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Corrosion Properties of Additively Manufactured 304L Stainless Steel

Introduction

Traditional manufacturing of wrought stainless steel parts by block milling, cutting, and welding sheets can be time consuming and limits design capabilities. Additive manufacturing (AM) allows custom, often intricate shapes, to be fabricated, which cannot be achieved via traditional methods. Different manufacturing processes results in microstructural changes, which can lead to different corrosion properties within the same alloy. Electrochemical testing in a seawater analog, 0.6M NaCl solution, was used to determine the differences in corrosion behavior of 304L stainless steel processed via a laser powder bed fusion (LPBF) additive manufacturing technique and a traditional wrought processing.

304L Coupons

Coupons were cut from 1”x1” bars of wrought and LPBF 304L Stainless steel. Each coupon was sanded to a 1200 grit finish and degreased. A laser cut polymide mask was applied to each coupon (Figure 1b). Each circular test area was measured and imaged pre and post test using a Keyence VHX-2000 optical microscope.

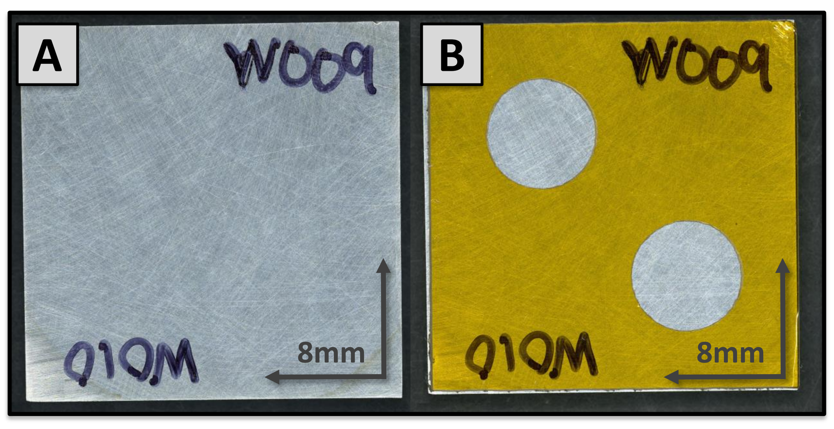


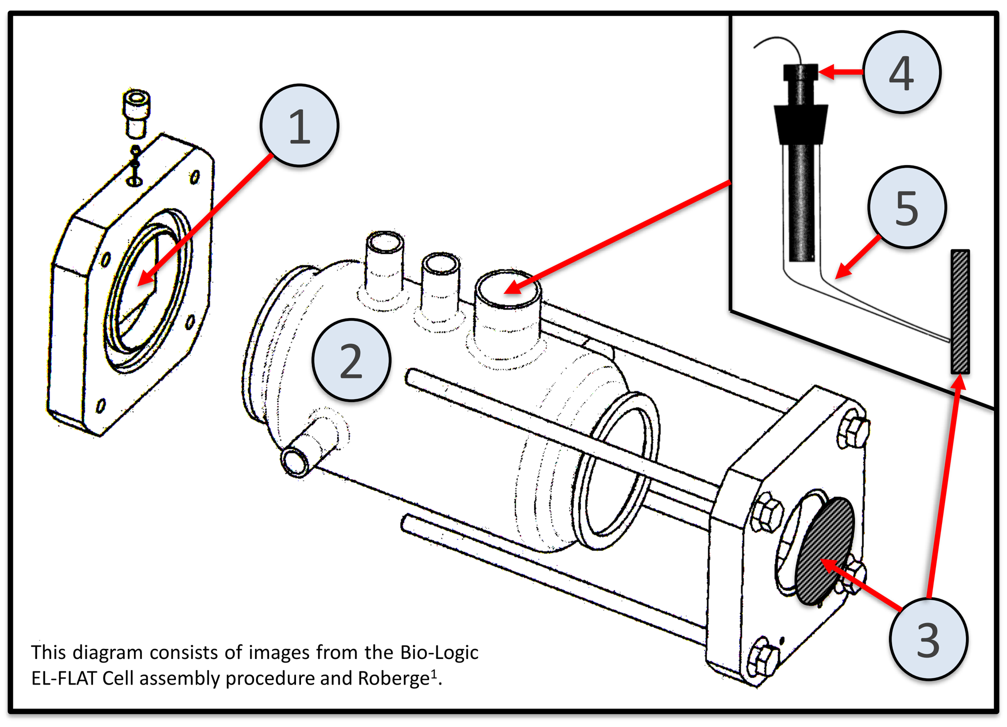
Figure 1: (a) Bare coupon of wrought 304L stainless steel (b) Same coupon with a polymide mask.

3-Electrode Flat Cell

A Bio-Logic EL-FLAT 3-electrode flat cell was used in combination with a bridge tube (5) and a Ag/AgCl / 3M NaCl saturated reference electrode (4). The reference electrode, used to determine a zero potential point, in combination with the bridge tube are connected to the flat cell’s 0.6M NaCl solution filled glass chamber (2). The bridge tube’s tip is placed in close proximity to the working electrode (3), the test coupon, which is clamped in place so that only the masked test area is exposed to the solution. A platinum mesh counter electrode (1) is placed in contact with the solution on the opposite end of the chamber as the working electrode.

