CHROME REPLACEMENT REPAIR DEVELOPMENT USING HPCS

CSAT 2020

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Honeywell

AGENDA

- Introduction
- Cr-replacement program qualification at Honeywell
  - Background
  - Spray activities at Army Research Lab (ARL)
    - Evaluation & testing results
  - Confirmatory spray activities at Honeywell
    - Evaluation & testing results
- Qualification testing summary
  - Remaining steps for production readiness
- Acknowledgments

INTRODUCTION

- Cold spray remains a core technology at Honeywell Aero R&O
  - Phoenix Sky Harbor: Low & High Pressure capability
    - VRC Gen 3 21 kW System, Centerline SST
- Honeywell currently repairs over 160 part features covered by more than 60 approved repair documents
  - Typical Features: Seal Surfaces, Housings, Flanges, etc.
  - Current approvals are limited to non-structural applications
- Cold Spray repairs are performed both in-house and using external suppliers
  - Supplier approval is powder composition, powder manufacturer, and base material specific
  - Authorization for part number application controlled through overhaul repair instructions (ORI)
- Current Cold Spray approvals include:
  - Powder Compositions: Aluminum + 30-40% Al_2O_3, CP Aluminum, Inconel 625
  - Base Materials: Aluminum, Magnesium, Titanium

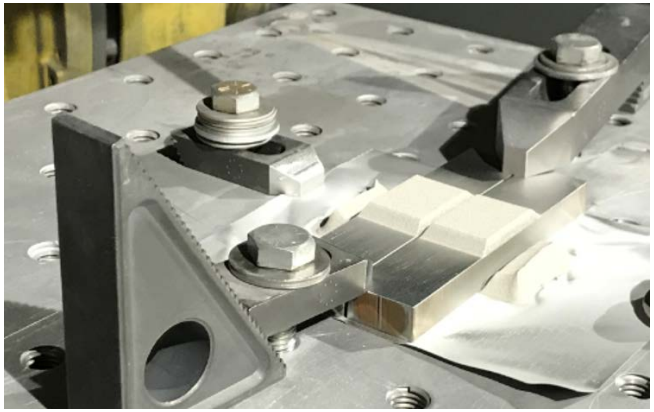
CR-REPLACEMENT PROGRAM QUALIFICATION

- Honeywell is a participant in completing the JTP WP19-5120 “Cold Spray Coatings for Cr and Ni Plating Replacement”
  - Objective: Validate the use of Cold Sprayed materials as replacements for Cr and Ni plating for DoD parts (due to hazards associated with plating processes).
    - Multiple substrates, powders, gases, and nozzles were evaluated as part of this JTP; the work presented here will focus on lug-shear validation testing and cold spray application for a single part number.
  - The Low Pressure Compressor Shaft for the AGT 1500 Engine
    - SAE 4140 steel per AMS6529
      - Normalized, quenched, and tempered ~40 HRC
    - Chrome plate per AMS2406
    - 8 Ra surface finish requirement
  - Work scope
    - Coupons and shaft Cold Spray repaired at ARL
      - Lug-shear evaluation (two spray parameter sets) & machining of repaired shaft
    - Confirmatory coupons Cold Spray repaired at Honeywell
      - Lug-shear evaluation
    - Summary of Results

CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear coupons and shaft Cold Spray repaired at ARL
  - Two different spray parameters used to deposit powder onto coupons designated ARL and HON:
    - Bond coat: WIP-BC1, 41% Ni, 2.6% C, Bal Cr
    - Top coat: WIP-C1, 31% Ni, 3% C, Bal Cr
    - VRC Gen 3 21 kW System
    - Spray gas: Nitrogen
    - Parameter changes made for HON repairs in an effort to offset reduction in temperature and maintain properties

