Cost and Lead Time Reduction of Replacement Piping using Additive Manufacturing

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Research Question

The pipeline system failed due to poor mechanical performance of conventional parts/weld (SS316) under corrosion and extreme conditions such as high pressure, severe loading and so on. Selective Laser Melting (SLM) printed SS 316L could be the potential improvement for its quicker turnaround time and better mechanical and corrosion performance. Here, the mechanical and corrosion performance of SLM printed SS 316L is analyzed and compared with wrought SS 316L using pressure testing, uniaxial tensile testing, electrochemical methods, gravimetry, and microscopic characterization

Materials & 3D Printing

Figure 1 : Failure of pipelines made of wrought materials

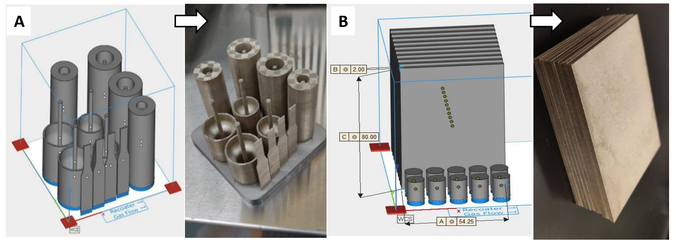
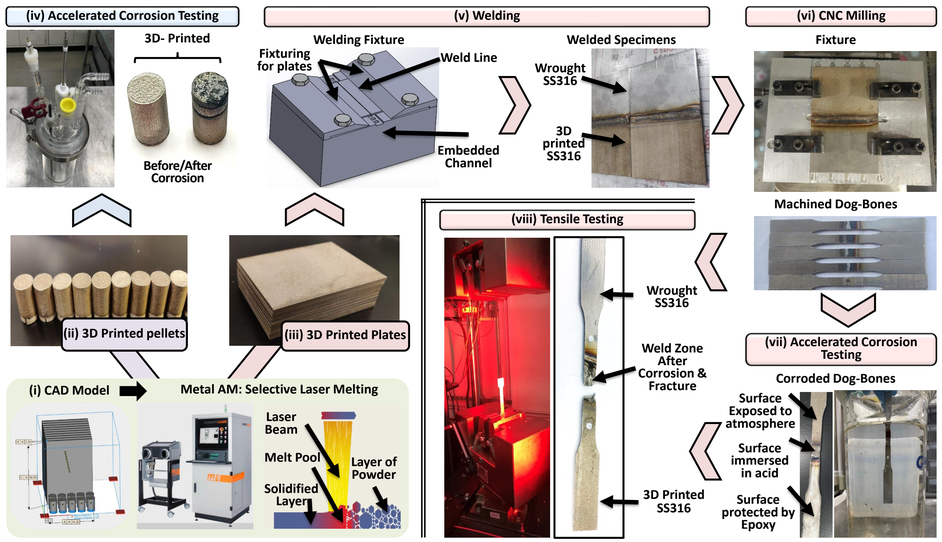


Figure 2: CAD model and 3d Printed specimens a) pipes, b) plates for Selective Laser Meting (SLM) printing

Corrosion, Welding & Mechanical Testing Setup



Flow diagram of the prepared samples (starting on the bottom-left corner): (i) 3D printing of SS 316L parts in two formats: (ii) pellets and (iii) plates. Pellets are submitted directly to (iv) accelerated corrosion testing while plates undergo (v) welding with its wrought counterpart and (vi) CNC milling for dog bone preparation. Next, a set of dog-bones undergo (vii) accelerated corrosion of the weld-zone only before (viii) tensile testing and another goes directly to it (viii) without corrosion

Pressure Testing

Tested 3D printed Pipes at high-pressures and low pressure to demonstrate mechanical integrity and strength of 3D printed pipes. The successful pressure test results are as follows:

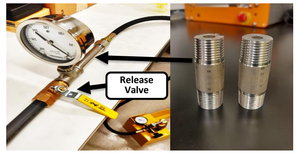


Figure 4: (left) Pressure setup, (right) 3D printed pipes to be tested

1) Low-pressure leak test successfully completed (@ 50 psi)
2) High-pressure leak test successfully completed (@ 725.2 psi)

CPP and Chronoamperometry

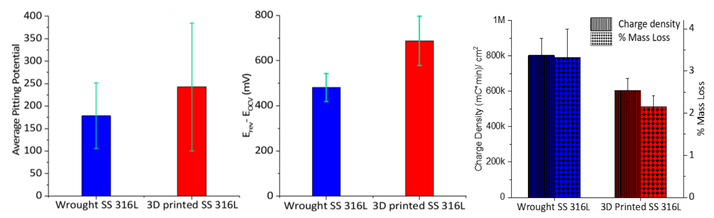


Figure 5: Cyclic Potentiodynamic Polarization (CPP) results (a) column bar comparing the average pitting potential of wrought and 3D printed SS 316L, (b) column bar comparing the average Erev- EOCV of wrought and 3D printed SS 316L

