The effect of laser glazing on the microstructure and mechanical properties of cold sprayed alloy 718

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Objective

To develop a repair method for components composed of alloy 718 using cold spray

Introduction

Alloy 718

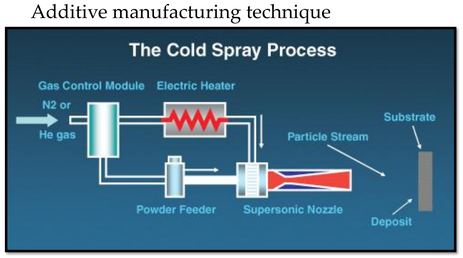
-Widely used in the aerospace industry

-Valued for high strength, low weight, and low creep rate

- Used at temperatures up to 700° C

Cold Spray

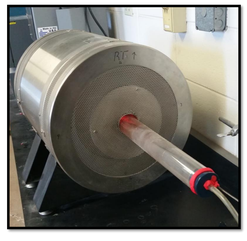
Additive manufacturing technique



Cold spray diagram. REF Army Research Lab website

Post Spray Heat Treatments

Repair Process using 3kW Laser. Taken from AML website



Tube Furnace used for post spray heat treatments

Material

Powder

- Alloy 718 in the solutionized condition
- Particle size

Mesh +120/-325

53 µm ≤ particles ≤ 44 µm

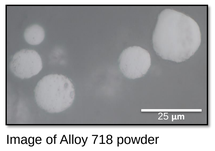
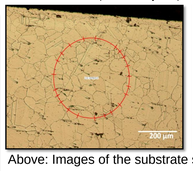


Image of Alloy 718 powder

Substrate

- Fin from gas turbine engine end plate
- Grain size ASTM 5 (57.12 µm)

XRF Analysis (Wt %)
Ni – 54.4
Cr – 17.0
Fe – 17.3
Nb – 4.7
Mo – 2.8
W – 1.8
Co - 0.5
Ti – 0.8
Mn- 0.5



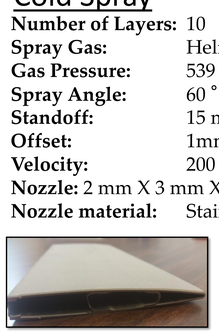
Above: Images of the substrate showing grain boundaries

Left: Chemical composition of the substrate

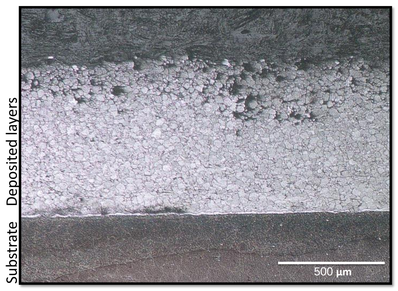
Procedure

Cold Spray

Number of Layers:	10
Spray Gas:	Helium
Gas Pressure:	539 PSI
Spray Angle:	60 °
Standoff:	15 mm
Offset:	1mm
Velocity:	200 mm/sec
Nozzle:	2 mm X 3 mm X 120 mm
Nozzle material:	Stainless Steel



Sample after cold spray



Cross section of cold sprayed sample showing grain boundaries in the substrate and particle size in the clad

Post Spray Treatments

Four testing conditions

-As deposited

-Solutionized & aged

-Aged

-Laser glazed

Solutionizing: 964 C for 1 hour, Air cooled

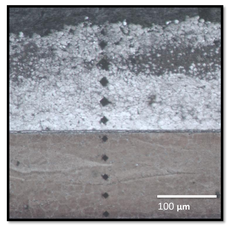
Aging: 718 C for 8 hours, Cool to 621 C, Hold for 8 hours, Air cool

Laser Glazing: 3kW Nd-YAG

Microhardness

ASTM E92 "Standard Test Method for Vickers Hardness of Metallic Materials"

500g load with a 10 second hold was used for all tests

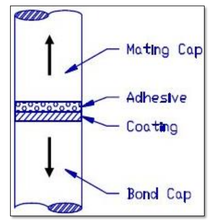


Test area from sample pictured on the left at 5x magnification.

Bond Strength

ASTM Standard C633

-Military repairs must be at least 68.9 MPa



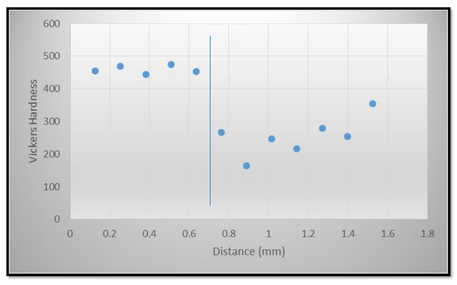
Three samples with mating caps attached. Each post spray condition is tested for bond strength three times.

