# 3D Printing of Stainless-Steel Replacement Piping for Corrosive and Low-Pressure Environments

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## Research Question

Process water containing salts and ions react with surfaces causing uniform and pitting corrosion leading to frequent failures. Selective Laser Melting (SLM) printed SS 316L could be the potential improvement for quicker turnaround time and corrosion performance. Here, the corrosion performance of SLM printed SS 316L is analyzed and compared with wrought SS 316L with electrochemical methods, gravimetry, and microscopic characterization

## Materials & Printing

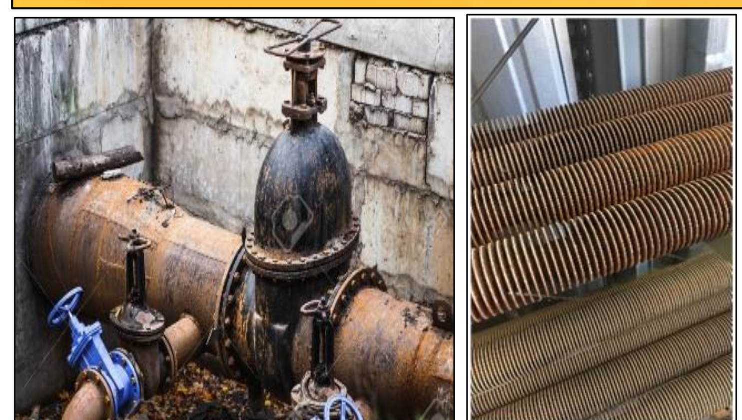


*Figure 1 : Corrosion of pipelines made from wrought materials*

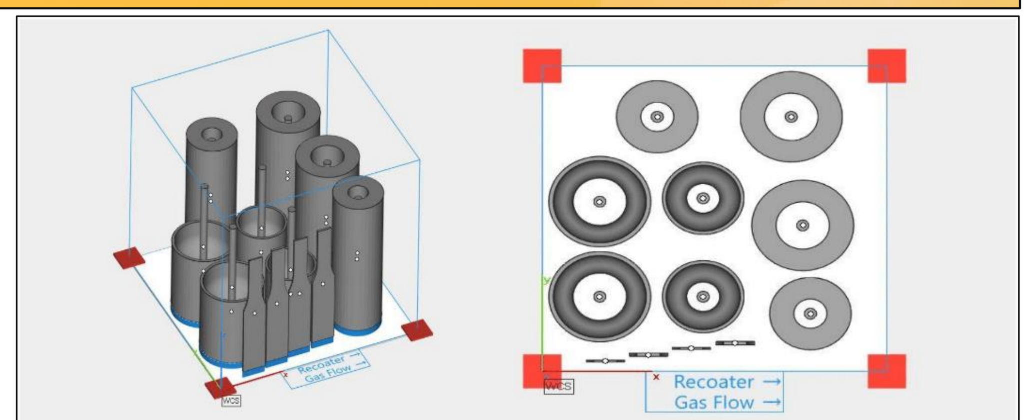



*Figure 2: CAD Design for Selective Laser Meting (SLM) printing of SS316L*

ASU Manufacturing: Metal Additive Facility

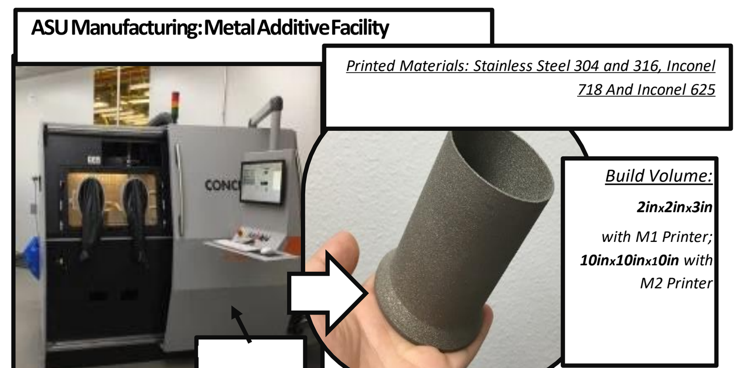



*Figure 3: Selective Laser Melting / Powder Bed Fusion Machine for 3D printing of Stainless Steel*

