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Development of Corrosion Resistant Laser Sintered Inconel 718 Material using Salt Spray Test

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Abstract: ***The conventional method is facing difficulty in manufacturing the nickel based alloys. Metal or composite components can be made using Direct Metal Laser Sintering (DMLS) process. Right now, Inconel 718 is a very much required alloy in defence, aerospace, chemical, oil and gas applications because of its admirable hot corrosion resistance and thermal –mechanical properties. In this research, we investigate the corrosion behaviour of the laser sintered and commercially available Inconel 718 alloy using salt spray test as per ASTM B117 for different exposing hours (24, 48, 72, 96, 120, 144, 168 hours). Samples prepared using laser sintering and commercially available Inconel 718 alloy were subjected to EDAX and SEM analysis to confirm the uniform distribution and chemical composition. Vickers Micro hardness test was conducted on samples to check surface hardness. From the results, it has been confirmed that prepared laser sintered Inconel 718 components shows the excellent corrosion resistance as compared to commercially available under harsh corrosion environment.***

Keywords: ***Corrosion. Direct Metal Laser Sintering, Inconel, Salt Spray***

I. INTRODUCTION

From the past years the additive manufacturing has been used in various industries in the manufacturing of complex and intricate parts. The additive manufacturing providing an extreme flexibility in the production and dimensional accuracy [1-2]. The additive manufacturing as compared to other process manufacture dense material [3]. Direct metal laser sintering (DMLS) is one of the procedures utilized to prepare a component under additive manufacturing technique [4]. In Laser sintering, laser irradiation process occurs to convert the powder particles into continuous medium. In Laser sintering process, 3D data from CAD file are slice into layer by layer, vectors of the laser are considered, and selectively melted the selected metal powders and allowed to solidified [5-6]. The high power of laser beam melts the metal powders completely, hence the bonding between the neighboring materials and previous layers. This procedure will repeat until the complete component is produced. Hence, by utilizing the laser sintering process difficult and intricate parts can be manufacture with small lead time [7-9]. In this study, Inconel 718 is chosen as a raw material, it is a Nickel based super alloy having good thermo mechanical, workability properties and good corrosion resistance, hence, it is used in the harsh engineering environment9 high temperature, automobile, and aerospace) [10-11]. However, the machining and welding of Inconel components is a difficult process. Direct metal laser sintering process could substitute the machining and welding in the manufacture of difficult and intricate shapes. By this, it has confirmed that stronger Inconel 718 components can be produce rapidly and at dumpy time [12]. [13-14] et all have conducted the tensile, creep, and high temperature corrosion resistance of Inconel 718 alloy produced by SLM process and results clearly shows the improvement of corrosion resistance of the SLM component. Regrettably, researchers has been paid the interest to the corrosion behavior of the laser melted Inconel 718 alloys even though the consequence in deliberation of their service conditions. Li et al. have stated that, in recent days focus has made on the effect of variety of corrosion testing solutions on the corrosion resistance behavior of the laser melted Inconel 718 alloy. In the results, he had concluded that, for different solutions and hat treatment process the corrosion resistance of the laser melted Inconel alloy was unclear.

In the light of the above, in the present work, corrosion behavior of the selective laser melted Inconel 718 and commercially available Inconel 718 was analyzed using salt spray corrosion test. This is as per ASTM B117 standard. Then, the resultant corrosion behaviors are studied based on the weight loss and identifying the red rust appearance on the surface of the subjected samples. The surface morphology of the samples before and after corrosion studies were analyzed in detail to reveal the corrosion behavior of the SLMed Inconel 718 alloy.

II. EXPERIMENTAL DETAILS

A. Materials and Sample Preparation

In the present research work, Inconel 718 alloy powder was used to prepare samples by using the direct metal laser sintering technique.

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The chemical composition of the Inconel powders is as shown in Table.1. Fig 1(a) and Fig 1(b) shows the laser sintered and commercially available Inconel 718 specimens.

