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Effects of Cold Spray Repairs on the Mechanical Properties of a Component

Nieto, Andy; Ansell, Troy

Monterey, California: Naval Postgraduate School

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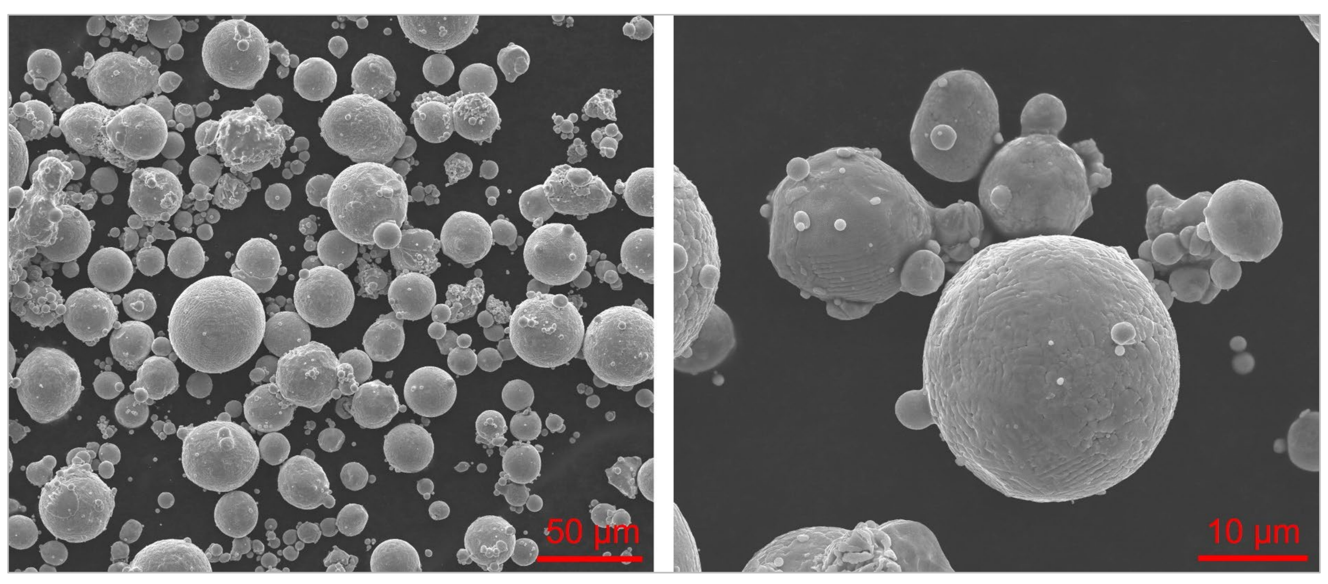
Background & Motivation

- Cold spray is a coating technology used to deposit metallic or metallic/ceramic coatings. The technology has the advantages of low processing temperature and scalability as compared to other thermal spray techniques.
- Cold spray is under investigation as a field repair technique for the Navy.
- An important alloy, Cu-Ni, is used in shipboard water pipes among other applications. Little research; however, has been conducted on cold spraying Cu-Ni coatings (for repair operations) or on cold spraying a coating onto Cu-Ni substrates.
- The study sought to characterize and investigate:
  - The powder behavior and coating quality in relation to the carrier gas pressure, carrier gas temperature, powder feed rate, nozzle travel speed, and number of passes of the nozzle.
  - Changes to the mechanical properties of the Cu-Ni coating and Cu-Ni substrate.
- Changes to the mechanical behavior of the substrate and coating due to heat treatment was investigated.

Materials & Methods



Low and high magnification SEM images of Cu-Ni cold spray powders.

