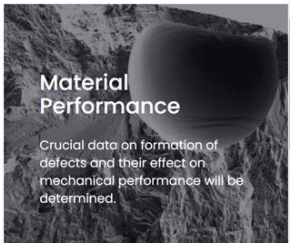
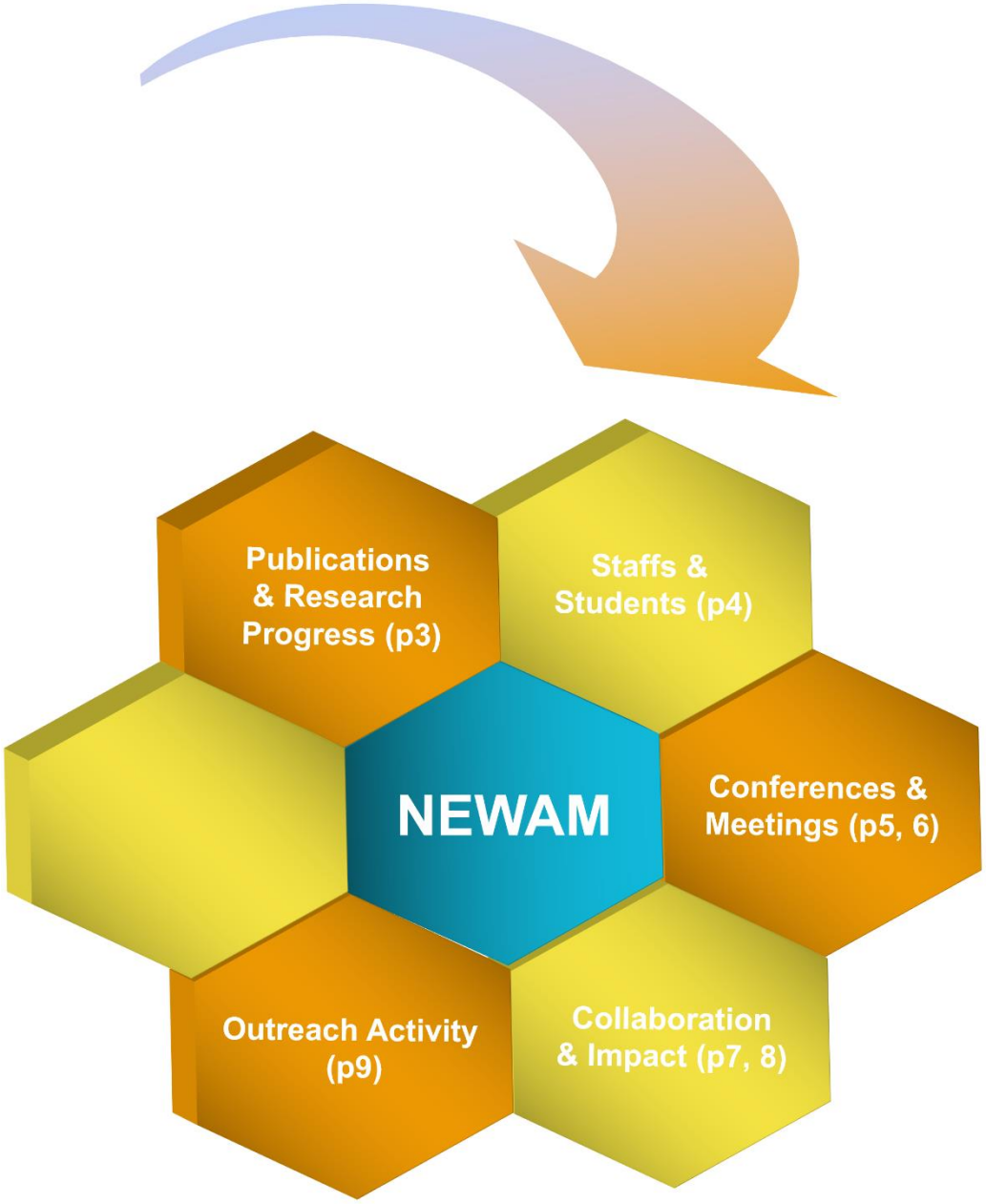
New Wire Additive Manufacturing

Newsletter (1st quarter, 2022)

