Interpass Peening Impact on Residual Stress in Wire-Arc Additive Manufactured Ti-6Al-4V Using Phased-Array Ultrasonic Testing

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Introduction:

- Collaborative effort between **Cranfield University** (WAAM sample manufacturing), and **The University of Strathclyde** (Phased array ultrasonic measurements).
- WAAM-manufactured titanium components, especially Ti-6Al-4V, are popular in aerospace and other industries.
- The major issue with WAAM Ti-6Al-4V is that lots of residual stress (RS) is produced due to the heat input required, potentially causing failure of the component. So, it is important to understand how to evaluate RS in these samples and minimise the effects of RS as much as possible.
- Interpass-peening is an existing method that can be used to potentially minimise RS.
- Non-destructive testing of both as-deposited and interpass-peened samples can be carried out to provide a comparative analysis.
- WAAM Ti-6Al-4V samples were measured for RS using a proposed method of phased array ultrasonic testing utilising Longitudinally Critically Refracted (LCR) waves.
- This method was used for the comparative analysis between as-deposited and interpass-peened RS in WAAM Ti-6Al-4V samples.

Objectives:

- Provide a comparative analysis between RS distribution in as-deposited and interpass-peened WAAM Ti-6Al-4V samples.
- Understand if interpass peening can be carried out on WAAM Ti-6Al-4V samples in order to reduce the amount of RS present.
- Understand the feasibility of measuring RS using phased array ultrasonics for WAAM Ti-6Al-4V samples.
- Fill a gap in research for how phased array ultrasonics can be used to evaluate RS.

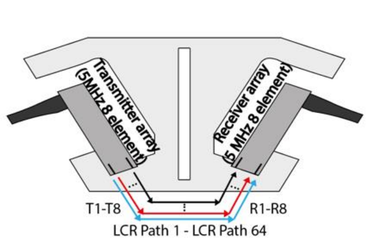

Figure 5 PAUT-LCR RS measurement approach set-up.

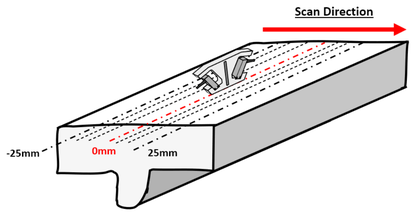

Figure 6 The scan path and direction when taking carrying out measurements on the Ti-6Al-4V samples.

Methodology:

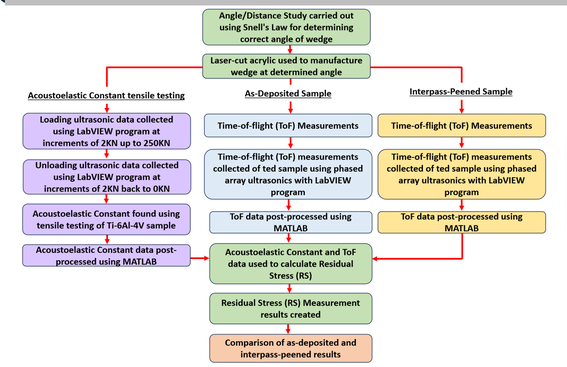

Figure 1 A flow chart showing the methodology for the experiments

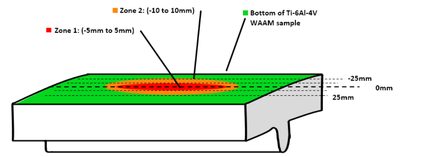

Figure 2 Bottom of WAAM Ti-6Al-4V sample with illustration showing different heat-effected zones (HAZ)

