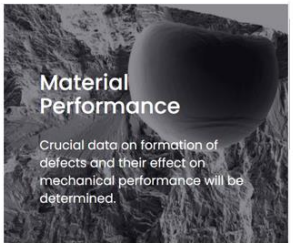
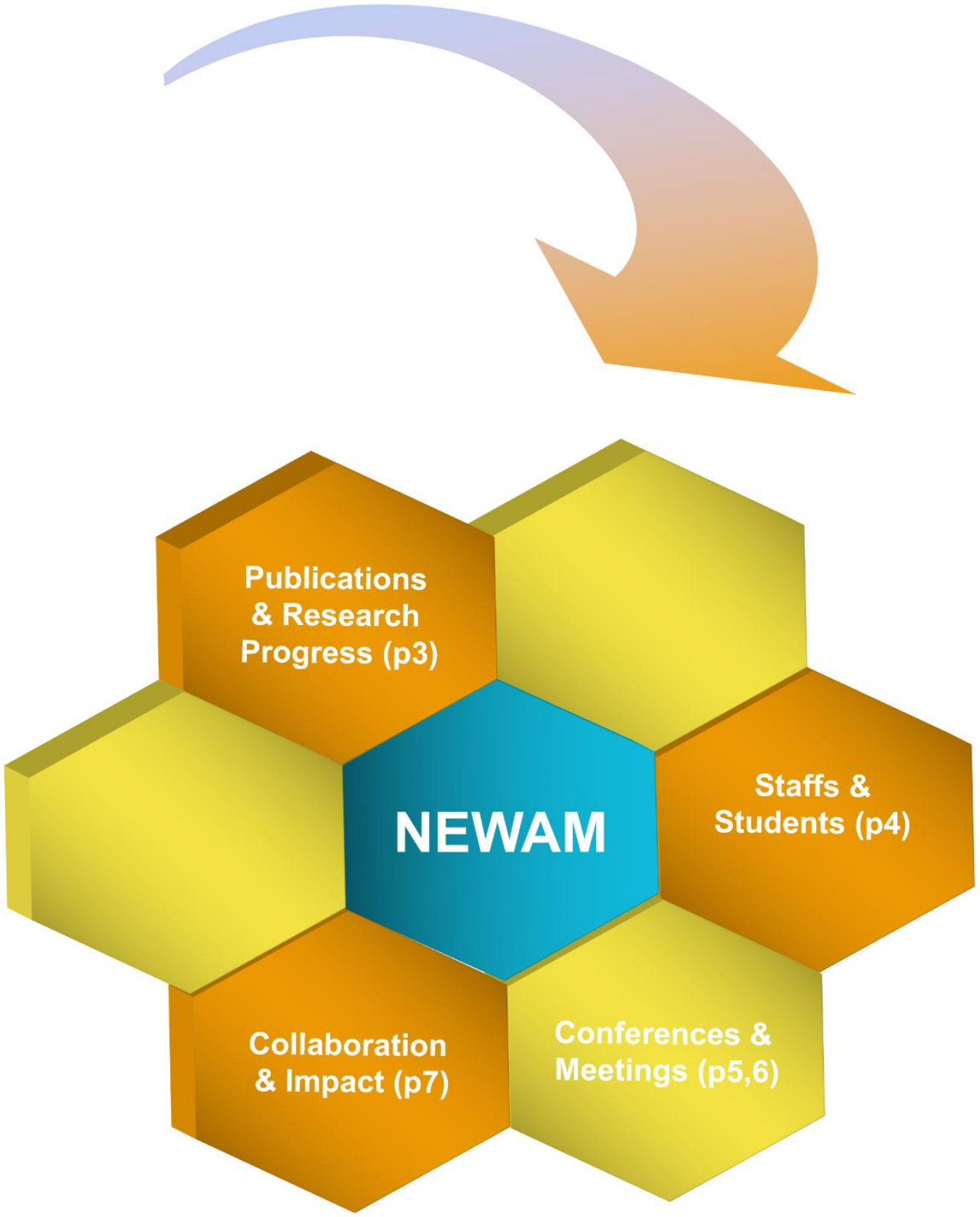
New Wire Additive Manufacturing

Newsletter (4th quarter, 2021)



