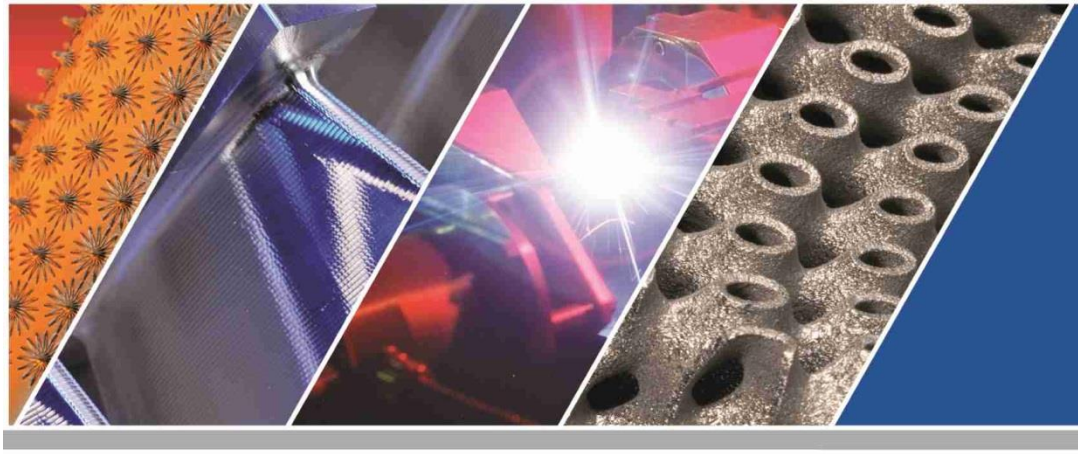
Improving and Industrialising Cold Spray Repair



JOINT INDUSTRY PROJECT OUTLINE

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Summary

Current repair technology

Many components are retired from service due to relatively minor damage resulting from corrosion, wear or foreign object damage. Implementing a reliable, repeatable, cost effective repair strategy putting components back into service could result in significant cost savings by eliminating the need to install new parts, thereby reducing the need for holding stock or taking platforms out of service while new components are manufactured. Repair also reduces the embodied energy and CO2 emissions associated with replacing parts with newly build.

Current fusion/weld-based repairs of metallic components add significant heat input into the material, which alters the underlying microstructure, often leading to unacceptable degradation to mechanical properties. Weld-based repairs can also be challenging for highly oxygen sensitive materials, such as aluminium, magnesium and titanium, and require inert environments which may be impractical. Weld-based repairs also result in residual stresses, which can lead to unacceptable part distortions or that degrade the fatigue life of the part.

Parts can also be repaired using polymer fillers (such as epoxy), which only provides limited mechanical properties and restrict the lifetime of the repair. The upper temperature limit of such repair is also significantly constrained.

Cold spray repair

Cold spray is a solid-state deposition technology that results in little to no heat input to the component, thereby retaining the original mechanical properties in the parent material. Oxygen-sensitive materials can be processed without the need for inert conditions and the resulting deposition generally results in compressive residual stresses that do not degrade the fatigue life of the component. Process variants exist that mean the process is highly flexible, allowing a range of different materials to be deposited at high rate across a range of cost-quality measures.

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Project Concept

Innovation and Industrialisation

While cold spray repair technology has been successfully implemented for some applications across a range of industry sectors, limitations still persist that prevent widespread adoption. Due to the nature of the deposition mechanism, mechanical properties (ductility in particular) can be limited and few comprehensive datasets exist that document performance as a function of spray conditions. In addition to the lack of independent performance data, few frameworks, guidelines or standards are available to support design engineers to implement such repairs on components where it could offer great benefit.

This Joint Industry Project aims to support member companies adopt cold spray technology across a range of technology/manufacturing readiness levels (TRL/MRL). Activities have been designed to enable cold spray to be rapidly adopted for dimensional/cosmetic repairs, while building the body of evidence needed to support more demanding applications. Finally novel developments will be explored that aim to push the boundaries of what can be achieved with cold spray.

Objectives

This Joint Industry Project aims to support TWI members in implementing cold spray as a repair technology by:

- Developing new approaches to cold spray to improve deposit performance and allow a broader range of materials to be sprayed;
- Generating independent data on the performance of cold spray deposits to aid users in the development of safety cases and future certification;
- Developing guidelines to support the implementation of cold spray, allowing sponsors to better understand potential benefits, limitations and costs.

Example of manual, low pressure cold spray being performed.