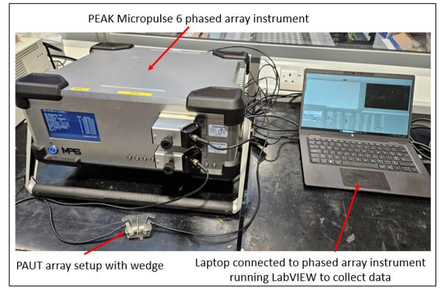

Figure 3 Phased array ultrasonic LCR RS Experimental Setup

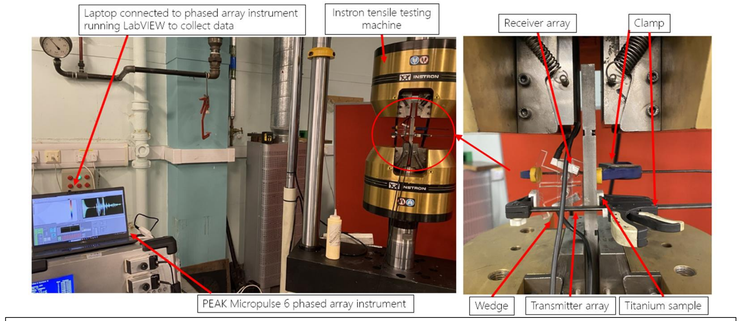

Figure 4 Experimental setup for finding the acoustoelastic constant of a Ti-6Al-4V sample.

Experimental Results:

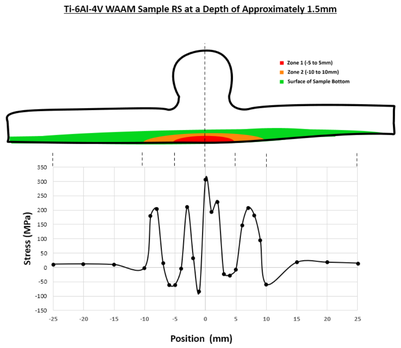

Figure 7 As-Deposited Sample Phased Array Ultrasonic Measurements [1]

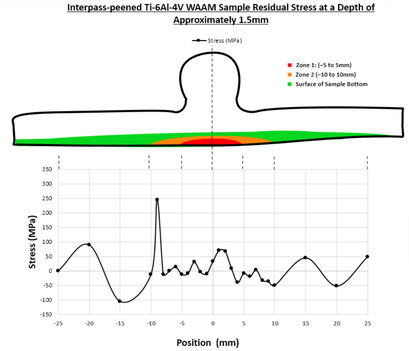

Figure 8 Interpass peened Sample Phased Array Ultrasonic Measurements

- In the HAZ, as-deposited RS measured from around 200MPa and peaked at 300MPa at the centre of the HAZ (0mm). Interpass peened showed a great reduction in stress.
- Anomaly present at -9mm where RS spikes randomly to 250MPa, but RS is low other than this and would range from around 75 to -50MPa without this anomaly.
- Comparing the results, some stress is redistributed to outside the HAZ as there is some higher RS measurements in this area compared to the as-deposited sample.
- Despite the error at -9mm, peak RS in the peened sample is measured at 200MPa and lowest at -100MPa, which is still lower than the as-deposited results.

Conclusions:

- When comparing the as-deposited and interpass peened results, there is a clear reduction in RS in the peened sample.
- The feasibility for phased array ultrasonic to evaluate RS in WAAM Ti-6Al-4V samples was proven and shows it is a viable method.
- An anomaly is present at -9mm in the interpass-peened results, which can be attributed to an issue during scanning. However, this can be further improved with robotic inspection.

Future Work:

- Carry out more testing on more WAAM Ti-6Al-4V samples to verify the results and the reduction of RS using interpass peening.
- Carry out measurements using robotic inspection rather than manual testing, to see how results can be improved and to mitigate errors such as the one mentioned at -9mm.

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Engineering and Physical Sciences Research Council

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References

[1] Walker, J., Mills, B., Javadi, Y., MacLeod, C., Sun, Y., Taraphdar, P. K., Ahmad, B., Gurumurthy, S., Ding, J., & Sillars, F. (2024). Study of Residual Stress Using Phased Array Ultrasonics in Ti-6AL-4V Wire-Arc Additively Manufactured Components. *Sensors*, *24*(19), 6372. https://doi.org/10.3390/s24196372