Cold Spray - Improved Corrosion and Wear Resistant Coatings by Cold Spray

PUBLISHABLE SUMMARY

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Background

With the high price of corrosion and wear resistant alloys in bulk form, there are major financial incentives to use coated, lower cost substrates. However, despite much research effort and many application development studies, corrosion resistant alloy (CRA) coatings, e.g. Ni alloy 625, prepared by thermal spraying still provide greatly inferior corrosion resistance when compared to parent material of the same composition. Even the most advanced thermal spray processes, such as high velocity oxy-fuel (HVOF) and plasma spraying, produce coatings with interconnecting pathways (due to the presence of micro-scale porosity and oxides); hence substrate attack by corrosive media is usually inevitable. However, the recent development of cold spray technology has made possible the deposition of virtually pore-free and oxide-free metallic coatings. The process involves the acceleration of fine powders to 500-1000$m.s^{-1}$ in a supersonic inert gas jet. On impact with the target surface, the solid particles experience very rapid deformation, forming a bond with the substrate and each other to produce a very dense and strong coating.

To date, published articles have related to demonstration of the concept, equipment development and process modelling using ductile metals e.g. Cu. Published data on corrosion and wear resistance are very limited, and data pertaining to cold spray deposit cohesive strength are limited to a few basic metals e.g. Cu and Ni. Data are needed for more useful engineering materials, e.g. corrosion resistant metals and alloys and metal-bonded carbide, so that cold spray can be validated for applications such as corrosion resistant vessels, hard-facing, spray-forming and additive manufacturing. There is, also, little understanding of the relationship between cold spray particle flight characteristics and coating properties, and no published process economic data. It is the aim of this project, therefore, to address these technology gaps.

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Objectives

- To demonstrate the feasibility of preparing corrosion barrier coatings by cold spray, hitherto not possible by conventional thermal spray processes.
- To demonstrate the feasibility of preparing hard-facing coatings by cold spray with wear properties superior to conventional thermal spray coatings.
- To demonstrate that high price corrosion or wear resistant bulk alloys can be replaced by cold spray coated, low cost substrates.
- To determine the mechanical strength of selected cold spray deposits with a view to use for spray-form manufacturing and component repair.
- To define applications where cold spray systems offer the greatest technical and economic benefits.

Project Outcome

- Quarterly e-mail progress reports.
- Progress report at 6 months
- Test coupons for Sponsor testing and evaluation.
- Final report including:
    - Feasibility of spraying selected coatings including process and materials-related issues such as powder feedability, spray particle size distribution.
    - Coating characteristics and corrosion, wear and mechanical properties.
    - Cold Spray process procedures and process cost analysis.
    - An outline of potential applications offering the greatest technical and economic benefits.

Benefits

It is claimed that various features of the Cold Spray process and coatings result in significant benefits for manufacturing and repair that cannot be achieved with conventional, thermal sprayed coatings. These include:

- Lower porosity (<0.5%)
    - superior corrosion resistance
    - replacement of high price CRA substrates with cheaper, CRA-coated substrates
- High substrate adhesion & inter-particle cohesion
    - high mechanical strength
    - fit for spray-form manufacturing & component repair
- Very high deposition efficiencies up to > 90% with a mechanised system
    - reduced manufacturing costs & increased productivity
- Wear resistance 3x better than HVOF WCCo
    - thinner coatings and / or increased component life
- Unlike thermal spray systems, no ignition source (arc or flame)
    - portable system safe for on-site use

Participants

- AREVA NP SAS
- Bodycote (Uk) Limited
- Linde AG/Linde Gas Divn
- Lockheed Martin Aeronautics Company
- Messier-Dowty Ltd
- Powdermet Inc
- Rolls-Royce plc

Scope of Work

Eight materials were selected for examination during Phase 1 of this study; aluminium, nickel, titanium, nickel alloy 625, nickel alloy 690, tungsten carbide–cobalt (WC-Co), chromium carbide (NiCr-Cr3-C2) and Stellite 6TM. For some of these materials, more than one supplier or size range was investigated, resulting in 12 powders being trialled.

All the development trial coatings were deposited onto carbon steel (EN32) substrates. For the final deposition runs some of the coatings were also deposited onto stainless steel (316) substrates to ascertain if substrate composition influenced bond strength. In the case of the alloy 690 deposits, alloy 600 substrates provided by AREVA were also used.

It was decided that initially, all the substrates were to be sprayed in the as-machined condition to provide a direct comparison between spraying characteristics. For certain materials, the deposition characteristics were such that it was not possible to build a coating on the as-machined substrates. In these cases the substrate was grit blasted to provide mechanical keying for a coating to build on.

All trials carried out at TWI used the CGT Kinetiks 4000/47 cold spray system. The system is capable of spraying at gas pressures and temperatures of up to 40bar and 800°C respectively. In all cases, the coatings were deposited using oxygen free nitrogen (OFN = <5ppm O_2, <8ppm H_2O). Phase 1 characterisation was carried out to the programme presented in the table:

Scope of Work Continued

Phase 1 Characterisation and testing conducted by TWI

Cold spray system	Coating	Characterisation and testing method				
		Micro-structure, hardness, deposit efficiency	O_2 content	Adhesion testing	QA salt spray test	Plastic strain bend test (1, 2, 3% strain)ø
Kinetiks 4000/47	Ni 625	✓	✓	✓	✓	
	Ni	✓	✓	✓	✓	✓
	Ni 690	✓	✓	✓	✓	✓
	Al	✓	✓	✓	✓	
	Ti	✓	✓	✓	✓	
	WC-Co	✓	✓	✓	✓	✓
	$NiCr-Cr_3C_2$	✓	✓	✓	✓	✓
	Stellite 6	✓	✓	✓	✓	
Estimated total number of test coupons		16	16	24	16	8

Bodycote conducted a limited series of trials to demonstrate the feasibility of preparing a selection of coatings using the Kinetiks 3000 cold spray system. This allowed the relative performance of the 1st and 2nd generation cold spray systems to be benchmarked.

Price and Duration

The project had a duration of 1 year and a budget of £140,000. It was funded by 7 sponsors each making a contribution of £20,000.

Further Information

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

http://www.twi.co.uk/services/research-and-consultancy/joint-industry-projects/

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