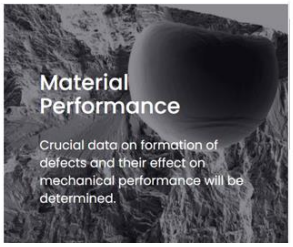
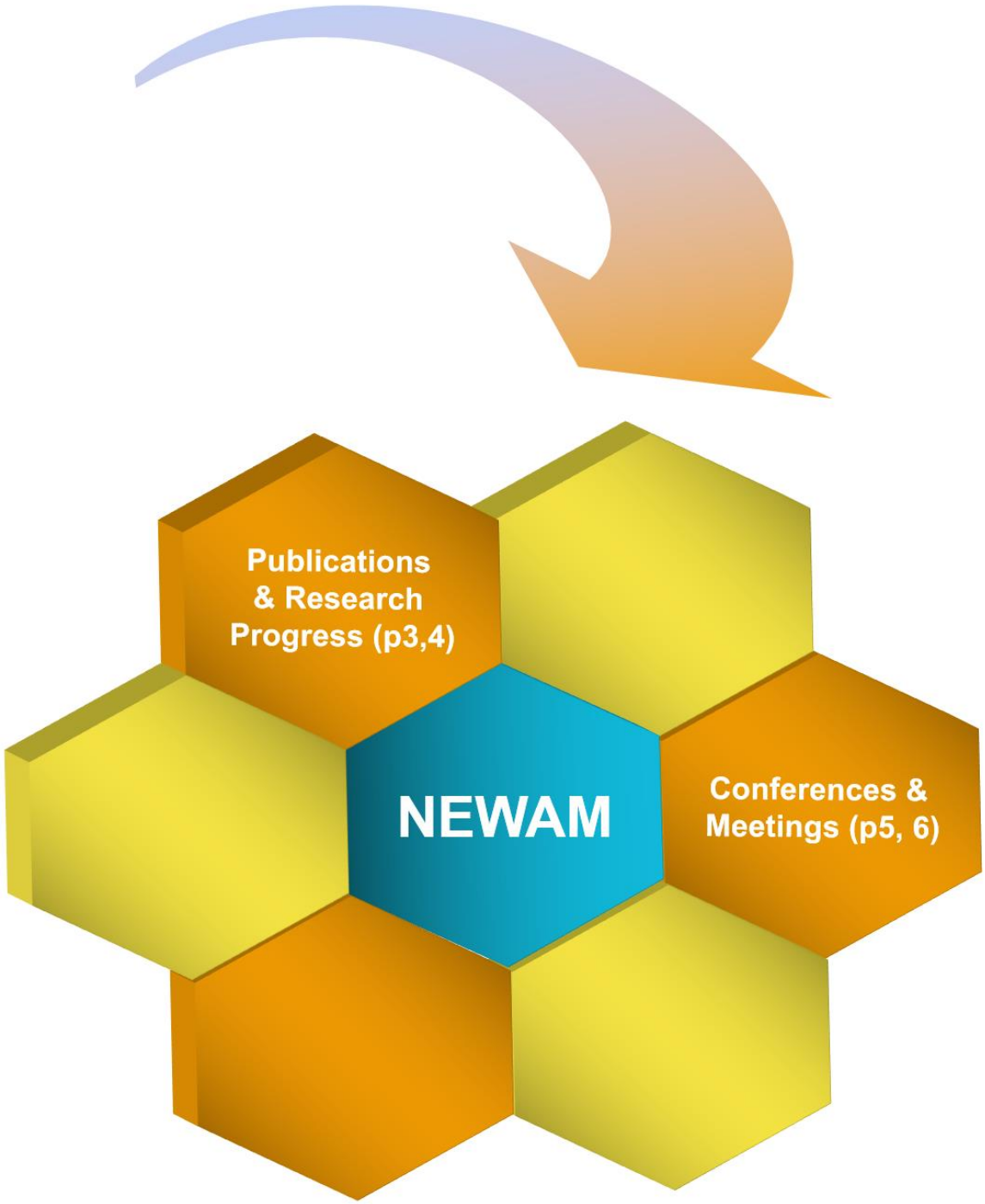
New Wire Additive Manufacturing

Newsletter (2nd quarter, 2023)

