NEWAM

New Wire Additive Manufacturing

Newsletter (2nd quarter, 2024)

Cranfield University

MANCHESTER 1824

University of Strathclyde

Coventry University

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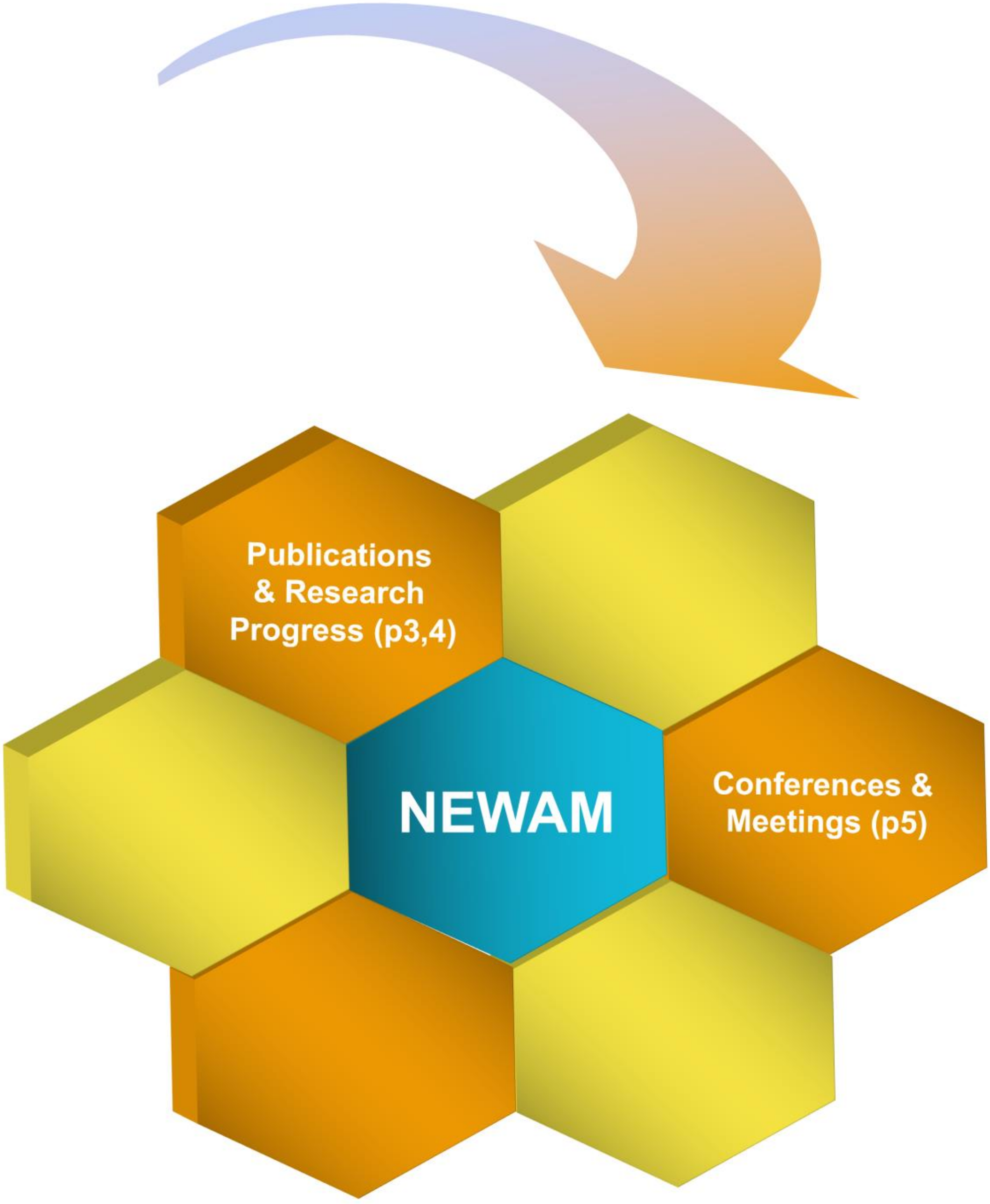
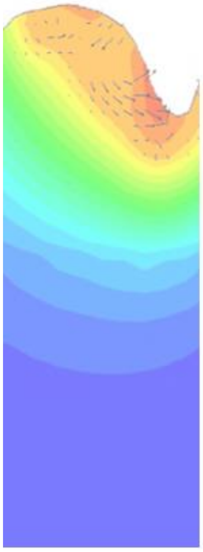
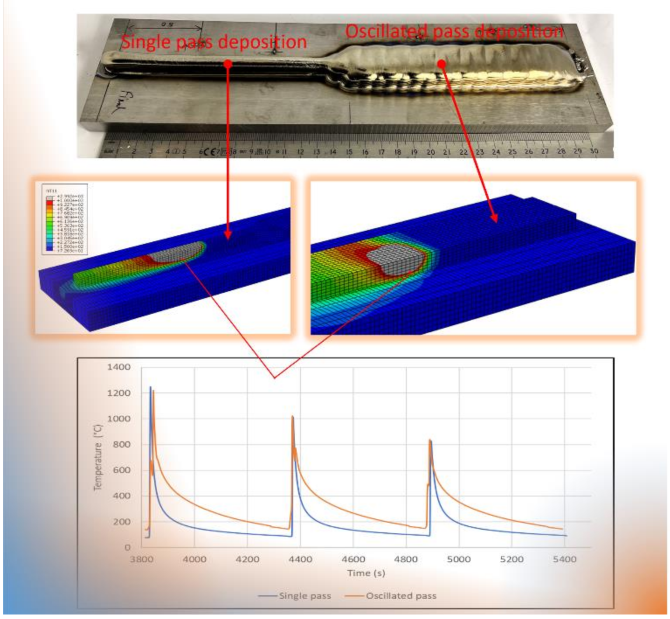
NEWAM in April – June 2024