Table-I: Chemical composition of Inconel 718 powders

Element	Al	Cr	Ti	Fe	Mn	Mo	Nb	C	Ni
Wt%	0.55	18.3	1.02	18.2	0.01	3	4.97	0.039	Bal

Along with the laser sintered samples, commercially available Inconel 718 samples were considered for the comparison in the corrosion mechanism. From the literature survey the optimal process parameters were considered to prepare a samples using Inconel 718 alloy, as showed in the Table.2

Table-II: Process parameters of DMLS technique. [15]

Equipment	LSNF-2 (self developed)
Power	350W
Scanning Speed	800 m/s
Hatch space	120μm
Sliced layer thickness	10mm
Primary Gas	Argon
Inconel 718 Powder particle size	45±10μm
Beam D	0.08mm

To avoid the subsequent surface change in the laser sintered samples and to study the surface morphology of the pre and post corrosion samples, cylindrical bars of 10 X 20 mm were prepared

B. Salt Spray Test

The corrosion mechanism of the laser sintered and commercially available Inconel 718 were conducted using salt spray test compartment as per ASTM B117. Salt spray test is one of the corrosion test. Laser sintered and commercially available Inconel 718 samples were subjected to corrosion test in a closed chamber which consists of 3.5% NaCl solution. The close exposed chamber was maintained at 37oC and maintained pH level of 6.1 to 7. Before subjecting to corrosion test, samples are weighed in a 0.0001 gm scale. Once corrosion test got over, samples were cleaned with acetone and final weights of the samples were recorded. Weight loss technique was used to measure the corrosion rate.

C. Characterization of Samples

The scanning electron microscope coupled with energy dispersive X-ray Analysis (EDAX) were used to view the surface morphology of the as built Inconel and commercially available samples before subjected to corrosion test to confirm the uniform dense distribution of the Inconel particles and to observe the defects in the sintering process (porosity). EDAX test was conducted to confirm the presence of Ni, Cr, and Fe elements. The Vicker's micro hardness test was conducted on both the sintered and non sintered samples before corrosion test to measure the surface hardness and laser sintered Inconel samples showed superior hardness as compared to other sample. The hardness values are showed in the Figure (3).

III. RESULTS AND DISCUSSION

A. Characterization of the Microstructure

Figure 1(a) and 1(b), shows the specimens which were subjected to corrosion test (before and after). To facilitate the comparison, both sintered and non sintered Inconel samples were imaged. The original material colour is grey, after exposing the specimens for different hours in the corrosion environment, samples turn to red rust is as showed.

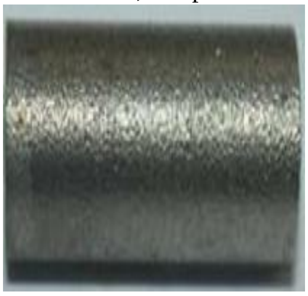

Figure 1(a). Laser sintered Inconel 718 component before corrosion

Figure 1(b). Laser sintered Inconel 718 component before corrosion

The surface morphology of the samples was observed with the help of SEM and EDAX analysis. The Figure 4 shows the uniform distribution of the Inconel particles and density. Due to the temperature difference in the manufacturing system, Inconel particles may freeze and un melting may happen, this leads to the agglomeration on the sintered samples which is as showed in the Fig. The melted particles create a grain growth and, thus the refining of grain size; this is sparkling in the increase in micro hardness and corrosion resistance of the sintered samples. The figure 3. shows the EDAX spectrum analysis of the Inconel particles and confirms the highest peak confirms the presence of Ni, Cr and other materials

B. Salt spray test

The influence of the corrosion environment on the laser sintered Inconel 718 and commercially available Inconel samples were recognized in 3.5% NaCl solution under closed fog container. The corrosion rate of the samples was analyzed by weight loss method. The Figure 2 shows the comparison of the corrosion rate of the both sintered and non sintered samples at different exposing hours. The figure 3 shows the micro hardness analysis of the samples. The corrosion rate is depends on the exposing time, if keep on increasing the exposing of samples to the corrosion environment, oxidation on the samples was observed and red rust also. After definite exposing time, samples were cleaned with the acetone and weighed. The corrosion rate is the determining of corrosion and describes how much quantity of material loss by reason of corrosion. Hence, lower the weight loss and the corrosion rate also reduced. The corrosion rate increases in the commercial Inconel as compared to laser sintered Inconel due to high hardness, less porosity and uniform distribution of the powder particles.