*Figure 4: (left) SLM-printed parts on build plate, (center-left) build plate mounted onto wire EDM, (center-right) 3D printed parts, (right) threaded 3D printed parts.*

## Methodology

Chronoamperometry is conducted by applying a constant voltage of 1250 mV for 30 minutes , the corresponding current is recorded as the function of time. The initial and final weight of the specimens are measured to get the percentage mass loss.

CPP is conducted by scanning the potential from the open circuit potential to the potential at which the current reaches 5 mA, then the potential is reversed to open circuit potential.

EIS test is conducted by applying a sinusoidal potential of 10 mV from a frequency range of 10000 Hz to 100 Hz. The Nyquist impedance plot is plotted between the imaginary and the real part of the impedance.

## Corrosion Testing Setup

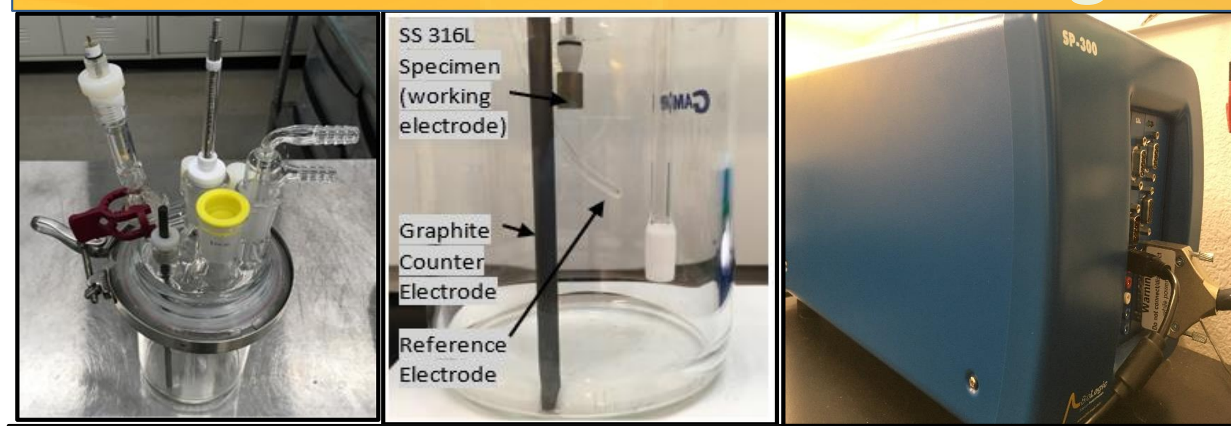
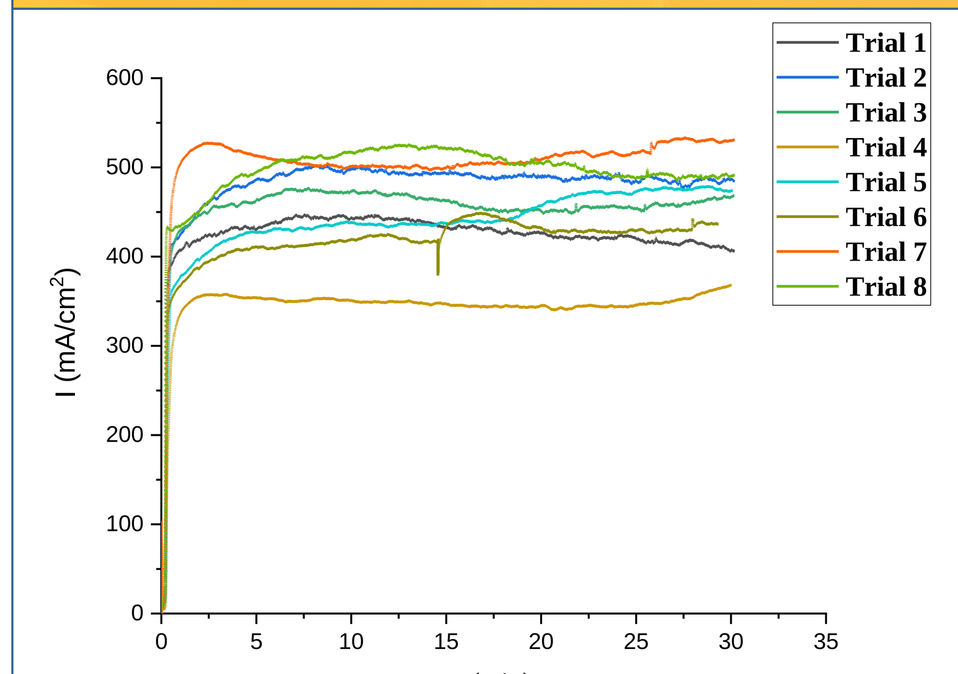
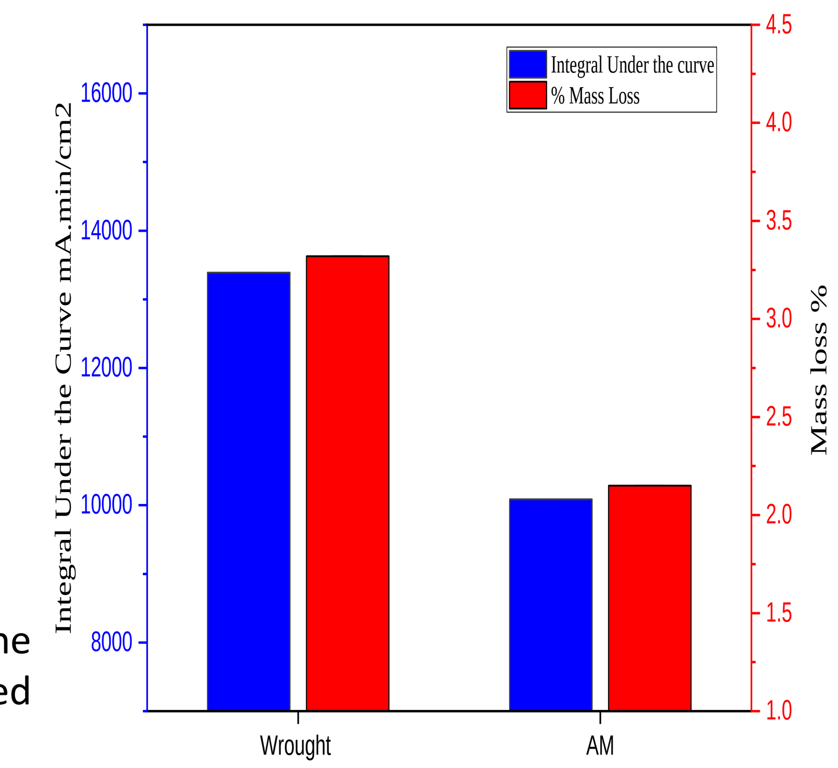



*Figure 5: (left) EC Cell (Center) Electrode setup inside EC Cell, (Right) Potentiostat*