New Wire Additive Manufacturing

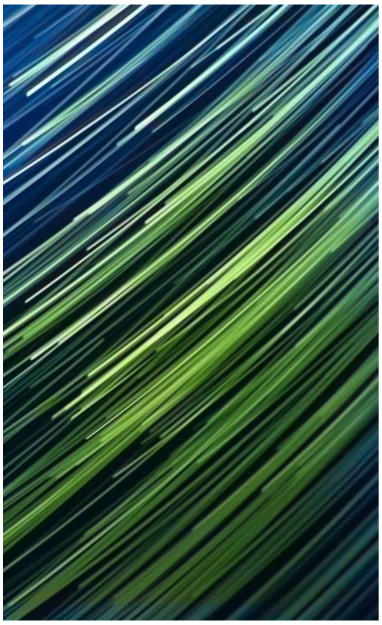
Publications & Research Progress





Cranfield modelling team revealed the thermal conditions in WAAM demo part building with multiple deposition strategies

- Multiple WAAM deposition strategies are necessary when building different sections and features in a part with complicated geometry. The change of deposition strategy, e.g., from single pass to oscillated pass, can lead to difference in thermal condition and hence generate inconsistent microstructure in the part
- To understand the thermal condition, Cranfield modelling team developed a finite element model to simulate a demo part building using both single-pass and oscillated-pass deposition strategies. The model shows the detailed thermal cycles and the critical temperature profiles that determine the microstructure
- The thermal modelling provides foundation to explain the process-microstructure relation and also informs the process design for achieving homogenous microstructure

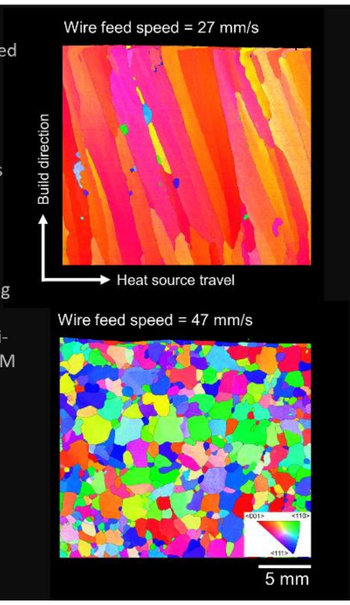


Manchester team found multiple titanium alloy WAAM grain refinement mechanisms

Due to the positive thermal gradient at the solidification front in a heated melt pool, and the low freezing range of titanium alloys, coarse columnar β-grain structures generally form in titanium alloy WAAM deposits, if prevention methods are not considered. The influence of these β grains on the room-temperature transformation microstructure is well known to be detrimental to material performance, most notably introducing mechanical anisotropy and unpredictable damage tolerance. This undesirable grain structure would be especially expected to be occurring during solidification of commercially pure titanium (CPTi) as it has little potential for developing sufficient constitutional undercooling to nucleate new grains during solidification.