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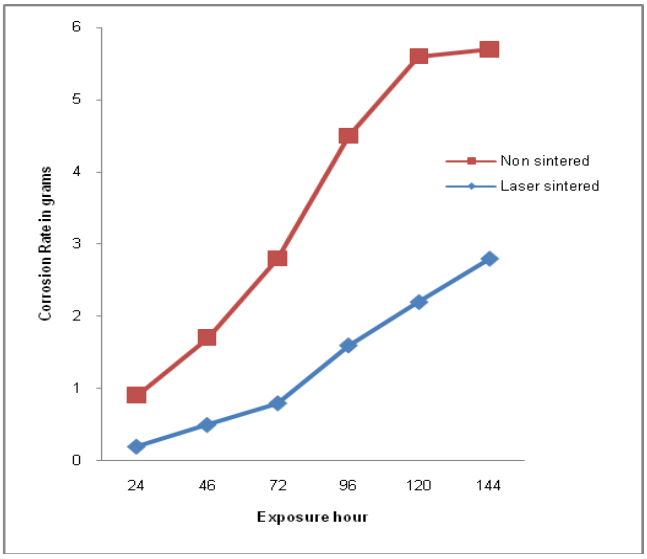

Figure 2: Effect of corrosion rate for different exposure time.

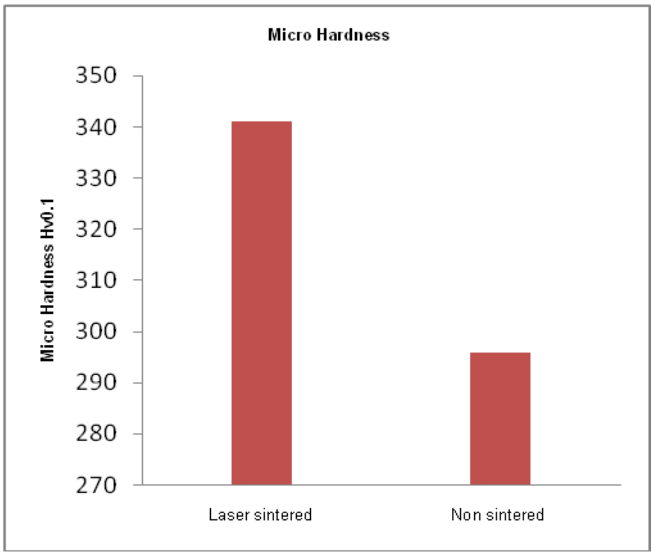

Figure 3. Micro Hardness of the sintered and non sintered Inconel 718

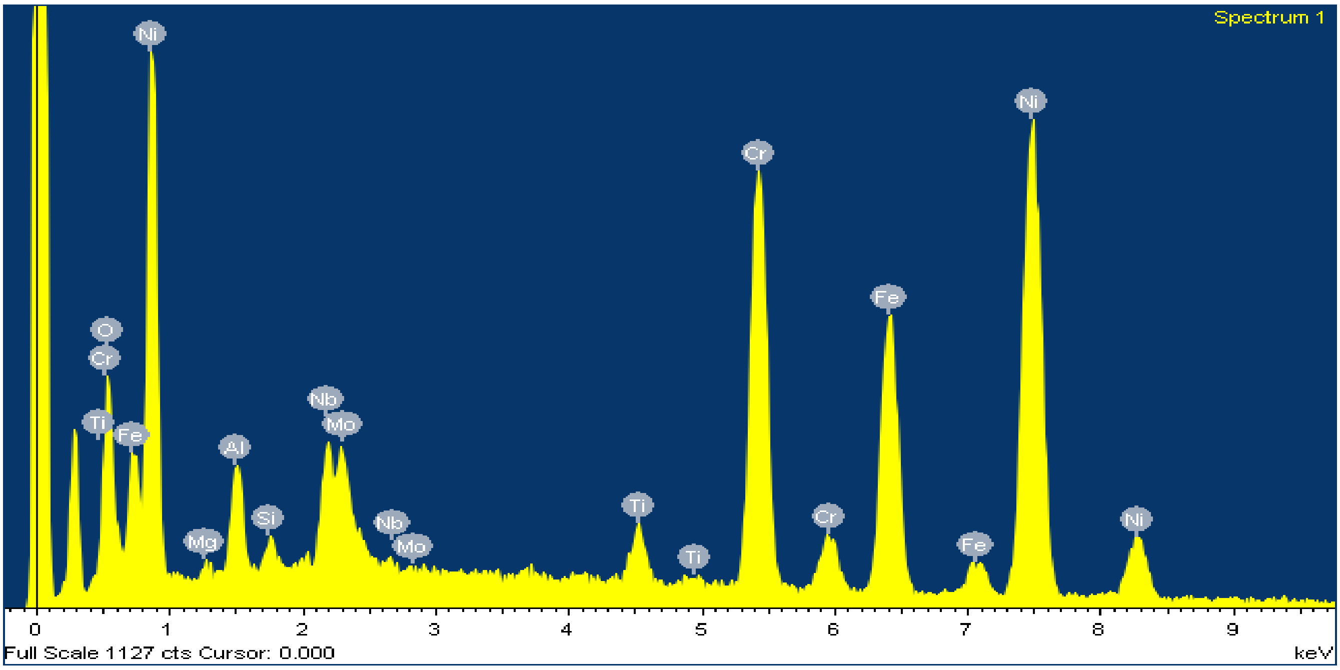

Figure 3. EDAX Spectrum Analysis of the Inconel Powder Particles

C. Corrosion Morphology Through SEM and EDAX

The EDAX spectrum analysis was used to confirm the chemical composition of the laser sintered Inconel materials and as shown in Figure 3. From the SEM analysis it is come to know that selected laser sintered Inconel material evident the dense and less porosity as compared to non sintered material is as showed in the Figure 5 (a) and (b).

