MOOG










Mid-America AVIATION

Cold Spray Repair of Aerospace Components

Christopher Howe

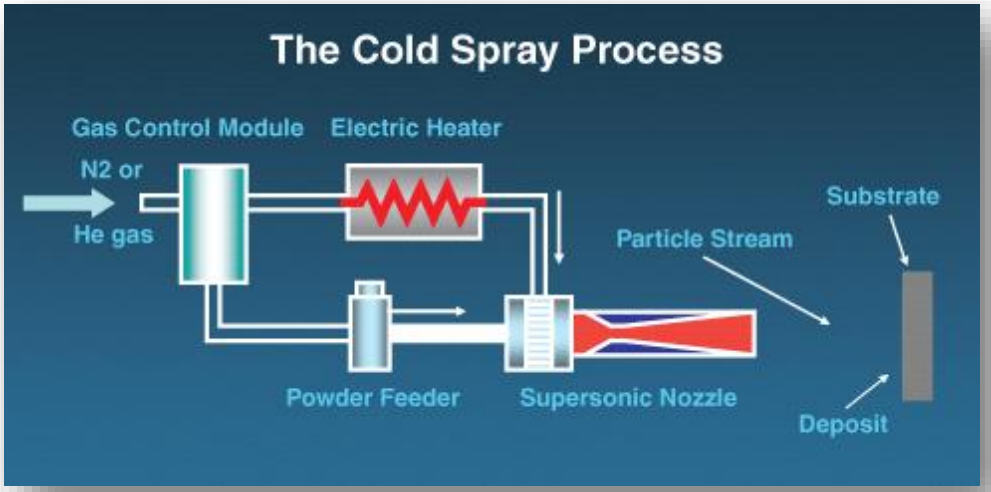
Project Engineer

Moog/Mid-America Aviation

(701)738-4284

chrish@midamericaaviation.com

Cold Spray – Technology



Cold spray is an additive manufacturing method where micron sized, metallic powder material is driven to high speed by a compressed carrier gas through a nozzle and directed at a substrate material. The resulting impact and associated particle/substrate's plastic deformation build a coating of the feedstock material onto the substrate. The resultant coating can be machined, heat treated or otherwise handled like stock material.

- Lowest operational temperature in thermal spray family
- Capable of highest particle velocity in thermal spray family
- Does not rely on melting/solidification of feedstock for adhesion

Cold Spray – Characteristics and Benefits

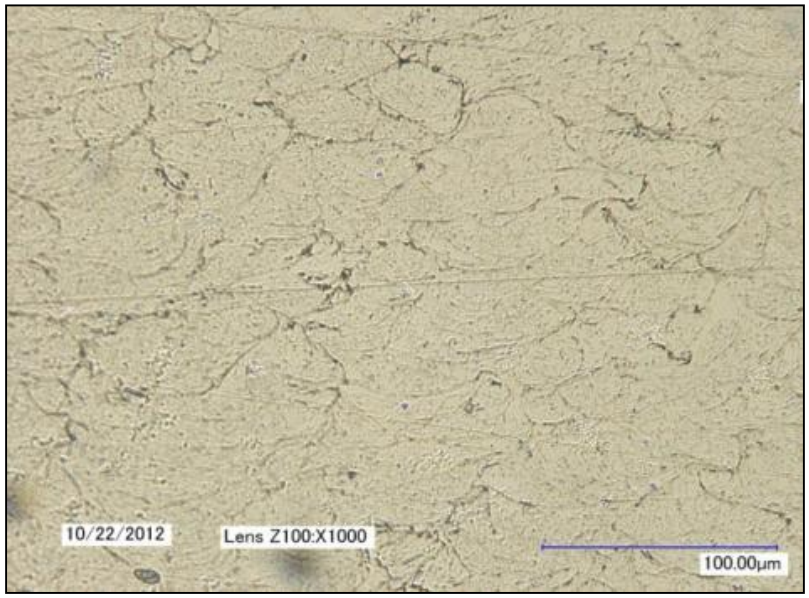
- HP Bond strengths ~ 80-100 MPa (12-15ksi)
- No oxidation
- Compressive residual stress
- Strain hardening
- High density – low porosity (<1%)
- Thick coatings
- Heat treatable free forms
- Minimal surface preparation
- No distortion of substrate
- Limited masking
- Low substrate temperatures heating<120C (250F)
- Variety of substrates (Al, Mg, Cu, Ti, Steel, Glass)

