IS THERE REALLY ANY VALUE TO MULTIPLE ANGLE MANUAL INSPECTION?

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Abstract

Phased array technology has crept into a wide range of traditional ultrasonic applications. Recent advances in battery powered computers, displays, and low power consumption components has allowed increasingly smaller ultrasonic testing equipment to be built. GE Inspection Technologies explores the Physics behind an increase in probability of detection when single angle manual ultrasonic inspections are replaced by multiple angle inspection techniques. Choice of angle for any inspection includes assumptions about the orientation of defects. Multiple angle inspection with manual Phased Array has been claimed to minimize missed defects as their orientation to the beam becomes more oblique. An exploration of the science behind these claims is made. The addition of real time imaging on battery powered field portable equipment supplies the user an understandable representation of the multi angle result. But: is there any real increase in probability of detection (POD)?

1. Introduction

In order to understand if and how multiple angle ultrasonic inspection influences the probability of detection of flaws a test set up had been created that could ensure a reliable comparability between inspection results gained with conventional single angle inspections and multiple angle inspections with phased array technique.

This paper will describe the applied experimental arrangement and equipment, give illustrations of the single steps that have been carried out during the comparison tests and finally give comments on the results and their relevance for POD.

2. General Test Setup

In a first step a test specimen had to be defined. A test block depicting defects in aluminum was created, patterned after IIW Type II or V1 (Fig.1, Fig.2). Aluminum was intentionally chosen to be the material of the block in order to avoid sound attenuative effects as much as possible. After having defined areas of interest on the test block a phased array probe and a conventional angle beam probe had been selected. Special emphasis had been put on the comparability of the phased array probe and the conventional probe regarding their ultrasonic properties. Comparison measurements on the selected areas were then exclusively conducted with these two dedicated probes.

2.1. Used equipment

The following gives a list of the equipment that had been used for the investigation:

- Phasor XS portable phased array instrument
- Phased array probe MWBPA-5 detachable wedge 32 element 0.5mm, pitch 10 mm elevation – 16 element aperture
- USN 60 conventional ultrasonic flaw detector
- Conventional shear wave probe MWB 70 – 4 with fixed wedge angle
- UltraDOC V 4.42 Software
- Modeling Excel sheet.

Fig. 1 Aluminum test block

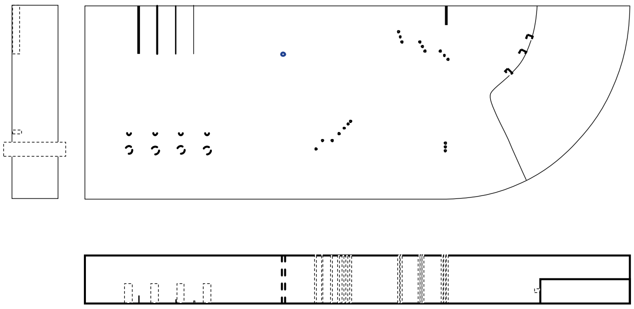

Fig. 2 Aluminum test block with groups of artificial flaws

2.2. Methodological approach

After having defined the areas of interest on the test piece in a first step the beam of the phased array probe was modeled with the a modeling Excel sheet. This is a tool where the sound path and sector coverage can be made visible as a 2D cross section against the applied probe, part and scan data such as probe and wedge dimensions, frequency, aperture, part size and geometry and scan pattern. The instrument settings of the portable phased array machine were then adjusted accordingly.

Within the test phase the conventional probe and the phased array probe were placed in the same positions and screen shots were taken from the corresponding instruments (phased array probe = Phasor XS, conventional probe = USN 60). Finally the results shown on both recorded displays were compared to each other.

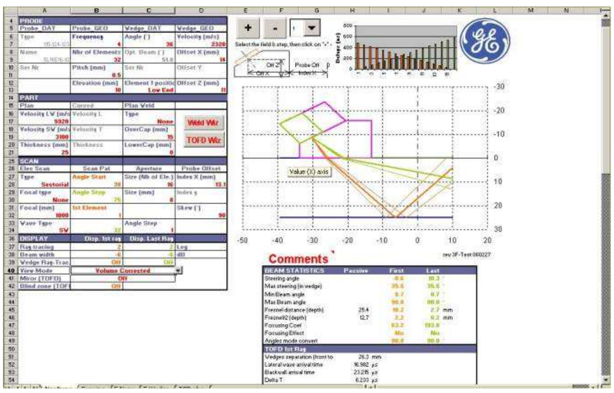

Fig. 3 Modeling Excel sheet

2.3. Inspected areas of interest

A certain quantity of areas on the test block had been defined to be inspected as described. This paper will describe the position and inspection of five of them (Fig. 4-8).

