Mechanical Testing of Additively Manufactured Aerospace Parts

Supporting the qualification of metal AM components through independent materials testing

Additive manufacturing is changing the way high-value aerospace parts are designed, made and repaired. Building metal components layer by layer can reduce waste, shorten lead times and make complex forms possible where conventional machining would be costly or impractical.

But AM parts cannot simply be judged against conventional wrought, forged or cast data. Build direction, deposition strategy, heat treatment and local microstructure can all change the result. For aerospace work, that makes testing essential rather than optional.

ASAMS supports metallic AM projects with practical destructive and metallurgical testing, including tensile, charpy impact, hardness, bend, macro and microstructural examination. Our role is to help turn test pieces into clear engineering evidence.

AM components cannot be qualified by alloy grade alone.
Build direction, deposition strategy, heat treatment and specimen orientation can all significantly affect the final mechanical properties of an additively manufactured part. Independent testing provides the evidence needed for qualification decisions.

Why additive manufacturing matters to aerospace

The aerospace sector uses high-performance alloys such as nickel-based superalloys, titanium alloys and aluminium alloys because of their strength-to-weight ratio, corrosion resistance and suitability for demanding service environments. These materials are often expensive and, when machined from solid, can generate significant material waste.

Additive manufacturing offers a route to improved buy-to-fly ratio by producing near-net-shape components with less wasted material. It can also support shorter production lead times, bespoke component manufacture, repair applications and the production of complex forms that may be difficult to manufacture conventionally.

To use AM safely in aerospace, the material properties have to be proven. Testing should be considered during process development and qualification, not left until the end as a final check.

The testing challenge for AM parts

Many established test standards were written around forgings, castings, plate, bar, weldments and machined parts. AM deposits are different. They are built through repeated heating and cooling, directional solidification and layer-by-layer addition.

Qualification risk
Two parts produced from the same alloy can perform differently simply because they were built using different AM process parameters.

This can lead to:

- variation between horizontal and vertical test orientations;
- differences between build direction and deposition direction;
- local changes in hardness or toughness;
- anisotropy in tensile properties;
- sensitivity to heat treatment condition;
- porosity or microstructural features associated with the AM process;
- differences between process strategies, even when the same alloy is used.

Good planning matters. Specimen orientation, extraction position, heat treatment condition and reporting requirements all affect how useful the results will be to the engineer reviewing them.

ASAMS testing support for additive manufacturing

ASAMS works with manufacturers, engineering teams and technology developers who need to understand how metallic AM materials are performing in practice.

Typical AM testing support may include:

- **Tensile testing** to evaluate proof stress, ultimate tensile strength, elongation and reduction or area.
- **Charpy impact testing** to assess impact toughness at specified temperatures.
- **Hardness testing** to identify local variation in mechanical response.
- **Bend testing** to assess ductility and detect surface or internal discontinuities.
- **Macro examination** to review section quality, fusion, porosity and deposit structure.
- **Microstructural examination** to assess grain structure, deposit features and metallurgical condition.
- **Test planning support** to help determine suitable specimen orientation, extraction locations and reporting requirements.

Testing can be aligned with recognised methods where appropriate, including ASTM E8/E8M for tensile testing, ASTM E23 for Charpy testing, BS EN ISO 6507 for Vickers hardness testing and BS EN ISO 5173 for bend testing. For the source project, qualification guidance was also taken from ASME Section IX QW-600, which treats several AM qualification requirements in an equivalent way to welding procedure qualification.

Where the method falls within scope, ASAMS can provide UKAS-accredited testing under accreditation number 0935. We also confirm scope and method suitability before work starts, so the final report is fit for the project, customer or qualification route.

"A material certificate alone is rarely sufficient for aerospace AM qualification."

Case study: Testing laser DED and arc DED materials for aerospace applications

A project involving ASAMS, TWI and ESA considered the mechanical testing of two directed energy deposition material and process combinations:

1. **Laser directed energy deposition using nickel alloy 718 powder**
2. **Arc directed energy deposition using aluminium 5183 wire**

The work looked at how material, process route and deposition strategy changed the measured properties of aerospace-relevant AM deposits.

Laser DED nickel alloy 718

Nickel alloy 718 is widely used in aerospace because it retains useful strength at elevated temperature. In this work, Ni 718 powder was deposited as a rectangular wall using an industrial laser DED cell. Process trials considered parameters such as laser power, scan speed, hatch distance and layer increment.

The deposit was then machined and heat-treated using solution treatment and multi-stage ageing. Tensile specimens were taken in horizontal and vertical directions to check for orientation effects. Hardness and Charpy impact testing were also used to build a fuller picture of the material response.

Figure 1Laser DED Trumpf 7040 Equipment Outside

What the testing showed

The laser DED Ni 718 deposit gave hardness and tensile results broadly in line with published work on similar laser DED and heat-treated material. It also showed why conventional heat treatments cannot always be assumed to give identical outcomes in AM material.

Key finding: Laser DED Nickel Alloy 718
The laser DED Ni 718 deposit produced tensile and hardness results broadly comparable with published work, but showed that conventional heat treatment assumptions cannot automatically be applied to AM material.

Figure 2 Laser DED Trumpf 7040 Equipment Inside

That matters in aerospace. AM material has its own thermal history. Solution treatment, ageing response, homogenisation and recrystallisation may not behave exactly as expected from conventional product forms. Mechanical testing provides the evidence needed to make that judgement.