Cold Spray – Common Applications

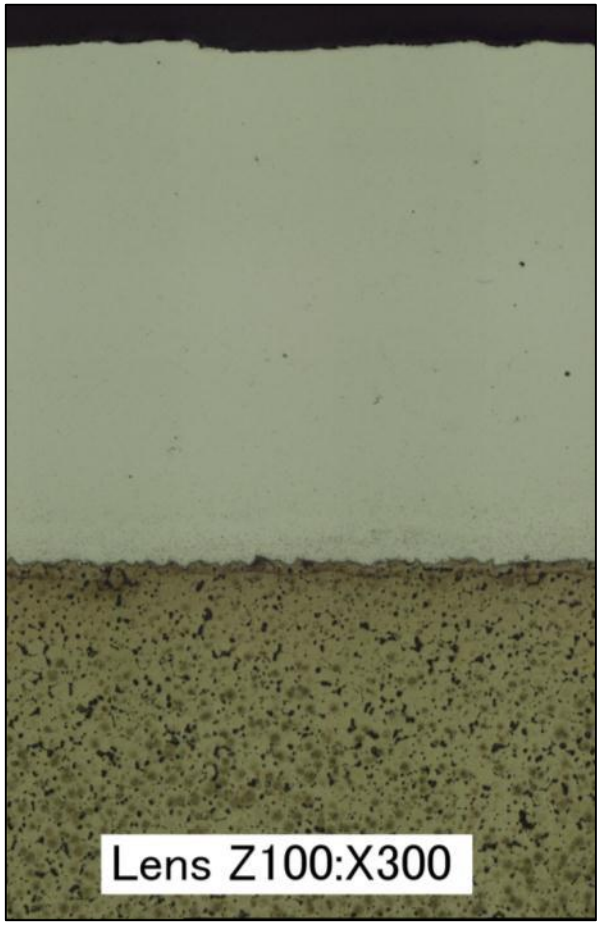
- Recover wear/damage areas
- Enhance wear resistance
- Repair corrosion damage
- Prevent corrosion damage
- Recover mis-machined parts/manufacturing defects
- Surface build up
- Conductivity
- Dielectrics
- Thermal management

Magnesium Repair with 6061 Al Cold Spray

- 6061 aluminum deposited on ZE41 magnesium
- Porosity: **<1%**
- Adhesion Strength (ASTM C633-01)
  - **>11,000 psi** (limited due to glue)
- Hardness: **≈100 HV**

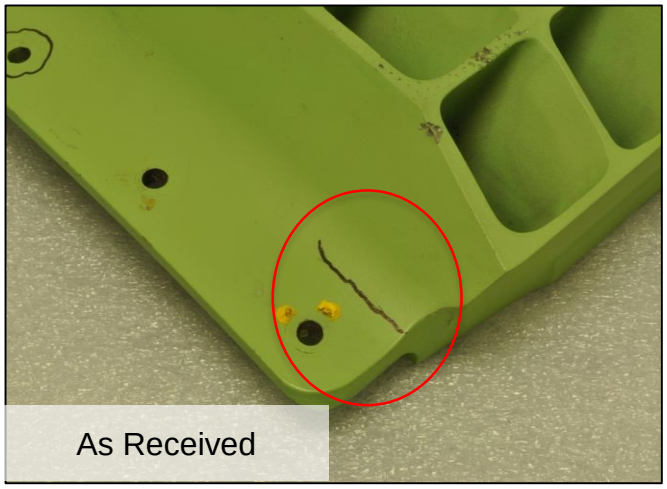


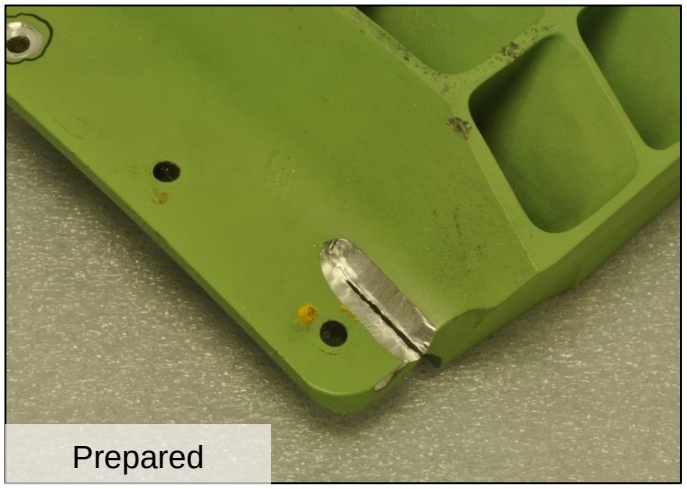
6061 coating etched to reveal splat deformation (1000X)

