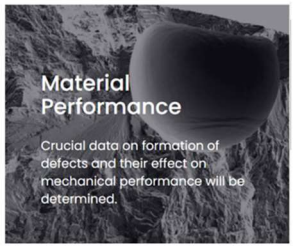
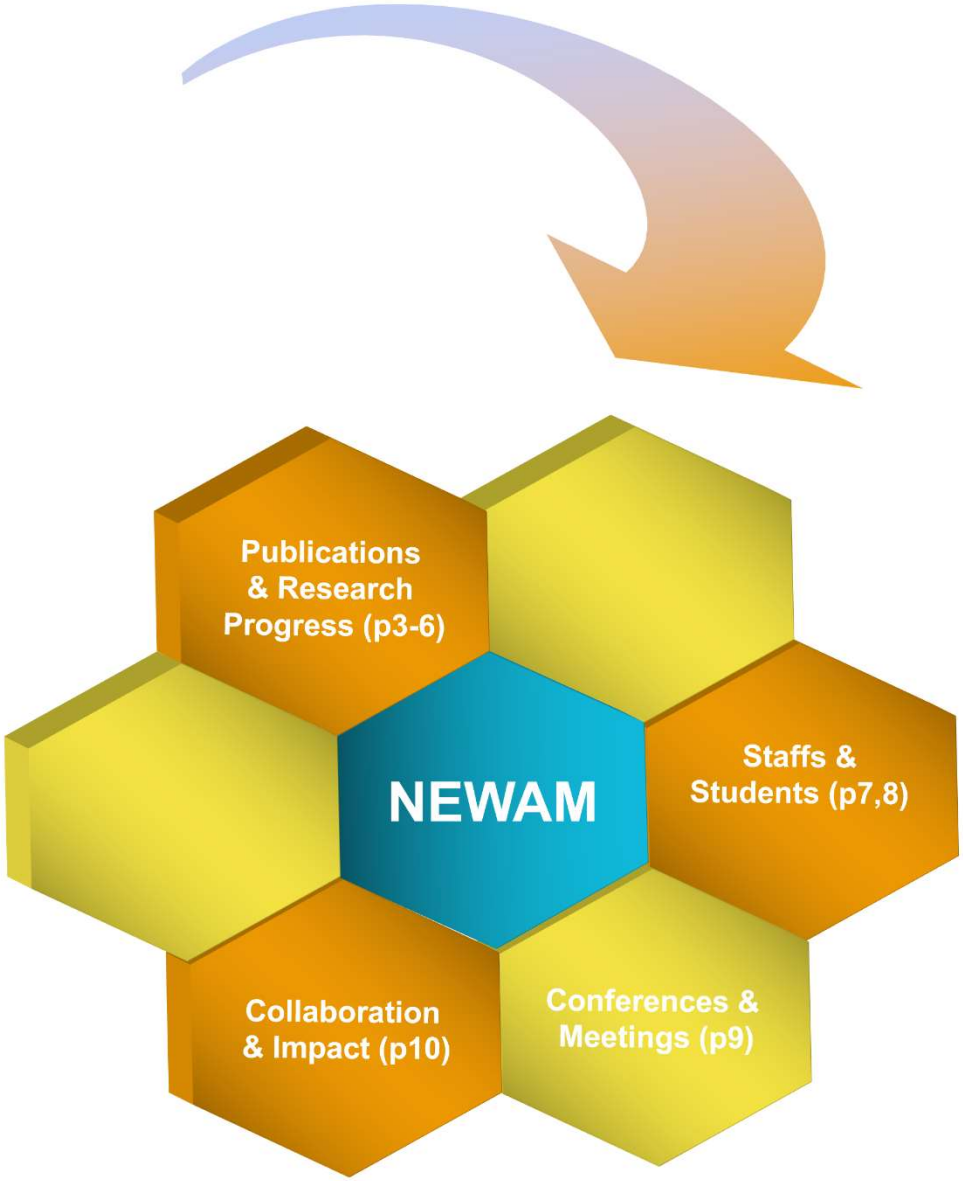
New Wire Additive Manufacturing

Newsletter (1st quarter, 2021)

