NEWAM

New Wire Additive Manufacturing

Newsletter (1st quarter, 2023)

Cranfield University

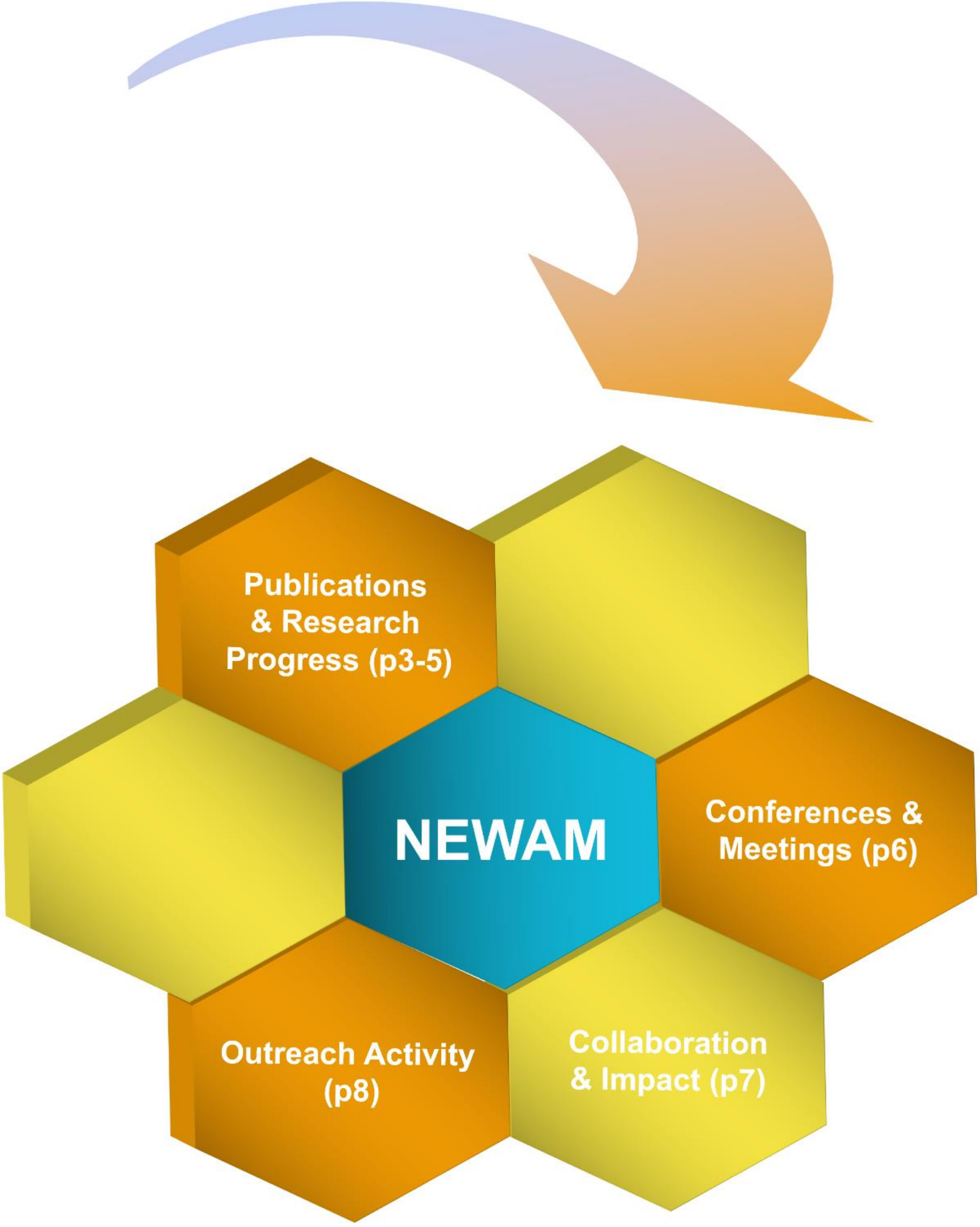
MANCHESTER 1824

University of Strathclyde

Coventry University

Compiled by NEWAM dissemination committee and released on 1 April 2023

Your NEWAM in January – March 2023

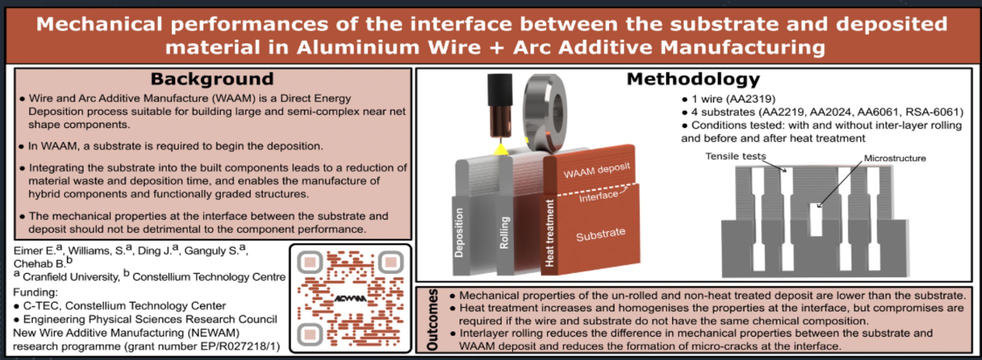


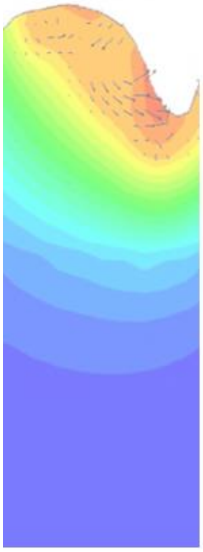
Publications & Research Progress

Cranfield process team published a paper on hybrid manufacture of aluminium components

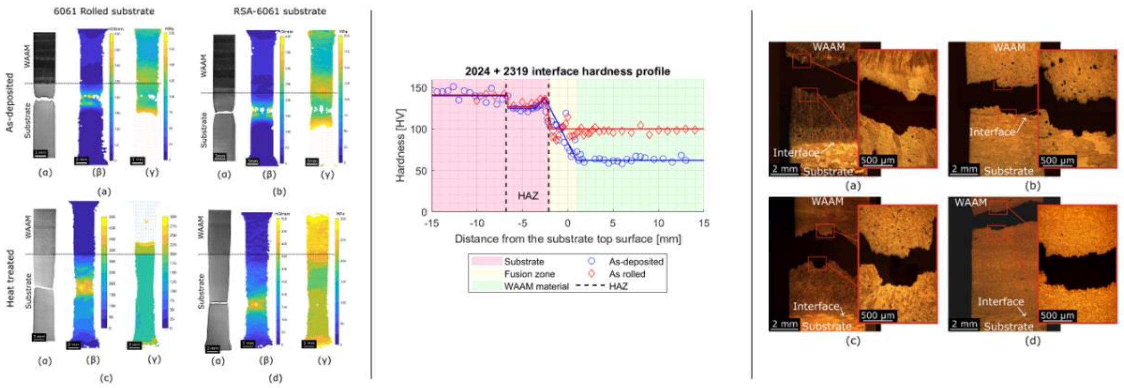
This paper aims to assess the possibility of including a substrate in a component by investigating the mechanical performances of the interface between a wrought plate and WAAM deposit. Four substrates alloys and AA2319 WAAM alloy were investigated. Inter-layer rolling and heat treatment, process steps known for improving the properties of WAAM deposit, were implemented. The WAAM deposit hardness was lower than that of the substrate in the as-deposited condition. Although the interface had no impact when using the same alloy for both substrate and wire, the weakest point of the combination was at the interface in dissimilar alloy combination. Heat treatment reduced the properties difference between the substrate and WAAM deposit. Inter-pass rolling strengthened the WAAM deposit without impacting the substrate and eliminated the micro crack that occasionally formed in the fusion zone in the as-deposited condition.

