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The Use of Phased Array UT Inspection of OCTG

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Abstract

This paper covers the use of new techniques for the automated full length ultrasonic inspection of tubular goods where additional (oblique) orientation angles are desired. These techniques include the use of phased arrays with focused transducers.

Introduction

API provides standards for the manufacture and performance of pipes and tubes used by the petroleum industry. Included in these standards are minimum requirements to address inspection for longitudinal (zero degrees to pipe axis), transverse (90 degrees to pipe axis) wall thickness and dimensional defects. Inspection for oblique oriented defects is related to the manufacturing process and/or specific use requirements.

Specifications vary according to performance requirements, company philosophy and associated risk. Requirements are different for a six hundred feet land well and a 25,000 feet offshore well. New opportunities often present challenges which require different or more stringent performance criteria and/or new technologies. To capitalize on these opportunities and address these challenges, major oil companies supplement standards with additional requirements to provide them with a competitive advantage over their competitors.

Supplementary specification examples may include inspection for oblique defects and laminations which may become detrimental in certain environments or the profiling of diameter and wall data to calculate more exact tubular performance and relative placement in the well.

A new technology to the OCTG and Line pipe manufacturers is Phased Arrays.

Technology

Ultrasonic phased arrays consist of a series of individual elements, each with their own connector, time delay circuit, and A/D converter. Elements are acoustically insulated from each other and are pulsed in groups with pre-calculated time delays for each element, i.e. “phasing”.

Probes

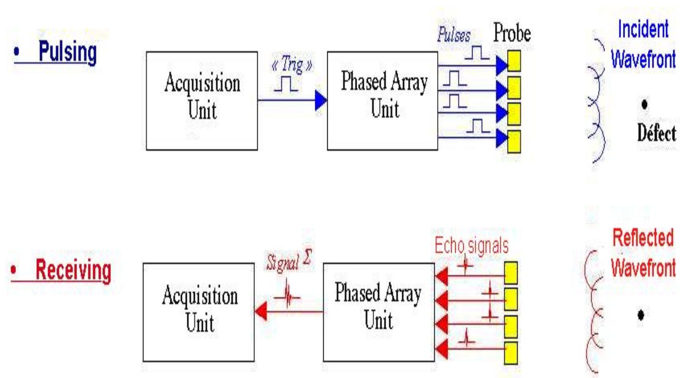
Typical array designs are Linear, Matrix, Circular and Sectorial-Annular .Custom probe shapes and design may be specifically built for specific applications. Linear arrays are the most common type and are fabricated with a single row or matrix.of elements. They are the most economical and widely used for the inspection of OCTG. Matrix arrays are used to scan in two dimensions and provide additional flexibility.

Linear **Matrix**

Instrumentation

Instrumentation may be tailored for specific applications. Various configurations include as a minimum, an ultrasonic channel with circuitry for time delay beam forming and data acquisition.

Instrumentation nomenclature such as a FOCUS 32/128 refers to an instrument with 32 multiplexed pulsers and a total of 128 ultrasonic channels. Many instruments may be used in parallel to increase the number of active elements for certain applications.



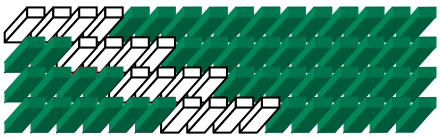
Features

Phased array provides a programmable means for electronic scanning and realtime control of three important UT probe parameters; Focal distance, Beam angle and Beam size.

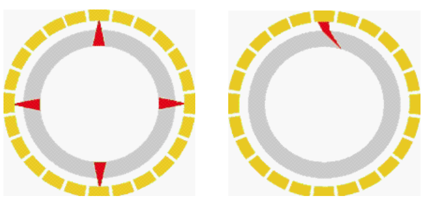
Electronic Scanning

Electronic scanning is moving the beam along one axis of an array without any mechanical movement. This movement is performed by time multiplexing the active elements along the probe geometry.Electronic scanning facilitates rapid scanning of components with constant geometry, e.g. tubes and pipes.

Linear scanning for tubes may be implemented either laterally or circumferentially.

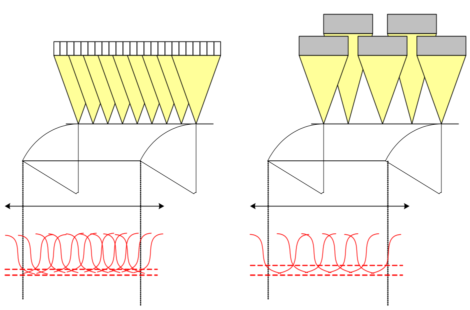


Lateral Scanning of active elements



Circumferential Scanning of beam around Tube

Electronic scanning overlap is adjustable between acoustic apertures can be optimized for advance and specified repeatability requirements.

