Virtual Round Robin 2

Introduction

Round-robin exercises are instrumental in assessing the current capability of non-destructive inspections. Especially for challenging inspections, such as dissimilar metal welds, blind exercises and comparative studies give vital information about the true capability of various used methods and procedures and enable comparison between currently used and newly developed methodologies. For inspection companies, round-robin exercises give rare opportunity to benchmark against other inspection companies.

Probability of detection (POD) analysis is routinely used in many industries to quantify the NDT performance. For the nuclear industry, POD has proven difficult to obtain. The key reason for this is, that proper POD determination requires statistically significant number of cracks in a blind inspection exercise and producing (and testing) large number of cracked samples has been economically infeasible. Recently, the use of virtual flaws have made it possible to increase the apparent number of cracks in ultrasonic data artificially and to produce statistically significant data set without manufacturing or scanning equal number of actual physical mock-ups. The way this works is, that a limited number of mock-ups and flaws are scanned to form a source data file. This source data file is then modified to produce number of data files with varying number and types of flaws included. Within the framework of international project "PIONIC" (Program for Investigation of NDE by International Collaboration), this new technology is put to use in the form of a new round-robin exercise. A blind data set is going to be manufactured, that contains sufficient flaw information for producing standard POD analysis. The data set is going to be analyzed by project teams from participating countries: U.S.A, Switzerland, Sweden, Korea, Japan and Finland. The round robin is open for everyone, and industry participation is invited.

Such a virtual round-robin provides several advantages over traditional round-robins: there's no need to ship the physical samples around and thus participating companies can act in parallel, greatly speeding up the process. While the data modification may induce some characteristic features on the data (e.g. repeating noise), the virtual flaws themselves are indistinguishable from normal flaws in the data. Furthermore, the repeated effort of scanning the samples is avoided, and the round-robin can be focused on data analysis only. This reduces the effort required to participate. At the same time, to provide sufficient result for statistical analysis and POD determination, significantly greater number of flaws and data are needed.

This is the second virtual round robin, and it addresses some of the limitations of the first round robin. In particular, the data is more comprehensive and more representative to actual field inspection. Sufficient data is provided for sizing as well as detection.

Arrangement

The round-robin concerns a dissimilar metal weld inspection, performed using phased array ultrasonic inspection. The source data is scanned at VTT (Finland) using a pre-manufactured mock-up. The data file is then modified in various ways. The existing flaw indications are removed to form a clean canvas. Then, number of flaw indications are re-introduced into the data, with possible modifications. To provide sufficient data-length for inclusion of statistically significant number of flaws and opportunity for false calls, a number of data files are generated to form the total data-set. For each participant, the data files are provided through a download link at a set date, and results expected via an upload link at given deadline. The data sets provided to each participant may be obfuscated to avoid direct comparison. However, each data set will contain similar flaw indications and thus present comparable data for comparison and benchmarking. The data files will be provided in UVData file format, and thus participation requires equipment capable of reading this fairly common file format. Limited conversion to open formats are available on request.

The data acquisition is done according to simplified procedure presented in Annex 1. The procedure also includes guidelines for data analysis. The participating companies are free to make exceptions to the procedure, but must document any such exceptions to the notes section in the Excel file.

The main focus of the round-robin is flaw detection. However, it is of interest to also use this opportunity to benchmark sizing capability. Each inspector is free to report either detection only or detection and sizing. Also, the inspectors may also choose to size just some of the flaws. If sizing is performed, the technique used shall be noted in the report.

The source mock-up is a dissimilar metal weld with thickness of 70 mm and OD of 1245mm. The scan data includes a single index line with TRL phased array beam focused at the weld root. The scan line has been pre-selected to represent the optimal probe location. The provided data files contain sections of the total mock-up spanning ≈ 500 mm each.

The data set contains 13 separate files, each representing a scan area of potentially different weld. The files are similar in all respects, except for the virtual flaws, which have been modified. The scan data has been slightly obfuscated to avoid direct comparison between individual data files within the set and across separate sets. In addition, number of virtual flaws have been inserted to facilitate the detection task. Number of separate files are needed to give sufficient inspectable area for the flaws needed for POD analysis.

Result analysis and anonymity

All participants are provided with full analysis of their own inspection results, as detailed below. In addition, all the teams are given anonymous designations, and anonymized data for all the participants are given to all the participants. Should the results include some identifying patterns that may jeopardize this anonymity, the participants are given opportunity to remove their data from the anonymized set. Selected summary statistics (such as average results and descriptive ranges) are shown, so that the participants can easily compare their results with general level of performance.

The flaw detection data is analyzed using ASTM-E2862 hit/miss POD analysis, as applicable. Each team/participant is provided with a POD curve describing their teams capability, if such can be obtained from the data. In addition, the true state information is provided to the participating team to allow further analysis of the results.

The standard POD analysis requires flaws small enough to be missed, flaws that are found and flaws in the range of non-zero and less than one probability of detection. Consequently, the data will include indications that are very difficult to detect. It is expected that some indications are missed by all the participating teams. Conversely, some indications are expected to be found by all the teams. Finally, many indications are in a range where some teams are expected to find them and some are expected to miss them. False call performance is analyzed and reported separately. If the number of false calls is great enough, that it significantly affects the computed POD, then the results may be disqualified. Therefore, it is important to only report sure findings.