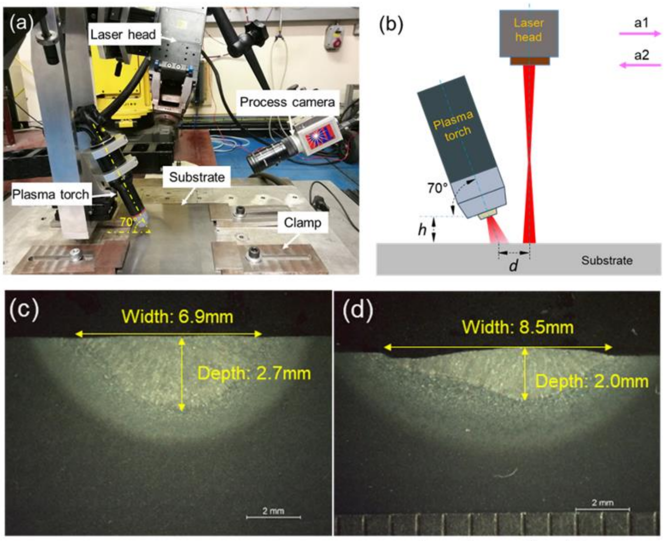
Eimer, E., Williams, S., Ding, J., Ganguly, S., & Chehab, B. (2023). Mechanical performances of the interface between the substrate and deposited material in aluminium wire Direct Energy Deposition. Materials & Design, 111594.





Cranfield highlight: Mechanical performances of the interface between the substrate and deposited material in aluminium wire Direct Energy Deposition





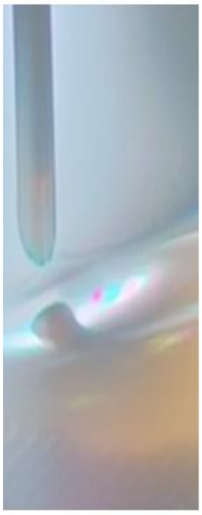
Laser beam size: 6mm   Laser beam size: 10mm

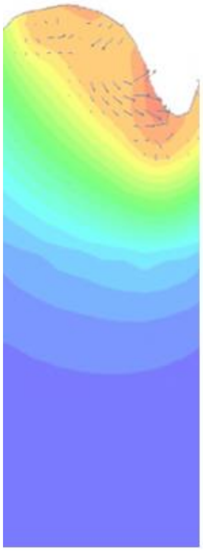
Cranfield process team's new paper on AM with combined energy sources

Cranfield's process development team recently published a paper on melt pool control in hybrid plasma arc-laser process. The study systematically investigates how the melt pool geometry is influenced by different process parameters in the hybrid process. The findings from this study provide a reference for melt pool control in wire-based hybrid arc-laser additive manufacturing.

Wang, C., Suder, W., Ding, J., & Williams, S. (2023). Parametric study of melt pool geometry in hybrid plasma arc-laser melting process for additive manufacturing application. Welding in the World, 1-12. https://doi.org/10.1007/s40194-023-01476-9

Publications & Research Progress





Coventry team published a new paper on fatigue behaviour of WAAM Ti64

- Strain-controlled fatigue testing allows a more rigorous and reproducible definition of failure than in load-controlled testing and provide insights into the applied elastic-plastic strain energy that is driving fatigue failure. Accurate local strain measurement within the gauge length allows to study the effect of plasticity, which is useful for predictive models, which cannot be determined in load-controlled fatigue testing for the stress-life fatigue property. Furthermore, applied loads in strain-controlled fatigue tests are fully reversed, with applied stain ratio $R\varepsilon=-1$ i.e., zero initial mean stress, to provide the baseline fatigue data from which the mean stress effect can be calculated, as in the variable amplitude load spectra in real world loading conditions. Additionally, because strain-life fatigue curves are based on the local strains, they are better suited to the predictive methods using the local stress or strain values, e.g., calculated by finite element analysis than using stress-life fatigue curves which are based on the nominal (applied) stresses.

- Therefore, this paper was focused on the strain-controlled fatigue behaviour, associated cyclic deformation and damage mechanisms of Ti64 deposited with oscillation build strategy developed for the WAAM process.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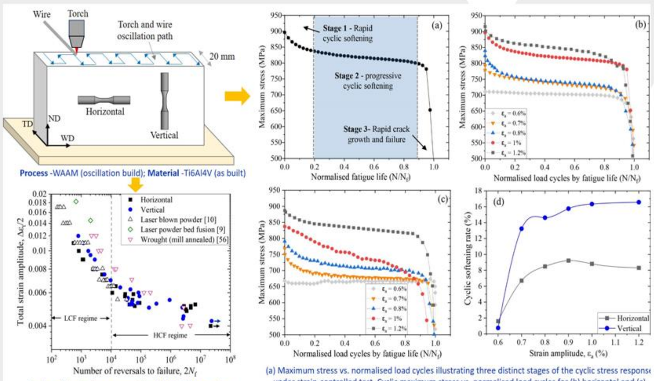
Strain controlled fatigue behaviour of a wire + arc additive manufactured Ti-6Al-4V

