffraction (TOFD) techniques, which offered a very reliable, accurate inspection, albeit with some limitations. Pulse-echo ultrasonic testing and TOFD are highly complementary and together provided significant improvement in probability of detection, and modern AUT systems are now a hybrid of fixed, phased array, and TOFD probes.

Typical AUT systems in current use

Today the most common form of AUT used on pipeline girth welds is based on the zone discrimination technique in conjunction with TOFD. There are four systems in wide use around the world, namely Olympus PipeWIZARD, RTD Rotoscan, Shaw Pipeline Services Infocus, and GE Weldstar. All the systems are similar and comprise fixed, phased array, and TOFD probes. The most significant difference between the systems concerns software and the way they present information on their strip charts.

A typical AUT system as shown in Figure 1, comprises a scanner which traverses around a band mounted on the pipe, (often similar to the band used for welding bugs). The various probes are mounted symmetrically around the centre line of the weld and the signal data from the probes is fed back to an acquisition unit which processes the information and in turn feeds it into a computer where software processes it for display in the form of a strip chart. PipeWIZARD is a typical system and Olympus provide detailed information online about the system and its various components (www.olympus-ims.com/en/pipewizard).

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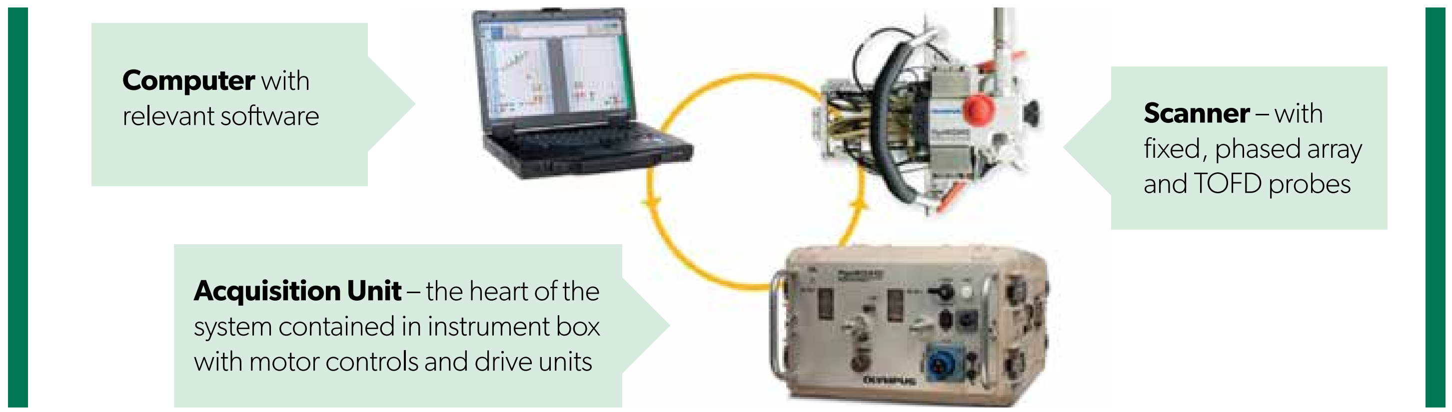

Figure 1 - PipeWIZARD AUT System Main Components [2] Reproduced by permission of Olympus NDT Solutions.

Zone discrimination is an inspection technique used with PipeWIZARD and other AUT systems that divides the weld into a series of well-defined, discrete zones, typically 2 to 3mm in height. Each zone is inspected by its own focused transducer(s) or focal laws if using phased array probes. A single phased array probe can normally generate sufficient focal laws to cover the entire bevel, therefore the AUT inspection can be carried out by means of only two phased array probes, one on either side of the weld. This approach is optimised for detection of fusion face flaws on narrow gap bevels in pipeline girth weld inspection, but can also be applied to other processes and wider bevels.

