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FLAW DETECTION AND CHARACTERIZATION IN WELDED SAMPLES USED FOR ULTRASONIC SYSTEM QUALIFICATION

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1. ABSTRACT

Offshore drilling platforms use a large amount of piping for risers that have wall thicknesses in the range of 1 to 1½ inches. These risers are welded on a piping barge with automatic welding tools that take approximately 2 minutes to complete a weld. To avoid possible environmental contamination and because the pipes are under tremendous stress, these welds must be inspected using an automated ultrasonic inspection system with a high defect detection sensitivity. In addition, the inspection must also be conducted in approximately 2 minutes or less.

The industry is very concerned about the quality of the automated ultrasonic inspections conducted, and has asked Southwest Research Institute® (SwRI®) to develop a method to independently characterize the probability of detection (POD) of automated ultrasonic inspection units. The procedure used to determine POD will be described.

2. INTRODUCTION

Often new off shore platforms take advantage of lessons learned from previous designs and installations. This could lead to new more efficient riser pipe weld designs, new weld prep designs, new materials, or different wall thicknesses. Changes in the welding process could also lead to new defect size distributions. A common weld inspection process is the use of a highly optimized, automated ultrasonic inspection (AUT) system that makes use of zone focused probes or phased array technology to provide a very good and very quick (often about 2 mintues/weld) inspection. To accomplish this high quality and fast inspection, the inspection equipment is often optimized to one pipe wall thickness and weld configuration to provide the most sensitive pipe inspection process possible. To meet the fatigue and life issues, often the defects that must be found are fairly small.

If changes in the weld configuration or pipe wall thickness are made, then usually the inspection system has to be re-optimized to account for these changes. There is a need to have an independent validation of the weld inspection process to provide a probability of detection (POD) for the inspection system.

SwRI has developed a process that can be used to provide an independent validation of the defect detection capability of the weld inspection system.

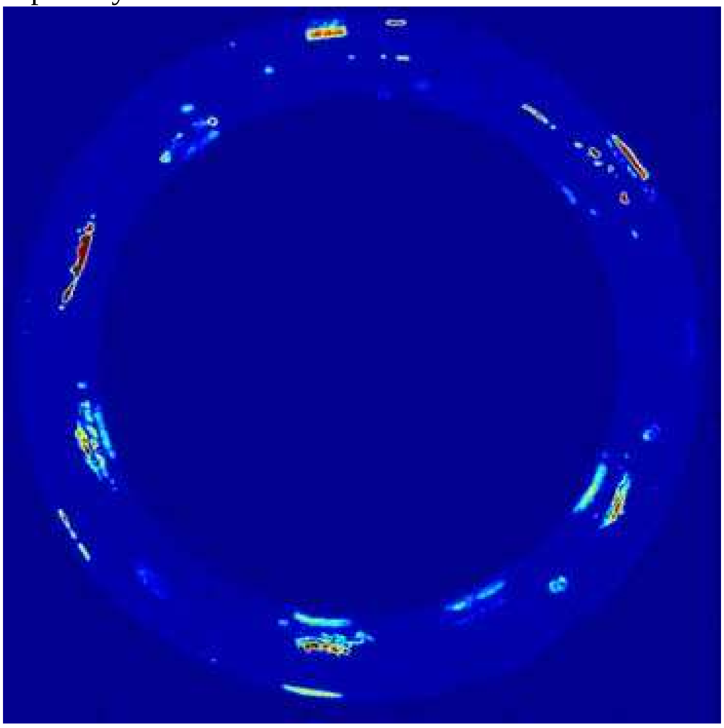
3. DESCRIPTION OF THE WELD VALIDATION PROCESS

To provide a thorough evaluation of the weld inspection system, the ground truth defect data must be available to compare to the results of the production ultrasonic inspection system. To accomplish this, SwRI first has the weld region cut out of the test pipe to produce a weld ring. Then, this weld ring is polished and inspected using 0-degree, focused L waves. This inspection process provides an image (illustrated in Figure 1). The weld ring is usually approximately 1- 1½ inches thick.

Figure 1.