Arc DED aluminium 5183

The second part of the project considered aluminium 5183 deposited by arc DED. Aluminium alloys are attractive in aerospace because of their low density and weightsaving potential. Here, two wall structures were produced using a Fronius CMT Advanced power source integrated with a Fanuc welding robot.

Figure 3 TWI Welding Robot used for Arc DED

The walls were not built in the same way. One used a longitudinal bead strategy. The other used an oscillating transverse strategy. Specimens were then taken in horizontal and vertical orientations so the effect of deposition pattern and sample direction could be compared.

What the testing showed

The oscillating bead strategy produced less scatter in tensile results than the longitudinal bead approach. Its tensile properties were broadly similar to standard ER5183 feedstock wire. The longitudinal wall performed less well, particularly in the vertical tensile samples.

Key finding: Arc DED Aluminium 5183
The oscillating bead strategy produced more consistent tensile results than the longitudinal bead strategy, highlighting the influence of deposition path on measured performance.

Figure 4 Laser DED Deposit

The message was clear: deposition strategy and specimen orientation can change the measured result. Horizontal samples generally performed better than vertical samples, possibly because vertical specimens cross more layer interfaces. Charpy results also varied by deposition strategy, wall region and test orientation.

Did you know?
Vertical AM test specimens often cross more layer interfaces than horizontal specimens, which can influence measured tensile and impact properties.

Bend testing and macro examination also identified pores and micropores in the aluminium deposits. That is not unusual for aluminium AM work, where porosity control can be difficult. It is exactly why destructive testing, sectioning and metallurgical examination are so useful during qualification.

AM qualification factors
Before qualifying a metal AM process, consider feedstock type, energy source, build orientation, deposition strategy, heat treatment, defect population, extraction location and test orientation.

What these results mean for AM qualification

The project demonstrates an important principle: the mechanical performance of an AM part is not determined by alloy grade alone.

“The mechanical performance of an AM component is determined by the manufacturing route, not just the alloy.”

For additively manufactured parts, performance is influenced by the complete manufacturing route, including:

- feedstock type;
- energy source;
- deposition method;
- build direction;
- bead or toolpath strategy;
- heat treatment;
- machining or post-processing;
- defect population;
- specimen extraction location;
- test orientation.

Qualification testing therefore has to represent the real manufacturing route and the intended service application. A material certificate or generic alloy data sheet is rarely enough on its own for aerospace AM work.

Independent testing helps close that gap. It shows whether the process is producing material with the required strength, ductility, toughness and consistency.

Why choose ASAMS for additive manufacturing testing?

ASAMS gives customers clear, practical evidence about metallic materials and components. For AM projects, that means more than recording a pass or fail. It means helping the project team understand what the results say about the process, the material and the next engineering decision.

Clients choose ASAMS for:

- **Over 35 years of practical testing experience** supporting engineering, inspection and qualification work.
- **Destructive and metallurgical testing in one place**, including tensile, charpy impact, hardness, bend, macro and microstructural examination.

- **Experience with aerospace-relevant materials**, including nickel alloys, aluminium alloys and other high-performance engineering metals.
- **Support with specimen planning**, including orientation, extraction location, heat treatment condition and reporting requirements.
- **Clear reporting** for engineering review, customer submission or project records.
- **UKAS-accredited testing where applicable** under accreditation number 0935, with scope suitability confirmed before work begins.
- **A responsive UK-based laboratory team** able to support development, investigation and qualification programmes.

Whether it is a one-off investigation, an AM qualification programme or ongoing production support, ASAMS can help generate evidence that engineers can use with confidence.

Why engineers use ASAMS
UKAS-accredited testing where applicable, over 35 years of testing experience, mechanical and metallurgical testing under one roof, support with specimen planning and clear engineering-focused reporting.

Applications supported

ASAMS can support testing programmes for AM parts used in sectors such as:

- aerospace
- space
- defence
- nuclear
- energy
- oil and gas
- marine
- motorsport
- research and development

Testing can be used to support:

- AM process qualification
- material comparison
- heat treatment assessment
- build orientation studies
- failure investigation
- supplier approval
- production validation
- customer acceptance testing
- research and development projects

Key takeaway

AM offers major opportunities for aerospace, but it needs careful qualification. The laser DED Ni 718 and arc DED aluminium 5183 work shows that process route, deposition strategy, heat treatment and build orientation can all affect mechanical performance.

For organisations developing or using metal AM parts, independent testing provides the evidence needed to understand material behaviour, compare process options and support qualification decisions.

Developing an aerospace AM qualification programme?
ASAMS can support tensile testing, Charpy impact testing, hardness testing, bend testing, macro examination, microstructural analysis and process qualification programmes.
Turn AM test data into engineering evidence.

Speak to ASAMS about AM testing

If you are developing, qualifying or investigating additively manufactured metal components, ASAMS can help plan a practical test programme and provide clear reporting for your project team or customer.

Contact ASAMS to discuss:

- tensile testing of AM metals;
- Charpy impact testing of AM components;
- hardness surveys;
- bend testing;
- macro and microstructural examination;
- AM process qualification support;
- aerospace material testing;
- testing of nickel alloy, aluminium alloy and other metal AM deposits.

ASAMS can help turn AM test results into clear engineering evidence.

A more detailed technical version of this whitepaper is available on request. To discuss access or request a copy, please contact thomas@asams.co.uk.

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