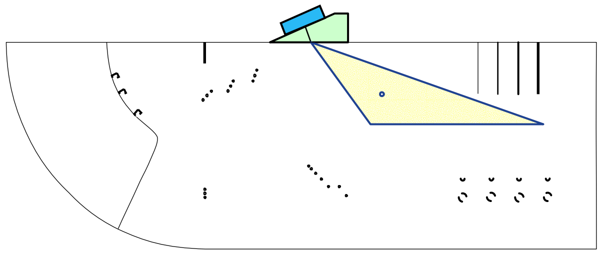

Fig. 4 Position A, Angle scanning on a 2 mm SDH

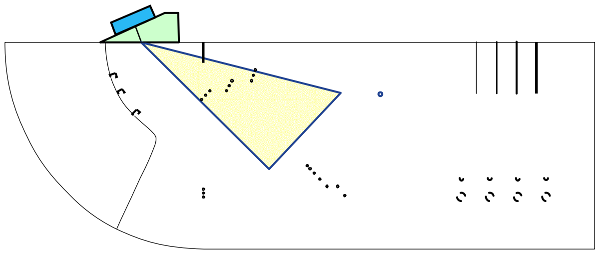

Fig. 5 Position B, Angle scanning on groups of square notches

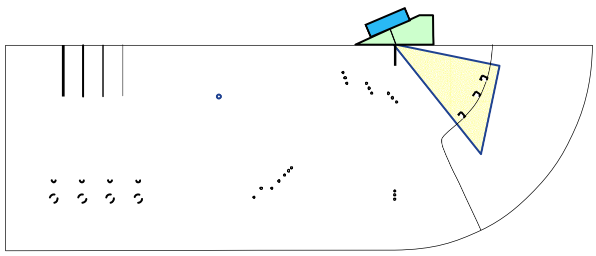

Fig. 6 Position C, Resolution before backwall (2 and 4 mm FBH)

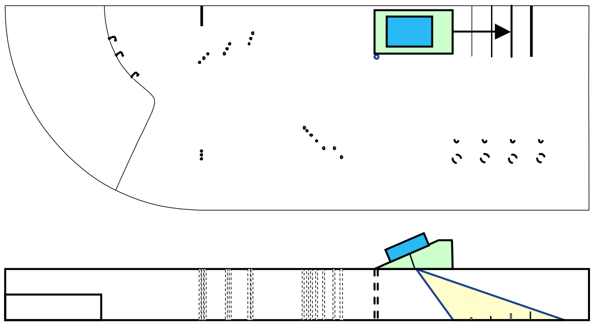

Fig. 7 Position D, Crack evaluation

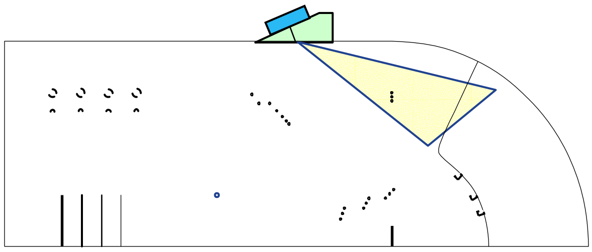

Fig. 8 Position E, Angle scanning resolution

3. Results

In the following the results of the inspections will be described and discussed. The initial calibration of both test systems, conventional and phased array was done on the 50 mm and 100 mm radii of the Aluminum test block.

