IIW Phased Array Calibration Block

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Abstract

The IIW is an active organization in the area of weld based topics. Within a structure of 16 independent commissions and other working groups, the IIW gathers together people from the perspectives of fabrication, maintenance, and inspection to discuss and forward the state of the art in welding. Within this framework, Commission V is dedicated to quality assurance of welded products and has four sub-commissions: VA on radiographic weld inspection; VC on ultrasonic weld inspection; VE on electric, magnetic and optical inspection; and VF on NDT reliability including simulation.

Commission V is probably best known around the world for design of the IIW calibration block used for ultrasonic inspection. This paper describes a project started within Sub-commission VC to design a calibration block specifically for phased array inspection. This calibration block is now being voted on at ISO, which should result in an international standard describing the blocks manufacture. This paper will describe the IIW project to design this block, along with the suggested usage of the block.

Keywords: Ultrasonic testing, UT, phased array, PAUT, calibration block

1. Introduction

For many years the IIW block, or more accurately referred to as the ISO 2400 block, has been used for basic ultrasonic calibrations. This block meets basic code requirements for calibration of ultrasonic systems when performing standard inspections, such as material velocity and wedge delay calibration over a range of material thicknesses. This block also has other features such as probe index measurement, probe angle verification and the ability to set AWS inspection sensitivity.

The history of the IIW block was that it was originally designed in Commission V of the International Institute of Welding. The IIW is an international organization that focuses on welding based topics, and has a series of Commissions dealing with aspects of welding. Commission V focuses on NDT and quality assurance of welded products, with Sub-commission VC dealing with ultrasonic based weld inspection techniques. The original IIW document describing the IIW block was eventually adopted and formalized as ISO 2400, which is the current standard describing manufacture of the this block.
Discussion within IIW Commission V started in roughly 2009 about phased array ultrasonic testing (PAUT) and the IIW block. With the introduction of PAUT and its subsequent widespread adoption in industry, there has been a significant change in the way that ultrasonic inspection is performed. There are international standards that describe how to perform PAUT, but no such standards describing what blocks should be used for calibrating PAUT systems. As such, people in different parts of the world deal with PAUT calibration in a variety of ways.

The original question asked in Commission V was: is the existing IIW block well suited for PAUT calibration or is another block required? The answer to this question turned out to be that the IIW block did not satisfy all PAUT calibration requirements, so Commission V started a project to design a calibration block especially for PAUT. A working group was formed with representation from many countries. This working group was active over a period of roughly five years, and performed the majority of the work electronically via Web based meetings. Project update reports were presented to IIW Commission V at the Annual Assemblies where approval for the ongoing work was received.

2. Discussion

2.1 Project Background

Initial work focused on defining the project scope and goals. The statement of purpose for this project was: design a practical and affordable phased array calibration block that can handle the basic calibration functions required by existing standards, which is widely applicable to many industries and countries. The basic PAUT calibrations are: material velocity calibration, wedge delay and angle corrected gain calibration. Other requirements for the block were as follows:

- The PAUT block must be backwards compatible with all existing ISO 2400 calibrations. It is not commercially feasible to require two calibrations blocks for PAUT and manual UT,
- The block must be portable and cost effective,
- The block must satisfy all relevant code requirements.

2.2 Codes

It was clear that the manufacture of the PAUT calibration block must be governed by an ISO standard in order for the block to be widely accepted in the world. IIW has a relationship with ISO, in that the IIW can write technical standards and submit them to ISO without the normal ISO review process. This path to standardization was chosen, with the IIW document submitted to ISO TC 135 SC 3, which is the ISO technical committee that is responsible for ultrasonic testing. If fact, we were able to invite experts from ISO onto the IIW committee to aid with development of the calibration block. The subsequent standard, ISO/WD 19675, is now in the final voting stage and it will hopefully be a full ISO standard later in 2015. Figure 1 shows the PAUT calibration block design as it appears in ISO/WD 19675.
Figure 1. PAUT Calibration Block
It was also clear that the calibration block must fulfill all necessary code requirements. The two main codes that were considered were ISO/EN and ASME code. These codes deal with PAUT slightly differently and have different requirements. In general, ASME doesn’t specify calibration blocks but rather guidelines on what calibration must accomplish. The ASME working group decided to defer to the IIW working group for calibration block design. EN code is more prescriptive and detailed with regards to calibration block requirements. CEN has drafted three phased array standards within ISO 18563 that are divided as follows: Part 1: Phased-array instruments, Part 2: Phased-array probes and Part 3: Phased-array systems. It is Part 3 that is most relevant for this work, and it requires several additional checks compared to ASME:

- Verification of channel assignment and measurement of relative sensitivity variations,
- Some beam characterization measurements, including squint angle and grating lobes,
- Simultaneous measurement of the index point and the angle of refraction,
- Check of imaging and imaging algorithms, which is mainly required for S-scans.