Over the NEWAM project, the materials development team at UoM have studied and advanced the knowledge of multiple titanium alloy WAAM grain refinement mechanisms – which includes two new discoveries – allowing the above detrimental mechanical properties to be prevented. All these mechanisms are tied together by a common theme – **crystallographic twinning**. Twins are regions of the atomic crystal structure that are orientated so that they are reflected about a particular axis. These can form during deformation, heat treatment, and even during metal solidification.

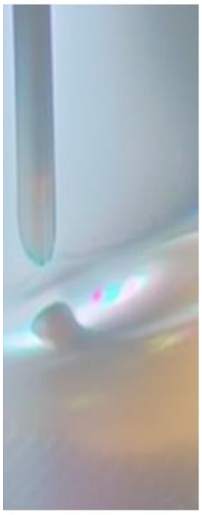
Reconstructed β-phase electron backscatter diffraction (EBSD) maps showing successful grain refinement via increasing wire feed speed in a Ti-6Al-4V WAAM deposition.

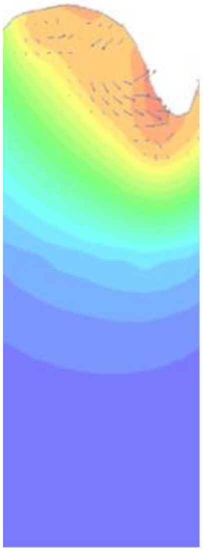


Dendrite twinning during Ti6Al4V WAAM

- Working with the Cranfield University team, Manchester researchers discovered – *for the first time* – the formation of twins during solidification (dendrite twinning) of Ti-6Al-4V during WAAM deposition, which led to the complete refinement of the β-grain structure, producing better-than-wrought material. This was achieved through increasing the wire feed speed within the stable WAAM processing window; i.e. without the introduction of lack of fusion defects.

Publications & Research Progress

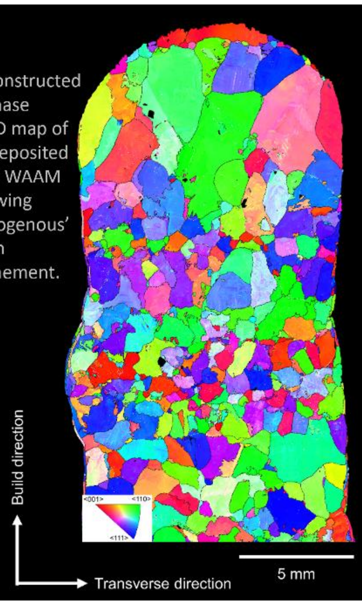




‘autogenous’ β-grain refinement

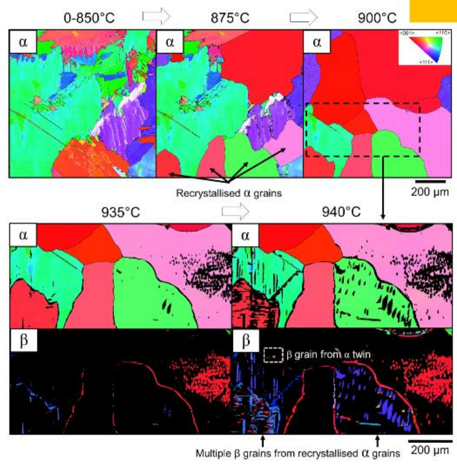
- Manchester’s final grain refinement study during the NEWAM project has been investigating the interesting effect of **‘autogenous’ β-grain refinement** discovered in CPTi WAAM depositions, which again produced weakly textured and mechanically isotropic material. Surprisingly, this grain-refinement mechanism operates without any user intervention and is intrinsic to the WAAM process.
- Metallurgical investigations, using ‘stop-action’ studies have demonstrated that twins were introduced into the room-temperature α grains via the relaxation of residual stresses in this softer material (deformation twinning) during initial WAAM deposition that, on subsequent reheating through the α → β transformation during printing of subsequent layers, develop new β grain orientations, overall refining the grain structure. Since this mechanism takes place at elevated temperatures, it required study with an in-situ heating stage in the scanning electron microscope to confirm the mechanism.