*Figure 6: Specimens for corrosion testing*

## Chronoamperometry



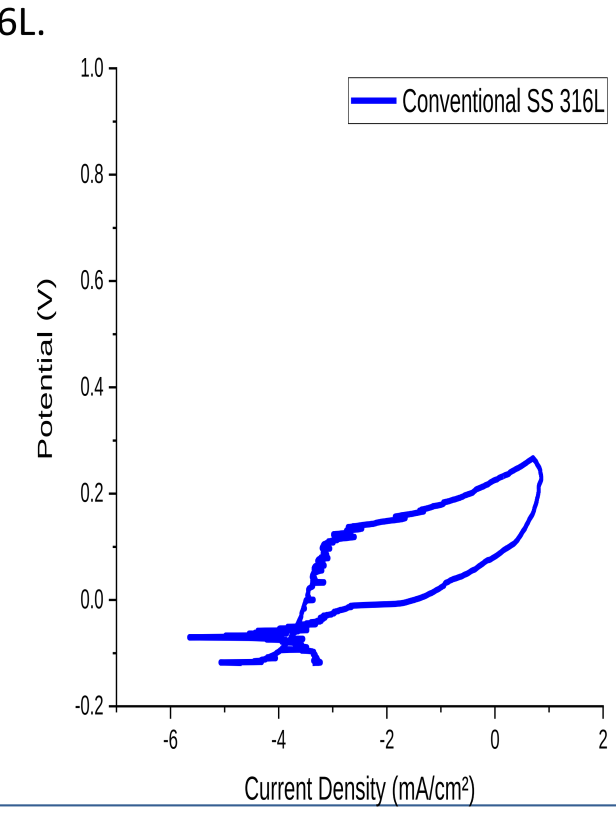



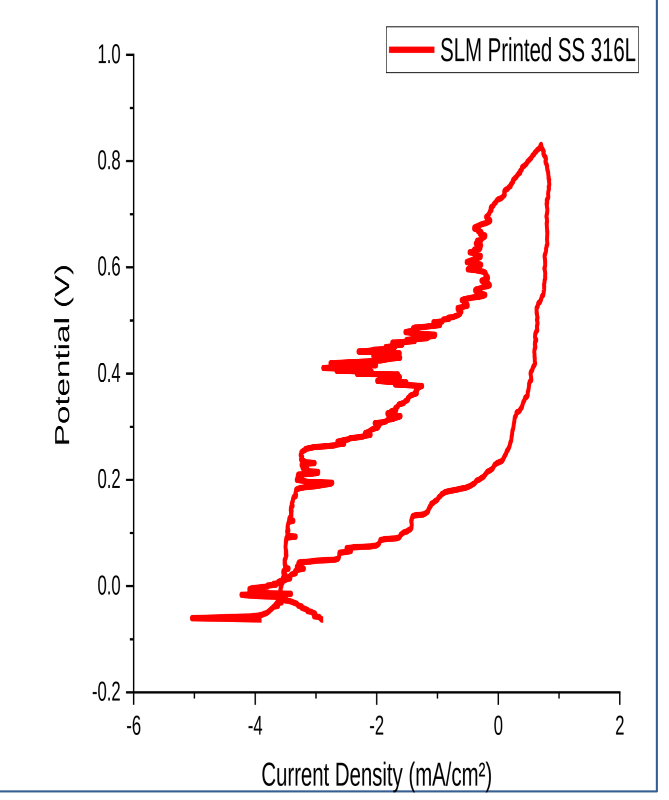

The wrought SS 316L has larger integral under the curve and percentage mass loss than the SLM printed SS 316L

## Cyclic Potentiodynamic Polarization (CPP)

From the CPP, it is apparent that the pitting resistance of the SLM printed SS 316L is greater than the wrought SS 316L. This shows that the onset of corrosion is delayed in SLM printed SS 316L and relatively quicker in wrought SS 316L.

