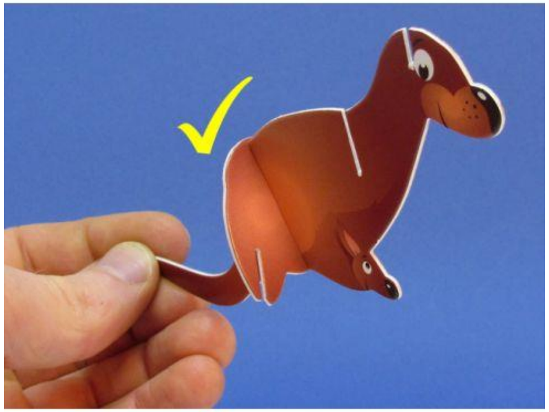



CSAT 24 June 20

COLD SPRAY IMPLEMENTATION AT RUAG


Neil Matthews
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Senior Manager Advanced Technologies

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Additive Manufacture – *Changing Nature of Sustainment*

ADDITIVE METAL TECHNOLOGIES (AMT)

SPD/COLD SPRAY (CS) ACTIVITY

MANUFACTURE

Net Shape/3D

- Ad Hoc Proof of Concept

SUSTAINMENT

Technology to the Target

- **Brolga # 1**
- **VRC Agreement**
- Other Trials

Repairs/ Enhancement

- **Released Repairs**
- **Post Heat Treat**
- **SI Evaluation**
- Proof of Concept Commercial and Defence

SURFACE APPLICATIONS

Coating

- **Coating Repair**
- **Coating Replacement**

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Surface Applications - Coating Alternative (1 of 2)

PROJECT OVERVIEW

- *The Loyal Wingman is the first in-country designed-and-built aircraft for over 60 years.*
- Loyal Wingman project, which will see three prototype autonomous aircraft (Airpower Teaming Systems, or ATS). The plan is for the ATS to accompany manned aircraft and supplement their capabilities using a variety of different payloads and possibly weapons systems

- *A combination of surface profiles require SPD application (i.e. outer diameters of varying sizes and lengths, flat surface perpendicular to shaft on Al part)*
- *SPD is to be applied to approximately 60 components across the 3 prototype shipsets.*

OBJECTIVES

- *To apply SPD Tungsten Carbide Coating to stainless steel and aluminium Loyal Wingman Landing Gear components in lieu of HVOF coating (protective wear surface).*

■ COATING SELECTION & VALIDATION

- SPD system modified to be capable of deposition
- Tested for
  - Hardness
  - Residual Stress
  - Corrosion Resistances
  - Porosity
  - Bond strength
  - Wear Resistance
  - Surface Defects
  - Interface /coherent defects

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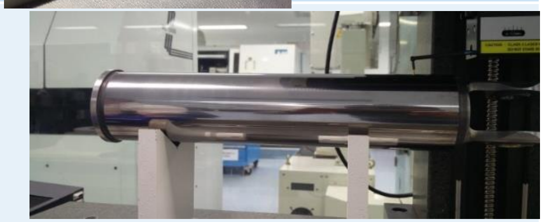
Surface Applications - Coating Repair (2 of 2)

PROJECT Status

- *- 4 MLG Part Numbers and 7 NLG Part Numbers with SPD have been delivered*

  - Both MLG and NLG (with spin up have successfully passed Drop test)

Item Name	Dia/Lgth (Ins)	Material	
MLG Pin	1.49/5.65	SS	 
MLG Piston	2.74/ 12.5	SS	 
NLG Pin	1.24/ 1.75	SS	 
NLG Piston	2.74/13.7 4	SS	 

Other substrate materials Aluminium alloy, steel and Nickel alloy

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Surface Applications - Coating Repair (1 of 2)

PROJECT OVERVIEW

- Explore the opportunity to use SPD as not only an alternate to existing aerospace immersion chemical coatings but as a repair to existing aerospace immersion chemical coatings.
- These current coatings by nature of their process are recognised as both potentially hazardous environmental and health safety risks. One of these processes known as electroless nickel (EN) provides extremely effective wear and corrosion protection. There are no current localised repairs for this coating. Repair of components with damaged EN coating in accordance with authorise maintenance process requires existing coating removal and full re-plating.
- The EN process is employed on several Australian defence aircraft including the F/A-18 Hornet. This aircraft uses EN on flight control and landing gear components.