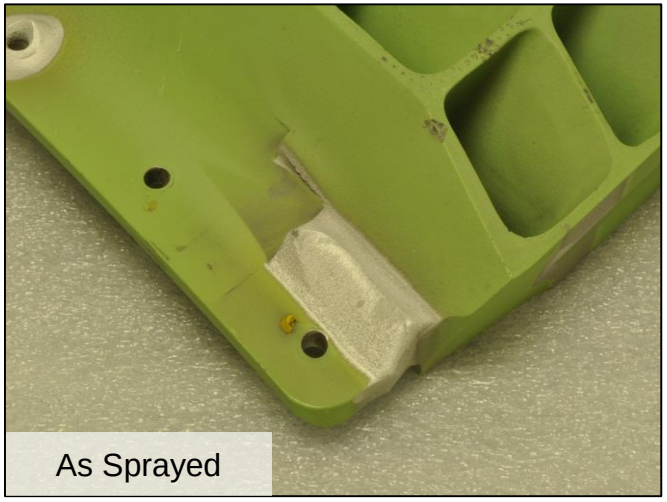


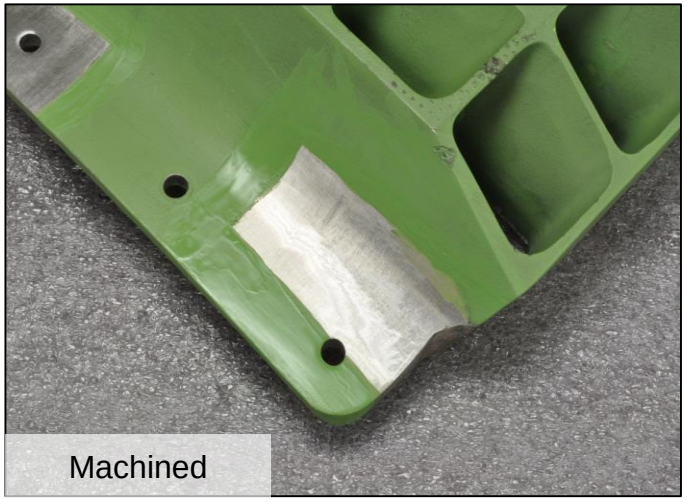
6061 cold spray coating (300X)