Reconstructed β-phase EBSD map of as-deposited CPTi WAAM showing ‘autogenous’ grain refinement.



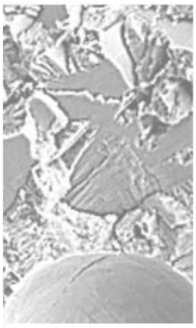
New WAAM grain refinement mechanism can lead to better-than-wrought properties

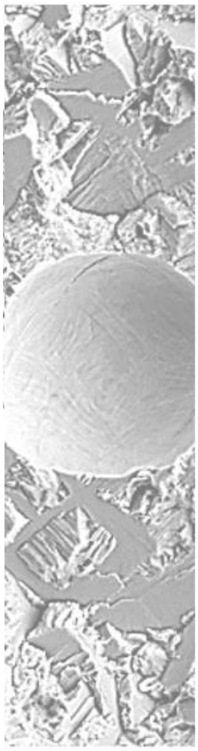
- Twining does indeed lead to the β-grain refinement, but recrystallisation also contributes to the process, which was particularly unexpected since such little strain rarely triggers such a mechanism.
- Overall, Manchester collaborative titanium WAAM studies have now revealed three new metallurgical grain refinement mechanisms that were not reported previously, and can be exploited to bring us closer to realising 3D printed titanium parts with fully refined primary grain structures and better-than-wrought properties.

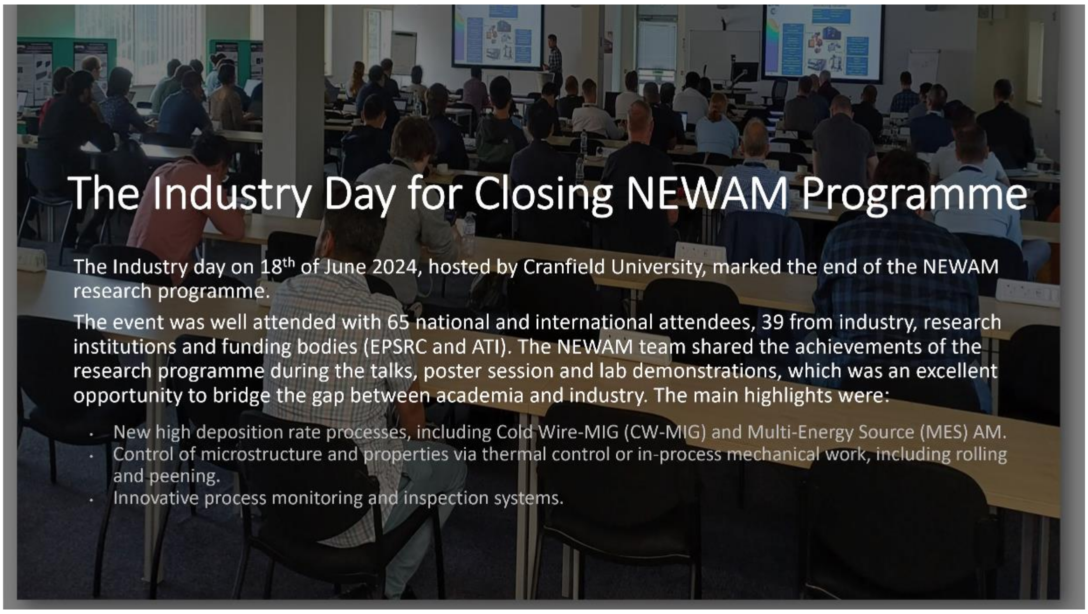


Results from an in-situ heating experiment where a CPTi sample deposited with WAAM was heated in-situ using a SEM equipped with a heating stage. The EBSD maps show apparent recrystallisation of the α phase as a result of residual stress, and how these recrystallised α grains and deformation twins led to the nucleation of new β grains, refining the overall grain structure in the sample.

Conferences & Meetings







The Industry Day for Closing NEWAM Programme

The Industry day on 18th of June 2024, hosted by Cranfield University, marked the end of the NEWAM research programme.

The event was well attended with 65 national and international attendees, 39 from industry, research institutions and funding bodies (EPSRC and ATI). The NEWAM team shared the achievements of the research programme during the talks, poster session and lab demonstrations, which was an excellent opportunity to bridge the gap between academia and industry. The main highlights were:

- New high deposition rate processes, including Cold Wire-MIG (CW-MIG) and Multi-Energy Source (MES) AM.
- Control of microstructure and properties via thermal control or in-process mechanical work, including rolling and peening.
- Innovative process monitoring and inspection systems.