2.3 Other Considerations

There were discussions about other capabilities that could be built into the block. With phased array, there are many application specific measurements that are outside code requirements but that can be required for specific applications. Examples of some of these possible measurements are: determining angular resolution, determining angular sensitivity, setting inspection sensitivity, setting notch sensitivity, maximum steering angles, etc.

When discussing these capabilities, it quickly became unclear how to handle these requirements. For each such capability that could be built into the block, there were many possibilities that could be required by a specific application. For example, when considering angular resolution, any measurement is a function of incidence angle, sound path, the size and spacing of the reflectors being used. If side drilled holes (SDH) of a specific diameter and spacing were used at a given sound path and angular direction, this only provides information about angular resolution in this narrow slice of phase space making it a limited measurement. This issue is similar for all of these measurements, meaning that no comprehensive solution is possible in a single block. For this reason, it was decided to not include these capabilities into the calibration block. These requirements are job specific, and must be addressed as such.

The exception to this is inspection sensitivity. The vertically oriented SDH’s have been added into the block for other reasons, but they provide a limited capability to set inspection sensitivity. The diameter of these holes is 3 mm, which allows sensitivity to be set as per European codes and a limited sensitivity range for ASME code.
3. Block Design

3.1 Modeling

To the best of the working group’s knowledge, this is the first ultrasonic calibration block designed primarily using ultrasonic beam modeling software. CIVA™ was used for this work, which is a software developed by CEA in France. CIVA™ is a sophisticated full beam propagation model that uses a semi-analytical method based on the synthesis of the impulse response function, allowing modeling of defect interaction as well as 3D anisotropy modeling.

Modeling for the PAUT calibration block was done in two stages as per a modeling matrix agreed upon by working group members. The first stage was to model the overall positioning of reflectors for high level block design. The goal of this stage was to set an overall block design that incorporates all of the required functions. An example of the type of modeling done in this stage was to model the response from the vertically oriented SDH to ensure that a quick calibration check can be done for S-scans without interfering echoes, as shown in Figure 2. Part of this stage was also to choose the outside dimensions of the block.

The second stage of modeling was to determine how the block responded to different PAUT probes and different levels of anisotropy in the steel. Much work was done on how to measure anisotropy and to set criteria with regards to the amount of anisotropy permitted for this block. Rolled steel will always have grain structure variations in different planes, which leads to variations in acoustic proprieties. This “birefringent” effect is shown in Figure 3.

Figure 2. Modeling of S-scan response from the vertically oriented SDH
Figure 3. Illustration of the birefringent effect observed in an anisotropic medium with transverse waves when rotating the probe in one position.

Figure 4. Annex B probe index measurement.
3.2 Block Usage

Included in Annex B of ISO/WD 19675 is a usage document that describes how to perform both manual UT and PAUT measurements using this calibration block. Annex B is a shortened version of an IIW Booklet that describes these measurements in greater detail. An example of how to perform a probe index measurement is shown in Figure 4 and a B-scan output from an element assignment measurement is shown in Figure 5. The element assignment measurement is done using the sloped back wall; note that element activity can be done on parallel flat surfaces but element assignment requires a sloped surface.

4. Conclusions

This project for design of a PAUT calibration block is now almost complete, with the ISO standard being issued later in 2015. It is the hope of the working group that this calibration block becomes a useful tool that is used in industry for calibration of both manual UT and PAUT inspections.

Acknowledgements

The authors would like to acknowledge all of the people on the IIW working group, in IIW Commission V and in ISO TC 135 SC 3 who contributed to this project: Krishnan Balasubramanian (India), Philippe Benoist (France), Colin Bird (UK), Rick Cahill (USA), Pierre Calmon (France), Daniel Chauveau (France), Gerd Dobmann (Germany), Ed Ginzel (Canada), Weina KE (France), Michael Moles (Canada), Guiseppe Nardoni (Italy), Udo Schlengermann (Germany) and Eric Sjerve (Canada).