3.1 Position A

Inspection on Position A was done by having the phased array probe fixed in one position while the conventional probe was scanning a certain area in order to find the amplitude maximum. Fig. 9 & 10 show the sector scan and A-scan of the phased array and the conventional inspection. Both methods lead to a clear amplitude maximum with an explicit evaluable TOF and depth position. What makes phased array technique superior in this case is the fact that the result has been gained without any physical movement of the probe while the conventional method requires a mechanical scanning with the probe in order to find the amplitude peak. This is a decisive advantage in case there is limited space for mechanical movement. Even with changing the probe angle on the conventional side it will not be possible to gain the same accuracy of the result. Another point not to be neglected is the time saving factor when using phased array technique.

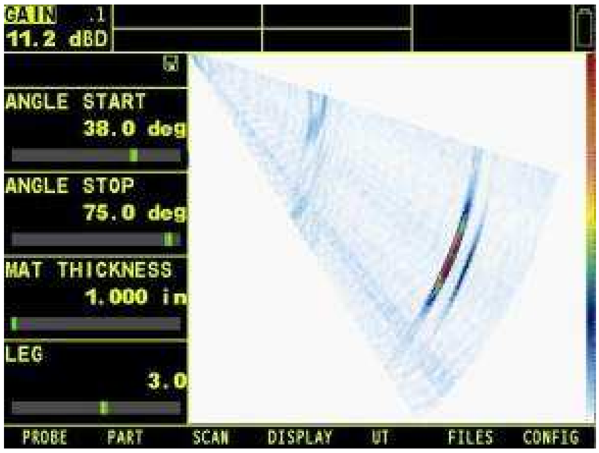

Fig. 9 Position A with phased array.

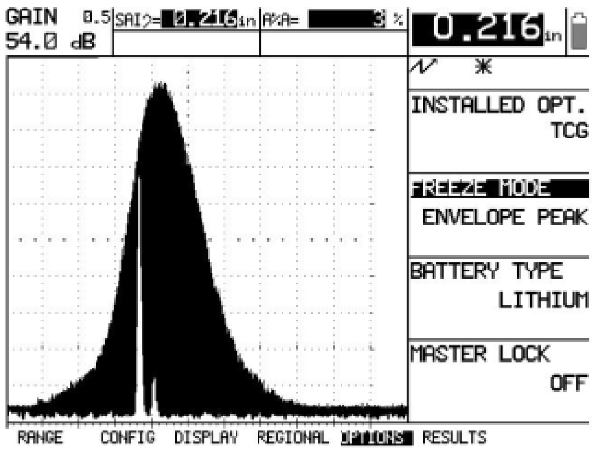

Fig. 10 Position A with conventional UT

3.2 Position B

The results of the tests in position B are displayed in Fig. 11 & 12. Three groups of square notches with 3 notches per group should be detected. The conventional ultrasonic inspection shows that due to the beam divergence it is possible to detect at least two groups without being able to differentiate the groups into single notches. A physical movement of the probe would make a detection of all three groups possible, but in the end it still would not be possible to resolve the single notches from each other easily.

Phased array inspection does not only detect all three groups of notches in a single shot, it also gives an image of the particular notches at a time!