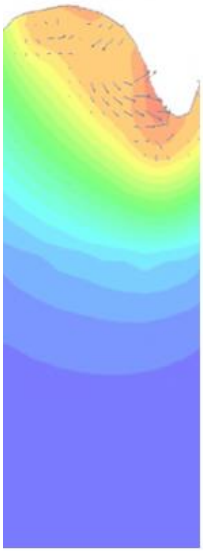


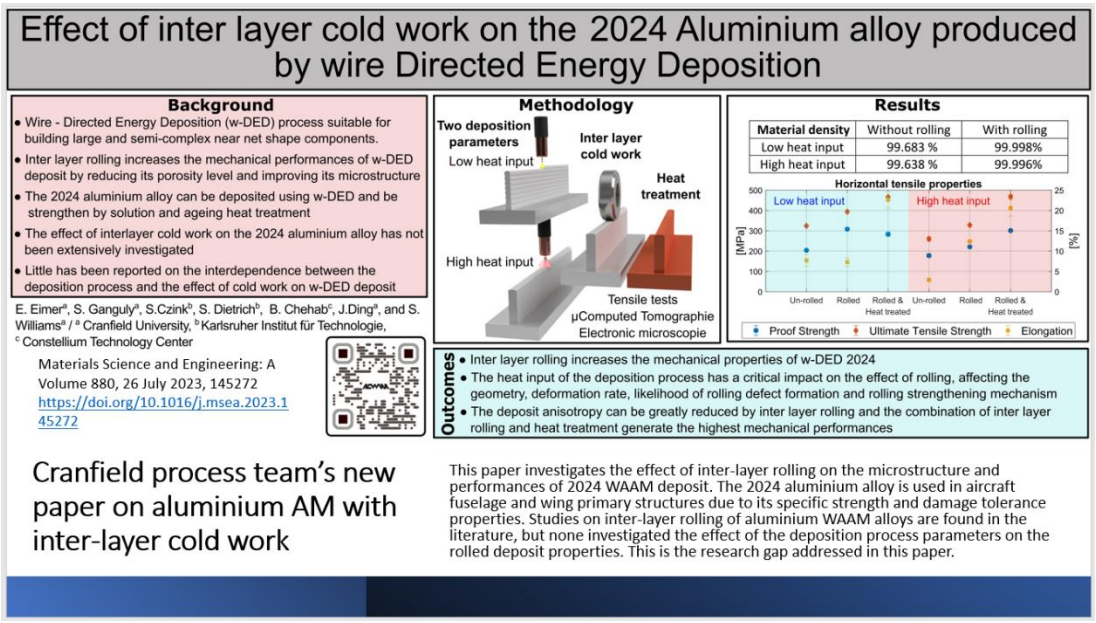
Compiled by NEWAM dissemination committee and released on 5 July 2023

NEWAM in April – June 2023



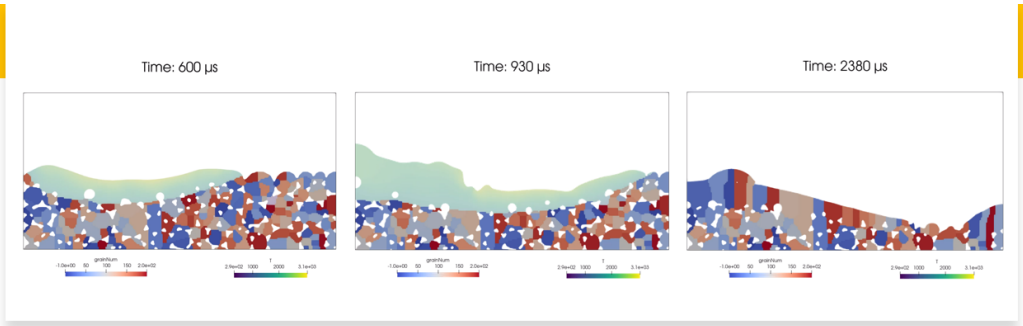
Publications & Research Progress





Cranfield process team's new paper on aluminium AM with inter-layer cold work

This paper investigates the effect of inter-layer rolling on the microstructure and performances of 2024 WAAM deposit. The 2024 aluminium alloy is used in aircraft fuselage and wing primary structures due to its specific strength and damage tolerance properties. Studies on inter-layer rolling of aluminium WAAM alloys are found in the literature, but none investigated the effect of the deposition process parameters on the rolled deposit properties. This is the research gap addressed in this paper.

