Ultrasonic Phased Array Inspection Technique Development Tools

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Abstract:
The escalated use of phased array ultrasonic instrumentation combined with the growing complexity and diversity of the associated applications has given rise to the requirement for enhanced inspection technique development. The standard tools used for conventional UT technique development fall short of the requirements for advanced techniques. Pencil and protractor fail to achieve the new enhanced objectives. These increased expectations of reporting, documentation and efficiency translate directly to greater demands on the technician.
Keywords: Phased Array, ESBeam Tool 2, Technique Development, Ultrasonic Modeling

Introduction:

In order to comply with the requirements of many applicable codes and standards, it is necessary to document in detail the inspection parameters of the UT technique. An example of these requirements is outlined in the following excerpt from ASME code case 2235 defining the use of ultrasonic examination in lieu of radiography.

(2)
(b) A documented examination strategy or scan plan
shall be provided showing transducer placement, movement,
and component coverage that provides a standardized
and repeatable methodology for weld acceptance.
The scan plan shall also include ultrasonic beam angle
used, beam directions with respect to weld centerline,
and vessel volume examined for each weld. The documentation
shall be made available to the Owner/User
upon request.[1]

ASME Code cases 2541*[2]*, 2557*[3]* and 2558*[4]* referencing the use of ultrasonic phased array inspection using single fixed beam, sectorial and linear techniques respectively, further define the required recorded scanning details.
Ultrasonic beam modeling, be it ray trace or Gaussian generated, has proven a powerful and accurate means of defining inspection parameters, however; the associated software costs and operational complexity has limited its widespread use within the ultrasonic field technician community*[5]*.

An accessible and comprehensive software tool that enables the UT technician to visualize and document the details of the required scan configuration has become a necessity. In recognition of this demand a team of advanced UT application developers and programmers have combined their lab and “real world” experience to produce the ESBeam Tool.

Technique Design Considerations:

A single ultrasonic phased array instrument equipped with the requisite scanning accessories is capable of producing many types of scans. The following is a list of the more common scan types that may be required in the day-to-day inspection activities:

- Conventional: single or multi element
- TOFD: transducer pair or multi Zonal
- Phased Array: sectorial, linear, fixed beam, with a variety of focus options and combinations of these scan types
- Advanced: PA zonal discrimination with tandem and PE, PA TOFD single or multi zonal, and combinations of these scan types

The variety of materials, joint and bevel configurations to be inspected is limited only by the industries being served. Therefore it is evident that a software tool designed to properly address this multitude of parameters requires inherent flexibility.

The information provided by the technique not only addresses the compulsory specifications outlined in the procedure, but also includes the specific details of the scan plan (essential variables) and inspection methodology used to accomplish coverage of the area to be scanned.
For most weld related phased array scans the following information should be included in the technique document:

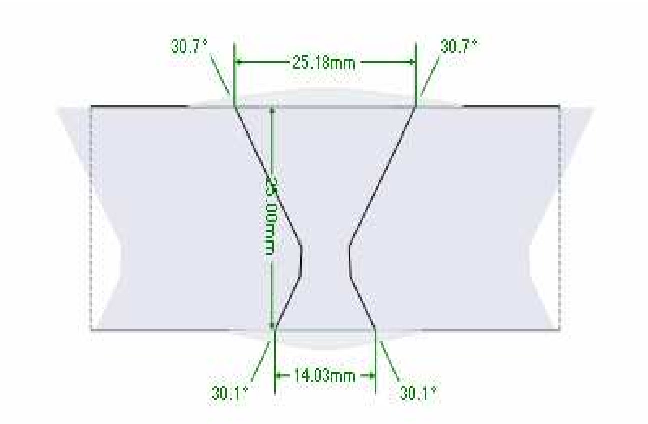
- Weld joint geometry and material velocities
- Extent of heat affected zone (HAZ) and additional coverage
- Transducer and wedge specifics
- Focal law parameters
- Probe and index offsets
- Scan patterns to ensure coverage

Practical Applications:

Developing techniques that ensure compliance with the inspection requirements and document the “inspection strategy” entails the demonstration of scan coverage. This demonstration is easily accomplished through an accurate graphic display of all relevant material/weld, probe and focal law parameters. Graphic overlay of specific dimensions combined with a report generator which summarizes all of these “essential variables” facilitates the complete technique generation process. The following examples demonstrate typical phased array weld scan configurations with technique considerations designed with the ESBeam Tool2.

