

Transitioning Cold Spray to DoD/Commercial Applications

Christian Widener, Ph.D.

**South Dakota School of Mines and Technology
& VRC Metal Systems**



Transitioning Cold Spray: Delivering a Whole Product Solution

Equipment Development



Training



Process & Application
Development



FUNDAMENTAL PROCESS
UNDERSTANDING

SOUTH DAKOTA



SCHOOL OF MINES
& TECHNOLOGY



Efforts to Assist Cold Spray Transition

- **Fundamental Process Understanding**

- Process Modeling - *nozzle design & parameter prediction*
- Microstructural Characterization & Material Testing
- Material Processing & Selection
 - *understanding metallurgy of powders & coatings*
 - *choosing the right powder/substrate combinations*



- **Equipment Development**

- VRC Gen III, VRC Viper™, Hybrid Manufacturing Systems, VRC Raptor™, VRC Dragonfly™, HMI, Nozzles & Applicators for Specific Applications

- **Training**

- Developing the workforce knowledge base

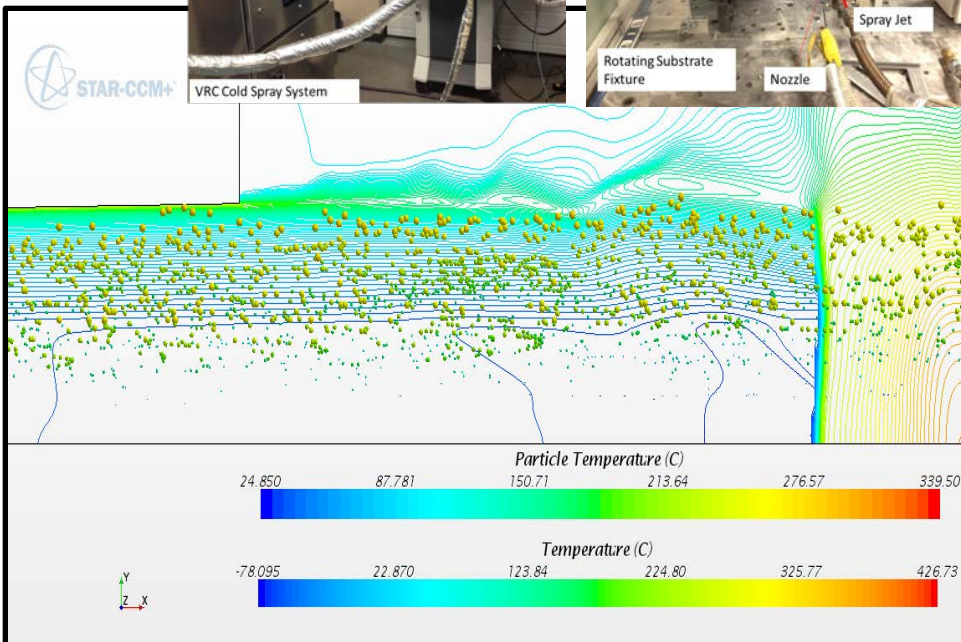
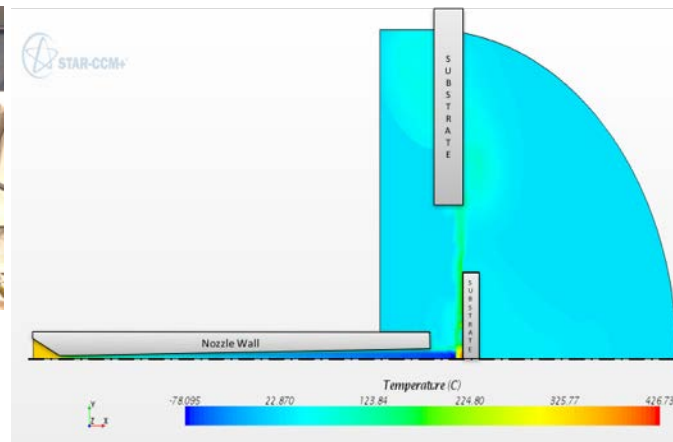
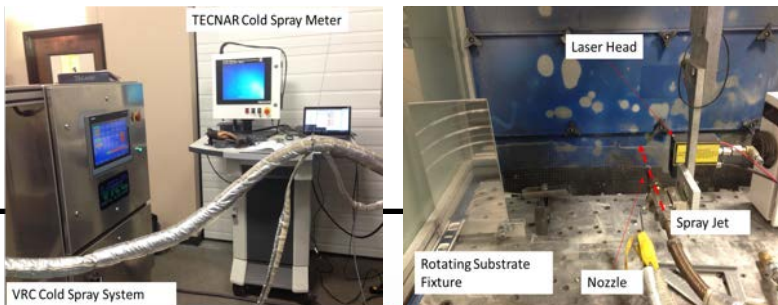
- **Process & Application Development**

