# PREPARATION OF 316L STAINLESS STEEL BY USING LASER POWDER BED FUSION TECHNIQUE

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**Abstract:**

The laser powder bed fusion is an additive manufacturing process which uses powdered metal in order to create complex shapes, it uses lasers for melting the metal powders. In this a bio-medical grade metal powder is used i.e., SS 316L by using iFusion 150 metal 3D printing machine, it uses Yb – Fibre laser in order to melt the SS 316L powder to the required shapes. The IFusion 150 metal 3D printer uses laser powder bed fusion (LPBF) technology. Mechanical properties like compression strength, micro hardness was examined and found an average of 1340.697 MPa compression strength, 206 BHN hardness values. Their micro structures were examined.

*Keywords:* SS 316L, Selective Laser Sintering, LPBF, bio – medical.

## 1. Introduction

The usage of SS 316L had increased numerously in the bio medical fields, due to its high corrosion resistance behaviour. By using additive manufacturing techniques like selective laser sintering intricate shapes can easily be manufactured, compared to that of conventional manufacturing processes.

The laser powder bed fusion (LPBF) is a powder based additive manufacturing technique which is the most studied additive manufacturing process. Process parameters like laser type, powder attributes etc., makes this process a bit complex [1]. Several process parameters can be varied while performing the fusion based additive manufacturing process to obtain different properties to the manufactured material.[2] The selective laser sintering is a process where the metal powder is deposited layer – by – layer in order to obtain the desired shapes [3]. Highly porous SS 316L was produced by using powder metallurgy process, which includes SLS (Selective Laser Sintering) process and the elastic modulus and compressive strength of porous SS 316L with porosity of approximately 50% are comparable to those of human cortical bone. [4]. For using the SS 316L metal in biomedical applications corrosion resistance has to be checked, so an additively manufactured component of SS316L were analysed with its counter parts, a higher pitting resistance and improved stability of the additively produced SS 316L was ascribed to its dense structure of oxide coating and precise microstructure. [5].

In order to produce high porosity metal parts, the fabrication circumstances that lead to specific melting of the powder particles should be employed [6].

In the present study SS 316L metal were additively manufactured, by using the SS 316L metal powder using IFusion 150 metal 3D printer.

## 2. Experimental Work

The metal SS 316L has good corrosion resistance and mechanical properties that's why it is very suitable for the bio medical applications. To obtain precise and intricate shapes in case of fractures etc., this SS 316L is fabricated using this additive manufacturing process.

The composition of the SS 316L is given in the table 1

**Table 1.** Composition of SS 316L

| **Material** | **Cr** | **Ni** | **Mo** | **Mn** | **Si** | **P** | **N** | **C** | **S** | **Fe** |
|---|---|---|---|---|---|---|---|---|---|---|
| **SS 316L** | 17.18 | 12.81 | 2.47 | 0.92 | 0.55 | 0.33 | 0.06 | 0.029 | 0.007 | Bal |

Two types of samples were manufactured using the iFusion 150 metal fusion 3D printing machine. The dimensions of the samples are 15mm x 20mm cylindrical sample and 15mm x 4mm tablet shaped samples.

The laser which is used in the 3D printer is Yb – Fibre laser, which melts the SS 316L powdered material into the required sizes. The images regarding the manufactured samples are shown below.

**Fig 1.** iFusion 150 metal fusion 3D printing machine and Fabricated Samples

The bigger samples were used for testing the compression tests, and the smaller ones were used for finding the micro hardness tests.

The mechanical characteristics of the additively produced SS 316L were investigated using compression and microhardness tests.

Large and irregular shaped voids are formed due to lack of heat transfer, at low energy heat inputs during the SLM process [7].

### 2.1 Compression Test

The compression tests were performed on the 15mm x 20mm samples, in order to find the ultimate compression strength of the additively manufactured SS 316L sample.


**Fig 2.** UTM Machine

The elastic modulus and other mechanical characteristics of the porous SS 316L are sufficiently similar to those of cancellous bone. [8]. The compression tests for the additively manufactured SS 316L were conducted on a total of three samples, and the compression strengths for the respective samples were found to be as 1333.744MPA, 1342.715MPA, 1345.632MPA respectively. By taking the average of these values the compression strength was 1340.697MPA, at an average ultimate load of 238.4KN. AlSi10Mg made by the SLM process shows ductile manner and the samples doesn't fractured during the compressive loading [9].

**2.2 Hardness Test**

The hardness values of the samples were examined by using Rockwell Cum Brinell Hardness tester having an indenter size of 5mm by applying a load of 250Kgf on the samples and IS 1500 (PART - 1): 2019 test procedure were followed for the hardness test.