Compiled by NEWAM dissemination committee and released on 3 January 2022

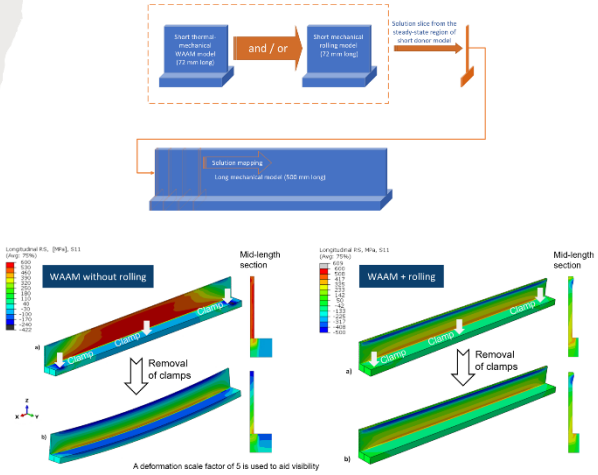
Your NEWAM in Oct. – Dec. 2021



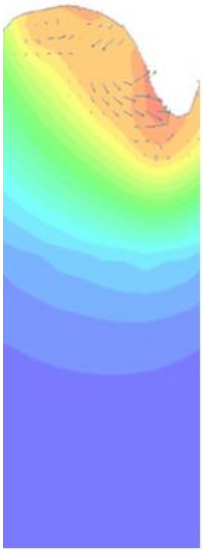
Publications & Research Progress

Cranfield process modelling team's new publication

- Cranfield process modelling team recently published a new paper on modelling of rolling for mitigation of WAAM residual stress and distortion
- An efficient modelling approach is developed to simulate both WAAM and rolling. For a clamped wall component, the computationally efficient reduced-size WAAM and rolling models (i.e., short models) can obtain steady-state solutions equivalent to those obtained by conventional full-size models. The steady-state solution obtained by the short model in clamped condition is then mapped to a long model for analysis of RS and distortion after removal of clamps. The high pressure rolling on the wall after WAAM deposition introduces tensile PS that compensates for the compressive PS induced by the WAAM deposition, thereby mitigating the tensile RS in the clamped wall and alleviating the bending distortion after the removal of clamps.



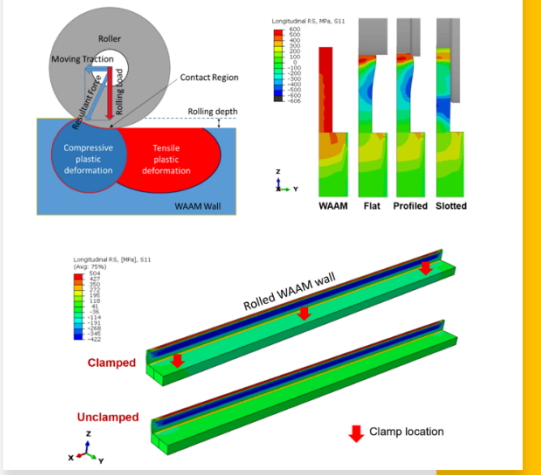
Gornyakov V., Sun Y., Ding J., Williams S. (2022). Efficient determination and evaluation of steady-state thermal-mechanical variables generated by wire arc additive manufacturing and high pressure rolling. Modelling and Simulation in Materials Science and Engineering, 30, 014001.



Cranfield process modelling team published a new paper

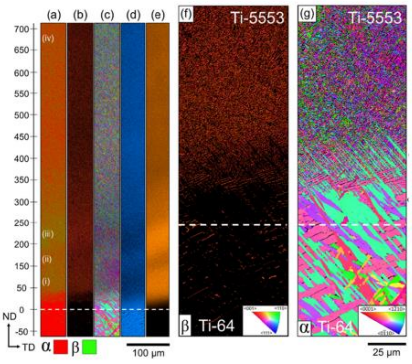
- Cranfield process modelling team recently published another new paper on modelling and design of post-build rolling for controlling WAAM residual stress and distortion.
- Post-build rolling can efficiently mitigate residual stress (RS) and distortion in large-scale WAAM components. The influences of process configuration and condition, such as roller design (flat, profiled and slotted rollers), rolling load (25-75 kN) and roller-to-wall friction coefficient (0-0.8) on the distributions of plastic strain (PS) and RS were investigated. The slotted roller is most effective to introduce tensile PS for counteracting the compressive PS generated by the WAAM deposition, thereby reducing the tensile RS in the clamped condition and the final distortion after removal of clamps. Higher rolling load increases the rolling-induced tensile PS, which leads to more extensive mitigation of the WAAM-generated tensile RS. The friction coefficient significantly affects the PS and RS when the slotted roller is employed. However, the efficacy of the flat/profiled roller is insensitive to friction coefficient.