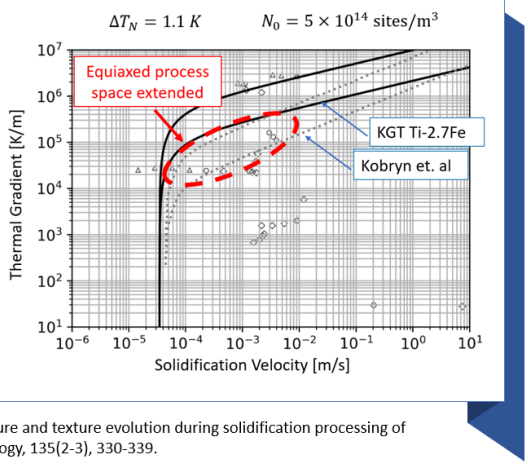


Manchester Modelling Team completed the coupled CFD + phase field solidification OpenFOAM solver

Development of the coupled computational fluid dynamics (CFD) + phase field (PF) model has been completed and is ready for public release. As an accompanying demonstration case to show the capabilities of the model, the above Ti64 L-PBF single melt track case was constructed. Snapshots at 3 stages during the simulation, which demonstrate much of the CFD physics including Marangoni and buoyancy driven convection. The final snapshot shows the familiar vertically aligned columnar grain structure that is typical in AM of Ti64.

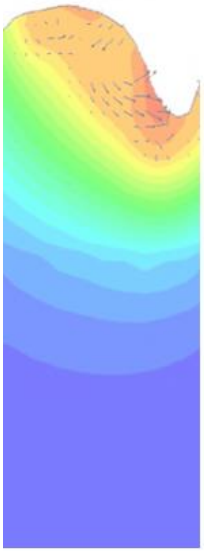
Manchester team's solidification map investigation into the extension of equiaxed process space by the addition of Fe to CP-Ti with the aid of the KGT dendrite tip kinetics model

The KGT dendrite tip kinetics model has been used in conjunction with Hunt solidification maps to investigate the effects of the addition of Fe to CP-Ti on CET, and was compared to the experimental work of Kobryn and Semiatin at the US air force [1]. The nucleation parameters used for the Hunt map were obtained by matching the KGT tip undercooling predictions for Ti64 to best match the experimental data points of Kobyrn et al. [1]. After applying to the KGT model to Ti-2.7wt.%Fe, it extends the equiaxed process space considerably, facilitating a CET at higher thermal gradients, which supports the finding of others that Fe is a good promoter CET in Ti.



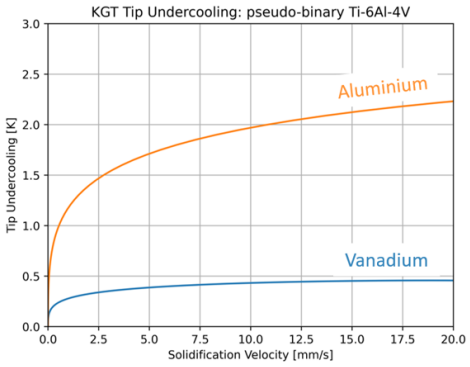
[1] Kobryn, P. A., & Semiatin, S. L. (2003). Microstructure and texture evolution during solidification processing of Ti–6Al–4V. Journal of Materials Processing Technology, 135(2-3), 330-339.

Publications & Research Progress



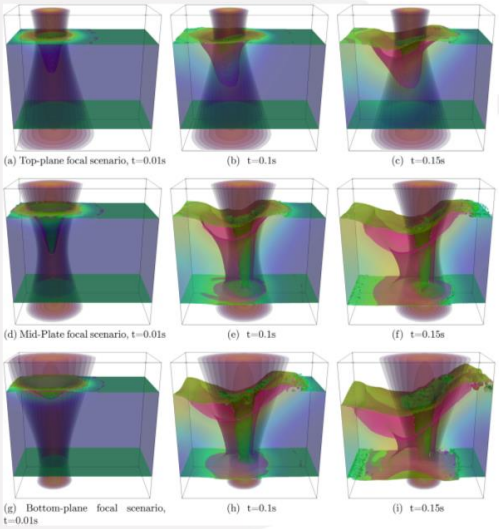
Manchester team demonstrated that Al is the dominant solute in contributing to tip undercooling in Ti64 according to the KGT model

- The KGT dendrite tip kinetics model has been applied to investigate the effects of both aluminium and vanadium on tip undercooling in Ti64. In each case, Ti64 was treated as a pseudo-binary alloy and each alloying addition was treated as the solute individually. From the plot of tip undercooling vs solidification velocity, we can see that both solutes produce a relatively low level of tip undercooling at the travel velocities common for WAAM, but aluminium has a markedly larger effect.
- Carrying out a polynomial curve fit to the data points generated by the KGT model, it is found that aluminium has a roughly 4 order of magnitude greater effect in slowing solidification velocity for a given undercooling, or in other words, contributes more to tip undercooling and the likelihood for a conventional thermal CET to occur.