In a total of three samples were tested with three indentations on each sample, and the results the hardness tests were as shown in the table 2.

**Table 2.** Hardness test results

| S.No | Name Of Sample | BHN VALUES | | | |
|---|---|---|---|---|---|
| | | BHN-1 | BHN-2 | BHN-3 | Average |
| 1. | SS 316L – 1 | 207 | 207 | 202 | 205.33 |
| 2. | SS 316L – 2 | 202 | 207 | 202 | 203.67 |
| 3. | SS 316L – 3 | 205 | 206 | 207 | 206 |

After the hardness test the Brinell hardness of the samples were noted as 206BHN. By taking the highest value which is obtained at the sample – 3 (SS 316L - 3).

The Vickers hardness of the FVS0812 alloy made by SLM has significantly improved compared to the as – cast alloy [10].

## 2.3 Microstructural Analysis

The microstructure of the LPBF SS 316L were examined using SEM.

The SLM 316L stainless steel received had several sub-grains, and after solution heat treatment, the dislocations in the sub-grain border shifted and vanished. [11]

The Al-8.5Fe-1.3V-1.7Si alloy powder and SLM treated samples shared similar constituent phases, including α-Al, Al12(Fe,V)3Si, and h-Al13Fe4. [10]

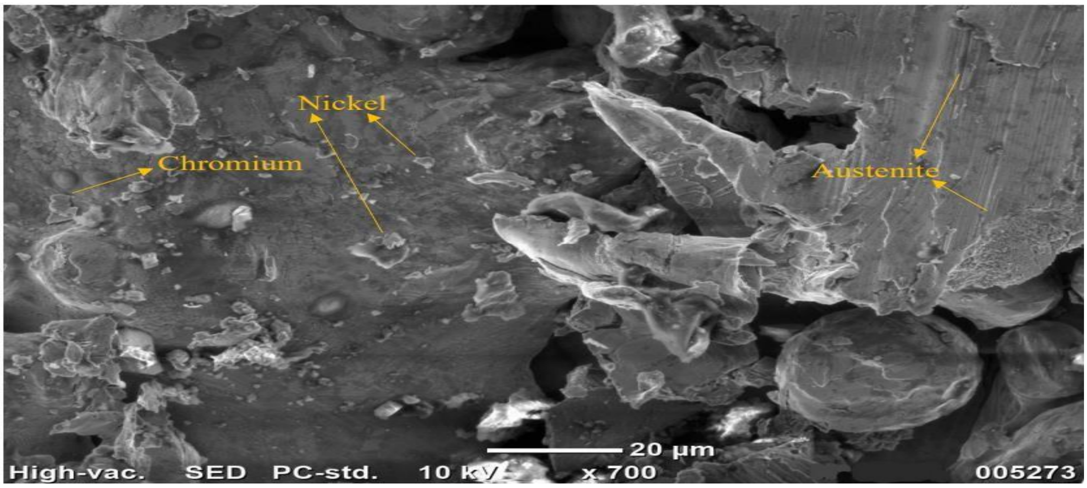


**Fig 3.** SEM image of LPBF SS 316L

The SEM analysis was conducted to examine if there are any changes or differences are present in the additively manufactured SS 316L in comparison with the conventional SS 316L metal. The SEM is conducted at 20µm scale and 700x zoom.

As like the conventional SS 316L we can observe the presence of Nickel, Chromium in the additively manufactured SS 316L. Also, we can observe the austenitic grain structure in the SEM image of the additively manufactured sample.

The fast cooling of the Ti–6Al–4V manufactured by SLM process results in the rise of martensitic phase [12].
Large grains are observed at the centre of each laser tracks and refined microstructure is evolved [13].

## 2.4 Conclusion

The mechanical tests and microstructural analysis for the additively manufactured SS 316L was successfully done, and the tests to find the mechanical properties like compression and microhardness were done.

The average compression strength of the additively manufactured SS3116L is found to be 1340.697MPA at an average ultimate load of 238.4KN.

The Rockwell Cum Brinell hardness strength of the sample is found to be 206BHN, which is almost near to the maximum Brinell hardness of commercial SS 316L i.e., 216 BHN.

The microstructure of the SS 316L sample shows the presence of the materials like nickel, chromium and austenitic phase which are present in the commercial SS 316L.

By considering the mechanical and microstructural analysis it is clear that the SS 316L which is manufactured by the LPBF process is suitable for making the intricate shapes in the use of bio medical implants etc.

## 3. References

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