Abdul Khadar Syed, Rob Plaskitt, Michelle Hill, Zsolt Pinter, Jialuo Ding, Robert Zboray, Stewart Williams, Xiang Zhang

- To deliver this key material property, Coventry University teamed up with Hottinger Bruel & Kjaer (HBK) UK Ltd (one of the NEWAM consortium industrial partner). HBK performed the strain-controlled fatigue testing on horizontal (αGB perpendicular to the loading) and vertical (αGB along the loading) orientation samples. All the tests were carried at room temperature. The experimental data was critically analysed, and the fracture surfaces were systematically studied at Coventry University to underpin the effect of sample orientation on strain-controlled fatigue performance.

Coventry highlight: Strain controlled fatigue behaviour of a wire + arc additive manufactured Ti-6Al-4V

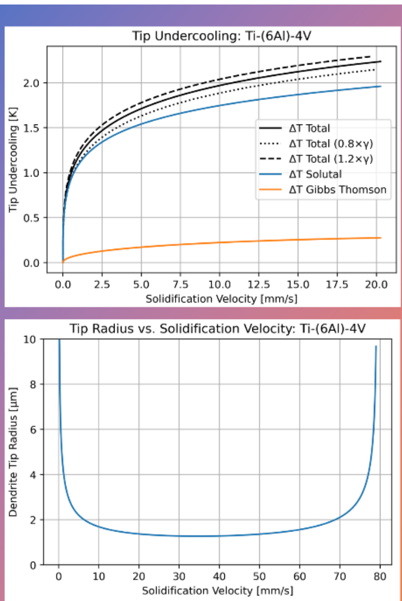
Between the two sample orientations, tensile and yield strengths are 5% higher in the direction normal to the material build direction (horizontal sample) owing to the columnar primary β grains with strong crystallographic texture along the αGB that is perpendicular to the loading axis. However, elongation is reduced by 60% in the horizontal samples due to preferential failure along the αGB of columnar β grain. Cyclic stress softening is observed in both sample orientations when the applied strain amplitude exceeds 0.6%. Because of higher ductility, the cyclic softening rate in vertical samples is approximately two times higher when strain amplitude is higher than 0.7%. As a result, horizontal samples show slightly higher peak stress by up to 4% compared to the vertical samples. In the low cycle fatigue regime (2Nf < 104 load reversals), the vertical samples' average life is about 2.5 times longer than that of the horizontal samples due to higher ductility in the former. In the high cycle fatigue regime (2Nf > 104), fatigue life property is almost isotropic.



Process -WAAM (oscillation build); Material -Ti6Al4V (as built)

Strain vs. life relation measured by WAAM Ti64 samples compared with other AM and wrought Ti64

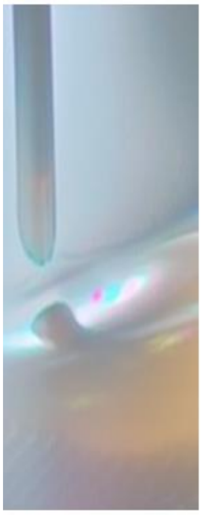
(a) Maximum stress vs. normalised load cycles illustrating three distinct stages of the cyclic stress response under strain-controlled test. Cyclic maximum stress vs. normalised load cycles for (b) horizontal and (c) vertical samples, (d) cyclic softening rate under different strain amplitudes.

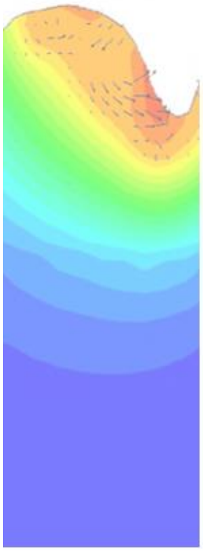


Manchester material modelling team investigated the relative contributions to tip undercooling in Ti64

The KGT dendrite tip kinetics model developed by Danny Dreelan has been used to investigate the relative contributions tip undercooling in Ti-6Al-4V, by separating out the effects of solutal undercooling and curvature undercooling via the Gibbs Thomson effect. Complementary to this is the variation of dendrite tip radius with respect to solidification velocity shown left, with transitions to planar solidification being observed at low and high velocities. The inflection point occurs at a solidification velocity of 35 mm/s, meaning that beyond this, the Gibbs Thomson undercooling decreases. Since there is often uncertainty in values for the surface energy of the solidification front, variations of +- 20% were also investigated in the tip undercooling plot above.