Cold Spray Repair of Magnesium Component



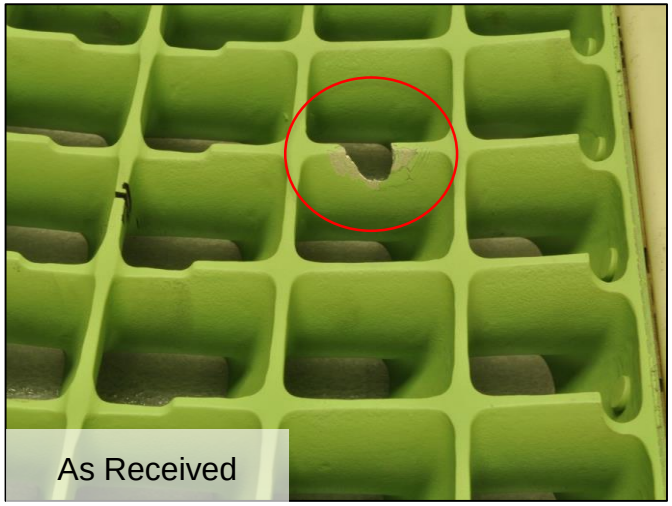


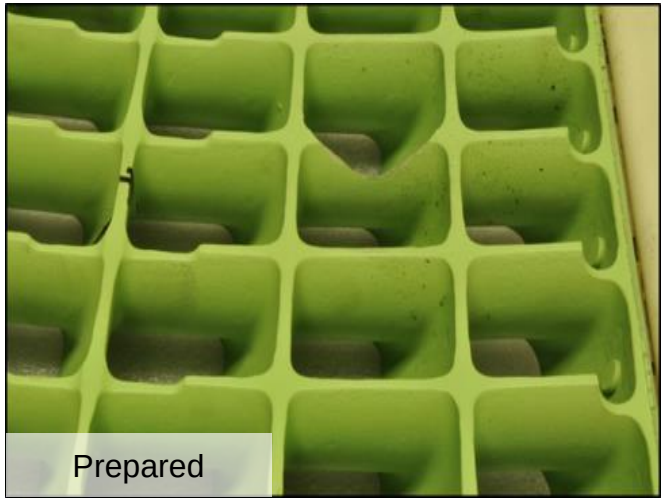


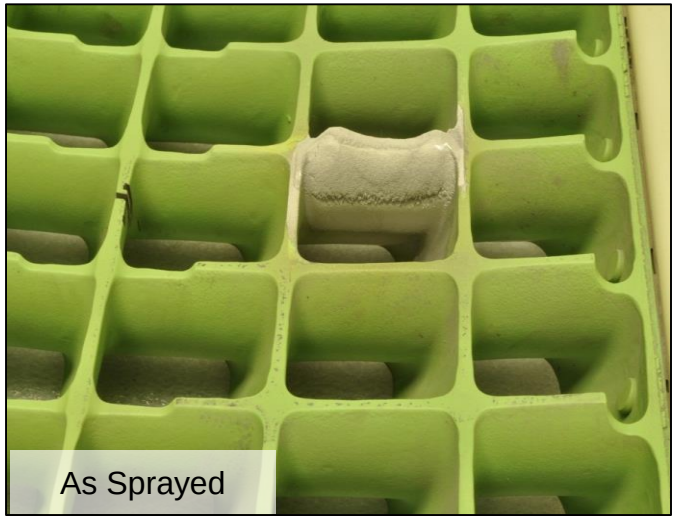


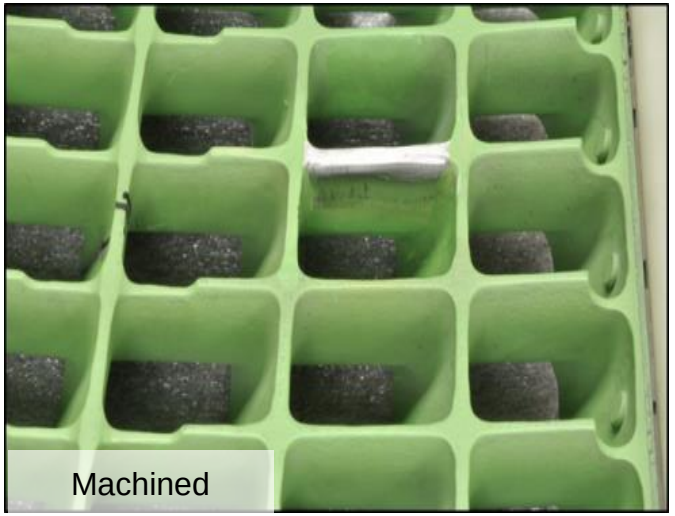
Thrust Reverser Cascade: through crack repair.

Cold Spray Repair of Magnesium Component



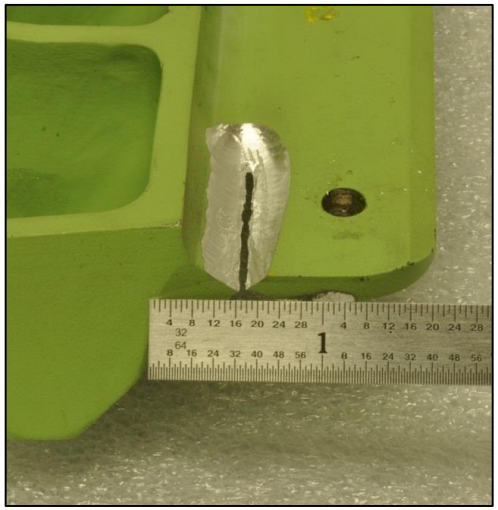


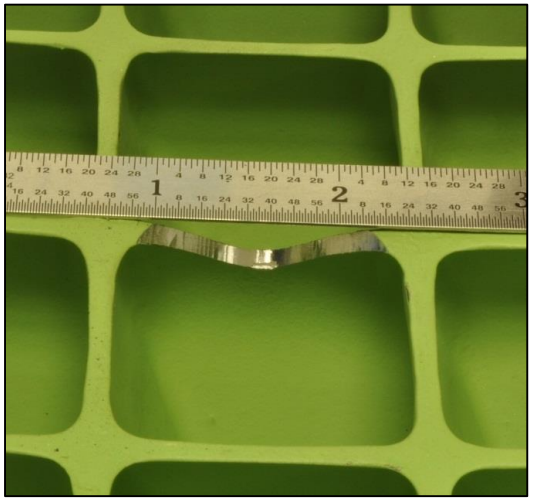




Thrust Reverser Cascade: vane damage repair.

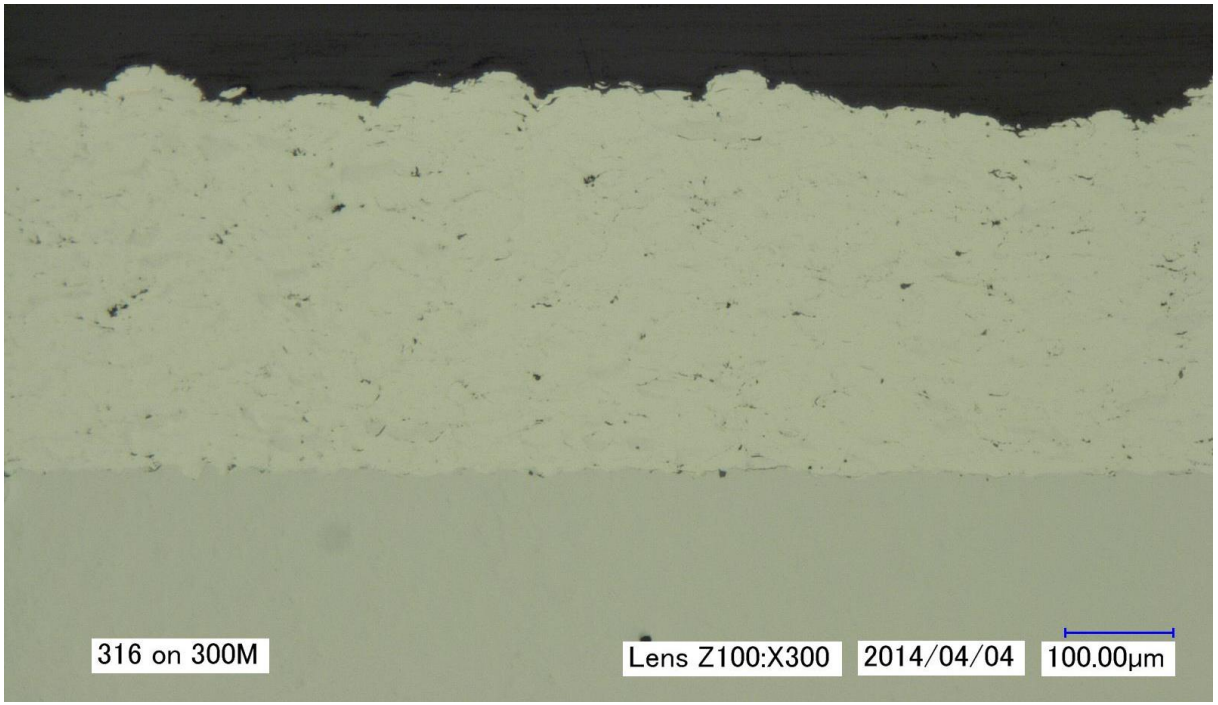
Cold Spray Repair of Magnesium Component