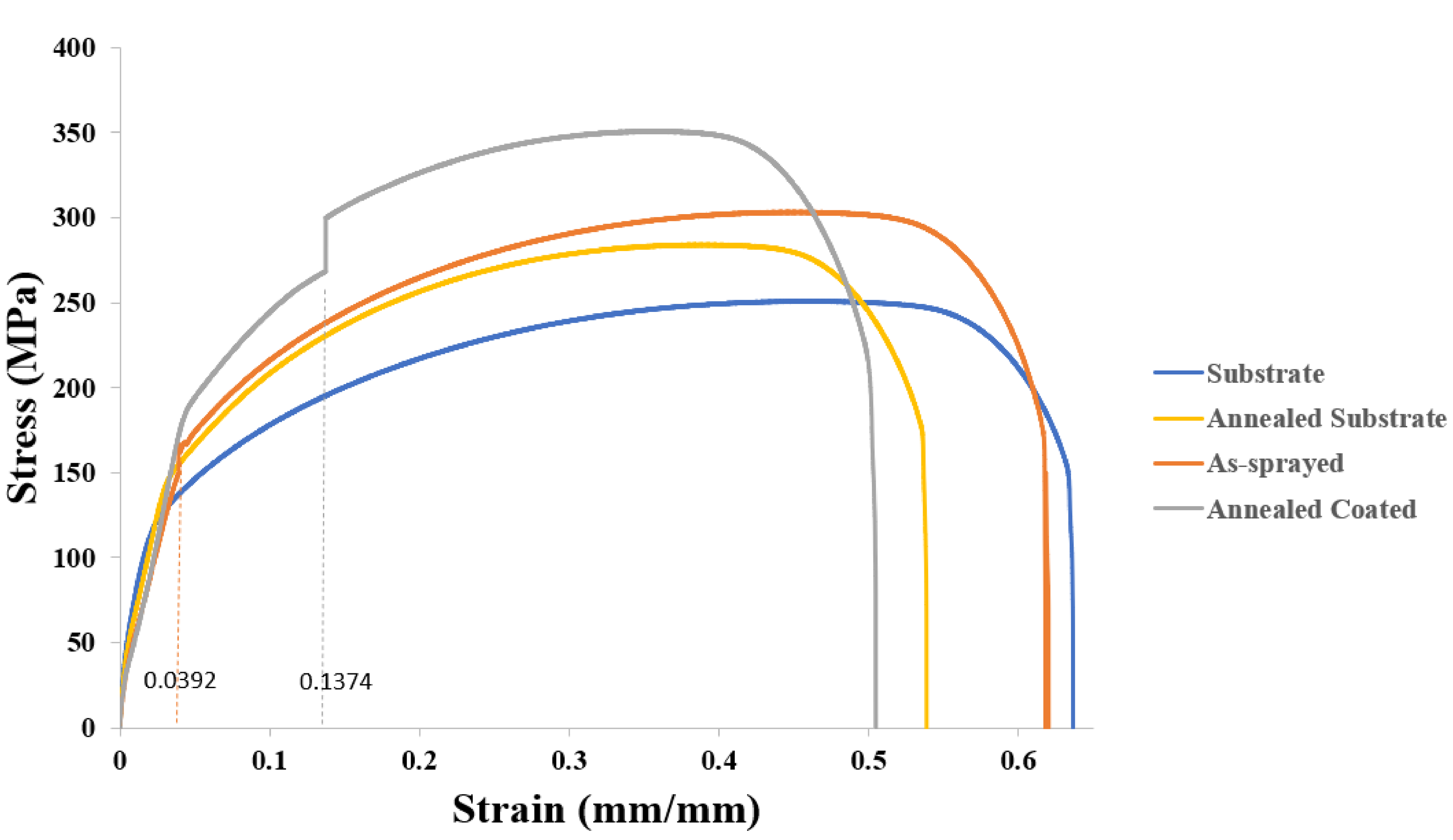
- Cold spray powder: CU-116 (Cu-38Ni from Praxair)
- Substrate: flat sheets of C70600 (Cu-10Ni), 6.35 mm (0.25”) thick.
- Coating of full sheets was performed (after surface preparation) with optimized spray parameters.
- Tensile specimens (ASTM E8/E8M standard) were then cut out of coated sheets.
- Annealing performed on coated samples.

Table of cold spray parameters. Parameters in bold were adjusted to study effect of changes to parameters on coating properties.

