**Review Paper on Experiment and Optimization of Surface Roughness and Hardness of Inconel718 in Selective Laser Melting Using Taguchi Method**

**Mohit Singh1, Hemendra Patle2, Puran Gour3**

1Research Scholar Master of Technology (APS) Department of Mechanical Engineering, NIIST, Bhopal

2Assistant professor, Department of Mechanical Engineering, NIIST, Bhopal (M.P.)

3Principal, NIIST, Bhopal (M.P.)

**Abstract**

## The main goal of this study was to create a totally dense portion of Inconel 718 that had been selectively laser-melted and had improved surface and mechanical qualities. Four important process parameters—laser power, scan speed, layer thickness, and orientation—are chosen from a variety of variables and have four different levels of variation. One of the most often used techniques for creating experimental plans is Taguchi. For test runs, the Taguchi orthogonal array L16 will be used. Here, a study will be conducted experimentally using Inconel 718 powder and a selective laser melting technique to investigate how process characteristics such as surface roughness, porosity, and built-in hardness affect quality responses. Utilizing optical microscopy (OM) and scanning electron microscopy (SEM) to characterize the microstructure of artificially manufactured SLM specimens. In this study Inconel718 powder material will be used in Selective Laser Melting and orthogonal array L16 will be used in Taguchi method on various parameters for surface roughness and hardness.