OBJECTIVES

- To develop a localised SPD repair process for damaged EN coatings.

COATING SELECTION & VALIDATION

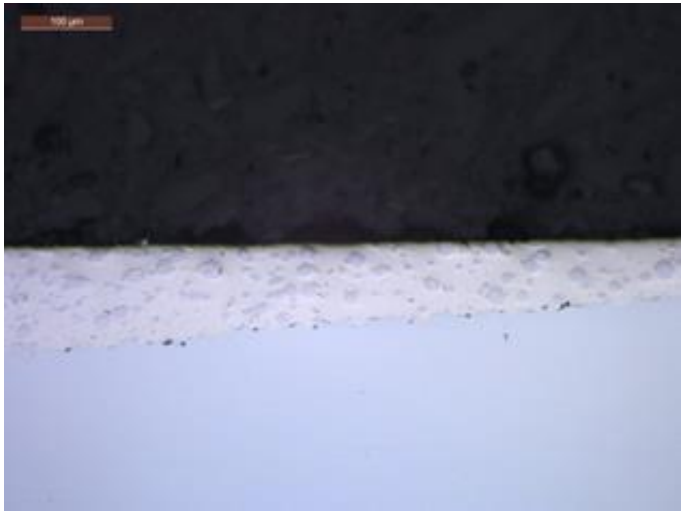
- A number of Nickel and Nickel based alloy powders were experimented with. These included Pure Nickel, Nickel/Aluminium Oxide, Nickel/Silicon Carbide, Nickel Chrome/Chrome Carbide. the Nickel Chrome/Chrome Carbide powder alloy was selected. The following tests/validations were performed
- Mircosection analysis the SPD coating and the interface
- Salt spray testing to assess the corrosion resistance of the SPD coating
- Adhesion Testing
- In addition, significant experimentation was conducted on the integration of the SPD Ni alloy into the existing EN coating.,

Surface Applications - Coating Repair (2 of 2)

OUTCOMES

- The SPD NiCr-/CrC demonstrated acceptable wear resistance and hardness properties that were better than /equivalent to the existing EN coatings
- The SPD NiCr-/CrC demonstrated acceptable corrosion resistance properties performance with no indication that there were any “dissimilar metal” issues between the SPD and the EN coating.
- The SPD was compact with no observed porosity.
- The SPD was well adhered to the EN coating
- Trial repairs confirmed the hypothesised potential that SPD technology using an optimised SPD nickel blend powder could provide a viable and very effective solution for localised damaged/pitted EN coatings.

(a)



(b)

Ni blend SPD coating at EN-Nickel and 4340 substrate transition area (a) and to 4340 (b) after grinding

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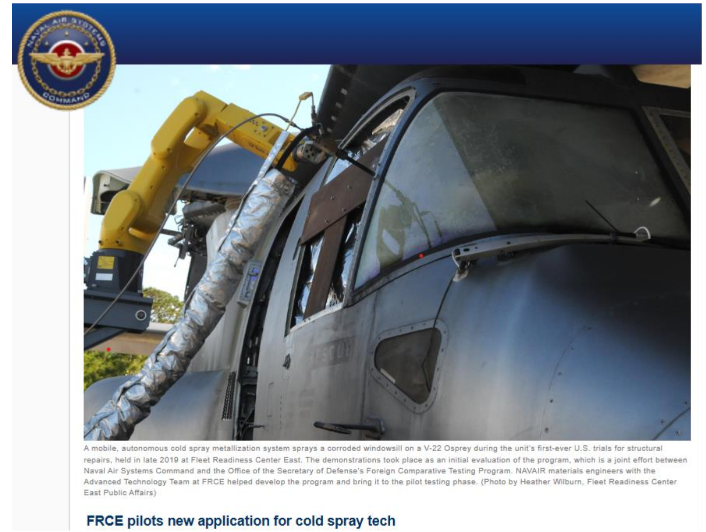
Technology to the Target