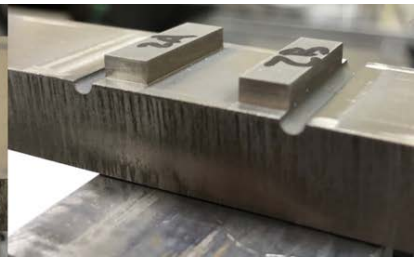
Parameter ID	*Nozzle*	*Pressure (bar)*	*Temperature (°C)*	*Carrier Gas Flow Rate (L/min)*	*Revolutions per minute (RPM)*	*Stand-Off Distance (in)*
HON	VRC NZZL0066	Increased	Reduced	No Change	Increased	0.985
ARL	VRC NZZL0058	44-46	700-720	100-150	5-7	

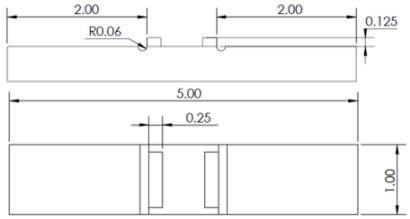


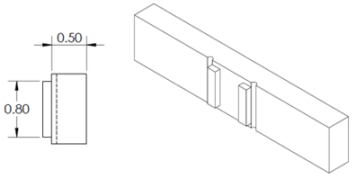
  - Shaft Cold Spray repaired using the HON parameter set

CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear & Shaft fabrication
  - Cold Spray coupons (ARL & HON) were machined per ARL-002
  - Repaired shaft successfully ground to achieve required surface finish (8 Ra)

