Developments in Ultrasonic Phased Array Inspection II

Inspecting with Volume Focusing and 2D Arrays (Part 2)
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ABSTRACT

2D arrays (also called matrix arrays), have recently appeared on the market, providing key advantages to improving the inspection methods and results. This paper is a continuation of the work presented at the 2007 6th International Conference on NDE in Budapest. The point focus ability and scanning with tilt and skew angles are two promising features that new electronic equipment manufacturers are promoting. Volume Focusing, when used with 2D arrays, can achieve high speed inspections, the interaction between UT waves and flaws, and the ability to image an entire volume of material without moving the probe. This paper goes more in depth than the previous paper, and clearly shows the advantages and disadvantages of this technique.

Keywords: Phased Array; Matrix; 2D; Ultrasonic; Inspection; Weld; Volume Focusing; Skew deflection; point focus

ABOUT VOLUME FOCUSING

Volume Focusing consists of firing all the elements from the probe and collecting each individual signal for mathematical processing. With a matrix (2D array), as only one transmit pulse irradiates through the volume, it is possible by calculation to form the beams that inspect this volume. This calculation is done in real time inside the electronics, and only the results are sent to the computer so that visualization is sped up.

The beam calculation usually consists of calculating several sector scans with different definitions of incidence, range and focus depth. Note that DDF (Dynamic Depth Focusing) is compatible with Volume Focusing.

One of the advantages of this technique is the gain in inspection speed. Only one transmit pulse is required to provide lots of beams cycles, possibly from different sub-sequences, and the calculation of the beam is done inside the electronic instrument so that it can be done with ultra-fast processing. This is illustrated in Figure 1.

Figure 1 - Comparison of conventional phased array acquisition in the left, and with Volume Focusing in the right with a sequence of 97 cycles.

AN EXPERIMENT WITH MATRIX PHASED ARRAY ON A THIN STEEL PLATE WITH SLITS

The configuration used for the matrix phased array was a sector scan without skew, as shown in Figure 2, A and B. Also, a sector scan with a skew of 90 degrees with a tilt angle of 45 degrees was used, as shown in Figure 2, C and D.
Figure 2 - FlashFocus Wizard View of the 2 configurations. A and B: conventional sector scan. C and D: 90° skew with 45° tilt.

The probe on the test plate has a wedge and a wire encoder to record the position. As described previously, the sequence contains 2 sub-sequences. The first subsequence, as shown in Figure 2, corresponds to the sector scan from 30 to 60 degree (no skew, no tilt). The second subsequence corresponds to Figure 2, C and D, with a sector scan along a 90° skew and 45° tilt.

The results are compared for different orientations of the slit:

Figure 3, Figure 4 and Figure 5 shows slit orientations of 0°, 10° and 20° respectively. The Volume Focusing results on the C-scan show that the slit is indeed shifted to one side. The main effect on the conventional sector scan is that the angle where the signal amplitude becomes the highest is lower when the slit is more angled. In addition, the sensitivity decreases.

Figure 3 - Results with the probe mechanically scanned perpendicular from the slit.

Just looking at the print-screens does not reveal the complete potential of this technique, but when we operate the instrument, we can see the difference by how it is easier to detect and size the flaw with the Volume Focusing view, and receive confirmation with the conventional sector scan.
Volume Focusing with Matrix Arrays: Study of the accuracy and lateral resolution
At first, an inspection with a 5MHz, 128 elements, and 0.5mm pitch linear phased array was done. The Volume Focusing configuration uses 128 elements for the pulse, and 32 elements to calculate and display the Bscan in front of the probe.

The inspection is done from the opposite side of the test block face seen in Figure 6, so that the SDH are in reality inspected as FBH. Their depth is 15mm, but more important is their proximity. They are separated by 5mm.

Figure 7 shows that the flaws are well discriminated, the signal to noise ratio is quite high. In addition to the FBH on axis A, as seen in Figure 6, the one FBH on the axis directly 10mm above A or the one FBH on the axis 10mm below are also visible in the Bscan due to the “width” of the linear probe (the width referred to here is the axis that is perpendicular to the electronic scan axis). The probe is only a 1D array so that the focusing occurs only in 1 plane (electronic scan axis). In the other plane, linear array “width”, the beam is quite large.

![Figure 7 - Volume Focusing results using the linear array](image)

Figure 8 shows the sector scan configuration that is applied to the matrix phased array. It is a simple sector scan from -30 to +30 degrees with no skew or tilt angles applied.

![Figure 8 - View of sector scan configuration used for the experiment](image)

The probe is positioned in front of the 3 FBH on axis A, as shown in Figure 6, which are all in a row. One can appreciate the regression of the sensitivity according to the deflection angle, as seen in Figure 9.
We can see that the flaw in the middle is more or less 6dB more sensitive than its two neighbors. The sensitivity loss is due to the fact that as much as the angle increases, the less energy there is, and at the same time, the less the Matrix phased array is sensitive in reception (due to deflection).

Then the probe is moved above axis B, which has only one FBH (#1, marked by an arrow) and above axis C, which has two FBH (#2 and #3, marked with arrows). It’s obvious, but note that axis B is slightly higher than axis C by less than 1mm and so the FBH are not exactly in a row. Instead, the 3 FBH are positioned along a large diameter curve, as shown in Figure 6.

The scan is first done on the axis B so that we can see the FBH #1 with a maximum amplitude as shown in Figure 10.

Then the probe is moved slightly to examine #2 and #3 FBH on axis C, so that are on each side of the FBH #1 are maximized in amplitude. As shown in Figure 11, the FBH #1 is almost not visible any more, but the FBH #2 and #3 are at maximum amplitude.
This proves that the beam spot size is truly small. This is in line with what was expected when using Volume Focusing with a matrix phased array probe. Remember that one of the key points of Volume Focusing is the ultra-high speed scanning and data processing. That being said, even with the increased scanning speed a small beam spot (good lateral resolution) is achieved.

CONCLUSION

A matrix probe used with Volume Focusing reinforces the advantages of 2D arrays. To summarize, matrix phased array technology is great for identifying oriented flaws due to the inherent characteristic of scanning with skew and tilt angles. Furthermore, finding flaws with unknown orientations are easier. Combining Volume Focusing gives faster inspection times as well as smaller beam spot sizes. An overall better ability to detect and size flaws can be expected.

A lot of application work still remains in order to evaluate more in detail the effectiveness of this combined technique, but the door to a new approach has already been opened.

REFERENCES

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