Vanadium $V_{(\mathrm{Ti-6Al})+4\mathrm{V}} = 1.967\,(\Delta T)^{6.263}$

Aluminium $V_{(\mathrm{Ti-4V})+6\mathrm{Al}} = 1.588 \times 10^{-4}(\Delta T)^{6.078}$

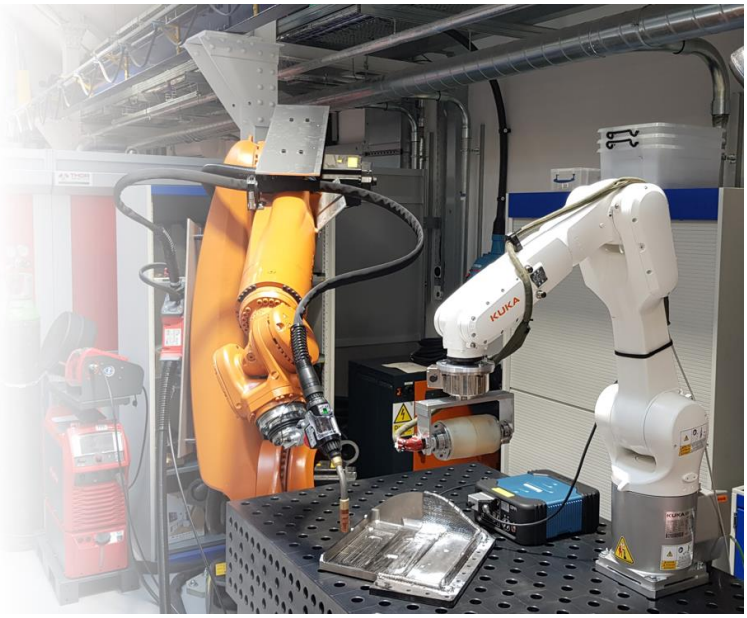


Manchester modelling team's new publication: High-Fidelity Multi-Component Thermal-Fluid-Dynamics Framework Applied to Electron Beam Welding

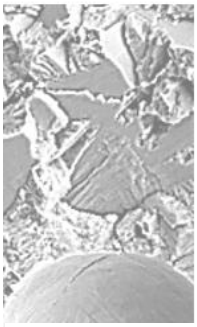
- In this publication the researchers used a high-fidelity, multi-component, thermal fluid dynamics framework that was developed at Manchester; to investigate the effects of electron beam (EB) characteristics on the development of the thermo-capillary or 'keyhole' during EB welding.
- Here we see that the beam divergence and focal point have a very important effect of the stability and penetration of a formed thermo-capillary. We also predict the preferential evaporation of alloying elements such as manganese and chromium. This work is the first in the literature to utilise first principles physical laws to capture these important and exciting phenomena.
- The full paper is available, open-access, at the following location: https://doi.org/10.1016/j.ijheatmasstransfer.2023.124262

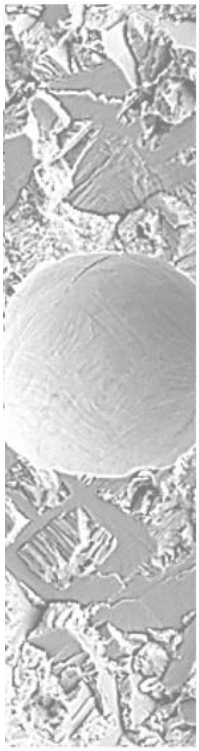
Strathclyde team is working on CW-MIG system now

- Strathclyde team is in process of commissioning a new WAAM cell based in SEARCH lab on campus
- The new system is based on CW-MIG (cold wire – metal inert gas) process delivered by KUKA KR90 robot and in-process NDT delivered by KUKA Kr10



Conferences & Meetings





- On 07-08 June 2023, the NEWAM team participated in the TCT 3Sixty 2023 at the NEC, the UK's largest event in 3D printing and additive manufacturing. The team had representatives from each partner university working on the project, including students, researchers, academics and administrative staff.
- Over the two-day event, there were thousands of visitors, with nearly 200 exhibitors and 100 speakers. The audience was broad, from industry, research centres, schools and the general public.

tct 3SIXTY 7 8 JUNE 2023 NEC, Birmingham, UK

Their response to our stand was very positive, and many visitors were interested to learn more about the new WAAM processes (e.g. CW-MIG and MES), ways to control the microstructure and other activities of the research programme.

