A Novel Procedure for the Ultrasonic Testing of Wind Turbine Bolts

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Keywords

Offshore Wind, Phased Array Ultrasonic Testing (PAUT), Bolt Stress Measurement

Abstract

Bolts are used as the fasteners on various sections of the Offshore Wind Turbine (OWT), and they require regular Non Destructive Testing (NDT). The current procedure requires permanent strain gauges, single element ultrasonic inspection, or a mixture of both in order to ensure that the specific preload is maintained throughout an OWT's operative cycle. Both of these methods have drawbacks: Strain gauges are mainly used on a smaller, experimental scale; and the ultrasonic method, traditionally carried out using single element transducers, has low accuracy and, additionally, the existence of the volumetric defects in the bolt (or a corrosion layer) can affect the stress measurement. This paper suggests a novel method to test bolts in an OWT quickly and efficiently, using a Phased Array Ultrasonic Transducer (PAUT) probe as opposed to a single element transducer. A PAUT probe has the ability to produce both a swept scan and a linear A – scan for each pair of transmitting and receiving elements or, if using the Full Matrix Capture (FMC) technique, a number of acoustic paths equal to the number of elements squared (i.e. 400 paths if using a 20 element probe).

A sector scan was initially performed to identify and roughly size defects, and if any were detected that were within the acceptance criteria a second, targeted scan was performed. Following this, the probe was moved to an optimum position where the acoustic paths will have minimal interaction with the defects and an FMC scan to measure Time of Flight (ToF) was performed, which allowed for stress calculation.

To justify the necessity of considering small acceptable defects in the follow-on ultrasonic stress measurement, two experiments were performed to study the effect of filling engraved text (0.5 mm depth) on the bolt head with gel used to represent the dust and debris from general use. We used a Detachable Active Array Head (DAAH) probe (2.25 MHz, 20 elements, Sonatest, UK) and a PEAK Micropulse 6 (PEAK Ltd, UK) as the controller. Using the PAUT system revealed that the gel caused a 10 ns difference in the ToF. This is equivalent to 40 MPa of stress, or an error of up to 20% of the yield strength (200 MPa). This shows the importance of pre-investigation of defects (PAUT defect detection) and choosing optimum acoustic paths for the follow-on stress measurement to avoid said defects and reduce measurement error.

A Novel Procedure for The Inspection of Wind Turbine Bolts

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Introduction

- Current Procedure
- Why use Phased Array?
- Proposed Procedure
- Conclusions
- Future Work

Current Procedure

- Current standards include use of a single or dual element probe, manually applied and verified with strain gauge
- Multiple areas must be scanned for full picture
- Takes several seconds per bolt
  - Becomes an issue with thousands of bolts to inspect

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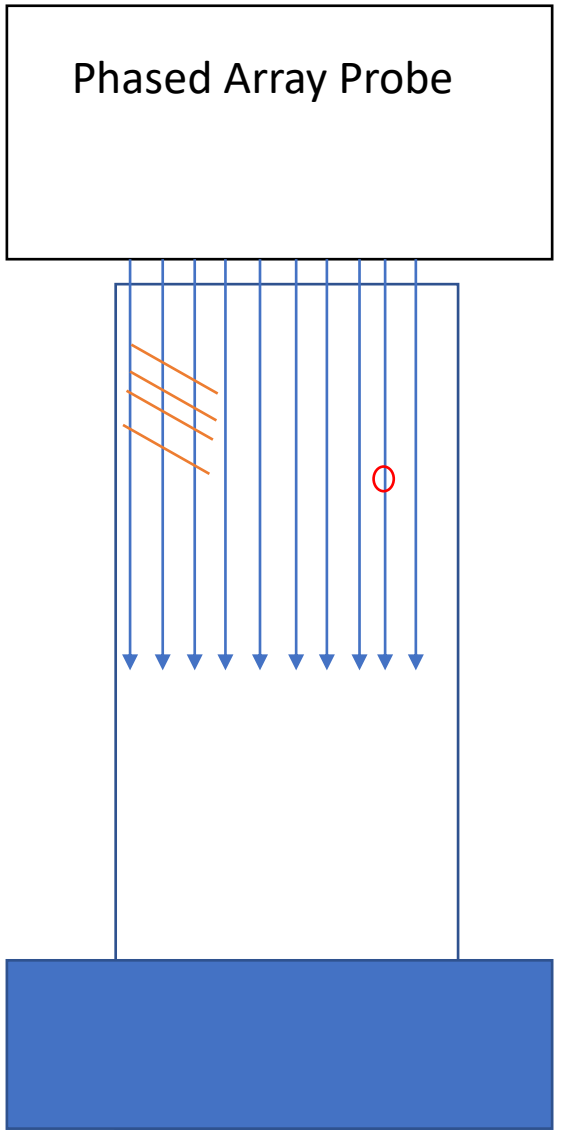
1: https://www.echobolt.co.uk/copy-of-solutions
2: https://boltsafe.com/applications/