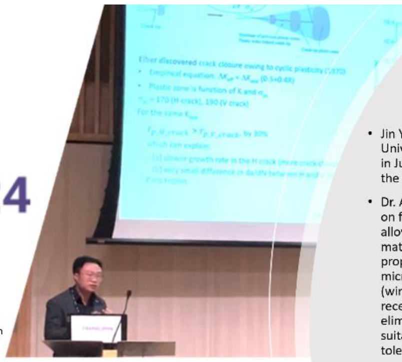
NEWAM Industry Day

At the end of the day, Prof Stewart Williams, the Principal Investigator of the research programme, presented the next steps in research towards the low-cost physics-based qualification of AM.

As the programme manager, Sonia would like to thank everybody involved in the research programme – Researchers, academics, students, administrative teams and industrial partners - for their continuous support and dedication to the project. The NEWAM programme would not have succeeded without them.

For more information about the NEWAM programme or next research programme on qualification of AM, please contact: s.a.martinsmeco@cranfield.ac.uk

FATIGUE 2024



[Photos: Jin presenting; Jin and Xiang with Prof. James C Newman and his wife]

Coventry team presented NEWAM at the Fatigue2024 Conference in Cambridge

- Jin Ye, Dr Abdul Khadar Syed and Prof. Xiang Zhang, of Coventry University, attended the Fatigue2024 Conference, in Cambridge, in June 19-21, 2024. It's attended by 170 delegates from around the World. Our latest findings were presented by two talks.
- Dr. Abdul Khadar Syed gave a talk on the role of columnar grains on fatigue crack behaviour in additively manufactured Ti6Al4V alloys. It's known that columnar β grains aligned along the material build direction can cause anisotropic mechanical properties; the average grain width varies between 50-100 microns (powder bed fusion processes) and 200-500 microns (wire DED). A systematic study was presented which was well received by the audience. It highlights the importance of eliminating columnar grains inherent to the AM processes by suitable grain refinement strategies, and so to build high damage tolerant titanium alloys with isotropic properties.
- Jin Ye presented his PhD study on fatigue crack behaviour in a WAAM AlMgSc material. He focused on the crack driving force in the threshold region and drew on the result of some fundamental research in the theory of crack closure. To Jin's delight, conference keynote speaker Professor James Newman (Mississippi State University, USA) was also in the audience and commended Jin's work in the Q&A session. Prof Newman gave Jin good advice for further studies, and wanted to keep in touch to find Jin's new results. It's worth mentioning that at the abstract submission stage some nine months earlier, Jin had no idea that he would meet Professor Newman, who is a leading researcher and authority in the crack closure theory. This was a nice coincidence! It has definitely given Jin a confidence boost for his future research.

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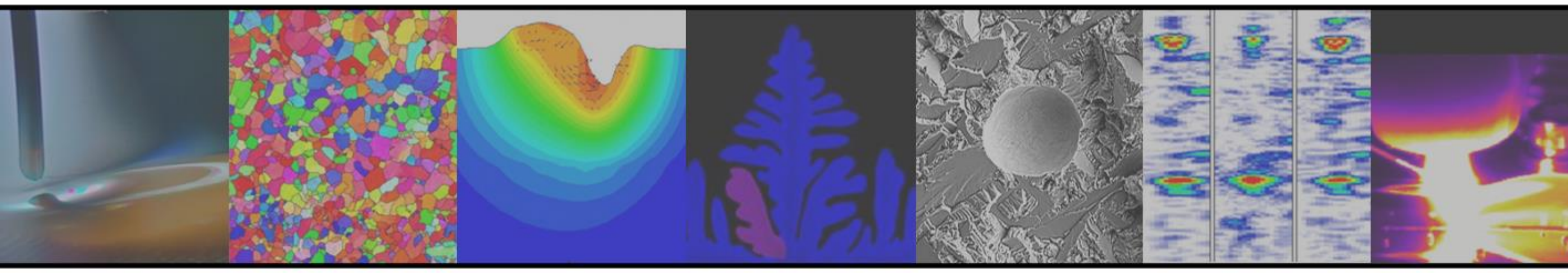

Further Reading

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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