RUAG/VRC Mobile System (Brolga #1) Trials

- May'19: Unit No 1 successfully trialed by USN with VRC Metal Systems support at Hawaii Oct '19:
- Oct 2019 - Completed trials @ USN Fleet Readiness Centre East (FRCE). Demonstrated to Boeing for V-22 airframe repairs as part of the trials. {USN Feedback – "The Brolga did great". "OSD (program sponsor very pleased with the trials")
- Nov'19: Completed trials at the USN Fleet Readiness Centre Southeast (FRC-SE) in Jacksonville, FL. {USN feedback – "Demo went great. They want to keep the unit".



RUAG/VRC Mobile System (Brolga) Agreement

- RUAG Australia and VRC metal Systems have signed a teaming agreement to deliver optimized RUAG/VRC Mobile High-Pressure Supersonic Particle Deposition (SPD) /Cold Spray Deposition Repair Technology to the target

- The long term Agreement recognizes the expertise and knowledge of both organizations and that we have collaborated to successfully deliver a mobile trailer mounted robotic cold spray metallization system "the Brolga" incorporating both RUAG's mobile system technology and VRC's portable high pressure and hand sprayable system for that can provide SPD/Cold Spray additive repair technology to aircraft in the field.

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Post Deposition Heat Treatment (1 of 4)

PROJECT OVERVIEW

SPD is acknowledged as a kinetic energy transformation process which by the nature of this process tends to work harden the deposition and reduce its ductility when compared against the metal powder type material produced by conventional manufacture. Whilst in many applications this reduced ductility is not an impediment for a successful SPD repair outcome there is a desire if possible, to increase the ductility of the deposited material to better match the substrate material. This desire is particularly raised for aerospace structural aluminium such as 7000 series aluminium alloys

OBJECTIVES

To evaluate if in-situe heat treating SPD post deposition could increase the deposition ductility to the such that SPD /SPD substrate failures under high strain loading could be reduced or eliminated.

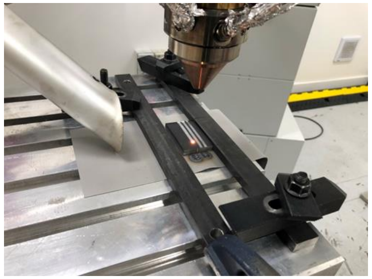
EXPERIMENTATION & TESTING

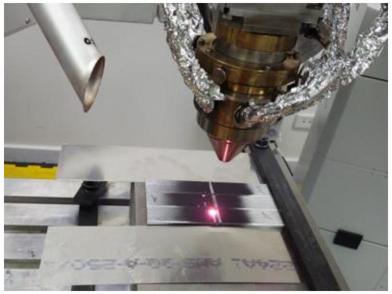
- ❖ Aluminium Alloy 7075 specimens were coated with 7075 SPD depositions and subsequently subjected to a range of laser post deposition heat treatments.
- ❖ The Laser source is a Laserline LDF 400-30 high-power diode laser. The treatment power was adjusted to 400W
- ❖ The laser heat treatment was performed at varying traverse speeds, ranging from 4mm/s to 19mm/s at intervals of 3mm/s.

