Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 55(10) (2024) 257-260
DOI: 10.22060/mej.2024.22323.7630

# Effect of Build Orientation and Size on the Defects Rate of Stainless Steel 316L Parts Produced by Selective Laser Melting Process

M. Ranjbarkohan[1], A. Sazgar[2]*, A. Pourkamali Anaraki[1]

[1] Faculty of Mechanics, Shahid Rajaee Teacher Training University, Tehran, Iran
[2] Nuclear Fuel Cycle Research School, Nuclear Science and Technology Research Institute (NSTRI), Tehran, Iran

**ABSTRACT:** The correct and optimal selection of selective laser melting process parameters prevents defects such as porosity, incomplete fusion holes, and cracks in the parts. This research focuses on the impact of zero, 45, and 90-degree build orientations, the effect of changing the size of the parts on mechanical properties such as tensile and shear strength, fracture strain, and the number of defects investigated. The built parts were subjected to tensile and shear tests. The fracture zone was investigated using Scanning Electron Microscopy, and existing defects were identified. Tensile test results indicated that larger samples have higher tensile strength than smaller ones. Moreover, samples produced in the zero-degree orientation exhibited higher tensile strength and lower fracture strain. Shear test results also showed that the shear stress strength for small and large samples produced in all orientations is almost the same, and the highest shear strain of failure is related to the samples produced at 45-degree orientation and independent of dimensions. Scanning Electron Microscopy results further demonstrated that the quantity and distribution of spherical holes and incomplete fusion holes in large samples at 90-degree are greater than the samples at other orientations.

**Review History:**

Received: Jul. 05, 2023
Revised: Jan. 13, 2024
Accepted: Jan. 14, 2024
Available Online: Feb. 07, 2024

**Keywords:**

Selective Laser Melting
stainless steel 316L
Build orientation and size effect
Defects and porosity

## 1- Introduction

One of the advanced methods in additive manufacturing is the selective laser melting (SLM) process, where metal powder layers are melted by laser beam irradiation from a laser source, leading to the fusion of powder particles. Dong et al. (2018) investigated the influence of structure size on microstructure, geometric defects, and mechanical properties through experimental tests. They observed that as the specimen size increased from a diameter of 1 millimeter to 5 millimeters, the porosity level decreased from 1.0% to 0.1% [1]. Harchunian and colleagues (2018) studied the effect of different build directions on the mechanical properties and microstructure of TI-6Al-4V components produced by the SLM process. They found that specimens built in the Z direction exhibited the lowest tensile strength compared to other directions[2]. Pan et al. (2020), in examining the physical and mechanical properties of SLM-produced stainless steel 316 L, discovered that optimizing process parameters can prevent the occurrence of defects [3]. This paper reviews the mechanical properties of stainless steel 316L parts produced using the selective laser melting process. Samples were produced in three manufacturing directions: zero, 45, and 90 degrees, with two different sample sizes, large and small. Then, the tensile test with the ASTM E8 standard (2010) and the shear test with the ASTM B831 standard method (2019) was performed on the samples. After completing the tests, the fracture zone and the depth of the cut zone in the samples were examined by using a scanning electron microscope, , and the existing defects were identified and analyzed.

## 2- Methodology

This article investigated the effect of zero, 45, and 90-degree manufacturing angles and the effect of size variation of parts on mechanical properties of stainless steel 316L produced by the SLM method, including tensile and shear strength, fracture strain, and number of defects. The ASTM E8 standard was used for the tensile test, which was made in large and small sizes shown in Figure 1[4]. Also, the ASTM B831 standard was used for the shear test of samples which was made in large and small sizes as illustrated in

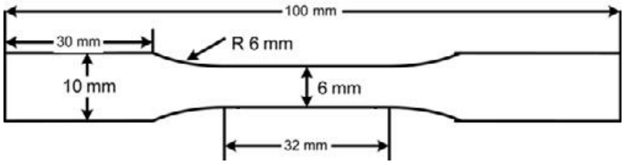

**Fig. 1. Tensile test sample based on ASTM E8 [4]**

---

*Corresponding author's email: Asazgar@aeoi.org.ir

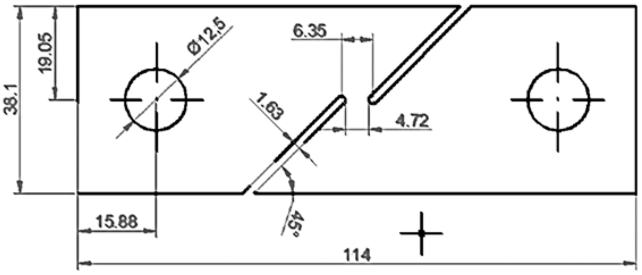

Fig. 2. Shear test sample based on ASTM B831 [5]