Why use Phased Array?

- Number of elements provide increase in quantity of data
- Further increased using Full Matrix Capture (FMC) Technique
- Optimises number of good acoustic paths – essential for practical use
- Additionally, allows for defect detection as well as stress measurement



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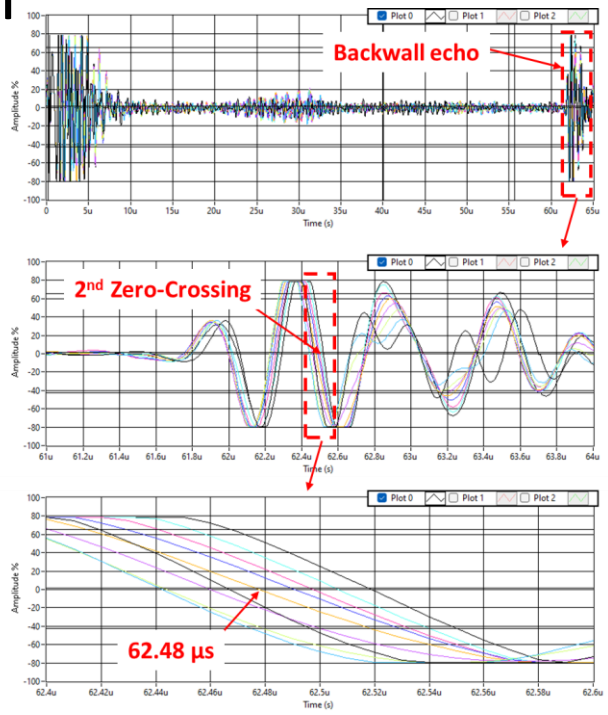
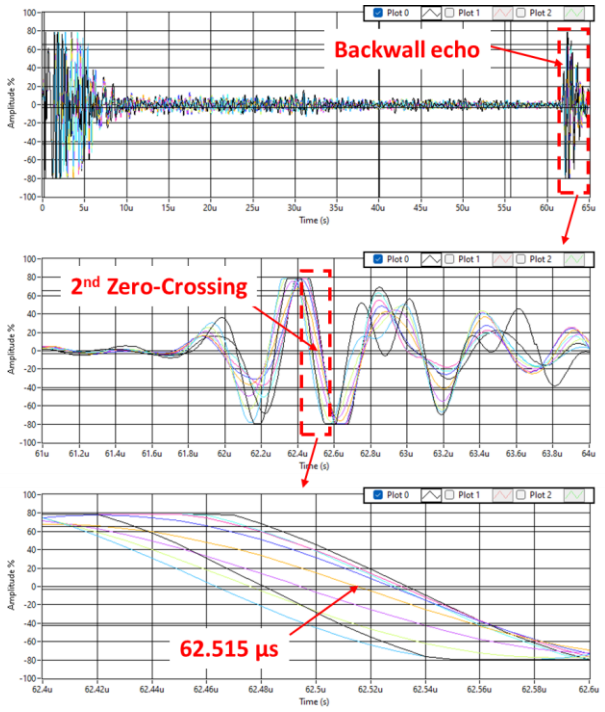
Why use Phased Array?