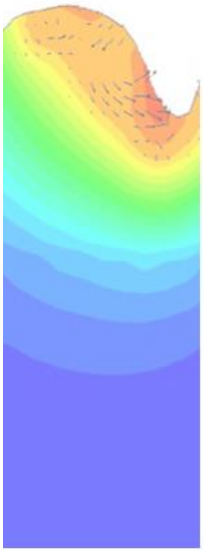


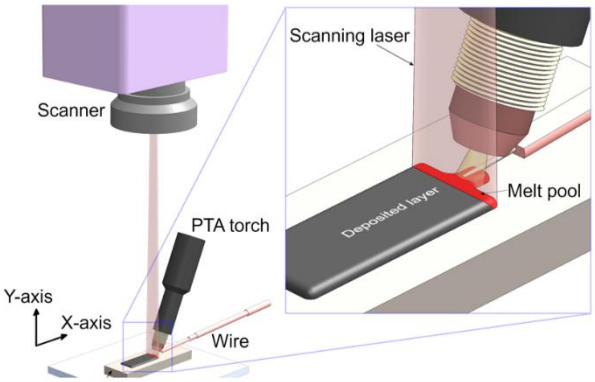
Compiled by NEWAM dissemination committee and released on 1 April 2022

Your NEWAM in Jan. – Mar. 2022



Publications & Research Progress



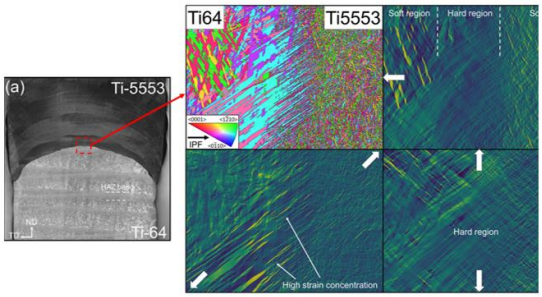


Cranfield Team's new publication on development of MES process

- Cranfield process team recently published a paper titled Multi-energy source (MES) configuration for bead shape control in wire-based directed energy deposition (w-DED)
- In this paper, a multi-energy source (MES) method featuring a high-power scanning laser (SL) was used to achieve independent control of layer width and height in a wire-based directed energy deposition (w-DED) process. Some single-pass walls were also built using the MES to show that MES can be used for w-DED additive manufacturing.

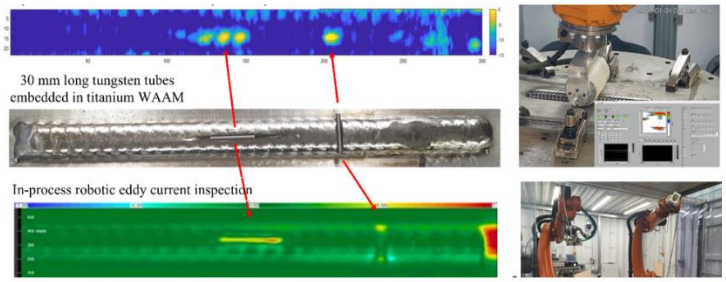
Chen, G., Williams, S., Ding, J., Wang, C., & Suder, W. (2022). Multi-energy source (MES) configuration for bead shape control in wire-based directed energy deposition (w-DED). Journal of Materials Processing Technology, 117549.

Manchester Team's research progress on crystal plasticity modelling



- WAAM-built titanium 'alloy-alloy composites', or AACs, can provide a significant increase in design freedom by utilising in-situ titanium dissimilar-alloy 3D printing to create site-specific properties, so that aerospace components are no longer over-engineered using a single material based on a minimum property compromise. However, when an alloy wire is switched in-situ during deposition with WAAM, the relatively large remelt depths result in dilution of the substrate with the newly melted wire, so that millimetre-scale chemical transitions gradients form throughout the build height, over several deposited layers, from the dissimilar alloy join. This can create heterogeneous microstructures with mechanical behaviour that is not well understood under deformation modes of interest, and these regions are therefore sites of potential risk for aerospace applications.
- Recently, a crystal plasticity finite element model has been developed that uses input from electron backscatter diffraction (EBSD) crystal orientation maps of the real microstructures of interest in these titanium AACs, and allows investigation of the micromechanical behaviour in these transition gradient regions under tensile load in different directions. The figure shows an EBSD map (top left) of the transition gradient between Ti-6Al-4V (Ti64) → Ti-5Al-5V-5Mo-3Cr (Ti5553) and simulated strain maps forming within the material after loading in the directions indicated by the arrows. The model shows how the sharp microstructure transition across the alloy-alloy boundary leads to the formation of 'hard' and 'soft' regions, which are dependent on the loading direction, and may lead to early fracture in service. Models of this type can help us guide future WAAM interface design in AACs and their post-build heat treatments to mitigate the impact of microstructure heterogeneities.

