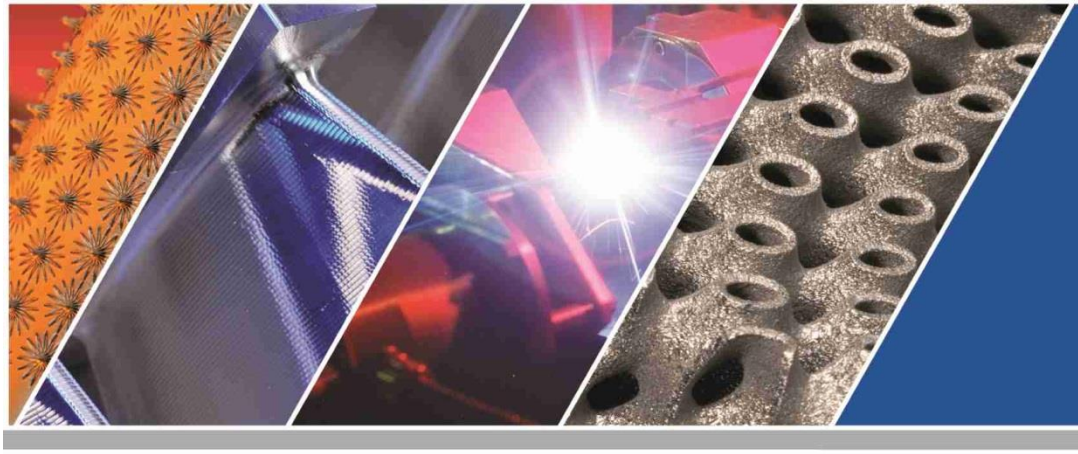
Achieving Regulatory and Code Compliance for Additive Manufacturing



JOINT INDUSTRY PUBLISHABLE SUMMARY

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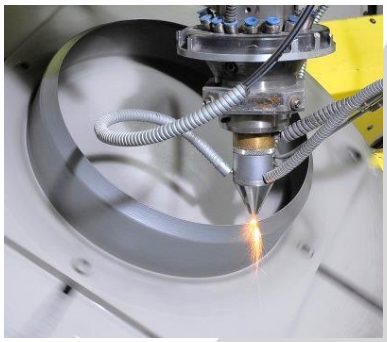
Summary

Additive manufacturing is a technology gaining multi-sectorial interest because of its increased design freedom and potential to reduce manufacturing cost and time.

Relatively little data are available pertaining to the properties and likely service performance of the materials in AM components and there is a need to generate such information to pave the way to compliance with regulations and Codes such as ASME, API and PED, thereby making AM components industrially acceptable.

The aim of this project is to investigate the route to compliance of 316L stainless steel deposited by the selective laser melting (SLM) and wire plus arc AM (WAAM) processes. A datasheet of material property data including microstructural characteristics, mechanical properties and corrosion resistance of 316L deposited by these AM processes will be produced to support the case for acceptance of 316L into Standards selected by the sponsor group.



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Project Concept

Additive manufacturing has previously been mainly limited to rapid prototyping and non-critical service components, where responsibility for acceptance lies with the end user. There is a desire to extend AM use to parts that are fit-for-use as final components so that the following benefits can be realised:

- Increased design freedom
- Reduced material cost (buy-to-use ratio improvement)
- Reduced lead time
- Security of supply (not reliant on single source)
- Manufacturing flexibility
- Manufacture of legacy spares
- Manufacture of plant and critical engineering structures
- Multi-material capability for functionally tailored properties

Typical AM test specimens made by arc welding using wire consumables

Currently the use of AM parts in critical applications is greatly restricted because they are not considered in most of the applicable Standards or any of the applicable Codes and regulations.

Incorporation of any material manufacturing method in the Codes and Standards relies on the demonstration that adequate material properties can be reliably obtained. Insufficient data exist for inclusion of AM in most industrial Codes at this time. In common with other organisations, including the classification societies, TWI has recognised this barrier and has for some time been gathering and generating data for AM of materials commonly used in plants and mechanical equipment.

Baseline AM properties in several materials including X-65 equivalent steel, 316 type stainless steel, nickel alloys 625, 718 and others, Ti-6Al-4V and several aluminium alloys have been generated in TWI Core Research Projects. These have highlighted that AM materials have unexpected microstructures when compared to the same alloys manufactured by traditional methods with subsequent levels of performance such as high fracture toughness, whilst other characteristics need further investigation.

This project will develop a datasheet of material properties for 316L stainless steel deposited by the SLM and WAAM processes. This material datasheet will provide a comparison between materials deposited by each AM process and will be used to engage with Standards bodies selected by the sponsor group with a view to achieving acceptance of 316L deposited by AM.

Objectives

The objectives of this project are to support the acceptance of 316L stainless steel, produced by the WAAM and SLM processes, into existing materials' Standards or to identify the critical parameters needed to define new AM materials' Standards. The project will examine the Codes and Standards selected by the Sponsor Group:

- To investigate the methodology for potential acceptance of WAAM and SLM deposited 316L and begin the process of introducing AM to the relevant regulatory bodies.
- To generate specific material data including comparative microstructures, tensile, fracture toughness and corrosion properties for 316L deposits produced by each process.
- To provide guidance for the introduction of AM technology into manufacturing.