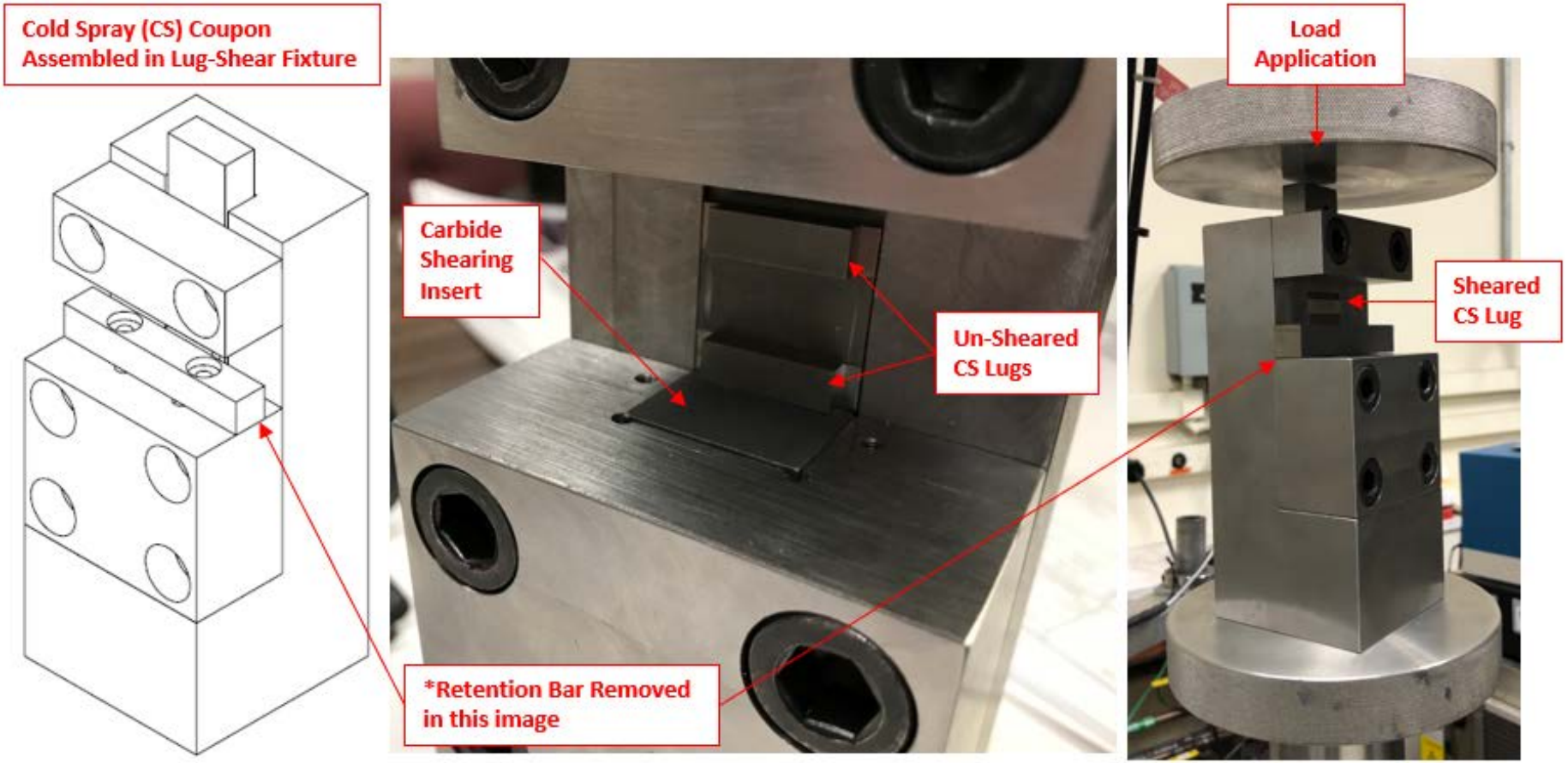






CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear Testing – per JTP (Modified Mil-J-24445A, ARL-001)
- Each lug sheared individually (2 lugs per coupon)



CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear Testing – per JTP (Modified Mil-J-24445A, ARL-001)
- All shear results exceed typical deposit property expectations: 20-30 ksi
  - Increase in HON shear strength may be attributed to increased displacement rate during initial testing (0.05 inch/sec vs in/min)

Sample ID	***Area (in^2)***	***Peak Load (lbs.)***	***Shear Stress (ksi)***	***Comments***
HON1A	0.2000	12,306	61.5	Testing Displacement rate: 0.05 in/sec Sprayed @ARL
HON1B	0.1941	12,185	62.8	Testing Displacement rate: 0.05 in/sec Sprayed @ARL
HON2A	0.1995	12,003	60.2	Testing Displacement rate: 0.05 in/sec Sprayed @ARL
HON2B	0.1988	11,519	58.0	Sprayed @ARL
ARL1A	0.1995	10,678	53.5	Sprayed @ARL
ARL1B	0.1998	10,198	51.1	Sprayed @ARL
ARL2A	0.1998	8,730	43.7	Sprayed @ARL
ARL2B	0.1946	10,885	55.9	Sprayed @ARL
		HON Average:	**60.6**	
		ARL Average:	**51.1**	

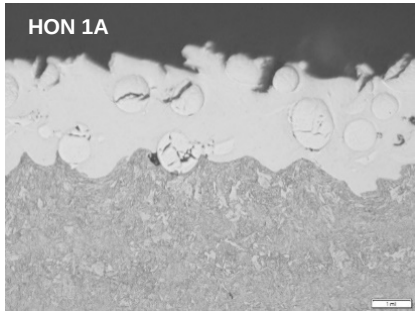
Notes: *HON Samples Recipe used was Honeywell HW-WIP-C1-001*

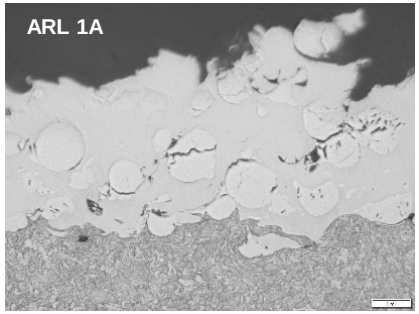
ARL Samples Recipe used was ARL VM-WIP-B1H-001 Bond Coat and ARL VM-WIP-C1N-001 Top Coat

Testing performed in accordance with ARL Joint Test Protocol WP19-5120

CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear Evaluation
  - Fracture primarily occurred through the Cold Spray deposit adjacent to or along interface
  - Exhibited satisfactory bonding along interface
    - No excessive voiding or oxide contamination noted
    - Significant material mixing at interface
    - No significant microstructural differences noted between spray parameters





