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A Comparison of Corrosion Resistance of Stainless Steel Fabricated with Selective Laser Melting and Conventional Processing

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Abstract: Selective laser melting is a recent technology which directly manufactures parts from metal powders. This paper mainly deals with the comparison of corrosion resistance behaviour of selective laser melted part and conventionally processed part. Moreover this paper also focuses on the microstructure and mechanical properties of the SLM and conventional part. The experimental studies reveals that SLM part have better corrosion resistance than the conventional.
The corroded morphology of SLM part depicts fine sized pores, whereas in the case of conventional one the size of the pore is larger. Hence the mechanical properties of SLM part are significantly better than that of the conventional one.
Keywords: SLM, Stainless Steel, Electrochemical Corrosion.

1. Introduction

Selective laser melting (SLM) enables the fabrication of additive manufacturing components with complex shapes directly from metallic powder[1,2]. Moreover, this technology is a promising method for production of functionally graded multi-material parts[3,4]. In laser melting process, parts are usually fabricated by melting a thin layer of metal powder on the substrate or on a previously melt layer using laser beam. In this process the interaction of the powder and laser beam raises the temperature to the melting point [5]. It influences the particle bonding/fusing themselves and the substrate to form the solid. The laser power is adjusted to bring the selected area of the powder to a temperature at which the particle just sufficient to get melted/bonded. Melting may take place through softening or partial melting of powder particles themselves or with the substrate. In this approach the melting begins when the viscosity of the grain drops with temperature creating an interfacial bonding of the grains without full melting[6,7].

Due to higher laser heating the microstructure, physical properties and corrosion behavior of an alloy alters [8-10].

Zeng et al.[11] stated that due to the presence of the fine-scale microstructure, the HV of the SLM specimens was higher than that of traditional cast specimens. According to Qin et al.[12] corrosion resistance can be improved with a decrease in grain size, although those casting defects did not lead to a significant difference in the corrosion resistance of the alloys.

The purpose of this study was to differentiate the changes in the corrosion behavior of an austenitic stainless steel alloy fabricated by the SLM technique and conventionally processed alloy. The main purpose of this study was to confirm that the SLM technique should have no significant effect on the corrosion behavior of an austenitic stainless steel alloy at any condition.

2. Experimental Procedure

Two set of austenitic stainless steel specimens were dedicated for the corrosion studies, one set processed by laser melting technique and another by traditional. All the specimen surfaces were polished through wet grinding with a series of silicon carbide papers (1200 grit) with a grinder-polisher machine. Each specimen were ultrasonically cleaned for 10 minutes in 95% ethanol and rinsed with distilled water to remove residual cleaner.

Microstructural characterization was performed by digital optical microscope. The surfaces of the porous alloys for microscopic analysis were mechanically polished with emery paper with 800 up to 2000 grit, degreasing in acetone, rinsing with ethanol and deionized water and then drying in air. Pore structural parameters were determined by quantitative image analysis using commercially available Image-Pro Plus software.

The Vickers hardness (HV) was measured for the specimens of each alloy, before and after firing, with a hardness tester. All the tests were conducted by using a load of 20 kg.f and a contact time of 10 seconds with the application of a 136-degree diamond pyramid penetrator. Each specimen was measured at 3 points around the center, and the measurements were repeated at each position to obtain the final HV values.

2.1 Potentiodynamic polarization study

To analyse the corrosion properties of both normal stainless steel and selective laser melting stainless steel, potentiodynamic polarization test was carried out. It was performed by using a computer controlled CH Instrument potentiostat (model: CHI604D) with CH software pack. In this experiment, the sample (with 0.785 cm^2 area exposed) was connected to working electrode, platinum electrode was connected to auxiliary electrode and the standard calomel electrode (SCE) was connected to reference electrode (RE). After an initial delay of 30 min, the polarization scan was conducted with a sweep rate of 0.01 V/s and a start potential of -0.6 V up to a final potential of 0.8 V. Corrosion tests were performed in neutral chloride solution of 3.5% NaCl with pH value 6.5.

3. Results and Discussion

3.1Corrosion study

Potentiodynamic polarization curves obtained for SS and SLM-SS are shown in fig. Tafel fit is used to analyse the curves and the resulting E_{corr}, i_{corr} and R_p values are summarised in table 1. It is very clear from the results (Fig.1) that, i_{corr} value of SLM-SS is lower than that of normal SS. So it indicates the better anticorrosion property of SLM-SS than normal SS.

Table 1 The results obtained from potentiodynamic polarization study

Sample	E_{corr} (V)	i_{corr} ($\mu A\text{-}cm^{-2}$)	R_p ($k\Omega\text{-}cm^2$)
SS	-0.206	0.487	76.76
SLM-SS	-0.294	0.306	174.04

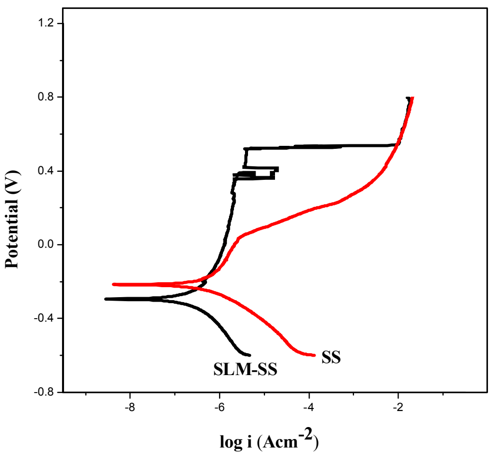

Figure 1 Potentiodynamic Polarization curve

Both the specimens show a constant passive behaviour. From the Fig.1 passive potential range of the SLM part was wider than the conventional part. The breakdown potential of the conventional part was greater when compared with SLM part. The results showed that the effect on corrosion resistance of the alloys don't have much deviation.