- Long term need to assist industry

Cold Spray Process Modeling

Predicting cold spray performance using computational fluid dynamics

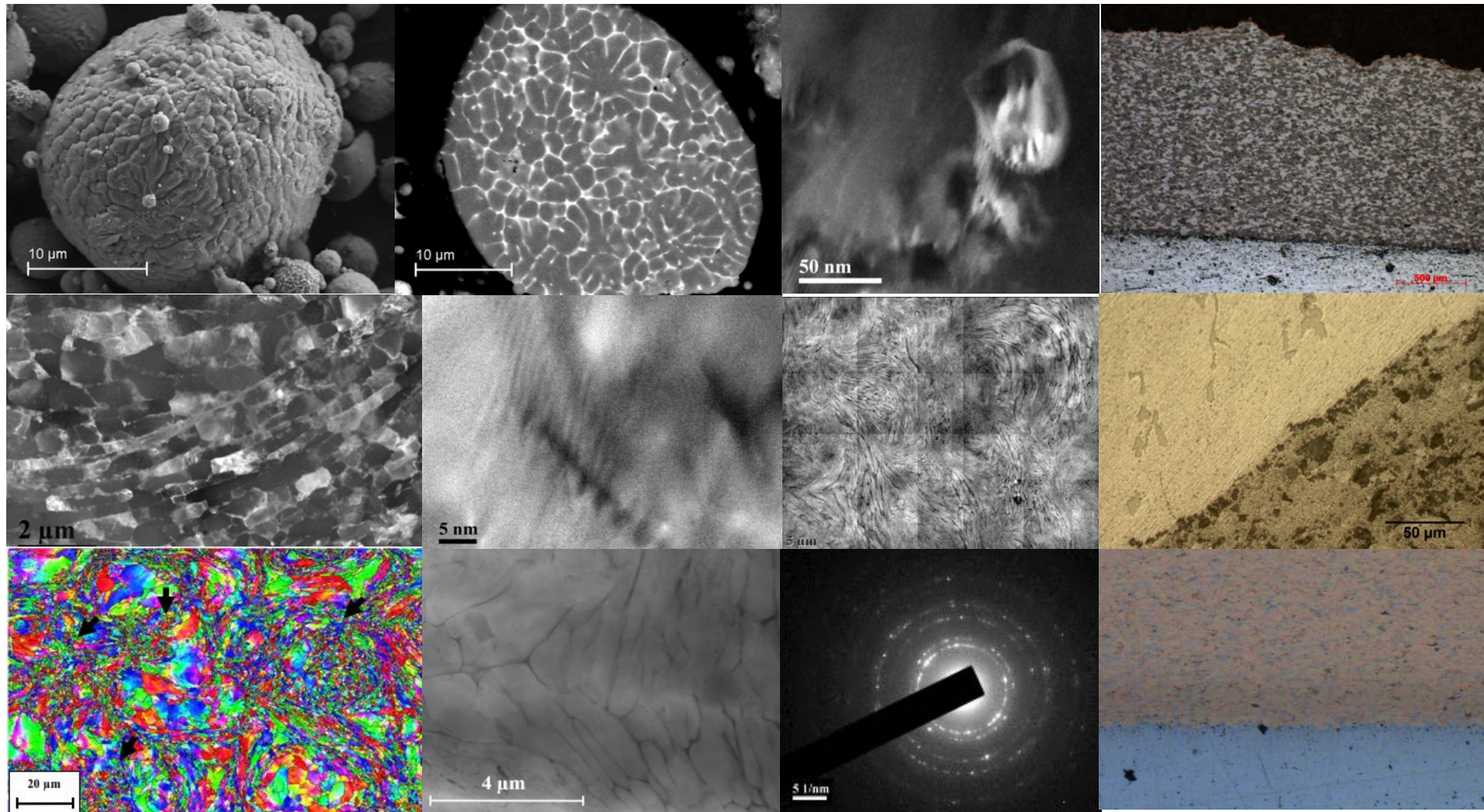
Full discussion: Ozan Ozdemir, Ph.D. Candidate, Wed. June 22, 9:30 a.m.