1. Linear scan plan example according to ASME requirements

a. Weld joint Geometry and HAZ representation

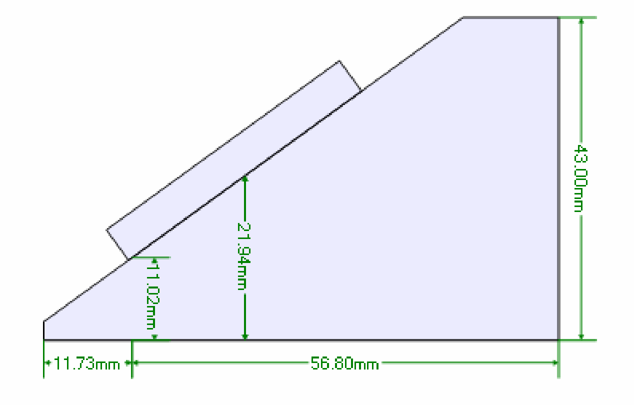


Left Side:		Right Side:	
Cap Width:	12.59 mm	Cap Width:	12.59 mm
Cap Height:	15.66 mm	Cap Height:	15.66 mm
Cap Angle:	30.67 mm	Cap Angle:	30.67
Root Width:	7.02 mm	Root Width:	7.02 mm
Root Height:	6.04 mm	Root Height:	6.04 mm
Root Angle:	30.14	Root Angle:	30.14

Part Thickness: 25mm

b. Transducer and Wedge specifications with index offset

Front Position: -30mm   Side Position: 10mm



Wedge: SA2-N55S dual 5L64

Velocity: 2.33

X	Xt	Length	Z	Height	Width	Angle
56.8	11.7	68.5	11.0	43	30	36

Transducer: 5L64-A2

Total Aperture: 37.76

Total Elements: 64

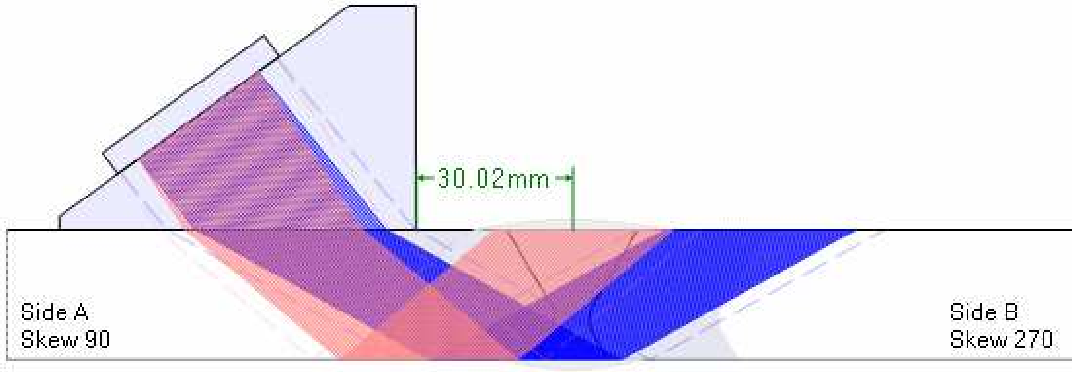
Element Pitch: 0.59

c. Focal law parameters

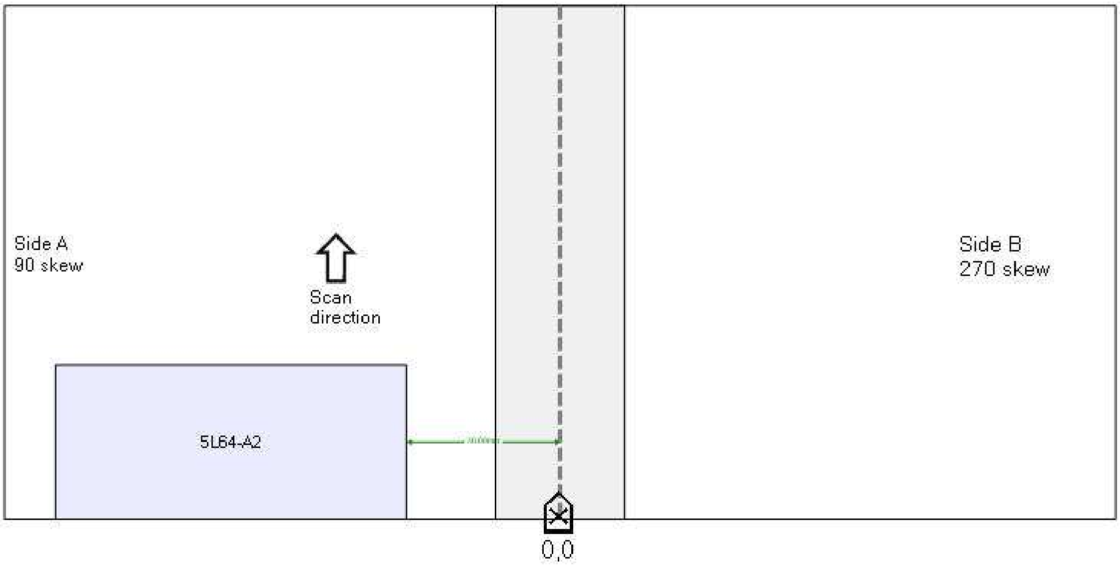
	Linear Beamset 1 (Shear)							
Alpha Angle	Refracted Angle	Num Skips	Start Element	Element Step	Focal Laws	Used Aperture	Aperture Elements	Beam Sweep
38.97	61	2	1	1	49	9.44	16	2.97