Time of Flight Diffraction (TOFD) uses diffraction rather than reflection properties of ultrasound and as a result of the different physical principles involved provides a complementary NDT to pulse-echo. This delivers a marked improvement in a system's Probability of Detection (PoD) for weld flaws. TOFD relies on diffraction tips at the top and bottom of flaws and, apart from the dead zone up to approximately 5mm below the probe surface, can reliably size and position flaws at both weld fusion line and within the weld volume. It is normal to use specific TOFD probes which are optimised for focus depth and frequency depending upon thickness of pipe.

Figure 2 shows a macro of a typical weld defect at x2 and x10 magnification along with the PipeWIZARD strip chart elements including volumetric, root, fill and cap channels for upstream and downstream sides of the weld. The centre strip is the TOFD display for which an expanded view is also provided. For the case shown, the defect can be clearly seen in the downstream, volumetric 3 and fill 3 to 5 channels. It can also be clearly seen in the TOFD channel which would normally be used to provide better depth and height sizing.

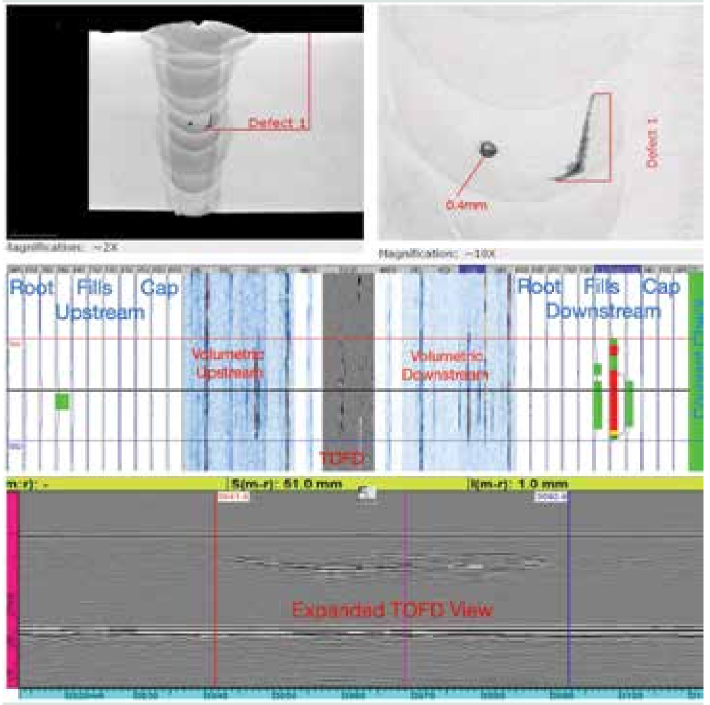

Figure 2 Typical Defect with PipeWIZARD Strip Chart Display.

Preparations for pipeline inspection using AUT

AUT requirements are dependent upon the pipeline code e.g., API 1104 (ASTM E1961), DNV-ST-F101 (Appendix E) [3] which require a system be qualified/validated specifically for pipeline girth welds. DNV-ST-F101, Appendix E is a typical example of standard requirements for AUT inspection. This requires the AUT system performance be documented to confirm adequate detection and sizing which must be demonstrated during qualification testing. A typical qualification is performed on a series of seeded defect welds and accompanying calibration blocks. The system's reliability and repeatability are documented for a range of approval considering base and weld material, welding method, bevel geometry, and wall thickness limitations. DNV will regard the system to be qualified if it demonstrates a probability of detection for the smallest allowable flaw height at 90% with a 95% confidence level (90% |95% POD). This usually requires 29 seeded defects in each weld zone and a typical qualification for a mechanised weld with J-bevel in carbon steel will require a total of 120 defects.