Stainless Steel Repair with 316 SS Cold Spray

- 316 Stainless Steel on Various Steel and Stainless Steel Alloys
- Porosity: **≈0.5%**
- Adhesion Strength (ASTM C633-01)
  - **>11,000 psi** (limited due to glue)
- Hardness: **45 HRC**



Stainless Steel Repair Cold Spray

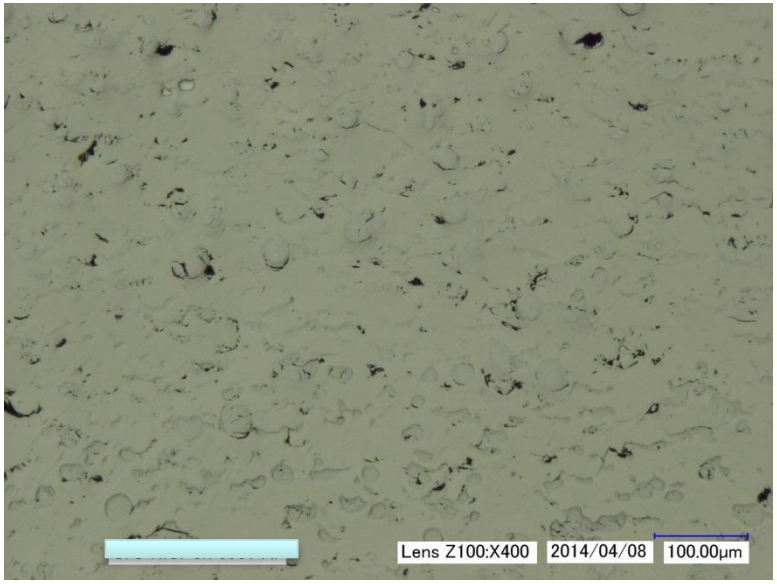
- Repair of Aerospace Valve Component

Stainless Steel Cold Spray Repair

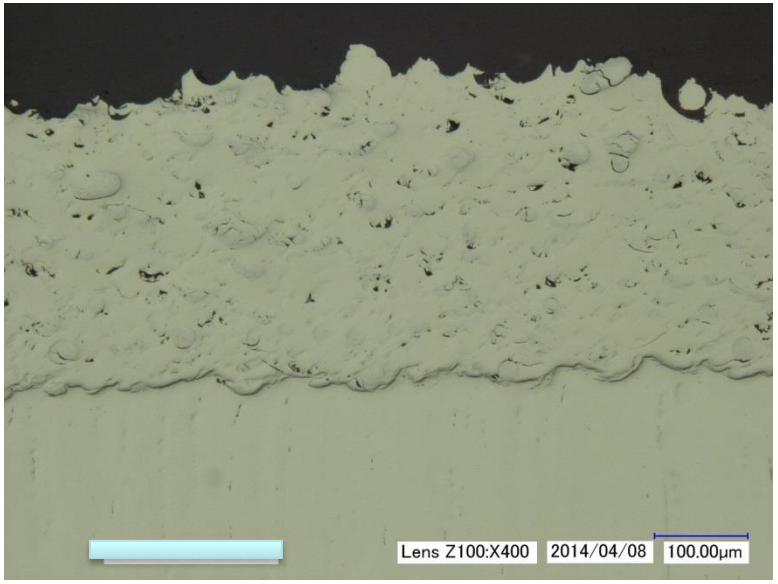
- Two Repair Areas
  - Mid Shaft
  - Wear Lugs

Cold Spray Repair with Nickel-Carbide Matrix

- Nickel-Carbide Matrix on various Stainless Steel and Inconel Alloys
- Porosity: **<1%**
- Adhesion Strength (ASTM C633-01)
  - **>10,000 psi** (limited due to glue)
- Hardness: **400-460 HV**