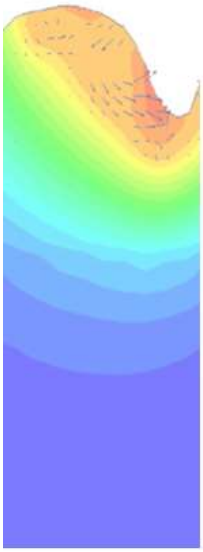


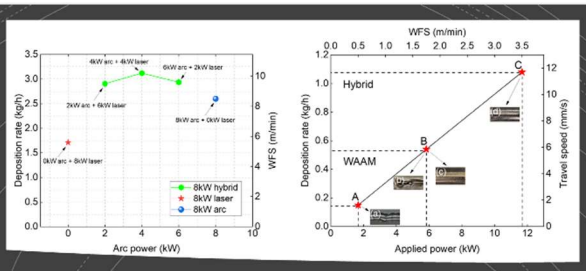
Compiled by NEWAM dissemination committee and released on 1 April 2021

Your NEWAM in Jan. – Mar. 2021



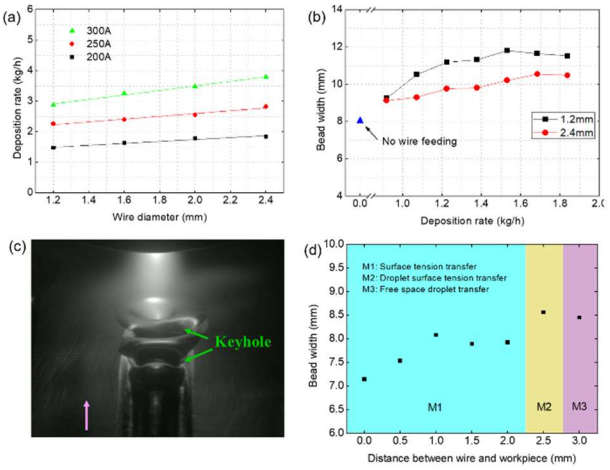
Publications & Research Progress





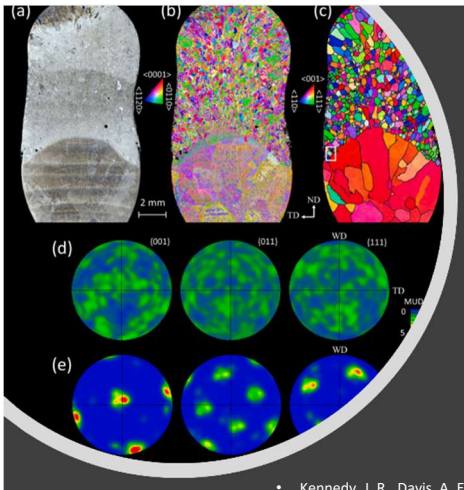
Cranfield Process Development team published a paper on hybrid arc and laser WAM process

- The wire based plasma arc and laser hybrid additive manufacture process is aimed to improve the deposition rate and better control the melt pool. The best configuration for the hybrid process was found to be PTA leading combined with front feeding of the wire, which allows independent control of deposition rate and bead shape. It was also found that compared to the single PTA process, the hybrid process gives a higher deposition rate, while compared to the laser process, the hybrid process has a much higher wire melting efficiency and tolerance to wire positioning accuracy. In addition, the likelihood of keyhole formation in the hybrid process is lower than that in the single PTA process. A multi-energy source approach with one PTA and two lasers has been proposed to overcome the limitations of the standard hybrid process.
- Wang, C., Suder, W., Ding, J., & Williams, S. (2021). Wire based plasma arc and laser hybrid additive manufacture of Ti-6Al-4V. Journal of Materials Processing Technology, 293, 117080. https://doi.org/10.1016/j.jmatprotec.2021.117080



Cranfield Process Development team published their study of wire size effect on high deposition rate of Ti64 WAM

- This study is aimed to identify the limitation of the plasma transferred arc (PTA) based WAM process in terms of the deposition rate and process tolerance. It was found that the melting efficiency can be improved by distributing more energy on the wire and less energy on the workpiece, resulting in a higher deposition rate. This can be done by increasing the wire diameter or changing the position of the wire with respect to the arc column. In addition, the keyhole formation and metal transfer behaviour has been also investigated.
- Wang, C., Suder, W., Ding, J., & Williams, S. (2021). The effect of wire size on high deposition rate wire and plasma arc additive manufacture of Ti-6Al-4V. Journal of Materials Processing Technology, 288, 116842. https://doi.org/10.1016/j.jmatprotec.2020.116842