These data are then correlated to the defect detection data obtained from the production weld inspection system to locate regions to be cut out and characterized. Defects as small as 1 mm by 1 mm can be detected with this type of focused inspection. In addition, based upon the B-scan, the through weld location of the defect can be determined. An example of a weld cut out and the ultrasonic image obtained from that region is shown in Figure 2.

Once the weld region has been cut out and mounted, a very careful process of slowly removing material and then taking sequential photomicrographs allows very accurate characterization of the defect. Since the production ultrasonic inspection systems are used for defect sizing as well, it is important to not only perform a POD but also to determine the accuracy of the defect sizing capability.



4. INSPECTION SYSTEM VALIDATION AND POD STUDY

Full blown POD studies are often specified for new inspection systems or weld joints with unusual geometry or materials such as thick-wall pipe or clad pipe. Less extensive studies can be used to validate a particular AUT system setup for a specific joint bevel design, welding process, and inspection orientation. Typically, the goal of a full POD study is to determine the flaw size that can be reliably detected 90 percent of the time with 95 percent confidence (90/95), and the goal for system validation is to check to see that a previously qualified system is performing adequately for a specific application. The main difference is the number of flaws needed to conduct the study and interpretation of the results.

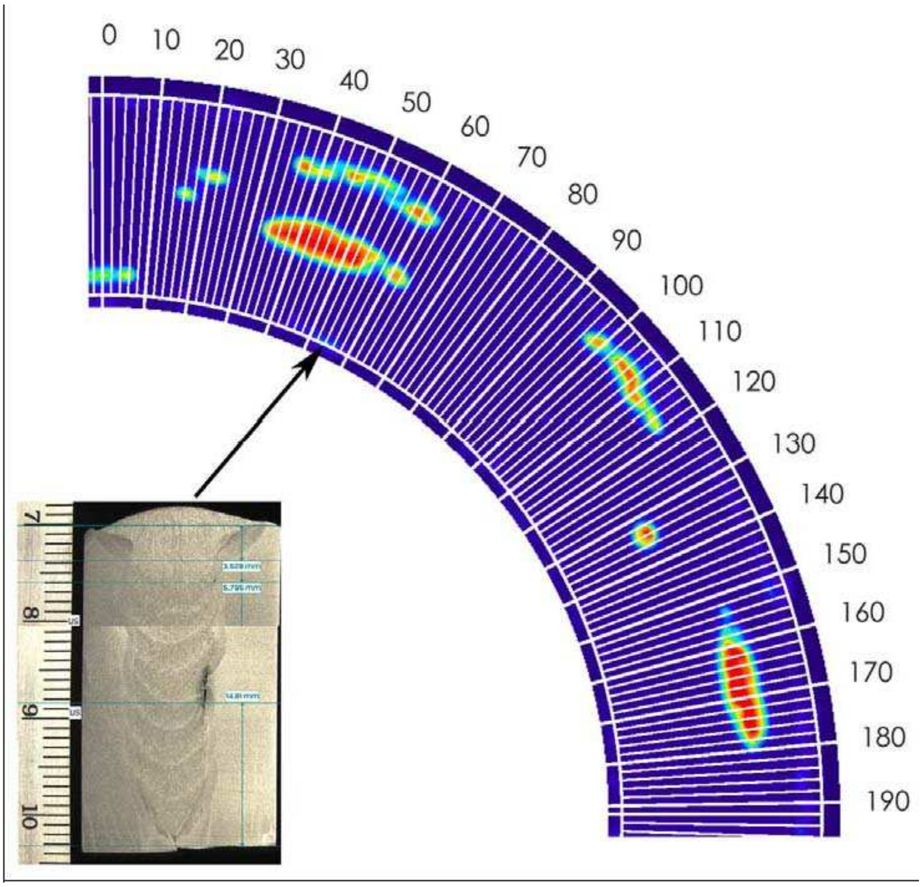


Figure 2.

For either a POD or validation study, flawed test welds are needed to conduct the study. Typically, seeded defects are placed in the weld during manufacture. Defect size, type, and location should be representative of defects known to occur in the welding process under investigation. A good distribution of defects for a POD study should include a minimum of 60 defects to support the 90/95 POD calculation. These tests are typically scored on a hit or miss (binary) basis. However, to achieve a more precise estimate of the 90/95 flaw size detected, the use of 120 defects is recommended.