Gornyakov V., Ding J., Sun Y., Williams S. (2022), Understanding and designing post-build rolling for mitigation of residual stress and distortion in wire arc additively manufactured components. Materials & Design, 213, 110335.



Manchester Team's new paper on microstructure of dissimilar alloy deposit

- Manchester team have recently published a paper entitled 'Microstructure transition gradients in titanium dissimilar alloy (Ti-5Al-5V-5Mo-3Cr/Ti-6Al-4V) tailored wire-arc additively manufactured components'. This research sought to understand the impact of the chemical gradients that develop on microstructure formation between dissimilar alloys when they are deposited with WAAM, by switching the alloy wire-feed in-situ during deposition. In this test sample, we deposited Ti-6Al-4V – a medium strength, damage tolerant alloy – on Ti-5Al-5V-5Mo3Cr – a high strength but heavier alloy – and vice versa. The results showed that the microstructure transitions had a stepped profile, where there were several abrupt changes in the first 3 new alloy layers deposited; and, importantly, the alloy deposition order affected the nature of the transitions. This work represents a step towards a new design platform for aerospace component production unique to high-deposition-rate AM processes, where site-specific properties and tailored microstructures can be achieved in more efficient, lightweight parts.



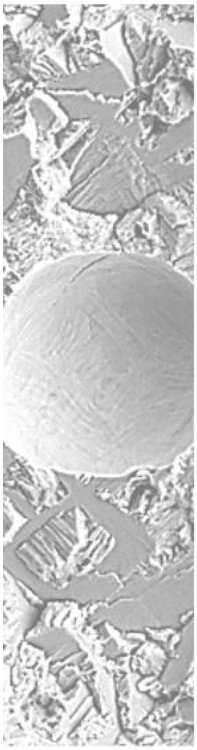
- Kennedy, J. R., Davis, A. E., Caballero, A. E., White, M., Fellowes, J., Pickering, E. J., & Prangnell, P. B. (2021). Microstructure transition gradients in titanium dissimilar alloy (Ti-5Al-5V-5Mo-3Cr/Ti-6Al-4V) tailored wire-arc additively manufactured components. Materials Characterization, 182, 111577.

Staffs & Students

Cranfield Team's new Research Fellow: Guangyu Chen

- Guangyu comes from a small town in the south of China. He has just submitted his PhD thesis. His PhD project mainly focused on the study of the MES for the wire-based AM process. Independent control of layer width and height is essential to achieve a simultaneous high build rate with precision net shape and thermal control independent from deposition shape in the wire-based direct energy deposition (w-DED) process. Bead shape control using a multi-energy source (MES) method was studied to achieve independent control of layer width height of a bead for the w-DED process.
- He will continue to work in the WELPC of Cranfield as a research fellow after finishing his PhD. His main task will be continuing the study of the MES AM technique, including bead shape control, dynamic bead shaping, flexible deposition, etc. He is looking forward to spending more time with this wonderful team.

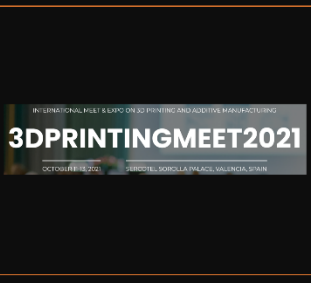
Conferences & Meetings



Cranfield process modelling team gave three invited talks in 3D Printing Meet 2021

Cranfield process modelling team delivered three presentations in International Meet & Expo on 3D Printing and Additive Manufacturing, October 11-12, 2021. This conference was planned to be held in Spain, but later it was converted to online meeting due to Covid-19 restrictions. The presentations include

- **Invited Keynote talk** delivered by Dr Jialuo Ding, entitled "A New Wire Based Direct Energy Deposition Process - Higher Deposition Rate with Accurate Bead Geometry Control"
- Invited talk delivered by Dr Yongle Sun, entitled "Modelling and Understanding the Rolling-Enabled Mitigation of Residual Stress and Distortion in Wire Arc Additive Manufacturing"
- Invited talk delivered by Dr Jian Qin, entitled "Bi-directional Machine Learning (ML) Modelling for Direct Energy Deposition Additive Manufacturing (DED-AM) Processing Design"



NEWAM Team presented in "2021 Prenscia Technology Days – Virtual Seminar Series"