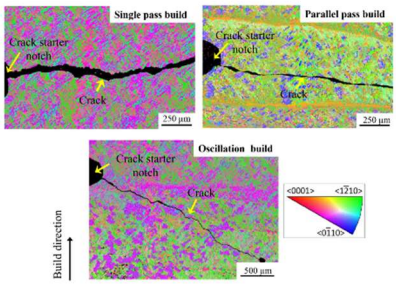
Manchester Material Development team's new publication

- During first quarter of 2021, Manchester team has published one paper, with Jacob Kennedy as the lead author, 'The potential for grain refinement of Wire-Arc Additive Manufactured (WAAM) Ti-6Al-4V by ZrN and TiN inoculation'. In this study, Kennedy et al. adhered ZrN and TiN particles onto newly deposited WAAM layers in order to provide nucleation sites for new grains to form in the subsequent layers. The motivation for this was to improve the microstructure of the build, by increasing the rate of grain nucleation. Using TiN particles successfully refined the microstructure, reducing the grain size and the undesirable columnar grains, typical in WAAM builds, were replaced by equiaxed grains. However, Kennedy et al. found the addition of ZrN to be ineffective. This study provides a promising basis to solve the problem of poor microstructure typical in WAAM builds, which is one of the major hurdles blocking the adaptation of WAAM by industry.
- Kennedy, J. R., Davis, A. E., Caballero, A. E., Williams, S., Pickering, E. J., & Prangnell, P. B. (2021). The Potential for Grain Refinement of Wire-Arc Additive Manufactured (WAAM) Ti-6Al-4V by ZrN and TiN Inoculation. Additive Manufacturing, 101928. https://doi.org/10.1016/j.addma.2021.101928

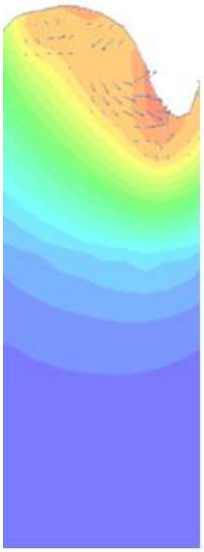
Publications & Research Progress

Coventry Material Performance team's new publication

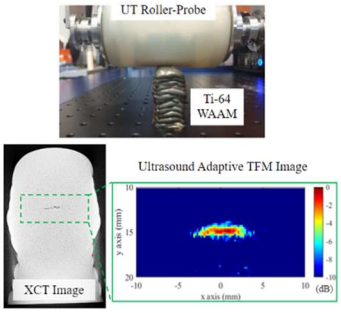
- Coventry team has published one paper with Abdul Khadar Syed as the lead author, and with collaborative effort from Coventry, Manchester and Cranfield teams. Compact tension fatigue crack growth test samples were prepared using single pass, parallel pass, and oscillation deposition strategies and tested with cracks propagating parallel and normal to the plane of deposition. The oscillation build exhibited a significantly coarser columnar β grain structure as well as a coarser transformation microstructure, compared to the single pass and parallel pass builds, which were very similar. For each build strategy, a greater microstructural influence on crack growth rate was found at lower levels of stress intensity factor range (< 25 MPa.m1/2). The oscillation build strategy showed lower crack growth rates due to the stronger α microtexture heterogeneity which led to a greater crack deflection and bifurcation, giving rise to lower crack growth rates and a higher sensitivity to the anisotropy caused by the directional β grain structure. This research has demonstrated the potential of WAAM process to tailor the microstructure and to achieve desired microstructure and material performance by changing the layer deposition strategy.



- A K Syed, X Zhang, A E Davis, J R Kennedy, F Martina, J Ding, S Williams, P B Prangnell. Effect of deposition strategies on fatigue crack growth behaviour of wire + arc additive manufactured titanium alloy Ti-6Al-4V. Materials Science & Engineering A (Accepted on 27/03/2021).