For a POD study, the range of seeded flaw size must include small flaws that will not usually be detected and large flaws that will almost always be detected. Ideally, seeded flaw size will be distributed linearly and include flaws of various types and located at various depths in the weld. For a verification study, the goal is to confirm that some specified flaw size will be detected, and seeded flaw sizes should be selected at or near this threshold to confirm performance. If the seeded flaws are detected, system performance is verified. If the threshold flaws are not verified, then additional action must be taken to determine if the system is suitable for use. This might warrant a full POD study to determine actual system performance or further optimization to the system or operating procedure to correct the deficiency.

Test welds for the study should be manufactured using the same pipe, bevel design, materials, and welding procedure that will be used during fabrication. Several methods for creating flaws are available. Since these flaws will be destructively sectioned to determine true flaw size, precise control of flaw size during welding is less critical than for test pieces intended for continuing use without a destructive test. It is important to keep the welds clean in the unflawed areas to avoid confusion when the AUT test results are matched with the flaws. Crowding of flaws only leads to confusion later on in the process.

After the test welds are complete, they are sent to the AUT vendor for scanning. The vendor should build a calibration block from the same pipe material as the test welds and have adequate time to setup the scanner and confirm reliable operation and prepare a written procedure for data collection and reporting. The test welds should be scanned with the welds in the same orientation as they will be tested after fabrication (i.e., 2G or 5G). Once the test data has been collected the operator should report the results in considerable detail. Each flaw should be reported individually including detailed measurements on flaw location around the pipe, flaw depth in the material, flaw height, flaw length, and flaw location relative to weld centerline. If flaws are interpreted to be interactive with each other or one of the pipe surfaces, the resulting interactive flaw size should be reported along with identification of the individual flaws that are interactive.

Supplemental NDE is then performed on the test welds to learn as much as possible about the flaws. Typically radiographic tests (RT), magnetic particle tests (MT), visual test (VT), and an immersion ultrasonic test (IUT) are performed on each test weld. The RT test is conducted first while there is sufficient pipe adjacent to the weld. Then, the weld is cut from the pipe to form a ring with flat and parallel sides. Flat bottom hole reflectors are machined into the pipe ring to provide a confirmation of scan sensitivity and as reference locations when marking the weld for destructive sectioning. Figure 3 shows a weld machined for IUT. This is also a convenient time to conduct VT and MT inspections while the weld root area can be easily viewed.

A preliminary report is then prepared to summarize the supplemental NDE data. Each identified flaw is listed along with pertinent data, including flaw location, depth, height, length, and location in the weld (upstream or downstream). These data are then matched to the AUT test report. Flaws with matches between the validation data and the inspection data are further compared to determine agreement in flaw size measurement. Flaws detected using the supplemental NDE process with no matches in the AUT data are listed as misses and AUT indications that don't match up to flaws detected with the validation process are listed as false calls. A careful review of the preliminary matching data is made to determine where destructive sections will be made. The destructive sections are used to confirm false calls, confirm misses and to resolve discrepancies in flaw size. Additional cuts are made at locations where maximum flaw size is indicated by either supplemental NDE or AUT to determine actual flaw size.

Figure 3.

Destructive flaw reports are then integrated with the supplemental NDE reports to compile a final list of flaws and locations where no flaws were found. These data are then matched with the

AUT test report to arrive at the final hit/miss score for each flaw and false call. At this point a flaw population chart can be made showing the distribution of flaws by depth, length, and height. Using the final flaw list, a POD curve is fit to the hit/miss data and confidence limits are calculated. There are several POD model curves available for use at this point and a choice of using the flaw size or log of the flaw size when fitting the curve. The February 2007 Draft of MID-HDBK-1823 offers a brute force approach to selecting the best model by solving eight different POD (a) models and reporting the deviance for each. After selecting the best model for the data set, confidence limits are calculated and the resulting curve is the POD for the study. A typical POD result curve is shown in figure 4. The solid curve represents the best fit of the POD model to the data. The dashed curve represents the 95% confidence limit. The 90/95 defect size is larger as would be expected.