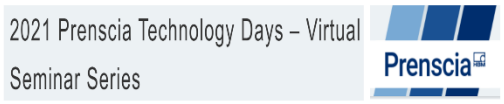
Presentation titles and the lead presenter:

1. New Wire Additive Manufacturing (NEWAM) programme for next generation wire based additive manufacture. Prof. Stewart Williams, Director of the Welding Engineering and Laser Processing Centre, Cranfield University.
2. Structural Integrity of Titanium Ti-6Al-4V additively manufactured by w-DED Professor Xiang Zhang, Coventry University.
3. Cyclic Deformation and Fatigue Behaviour of Titanium Ti-6Al-4V additively manufactured by w-DED. Dr. Abdul Khadar Syed, Coventry University; Mr. Rob Plaskitt, Prenscia (HBK)

https://www.hbmprenscia.com/about/events/2021-prenscia-technology-days-virtual-seminar-series/archive-2021

Summary

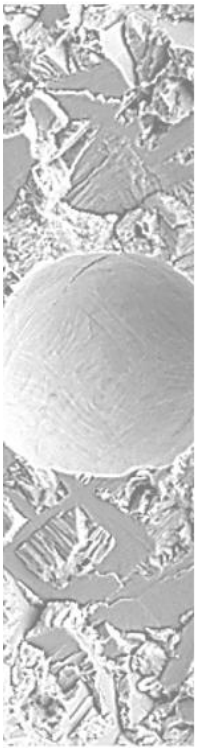
During this seminar, NEWAM team led a session titled "New Wire Additive Manufacturing (NEWAM) programme for next generation wire based additive manufacture". During this, three presentations were made by Prof. Stewart Williams (Cranfield University), Prof. Xiang Zhang and Dr Abdul Khadar Syed (Coventry University). These presentations cover an introduction to the NEWAM research programme, focused on the process, material and structural integrity of wire based directed energy deposition AM (w-DEDAM) processes followed by the influence of deposition strategies and process induced residual stress on strain controlled fatigue performance and fatigue crack growth behaviour for the high strength titanium alloy Ti-6Al-4V. Material was manufactured with three different deposition strategies; single pass, parallel pass, and oscillation wave builds. The single pass build is limited to a maximum thickness of around 8 mm, whereas the other two methods can build thicker materials as well as parts with variable thickness. All samples were tested in the as-built condition with standard surface machining and polishing.



Cranfield and Manchester team members participated in NAFEMS World Congress

- Cranfield process modeling team member, Dr Yongle Sun, gave a talk in the prestigious NAFEMS World Congress 2021, and the presentation title is *Finite Element Analysis of Post-build and Inter-layer Rolling for Large-scale Components Deposited by Wire Arc Additive Manufacturing*
- Both Yongle Sun and Manchester team member Pratheek Shanthraj were invited to be panelist in the wrap-up session for the theme of Additive Manufacturing in the Congress

Conferences & Meetings

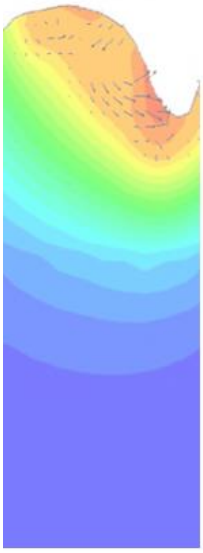


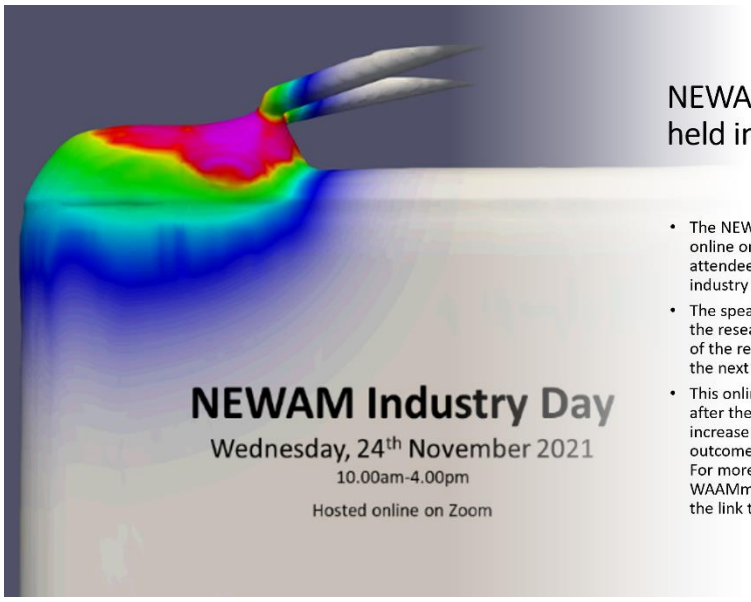
Coventry team presented in "4th International Conference on Light Materials - Science and Technology"