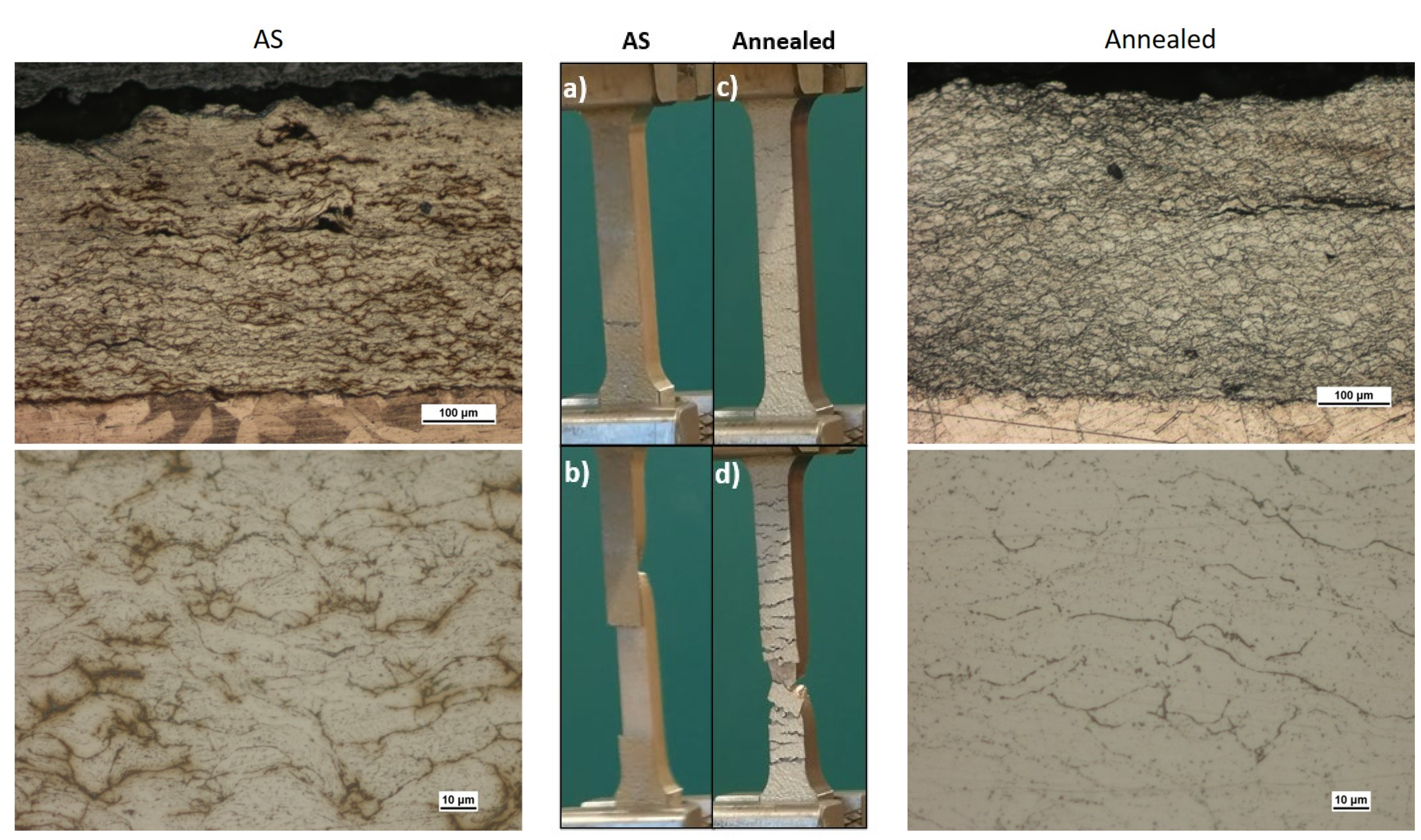
Parameters	Settings
Nozzle Diameter	6.35 mm
Nozzle Standoff distance	12.70 mm
Nozzle Travel Speed	**20 to 50 mm/s**
Spray Angle	90°
Number of Passes	**1, 2, or 4**
Carrier Gas	Nitrogen
Carrier Gas Pressure	**0.69 to 1.38 MPa**
Carrier Gas Temperature	**300 to 500 °C**
Powder Feed Rate	**4 to 20%**

Results & Analysis

- Optimal spray parameters were found to be nozzle travel speed of 30 mm/s, two passes, carrier gas pressure of 1.38 MPa, carrier gas temperature of 500 °C, and a powder feed rate of 15% (~18 g/min).
- Mechanical behavior of the coating for the as-sprayed (AS) and annealed samples were markedly different. The AS coating (dark orange curve below) failed around a single stress (~ 150 MPa) and strain (0.0392) while the annealed (gray curve) coating exhibited significant yielding before final failure at a much higher stress level.



Stress strain curve for uncoated (substrate) and coated (either annealed or as-sprayed, AS) samples.



Comparison of tensile behavior of AS and annealed samples. Optical micrographs of AS sample (right); video stills of AS and annealed samples during tensile loading; and micrographs of annealed sample.

Summary & Recommendations

- The tensile behavior of Cu-Ni cold-sprayed coatings applied to a Cu-Ni substrate was investigated. The coating thickness was targeted to be around 9% the substrate thickness using optimized spray parameters.
- Porosity was observed in the as-sprayed coatings especially along the interface between the two coating layers. Heat-treatment or annealing was shown to reduce porosity leading to enhanced ductility and strength.
- To further improve coating performance, the carrier gas may need to change from nitrogen to helium as the later would possess higher average particle energy that would increase metallurgical bonding.

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Researchers: Prof. Andy Nieto, Prof. Troy Ansell, Dr. Chanman Park, and ME5 Adrian Chua
Graduate School of Engineering and Applied Sciences

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