## *Keywords:* ANOVA, Inconel718, Microstructure, Selective Laser Melting, Taguchi, Porosity, Hardness

1. **Introduction**

Rapid prototyping (RP) has given way to additive manufacturing (AM), a manufacturing technology that has continued to grow. Originally, additive manufacturing (AM) was mostly used for prototyping; however, with time and the efforts of numerous researchers, it is now also used in the commercial manufacturing of prosthetics, airplane components, spacecraft parts, high-strength military equipment, auto parts, and other products. AM creates the components from scratch by adding materials in a layer-by-layer order straight from the sliced CAD model, in contrast to conventional machining, which produces the result by eliminating undesired materials from the blank. AM has many benefits, including the ability to print parts made of multiple materials, produce functionally graded materials, print highly specialized biomedical components, and modify tool and machine layouts slightly to accommodate new designs. One further advantage that additive manufacturing (AM) offers over traditional machining techniques in the aerospace sector is its capacity to create complicated shapes out of lightweight materials without sacrificing strength. Wang Wenquan and others. Using selective laser melting (SLM), the Inconel 718 superalloy (IN718) was successfully created in this work. The optimization of process parameters and effects of three heat treatment processes on the microstructures and mechanical properties of samples were also systematically investigated. The relationship equation between relative density (RD) of SL Med samples and [energy density](https://www.sciencedirect.com/topics/engineering/flux-density) (ED) coupled by laser parameters was determined. After the solution aging (SA) heat treatment, a large amount of needle-like δ phases precipitated and the precipitation of ultrafine spherical γ'/γ” strengthening phases as well as complete recrystallization appeared after homogenization + solution aging (HSA) heat treatment. The overall performances of SL Med IN718 samples were improved significantly using the HSA treatment, with the increase of [tensile strength](https://www.sciencedirect.com/topics/engineering/ultimate-tensile-strength) from 946 MPa to 1570 MPa.[1]. [Jiun-Ren Hwang](https://sciprofiles.com/profile/2191932" \t "_blank) et.al. The study investigated the optimization of the LPBF Inconel 718 alloy with the Taguchi method and principal component analysis (PCA), covering four control factors at three levels in the manufacturing process. The results show that the highest tensile strength is obtainable at a laser power of 140 W, scanning speed of 800 mm/s, scanning pitch of 70 μm, and interlayer angle of 45 degrees. The optimal combination of process parameters for multi objective optimization is just the same as that for single-objective optimization for tensile strength. The difference between the predicted and experimental average tensile strength is 1.2%, and the error of the predicted optimal strength index is 12.6%. The most important control factor for tensile strength and multiple responses is the angle between layers, with a contribution rate exceeding 90%. With a given volume energy density of the LPBF process, the higher the power and scanning speed, the higher the accumulated energy and the larger the amount of dendritic or cellular crystals formed.[2]. Eslam M Fayad In the present study, multi-objective optimization is employed to develop the optimum heat treatments that can achieve both high-mechanical performance and non-distinctive crystallographic texture of 3D printed Inconel 718 (IN718) fabricated by laser powder bed fusion (LPBF). Heat treatments including homogenization at different soaking times (2, 2.5, 3, 3.5 and 4 h) at 1080 °C, followed by a 1 h solution treatment at 980 °C and the standard aging have been employed. 2.5 h is found to be the homogenization treatment threshold after which there is a depletion of hardening precipitate constituents (Nb and Ti) from the γ-matrix. However, a significant number of columnar grains with a high fraction (37.8%) of low-angle grain boundaries (LAGBs) have still been retained after the 2.5 h homogenization treatment. After a 4 h homogenization treatment, a fully recrystallized IN718 with a high fraction of annealing twins (87.1%) is obtained. 2.5 and 4 h homogenization treatments result in tensile properties exceeding those of the wrought IN718 at both RT and 650 °C. However, considering the texture requirements, it is found that the 4 h homogenization treatment offers the optimum treatment, which can be used to produce IN718 components offering a balanced combination of high mechanical properties and adequate microstructural isotropy.[3]. [Cho-Pei Jiang](https://pubmed.ncbi.nlm.nih.gov/?term=Jiang%20CP%5BAuthor%5D) et. al. (2023) The optimal printing and HT parameter values are used to manufacture a die and a punch to verify the suitability of the manufactured tool for deep drawing applications. The experimental results show that the greatest UTS is 1091.33 MPa. The optimal printing parameters include a laser power of 190 W, a scanning speed of 600 mm/s, a hatch space of 0.105 mm and a layer thickness of 40 μm, which give a UTS of 1122.88 MPa. The UTS for the post-processed specimen increases to 1511.9 MPa. The optimal parameter values for HT are heating to 720 °C and maintaining this temperature for 8 h, decreasing the temperature to 620 °C and maintaining this temperature for 8 h, and cooling to room temperature in the furnace. Surface finishing increases the hardness to HRC 55. The parameter values that are defined can be used to manufacture IN 718 tools with a UTS of more than 1500 MPa and a hardness of more than 50 HRC [4].Karia M.C et. al. In this work, the experiments were carried out as per the Taguchi experimental design and an L16 orthogonal array was implemented to study the influence of various combinations of process parameters. Analysis of variance (ANOVA) was performed to determine the significance of each process parameters on response. Results indicate that the most significant factor influencing surface roughness is layer thickness followed by orientation, power and scan speed. The work is useful in selecting optimal process parameters that would minimize the surface roughness and to obtain improved quality with minimal post processing requirements [5]**.** D.A. LesykThe turbine blade test parts were manufactured by the [selective laser melting](https://www.sciencedirect.com/topics/physics-and-astronomy/selective-laser-melting) (SLM) process using a nickel-based pre-alloyed [Inconel](https://www.sciencedirect.com/topics/materials-science/inconel) (IN) 718 powder. Various mechanical post-processing techniques, such as barrel finishing (BF), [shot peening](https://www.sciencedirect.com/topics/materials-science/shot-peening) (SP), [ultrasonic](https://www.sciencedirect.com/topics/physics-and-astronomy/ultrasonics) shot peening (USP), and ultrasonic impact treatment (UIT), were applied to improve the surface layer properties of the SLM-built specimens. Effects of mechanical surface treatments on [surface topography](https://www.sciencedirect.com/topics/materials-science/surface-topography), porosity, hardness, and residual stress were studied. In comparison with the SLM-built state the [surface roughness](https://www.sciencedirect.com/topics/materials-science/surface-roughness) (Sa = 5.27 μm) of the post-processed specimens were respectively decreased by 20.6%, 26.2%, and 57.4% after the BF, USP, and UIT processes except for the SP-treated ones. The Sz parameter was reduced in all treated SLM-built specimens except for the SP-treated ones. The surface [microhardness](https://www.sciencedirect.com/topics/materials-science/microhardness) of the SLM-built specimen (~390 HV0.025) was increased after the BF (by 14.2%), USP (by 23.8%), UIT (by 50%), and SP (by 66.5%) processes. Wenquan Wang The Inconel 718 superalloy (IN718) was fabricated by selective laser melting (SLM) successfully in this work. The optimization of process parameters and effects of three heat treatment processes on the microstructures and mechanical properties of samples were also systematically investigated. The relationship equation between relative density (RD) of SLMed samples and [energy density](https://www.sciencedirect.com/topics/engineering/flux-density) (ED) coupled by laser parameters was determined. After the solution aging (SA) heat treatment, a large amount of needle-like δ phases precipitated and the precipitation of ultrafine spherical γ'/γ” strengthening phases as well as complete recrystallization appeared after homogenization + solution aging (HSA) heat treatment. The overall performances of SLMed IN718 samples were improved significantly using the HSA treatment, with the increase of [tensile strength](https://www.sciencedirect.com/topics/engineering/ultimate-tensile-strength) from 946 MPa to 1570 MPa.[7]