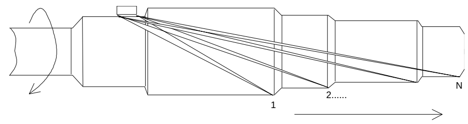


Adjustable overlap to satisfy repeatability requirements

Sectorial scanning

Sectorial scanning is the scanning of a complete section of a volume without probe movement. Sectorial scanning is useful for the inspection of complex geometry's or those with space restrictions. This feature combines the advantages of multiple conventional probes in a single phased array probe. By changing the incident angle between apertures a variety of inspections can be performed without changing the position of the probe.

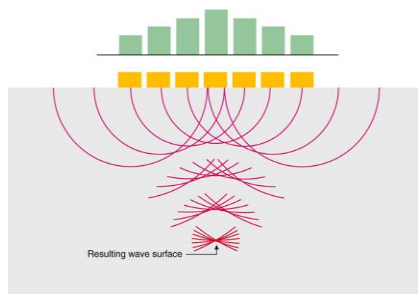
Phased Array Diagram



Inspection of complex geometry with a single Phased Array Probe

Beam Focussing

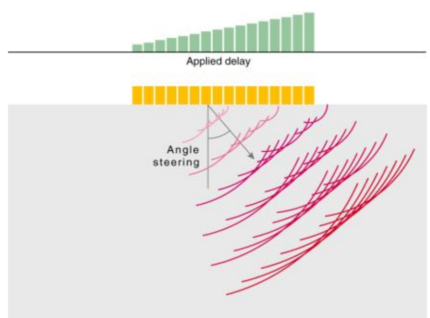
Beam focusing in the steering plane is achieved using symmetrical time delays between element firings relative to the element position.



Symmetrical time delayed firing of elements to focus beam

Beam Steering

Beam steering is selected by using asymmetrical (e.g. linear) focal laws to the element firing order. Beam steering provides the flexibility for multiple angle inspections, using a single probe. Different focal laws can be used to generate both compression and shear waves with the same probe.



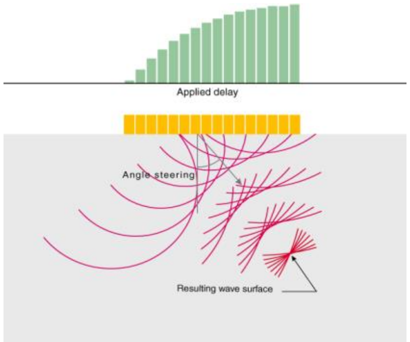
Asymmetrical time delayed firing of elements to steer beam

Beam Size

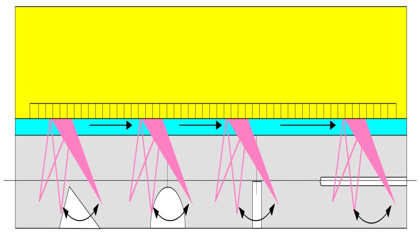
The beam size is determined by the element characteristics and the number of elements used for the aperture.

Feature Combinations

Features are often combined to optimize inspection variables associated with changing parameters in the same or other pipes.



Focusing and Steering combination



Steering and Scanning combination

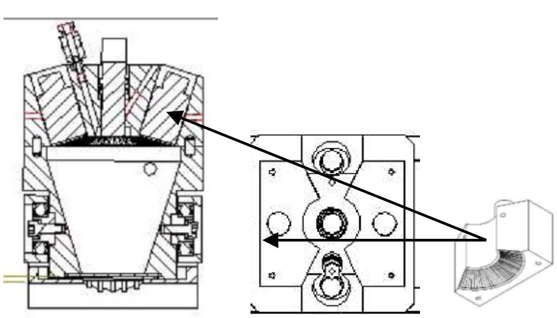
OCTG applications

A variety of systems are available to satisfy industry needs. These systems include circular arrays, conical arrays and axial array clusters which are used to measure wall thickness and detect laminar, longitudinal, transverse and oblique defects. They often incorporate specific features such as dynamic depth focussing, weld profilimetry, and defect discrimination and imaging software.

Conical Array Cluster

The Conical Array Cluster consists of two phased array probes, a coupling column and a shoe with wear plate to match the diameter of the pipe. Linear scanning is used to provide inspection of the complete angular sector of the pipe covered by array probe.

Defect orientation is easily discernible by monitoring those apertures (group of elements to form the beam) with the greatest response.