	Linear Beamset 2 (Shear)							
Alpha Angle	Refracted Angle	Num Skips	Start Element	Element Step	Focal Laws	Used Aperture	Aperture Elements	Beam Sweep
33.43	50	2	1	1	49	9.44	16	-2.57

d. Beam Coverage with HAZ

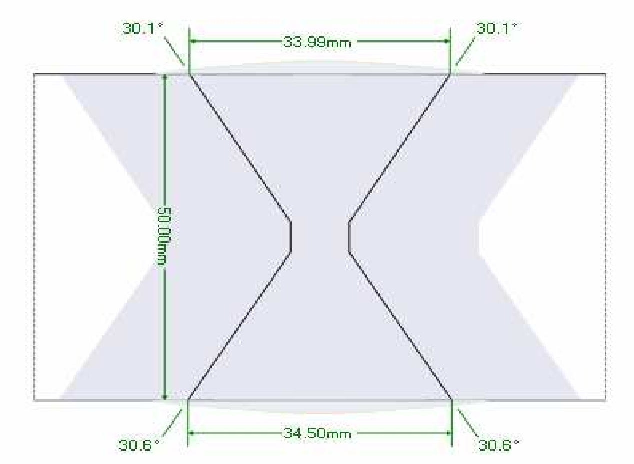


e. Scan Pattern



2. Sectorial scan plan example according to ASME requirements

a. Weld joint Geometry and HAZ representation



Left Side:

Cap Width: 16.99 mm
Cap Height: 22.72 mm
Cap Angle: 30.14 mm
Root Width: 17.25 mm
Root Height: 22.72 mm
Root Angle: 30.62

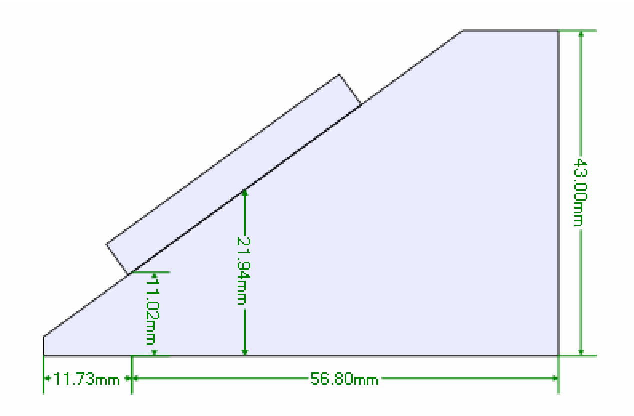
Right Side:

Cap Width: 16.99 mm
Cap Height: 22.72 mm
Cap Angle: 30.14
Root Width: 17.25 mm
Root Height: 22.72 mm
Root Angle: 30.62