T [C]	P [psi]	500	600	700	800	900	1000
300		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
350		0.00%	0.00%	0.00%	0.00%	0.00%	0.10%
400		52.56%	63.80%	73.22%	82.13%	86.71%	91.12%
450		92.52%	96.82%	98.56%	99.54%	99.93%	99.93%
500		100.00%	100.00%	99.97%	99.97%	99.97%	99.97%

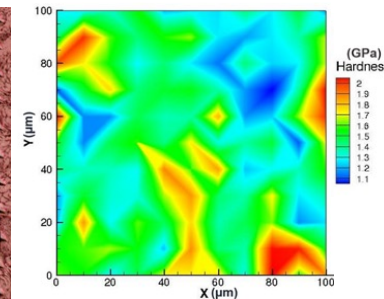
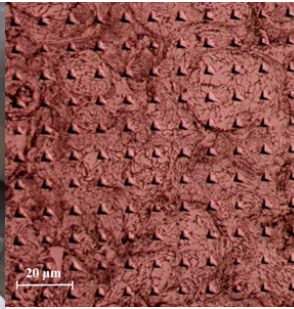
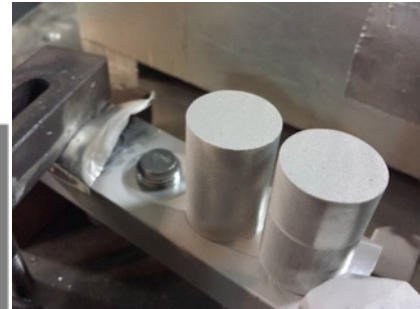
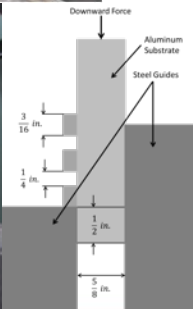
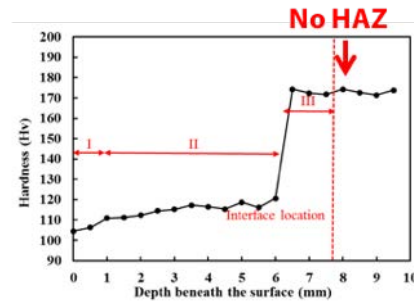
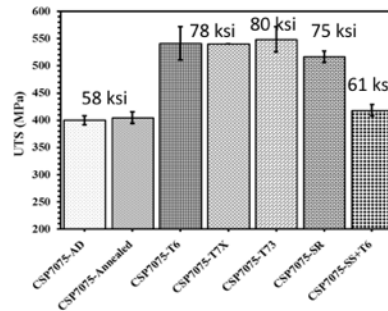
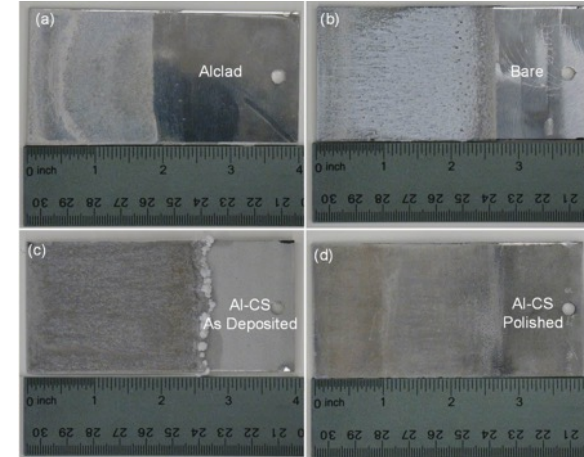
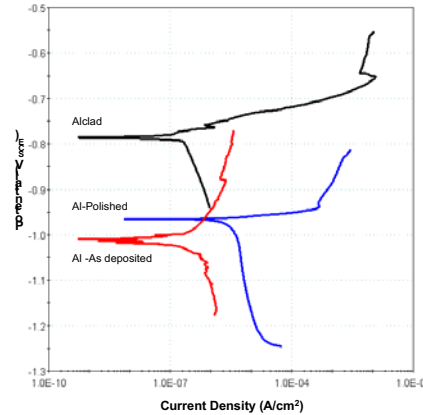