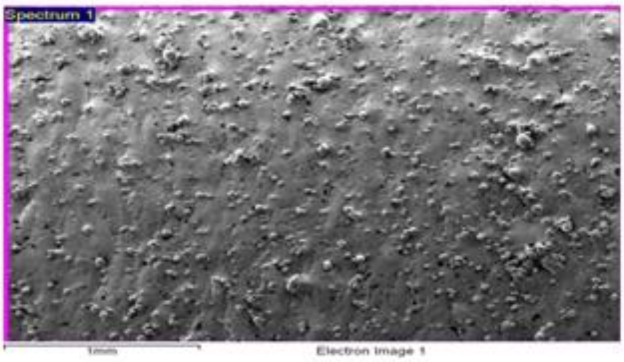

Figure 4. SEM image of the uniform distrubution of the Inconel particles

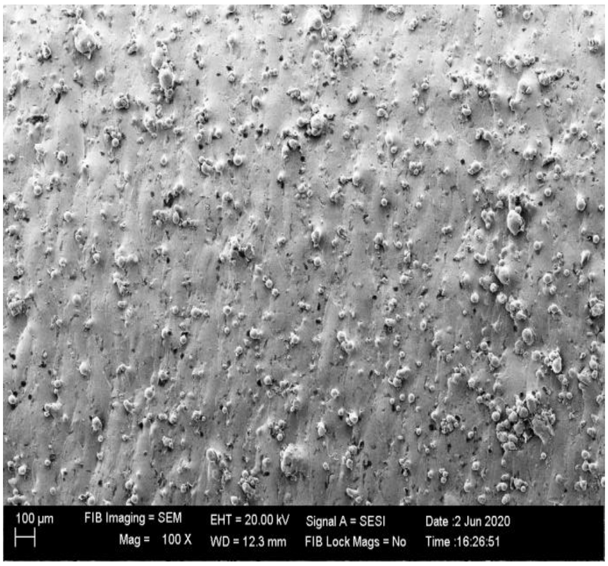

Figure 5 (a) Uniform dense distribution of Laser sintered Inconel 718

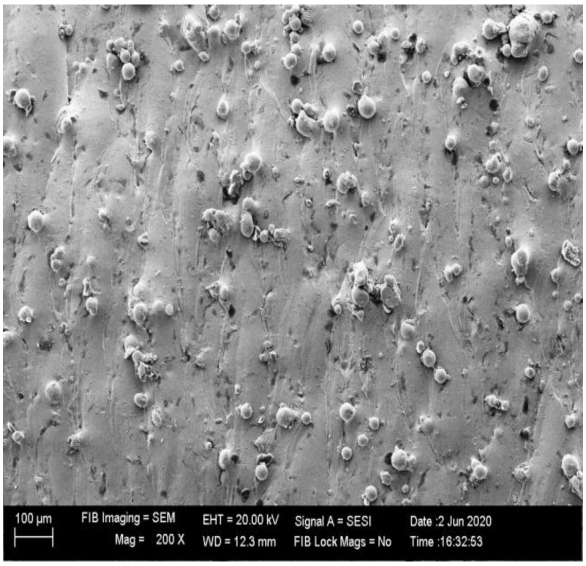

Figure 5(b): Insignificance distribution of non Laser sintered Inconel 718

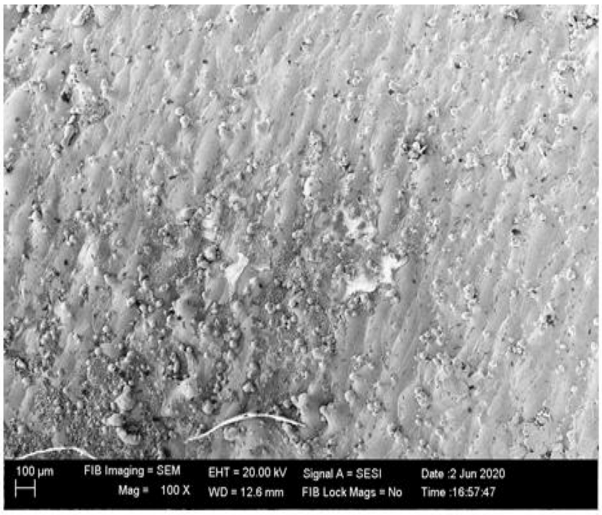

Figure.6 (a): Corroded surface of the laser sintered component at 72 hours

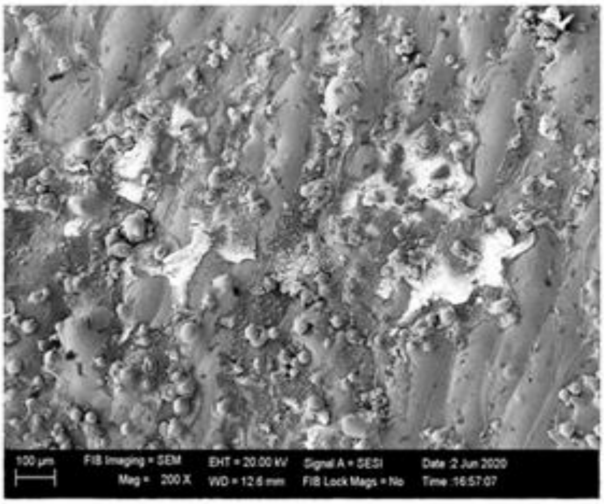

Figure.6(b): Corroded surface of the Non laser sintered component at 72 hours

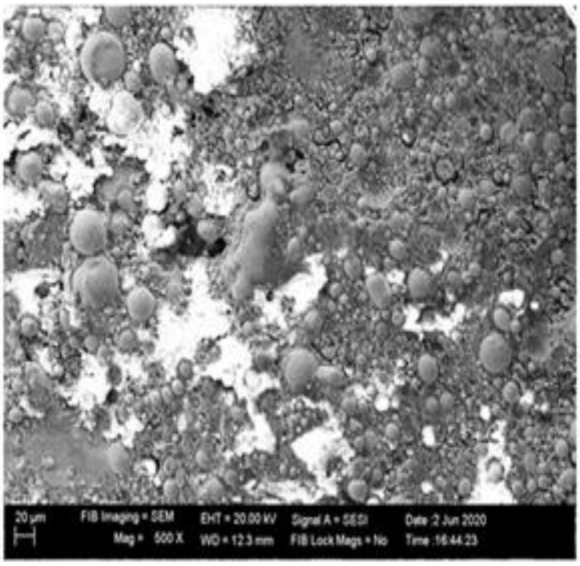

Figure.6 (c): Corroded surface of the laser sintered component at 144 hours

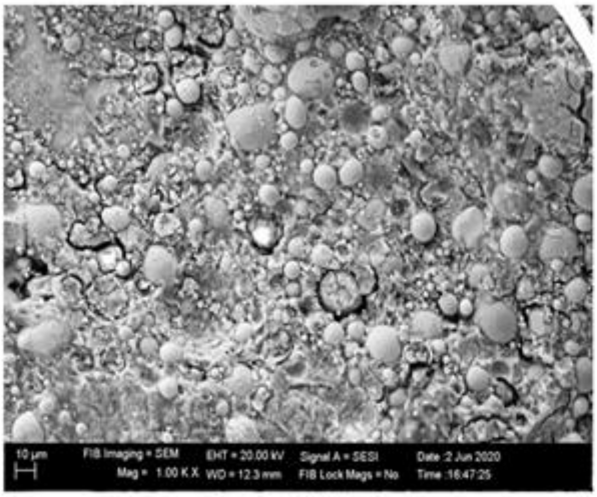

Figure.6 (d): Corroded surface of the Non laser sintered component at 144 hours

In the present work to study the morphology of the corroded surface was investigated by SEM equipped with EDAX. The Figure 6(a)-6(d) shows the samples exposing to the corrosion environment under different time period (24, 48,72,96,120,144 hours) with 3.5% of NaCl solution.

Revilla RI et.al [16] have confirmed that the metal pool boundary is the initiating and penetrating point for attacking the corrosion. In the same way, the corrosion takes place uniformly in the overlap section of the samples. The Figure.6 (a) shows the formation of small lip like structure and small pits. The uniform large pits are seen on the non laser sintered Inconel sample at 72 hour as imaged in the Figure.6(b). After keep on increasing the exposure time it is noted that, pits are formed in the both interior and exterior grain boundary of the samples at 144 hours of exposing time is as showed in Figure.6(d), and also confirmed that inter granular corrosion was happened for the non sintered Inconel 718 samples. From the results it has confirmed that, laser sintered Inconel 718 samples shows superior corrosion resistance for harsh corrosion environment

IV. CONCLUSION

1.The DMLS technique was used to produce the Inconel 718 samples successfully.

2.The surface morphology and micro hardness test were used to analyze the corrosion rate of the laser sintered and non laser sintered samples: higher the micro hardness lesser the corrosion rate.

3.The pits and lip like structure are to be the main reason for corrosion appear on the Inconel 718 samples.

4.The corrosion resistance of the laser sintered Inconel 718 samples are in superior position as compared to non sintered Inconel 718 samples.

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