## Experimental Details

### **2.1 Specimen Material Details**

A gas atomized preprocessed Inconel718 powder (CL 100 Nb) will be for experiment. The average size of powder particles will be 38 µm. The morphology and particle shape and size are important factors as they determine ability to flow, capacity to absorb laser energy and thermal conduction through powder bed. Spherical particle morphology helps to obtain high packing density during the process that helps to obtain high relative density of SLM built component. The chemical composition of alloy powder is presented in table 1.

Table 1: Chemical composition of metal powder

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Element | Ni | Cr | Fe | Mn | Co | Ti | Al | Hg |
| Weight % | 54.33 | 19.9 | 17.44 | 1.46 | 1.76 | 1.26 | 0.76 | 3.11 |

### **2.2 Machine**

The machine was interfaced with a computer system for process control. Samples were built with varying four process parameters: laser power, scan speed, layer thickness and build orientation. The beam diameter 0.15 mm and hatch spacing 0.105 mm were kept constant. 5 mm X 5 mm island scanning strategy was used for building samples.



Figure 1:SLM Machine

**3.3 Taguchi Method**

The Taguchi method (TM) is a problem-solving technique to help improve process performance, to increase efficiency and productivity. The Taguchi method is centred around reducing potential variations in a process through [design of experiments](https://checkify.com/blog/design-of-experiment/). The objective of using the methodology is to produce high-quality products with low costs to the manufacturer. Reducing variations in processes through the robust design of experiments. Taguchi developed this method for designing experiments as a way to investigate how different parameters affect process performance and a way to define how well the process is functioning. The Taguchi method is about quality control that focuses on the importance of research and development (R&D), and product design and development as a key way to reduce the occurrence of failures in the manufacturing process.

As Taguchi looked to improve product design while lowering costs, he explained that the framework can be viewed in three main components:

**Systems Design**: Focuses on the primary aspects that are necessary to produce the required product. It can include the best combination of materials and processes.

**Parameter Design**: Involves the most suitable set of rules that govern the established design elements. Defining the components in each parameter makes it easy to minimise the variation from a product. The Taguchi approach empathises this stage because it is often overlooked during industrial design practice.

**Tolerance Design**: Look at the factors that play a significant role in product quality. It then identifies tolerance limits that provide the variation required in the design.

1. **Conclusion**

Using the Taguchi method, the machinability of an Inconel 718 under selective laser melting will be examined. L16 orthogonal arrays will be used in the Taguchi techniques. The chosen parameters for the Selective Laser Melting procedure include laser power, scan speed, layer thickness, and orientation. We'll employ statistical software. Taguchi will look at the effects of laser power, scan speed, layer thickness, and orientation. This study's primary goal is to determine which parameters have the most influence on surface hardness and roughness.

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