Microstructural Characterization



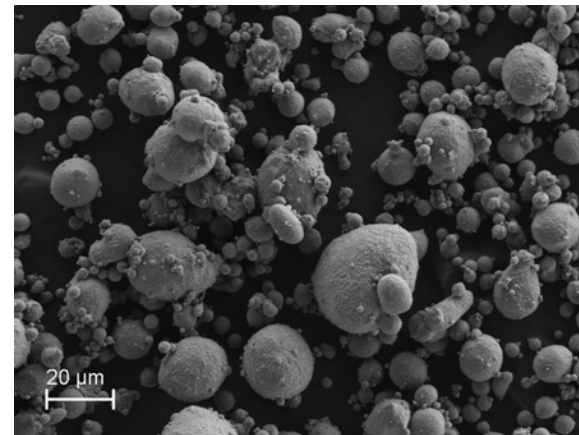
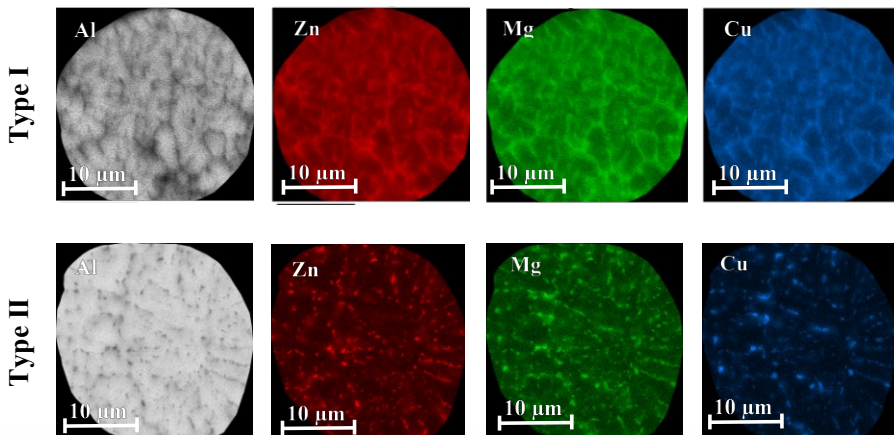
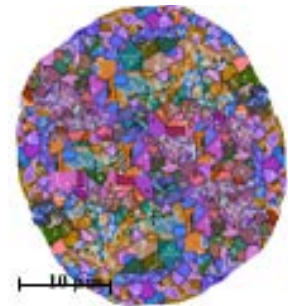
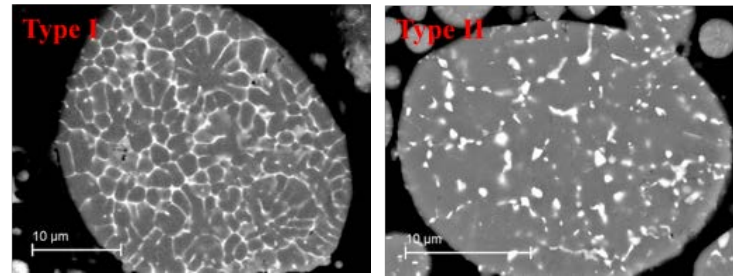
Material Testing

- ASTM C-633 Bond Testing
- ASTM E-8 Tensile Testing
- 3-Lug Shear Testing – per MIL-J-24445A
- Vickers Microhardness
- Nano-indentation
- Shear Load Bearing
- Fatigue Testing
- Corrosion & Wear Testing
- Etc.