Strathclyde Team's research progress on NDT



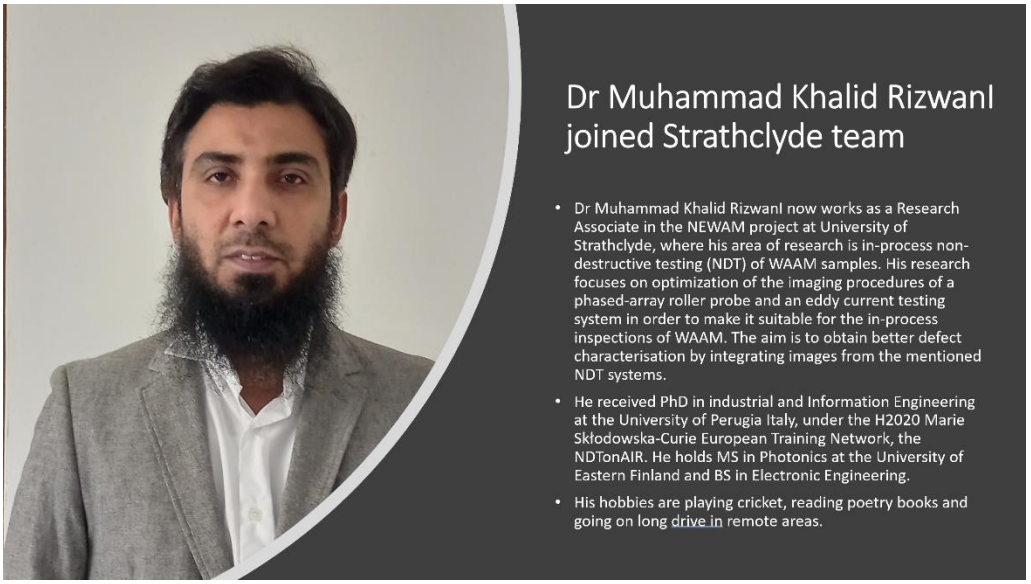
Initial Trials of In-Process NDT Using Roller-Probe

- The NDT has been fully integrated into the RoboWAAM cell, based in LMC (Renfrew, UK) to test the developed inspection packages in-process. An additional development/test kit has been integrated into the general inspection cell in SEARCH lab (Royal collage, Strathclyde main Campus), where the team can advance the development prior deployment in WAAM cell.
- Initial in-process inspection experiments were conducted showing a first results from inspection of as-built WAAM components taking place in-process after a specific layer. Recent demonstration videos have been shared on NEWAM (November 2021) meeting showing, for the first time, in-process NDE of defect embedded WAAM using both ultrasound roller-probe and eddy current packages.

Staffs & Students

Dr Alec Davis has been awarded a lectureship

- NEWAM post-doctoral research associate Dr Alec E Davis has recently been awarded a lectureship in the Department of Materials at the University of Manchester. Alec obtained his PhD in Materials Engineering through the Advanced Metallics CDT at the University of Manchester, where he worked on the design of precipitation-hardenable wrought magnesium alloys. His post-doctoral research with the Open Architecture Additive Manufacturing (OAAM) and NEWAM projects has focused primarily on the development of high-deposition-rate additive manufacturing (AM) processes, and materials characterisation, development, and design of bespoke AM titanium aerospace components. This includes development of alloy-alloy composite parts, where multi-alloy AM technologies are utilised to deposited dissimilar alloys in different component locations for site-specific and tailored mechanical properties.