Part Thickness: 50 mm

b. Transducer and Wedge specifications with index offset

Front Position: -75mm Side Position: 15mm



Wedge: SA2-N55S dual 5L64

Velocity: 2.33

X	Xt	Length	Z	Height	Width	Angle
56.8	11.7	68.5	11.0	43	30	36

Transducer: 5L64-A2

Total Aperture: 37.76

Total Elements: 64

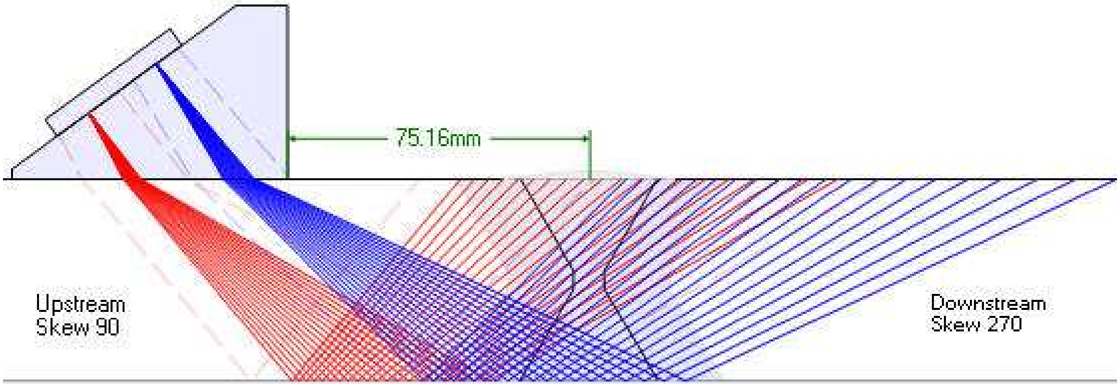
Element Pitch: 0.59

c. Focal law parameters

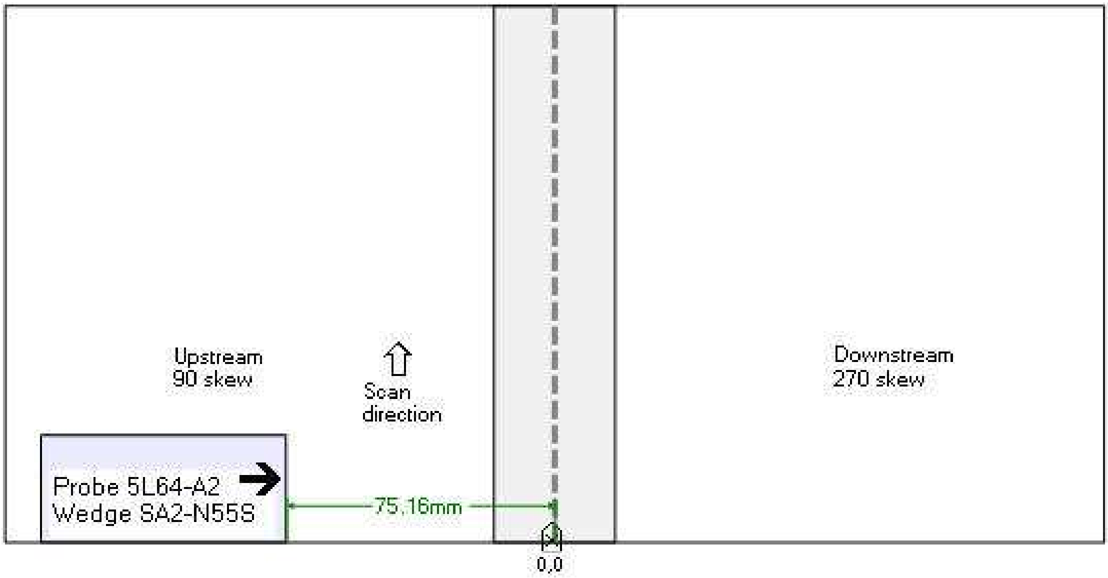
	Sectorial Beamset 1 (Shear)					
Min Angle	Max Angle	Num Skips	Start Element	Focal Laws	Aperture Elements	Beam Sweep
40	60	2	1	20	32	1

	Sectorial Beamset 2 (Shear)					
Min Angle	Max Angle	Num Skips	Start Element	Focal Laws	Aperture Elements	Beam Sweep
45	65	2	40	20	24	1

d. Beam Coverage with HAZ



e. Scan Pattern



These graphic screen captures and parameters are extracts from a demonstration report generated by ESBeam Tool. The software gives the operator all the documentation tools necessary to generate a complete scan plan according to ASME and most UT inspection codes requirement.

Conclusions:

Utilization of ultrasonic beam modeling tools with integrated target and weld overlay facilities greatly enhance the technique development process. When employed by a project auditor, technique deficiencies will be made apparent. In the hands of an AUT technician it enables a complete and well documented technique.
When utilized to its fullest capabilities it facilitates the design process for most of the critical UT variables including:

- Wedge and transducer design parameters
- Calibration block design with target size and placement
- Index offsets and probe placement optimization
- Weld or component geometry and HAZ definitions
- Zonal coverage and beam placement

Watch for upcoming articles on specific code applications, ToFD parameter modeling and Zonal Discrimination technique development using ESBeam Tool2.

References

1. ASME Code Case 2235-9, Cases of ASME Boiler and Pressure Vessel Code. Use of Ultrasonic Examination in Lieu of Radiography Section I; Section VIII, Divisions 1 and 2; and Section XII. Approval Date: October 11, 2005

2. ASME Code Case 2541, Cases of ASME Boiler and Pressure Vessel Code. Use of Manual Phased Array Ultrasonic Examination Section V. Approval Date: January 16, 2006

3. ASME Code Case 2557, Cases of ASME Boiler and Pressure Vessel Code. Use of Manual Phased Array S-Scan Ultrasonic Examination per Article 4 Section V. Approval Date: September 18, 2006

4. ASME Code Case 2558, Cases of ASME Boiler and Pressure Vessel Code. Use of Manual Phased Array E-Scan Ultrasonic Examination per Article 4 Section V. Approval Date: December 30, 2006

5. E. Ginzel, R. Ginzel, D. Cziraki, Ultrasonic Modeling & Sound Visualization, www.ndt.net/article/v08n11/ginzel/ginzel.htm