Material Processing

- Powder Analysis
 - Hardness, SEM Imaging, Phase Distribution, Grain Size Particle Size Analysis, DSC & EBSD
- Powder & Substrate Treatments
 - Sieving
 - Thermal softening
 - Strain recovery
 - Enhanced properties



Material Selection

Knowledge Base

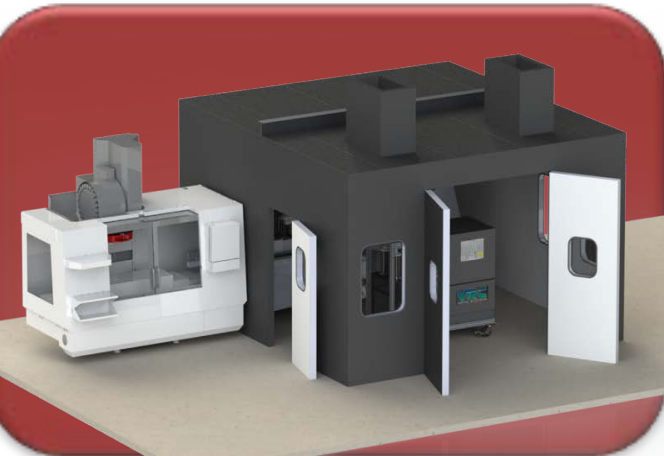
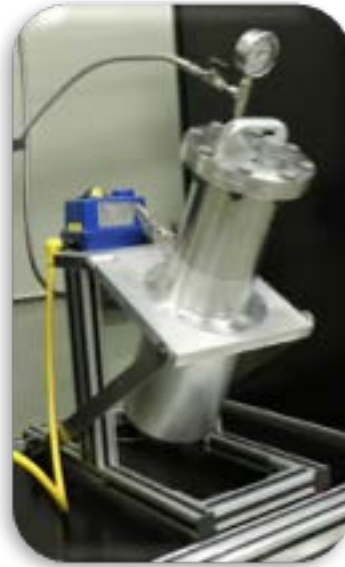
1. Cold Spray Process

2. Component Design

3. Materials Science

- **Properties vs. Requirements**
 - The “Best” or “Good Enough”
- **“Sprayability”**
 - How difficult is it to spray with current technologies?
- **Environmental Compatibility**
 - Corrosion, wear, thermal expansion, etc.
- **Cost**
 - Helium vs. Nitrogen, Powder processing, Volume/Area
- **Reliability & Repeatability**
 - Is the process under control?
 - Can the same results be achieved in production?

Equipment Development



Controls & HMI

- **Development of a new HMI interface and enhanced control system for the VRC Gen III™ is underway**
 - More intuitive automatic control
 - Recipe screens
 - In-process monitoring and warnings for quality control
 - Built-in troubleshooting
- **SDSM&T is working with VRC to assist with design concepts, development, and testing**



Coming soon...



Log in

5:59:29 PM
6/16/2016

System Overview 9:50:58 AM 6/17/2016

Local/Remote: Local Remote
 Operation Mode: Auto Manual
 Gas Selection: Helium Nitrogen
 Spray Mode: PreHeat Spray
 Enable System
 Disable System

Parameter Window: Parameter, Recipe Window: Recipe, Gas Mix Window: Gas Mix
 PreHeat Cycle Window: PreHeat, Cool Down Cycle Window: Cool Down
 System Warnings/Alarm: [Yellow Box]

System Sequence of Operation

- Automatic PreHeat Cycle: In progress, Complete
- Automatic Spray Cycle: In progress, Complete
- Cool Down Cycle In Progress: In progress, Complete

