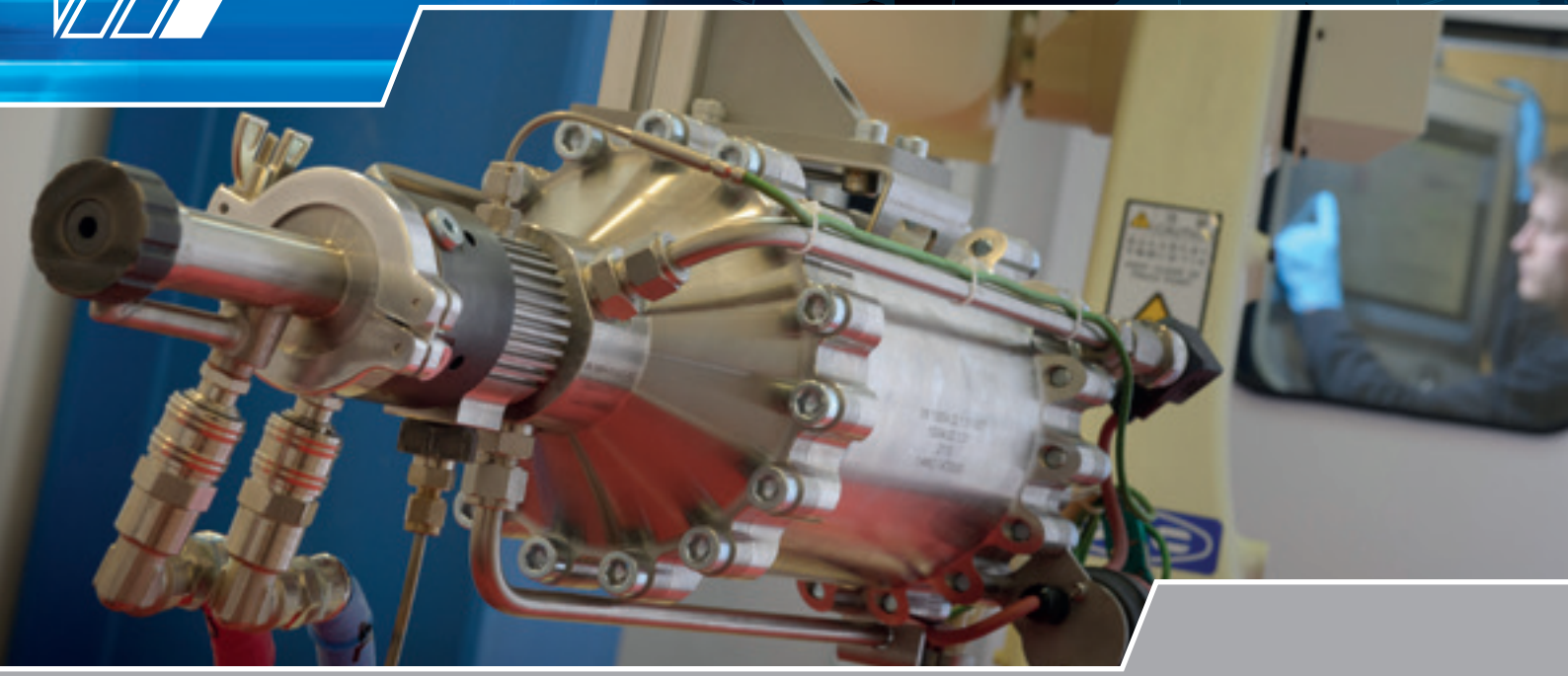

Cold Spray Technology

Cold spray is a solid state process by which a fine powder is projected at high velocity by a carrier gas onto a substrate surface, to build up a coating or a near net shape free-form deposit. The powder particles deform on impact and bond with the surface, in a mechanism similar to explosion welding. Usually, both the powder and the substrate are metals, but this is not always the case. The main applications of cold spray include:

- functional coatings,
- cosmetic/dimensional repairs,
- load-bearing/structural repairs of high-value components,
- near net shape additive manufacturing.