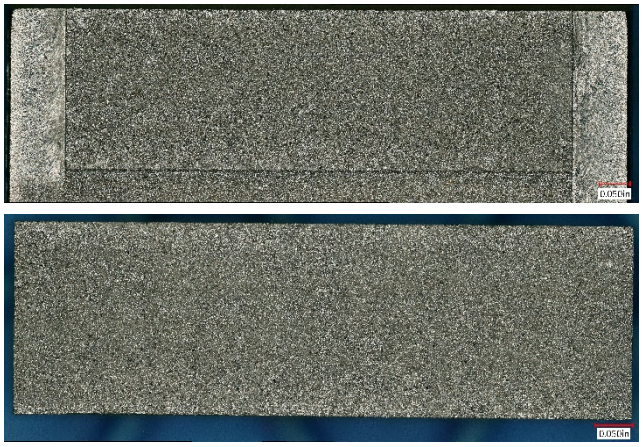
CR-REPLACEMENT PROGRAM QUALIFICATION

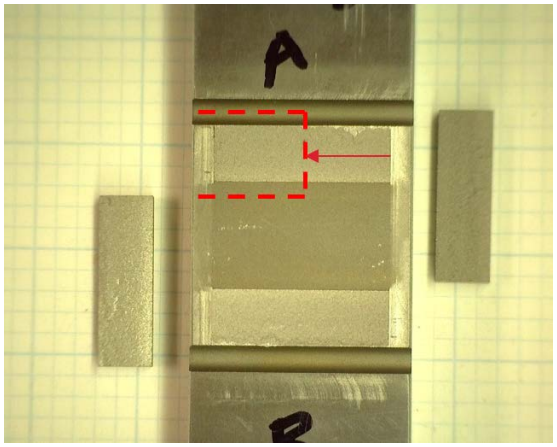
- Confirmatory Lug-shear coupons Cold Spray repaired at Honeywell
  - Only HON spray parameters evaluated
  - Identical fabrication and testing processes employed
- Shear results exceed typical deposit property expectations: 20-30 ksi
  - Average shear strength: 54 ksi

Sample ID	***Area (in^2)***	***Peak Load (lbs.)***	***Shear Stress (ksi)***	***Comments***
HON3A	0.1979	10,187	51.5	Sprayed @HON
HON4A	0.1974	11,140	56.4	Sprayed @HON
		HON Average:	**54**	

Notes: *HON Samples Recipe used was Honeywell HW-WIP-C1-001*

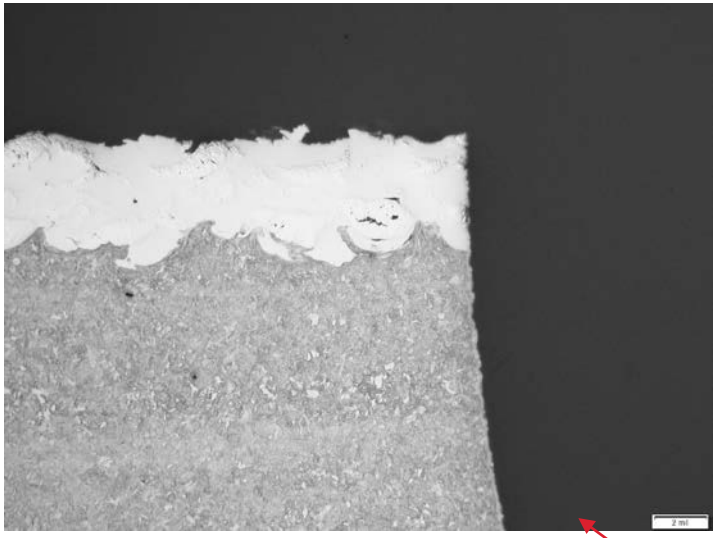
Testing performed in accordance with ARL Joint Test Protocol WP19-5120