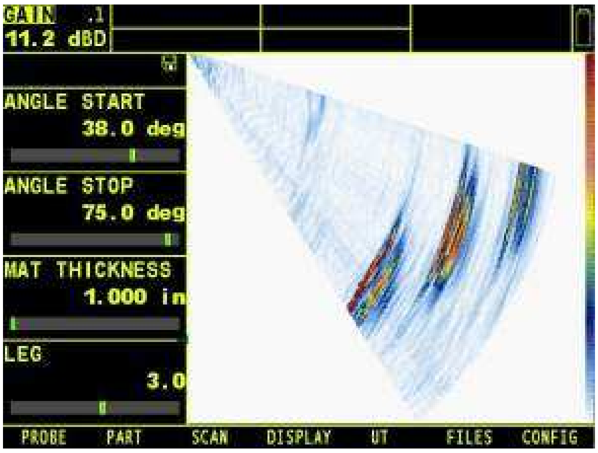

Fig. 11 Position B with phased array technique

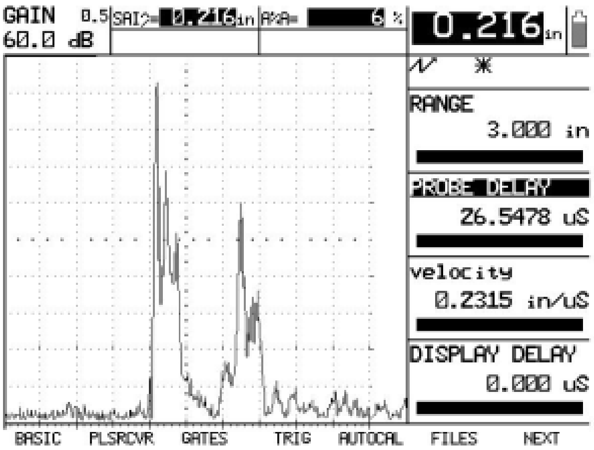

Fig. 12 Position B with conventional UT

3.3 Position C

This example shows the superiority of phased array technique compared to conventional ultrasonic inspection. The measurement with the single element probe gives a clear indication of the backwall but the flat bottom holes can only be anticipated as a small bulb in front of the BWE as the reflector is not hit in an angle that allows a good reflection back to the probe (Fig. 14).

In opposition to that phased array technique gives a clear signal from the back wall as well as a well defined indication of all three flat bottom holes in just a single measurement step (Fig. 13). No physical movement nor any exchanging of the probe wedge is required, all is done by placing a completely electronically steered probe in one position.

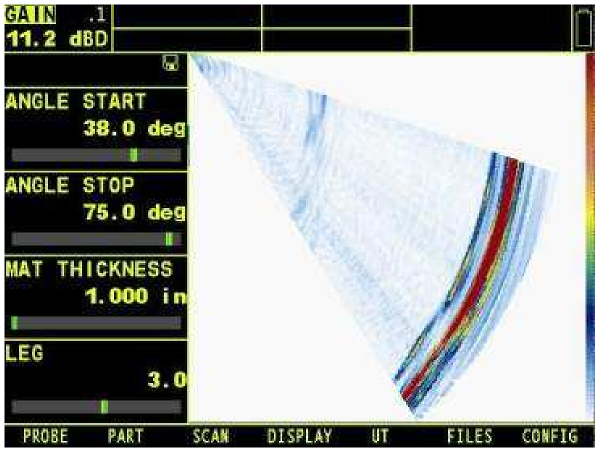

Fig. 13 Position C with phased array

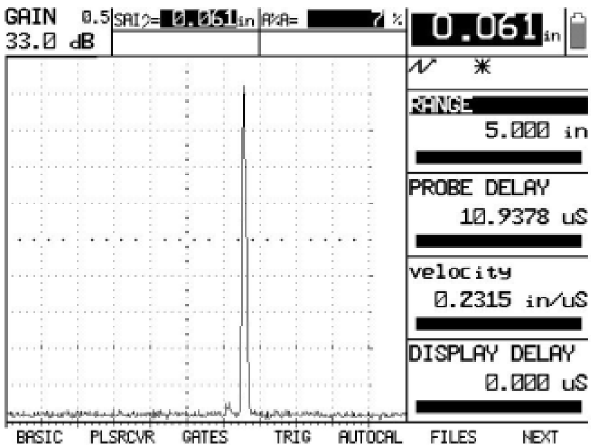

Fig. 14 Position C with conventional UT

3.4 Position D

Position D shall simulate the detection of surface cracks from the opposite side of the test specimen. Four cracks of different depths are lined up in a row and can be detected by a single setting up of the phased array probe. All cracks get visible in the sector scan and can easily be identified. Even the different sizes of the cracks are reflected in the width of the screen image of the phased array inspection (Fig. 15).

In opposition to that conventional ultrasonic inspection needs at least again some mechanical movement of the probe in order to get all cracks properly detected. In fact also the furthermost crack is visible due to the flat beam angle, but shadowing effects make it's reflection appear to be the smallest crack instead of being the biggest one in reality (Fig. 16).