The main advantages of cold spray include

- No heat affected zone (HAZ) in the coated substrate; unweldable materials can be repaired/coated.
- The powder consumable is at a low temperature relative to its melting point; oxygen-sensitive materials can be deposited under ambient conditions without significant O_2 or N_2 pickup.
- In many cases, very thick layers (several mm or cm) can be built up.
- Cold spray systems can generally be divided into 'low pressure' and 'high pressure' systems, the main difference being the injection point of the powder (pre or post nozzle throat).
- Both portable and fixed cold spray systems are available, but at the current time their capabilities differ.

Cold spray formed Ti-6Al-4V half shells made as part of a recent TWI funded research project

Confidential project work for industrial clients

Since 2010, TWI has completed over 40 individual cold spray projects for some 30 TWI Industrial Member companies in sectors as diverse as oil and gas, renewable energy, aerospace and medical implants.

More than half of these projects have been for the aerospace and defence industries and have involved cold spray deposition of materials of interest to these sectors, including Al, Ti and Ni alloys.

Core Research Projects

TWI's Industrial Members have exclusive access to the Members' Reports of the following cold spray research work to the value of over £600k which has been funded by TWI Industrial Members:

CRP Report Title	Report Number
A new approach to structural cold spray repair of Ti-6Al-4V components	To be published 2019
Structural cold spray repair using thermally treated precipitation hardenable Al alloy powders	To be published 2019
A new epoxy-free adhesion test method for cold spray coatings	To be published 2019
Assessment of Cold Spray Systems for the Deposition of Nickel Alloy 718 Coatings	1063/2015
Corrosion Behaviour of Cold Sprayed Tantalum coatings	1016/2012
Preliminary evaluation of spray-formed Ti and Ti coatings prepared by cold spray	0995/2011
Cold spray technology update and TWI facility installation	0947/2010
Preliminary evaluation of metallic coatings deposited using the cold spray process	0787/2004

Industry sector case studies

Recently, TWI was a key partner in Europe's largest collaborative cold spray project, CORSAIR. This 3½ year, €4m project significantly advanced the understanding of cold spray deposition of structural Al alloys as well as Ti-6Al-4V for aeronautical component repairs.

TWI was also a key partner in the COLA (http://www.cola-project.eu/) project working on laser-assisted cold spray. TWI is still active in this area and has developed a laser-assisted cold spray and has subsequently developed a new laser-assisted cold spray capability in Cambridge.

In late 2017, TWI started work on a 2½ year Innovate UK-funded collaborative project with two UK-based SMEs. The aim of the project is to establish a European supply chain for proprietary thermally treated Al alloy powders. A small-scale powder heat treatment capability is also being established at TWI as part of this project. The work is expected to facilitate industrial uptake of structural cold spray repairs of high strength Al alloys.

Cold spray equipment

TWI owns two cold spray systems and has invested in a large-scale spray booth so that coatings development work can extend to prototype component scale. These systems include:

- A state-of-the-art Impact 5/11 system with maximum pressure/temperature capability of 50-60 bar and 1000-1100°C, commissioned in December 2015
- A CGT Kinetiks 4000/47 system with maximum pressure/temperature capability of 40 bar and 800°C, commissioned in 2007

Our large scale thermal and cold spraying facility factsheet is available as a PDF download from our website, www.twi-global.com/capabilities/equipment-directory/

Cold spray training

TWI offers bespoke cold spray training. Presented over two days, the course is intended for materials and design engineers who are considering the use of cold spray as a coating, repair or additive manufacturing technology. Course attendees will gain a detailed appreciation of where cold spray fits into the wider field of thermal spray technology, surface engineering and coating processes.

Please contact us for more information.

Industrial mentoring and sponsorship of PhD students

TWI currently sponsors three PhD students through TWI's National Structural Integrity Research Centre (NSIRC). They are working on the following cold spray related topics:

- Cold Spray Deposition of Precipitation-Hardenable Aluminium Alloys for Structural Repairs
- Cold Spray Additive Manufacturing
- Fatigue and Fracture Properties of Cold Spray Additive Manufactured Materials

Intellectual property

TWI holds intellectual property in-house relating to methods for evaluating coatings during cold spray parameter development, methods for handling of oxygen-sensitive powders and the heat treatment of powders.

