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International Committee on Aeronautical Fatigue and Structural Integrity

Digital Engineering – UK examples

Dr David Hallam – ICAF National Delegate - UK
| 26th June 2023

Digital Engineering II

- A second National Review on the topic of Digital Engineering is to be delivered on Thursday.

Thursday 29 June 2023 - 08:30h

08:30 **Topical National Review by Yuval Freed & Eric Lindgren**

09:00 **Session 16; Digital engineering III**
Chair: David Hallam

Meso-scale models to analyse the interactions of damage modes in composites laminates
Sara Ghiasvand, Alessandro Airoldi, Giuseppe Sala, Pietro Aceti, Pietro Ballarin, Andrea Baldi, Emanuele Mesiani

A holistic digital twin for service life extension programs
Javier Gomez-Escalonilla, Fernando Sanchez, Oscar Valencia, Manuel J Rebollo

Model based engineering approach in aeronautical fatigue and structural integrity testing
Shawn You, Shawn Gao

- This will provide a greater focus on:
  - Digital engineering terminology
  - Opportunities and challenges
  - National examples relating to:
    - Full scale fatigue testing anomaly detection; development of a ML-based assessment tool and initiatives/activities that have an emphasis on the latter stages of life management

- This remainder of this review will therefore provide a greater emphasis on the **materials and manufacturing** area of Digital Engineering

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Materials development and manufacturing: UK examples

1. *Rapid materials development and optimisation* – Alloyed Ltd

2. *Microstructural imaging* – University of Nottingham

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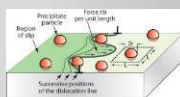
Materials development and optimisation

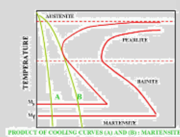
Alloyed Ltd

Alloys-by-Design (ABD®): Platform comprises both computational and experimental capabilities

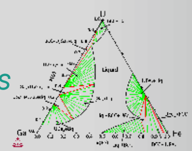
Physical metallurgy



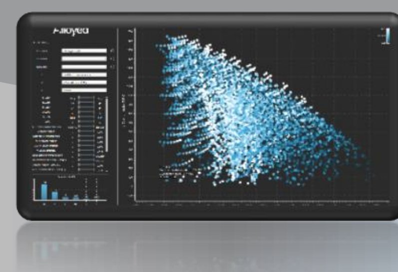
Kinetics



Thermodynamics



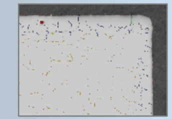
Composition and process information for increased performance



Materials Data for model validation and refinement

Alloy manufacture and processing

Performance measurement



Characterization and analysis

Modular software platform for optimizing alloy composition for targeted material performance

Rapid alloy research facility for production and testing of alloys

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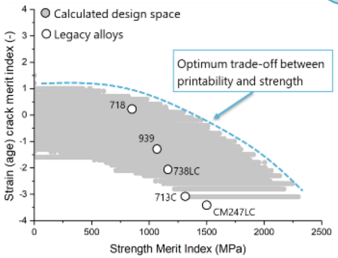
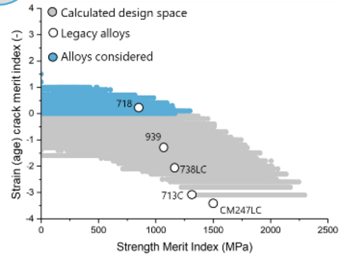
ABD®-900AM – a nickel-based superalloy optimised for additive manufacturing process - Alloyed Ltd