Figure 6: Comparison of Integral under the curve- corrosion-time transient and % mass loss from gravimetric analysis

Electrochemical Impedance Spectroscopy

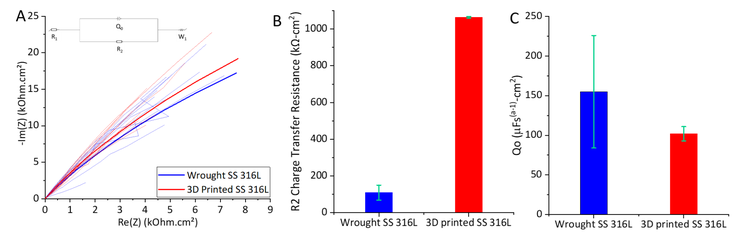


Figure 7: EIS test for the wrought and 3D printed SS 316L samples A) Nyquist plot B) comparison of charge transfer resistance R2 and C) comparison of constant phase element Qo . Error bar is the standard deviation for all the Z fits.

SEM Images and Tested Specimens

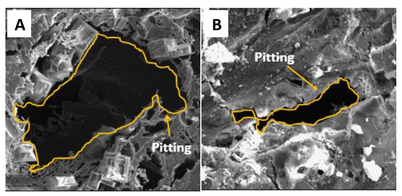


Figure 8: SEM Micrographs of A) Wrought SS 316L and B) 3D printed SS 316L after the same corrosion conditions

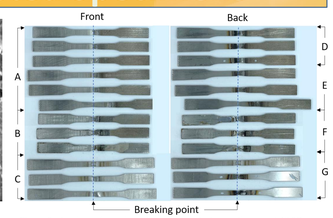


Figure 9: A subset of tested specimens post uniaxial tensile test: a) W-3D non corroded, b)W-3D corroded, c)W-W non corroded, d) W-3D non corroded failed at weld, e)W-3D non corroded failed at wrought, f)W-3D corroded failed at weld, g) W-W non corroded failed at weld (reference)*

Mechanical Tensile Testing

Tensile testing of welded samples (Wrought and Printed SS 316L) is carried out and the engineering stress-strain curve is plotted to analyze mechanical properties. It is observed that more than 80% of the samples as shown below failed at weld interface between wrought and weld zone which implies the better weld strength between weld zone and 3D printed parts.

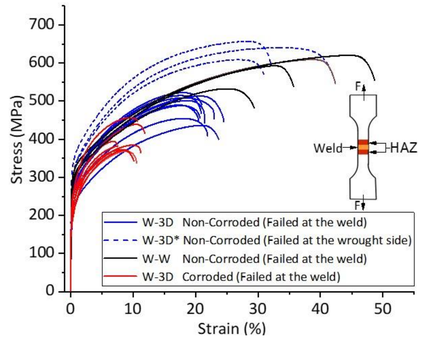


Figure 10: : Mechanical Tensile Testing Stress (MPa) vs Strain (%) curve for W-W non-corroded, W-3D non-Corroded, W-3D non-corroded,W-3D corroded including dog-bone specimen with heat affected zone (HAZ) and weld line under uniaxial tensile force (F)*

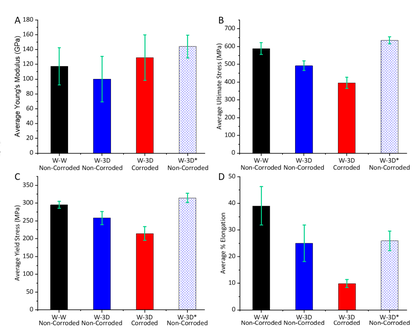


Figure 11: : Comparison of mechanical properties by sample type derived from uniaxial tensile tests for W-W non-corroded, W-3D non-corroded, W-3D non-corroded and W-3D corroded specimens, including: (a) average Young's modulus, (b) average ultimate stress, (c) average yield stress, and (d) average percentage elongation*

Conclusion

With the scope of this study, the following can be drawn:

1. 3D printed pipes can effectively work under high (725.2 psi) and low pressure (50psi) without leakage.
2. Both the pressure and tensile testing conveys that the SLM printed SS 316L can be used as replacement parts in pipeline system for quicker turnaround time and improved mechanical performance
3. Cyclic Potentiodynamic Polarization, Chronoamperometry and EIS along with Scanning Electron Microscopy images shows that the 3D printed parts are more resistant to corrosion as Manganese Sulphide) MnS precipitates are less in SLM printed parts when compared to wrought
4. The combination of quicker turnaround time and better mechanical performance of 3D printed parts can effectively reduce cost and lead time.

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