Selected papers and publications (TWI authors are in bold)

Sabard A., **de Villiers Lovelock H. L., McNutt P., Harvey M.D.F.H.** and Hussain T., 2017, Solution heat treatment of gas atomized aluminium alloy (7075) powders: microstructural changes and resultant mechanical properties (presented at ITSC2017, Düsseldorf, June 2017 and invited to be expanded into a paper for JTST in 2017)

Harvey, D., McNutt P., Barnett, R., de Villiers Lovelock H.L. et al. 2017 Characterisation and testing of Cold Spray deposited Ti-6Al-4V and Al alloy C355; presented at AeroMat 2017, Charleston, South Carolina, USA, April 2017

Peat, T., Galloway, A., Toumpis, A., **McNutt, P.** and Iqbal, N., 2017. The erosion performance of cold spray deposited metal matrix composite coatings with subsequent friction stir processing. Applied Surface Science, 396, pp.1635-1648.

Peat, T., Galloway, A., Toumpis, A., **McNutt, P.** and Iqbal, N., 2017. The erosion performance of particle reinforced metal matrix composite coatings produced by co-deposition cold gas dynamic spraying. Applied Surface Science, 396, pp.1623-1634.

Peat, T., Galloway, A., Toumpis, A., **McNutt, P.** and Iqbal, N., 2016, August. Cold gas dynamic spraying of metal matrix composite coatings with subsequent friction stir processing. In 11th International Symposium on Friction Stir Welding (pp. 1-15).

P. Sirvent, M. A. Garrido, C. J. Múnez, P. Poza, **A. Cazacu, R. Barnett, H.L. de Villiers Lovelock**, 2016, Effect of Powder Geometry on the Mechanical Performance of Cold Sprayed Ti-6Al-4V Coatings; XXX International Conference on Surface Modification Technologies (SMT30), 29th June – 1st July, 2016, Milan, Italy.

Allen C.M., Marrocco T., McNutt P., et al. 2015 A Novel Coaxially Laser-Assisted (COLA) Cold Spray System; presented at ITSC 2015, Long Beach CA, 11-14 May 2015

Marrocco T., McNutt P., Barnett, R., and de Villiers Lovelock H.L. et al. 2015 Evaluation of powder properties on the performance of cold sprayed Ti6Al4V for aerospace repairs; presented at AeroMat 2015, Long Beach CA, 11-14 May 2015

Barnett R., Harvey M.D.F., McNutt P. and de Villiers Lovelock H.L.: 2015, Variation in Nickel Alloy 718 coating properties deposited using a variety of cold spray systems and spray conditions, 10th Colloquium on High Velocity Oxy-Fuel Flame Spraying, publ. DVS Germany, October 2015

Cazacu A., Barnett R., McNutt, P. and de Villiers Lovelock H.L., 2015 Characterisation of Ti-6Al-4V cold sprayed coatings for aeronautical repairs: effect of powder feedstock properties, process parameters and surface preparation; 5th International workshop on Aerostructures, Manchester, 2-4 Sept 2015

Barnett R., Marrocco T., McNutt P., Cazacu A. and de Villiers Lovelock H.L., 2015, Effect of Powder Feedstock Properties on Ti-6Al-4V cold sprayed coating characteristics; 4th International Conference of Engineering Against Failure (ICEAF IV); 24-26 June 2015, Skiathos, Greece

Harvey, D. and Marrocco, T., 2012. The Potential of the Cold Spray Process for the Repair and Manufacture of Aluminium Alloy Parts. In ICAA13 Pittsburgh (pp. 257-263). Springer, Cham.

Marrocco, T. and Harvey, D., 2012. Cold standard. Materials World, 20(9), pp.30-31.

Hussain, T., McCartney, D.G., Shipway, P.H. and **Marrocco, T.**, 2011. Corrosion behavior of cold sprayed titanium coatings and free standing deposits. Journal of Thermal Spray Technology, 20(1-2), pp.260-274.

Marrocco, T., Hussain, T., McCartney, D.G. and Shipway, P.H., 2011. Corrosion performance of laser post-treated cold sprayed titanium coatings. Journal of Thermal Spray Technology, 20(4), p.909.