Diagram of bond strength test. Taken from ASM Thermal Spray Society

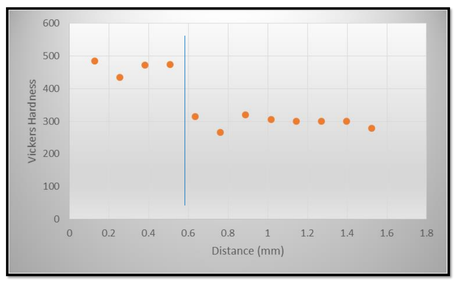
Results

Microhardness

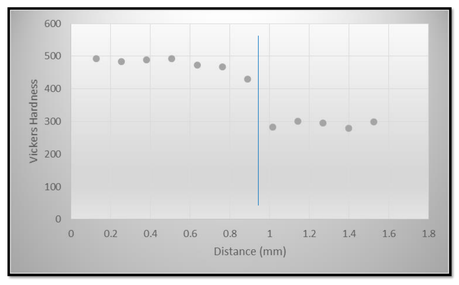
Post spray aging treatments produce more consistent results over the sample while slightly increasing microhardness in the substrate as well as the deposited layer.



As deposited



Aged



Solutionized and aged

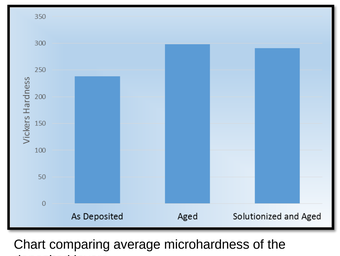


Chart comparing average microhardness of the deposited layers

Bond Strength

Bond strength for all samples tested below the accepted standard for cold spray. Each sample was subjected to three bond strength tests.

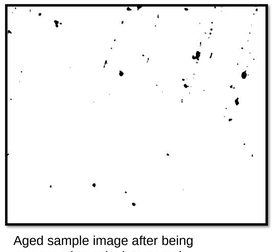
Post Spray Condition	Mpa	ksi
As Deposited	9.22 ± 2.93	1.34 ± 0.42
Aged	8.54 ± 1.06	1.24 ± 0.15
Solutionized and aged	10.76	1.56

Table showing bond strength results

Porosity

Condition	Porosity
As deposited	1.98%
Aged	1.95%
Solutionized and aged	0.75%
Laser Glazed 400 Watts	0.24%

Porosity data table

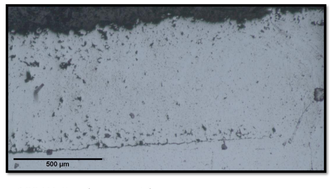


Aged sample image after being processed to calculate porosity

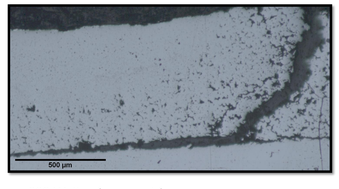
Laser Glazing

A half inch by 3 inch sample was used to begin developing parameters for laser glazing. 10 spots were glazed using varied parameters. Wattage ranged from 100 W to 700 W. Samples at focus were glazed with the smallest laser point possible. Four other samples were glazed with the laser point 3 times larger. The first 2 images show the only samples that did not experience cracking. The last 2 images show cracking of the deposition and separation from the substrate.

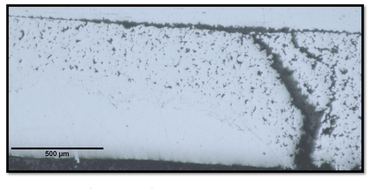
300 Watts at 3 times focus



100 Watts of power at focus



200 Watts of power at focus



400 Watts of power at focus

Conclusion

Microhardness

- **Similar microhardness results between heat treated samples suggests powdered 718 was in solutionized condition**

Bond Strength

- **Low results show need to improve cold spray parameters**

Porosity

- **Results are consistent with literature**

Laser Glazing

- **Cracking occurred outside of glazed area due to residual stresses from work hardening during deposition**

Future Work

- **Optimization of cold spray parameters to improve bonding strength**
- **Testing different mechanical and chemical substrate preparation methods**
- **Reduction of residual stress by heat treating before laser glazing**
- **Further optimization and testing of laser glazing**

Acknowledgments

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