The flaw sizing data is analyzed using standard RMS-values and individual result differences. No procedure is provided for flaw sizing. The teams are encouraged to use their own procedure and to report the procedure they used. It is understood, that the available data may limit the available sizing procedures and capability. Thus the capability will provide comparative information and benchmarking and may not reflect the capability of any particular team with different acquired data.

Participation

Any interested party is invited to participate in this round robin. The blind data files will be made available on 2022-06-01 and responses expected no later than 2022-09-01. Within this period, the teams will have 14 days to complete the inspection, starting from the moment the data files are downloaded. The data files will be provided by individual download links. Results shall be reported with a given Excel sheets that will be uploaded to the download server. To facilitate rapid analysis, the results are read automatically and thus it is vital that the results are reported following the sheet format.

Inspection procedure

```
Identification: 2022 virtual round-robin 2 procedure
Revision: 1
Date: 2022-05-24
```

Introduction

This annex describes a simplified inspection procedure for supporting data evaluation in virtual round-robin exercise. The procedure is not complete in the sense, that it could be used to replicate the inspection. For brevity, many details of the instrument set-up and the like have been left out, since these would not affect the data analysis in the round-robin.

The round robin is concerned with ultrasonic examination of dissimilar metal piping butt weld, as described in the following. The inspection is conducted from the outer diameter (OD) using automated scanning.

The round robin data contain cracks and crack-like defects. All the cracks are ID connected circumferential defects.

Reference

This procedure is based loosely on EPRI enc-DMW-PA-1 procedure.

Inspection set-up

Component geometry

The component geometry is depicted in Figure 1. The component is inspected for circumferential flaws. All flaws are ID connected. Weld centerline is at zero, with positive coordinates towards stainless steel side (and negative towards carbon steel side).

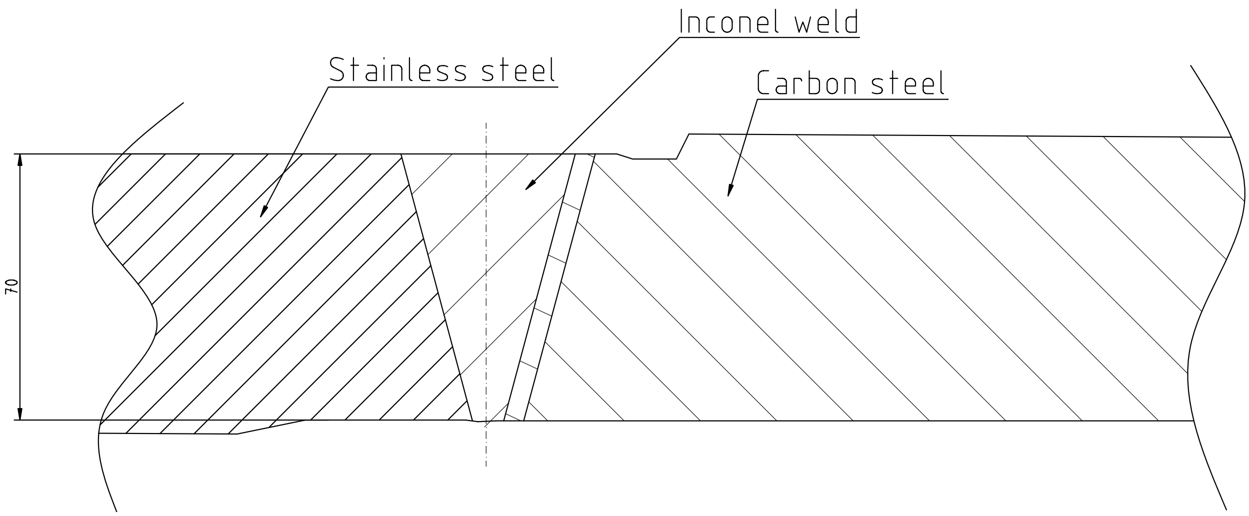

Figure 1. The component geometry

Equipment and acquisition set-up

The acquired data files are saved in the UVData file-format. The files are subsequently modified to introduce various virtual flaw indications. However, the modification is limited to the raw ultrasonic data, and the file retains the scan data, coordinate values, etc. from the original saved scan file. Data is acquired with 16 bit depth, 100MHz digitizing frequency. Data is saved from flight time 24.7 – 45.68 µs or 53–98 mm true depth.

The applied phased array focal laws are computed to create a focused beam at the weld root area using the whole aperture of the probe.

Scan plan

The weld is inspected from the stainless-steel side using automated scanning. A single scan line is acquired from number of different sections of the sample (each in a separate file).

Calibration

The ultrasonic signal strength is calibrated against 3 mm side drilled hole. The echo amplitude from side drilled hole at 35 mm distance is set to 80% of full amplitude.

Data analysis and evaluation

The inspectors are free to use other views or settings as per their respective procedure.