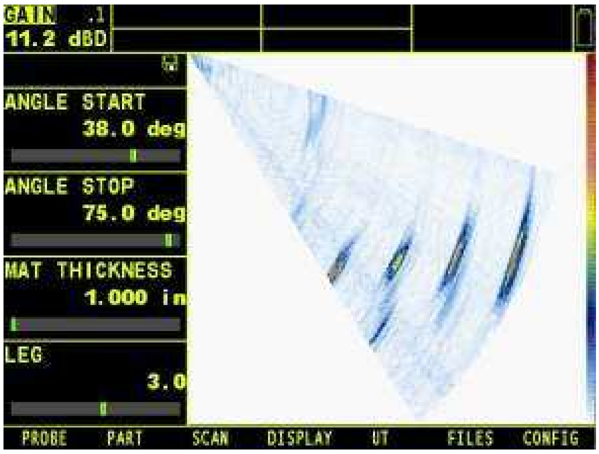

Fig. 15 Position D with phased array

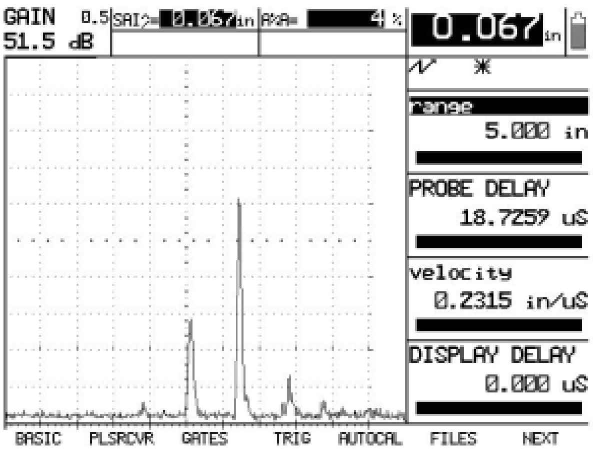

Fig. 16 Position D with conventional UT

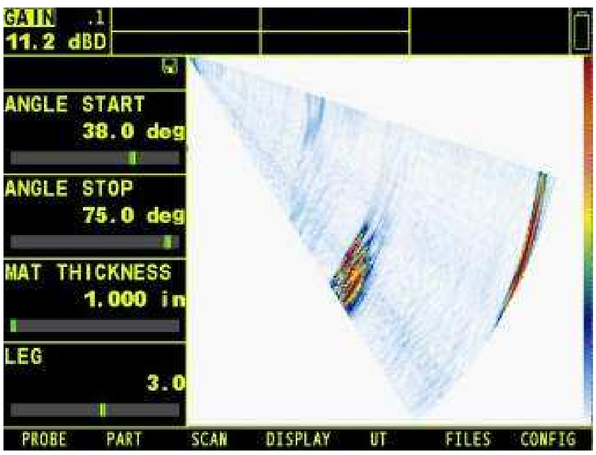

Fig. 17 Position E with phased array

3.5 Position E

The measurements in Position E finally document the capability of phased array technique in terms of resolving small reflectors located close to each other. The conventional A-scan shows, besides a clear backwall echo, just one echo reflecting the group of notches but not every single notch (Fig. 18). In opposition to that the image of the phased array sector scan impressively allocate all three notches in one single measurement (Fig. 17).

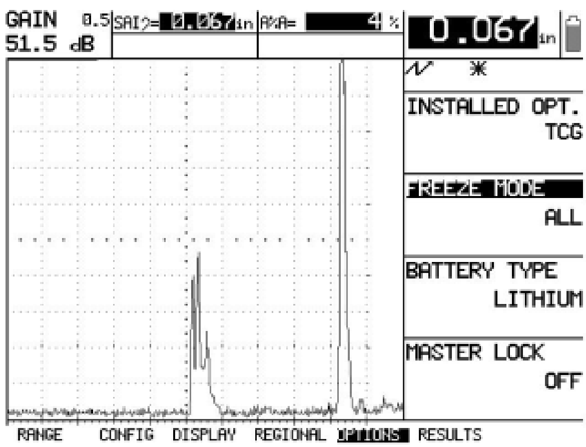

Fig. 18 Position E with conventional UT

4. Conclusions

The conducted comparison measurements have shown that true depth imaging provides spatial relationship of multiple defects when beam spread is controlled. The multiple angle inspection improves the chance for right angle acoustic impingement on a defect and improve the probability of detection POD when there is limited access to an inspection surface. Multiple angle inspection from one probe saves time and equipment expense compared to achieving the same results conventionally. And finally the visualization of the ultrasound helps to distinguish echoes from acceptable geometry from unacceptable reflections.