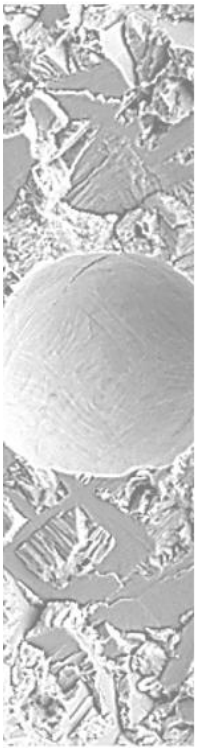
Conferences & Meetings

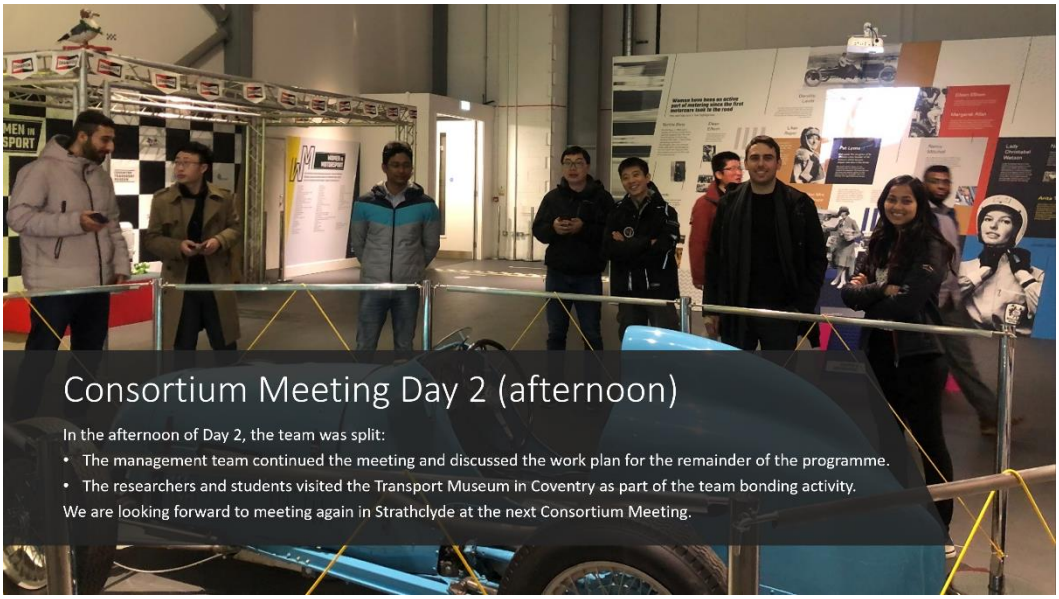
11th NEWAM Consortium Meeting, 16-17 March 2022, Coventry

The NEWAM team met at Coventry University on the 16th March 2022 to participate in the 11th Consortium Meeting. This was a two-day event with 32 people attending the meeting in person and three others presenting online.

Consortium Meeting Day 1 & Day 2 (morning only)

- On both days, the research area leads, researchers and students presented their work in great detail. The team discussed the progress of the project, the support required within the team and the future work.
- At the end of Day 1, the consortium dinner was great for team bonding. The team had the opportunity to meet face-to-face, talk in an informal environment and get to know each other, especially the new members.





Consortium Meeting Day 2 (afternoon)

In the afternoon of Day 2, the team was split:

- The management team continued the meeting and discussed the work plan for the remainder of the programme.
- The researchers and students visited the Transport Museum in Coventry as part of the team bonding activity.

We are looking forward to meeting again in Strathclyde at the next Consortium Meeting.

Conferences & Meetings

Coventry participated and presented in "1st International Conference on Advanced Manufacturing for Aerospace, Space and Land Transport"

Research Centre Manufacturing and Materials Engineering | Coventry University

Wire + Arc Additive Manufactured Al-Mg-Sc alloy: Fatigue crack growth behaviour

Presenter: Jin Ye (Coventry University, UK)

Co-authors: Xiang Zhang, Abdul Khadar Syed (Coventry University)

Eloise Eimer, Stewart Williams (Cranfield University)

