Phased Array Ultrasonic Sizing Performance on Artificially Produced Fatigue Cracks in Austenitic Stainless Steel Weld

12th International Conference on Non Destructive Evaluation in Relation to Structural Integrity for Nuclear and Pressurized Components, Dubrovnik, Croatia

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Background

- Reliable evaluation of the performance of in-service inspection procedures, equipment and personnel requires representative artificial defects.
- Ultrasonic indications are dependent on defect characteristics like roughness, crack opening, tilt, skew and branching.
- The use of artificial defect can lead to an error, if the limitations of the artificial defects used for the NDE procedure design or qualification compared to ISI defects is not known.

a) EDM-notch
b) Welded crack simulation
c) Grown crack
d) Service-induced crack
Open piping test block

- Austenitic AISI 321 piping component:
  1. Similar as in PWR cooling line
  2. Five mechanical fatigue cracks
     1. Different sizes
     2. One skewed 8°, two tilted 10°
  3. One EDM notch
Ultrasonic Evaluation

- Three qualified PAUT procedures
  - 1.5 MHz Linear (TRL and TRS)
    - Minimal amount of scan lines
  - 1.5 MHz Sectorial (TRL and TRS)
    - Small footprint probes
    - Skew
  - 2.25 MHz TRS Sectorial and MC
    - Small footprint probes
    - ID creeping wave
- Inspection from the near side and the far side
- Scanning with pipe scanner
Defect sizing and performance

- Height sizing
  - Crack tip diffraction
  - 6 dB drop estimation when crack tip diffraction not applicable

- Length sizing
  - Full amplitude drop

- Signal to noise ratio (SNR)

- Performance
  - Measurement error
  - Standard deviation
  - Root mean square error (RMSE)
Height sizing near side
Height sizing far side

![Graph showing the relationship between measured and true height for all techniques on the far side.](image-url)
Height sizing

- Procedures
  - Near side results good with maximum RMSE of 3.2
    - LW and SW equally good
  - Far side results also relatively good with maximum RMSE of 3.7
    - SW performed better
- Techniques
  - All qualified techniques performed well
    - TRL 1 and TRS 1 45° best for near side
    - TRS 3 (40° to 70°) best for far side
- Defects mostly oversized
- Far side height sizing not possible with all techniques
Length sizing near side

![Graph showing the relationship between measured length (mm) and true length (mm).]
Length sizing far side

![Graph showing measured length against true length for all techniques on the far side. The graph includes a scatter plot with data points and a line of best fit.](image)
Length sizing

- Procedures
  - Near side results good with RMSE of 9.9
    - MC the best performance, SW better than LW
  - Far side results acceptable with RMSE of 12.6
    - SW performed better also in length sizing

- Techniques
  - All qualified techniques performed within acceptable limits
    - TRS 1 45°, TRS 3 (40° to 70°) and MC best for near and far side

- Defects mostly oversized with near side access
- Shorter defects oversized and larger undersized with far side access
- Some artefacts due to defect production
Conclusions 1/2

- Artificial mechanical fatigue cracks and EDM notch in austenitic stainless steel open piping test block were inspected with phased array ultrasonic methods.
  - Three phased array procedures using TR probes
- Share wave techniques were generally performing well
  - Use of longitudinal waves not always essential
- Far side access
  - LW and SW suffering from noise
  - LW might be required, not always performing well enough with smaller defects
- Combination of SW sectorial scan and MC showed good performance
Conclusion 2/2

- Good coupling important for the reliability and repeatability of an inspection

- Large footprint probe
  - Good coverage of single scan line (wide electronic linear scan) → Less inspection time
  - More susceptible for loss of proper coupling → Decrease of reliability

- Smaller footprint probe
  - Good coupling easier to reach → More reliable results
  - More scan lines needed → More time
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