MATERIAL CHARACTERIZATION OF COLD SPRAYED 3D PRINTED COPPER PARTS

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Introduction

- “Cold Spray” is an additive manufacturing process traditionally used as a tool to repair metal structures/parts.
- Often used to repair aircraft structures that receive extensive wear and would otherwise require often and expensive replacement.
- Spee3D, an Australian research and development company, developed the worlds first commercially available additive manufacturing machine which uses cold spray to build 3D objects.

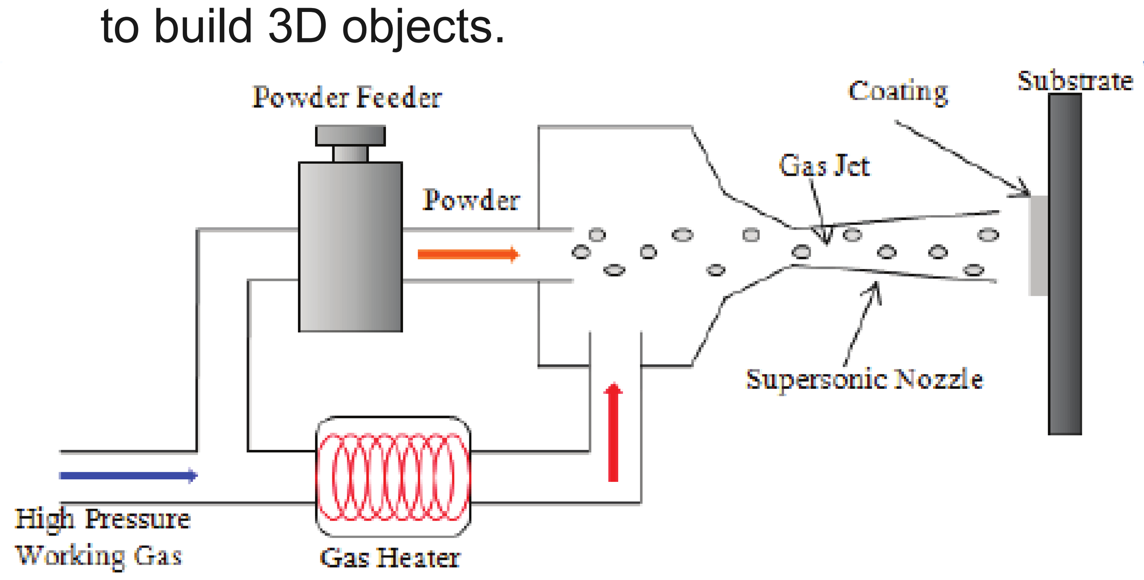

Figure 1: Cold spray diagram

- Metal powder sprayed through rocket nozzle.
- Mechanical bond formed when particles plastically deform.

Figure 2: Spee3D printer in action

Objectives

- Characterize cold sprayed parts for future applications.
- Explore printing parameters to maximize conductivity, ductility and strength.
- Experiment with different annealing times and temperatures to determine ideal post processing procedures.
- Compare specimen conductivity, strength, and ductility to that of “pure” copper.

Specimens printed via cold spray in the Spee3D are printed in environmental conditions. Although heat is not used to bond particles together, there is heat produced in the process. This heat leads to oxidation between layers. The cold spray process also produces brittle parts making annealing a necessary post processing procedure

Procedure

- Rectangular test samples printed onto aluminum substrates.
- Specimens machined to achieve uniform cross-sectional area.
- Using a Fischer Sigmascope, eddy current testing on samples from each category was performed to determine conductivity.
- Compared conductivity data to flexural test data previously done on similar specimens printed on the same machine.

Results

- Higher sprayed-at temperatures are generally slightly higher in conductivity.
- Strong correlation between conductivity and ductility at all parameters.
- Annealing at 500C for 4 hours appears to be best post-processing treatment for obtaining max conductivity and ductility.
- Increased length spent annealing positively impacts both strength, ductility, and conductivity
- Dissipation of oxidation between layers observed in all specimens
- Imperfections become magnified when annealed at 600C