Microstructure

Adhesion

Hardness





Tensile

Compression

Fatigue

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Post Deposition Heat Treatment (2 of 4)

- **SPD coating microstructure**
  - The applied SPD 7075 was a high quality, very compact coating. The porosity level was <0.1%
  - The laser treatment did not cause any change to the porosity

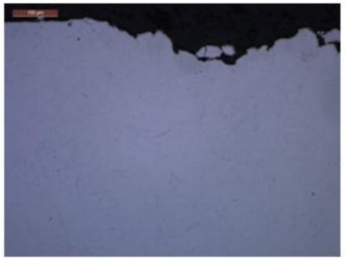

Figure 2a
SPD as sprayed

Figure 2b
Laser treatment at 4 mm/s

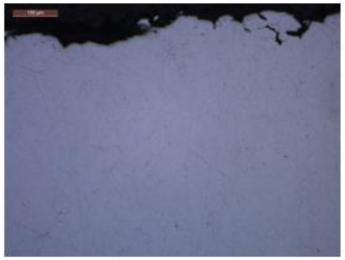

Figure 2c
Laser treatment 7 mm/s

- **SPD coating adhesion**
  - The as-sprayed coating tested to 25.64MPa with adhesive failure, and the laser treated coatings produced adhesion up to 28MPa (all samples were > 25.3MPa) also with adhesive failure.
  - These results indicated that laser treatment has no adverse effect to the bond strength

- **SPD/Substrate Hardness**
  - The test results revealed that laser treatment, regardless of traverse speed used, has softened the coating and substrate by about 10%. .

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Post Deposition Heat Treatment (3 of 4)

Tensile test on the laser treated specimens

- Stress-strain curve of the laser treated SPD 7075 on 7075-T7351 substrate shows very similar results to the non-heat treated samples
- The coating was closely monitored during the test. It was seen that coating does not crack in the elastic period. Both the applied and heat treated coating he coating started to crack after the material passed the yield point, at approximately 2.82% elongation.

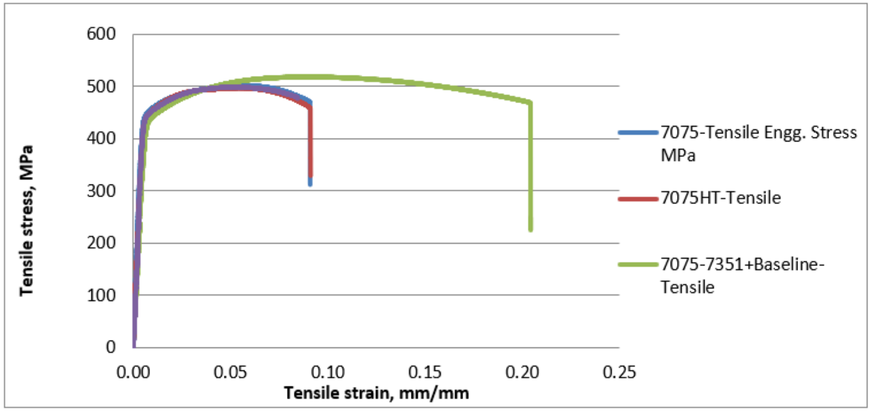

Figure 7: Average tensile stress/strain comparison to the as-sprayed and post-laser heat treated specimens

Compression test on the laser treated specimens

- All specimens (except first baseline specimen) retain integrity after compression test.
- No adverse effect of reduced hardness was evident.

