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A Comparative Evaluation of Additive Manufactured Stainless Steel Test Pieces

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A Comparative Evaluation of Additive Manufactured Stainless Steel Test Pieces

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Background

- Stainless steel is used for variety of applications with different grades, alloys, filaments and powders.
- Additive manufacturing (AM) enables unique design features and refined microstructures.
- Performance testing on AM parts are needed as input to modeling and accelerated qualification processes.
- The objective of this work is to determine the effect of surface roughness on corrosion rate for from different manufacturers.

Methods

Surface Roughness Testing:

- Initial surface roughness measurements were performed on each of the 72 samples.
- The surface roughness measurements were performed employing a Mitutoyo SJ-210 portable surface roughness tester.
- The calibration was executed employing a precision reference specimen (Ra: 2.94 µm).

Corrosion Rate:

Reference: ASTM G-1,G-31,G-42:

Corrosion rate = (K x W)/(A x T x D)
K = constant (mils per year- mpy)
T = time of exposure (0.01 hrs)
A = area in cm^2 to nearest 0.01 cm^2
W = mass loss in g, to nearest 1mg
D = density in g/cm^3

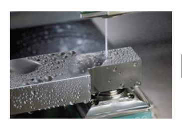
Sample Test Groups:

- 500, 1000 and 1500 hours.
- Each group was separated into smaller sections to investigate different surface structure and the effect of annealing.
- Sample groups are also reviewed to investigate vendor preference.

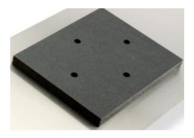
Initial Setup

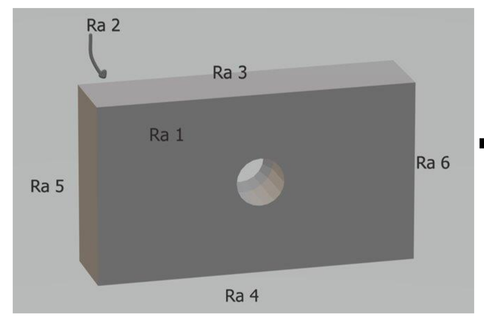

Polished


AM

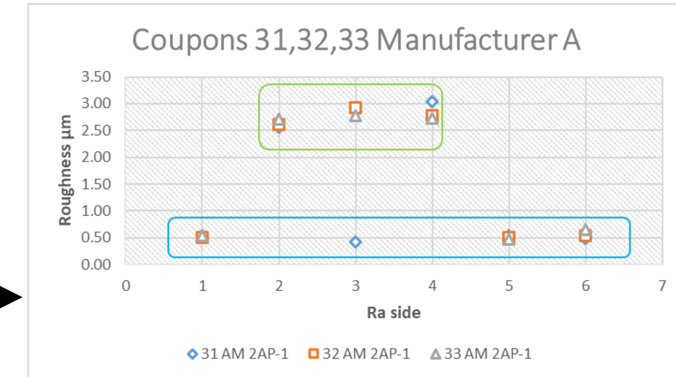

EDM

Annealed



As-Printed

Sample Layout


Roughness Tester

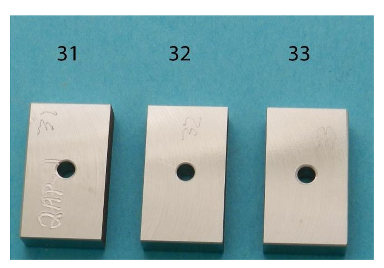



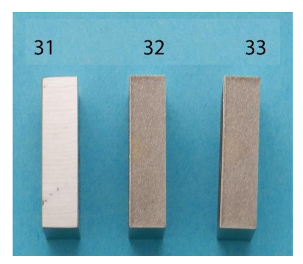
Coupon ID	Material	Temp ©	Ra 1	Ra 2	Ra 3	Ra 4	Ra 5	Ra 6
31	AM 2AP-1	50	0.54	2.57	0.42	3.04	0.53	0.49
32	AM 2AP-1	50	0.50	2.61	2.93	2.77	0.51	0.54
33	AM 2AP-1	50	0.54	2.71	2.77	2.73	0.47	0.66

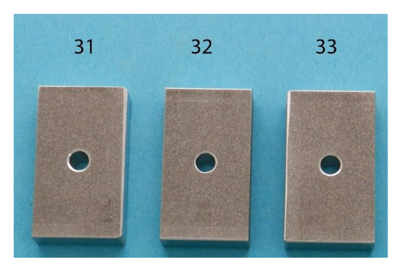
Figure(s) above shows roughness measurement results for the different faces of samples 31-33.