- To justify this project we induced a small irregularity in a bolt
- This caused average difference of 10ns, equivalent to an error of 40MPa
- This could equally be caused by any given irregularity
- PAUT probes allow for acoustic path selection and averaging

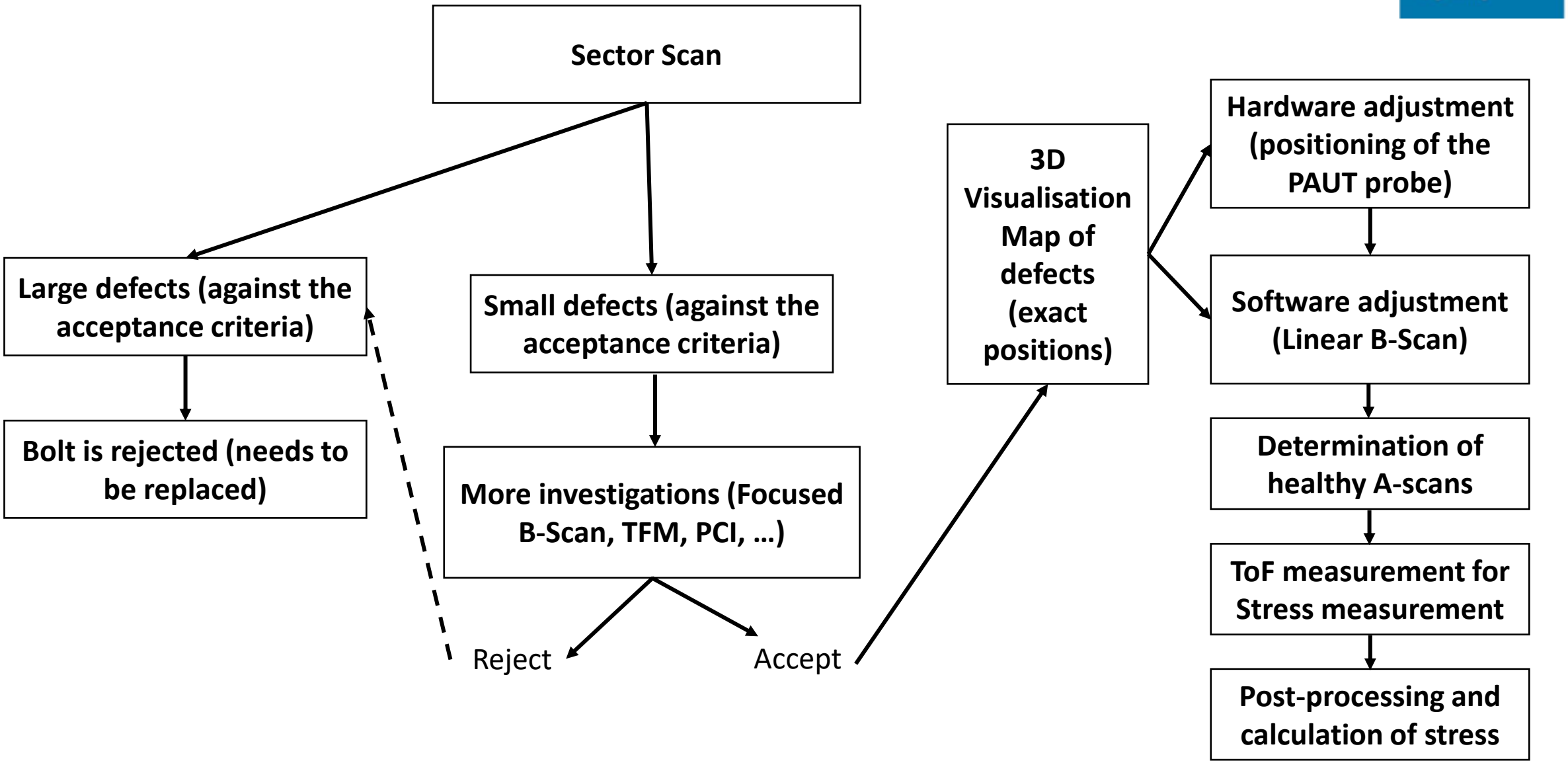