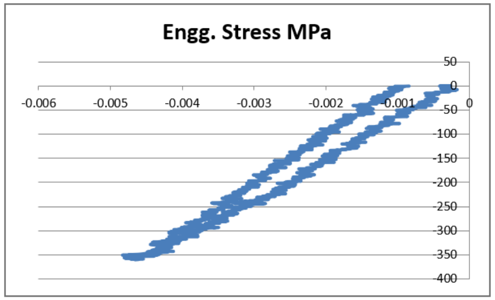

Figure 10b: Compression test curves of SPD 7075

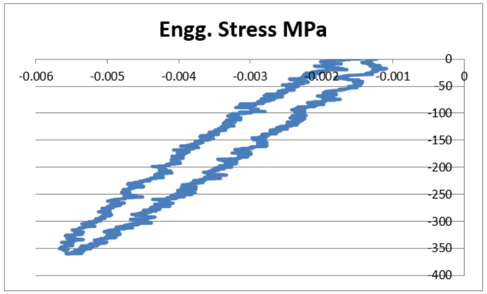

Figure 10c: Compression test curves of laser-treated coating

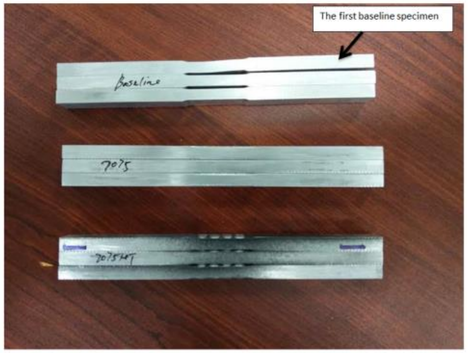

Figure 8: All specimens (except first baseline specimen) retain integrity after compression test.

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Post Deposition Heat Treatment (4 of 4)

OUTCOMES

- Heat treatment showed no adverse effect on the bond; overall, a slight increase in bond strength was observed. It is possible that when coating system was subjected to the temperatures experienced, an increased portion of metallic bonding occurred.

- The porosity of the coating was not affected by the laser treatment within the tested parameters.

- A reduction in hardness of the coating system was observed within the tested range. This indicated that laser can be used to anneal the coating, but accurately controlling the energy input is difficult.

- All SPD 7075 systems performed well during the tensile test, resulting in a yield strength increase of approximately 3%. The coatings remained intact during the elastic stage of tensile test, with crack initiation only commencing when elongation reached approximately 3%.

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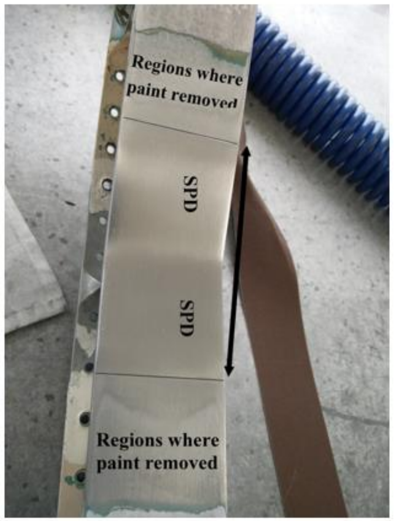
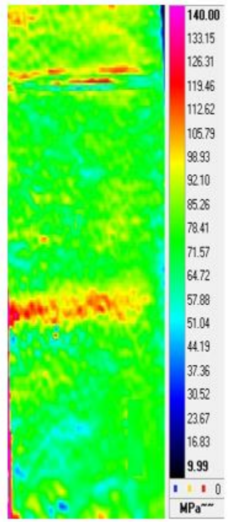
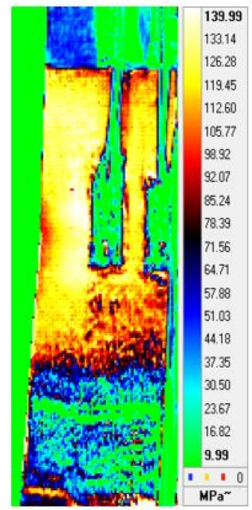
Future Quantifiable SI (Credits) _ F/A 18 Door Frame 68 *(RA/RAIA/Monash)*

