Phased Array Ultrasonic Technology Theory(PAUT Inspection)

Principle (1/5)

ULTRASONIC WAVES

These are the 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 to 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 miss-oriented small cracks.

Assume the monoblock is cut in many identical elements, each with a width much smaller than its length. 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.

Phased Array Ultrasonic Technology Theory(PAUT Inspection)

Principle (2/5)

THE MAIN FEATURE OF PHASED ARRAY ULTRASONIC TECHNOLOGY AND PHASED ARRAY ULTRASONIC TESTING is the computer controlled excitation (amplitude and delay) of individual elements in a multi-element probe. The excitation of piezo-composite 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 miss-oriented 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 miss-oriented cracks, or cracks located away from the beam axis (see Figure 1).

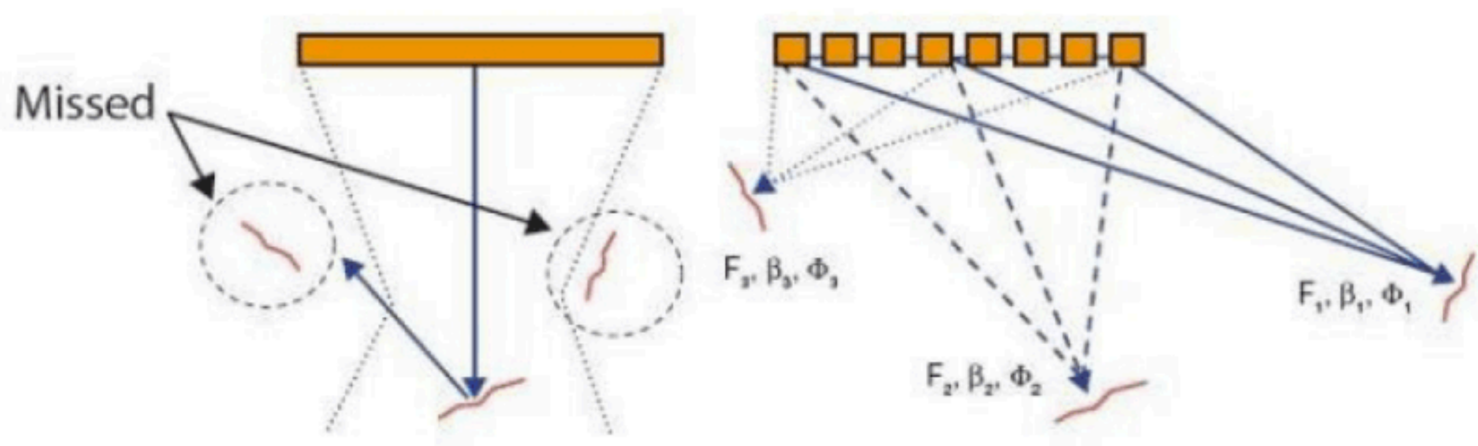

Figure 1: Detection of miss-oriented cracks by monocrystal (left) and multielement probes (right)

The beam is divergent and unidirectional for the monocrystal probe, while it is focused and multi-angled for the phased array probe. Cracks of most orientations can be detected by the phased array probe.

Phased Array Ultrasonic Technology Theory(PAUT Inspection)

Principle (3/5)

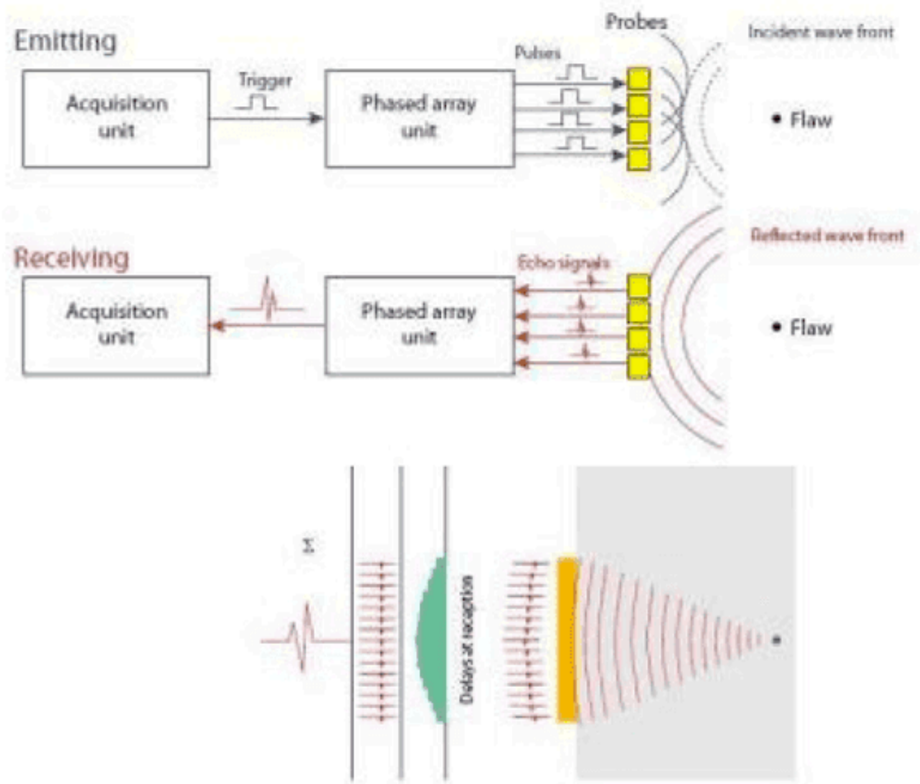

Figure 2: Beam forming and time delay for pulsing and receiving multiple beams (same phase and amplitude)