Engineer Dustin Menu

Operator Screen 6:08:16 PM 6/16/2016

Recipe: 0
 Local/Remote: Local Remote
 Powder Feeder Status: OFF
 Gas: Helium
 Feed Rate: 0 RPM
 Heater Status: OFF
 Nozzle Size: 0

Recipe Window: Recipe
 PreHeat Cycle Window: PreHeat
 Spray Cycle Window: Spray

System Sequence of Operation

- Automatic PreHeat Cycle: In progress, Complete
- Automatic Spray Cycle: In progress, Complete
- Cool Down Cycle In Progress: In progress, Complete

Engineer Dustin Menu

Recipe Screen 6:39:41 PM 6/16/2016

Recipe Name: Spray Collection No.: 1
 Data Record Name: [Dropdown] No.: [Dropdown]

Entry Name	Value
System Temperature SetPoint	0
System Pressure SetPoint	0
PowderFeeder Feed Rate	0
System Gas Selection	0
Cool Down Temp SetPoint	0
Gas Mixing	0

Ready
 Engineer Dustin Menu

Cold Spray Training

- ***The success and growth of the COLD SPRAY INDUSTRY will depend on the **Quality and Availability** of TRAINING...***
- **Needs exist across job functions:**
 - Operators /Technicians
 - Engineers / Scientists
 - Managers / Executives
 - Other Sales & Support Staff



Projected Training Needs

- We are projecting dramatic growth in the cold spray industry for the next 5 years and beyond...

5 Year Cold Spray Training Needs Projection



Cold Spray Training Current State

➤ System manufacturer training



➤ ASM Thermal Spray Certificate

- Includes some Cold Spray



➤ No active certification program

- The ASM Certified Thermal Spray Operator (CTSO) is currently inactive.



VRC / SDSM&T Developed Course: Introduction to Cold Spray

- **Partnered with ASM for Thermal Spray Management Certificate Training**

- First class held September 14-18, 2015
- 16 students taught at SDSM&T in Rapid City, SD



www.asminternational.org

- **Cold Spray Basics Course developed for all audiences**

- Day 1 – Eight hours classroom instruction
- Day 2 - Six hours hands on operation



- **First VRC cold spray class taught February 16 & 17, 2016**

- 14 students taught at SDSM&T in Rapid City, SD



SOUTH DAKOTA



SCHOOL OF MINES
& TECHNOLOGY



Introduction to Cold Spray

Day 1 – Eight hours classroom instruction

➤ Familiarization level training

➤ Overview:

1. BASIC TERMS
2. HISTORY OF COLD SPRAY
3. COLD SPRAY PROCESS
4. COATINGS
5. ADVANTAGES / DISADVANTAGES OF COLD SPRAY
6. AVAILABLE EQUIPMENT
7. CURRENT APPLICATIONS
8. SAFETY
9. SETUP AND PART PREP
10. SYSTEM OPERATION
11. TESTING AND CHARACTERIZATION



VRC
METAL SYSTEMS

SOUTH DAKOTA

M

SCHOOL OF MINES
& TECHNOLOGY

Introduction to Cold Spray

Day 2 – Six hours hands on operation

➤ All students get hands on for:

- Shop and Process Safety
- Powder prep
- Powder feeder cleaning
- Part prep
- System controls
- Robotically controlled spraying
- Hand spraying



VRRC
METAL SYSTEMS

SOUTH DAKOTA
M
SCHOOL OF MINES
& TECHNOLOGY

Future Training Needs

- **Growing need for certified operators** with documented qualifications
- Build on existing ASM International Thermal Spray Curriculum
- Explore options to develop Cold Spray Technician Certificate
 - ASM International
 - National Institute for Certification in Engineering Technologies (NICET)
- **Expand VRC's Introduction to Cold Spray course to week long and then multi-week training for cold spray operators.**