Conical Array Cluster

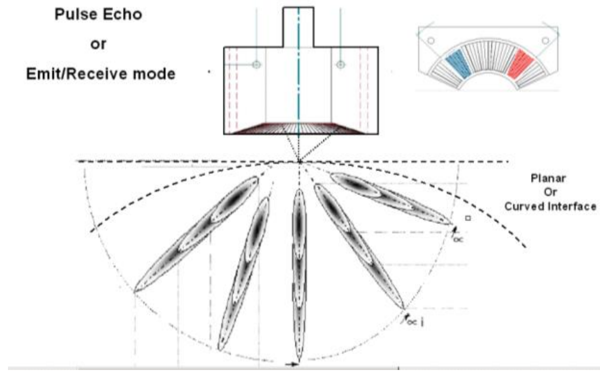
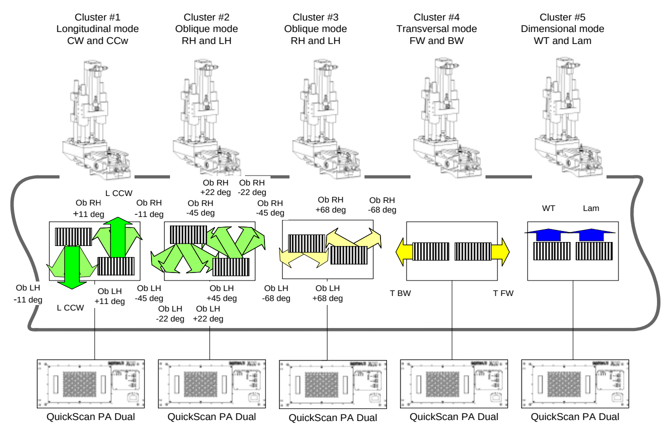


Figure to demonstrating oblique defect detection and discrimination

Axial Array Clusters

The axial array cluster consist of two simple linear array probes with preset incident angles in a shoe, a coupling column and a wear plate to match the diameter of the pipe.

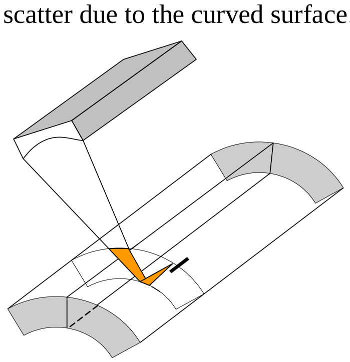
The array probes can be used for multiple defect orientations by generating compound angles between the fixed incident and steered programmable angles.



Typical Axial Array Cluster System configuration

Longitudinal defect Detection

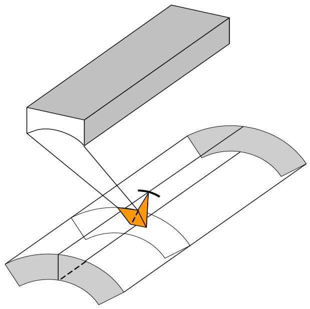
The array probe is oriented with a predetermined fixed incident angle to generate the desired shear wave in steel. The aperture length is programmed by selecting the number of elements used to form the aperture. The array is mechanically focussed parallel to the axis of the pipe to concentrate the sound energy on the surface of the pipe and reducing the scatter due to the curved surface.



Longitudinal defect Detection

Transverse Defect Detection

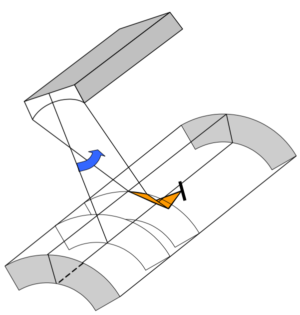
The array probe is parallel to the axis of the pipe with no incident angle. The aperture size and incident angle is programmed by selecting the number of elements used to form the beam and the desired steering angle. The same array is used for inspection in both the forward and backward directions by using two different focal laws.



Transverse Defect Detection

Oblique oriented Defect Detection

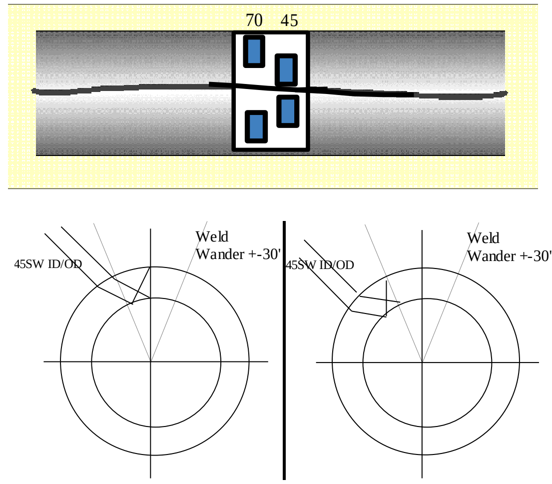
The array probe is axially oriented to the pipe surface with a fixed incident angle relative to the y-axis and a second angle is created by electronically steering the beam along the x-axis to form a compound incident angle. The resultant refracted oblique beam is used for the detection of an oblique defect. The compound angles can be varied to create specific oblique angles. Additionally in this example the beam is manually focussed along the axis of the pipe to optimize sound energy on the surface.