Once a qualified system is available, a project specific validation will be required based on the proposed AUT procedure. The weld bevel is evaluated and the requirements for inspection of each weld zone, (root, hot pass, fill passes and cap), defined. The phased array probe is configured with focal laws to achieve probe set up for each zone. TOFD probes are optimised for the thickness. Calibration blocks are prepared with appropriate reflectors (notches and flat bottom holes) and these are used with seeded defect welds to confirm the procedure. The number of seeded defects will usually be 12 or 29 depending on various factors (range of approval, sizing capability required etc.). As well as confirming system performance for the specific case, the validation will deliver a sizing accuracy that feeds into defining flaw acceptance. DNV require 90%|95% POD for the smallest allowable flaw height and sizing accuracy to be within ± 1 mm for height,± 2mm for depth and 15 mm for length.

The importance of appropriately trained, experienced operators cannot be understated. The system capability is highly dependent on operator skill and this needs to receive appropriate attention. Operators shall be level 2 certified and are often required by clients to demonstrate their capabilities calibrating equipment and performing an operational test under field conditions evaluating size, nature, and location of imperfections.

Field Inspection

AUT systems are used both on and offshore, and the inspection cycle will usually be between 5 and 10 minutes depending upon the pipe size and complexity of the set up. It has become normal to carry out a calibration for each weld and this, with interpretation of the strip chart, is included in the cycle time. After a short period, frequency of calibration may be reduced to one in every 10 welds for normal pipelines. For offshore welding on an s-lay vessel firing line, the weld needs to be rapidly cooled to keep the cycle time short. The maximum temperature has to be proven to be acceptable during welding procedure qualification and usually restricted to 300 °C. Cold water is deluged over the weld until it is well below 100 °C, usually between 70 - 80 °C that is needed for good coupling. The maximum temperature allowed for AUT is an essential variable and will have been proven during qualification and validation testing. The weld must be thoroughly cleaned with no spatter present and scribe lines made during pipe bevelling checked for accuracy and legibility. While the calibration scan is ongoing the scanner technician will position the band using the scribe lines and on successful calibration, place the scanner on the pipe, monitoring it during its traverse around the pipe. During scanning the technician will be in communication with the operator and will address any anomalies that may come up. The operator will advise the technician when they can remove the scanner and band; usually after the weld has been sentenced. If a repair is called it would be normal for the technician to mark the location by positioning the probes at the start and finish of the repair area.

For information on careers in welding engineering, visit The Welding Institute Website, https://theweldinginstitute.com/careers-and-education

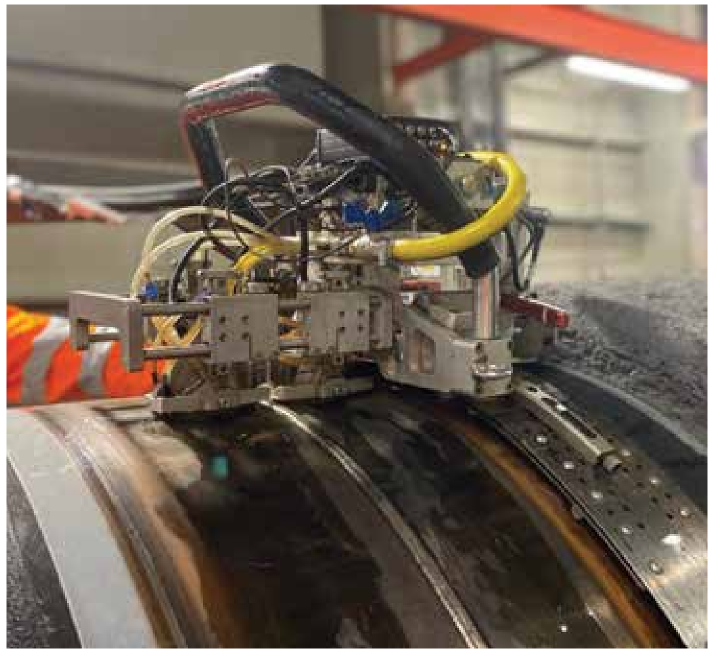

Figure 3 PipeWIZARD AUT Inspection during Offshore Pipeline Installation (courtesy of BCS-NDT).