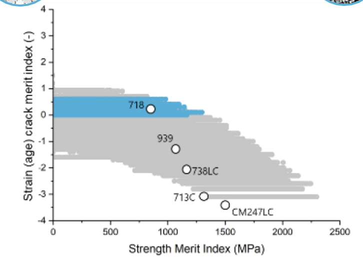
1. **High strength AM alloys**



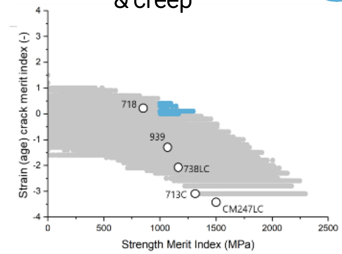
2. **Low strain-age cracking**



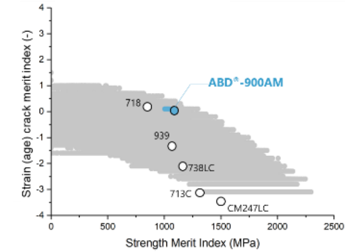
3. Low hot cracking



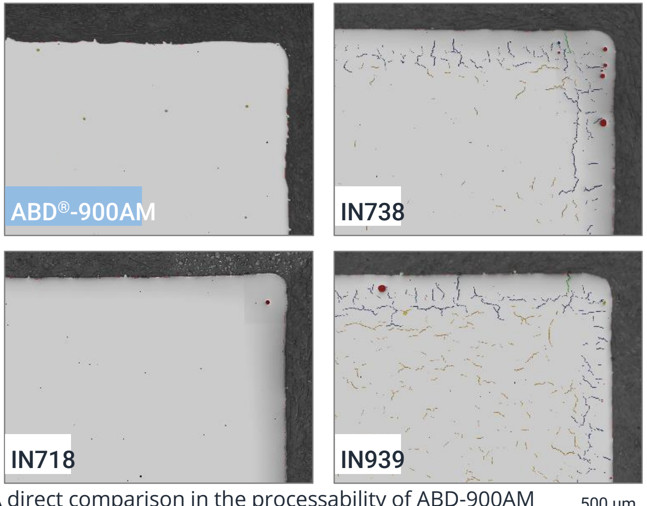
4. High temp strength & creep



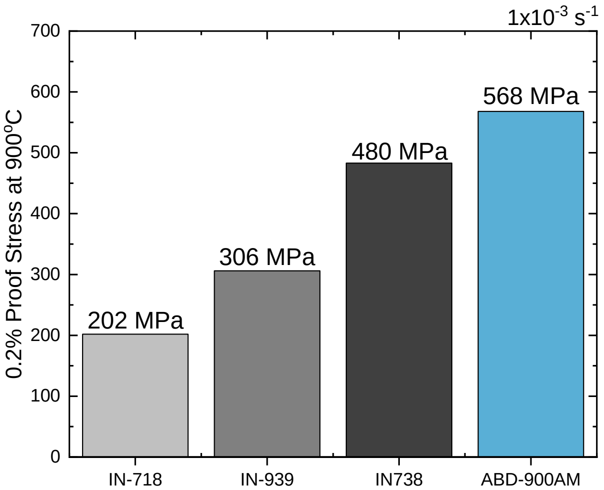
5. No TCP & oxidation resistance



- Millions of potential alloys are assessed in parallel to isolate the best trade-off in **performance vs printability**
- Shown above is an example of the process used to isolate a **novel nickel alloy for additive manufacture**, ABD®-900AM, which allows for crack-free processing



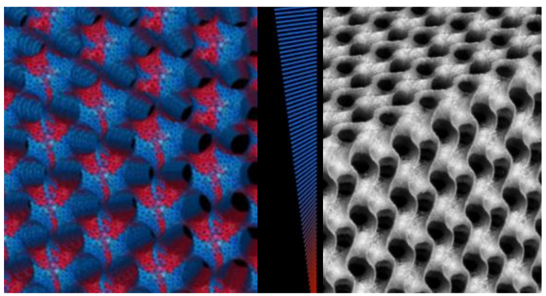
A direct comparison in the processability of ABD-900AM vs legacy nickel superalloys. All samples printed with standard IN718 parameters on a Renishaw AM400



Software platforms which transform cost of additive manufacture - Alloyed Ltd

Additive design platform

Engine® for process control (CAM)

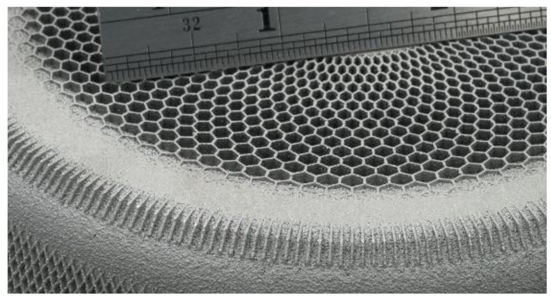


Gyroid structure with angle-dependent laser parameters (colour coded) for more accurate and stronger thin walls