5. CONCLUSIONS

Even though a few random sections are cut, POD studies that rely solely on the AUT test data to determine where cross sections are to be made may overlook significant flaws and reach misleading conclusions. High resolution immersion scan images of test welds have led to significant cost savings and improved understanding of test results in POD studies. AUT system verification tests may be run on rejected production welds by performing immersion ultrasonic testing of welds, weld cut-outs to verify accuracy of the calls, and a quick review for missed defects.

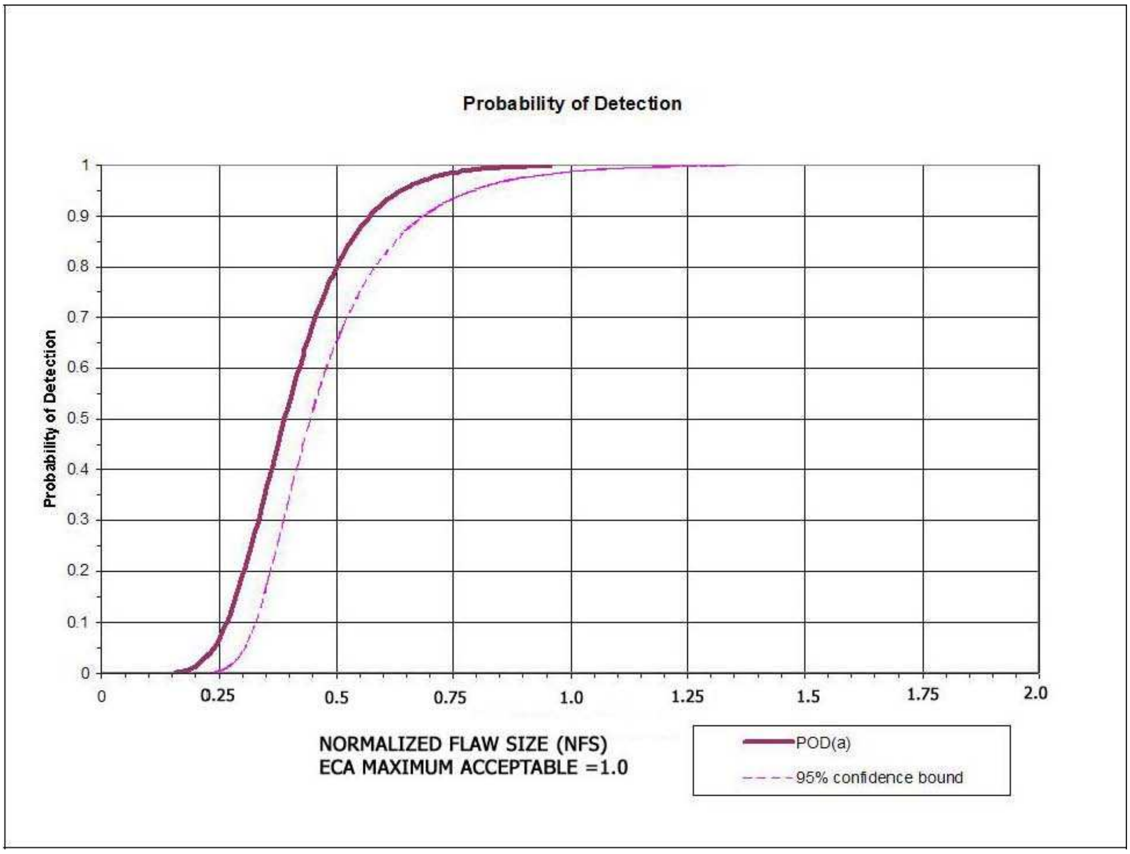


Figure 4.

6. LIST OF FIGURES

Figure 3. Photograph of a weld ring removed from a pipe and used for ultrasonic immersion testing

Figure 4. An example POD curve. The solid curve represents the best fit of the POD model to the data. The dashed curve represents the 95% confidence limit.