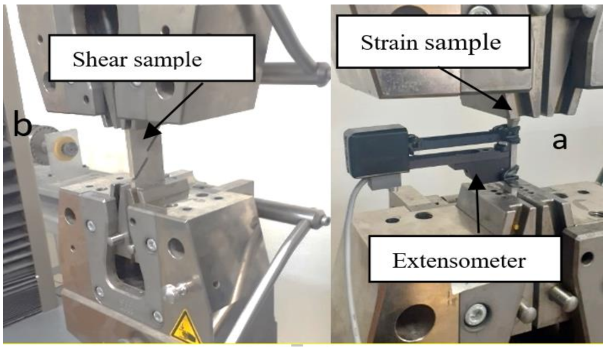

Fig. 3. a) Tensile test with Extensometer; b) Shear test.

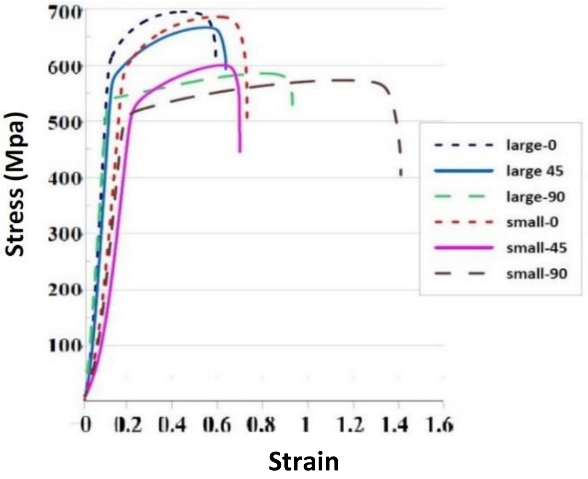

Fig. 4. The stress-strain curves of large and small parts.

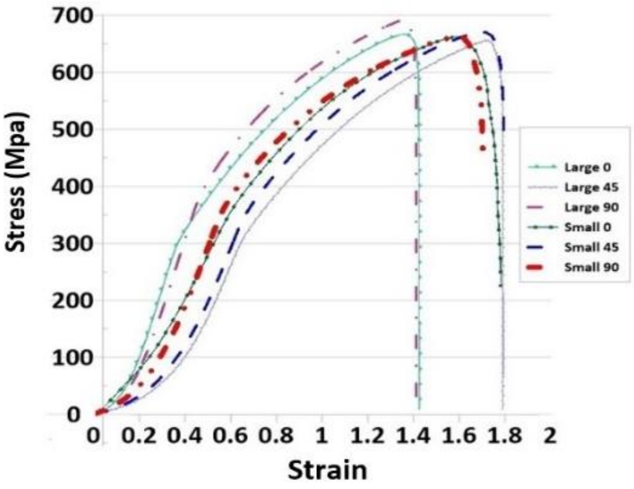

Fig. 5. Shear strength and shear strain of large and small shear samples.

Figure 2 [5]. Figure 3 provides a visual representation of the tensile and shear test samples. A tensile test was performed with an extensometer.

## 3- Results and discussion

Figure 4 shows that the lower tensile strength observed in the specimen constructed at the 90-degree direction can be attributed to the weak bonding between its layers in that direction and its alignment with the tensile direction. The obtained results align with the observations made by Deng et al. (2022) and Ratger et al. (2020) [6, 7].

The shear strain of larger parts is lower than smaller parts, which can be attributed to the difference in grain size and grain growth due to the more significant thermal gradient of larger parts than smaller parts during manufacturing as illustrated in Figure 5.

Due to the higher volume percentage of holes in the sample produced at the 45-degree direction compared to the sample manufactured at the zero-degree direction, the sample produced in the 45-degree direction exhibits more shear strain and more ductility. Also, the results of this research are compatible with the findings of Yang et al. (2022)[8].

The Scanning Electron Microscope test was performed on the fracture location, and the fracture zone of large parts produced in three directions (zero, 45, and 90-degree). This examination aimed to investigate the voids, morphology of spherical holes, the incomplete fusion holes and distortions of defects.