Voxel-by-voxel control of path and energy of laser in additive processes. Allows unprecedented level of:

- Performance (part detail, material properties)
- Cost (through-put optimisation)

Architect® for high-complexity design (CAD)

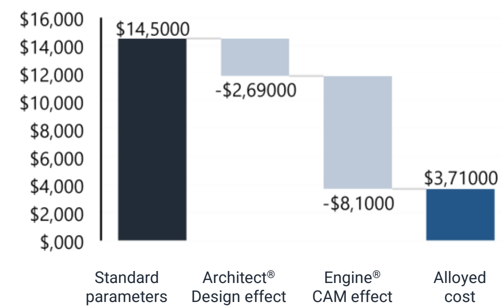


DfAM component enabled by Architect® and built using Ti-6Al-4V

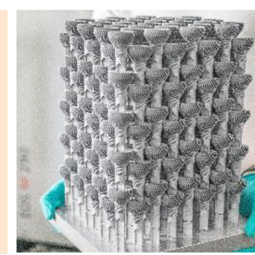
- Superior functional performance
- Superior productivity through reduced material usage in part and support
- Optimal use of build plate

Industry-leading cost/performance

Real case study: cost savings on LED heatsink



World's best performance/price for any given application on any given AM system



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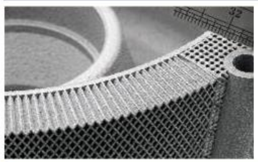
Ultimate opportunity: components optimized from nanoscale up - Alloyed Ltd

Computational platforms

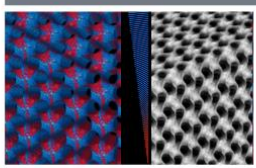
Additive design

Architect® for component design



- More faithful reproduction of complex geometries

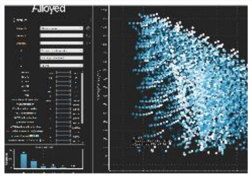
Engine® for processing



- Thinner, stronger walls
- Shorter build times => lower cost

Materials design

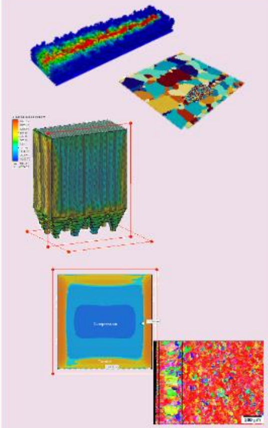
ABD® for advanced alloy design



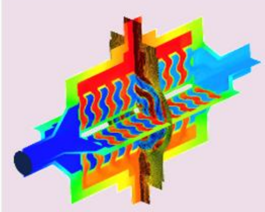
- Higher conductivity
- Improved processing
- Lighter weight
- Lower cost