Oblique Defect Detection

Weld-line Inspection

Electronic scanning of the beam around the weld sector is used to provide for weld line wander while maintaining calibrated response from weld flaws. Scanning at 90 degrees to the weld is also used to provide a profile of the weld area trim. Beam steering or sector scanning can be used to produce multiple inspection angles to optimize the inspection for anticipated defects.



Electronic Scanning to provide for weld wander

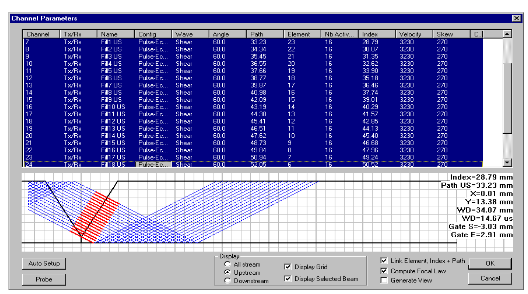
Curved Probe for Electronic scanning of weld area

Evaluation and Interpretation

Defect Sizing

Phased Array inspection lends itself to all proven conventional means of defect sizing including amplitude comparison, dB drop, time of flight diffraction and zone discrimination methods.

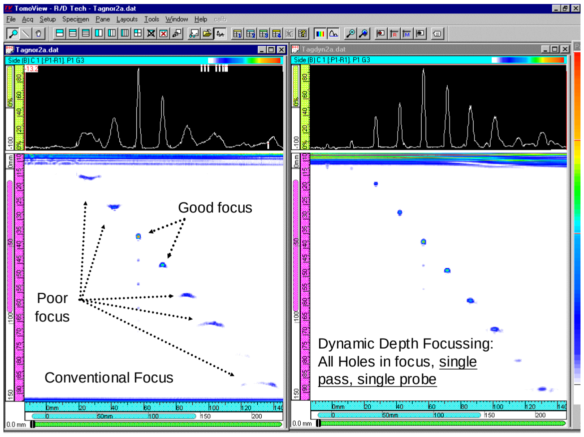
Features such as Electronic scanning make it better suited for repeatability when making zone discrimination measurements and dynamic depth focusing provides a more consistent beam focus when using the dB drop method for measurement throughout the depth of the wall thickness.



Electronic Scanning of Weld zones for sizing

Dynamic Depth Focusing

Dynamic depth focusing uses a series of programmable delays and apertures (focal laws) to provide for focusing at several depths using a single probe. A single pulse provides examination throughout the full depth of the wall thickness with near-optimal focus. A single probe with Dynamic Depth focusing can replace many probes with different focal lengths.

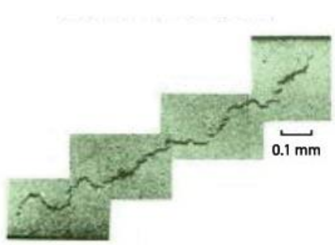


Comparison of probe with Dynamic Depth Focusing

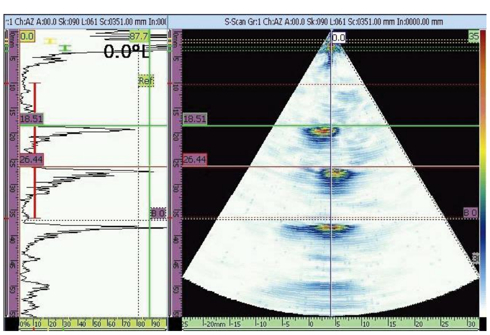
Defect Interpretation

Hydrogen-induced cracking can occur in susceptible steels exposed to aqueous environments containing hydrogen sulphides. The inspection requires characterization of the defect areas to differentiate between spot inclusions, laminations, and different stages of hydrogen-induced cracking.

The benefit of electronic sectorial scanning allows simultaneous scanning from −30 to +30 degrees. The imaging from this scanning technique allows the user to distinguish between spot indications and interconnected defects.



SOHIC micrograph



Sectorial scan of SOHIC defect

Summary

Phased Arrays are flexible and can be used to match Inspection performance and product requirements such as;

- Increased sensitivity to small defects by optimizing the beam shape for each wall thickness and defect shape.
- Variable repeatability control by adjusting the overlap of consecutive apertures and electronic scanning.
- Optimizing focal length and spot size for various wall thickness and complex parts.
- Generating multiple beam angles from a single probe to detect different defect orientations.
- Defect interpretation using sector scans and angle correlations.
- Improved flaw sizing with features including electronic scanning and dynamic depth focusing.

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