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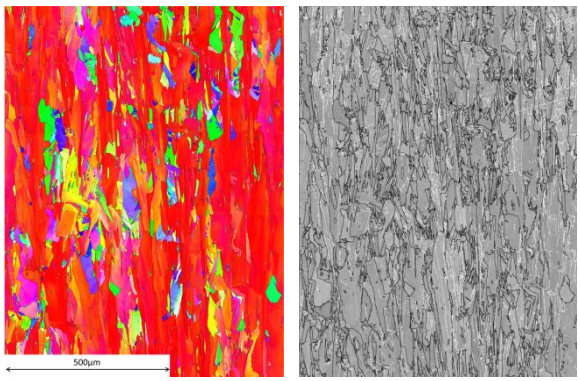
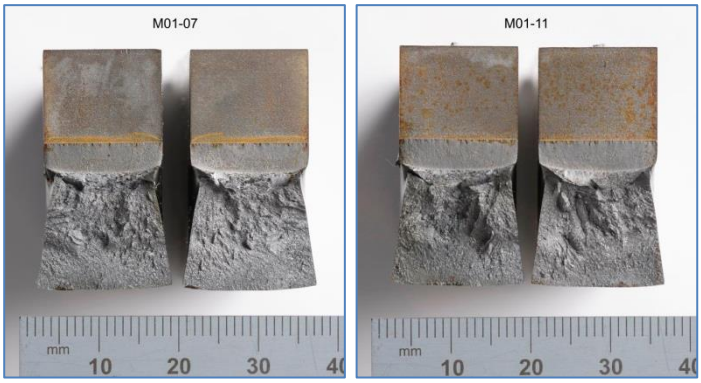
Benefits

Sponsors of this project will:

- Gain an appreciation of the scope of existing Codes and Standards when considering AM methods.
- Understand the relationship between processing method, microstructure, quality and properties of AM materials, providing confidence in design and manufacture.
- Obtain data supporting the industrial exploitation of AM products in critical and non-critical applications.



AM Inconel 718 EBSD and micrograph



X-65 equivalent AM Fracture toughness test coupons

Approach

This project will comprise several tasks:

- Review of an industry relevant Code or Standard selected by each project sponsor to identify a 'path to acceptance' for AM material.
- Design and manufacture of appropriate test pieces using the WAAM and SLM processes suitable for generating relevant material property data.
- Conduct a materials testing programme to evaluate the properties of 316L stainless steel deposited by AM including fracture toughness and corrosion resistance of AM deposits.
- Microstructural evaluation including crystallographic texture analysis of AM deposits.
- Chemical analysis including bulk and local chemical compositions and heterogeneity.
- Measurement of physical and mechanical properties accounting for anisotropy and environment.
- Producing a 'gap analysis' detailing any additional requirements/activities for AM material to comply with the selected Standards.

Project Organisation Roles

TWI's role in the JIP is to lead the additive manufacturing element of the project. TWI has been involved in the development of AM technologies for a number of years. This has included process development and materials characterisation, testing and inspection. TWI has experienced staff available to support the project in both project management and delivery of results.

Lloyd's Register's (LR's) role in the JIP is to act as an independent third-party inspection organisation, providing validation and (conditional) certification of the intended design, materials, facilities and manufacturing method. LR's experience in certifying products to many global Codes and regulations will ensure appropriate and necessary steps are taken to work towards compliance to the Standards of an independent, third-party certification body. LR will share its knowledge and expertise in a wide variety of disciplines from design and

metallurgy through to final inspection in an impartial manner, providing a grounded and real-world focus on safety, quality and compliance.

LR has also been researching and developing audit and assurance products and services for additive manufacturing across a number of industries over the past 18 months, including our global launch of goal-based certification guidance notes and our collaboration with TWI, Rolls Royce Nuclear, ENGIE Lab-Laborelec and Suzhou Nuclear Research Institute in a previous Joint Industry Project.

LR has representation on several working groups and conduits to formal Standards organisations, including ISO TC/261 (Standardization in the field of AM) and ASME Y14.46 (Product Definition for AM) and the EU PED Conformity Assessments Body Forum (CABF). Furthermore, LR is funding PhD research in specific areas of Additive Manufacturing and also supports the work of the UK National Strategy Group for AM.

TWI and LR are collaborating with the aim of enhancing the knowledge and adoption of AM within key industries. We have connections to the various parts of the additive manufacturing community, supporting and contributing our expertise and knowledge to help clients better understand and utilise this technology.

Deliverables

The main deliverables of the project are:

- Material datasheet for AM deposited 316L including comparisons between microstructures, fracture toughness and corrosion performance of 316L deposited by the SLM and WAAM processes.
- Gap analysis for the acceptance of AM materials to Codes and Standards selected by the Sponsor Group.
- Recommendation on methods for inspection of AM parts.
- Guidance for introduction of AM technology into manufacturing.

Participants

- AECC BIAM
- AVIC MTI
- Chevron
- Sellafield

Price and Duration

The overall estimated price for the work is £360,000 (excluding VAT), which requires £60,000 per company from each of the six Sponsors. Further Sponsors are sought in addition to those listed above.

Further Information

For further information on how a Joint Industry Project (JIP) runs please visit:

http://www.twi-global.com/services/research-and-consultancy/joint-industry-projects/

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