SLM is a new technique widely used in the metallurgical industry. It produces metal products by fusing metal powder; the laser can melt metal powder quickly and then cool it rapidly, hence phase change happens during SLM process which may change the corrosion resistance of the products. However, few studies have been investigated the corrosion resistance of the SLM alloy. Icorr and Rp values represent the ability to resist corrosion and are inversely proportional. In this study, the comparisons of Icorr and Rp values used to analyze the corrosion resistance of the two alloys, SLM alloy and conventional cast alloy

3.2 Microstructure

The pore morphology of SLM and cast part is shown in Fig. (2,3) respectively. All the SLM alloys have small shaped pores and a uniform pore distribution throughout the whole samples fig.2. Whereas the conventional austenitic stainless steel (fig.3), the pore characteristics change from large, open and interconnected pores to small, closed and isolated pores.

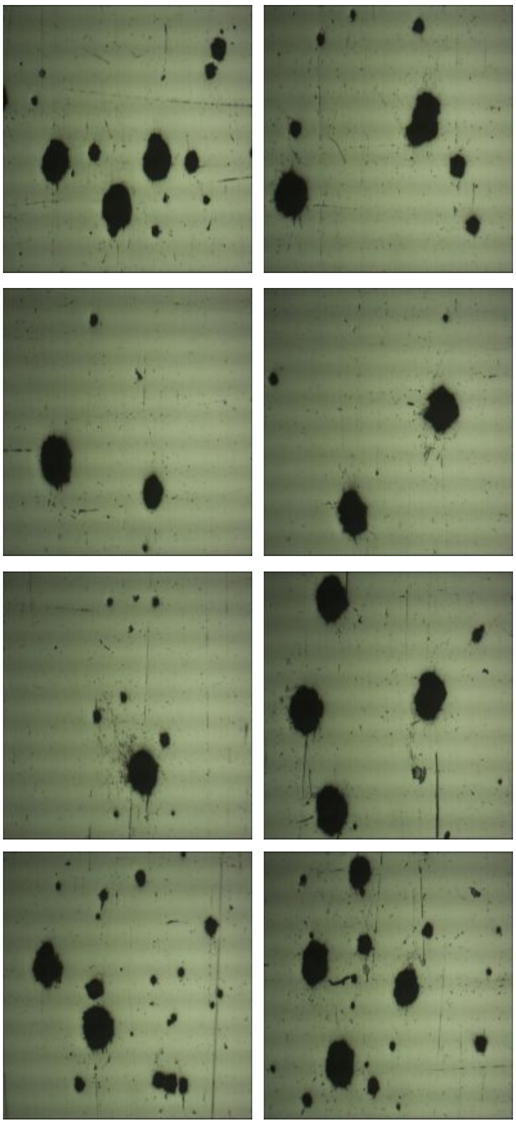

Figure 2 Corroded Specimens of SLM

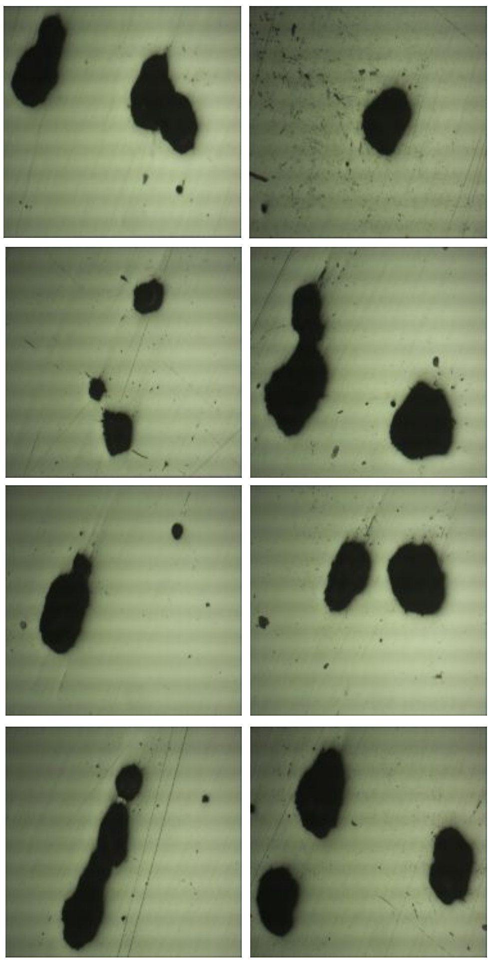

Figure 3 Corroded Specimens of Conventional processing

3.3 Mechanical Properties

Vickers micro hardness (HV) for each alloy is shown in table 2. The SLM part showed a significantly higher micro hardness than conventional part. This is mainly due to the powder compaction happens during selective laser melting process, the powder compaction enhances the mechanical properties especially hardness.

Table 2 Vickers micro hardness values for SLM and traditional specimens after corrosion

Sample	Hardness Ttrials			Mean
SS	110	127	115	117
SLM-SS	208	220	218	215

4. Conclusions

Laser melted stainless steel part showed significantly better corrosion resistance than the conventional cast stainless steel. Because of the fine-scale microstructure, the HV of the SLM specimens was higher than that of convectional cast specimens after corrosion. After electrochemical corrosion the pore size of the SLM alloy was much smaller than that of the conventional cast austenitic stainless steel.

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