Science and Technology Facilities Council

Analysing the texture of superalloys produced by additive manufacturing

Neutron diffraction reveals how the microstructure of nickel superalloy specimens are affected by the additive manufacturing parameters.

Challenge

Additive manufacturing is a technique that can be used to build metal components layer by layer, to the specification of a 3D model. This enables intricate parts to be made at a small scale without the need to invest in niche manufacturing equipment. However, alloys produced by additive manufacturing can develop a strong texture that affects their mechanical properties, and hence a component's performance.

A Canadian research collaboration, including Siemens Energy, wanted to understand the microstructural changes caused by altering various parameters during laser powder bed fusion (LPBF) additive manufacturing. They focussed on components made from a nickel-based superalloy known as Hastelloy-X, which is used to make gas turbines.

Solution

The researchers used the specialised setup on the ENGIN-X beamline at ISIS Neutron and Muon Source to test how Hastelloy-X components behave under operational conditions, using neutron diffraction to characterise residual stresses and texturing under compression.

Benefits

The team determined that the specific energy, power and scanning speed of the laser influence the microstructure of Hastelloy-X samples, with increasing laser power inducing a preferred orientation of the grains.

This initial study confirms that it is crucial to control the individual parameters of LPBF, as this will determine the structure, and therefore properties, of the end component.

> **"The laser powder-bed fusion additive manufacturing process produces an intense temperature gradient within the fabricated components as a result of the fast thermal and cooling cycles that occur during the process. Therefore, residual stresses and deformations are inevitable in the manufactured parts. In order to minimise deformation, residual stresses must be measured and analysed to optimise the LPBF process parameters. Due to the capabilities available at ENGIN-X, we were able to measure residual stresses precisely."**
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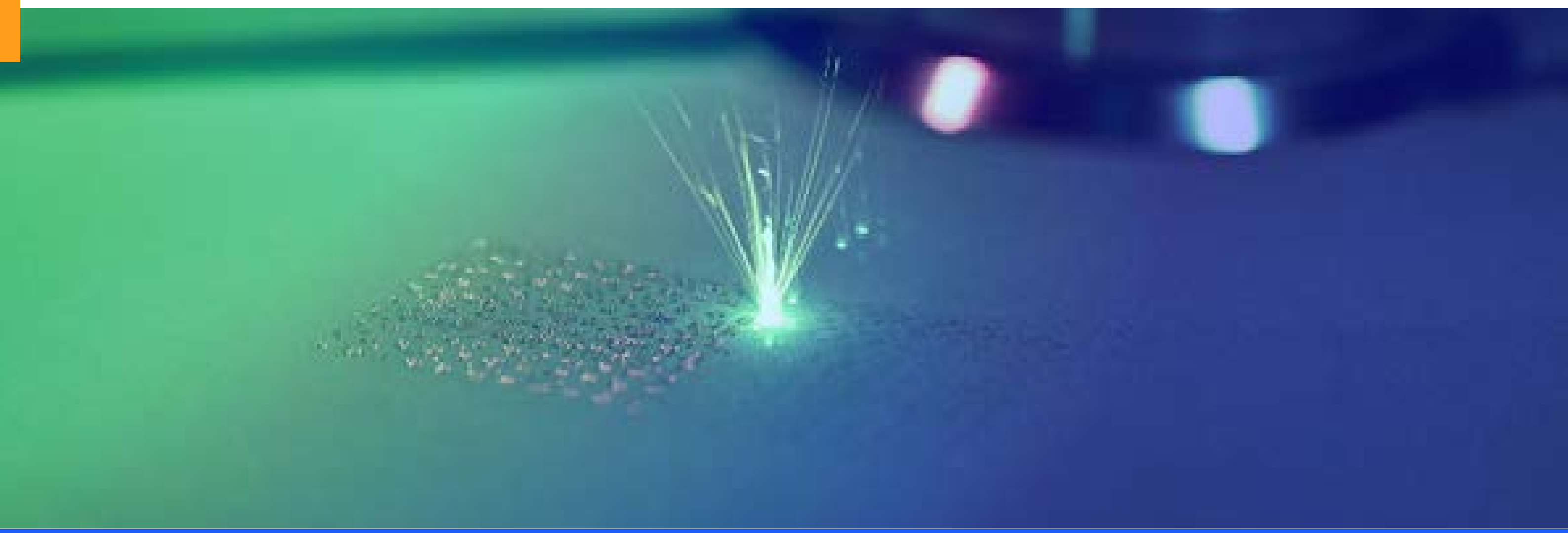
> Ali Bonakdar - Advanced Manufacturing Research Lead, Siemens Energy



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ISIS Neutron and Muon Source

ISIS Neutron and Muon Source has successful collaborations with many different industries, delivering insights to develop new and improved materials and processes.

Why use neutrons?

Study structure
Neutron wavelengths are comparable to the spacings of atoms and molecules.

Study dynamics
Neutron energies are comparable to the time scales of molecular diffusion, vibrations and rotations.

Study magnetism
The neutron's magnetic moment can be used to study the microscopic magnetic properties of materials.

Penetration power
Neutrons can penetrate deep into matter (including many different metals) enabling the study of large samples – even within complex sample environments.

Non-destructive
As a non-destructive, non-invasive probe, neutrons are suitable for the characterisation of delicate and precious samples.

Versatile sample environments
Sophisticated sample environments enable measurements under operating conditions – including extreme temperatures and pressures.

Sensitivity to light elements
The neutron scattering power of nuclei varies in a random manner such that lighter atoms (e.g. H, Li) can be studied in the presence of heavier ones.

Isotopic contrast
Neutrons are sensitive to different isotopes of the same element, so isotopic substitution (e.g. H/D) can be used to highlight specific structural features.

Complementarity
Neutron scattering is highly complementary to other techniques, such as X-ray scattering, electron microscopy, magnetic resonance and computational methods.

How to work with ISIS

ISIS offers industrial users access to advanced analytical techniques and expert scientific and technical support for materials characterisation. Access options include proprietary use, academic partnerships, grant funded access, and the Industrial Collaborative Research and Development (ICRD) program.

For more information, email ISISindustry@stfc.ac.uk to discuss the most suitable method to solve your challenge.