Flaw detection

Each data file and corresponding channel shall be evaluated in detail, to identify indication responses withing the volume, which exceed the typical baseline noise level. The following procedure is provided for guidance:

1) Gate the examination volume to validate coverage and identify general benchmark information (root geometry, interface responses, etc.)
2) Gate specific regions withing the volume. Isolate unique patterns and responses. Compare the responses from different angles and skews to establish relevancy.
3) Adjust soft gain or palette range as needed to improve pattern contrast.

Indication classification

All indications, regardless of amplitude, shall be investigated to the extent necessary to characterize and determine the nature of the indication. Indications shall be classified as either non-relevant or flaw indications.

1) Non-relevant indications are indications produced by reflectors within the volume to be examined that can be attributed to the geometrical or metallurgical properties of the weld configuration.
2) Flaw indications are indications within the examination volume, regardless of amplitude, which cannot be clearly classified as non-relevant.

The following characteristics may, among other, indicate an indication is non-relevant:

1) The indication can be seen across the entire length of the scan (continuously or intermittently) at consistent amplitude and position responses
2) The indication possesses very little or no echo dynamic travel in the depth direction
3) When compoarison is made between responses from lower and higher beam angles, the indication responses are significantly lower or not detected with the higher beam angles

The following characteristics may, among other, indicate an indication is a flaw indication:

1) The indication has high signal-to-noise ratio
2) The indication response is isolated from common geometrical benchmark responses
3) The indication displays several areas of unique and inconsistent amplitude peaks
4) The indication has defined start and end points
5) The indication shows evidence of flaw tip signals
6) When comparison is made between responses from lower and higher beam angles, the indication responses are comparable or higher amplitude with the higher beam angles

Please note, that no signal threshold or reporting threshold is given, and all signals distinguishable from the background noise have to be classified. Only indications classified as flaws are to be reported.

Flaw sizing

The participants may optionally take part in flaw sizing exercise either both circumferential sizing and depth sizing or just either one. If some of the flaws are considered impossible to size, this shall be clearly noted in the excel sheet. To avoid selection bias, it is forbidden to only size selected flaws. If the inspector wishes to limit the effort spent on sizing, they may omit sizing in number of high-numbered files of their selection. That is, the inspector may (separately for length and depth):

1) Choose not to participate in sizing
2) Choose to participate in sizing for all files and all marked indications
3) Choose to participate in sizing for selected n number of files, which then must be the files numbered 0…n-1, and for those files the sizing must be complete (all marked indications chosen)

Circumferential flaw length sizing is to be performed as follows:

1) Position the software gates in an unflawed region and observe the general benchmark responses (e.g. those attributed to root geometry or interface response). Adjust system sensitivity (soft gain or palette range) as needed to improve pattern contrast
2) Position the software gates to optimize the flaw response, again adjusting system sensitivity as needed to isolate the flaw responses from the general benchmark responses. Identify the beam directions and examination angles yielding adequate flaw response.
3) The length of the circumferential flaw is determined using the full amplitude drop method.

The technique above provides an outside diameter length dimension, which is longer than the actual inside diameter length dimension. Report this outside diameter length, do not correct to estimate inside length.

Circumferential flaw depth sizing is to be performed as follows:

1) Preferred method for depth sizing is using the absolute arrival time technique, i.e. identifying the echo attributable to the highest flaw tip and determining its height using the analysis software. Flaw depth (through-wall extent) is then computed by subtracting the remaining amount of unflawed material from the actual measured thickness at the flaw. When sizing is based on this method, it shall be indicated in the results by noting "flaw tip" in the notes.
2) If direct signal response from the flaw tip cannot be obtained, a conservative measurement shall be made using the upper extend of the flaw image. This shall be indicated in the results by noting "flaw image".
3) Available software tools (e.g., echo dynamic curves, single plane and projection modes, raw A-Scan data, volumetric merges, digital smoothing, etc.) shall be used to optimize component and flaw responses.
4) Evaluate all available data and identify the beam directions and -angles that provide adequate flaw responses. Compare them to identify flat tilt/skew and estimated flaw depth.
5) Gate and isolate unique patterns and responses associated with the flaw in the C-Scan and B-Scan or D-Scan views. A specific emphasis needs to be placed on isolating the direct longitudinal wave responses from accompanying shear wave or mode conversion responses.
6) Relocate the gates to nearby unflawed region and compare the general benchmark responses. Adjust system sensitivity (gain or palette range) as needed to improve pattern contrast.

7) A-scan data from each beam angle and wave mode that adequately detects the flaw shall be evaluated prior to final depth sizing determinations.

8) Final flaw depth shall be measured using the beam angle (channel) which provide the most reliable and credible tip responses. This channel shall be noted in the report notes.

Reporting

All reporting is done electronically using the Excel sheets provided together with the data files. The sheets are read programmatically, and thus should be filled in with care and only with indicated cells. The sheets include team identification data on the first sheet. The second sheet provides space for reporting the found flaws. Each detected flaw is reported on a separate row with reference to the file name, x (scan direction) location, flaw start location, flaw end location and for sized flaws through-wall extent. The filled-in Excel sheets are returned by uploading on the web-site.