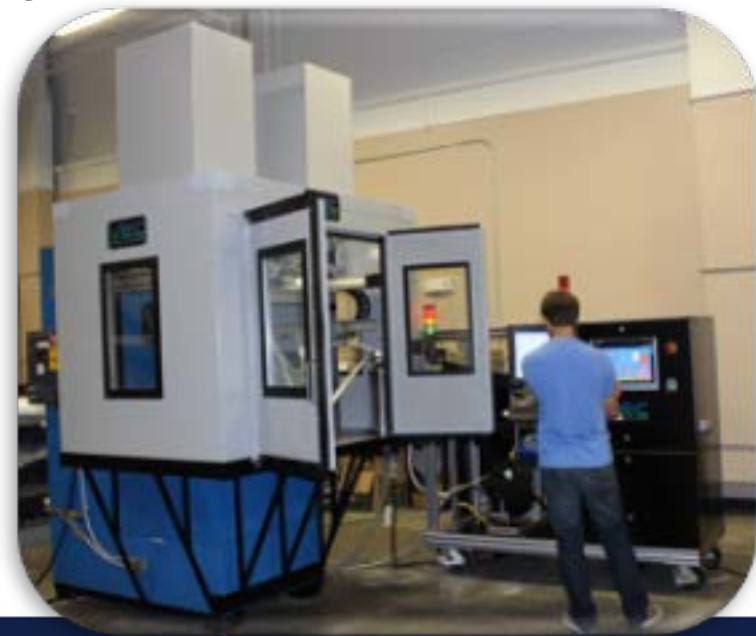
ASM
INTERNATIONAL

VRC
METAL SYSTEMS

SOUTH DAKOTA
M
SCHOOL OF MINES
& TECHNOLOGY

Types of Training

- **Cold Spray 101**
 - Familiarization with Cold Spray
 - Target management, technicians, and engineers
 - One day or two with hands-on
- **Training for machine owners**
 - Include any of the types of training above
 - Site preparation
 - Routine maintenance
 - Consumable rates and acquisition
 - Warranty details for new machines



More Types of Training

- **Technician training**

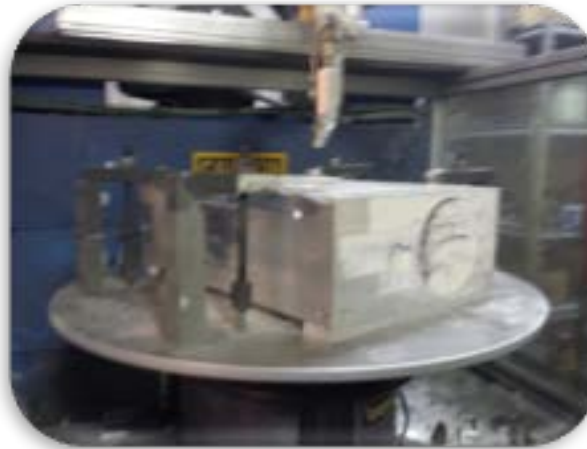
- Can be 1 week on or off-site for machinists, welders, thermal spray operators, etc.
- Demonstrates basic proficiency in a particular or general cold spray application

- **Certification**

- Satisfy DoD and other customer needs for quality control
- 4 - 8 week course for a certified technician
- Minimum experience levels
- Can be incorporated as a section of a Technical College Machinist, Welder, other shop technician program



Applications Development



Cold Spray Properties

- **ASTM E8 – Subscale Coupon**

- Machined from a large build-up of cold spray material.
- Substrate material is not included

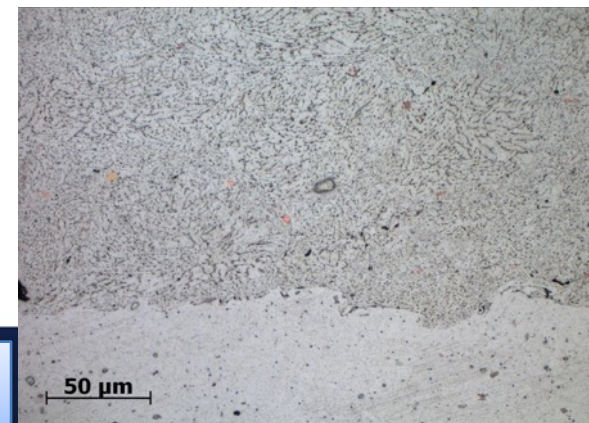


- **Al 6061 - Helium**

- Yield Strength = 35.5 ± 1.05 ksi [BULK Typical – 40 ks] [**245 MPa**]
- UTS = 45.4 ± 0.37 ksi [313 MPa] **![Matches BULK 6061 UTS – 45 ksi]!***
- %EL = $5.5\% \pm 0.77\%$ [BULK Typical 12%]
- Hardness = 90 HV

