DNT INSPECTION SERVICE CO.,LTD.

PHASED ARRAY ULTRASONIC TEST

The development and application of phased array ultrasonic technology as a stand-alone technique has reached a mature phase at the beginning of the twenty-first century.

Phased array ultrasonic technology moved from the medical field[1] to the industrial sector at the beginning of the 1980s.[2,3] By the mid-1980s, piezocomposite materials were developed and made available to manufacture complex-shaped phased array probes.[4-13]

By the beginning of the 1990s, phased array technology was incorporated as a new NDE (nondestructive evaluation) method in ultrasonic handbooks[14,15] and training manuals for engineers.[16] The majority of the applications from 1985 to 1992 were related to nuclear pressure vessels (nozzles), large forging shafts, and low-pressure turbine components.

Advances in piezocomposite technology,[28,29] micromachining, microelectronics, and computing power (including simulation packages for probe design and beam-component interaction), contributed to the revolutionary development of the phased array technology. Functional software was also developed as computer capabilities increased.

The phased array ultrasonic technology for NDT (nondestructive testing) use was triggered by the following power generation inspection problems:

1. The need to detect cracks located at different depths with random orientations using the same probe in a fixed position
2. The requirement to improve SNR (signal-to-noise ratio) and sizing capability for dissimilar metal welds and centrifugal-cast stainless steel welds
3. The requirement to increase the scanner reliability
4. Increased accessibility requirements for difficult-to-reach PWR/BWR (pressurized water reactor / boiling water reactor) components
5. Decreased setup and inspection time (productivity)
6. Detection and sizing of small SCC (stress corrosion cracking) in turbine components with complex geometries
7. A requirement to decrease the amount of radiation the personnel is exposed to
8. A requirement to increase the accuracy in detection, sizing, location, and orientation of critical defects, regardless of their orientation
9. The need to provide a quantitative, easy-to-interpret report for *fitness for purpose* (also called "engineering critical assessment," or "life assessment/disposition-inspection interval strategy")

PRINCIPLES

Ultrasonic waves are mechanical vibrations induced in an elastic medium (the test piece) by the piezocrystal probe excited by an electrical voltage. Typical frequencies of ultrasonic waves are in the range of 0.1 MHz to 50 MHz. Most of the industrial applications require frequencies between 0.5 MHz and 15 MHz.

Most conventional ultrasonic inspections use monocrystal probes with divergent beams. The ultrasonic field propagates along an acoustic axis with a single refracted angle. The divergence of this beam is the only "additional" angle, which might contribute to detection and sizing of misoriented small cracks.

Assume the monoblock is cut in many identical elements, each with a width much smaller than its length (elevation [$e < W$]) [for definitions, see "Glossary" on page 307]. Each small crystal may be considered a line source of cylindrical waves. The wavefronts of the new acoustic block will interfere, generating an overall wavefront.

The small wavefronts can be time-delayed and synchronized for phase and amplitude, in such a way as to create an ultrasonic *focused* beam with *steering* capability.

The main feature of phased array ultrasonic technology is the *computer-controlled excitation* (amplitude and delay) of individual elements in a multielement probe. The excitation of piezocomposite elements can generate an ultrasonic focused beam with the possibility of modifying the beam parameters such as angle, focal distance, and focal spot size through software. The sweeping beam is focused and can detect in specular mode the misoriented cracks. These cracks may be located randomly away from the beam axis. A single crystal probe, with limited movement and beam angle, has a high probability of missing misoriented cracks, or cracks located away from the beam axis (see Figure 1-1).

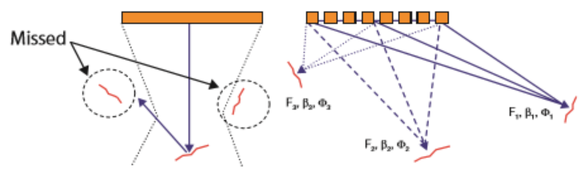


Figure 1-1 Detection of misoriented cracks by monocrystal (*left*) and multielement probes (*right*). The beam is divergent and unidirectional for the monocrystal probe, while it is focused and multiangled for the phased array probe. Cracks of most orientations can be detected by the phased array probe.

To generate a beam in phase and with a constructive interference, the various active probe elements are pulsed at slightly different times. As shown in Figure 1-2, the echo from the desired focal point hits the various transducer elements with a computable time shift. The echo signals received at each transducer element are time-shifted before being summed together. The resulting sum is an A-scan that emphasizes the response from the desired focal point and attenuates various other echoes from other points in the material.

- During transmission, the acquisition instrument sends a trigger signal to the phased array instrument. The latter converts the signal into a high-voltage pulse with a preprogrammed width and time delay defined in the focal laws. Each element receives one pulse only. This creates a beam with a specific angle and focused at a specific depth. The beam hits the defect and bounces back.
- The signals are received, then time-shifted according to the receiving focal law. They are then reunited together to form a single ultrasonic pulse that is sent to the acquisition instrument.