1st International Conference on Advanced Manufacturing for Aerospace, Space an

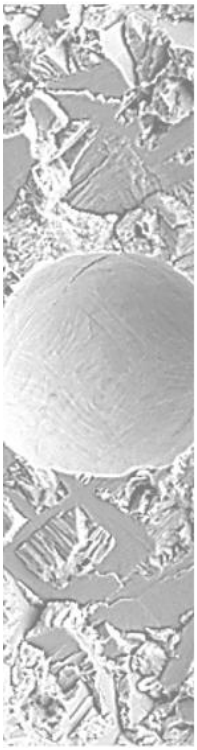
7-11 March 2022

- In this study, fatigue crack growth behaviour and crack growth rate of a WAAM Al-Mg-0.3Sc alloy has been investigated. Specimens were prepared using WAAM single pass deposition strategy and tested with cracks propagating parallel or normal to the build direction (BD) under constant amplitude loading and a load ratio of 0.1. At lower levels of stress intensity factor range (<10 MPa m1/2), fatigue crack growth rate was 50% lower when cracks propagating normal to BD.
- The crack path analysis has revealed that most cracks normal to BD propagated through larger grains, resulting in greater microscopic crack deviation, and thus lower crack growth rate. However, at higher level of stress intensity factor range (>10 MPa m1/2), similar crack growth rate values were measured for the two crack orientations. The modified Hartman-Schijve equation was successfully applied to represent the crack growth rate including the threshold regime.

QNDE

49th Annual Review of Progress in Quantitative Nondestructive Evaluation

San Diego, CA

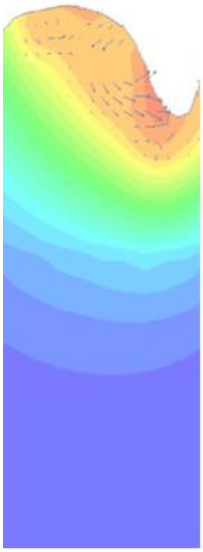


Strathclyde researcher planned to attend ONDE 2022 conference

Randika submitted an abstract to "49th Annual Review of Progress in Quantitative Nondestructive Evaluation" to be held from July 25-27 in San Diego California.

- **Title**: "Flexible Robotics to Inspect High-Value Components"
- **Authors**: Randika K. W. Vithanage, Kenneth Burnham, Momchil Vasilev, Charalampous Loukas, Harry Gover, Ehsan Mohseni, Rastislav Zimmermann, David Lines, Yashar Javadi, Charles N.Macleod, Stephen G. Pierce, Anthony Gachagan, Stewart Williams and Jialou Ding

Collaboration & Impact



Cranfield team, along with Manchester team, have been granted a new EPSRC project on DEDAM process development

SAM – Sustainable Additive Manufacture project proposal is successful

The project PI is again Professor Stewart Williams and is a partnership between Cranfield University (Welding Engineering and Laser Processing Centre and Sustainable Manufacturing Systems Centre) and University of Manchester, Light Alloys Group, led by Professor Phil Prangnell.

This project aim is to increase the sustainability benefits of w-DEDAM by utilising swarf material directly as feedstock instead of or in addition to wire. There are several major scientific, and engineering research challenges:

- ✓ Defining a quantification morphology for swarf quality that can be related to the required process conditions and the resultant in-fill material properties.
- ✓ Development of reliable, controllable, swarf in-fill processes for a range of deposition geometries and materials including:
  - Precise control of the deposition melt pool, for defect free builds with variable geometry,
  - Processes with efficient melting, shielding, and precise consistent flow control.
- ✓ Achieving property levels sufficient to enable a wide range of applications
- ✓ Developing novel process models capable of simulating swarf melting and melt pool flow behavior.
- ✓ Life cycle analysis and cost benefit models integrated into a multi-objective optimisation tool.

EPSRC Reference:	EP/W01906X/1
Title:	Sustainable Additive Manufacturing
Principal Investigator:	Williams, Professor SW
Other Investigators:	Jolly, Professor M; Ding, Dr J; Sun, Dr Y; Rodrigues Pardal, Dr GN; Prangnell, Professor P; Pickering, Dr E; Suder, Dr W; Salonitis, Professor K
Researcher Co-Investigators:	
Project Partners:	Airbus Group Limited; WAAM3D
Department:	Sch of Aerospace, Transport & Manufact
Organisation:	Cranfield University
Scheme:	Standard Research
Starts:	01 April 2022 — Ends: 31 March 2025 — Value (£): 1,665,172
EPSRC Research Topic Classifications:	Manufacturing Machine & Plant; Materials Characterisation
EPSRC Industrial Sector Classifications:	Manufacturing
Related Grants:	
Panel History:	Panel Date: 02 Nov 2021 — Panel Name: Sustainable manufacturing Full — Outcome: Announced