Figure 2: Diagram of the major components of the 3 electrode flat cell.

(1) Platinum mesh counter electrode
(2) Glass chamber + 0.6M NaCl Solution
(3) Working electrode (304L Coupon)
(4) Ag/AgCl / 3M NaCl reference electrode
(5) Bridge Tube



Electrochemical Testing

Each electrochemical test consists of two phases. First is a one hour open circuit monitoring phase. During this phase the potential is measured as the sample stabilizes in a 0.6M NaCl solution (Figure 3a). The second phase is a potential sweep of 1.25V administered at a rate of 10mV/min. Both LPBF and wrought 304L underwent three separate anodic sweeps and three cathodic sweeps. The current is monitored during this phase as the potential changes (Figure 3b). All testing was done using a Bio-Logic SP-200 Potentiostat with an Ultra Low current cable attachment.

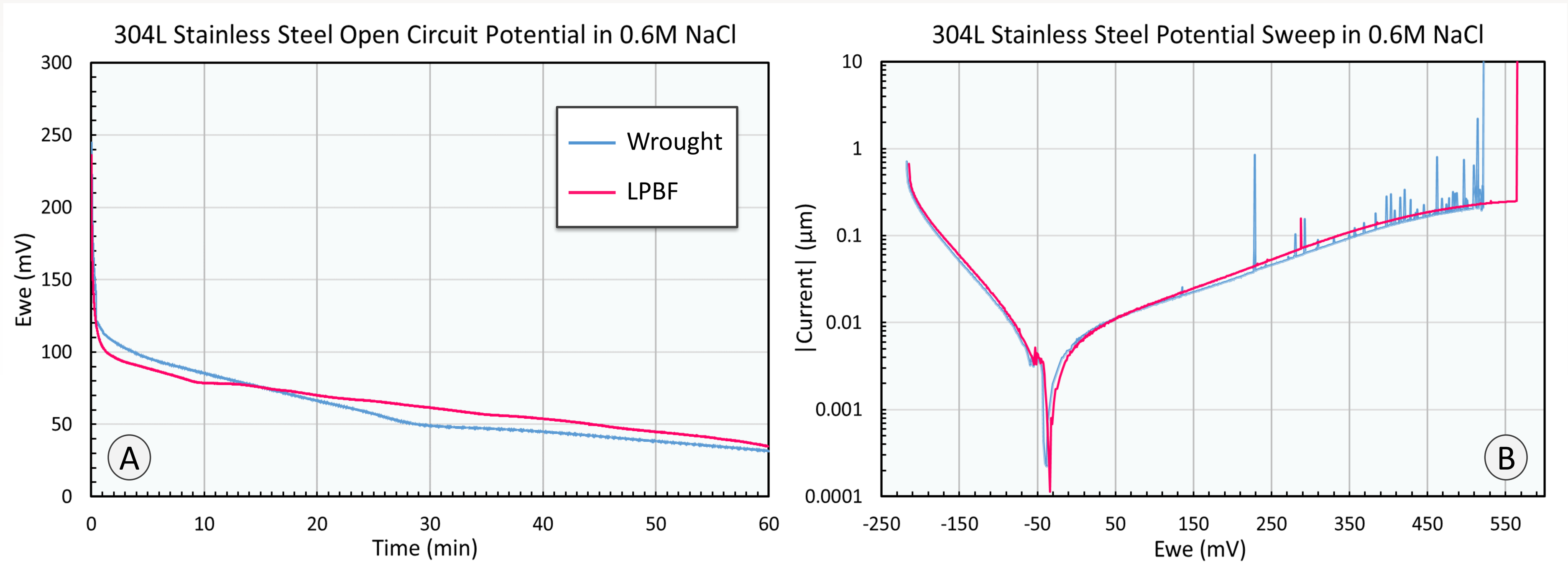


Figure 3: (a) Monitored potential during a one hour open circuit test. (b) Absolute current vs potential as a potential sweep in done.

Results

The corrosion current for each test was found using the Bio-Logic EC-Lab software’s tafel plot calculator functionality. Using the corrosion current and the measured test area, the current density was calculated and converted to a corrosion rate measured in millimeters per year (mmpy).

Type	Current Density (A/cm^2)	Corrosion Rate (mmpy)
Wrought	$(1.00 \pm 0.34) \times 10^{-8}$	$(3.2 \pm 1.1) \times 10^{-5}$
LPBF	$(1.06 \pm 0.65) \times 10^{-8}$	$(3.4 \pm 2.1) \times 10^{-5}$

Conclusion

Electrochemical testing shows that, when similar surface finishes are applied, LPBF manufactured 304L stainless steel in 0.6M NaCl solution has similar corrosion properties to its traditionally manufactured counterpart.

References

[1] Roberge, Pierre R. Corrosion Engineering Principles and Practice. New York: McGraw-Hill, 2008. Print

[2] Schaller, Rebecca F., Jason M. Taylor, Jeffrey Rodelas, and Eric J. Schindelholz. "Corrosion Properties of Powder Bed Fusion Additively Manufactured 17-4 PH Stainless Steel." Corrosion 73.7 (2017): 796-807. Web.

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