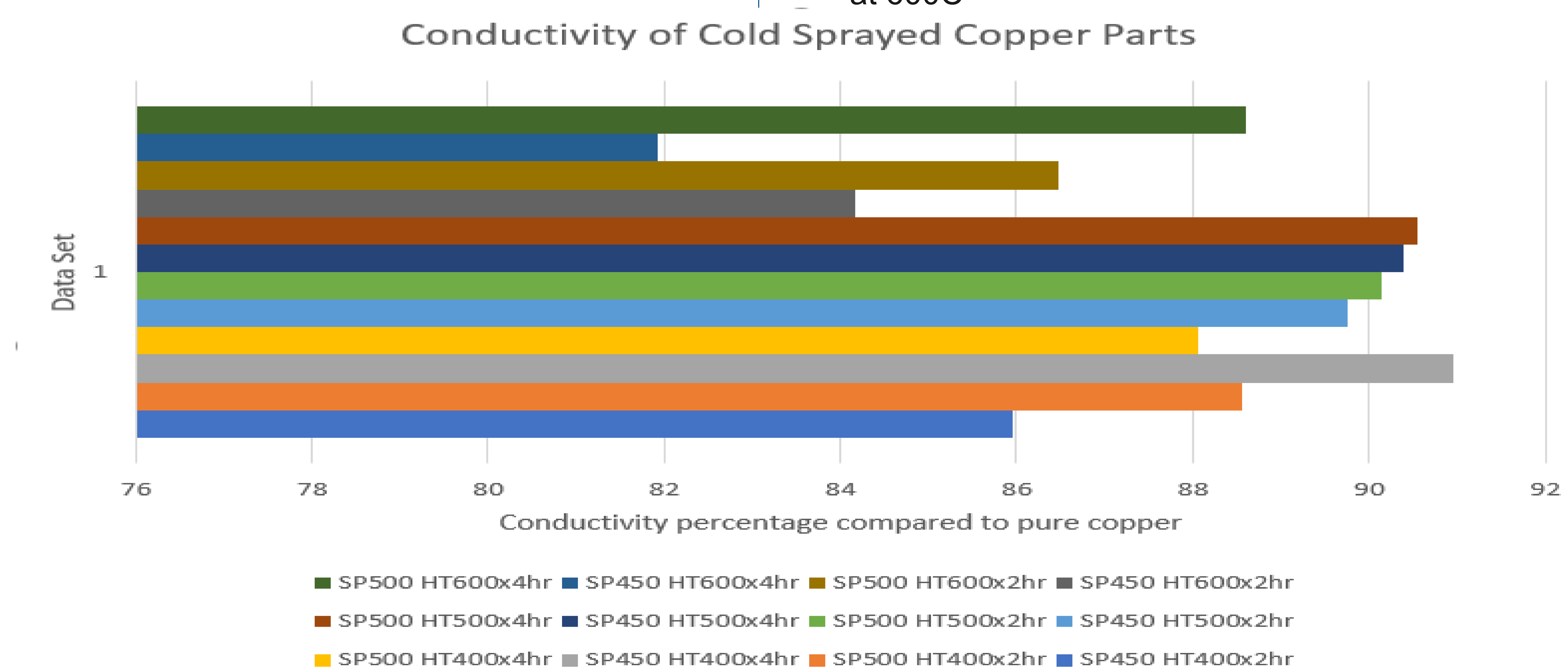

Figure 3: Conductivity percentages of printed parts **Conductivity of pure copper is 100**