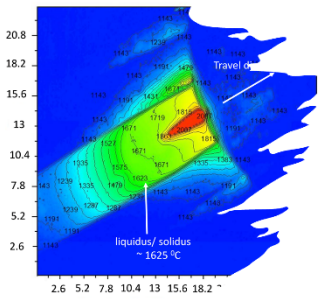
More about EPSRC research grant on Sustainable Additive Manufacturing (SAM)

The specific objectives for SAM are:

- ✓ A swarf in-fill process with rates of >4kg/hr (Ti64), no defects and equivalent wrought alloy performance levels
- ✓ A quantified relationship between swarf form, process conditions and material properties
- ✓ Quantified SAM LCA models combined with cost models into a multi-objective optimisation tool
- ✓ Robust useful process models for the melting behaviour for a wide range of swarf morphologies

SAM will utilise the multi-energy source concept developed in the NEWAM programme. It will become an associated project of NEWAM, so partners will be informed of the potentially high impact outcomes from SAM.

If any partners are interested in being directly involved in the SAM project, please let us know and we can provide more information or discuss this with you 🙂



Cranfield team has been granted a new EPSRC project on process monitoring

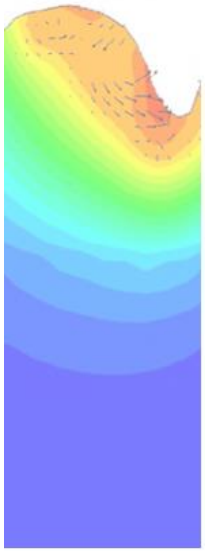
- **Title**: Thermal monitoring instrumentation for metal additive manufacturing - PYRAM
- **Aim**: Developing a temperature measurement instrument for use in a wire based additive manufacturing (AM) processes. The instrument will use a lensed fibre-optic cable fed to a camera-based design, allowing it to operate in different deposition environments and will be compatible with a variety of metals

"There were 51 submissions and this grant was ranked 2nd"

EPSRC Reference:	EP/W025035/1
Title:	Thermal monitoring instrumentation for metal additive manufacturing - PYRAM
Principal Investigator:	Tatam, Professor RP
Other Investigators:	Ding, Dr J; Williams, Professor SW; Mullaney, Dr K; Charrett, Dr TOH
Researcher Co-Investigators:	
Project Partners:	WAAM3D
Department:	Sch of Aerospace, Transport & Manufact
Organisation:	Cranfield University
Scheme:	Standard Research
Starts:	03 October 2022 — Ends: 02 October 2025 — Value (£): 961,863
EPSRC Research Topic Classifications:	Control Engineering; Instrumentation Eng. & Dev.; Manufacturing Machine & Plant
EPSRC Industrial Sector Classifications:	Manufacturing
Related Grants:	
Panel History:	Panel Date: 09 Feb 2022 — Panel Name: Manufacturing Instrumenting the Future — Outcome: Announced

- ✓ The system will provide real-time temperature images of the AM melt pool that will improve the effectiveness of the additive manufacturing processes. Custom software will produce a real-time temperature map of the melt-pool, and allow the instrument to be then used with the process software controlling the AM machine.
- ✓ This will allow power feedback control of the welding arc and hence limit significant variations in the melt pool temperatures. The research will develop a state-of-the-art instrument addressing one of the major challenges facing metal AM processes and provides a route to fabricating reproducible and specification compliant components.