Benefits

By participating in this project, TWI members will have access to:

- The latest techniques for improving the properties of cold spray deposits, increasing the number of potential candidate repairs that could be considered and/or increasing the performance and lifetime of repaired components;
- Tools to monitor and control the cold spray process, allowing greater confidence in the quality and repeatability of repairs that can be achieved;
- Independent datasets on the performance of cold spray repairs that allow informed decision making and support future verification/qualification/certification activities for potential cold spray repairs;
- Repair frameworks, guideline documents, proven QA and NDE techniques that reduce the cost burden and accelerate the ability to adopt cold spray within a commercial environment.

Track Record

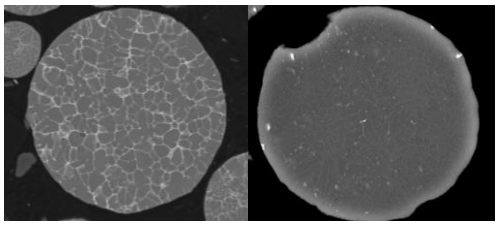
TWI have been active in cold spray research since 2007, running research and development projects for industrial members and leading large-scale programmes of work for government organisations. As an active member of the global cold spray community, TWI have pioneered new developments on powder modification and hybrid laser processes. In the past 2 years, TWI have invested heavily in new cold spray equipment (>£1.5m) and have access to world class facilities, including our newly commissioned TKF-1000. TWI has experts with deep technical knowledge and a broad understanding of the benefits and limitations that cold spray can bring to repair and remanufacture.

Approach

WP1: Process Developments (low TRL)

This work package will explore methods for improving the properties of cold spray deposits and will include:

- Powder modification. Feedstock powders are manufactured by gas atomisation and result in non-equilibrium microstructures. Heat treatments will be explored to improve deposit properties. New powder blends will also be explored to determine if enhanced performance can be achieved.
- Process modification and control. Hybrid laser processing will be explored to determine if in-line heating can be used to recover/recrystallize microstructures, without affecting underlying parent metal. Understand if diagnostic/process monitoring tools can increase process quality and repeatability.



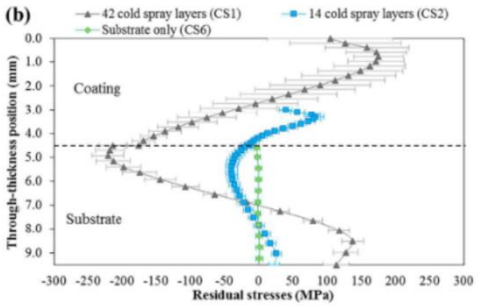
Example of microstructural changes to powder due to heat treatment.

- Pre and post treatment. Understand if new approaches to surface preparation can enhance bonding, if local heat treatment can enhance ductility, or if coatings can be successfully anodised or conversion coated.

WP2: Performance Data (mid TRL)

This work package will generate data on cold spray deposits to support structural design and certification activities. Data will allow sponsors to build specific safety cases for particular materials/applications. It seeks to:

- Understand the limits of spray conditions (temperature, pressure, angle, gas composition, etc) and the effect on performance. In an attempt to be agnostic to the cold spray system, properties will be correlated with particle velocity measurements.
- Understand the evolution of residual stress during deposition using in-line monitoring techniques and post deposition analysis.
- Compare mechanical properties (tensile, fatigue, fracture) for different coupon geometries.
- Explore performance differences between manual and mechanised application to estimate potential knock-down factors which may need to be applied.



Example of residual stress evaluation of cold spray in Ti-6Al-4V

- Generate detailed performance data for selected spray conditions.

WP3: Cold Spray Guidelines (High TRL)

This work package will support the implementation of cold spray within a practical environment by:

- Creating repair frameworks allowing members to categorise repair situations and select the most appropriate cold spray process (if applicable);
- Developing template repair instructions that can be adapted by member companies to fit their specific needs;
- Exploring applicability of destructive and non-destructive examination methodologies to support quality assurance procedures;
- Developing best practice guidelines;

TWI will aim to engage with certification bodies (e.g. EASA/CAA/FAA/MAA) and seek feedback on documentation to ensure harmonisation with existing and future repair standards.

Deliverables

- Technical report on the use of novel process developments to improve cold spray deposit performance.
- Technical report on the performance of cold spray deposits, including access to raw datasets on detailed performance for selected spray conditions.
- Example documentation pack to support the adoption of cold spray, including:
  - Repair framework
  - Template repair instruction
  - Best practice guidelines

Price and Duration

The overall estimated price for the work is £750,000 (excluding VAT), which requires £75,000 per company per annum for 2 years (£150,000 total) from each of the five (5) Sponsors. It is anticipated that the project will commence with an agreed scope of work with a minimum of two (2) Sponsors.

TWI welcome feedback from potential sponsors on the scope of work and budgeted costs and will seek to tailor the final proposal to maximise value for TWI members.

Further Information

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

https://www.twi-global.com/what-we-do/research-and-technology/current-research-programmes/joint-industry-projects#/

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