(https://dgm.de/lightmat/)

- **Conference presentation details:** This contribution is a joint effort from Coventry University, University of Manchester, Cranfield University and the industrial partner HBM Prenscia, UK.
- **Authors:** A.K. Syed, A.E. Davis, J.R Kennedy, M. Hill, R. Plaskitt, S. Williams, P.B. Prangnell, X. Zhang
- **Title**: Cyclic deformation and fatigue behaviour of titanium Ti-6Al-4V built by directed energy deposition AM process.
- There are many challenges for full qualification of this material and manufacturing process. One of these key requirements from the aerospace and energy industries, and their regulatory authorities, is the material structural integrity performance under fatigue loading. This talk presented fatigue behaviour under fully reversed cyclic loading and fatigue crack growth behaviour of WAAM Ti-6Al-4V in as-deposited condition. Detailed microstructure and fractography analyses were performed to understand the roles of microstructure and small gas pores on fatigue crack initiation and crack growth behaviour.

Collaboration & Impact





NEWAM Industry Day held in November!

- The NEWAM Industry Day took place online on 24th November with nearly 70 attendees of which 40 were from the industry
- The speakers gave a general overview of the research programme, shared some of the research highlights and presented the next steps
- This online event was organised just after the WAAMmat Industry day to increase the visibility of the research outcomes beyond the academic sector. For more information about the WAAMmat programme please click on the link to https://waammat.com/

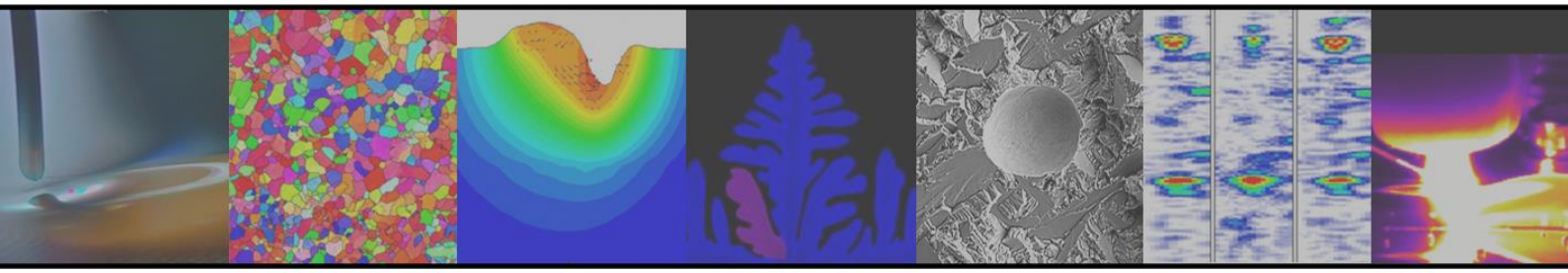
Outcome of NEWAM mid-term review

We are pleased to announce that we have passed the mid-term assessment for the NEWAM project with flying colours and that the project will continue until the current end date of June 2023. The project was assessed by external reviewers, an expert panel assembled by EPSRC, and our own Strategic Advisory Group. NEWAM overall was rated as strong. All bodies agreed that the quality of the research is excellent with a many high-quality joint publications, we are providing good added value and utilising the flexibility of the programme grant well. Reviewers particularly liked the integrated intermediate challenge approach that we have adopted. Detailed plans have been put together for the remainder of the project when great strides forward are expected in many areas. These include

- Investigation of the science and capabilities of the now proven, multi-energy source concept
- New material concepts
- In-process quality assurance

Due to issues with the pandemic the project will also be seeking a 6-12 month extension period.

New Wire Additive Manufacturing



Further Reading

NEWAM website: https://newam.uk/
NEWAM LinkedIn: https://www.linkedin.com/in/newam-epsrc-programme-grant-6617091a9/
NEWAM ResearchGate: https://www.researchgate.net/project/New-Wire-Additive-Manufacturing-NEWAM

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