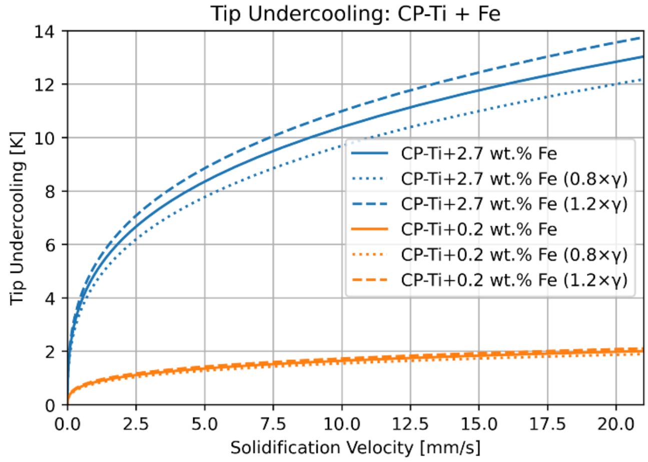
Publications & Research Progress





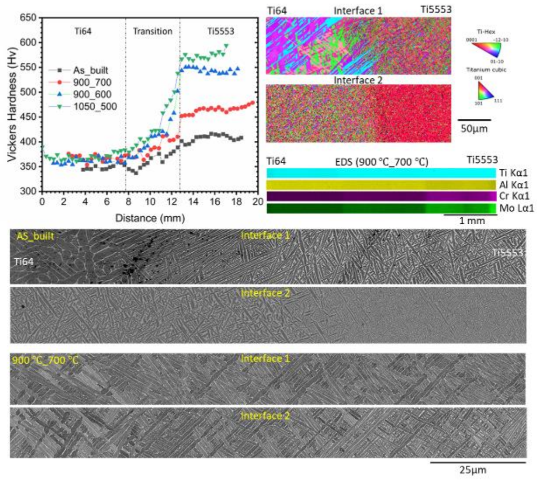
Manchester material modelling team's study on the effect of Fe content on tip undercooling in CP-Ti

Using the same KGT dendrite tip kinetics model, the effect of low/impurity level, and higher levels of Fe in CP-Ti on tip undercooling was also investigated. Similar to before, a +-20% uncertainty in surface energy was also included. Interestingly, even the low level of 0.2wt.% Fe can have the same level of effect on tip undercooling as 4wt.% Al in Ti64, demonstrating both the weak partitioning effects of Al in the Ti64 system, as well as the significance of impurities in CP-Ti. Increasing the Fe content to 2.7wt.% in CP-Ti considerably increases tip undercooling to 13 K at a solidification velocity of 20 mm/s, which has been found by others (Welk, Frasser et al.) to induce a CET.



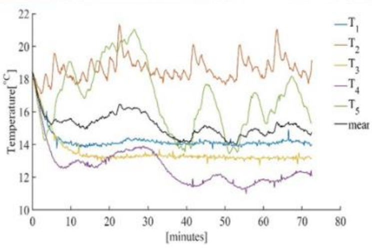
Manchester material development team's recent research on tailored mechanical property of WAAM-AAC (Ti64-Ti5553)

Hight deposition rate WAAM 3D printing provides design flexibility through layer-by-layer deposition to produce a cost-effective, near-net-shape product for the engineering components in the aerospace applications. By switching the compositionally different metal wire feed in 3D printing, we can produce compositionally gradient microstructure with tailored mechanical properties for the aerospace applications and eliminate the inefficient joint utilizing fastener and weld in the engineering design. In the present research, an alloy-alloy composite (ACC) of Ti-6Al-4V and Ti-5Al-5V-5Mo-3Cr was built using WAAM deposition, and post heat-treatment was performed at various temperatures to comprehend the mechanism of spatial hardness value. Microstructural characterization exploiting EBSD, EDS, BSE imaging suggests that spatially different hardness values result from a combined effect of α and β phase fraction, lamellar spacing/alpha precipitation and solid solution strengthening mechanisms.