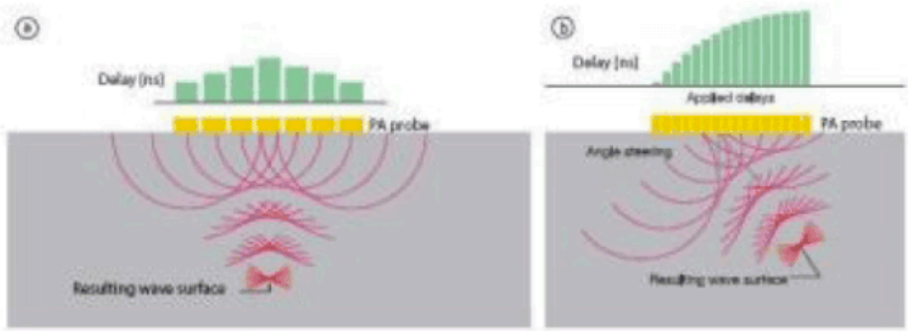

Figure 3: Beam focusing principle for (a) normal and (b) angled incidences.

Phased Array Ultrasonic Technology Theory(PAUT Inspection)

Principle (4/5)

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 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 pre-programmed 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.*
- *The delay value on each element depends on the aperture of the phased array probe active element, type of wave, refracted angle and focal depth. There are three major computer-controlled beam scanning patterns (see also chapter 3 and 4):*
- *Electronic Scanning: the same focal law and delay is multiplexed across a group of active elements (See Figure 4); scanning is performed at a constant angle and along the phased array probe length (aperture). This is equivalent to a conventional ultrasonic transducer performing a raster scan for corrosion mapping or shear wave inspection. If an angled wedge is used, the focal laws compensate for different time delays inside the wedge.*

Phased Array Ultrasonic Technology Theory(PAUT Inspection)

Principle (5/5)

- *Dynamic Depth Focusing or DDF (along the beam axis): scanning is performed with different focal depths. In practice, a single transmitted focused pulse is used, and refocusing is performed on reception for all programmed depths (see Figure 5).*
- *Sectorial Scanning (also called azimuthal or angular scanning): the beam is moved through a sweep range for a specific focal depth, using the same elements; other sweep ranges with different focal depths may be added. The angular sectors may have different values.*

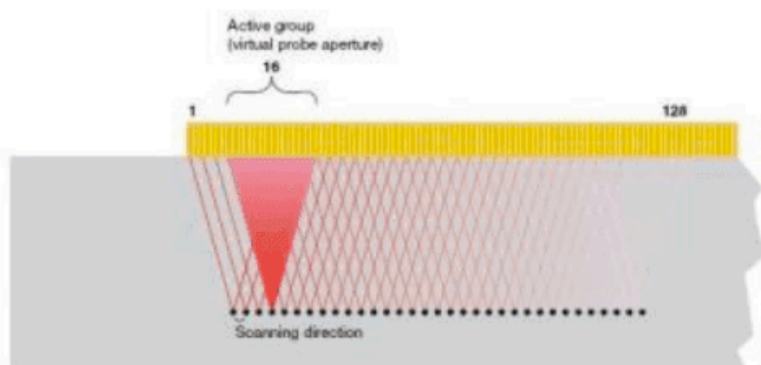

Figure 4: Electronic scanning with normal beam (virtual probe aperture = 16 elements)

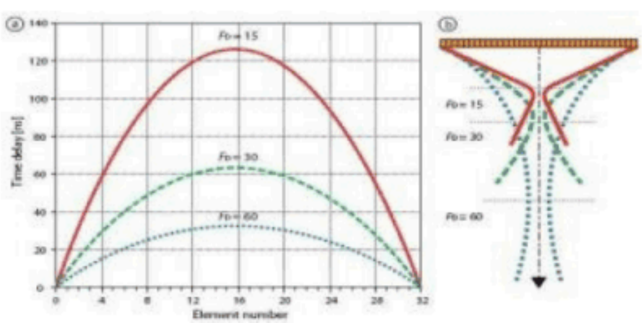

Figure 5: Delay values (left) and depth scanning principles (right) for a 32-element linear array probe focusing at 15mm, 30mm and 60mm longitudinal waves. Direct contact,no angle wedge