Capabilities

Multi-scale simulation



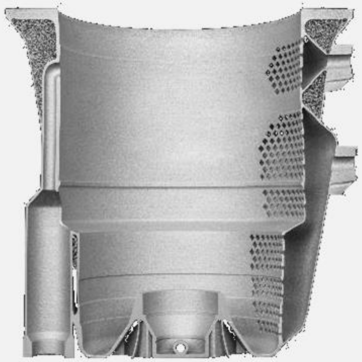
FEA / CFD



Optimal components

Components optimised from materials up

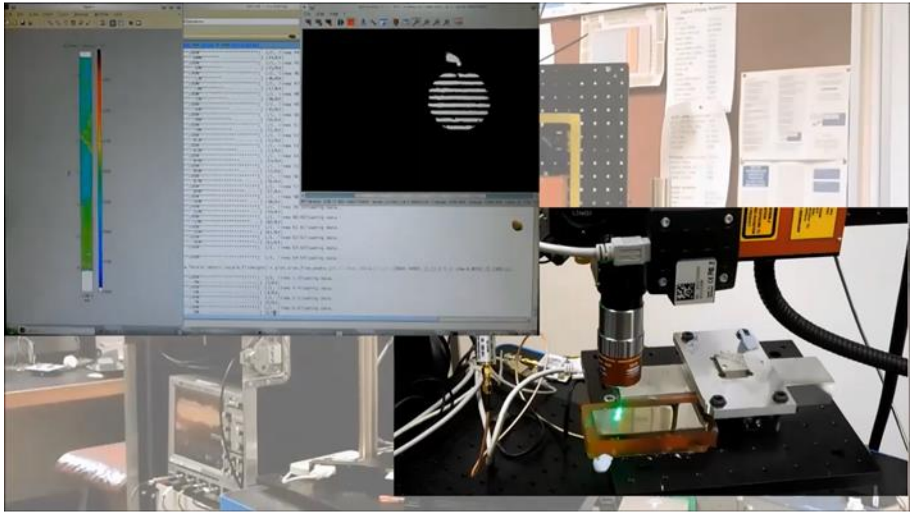
- Lighter, stronger
- Thinner walls, denser function
- Better thermal properties
- Lowest cost



Spatially Resolved Acoustic Spectroscopy (SRAS)

University of Nottingham

- Remote/Non-contact
  - laser generation & detection
- Simple operation
  - no vacuum chamber
  - no temperature requirements*
  - plug-n-play (when enclosed)
- Unrestricted scan sizes
  - limited by mechanics
- High resolution
  - resolution of tens of microns
- Rapid scanning
  - Up to 10000 points/s (laser limited)



“Spatially resolved acoustic spectroscopy for fast noncontact imaging of material microstructure”, S. Sharples, Optics Express 14(22):10435-10440 (2006)
“Spatially resolved acoustic spectroscopy for rapid imaging of material microstructure and grain orientation”, R. J. Smith, Meas. Sci. Technol., vol. 25, no. 5, p. 055902, (2014)
Patent: GB 2441953B, US 8006558B2, EP 1910815B1, JP 2008545147A, WO 2007003952A2

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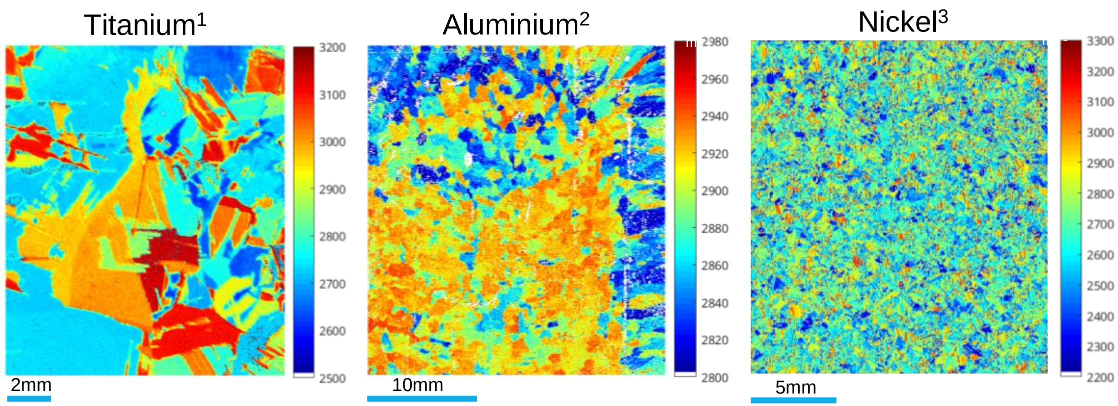
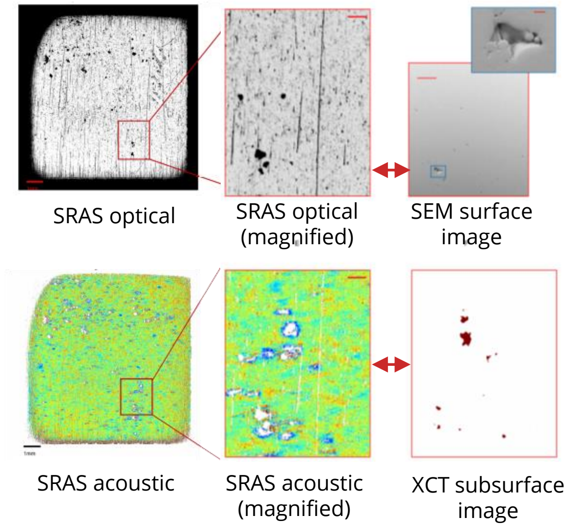
SRAS+ (microstructural imaging)