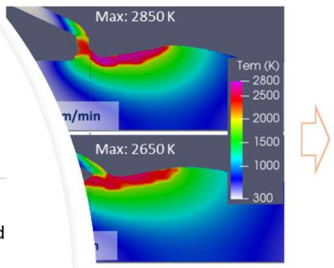
Strathclyde NDT team submitted new journal paper



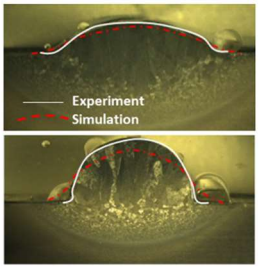
- In March 2021, Strathclyde team with Rastislav Zimermann as a lead author, has submitted a journal paper with the title of 'Multi-Layer Ultrasonic Imaging of As-Built Wire + Arc Additive Manufactured Components' to the journal of Additive Manufacturing. The paper has presented an advancement in ultrasonic imaging algorithms developed for inspection of as-built WAAM components using a high temperature roller-probe. The paper has demonstrated the ability to detect a lack of fusion defect, as small as 0.5 × 5 × 0.5 (mm), using a hybrid Total Focusing Method (TFM) and Synthetic Aperture Focusing Technique (SAFT), where SAFT reconstructed a precise WAAM surface curvature and TFM formed a fully focused interior image with consideration of two interfaces (1 flat & 1 curved) between the phased array transducer and image pixel.

Cranfield Process Modelling team gained new insights into the relation between WAM deposition and bead geometry

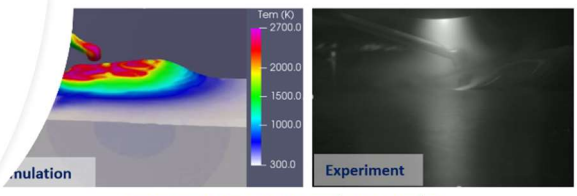
- A 3D wire-feeding model for heat and mass transfer, fluid flow, and bead shape in wire-based AM has been developed. The plasma deposition process was reproduced virtually for the first time. The simulation results show that: as the wire feeding speed increases from 3 to 5 m/min, the droplet-liquid bridge transfer mode turns to be the solid-liquid transfer mode; about a 200 K drop of maximum central temperature of melt pool occurs due to the arc shading effect and heat loss of melting solid wire in the melt pool. These cause the decrease of transverse Marangoni flow, leading to the decrease of bead width.
- A paper based on the novel model and new findings is about to finish and will be submitted for publication soon.



Central slice of temperature



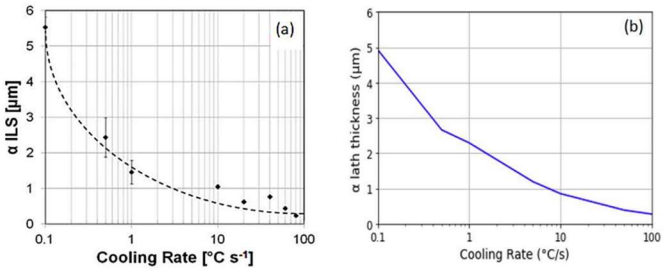
Cross section of deposit



Parameters: I = 200 A; TS = 4.5 mm/s; WFS = 4 m/min

Publications & Research Progress

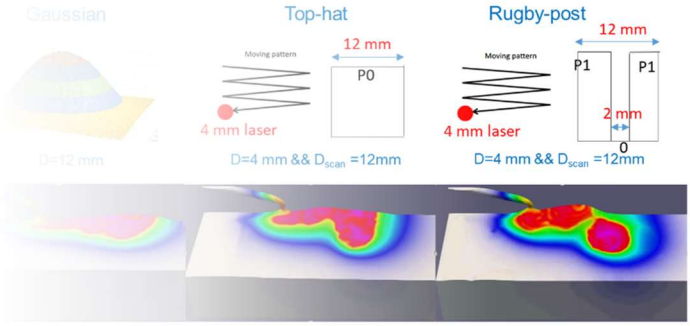
Manchester Material Modelling team started SSPT work



- Recently, the Materials Modelling team at University of Manchester have begun to model the beta to alpha solid state transformation (SSPT) in Ti64. They hope that this can be used to complement experimental observations of alpha lath growth in Ti64. This may possibly offer insights into how the addition of extra alloy elements, and the alteration of thermal conditions, affects the lath growth and hence the microstructure.