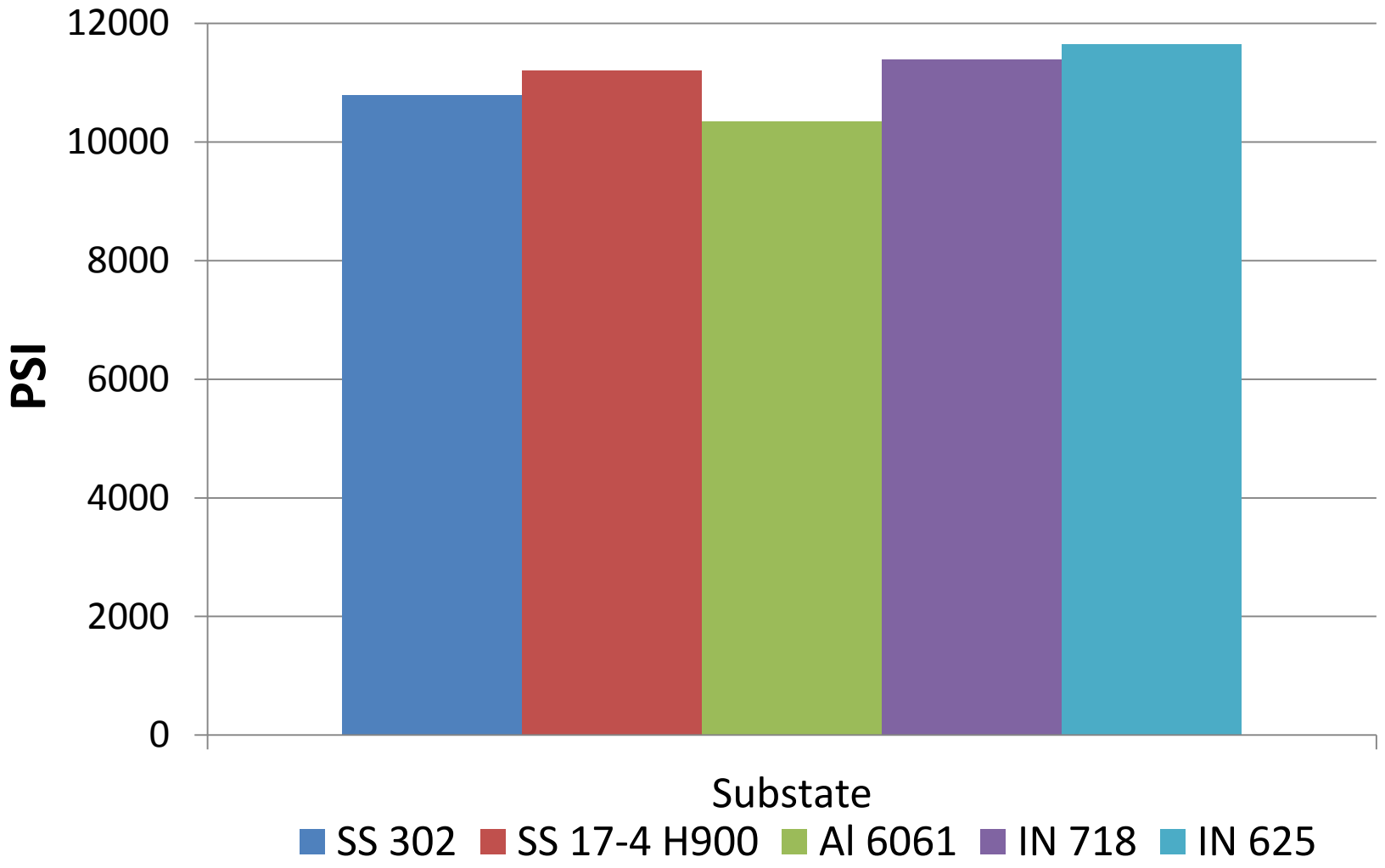


Ni-Carbide Matrix (400X)



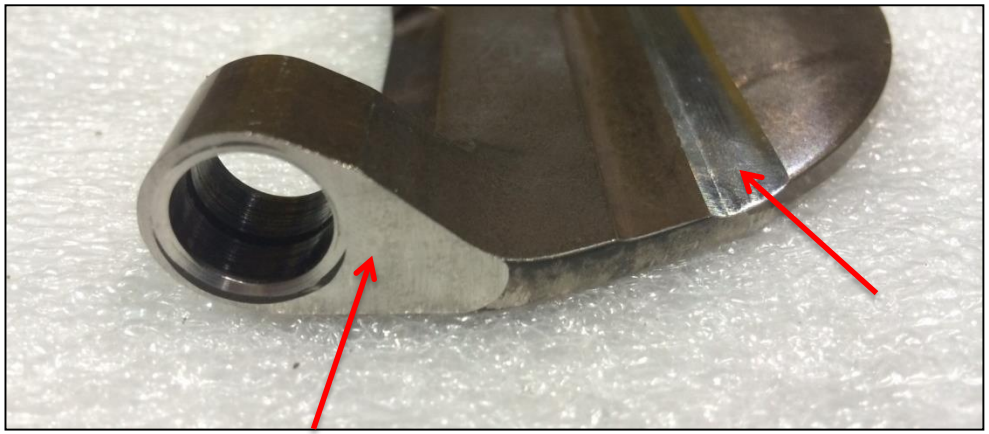
Ni-Carbide Matrix on SS 302 (400X)