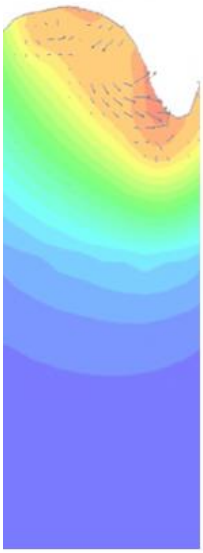
Collaboration & Impact

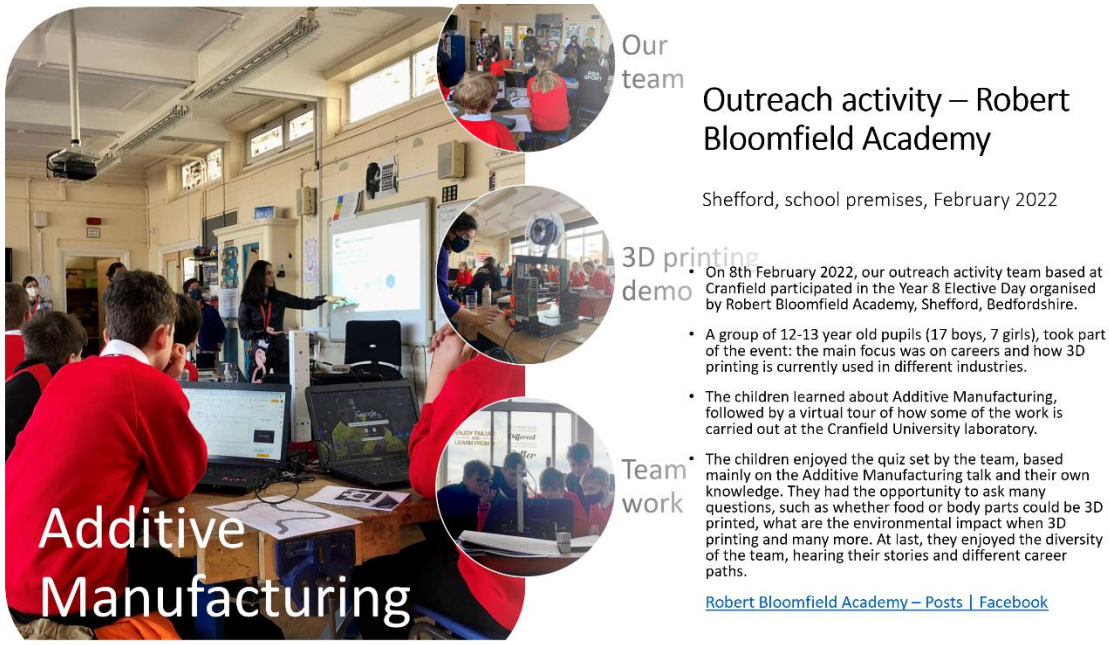


Strathclyde Team Dr Ehsan Mohseni secured funding for development of sensor data fusion

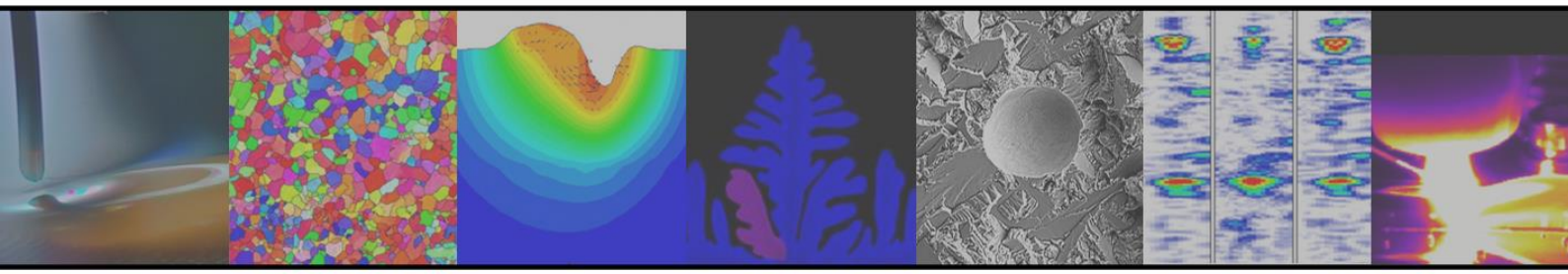
- A recent feasibility study application with a total value of £ 34k was submitted to the Research Centre for Non-Destructive Evaluation (RCNDE) with the title of "**Ultrasound and Eddy currents sensor data fusion for welding and additive manufacturing**", and the outcome was positive with the project receiving funding.
- The project will be led by Ehsan and it will run from August 1st for 9 months. In its framework: a) Design and fabrication feasibility of the combined dual-sensor system and its robotic automation, b) Two-staged data fusion feasibility for the dual-sensor system, and c) thermal impact on the UT and EC signal will be investigated.

Outreach activity





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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