Special Cases

Weld repairs. Unacceptable flaws are removed by arc-air gouging and grinding. The resulting irregularly shaped weld volume cannot be properly inspected by AUT configured for the original weld, so special measures are usually implemented. Repair welds are inspected with AUT to confirm the removal of the flaw found in the original weld, with TOFD and manual ultrasonic testing used to inspect the new weld volume. Limitations with MUT mean that ECA based acceptance cannot be used and welds must meet standard flaw acceptance criteria, (i.e. workmanship).

CRA and CRA clad pipelines. Corrosion Resistant Alloy (CRA) pipelines present many challenges for AUT inspection. Solid CRA, metallurgically clad or lined can be in various CRA alloys ranging from 316L and duplex stainless steels to Inconel 625. Due to the diversity of base materials, filler metals, internal CRA layers, and their manufacturing processes, various solutions have been used. For instance, lined pipes cannot be fully inspected by AUT, (the air gap between liner and carbon steel prevents passage of ultrasound) so CRA lined pipes are produced with a CRA welded overlay layer at both ends: the weld overlay ensures continuity between the CRA and the base material. The irregularity of the weld overlay fusion line generates distortion and diffusion of ultrasound energy, making the inspection extremely complicated. With a welded overlay, it is preferred to work with ultrasonic beams that do not skip on the internal diameter (i.e. zone discrimination) and instead go directly through the weld metal. In order to reduce the effect of attenuation from austenitic, coarse grain weld metal, low frequency, longitudinal wave probes are used. Phased array techniques provide many advantages for CRA and CRA clad inspection due to the possibility of generating multiple angles focusing at different positions in the welds. Nowadays it is common to see a combination of linear and sectorial compression wave scans, used on CRA lined pipes and this has only been made possible with phased array probes. CRA and CRA clad pipe offers better inspection options, but still require extra work with specific tests and developments.

Steel Catenary Risers. In critical areas (touch down and flex/stress joint area) the fatigue loading can be severe and tolerance to weld flaws very low. In such cases allowable flaw sizes are extremely small and on the limit for detection by AUT, e.g., surface defect 10mm long x 1.0mm high. Repair welding is not allowed, so consequence of a failed weld is a cut out. To achieve the required detection capability while reducing the number of false calls additional measures are often put in place. These can include items such as, increased number of zones with reduced height, smaller calibration reflectors, e.g. 0.5 mm deep surface notches, reduced range of thickness for calibration blocks, and special training and qualification of operators etc.

Future of AUT

The zone discrimination method applied with TOFD has shown itself to be reliable and address concerns for safety and speed. The introduction of phased array probes improved its flexibility and significantly shortened lead-in and preparation times. So far, (apart from use on CRAs), these probes have only been used to emulate fixed probe set-ups but they are capable of much more. From around 2004 articles started to appear describing methods to make better use of phased array probes and in 2015 Ginzell, Volf and Brown provided a full description of Full Matrix Capture (FMC) and Total Focus Method (TFM).[4] All of the suppliers and users of equipment for AUT are currently exploring these methods with a view to implementing them on pipeline welds.

Summary

AUT employing phased array and TOFD probes has shown itself to be fast, reliable and safe when used for pipeline girth weld inspection. Brief details of a typical AUT system and its application has been provided. For those wanting more details about the equipment and techniques, Olympus provide detailed information on their website.[2] A step change improvement is imminent since most involved in this area are investigating methods making better use of the phased array probes.

References

1. Amend, B., 2010. Early generation pipeline girth weld practices and their implications for integrity management of North American Pipelines. *8th International Pipeline Conference, Volume 1, Calgary, Alberta, Canada.*

2. www.olympus-ims.com/en/pipewizard/

3. DNV, 2021, DNV-ST-F101 Submarine Pipeline System. Edition 2021-08 - Amended 2021-12

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