BASIC SCANNING & IMAGING

During a scan with mechanical device, data is collected based on encoder position. The data is displayed in different views for interpretation.

Typically, phased arrays use multiple stacked A-scans (also called "B-scans," see details on chapter 4) with different angles, time of flight and time delays on each small piezocomposite crystal (element) of the phased array probe.

The real-time information from the total number of A-scans, which are fired for a specific probe position, are displayed in a *sectorial scan* or *S-scan*, or in a *electronic B-scan* (see chapter 4 for more details).

Both S-scans and electronic scans provide a global image and quick information about the component and possible discontinuities detected in the ultrasonic range at all angles and positions (see Figure 1-10).

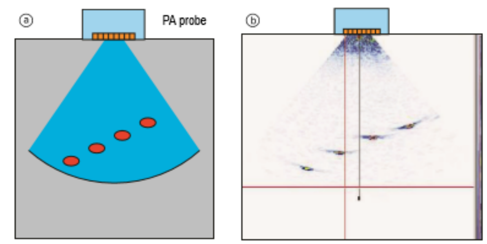


Figure 1-10 Detection of four side-drilled holes (SDH): (a) sectorial scanning principle; (b) S-scan view using ±30°.

Data plotting into the 2-D layout of the test piece, called "corrected S-scans," makes the interpretation and analysis of ultrasonic results straightforward. S-scans offer the following benefits:

- Image display during a scan
- True depth representation
- 2-D volumetric reconstruction

Advanced imaging can be achieved by a combination of linear and sectorial scanning with multiple-angle scans during probe movement. S-scan displays in combination with other views (see chapter 4 for more details) lead to a form of defect imaging or recognition. Figure 1-11 illustrates the detection of artificial defects and the comparison between the defect dimensions (including shape) and B-scan data.

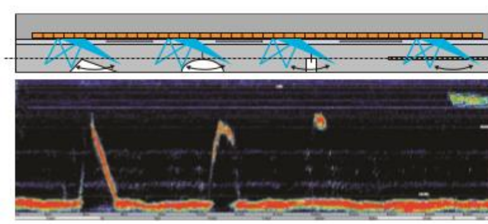
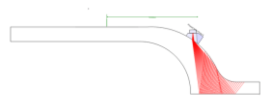


Figure 1-11 Advanced imaging of artificial defects using merged data: defects and scanning pattern (*top*); merged B-scan display (*bottom*).

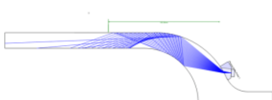
DNT APPLICATION


Critical area of inspection
is area danger .
1.When have gas flow in-out this area may be have corrosion.
2.When have take out of gas tube may be have fatigue crack on neck tube.

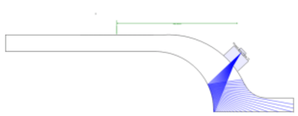
Sectorial Scan used angle 43°-72° for detect crack.



Sectorial Scan used angle 43°-72° for detect crack.



Sectorial scan used angle -23° to 23° for detect corrosion



Sample crack from Olympus book

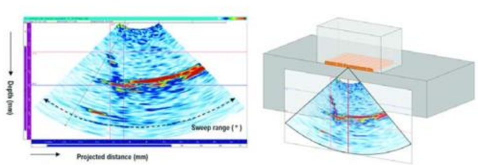
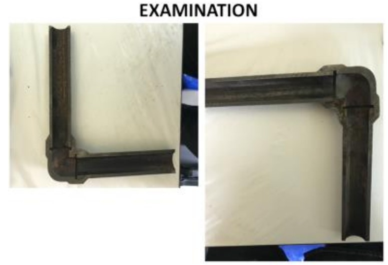


Figure 2-23 Example of TomoView™ VC Sectorial Scan (volume-corrected sectorial scan or "true depth") display for detecting and sizing a crack by longitudinal waves (*left*), and an isometric view of the specimen, probe, and crack (*right*).

Phased Array Ultrasonic Test(PAUT) Socket weld.

SMALL BORE SOCKET-TO-PIPE WELD EXAMINATION

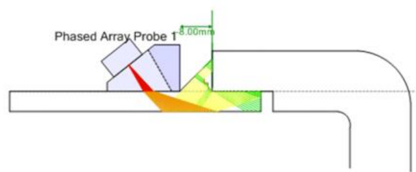


SMALL BORE SOCKET-TO-PIPE WELD EXAMINATION

DAMAGE MORPHOLOGY
The types of small bore socket weld damage commonly
- Vibration fatigue
- Stress corrosion cracking (SCC)
- Weld lack of fusion (LOF)
- Engagement

Each of these mechanisms are be discussed separately.

SMALL BORE SOCKET-TO-PIPE WELD EXAMINATION



PHASED ARRAY ULTRASONIC TEST HIGH DENSITY POLYETHYLENE