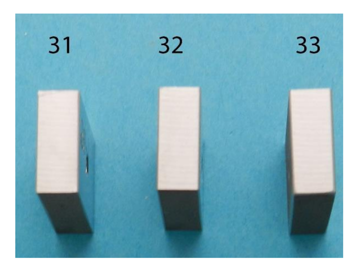
- Surfaces studied were additively manufactured, polished and electrical discharge machined (EDM). Hardness testing measurements in µm.

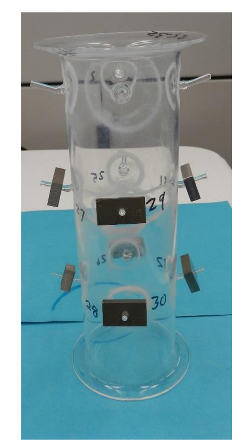
Pre 5% NaCl Immersion

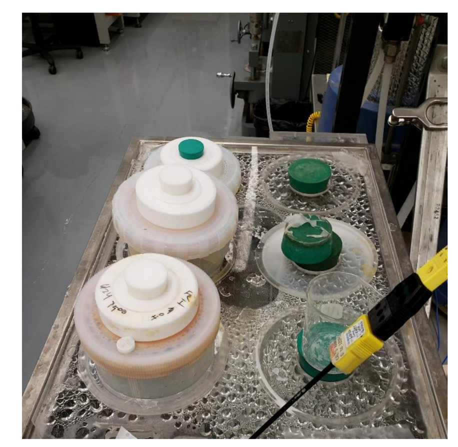
Ra 1


Ra 3


Ra 2


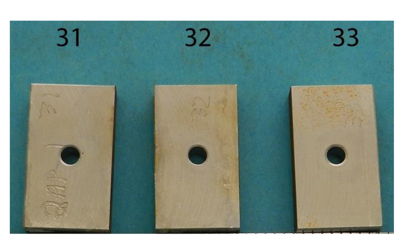
Ra 5


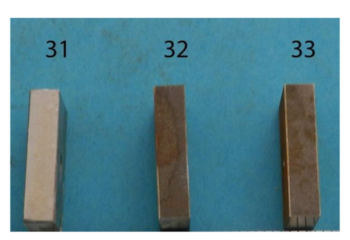
Sample Frame


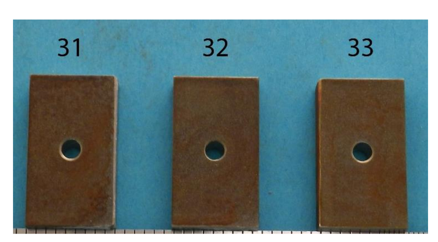
5% NaCl Immersion at 50°C


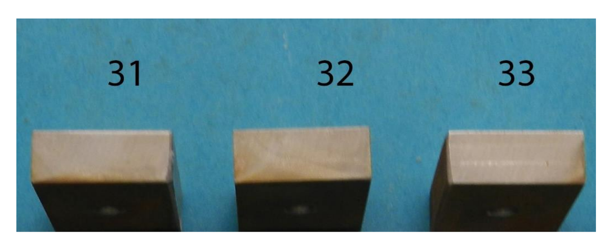
- Samples were placed into static solution for predetermined time. Samples 31-33 above taken from the 1000-hour data set.

Post 5% NaCl Immersion

Ra 1


Ra 3


Ra 2


Ra 5


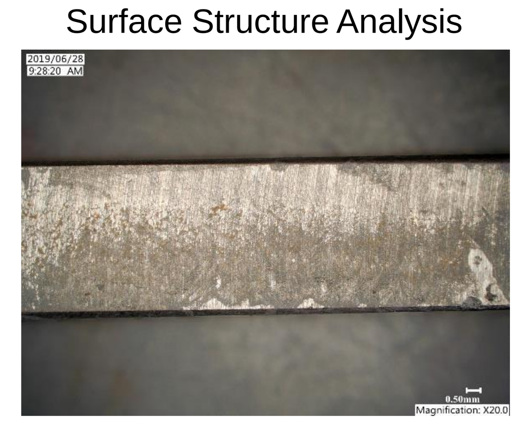
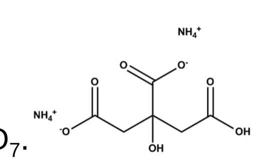
Surface Structure Analysis


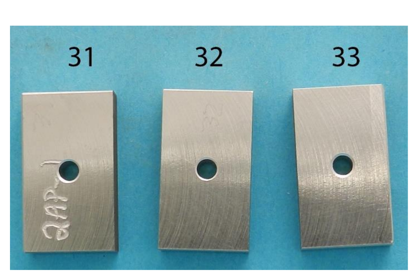
Image above displays post NaCl immersion Ra3 (top) for sample 31.