With gel



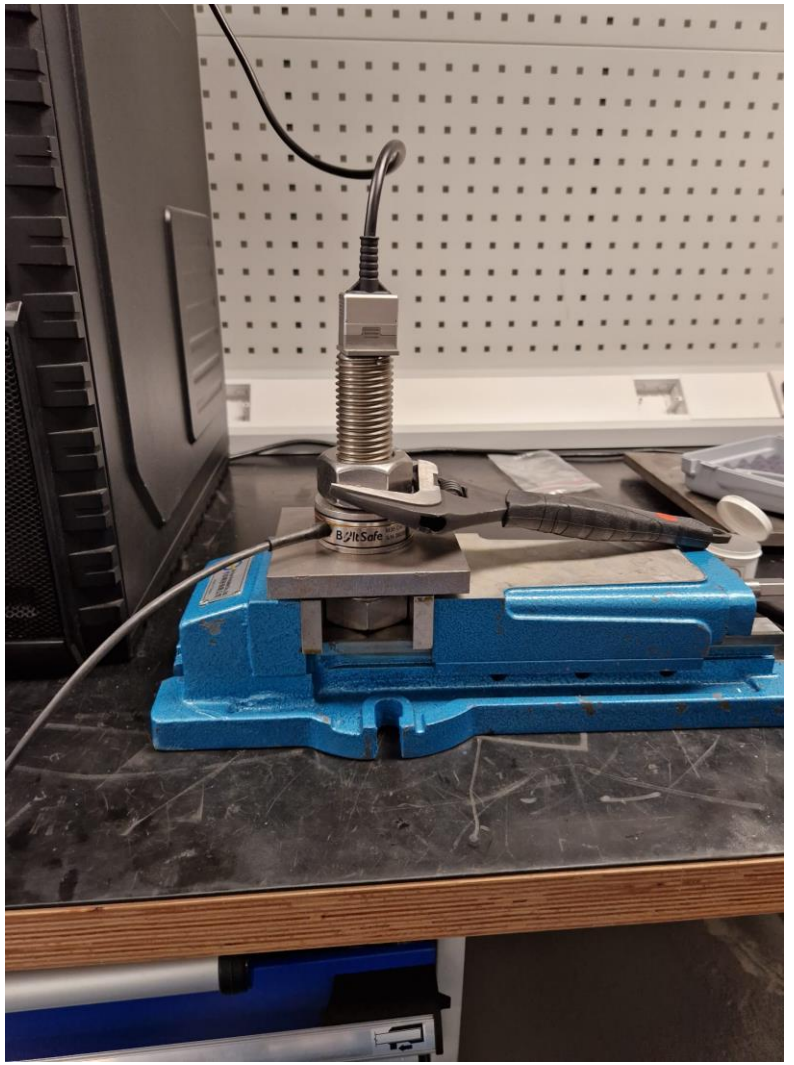
No gel

Methodology



Experimental Verification

- Experiment set up as shown (right)
- Nut was tightened with wrench to generate axial force
- Force monitored using strain gauge
- Time of flight measured using 20 element PAUT probe (top)