The stand had a range of WAAM parts of different sizes and complexities, built with various processes and materials. There was a live demonstration of automated NDT using a small Kuka robot with the prototype High Temperature (HT) roller probe. On the screen, the visitors could see the research programme highlights, covering the seven research areas and videos of the new WAAM processes and NDT techniques.

- In summary, this was a successful event in which the NEWAM team had a great time disseminating the next generation of additive manufacturing, its main achievements and the next challenges

tct 3SIXTY 7 8 JUNE 2023 NEC, Birmingham, UK

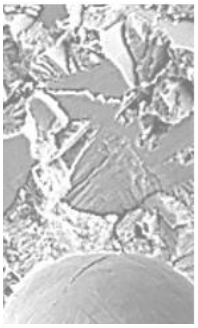
Strathclyde team member attended two conferences

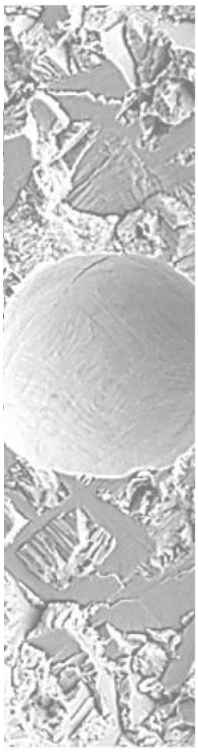
ASNT 2023 THE ANNUAL CONFERENCE

- Rastislav Zimermann has attended and presented at ASNT 2023 (Columbus, Ohio, USA) research symposium a talk with a title: **Dry-coupled ultrasound phased array inspection of as-built complex geometry metal additive manufactured components.**
- In addition, Rastislav co-chaired a session at ECNDT2023 conference (Lisbon, Portugal), where he also presented a talk with a title: **In-process Non-Destructive Evaluation of Wire + Arc Additive Manufacture Components Using Ultrasound High-Temperature Dry-Coupled Roller-Probe**

13th ECNDT 3–7 JULY 2023 | LISBON

Conferences & Meetings

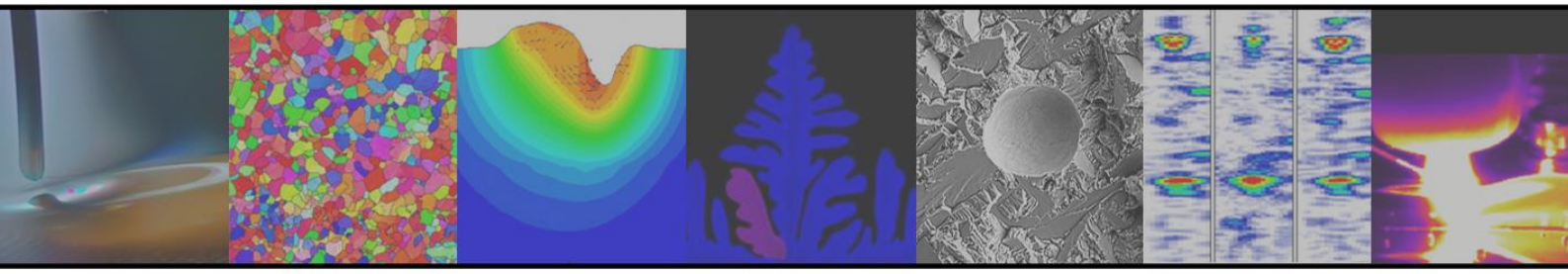




Cranfield team member, Dr. Yongle Sun, delivered an invited talk on **physics-based process modelling for wire directed energy deposition** in the symposium of Advances in Additive Manufacturing: Experiments and Modeling from Cutting-edge Fundamental and Applied Research, part of the 11th ICAMT conference 2023

In this presentation, modelling of wire DED and its ancillary process is discussed, with a focus on WAAM but also including arc-laser hybrid DED. The wire melting and fluid flow behaviour in molten pool are simulated using computational fluid dynamics (CFD) models, which can realistically predict layer geometry and thermal variables for designing and understanding a wire DED process. However, CFD simulation is computationally demanding and unfeasible for large parts. To complement CFD, on one hand, analytical models based on thermo-capillary-gravity equilibrium are formulated to predict layer geometry, which can also inversely estimate the process parameters for given layer geometry. On the other hand, a Eulerian approach is adopted in finite element analysis (FEA) to rapidly determine the cooling rates and temperature gradients for a hybrid DED, which can inform microstructural modification. Furthermore, efficient FEA models are developed to elucidate and optimise post-build and in-process rolling for mitigating WAAM residual stress and distortion. These physics-based models are powerful for addressing the key challenges facing wire DED.

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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