Dr. Xin Chen is modelling melt pool generated by multiple energy source

- Recently, Cranfield researcher Dr. Xin Chen extended his work based on the novel wire-feeding model, and he is investigating the thermal fluid behaviour in multi-energy-source (plasma + laser) additive manufacturing process. The mechanism of bead shape control through designing energy distribution is to be revealed hopefully.

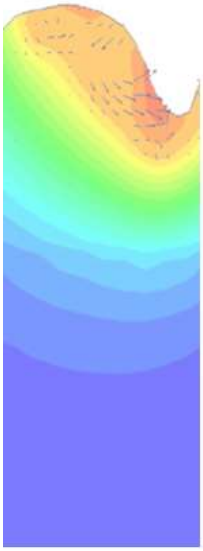


Parameter: I=200 A; TS=4.5 mm/s; WFS=4 m/min; D_{L-A}=10 mm; P=5 kW.

Guangyu Chen has made a milestone in his PhD research on WAM deposition using multiple energy source (MES)

- Guangyu Chen, a PhD student at Cranfield University, has recently finished his initial MES wall building experiment. Preliminary experimental result has proven the capability of dynamic bead shape control by MES. A multi-width wall was built. Constant layer height was maintained when changing the layer width from 16 mm to 26 mm. More work on the bead shape control of the MES system is ongoing. Hopefully, it can be integrated to the NEWAM system and contribute to actual part building to achieve high building rate with high resolution.

Publications & Research Progress



Strathclyde NDT team has begun the integration of inspection package into the RoboWAAM cell at LMC

In the beginning of 2021, the CUE team has begun integrating the developed high-temperature ultrasound phased array roller-probe into the RoboWAAM cell at Lightweight Manufacturing Center (LMC), one of the sister organizations of University of Strathclyde and a part of UK manufacturing CATAPULT, bringing all the planning, designs, research and developments that take place since the beginning of the project into the industrial settings of the LMC. These efforts are aimed at commencing in-process inspection trials within the WAAM deposition cell in the second quarter of 2021!

The NDT team are hiring !

University of Strathclyde is looking to hire a new Research Associate dedicated to the NEWAM project. The qualified applicants interested in the post are invited to apply.

Staffs & Students

From a laser research student to a senior academic

Cranfield University

"lasers are like beer, when you try it you do not want anything else. This project gives us an enormous opportunity to think outside the box and test our radical ideas and most importantly develop them into a technology demonstrator by developing an industrial-scale additive manufacture system. We also hope to develop and educate the next generation of engineers needed for the future of smart manufacturing."

– Wojciech Suder

- NEWAM Process Development lead, Dr. Wojciech Suder, has been recently promoted to a senior lecturer in laser processing and additive manufacture. He has joined Cranfield University in 2007 as a PhD student and has grown to an expert and enthusiast of modern high power laser processing. Unravelling the secrets of laser-matter interactions and the response of different materials to laser irradiation has been his passion since then.
- Wojciech is proud of the NEWAM project where he leads the laser activities and helps design and facilitate the novel ideas and development from all the partnering universities into a working system. The highly innovative and radically new multi-energy process, developed in this project has a great potential to revolutionise wire-based additive manufacture and become a major game-changer of this technology.

Dr. Jacob Kennedy started new position

- Manchester team bid *au revoir et bonne chance* to PDRA Jacob Kennedy, who will soon start a new role as assistant professor, industrial chair in solidification, at the University of Lorraine in France. Jacob joined NEWAM as a PDRA after completing his PhD, also at the University of Lorraine. During Jacob's two years with NEWAM, Jacob explored grain refinement via the addition of inoculant particles.

UNIVERSITÉ DE LORRAINE

Congratulations to Philippe Bridgeman who recently gained his doctoral title!

- Philippe Bridgeman completed his PhD at Cranfield University in March 2021 and now hopes to return to whence he came - Industry. His thesis was entitled 'Investigation of plasma transferred arc dynamic effects in wire + arc additive manufacturing'.
- Plasma transferred arc (PTA) WAAM's rate of deposition needs to increase to meet industry demand but is hindered by arc pressure defects and keyhole initiation. To resolve this, his study identifies how PTA variables, nozzle and electrode geometries and electrode wear affect arc pressure and how it can be minimised and predicted and determines the arc pressure transitions for keyhole initiation to mitigate keyhole. Additionally, electrodes were investigated, materials and wear mechanisms to increase electrode longevity and maximise equipment availability.