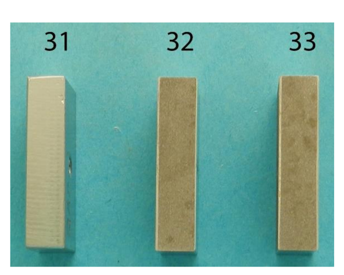
- Corrosion Solvent used for cleaning: Ammonium Citrate Dibasic, $C_6H_{14}N_2O_7$.

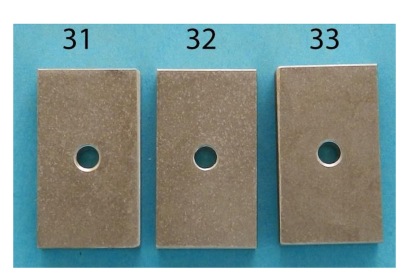


Surface structure analysis was completed with the Keyence VHX-6000 at ~20x magnification.

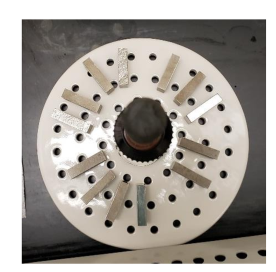
Post Corrosion Cleaning

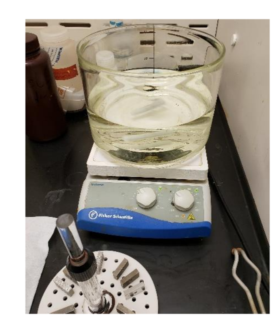
Ra 1


Ra 3


Ra 2


Ra 5



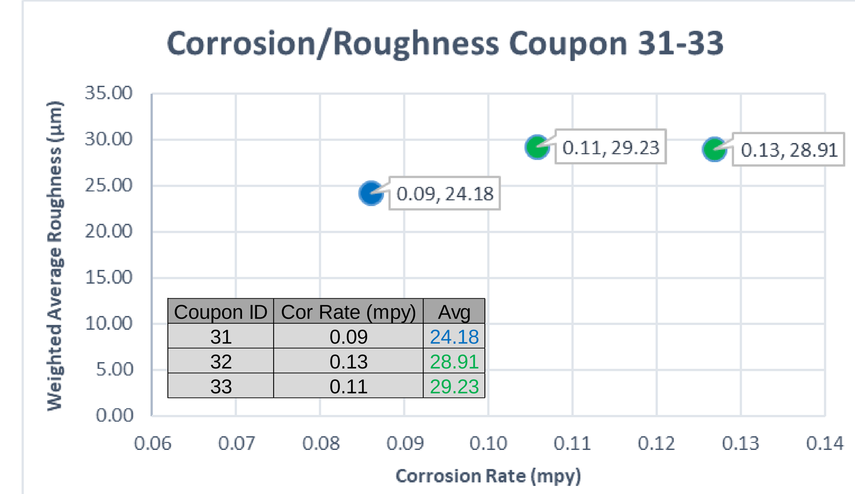
Coupon ID	Material	Time (hr)	*Cor Rate (mpy)*	*%POL*	*% EDM*
31	AM 2AP-1	1000.00	**0.09**	**57.05**	**42.95**
32	AM 2AP-1	1000.00	**0.13**	**44.50**	**55.50**
33	AM 2AP-1	1000.00	**0.11**	**44.69**	**55.31**

Table displays corrosion rates for samples 31-33.

- The corrosion weight loss stabilized four cleaning cycles, each cycle was 8 minutes with predetermined temperature and flow requirements based on ASTM-G-31.

Discussion and Preliminary conclusions

- Although data analysis are in progress, as expected, the corrosion rate are lower on the polished surfaces compared with the surface finished as manufactured.



Coupon ID	Cor Rate (mpy)	Avg
31	0.09	24.18
32	0.13	28.91
33	0.11	29.23

In the graph above the weighted average roughness was calculated by the percent surface area of the side (Ra #) divided by the total surface area then multiplied by the side surface roughness.

- Preliminary evaluation shows that the 500-hour data set was scattered, and trend analysis are complex, while the 1000h and 1500h test results evaluation show more distinct trends.

Future Work

Further analysis of the collected data aim to provide:

- A corrosion rate comparison between two manufacturers.
- Effect of increased corrosion holding time on the corrosion rates.
- The effect of annealing has on AM surfaces.

Acknowledgements

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