

DISCIPLINE INFORMATION NOTE

Miscellaneous

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To: All Mechanical Engineering Specialists in HSE

RECOMMENDATIONS ON THE USE OF PHASED ARRAYS FOR THE NON-DESTRUCTIVE TESTING OF SAFETY CRITICAL COMPONENTS

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INTRODUCTION

HID CD5 were involved in a joint industry project (JIP) run by Mitsui Babcock that evaluated the benefits of using phased array ultrasonic inspection. Members of the JIP included Magnox, SAFed, MOD, BAE Systems and R D Tech, all of whom had expertise or specific interests in the use of phased arrays.

The project deliverables are summarised in this paper for use as guidance to those who need to assess any NDT report or procedure that includes phased array technology.

BACKGROUND TO PHASED ARRAY TECHNOLOGY

Phased array ultrasonics can offer improved defect detection and sizing capability over conventional ultrasonic techniques. It also offers improved inspection speed compared to conventional ultrasonic probes. These benefits arise from the ability to vary the beam angle and focal range, and to sweep the beam along the length of the probe. Associated advantages are that a phased array probe can replace a bank of conventional probes for automated inspection simplifying manipulator requirements. Phased array probes can be applied from surfaces where restrictions would limit scanning with conventional probes.

As with any ultrasonic system, the inspection procedure must be properly designed, the equipment checked and the beams properly characterised. A phased array probe contains a number of elements and a particular probe - wedge combination can generate a very wide variety of beam angles and shapes. Characterisation and checking of phased arrays therefore requires consideration of a wider range of issues than is the case for conventional ultrasonic probes.

Extensive work on the assessment of phased array probes, probe - wedge combinations and beams has been performed as part of this project. The work is reported in the document "Phased Array Probes: Assessment of Basic Parameters and Beam Characteristics", that is available within HID CD5.

KEY RECOMMENDATIONS

- ESI and BS-EN standards can be used as the main basis for checking array probes and characterising beams, but with different tolerances for signal-to-noise ratios and spurious echoes.
- A simple probe acceptance test is required as, for example, the one described in section 2 of the referenced report used to verify the ultrasonic response for varying combinations of probe elements.
- This test of the probe elements should also be carried out on a routine basis in accordance with the requirement for periodic checking defined in BS – EN 12668, Part 3:2000
- Ensure that, when used, beams are characterised and sensitivity is set before, and checked after an inspection.
- The use of a run gain correction factor (additional 2dB gain or similar) may allow for a number of probe elements to fail over the course of an inspection while maintaining the sensitivity of the inspection system above some threshold.
- The generated beam angles and index points should be confirmed using an effective and rapid beam characterisation procedure. An example procedure is presented in Appendix F of the referenced report.
- The influence of wedge material should be accounted for in terms of the effect on beam frequency as it passes through the wedge.
- There needs to be a set of tolerances that are used for the key probe / wedge parameters, that determine the focal law calculations.

KEY POINTS TO AUDIT PHASED ARRAY REPORTS AND PROCEDURES

Practical trials have been performed on a number of test pieces containing real or synthetic defects to investigate the detection and sizing performance of phased array probes, and to provide guidance on the design of phased array procedures. This work was split into two phases, with phase 1 concentrating on simple ferritic butt welds and phase 2 concentrating on more complicated applications.

The main recommendations and guidelines from these trials (and from the JIP Steering Committee's experience) are as follows:

- Staff operating phased arrays need to be fully trained to operate the equipment successfully and to recognise when the equipment is not operating in the way specified by the NDT procedure. This is far beyond PCN Level 2 Ultrasonics, that could form the initial procedural basis, and should be specific for the equipment, materials and geometries to be inspected.
- Ensure that when used, beams are characterised and sensitivity is set before, and checked after an inspection.
- A full raster scan employing a large number of different generated beams (e.g. different beam angles) may generate an overwhelming amount of data. Combining data from such a scan into composite images can be useful for initial assessment, but detailed

characterisation of defect images is likely to require separate analysis of each relevant beam.

- A particular probe - wedge combination will only generate useful beams over a limited angular range. For the probes used in this project the range was typically $\pm 15^\circ$ either side of the wedge nominal angle.
- Phased array equipment and techniques are more sophisticated than is the case for conventional ultrasonic inspections. Procedure design is therefore likely to require more care and effort.
- Careful design of probe - wedge and generated focal laws is required to reduce the effect of standing echoes.
- Scan time can be significantly reduced by scanning the probe parallel with the weld (repeated at different stand-offs if required) and performing either an azimuthal scan (sweeping the beam angle) or an electronic linear scan (sweeping the beam along the length of the probe) to achieve coverage of the inspection volume.
 - From the work performed on the specific test pieces and defects used in this project there appeared to be no significant difference in capability for detection or sizing between the azimuthal and electronic linear scanning approaches
 - In terms of application, the azimuthal approach is simpler since the linear scanning approach generally requires scans to be repeated at different stand offs
 - An azimuthal scan from a fixed stand off requires full skip inspection to achieve coverage of near surface zones.
 - Note that as with any ultrasonic inspection procedure, consideration must be given to whether the beams and sensitivities employed will provide reliable detection for the defect types and orientations of concern, not just whether full coverage of the inspection volume is achieved.
- Focusing improves detection capability by improving signal to noise ratio close to the focal depth (particularly beneficial for scattering material such as austenitic welds) and by improving tolerance to defect orientation. Focusing will be stronger the more elements are used to generate the beam, although this will be at the expense of reducing the depth of focus (the distance along the beam over which useful focusing is achieved). Note that no probe can produce a focus beyond its near field range.
- Phased array techniques can offer significant benefits for the inspection of complex geometry components. In such cases modelling is highly recommended in order to develop the inspection procedure, illustrate the achievable coverage and assist in the interpretation of scan data.
- Modelling of beam performance is important to ensure that beam side lobes and array grating lobes will not interfere with the inspection.

CONCLUSIONS

Phased array ultrasonics are already in use and may come into more common usage for the inspection of safety critical components. They may be particularly useful for non-invasive inspection methodologies and replace more traditional NDT practices.

Basic parameters that can be audited during an inspection have been reported in this DIN.

For further information please contact the HID CD5 General Office.