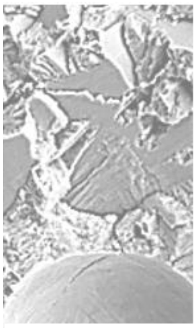
Strathclyde team developed a new Active Cooling System for High Temperature Roller Probe

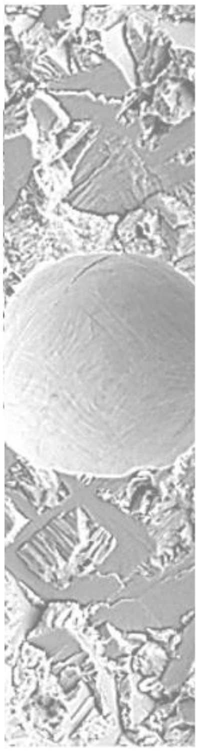
- The phased array ultrasound (PAUT) roller probe has designed for the in-process inspections of additive manufacture (AM) components, where the transducer is deployed at elevated temperature of > 350 °C. However, the maximum operating temperature of commercial ultrasound transducers is 60 °C.
- Hence, an active cooling system was designed which can maintain the temperature of ultrasonic transducer and the internal, complementary assembly of roller probe below 20 °C during the inspection of a test sample heated to a temperature of 450 °C. An optimized liquid pressure and temperature in the roller tire was achieved through a control flow rate and cooling cycles using an industrial chiller.



Temperature of the roller probe's internal assembly

Conferences & Meetings

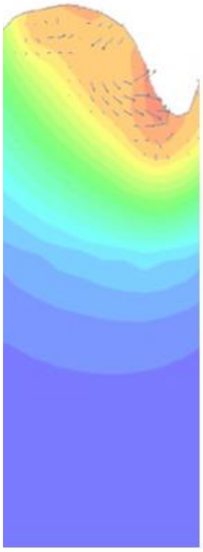




Strathclyde team member, Dr. Rastislav Zimermann, has submitted an abstract to the ICAM 2023 conference, entitled "Towards fully automated quality assured metal additive manufacturing", and another abstract to the ASNT 2023 Conference with the title of "Dry-coupled ultrasound phased array inspection of as-built complex geometry metal additive manufactured components"

Cranfield team member, Dr. Yongle Sun, has been invited to deliver a presentation 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 congress 2023

Collaboration & Impact

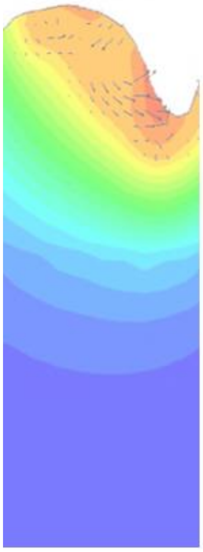


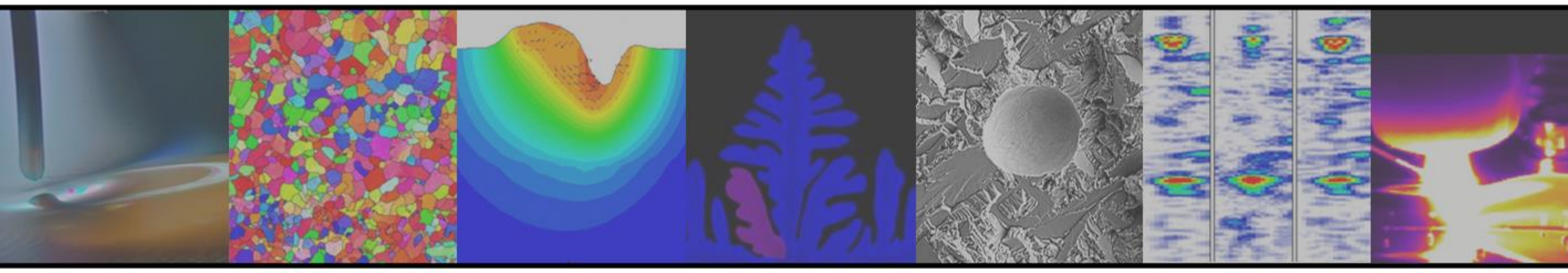
Department for Science, Innovation & Technology

GLASGOW CITY REGION Innovation Accelerator

Professor Charles MacLeod in Strathclyde team has obtained funding as a part of Glasgow's Innovation Accelerator project. Approved by the UK Government Department for Science, Innovation and Technology (DSIT), the project has share of the Levelling Up funding for 11 ambitious local projects to further accelerate the Glasgow's booming innovation economy.

Outreach activity





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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