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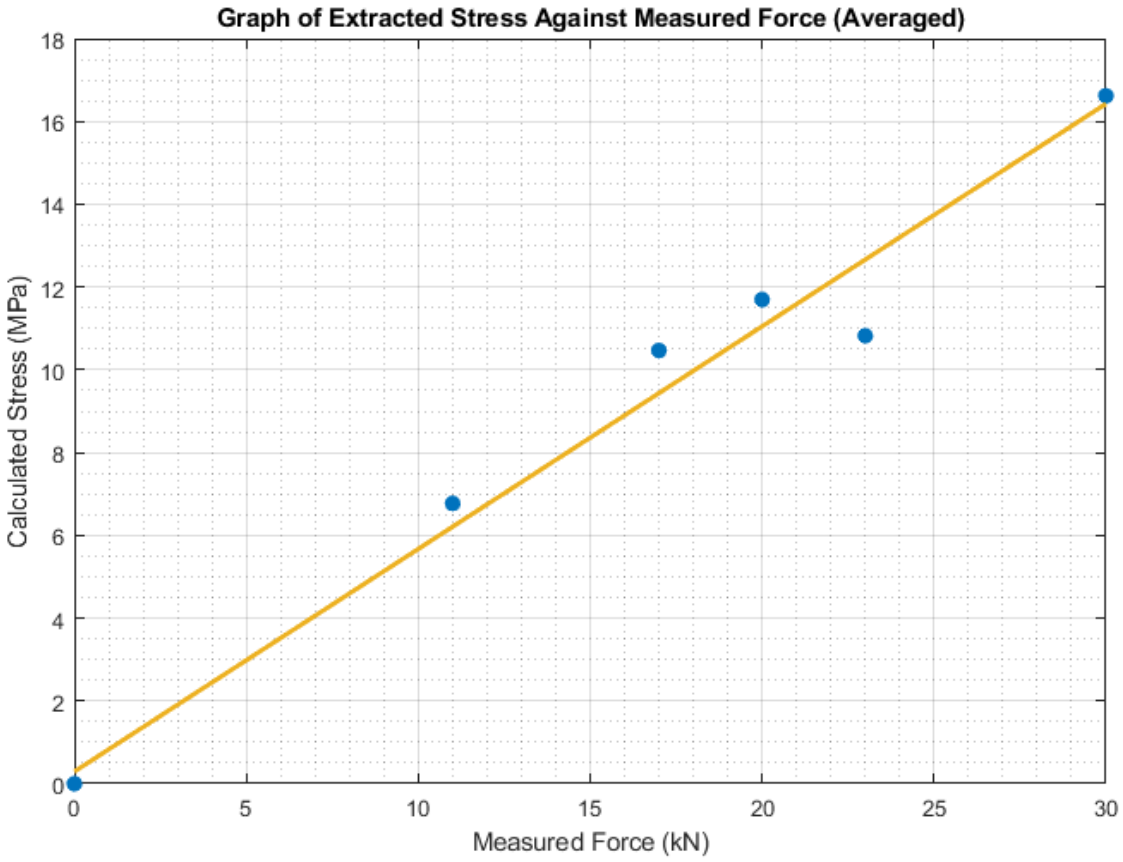

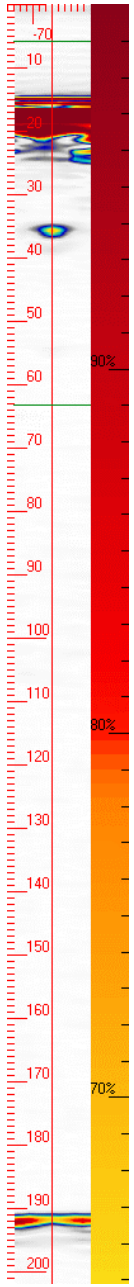

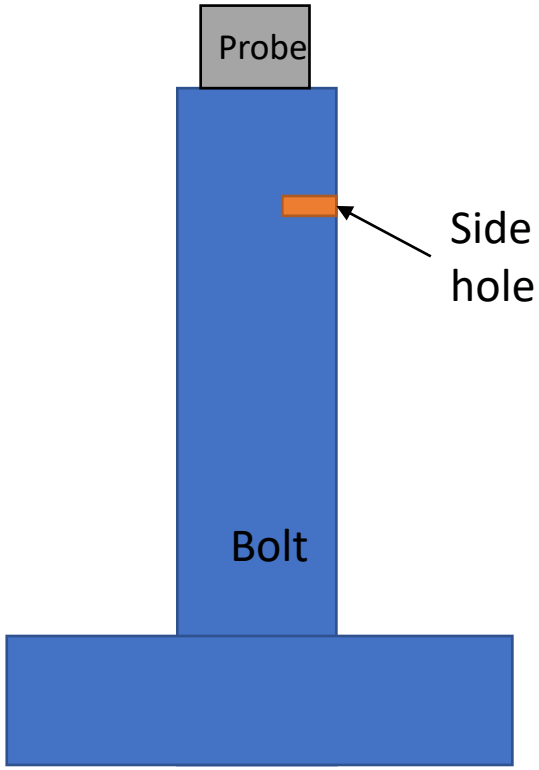

Conclusions

- This methodology allows for both stress detection and defect detection
- It can account for defects and grainy areas in the material
- It can easily be adapted for use in other applications where stress and defects must be monitored
- Even if kept in the same spot, sector scanning and FMC capabilities of PAUT probes allow for a robust scan

Future Work

- At the SEARCH lab, a major focus is Robotics and Control

- A major aim is to automate this entire process, including calibration and stress analysis

Thank you for your attention

Please feel free to ask any questions, or contact me at brandon.mills@strath.ac.uk