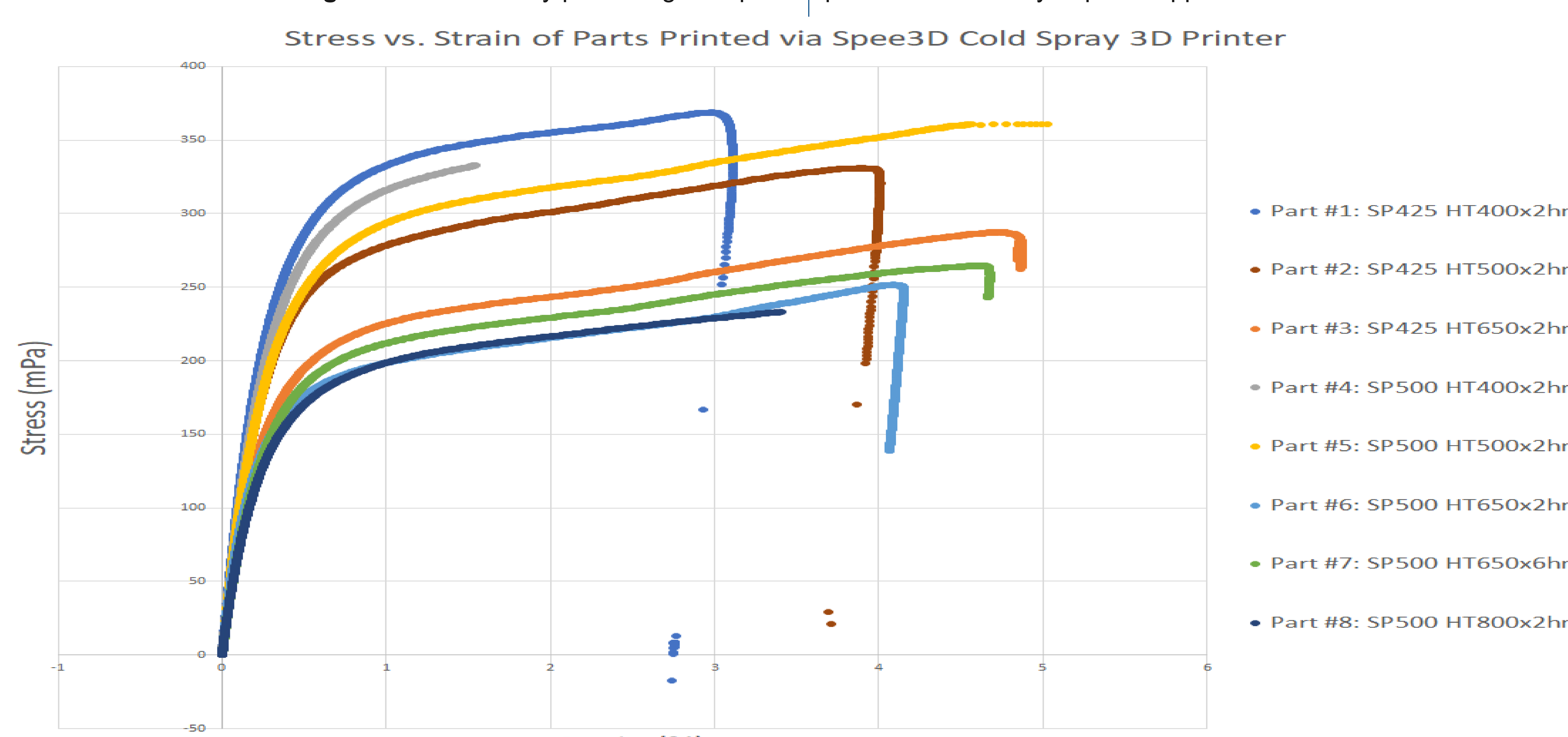

Figure 4: Comparison of specimens of varied printing and post-processing methods

Path Forward

- Replicate previous four-point flexural test results with current specimens:
- Apply strain gauges to each sample
- Follow procedures outlined in ASTM D790
- All samples to be tested in Instron 5567 Universal Testing Machine with 5 kN load cell and strain rate of 0.5 inches per minute
- Flexural stress (σ_f) calculated by

$$\sigma_f = \frac{3}{4}\frac{FL}{bd^2},$$ where

  - F is load
  - L is length of support span
  - b is the width of the specimen
  - d is the thickness of the specimen

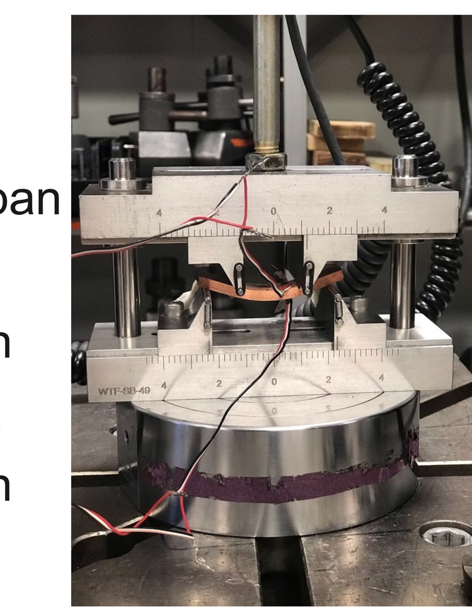

Figure 5: Four-point flexural testing in progress

Future Work

- Apply data to future projects
- Replicate results
- Investigate coating applications and various substrates

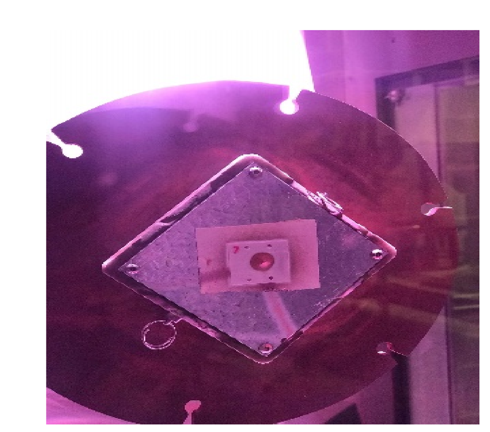

Figure 5: Copper spray adhering to zirconia ceramic

Figure 7: Shaped charge liner

Acknowledgements

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