- **Al 2024 - Helium**

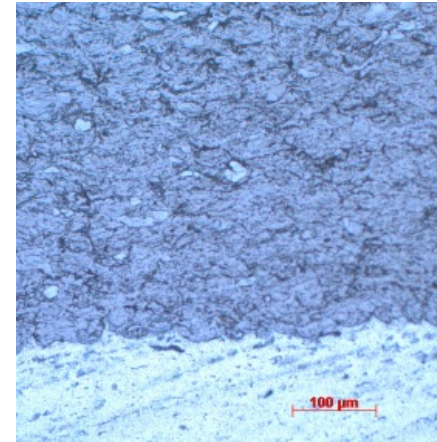
- Yield Strength = 45.9 ksi **![Nearly BULK 2024 YS – 47 ksi]!***
- UTS = 50.1 ksi [Bulk Typical 68 ksi] [**345 MPa**]
- %EL = 5.5 ksi [Bulk Typical 19%]
- Hardness = 167 HV



More Cold Spray Properties

- **CP Titanium - Helium**

- Yield Strength = **62.5 ksi** ![BULK CP Ti Grade 3 – 65 ks]!*
- UTS = **78.5 ksi** ![BULK CP Ti Grade 3 UTS – 85 ksi]!*
- %EL = **2.8%** [BULK Typical 25%]



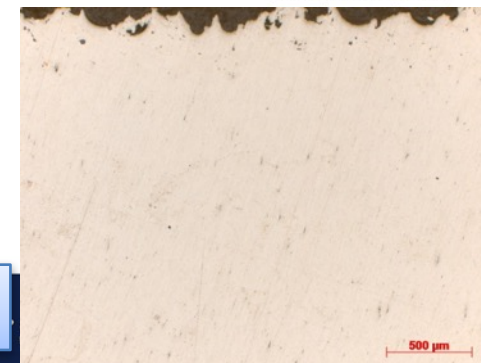
- **CrC-NiCr – Nitrogen**

- Adhesion Strength – 10 ksi [**69 Mpa**]
- 3-Lug Shear Strength – 13 ksi [**90 Mpa**]
- Hardness – HRC 34



- **Al 6061 - Compressed Air**

- Yield Strength = 18.8 ± 0.25 ksi
- UTS = 19.7 ± 0.4 ksi [**136 MPa**]
- %EL = 1.8%
- Bond Strength = 9.2 ± 0.4 ksi [**63.4 MPa**]
- Hardness = 70 HV



Summary

- Working on the **whole product solution**
- **This starts with a solid fundamental process understanding**
 - Process Modeling
 - Microstructural Characterization & Material Testing
 - Material Selection & Processing
- **SDSM&T and VRC are using this knowledge to guide:**
 1. Equipment Development
 2. Application Development
 3. Training



Acknowledgements

- **These research projects have been made possible with funding from:**
 - The State of South Dakota AMPTECH Center – (Governor’s Research Center and Office of Economic Development)
 - The Army Research Lab
(contract #W911NF-15-2-0034)
 - H.F. Webster Engineering Services
 - VRC Metal Systems



Thank you for your attention!

- **Dr. Christian Widener**

- Director/ Associate Professor
Arbegast Materials Processing Lab
South Dakota School of Mines & Technology
Ph. 605-394-6924
Email: christian.widener@sdsmt.edu
<http://www.sdsmt.edu/amp>
- Chief Technical Officer
VRC Metal Systems
<http://www.vrcmetalsystems.com>