Cold Spray Repair with Nickel-Carbide Matrix



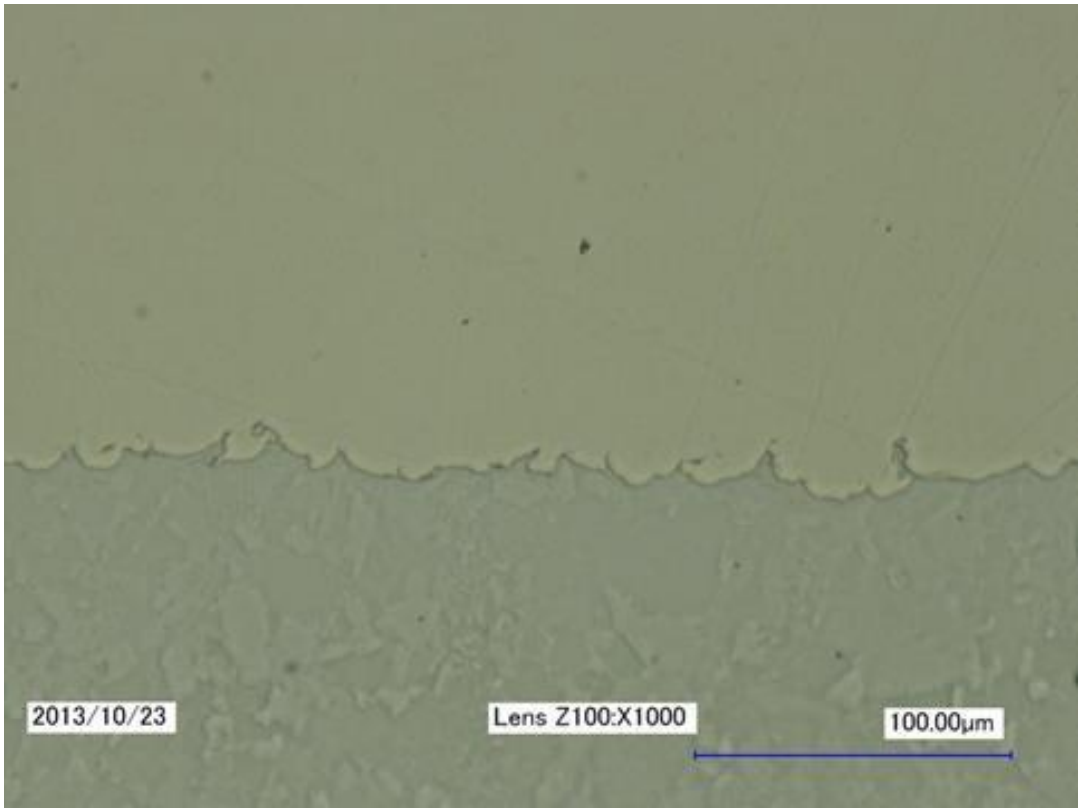
Cold Spray Repair with Nickel-Carbide Matrix