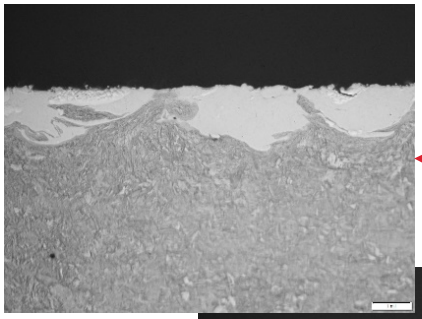


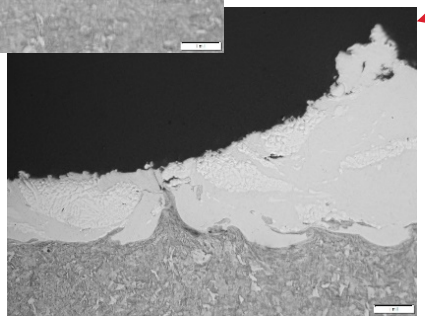


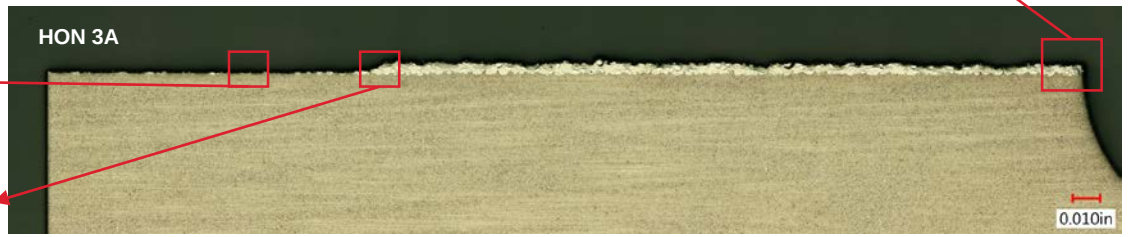
CR-REPLACEMENT PROGRAM QUALIFICATION

- Lug-shear Evaluation
  - Fracture primarily occurred through Cold Spray deposit adjacent to bond interface
  - Exhibited satisfactory bonding along interface
    - No excessive voiding or oxide contamination noted
    - Significant material mixing at interface









CR-REPLACEMENT PROGRAM QUALIFICATION

- Cold Spray Parameters Evaluated

Parameter ID	*Nozzle*	*Pressure (bar)*	*Temperature (°C)*	*Carrier Gas Flow Rate (L/min)*	*Revolutions per minute (RPM)*	*Stand-Off Distance (in)*	*Spray Gas*	*Spray System*
HON	VRC NZZL0066	Increased	Reduced	No Change	Increased	0.985	Nitrogen	VRC Gen III
ARL	VRC NZZL0058	44-46	700-720	100-150	5-7			

  - Variation evaluated due to difference in CS system restrictions
- Shear test results
  - ARL and HON parameter sets resulted in similar shear strength values, both of which surpassed the expectation of 20-30 ksi

Sample ID	*Area (in^2)*	*Peak Load (lbs.)*	*Shear Stress (ksi)*	*Comments*
HON2B	0.1988	11,519	58.0	Sprayed @ARL
HON3A	0.1979	10,187	51.5	Sprayed @HON
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ARL1A	0.1995	10,678	53.5	Sprayed @ARL
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ARL2A	0.1998	8,730	43.7	Sprayed @ARL
ARL2B	0.1946	10,885	55.9	Sprayed @ARL
		HON Average:	**55.3**	
		ARL Average:	**51.1**	

Notes:

HON Samples Recipe used was Honeywell HW-WIP-C1-001

ARL Samples Recipe used was ARL VM-WIP-B1H-001 Bond Coat and ARL VM-WIP-C1N-001 Top Coat

Testing performed in accordance with ARL Joint Test Protocol WP19-5120

CR-REPLACEMENT PROGRAM QUALIFICATION

- Remaining steps for production readiness
  - Document substantiation & initial part results – Complete
  - ARL / Army submission for approval – In-Process
  - Create repair instruction – ECD August 2020
    - To authorize application of Cr-replacement Cold Spray on subject part number
  - Revision of Cold Spray supplier control document – ECD August 2020
    - To include applicable powder manufacturer, composition, and base material
  - Process initial part at Honeywell R&O – ECD September 2020
    - Approve source for processing to repair instruction
    - Begin routine production

ACKNOWLEDGMENTS

- Bruce Almond & Billy Simmons at Honeywell
- Vic Champagne, Isaac Nault, Aaron Nardi, & Matt Siopis at ARL

QUESTIONS?