University of Nottingham





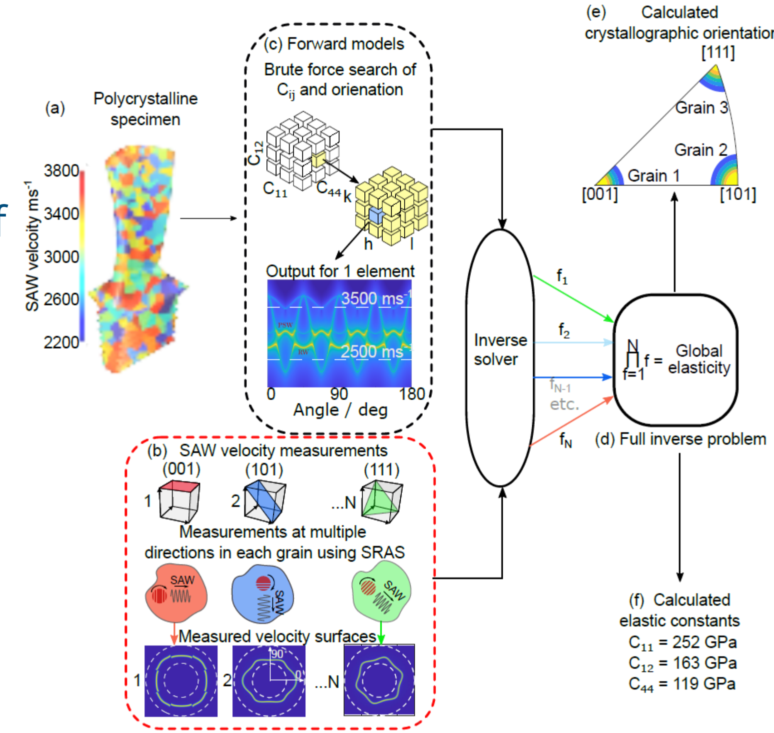
- In-situ rough surface microstructure inspection[4]
  - Recent advancements have made it possible to use the SRAS technique on as-fabricated, as-deposited or machined surfaces.
  - The novel method developed enables the possibility of in-field and in-situ interrogation of samples with difficult geometries or parts that are difficult practically to remove and prepare, making it particularly useful for immediate part integrity and performance metrics.

[1] P Dryburgh, "Determining the Crystallographic Orientation of Hexagonal Crystal Structure Materials with Surface Acoustic Wave Velocity Measurements", Ultrasonics, 2020, 10.1016/j.ultras.2020.106171
[2] W Li, "Laser ultrasonic technique for crystallographic orientation determination", J. Phys. Conf. Ser. 2014, 10.1088/1742-6596/520/1/012017
[3] B Xiao, "Accurate finite element model of equiaxed-grain engineering material for ultrasonic inspection," Ultrasonics Sym (IUS), 2014, 10.1109/ULTSYM.2014.0337
[4] University of Nottingham; 2023 UK ICAF National Review, pg 57-62

SRAS++ (imaging material elasticity)

University of Nottingham

- New method for measuring the single-crystal elastic stiffness matrix of polycrystalline materials.
  - Uses velocity measurements for a range of propagation directions for each grain.
  - Measuring the elastic constants important for predicting the macroscopic mechanical behaviour of a material.
  - Future integration of the instrument in advanced material manufacturing environments will allow near real-time measurement of the elastic properties.
  - This will allow the rapid exploration of new materials with tailored mechanical properties.



University of Nottingham; 2023 UK ICAF National Review, pg 53-56