Figure 6 shows the scanning electron microscope images of the fracture cross-sectional area of the large tensile test specimen at the direction of 90 degrees. As can be seen, a spherical hole with a diameter of 38.83 micrometers and a deep gap with a length of 72.5 micrometers were created due to the incomplete fusion hole.

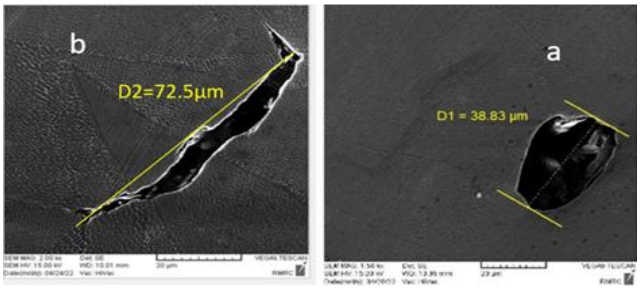

**Fig. 6. The fracture zone of the large tensile test specimen, 90-degree building direction: a) Spherical hole; b) Incomplete fusion hole.**

## 4- Conclusion

In the tensile test, the results indicated that the highest tensile strength corresponds to the large samples produced at the zero-degree direction, while the lowest is related to the 90-degree direction. Also, the highest tensile strength is related to the small samples produced at the zero-degree direction and the lowest is associated with the 90-degree direction. In general, the tensile strength of large samples produced in all directions is higher than small samples produced in the same directions and the fracture strain of small samples produced in all directions is higher than large samples manufactured in the same directions. In the shear test of samples with zero and 90-degree building angles, the shear strength and failure strain values depend on the sample's dimensions and are independent of the building angle. The shear strain and fracture toughness of samples manufactured at 45-degree are higher than samples manufactured at zero and 90-degree and are independent of dimensions. Also, the shear strain of larger pieces is less compared to smaller pieces. The SEM results also showed that the quantity and distribution of spherical voids and gaps related to incomplete fusion in large samples manufactured at a-90 degree degrees direction is more compared to samples produced at zero and 45-degree direction.

## References

[1] Z. Dong, X. Zhang, W. Shi, H. Zhou, H. Lei, J. Liang, Study of size effect on microstructure and mechanical properties of AlSi10Mg samples made by selective laser melting, Materials, 11(12) (2018) 2463.

[2] P. Hartunian, M. Eshraghi, Effect of build orientation on the microstructure and mechanical properties of selective laser-melted Ti-6Al-4V alloy, Journal of Manufacturing and Materials Processing, 2(4) (2018) 69.

[3] P. Lu, Z. Cheng-Lin, W. Liang, L. Tong, L. Xiao-Cheng, Research on mechanical properties and microstructure by selective laser melting of 316L stainless steel, Materials Research Express, 6(12) (2020) 1265h1267.

[4] ASTM E8/E8M, Standard test methods for tension testing of metallic materials, in, USA, (2011).

[5] ASTM B831 - 19: Standard test method for shear testing of thin aluminum alloy products., (2019).

[6] W. Deng, H. Lu, Y. Xing, K. Luo, J. Lu, Effect of laser shock peening on tensile properties and microstructure of selective laser melted 316L stainless steel with different build directions, Materials Science and Engineering: A, 850 (2022) 143567.

[7] A. Röttger, J. Boes, W. Theisen, M. Thiele, C. Esen, A. Edelmann, R. Hellmann, Microstructure and mechanical properties of 316L austenitic stainless steel processed by different SLM devices, The International Journal of Advanced Manufacturing Technology, 108 (2020) 769-783.

[8] H. Yang, B. Liu, P. Niu, Z. Fan, T. Yuan, Y. Wang, Y. Liu, R. Li, Effect of laser scanning angle on shear slip behavior along melt track of selective laser melted 316L stainless steel during tensile failure, Materials Characterization, 193 (2022) 112297.

**HOW TO CITE THIS ARTICLE**
*M. Ranjbarkohan, A. Sazgar, A. Pourkamali Anaraki, Effect of Build Orientation and Size on the Defects Rate of Stainless Steel 316L Parts Produced by Selective Laser Melting Process, Amirkabir J. Mech Eng., 55(10) (2024) 257-260.*

**DOI:** 10.22060/mej.2024.22323.7630