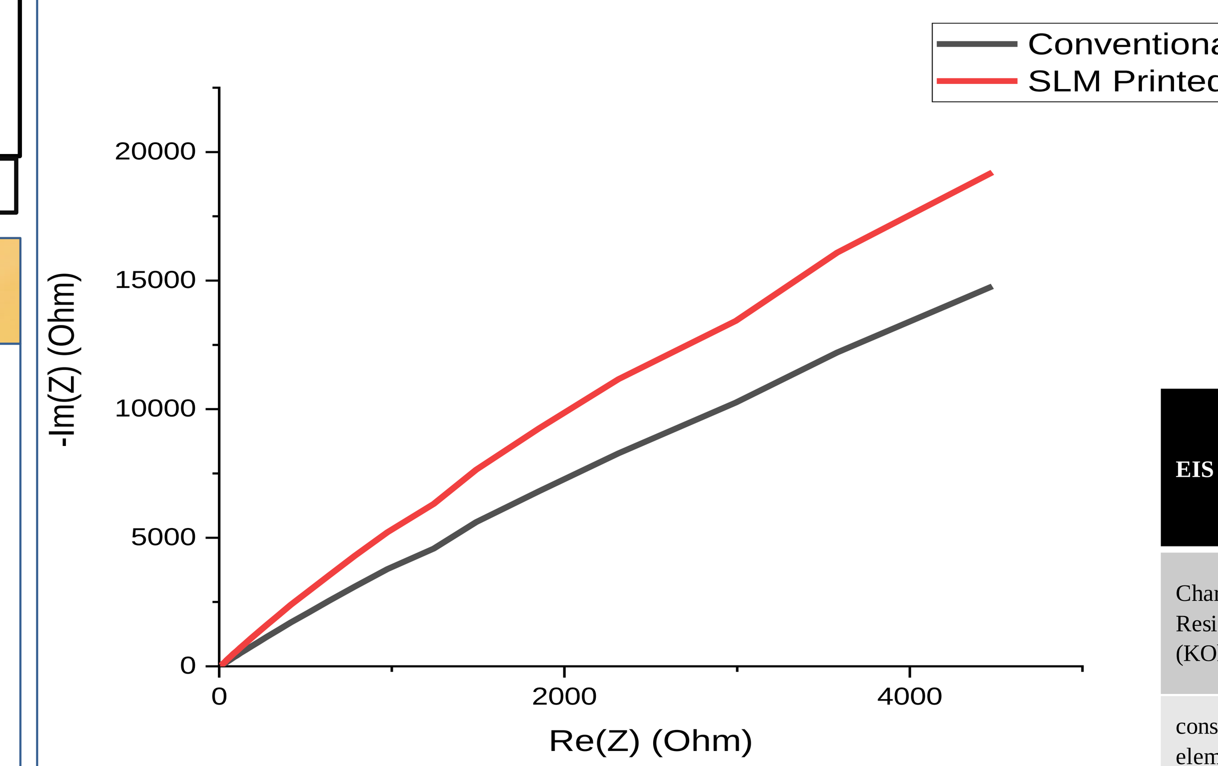
| CPP results | Wrought SS316L | 3D Printed SS316L |
|---|---|---|
| Open Circuit Potential (mV) | -115 | -105 |
| Pitting resistance (mV) | 471 | 697 |




## Electrochemical Impedance Spectroscopy

EIS results show that the charge transfer resistance of the SLM printed SS 316L is greater than the conventional SS 316L, also the constant phase element is less than the conventional 316L which is indicative of the dielectric characteristics of the specimen. The lesser constant phase element shows the stability of the oxide layer in the SLM printed SS 316L.




| EIS Results | Wrought SS316L | 3D Printed SS316L |
|---|---|---|
| Charge Transfer Resistance $R_{ct}$ (KOhm-cm$^2$) | 237 | 472 |
| constant phase element Qo (F.s$^{(a-1)}$-cm$^2$) | 0.000 15491 | 0.0001 2674 |

## Conclusion

The three electrochemical tests show that the corrosion resistance of the SLM printed 316L is better than the conventional SS 316L . One of the theoretical reasoning from the literature is that the MnS inclusions or precipitates, which act as the spots for corrosion initiation, is absent on the surface of the SLM printed SS 316L because of the rapid quenching during the SLM process

## Future Work

The next phase of the project would be to test the corrosion properties and the weld strength of the welded SLM printed 316L to the Wrought 316L and the microscopic characterization of the corroded and non-corroded specimens using SEM and EDS analysis.

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