Staffs & Students

New PhD student

A new PhD student, named Martin McInnes, is hired through University of Strathclyde's Research Excellence Award studentship, and will start in October 2021. Martin is about to complete his MEng degree in Electronic & Electrical Engineering at university of Strathclyde. Martin was first introduced to Non-Destructive Evaluation (NDE) in second year of university when he became interested in the area of research. He also used mode converted ultrasonic waves to detect defects within steel components in his 4th year project providing him with the essential knowledge of the testing technique to be deployed in WAAM inspection.

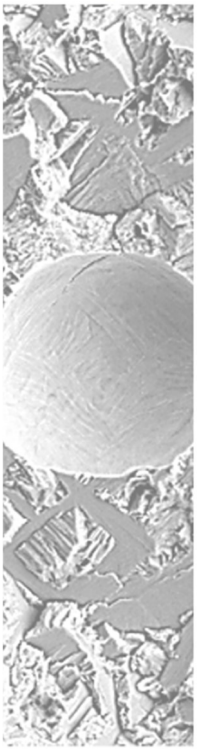
University of Strathclyde Engineering

Conferences & Meetings

Manchester researcher Dr. Alec Davis presented NEWAM research in the international conference ICOTOM 19

ICOTOM 19 (2021)

- In March 2021, Manchester team member Dr. Alec Davis delivered a talk at the 19th International Conference on Textures of Materials (ICOTOM 19). The title of his talk was 'Simulation and Texture Investigation of a Novel Recrystallisation Mechanism in Ti-6Al-4V during Wire-Arc AM with Inter-Pass Deformation'. ICOTOM 19 was planned to take place in Osaka, Japan, but due to COVID-19 restrictions this conference was held online.



Strathclyde NDT team aims to attend two international conferences in 2021

QNDE

NDT2021 59th Annual Conference

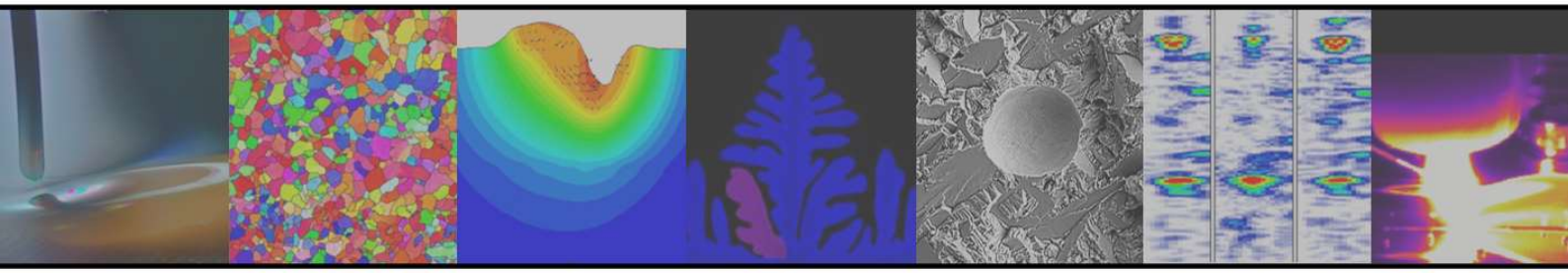
- During the year of 2021, the Strathclyde team is aiming to attend 48th Annual Review of Progress in Quantitative Non-destructive Evaluation (QNDE2021) conference and BINDT 59th annual conference, presenting newest developments in ultrasound imaging, sensor development + control and in-process inspection of WAAM. Due to Covid-19 restrictions, the QNDE2021 will be held online.

Collaboration & Impact

Successful joint application with WAAM3D for Impact Acceleration Account project

The internal application of Strathclyde team member, Dr. Ehsan Mohseni, for New Organization Engagement, with the support of WAAM3D as the new organization, through Impact Accelerate Account of the University of Strathclyde with a value of £10k has been successful. Following the preliminary promising WAAM inspection results obtained via Eddy currents testing, the project application was submitted in the end of 2020 and it was approved by the University in early 2021. The project will fund procurement of Eddy currents probe for electromagnetic inspection of WAAM components and helps to continue this research strand and strengthen the partnership with WAAM3D.

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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