- Repair of Aerospace Valve Components



Corrosion Protection with Nickel Cold Spray

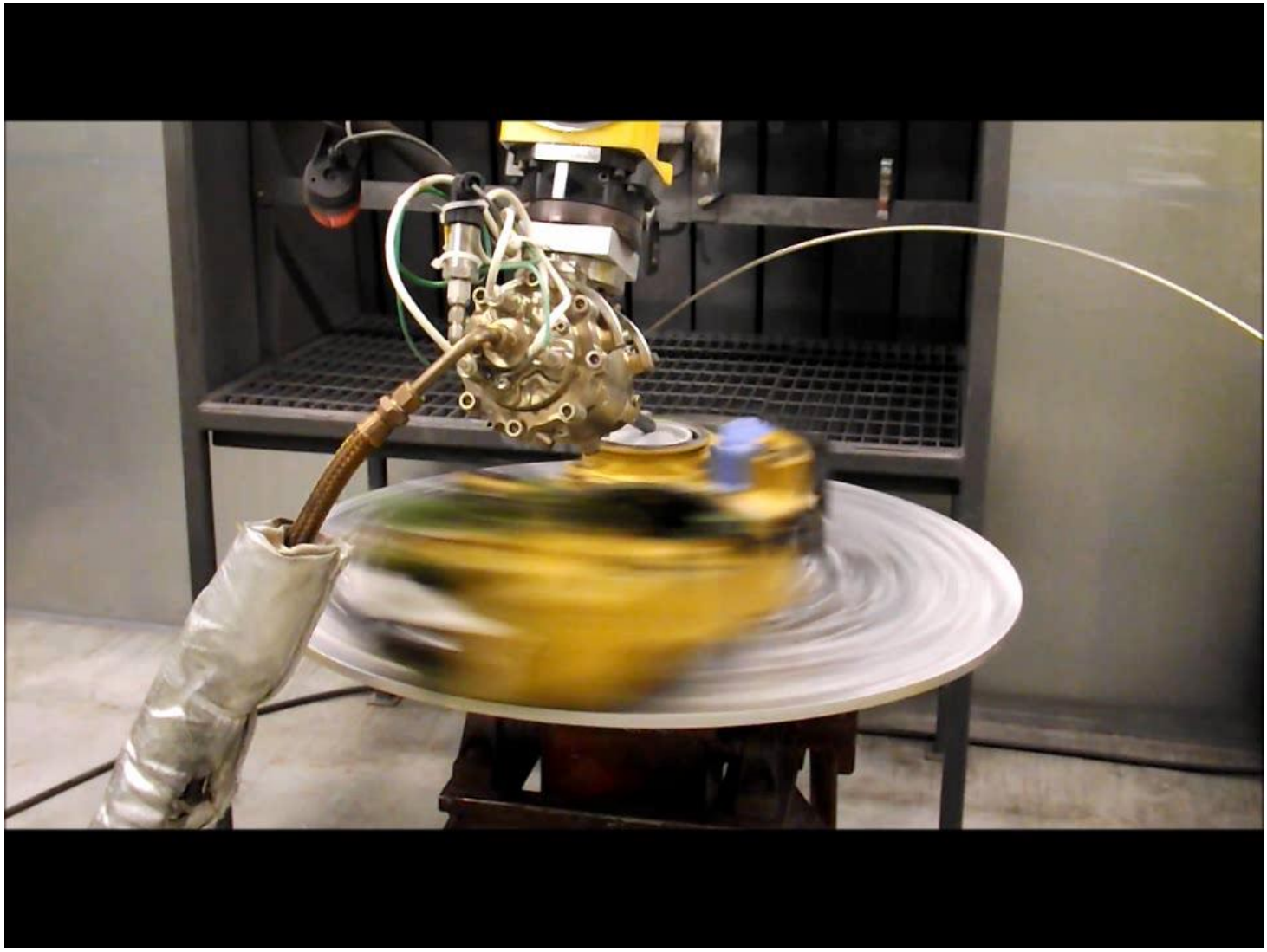
- Commercially Pure Nickel on 4340 Steel
- Porosity: **<0.5%**
- Adhesion Strength (ASTM C633-01)
  - **>10,000 psi** (limited due to glue)
- Hardness: **≈ 370 HV**



Nickel Cold Spray Repair

- Nose Wheel Steering Component
  - Refurbished with Nickel Cold Spray

Demonstration Video

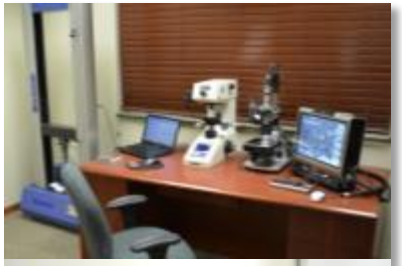


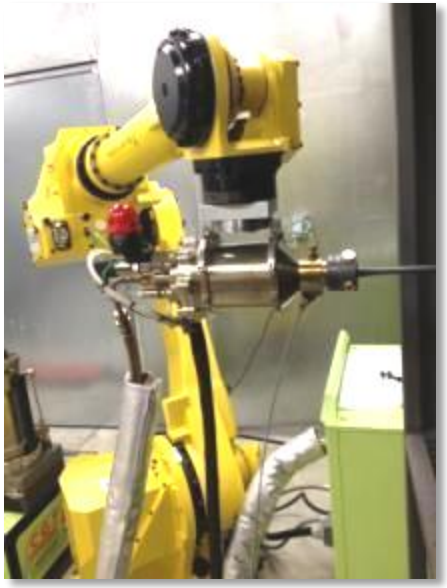
Staff

- Product Line Engineering
  - FAA DER on Staff
  - FAA DER Major Repairs Systems/Equipment, Propulsion Accessories, Repair Specifications
  - Delegations for fixed wing and rotorcraft (Parts 23, 25, 27, 29)
- Experienced Cold Spray Engineers –all Degreed engineers with 5+ years cold spray specific experience
- Metallurgical Engineer Ph.D. on Staff
- Cold Spray Technician – 10+ years of thermal spray experience and 20 years in aircraft and armament systems maintenance.
- AS9100 and AS9110 Certified
- FAA 145 Repair Station Certificate(s)
- Cold Spray Equipment - CGT HPCS, Plasma Giken HPCS, Centerline LPCS and MPCS
- Other – 5-Axis CNC, 3-Axis CNC's, Tooling Fixtures, CNC Lathes, NDT Capability, Full Metallurgical Lab Facilities

Moog Cold Spray Repair Capabilities

- High, Med, Low Pressure Machines
- Machining
- Inspection
- Testing





Benefits of Cold Spray Repair

- Significant total cost savings
  - Save on inventory, lead time and labor costs
- Repair time reduction
  - Can be used in-situ
- Improved production yield
  - Salvage parts with manufacturing defects
- Versatile coating method
- Numerous Coating/Substrate combinations
- Engineered coating properties

Acknowledgements

- **Jarrod Schell**, Product Engineer
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  Grand Forks, ND
- **Ranko Todorovic**, Chief Metallurgist
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