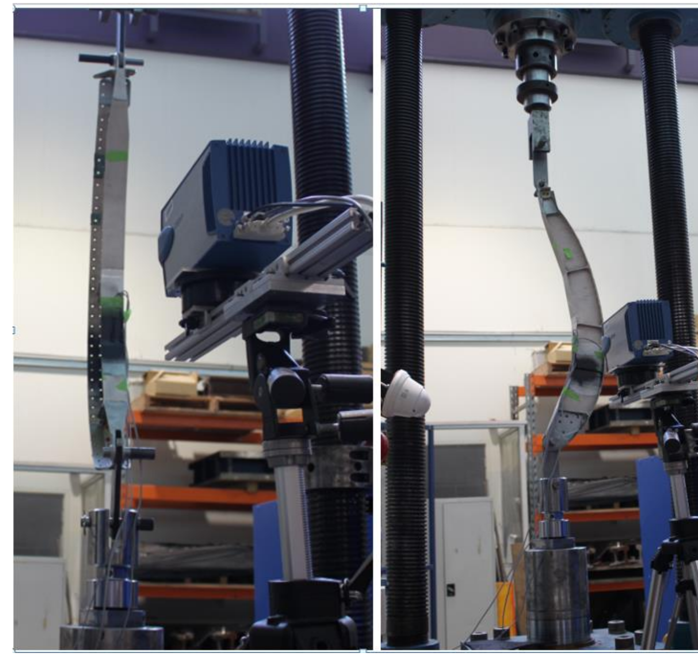


S P D





N o S P D



The resultant infrared thermography stress picture show approximately 16% reduction in the stress field at the critical location as a result of SPD Application.

Conduct fatigue life evaluation of SPD enhanced frame

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SI Crack Growth Behaviour and Predictability *(RAIA/Monash)*

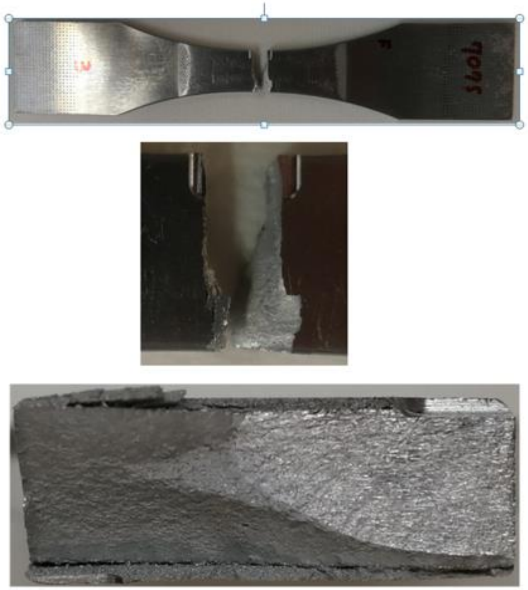

Figure 36 - *Failure in the specimen with a 7075 SPD application tested at the block loading spectrum*

For the 7075 SPD application under the cyclic fatigue loads spectrum, there is good agreement between the measured and predicted results.

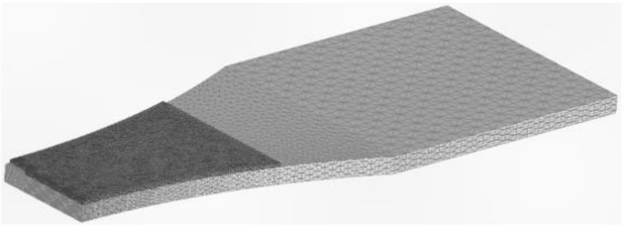

Figure 42 - *Mesh used in fatigue analysis*

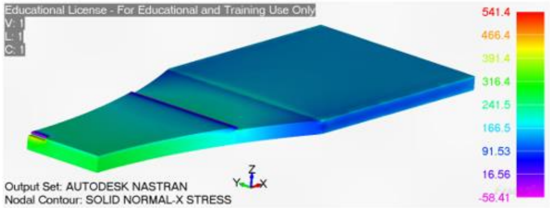

Figure 43- *Resultant normal-x stress for the case of notch length = 5 mm at a remote load of 30 kN*

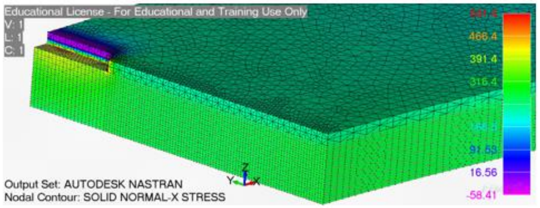

Figure 44 - *Local detail analysis for the case of a 5 mm long notch in the SPD*

QUESTIONS ?????