



# **Optimization of FDM Process Parameters for Improved Mechanical Properties of PLA Parts using Taguchi Method**

**Mr. Dhananjay R. Mane, Dr. A. S. Shelake**

P.G. Student, Department of Mechanical Engineering (Production), Ashokrao Mane Group of Institutions College, Vathar, Kolhapur, Maharashtra, India

Professor, Department of Mechanical Engineering, Ashokrao Mane Group of Institutions College, Vathar, Kolhapur, Maharashtra, India

**ABSTRACT:** Polylactic Acid (PLA) is a biodegradable plastic made from renewable resources. It has a low melting temperature and produces less environmental pollution, making it a popular material for 3D printing, especially in the FDM (Fused Deposition Modelling) process.

For industrial applications, PLA parts need to have reliable and consistent mechanical properties. The quality and strength of 3D-printed parts depend on several printing parameters that can be controlled through printing software. This review study examines how different FDM process parameters affect the mechanical properties of PLA parts. The researchers focused on six important parameters: layer thickness, printing speed, printing temperature, build plate temperature, build orientation, and raster angle.

The mechanical performance of the printed PLA specimens was evaluated using tensile, compressive tests. The review helps identify which process parameters have the greatest influence on the strength and performance of PLA parts produced by FDM technology.

**KEYWORDS:** FDM, PLA, Taguchi Method, Tensile Strength, Optimization, Additive Manufacturing

## **I. INTRODUCTION**

Additive manufacturing is a rapidly growing technology that allows the production of complex parts layer by layer. Among the different additive manufacturing methods, Fused Deposition Modelling (FDM) is widely used due to its simplicity, low cost, and material availability. In the FDM process, thermoplastic filament is melted and extruded through a heated nozzle to build a part layer by layer.

The mechanical properties of FDM printed parts depend strongly on process parameters such as layer height, infill density, raster angle, printing speed, and nozzle temperature. These parameters influence bonding between layers and ultimately affect the strength and durability of printed parts.

## **II. LITERATURE SURVEY**

Tesfaye Mengesha Medibew [1] explained about, Fused Deposition Modeling (FDM) is a kind of Additive Manufacturing technology, which can produce complex parts by adding layer-by-layer mold automatically from 3D computer-aided design (CAD) data. It can produce complex shapes, but parts often have low mechanical strength and heavier structure. This paper reviews methods to optimize parameters for better tensile strength of PLA parts. The quality of FDM parts depends strongly on process parameters.

ÜmitÇevik and Menderes Kam [2] explained about, Additive Manufacturing (AM) is widely used in modern industry. Fused Deposition Modeling (FDM) is one of the most common AM techniques. FDM parts made from polymers usually have low mechanical strength, so they are mainly used for prototyping. New improved materials can increase

strength and expand applications. This study focuses on metal/polymer composite filaments made using FDM. Adding reinforcement materials improves mechanical properties. As a result, stronger parts can be used in wider industrial applications.

Manoj Kumar Poddar and Saroj Kumar Sarangi[3] explained about, Fused Deposition Modeling (FDM) is a popular 3D printing method used to make complex parts. This study focuses on improving the strength of PLA printed parts by adjusting printing settings like infill pattern, speed, temperature, and layer thickness. Experiments were designed using the Taguchi method and tested using tensile and flexural tests as per ASTM standards. Results show that these parameters strongly affect the strength of printed parts.

Marta Mencarelli , MattiaSisella , Luca Puggelli , Bernardo Innocenti and Yary Volpe [4] explained about, This study examines how different 3D printing settings affect the strength of PLA parts made using FDM. Parameters like infill density, pattern, outer shells, and part orientation were tested using tensile, compression, and bending tests. Results show that infill density and number of outer shells have the biggest impact on strength. These findings help in improving and optimizing 3D printed parts.

GetuKoroMegersa, WojciechSitek ,Agnieszka J. Nowak and NevenTomaši [5] explained about, This study analyses how FDM printing settings affect the strength of PLA parts. Parameters like layer thickness, raster angle, build orientation, and temperatures were tested using the Taguchi method and ANOVA. Results show that build orientation has the biggest effect, with flat orientation giving the best strength. Optimal settings improve tensile strength and stiffness with high accuracy.

Vasile Cojocar, Doina Frunzaverde, Calin-Octavian Miclosina and Gabriela Marginean [6] explained about, PLA is a popular eco-friendly material used in FDM 3D printing. This study reviews how different printing parameters like layer thickness, speed, temperature, orientation, and raster angle affect mechanical properties. The behaviour of printed parts was analysed using tensile, compression, and bending tests. Results help in understanding and improving the strength of PLA printed parts.

Valentina Mazzanti, Lorenzo Malagutti and Francesco Mollica[7] explained about,This study reviews the use of natural fibre fillers in FDM 3D printing materials. While fillers can reduce cost and keep materials eco-friendly, they do not improve strength in common materials like PLA and ABS. However, some other polymers show better performance with fillers. More research is needed to improve results in this area.

Francesco Napolitano, Ersilia Cozzolino, IlariaPapa, Antonello Astarita Antonino Squillace[8] explained about,This study examines how FDM printing parameters affect both strength and energy use of PLA parts. Tests like tensile strength and energy consumption were analysed at different speeds and temperatures. Results show that higher speed and optimal temperature reduce time and energy while maintaining good quality. A new efficiency index is proposed to find the best printing settings.

#### CONCLUSION OF LITERATURE REVIEW

From the literature review, it is evident that FDM process parameters significantly influence mechanical properties of printed parts. However, further experimental studies are required to identify optimal parameter combinations that improve overall mechanical performance.

### III. STATEMENT OF THE PROBLEM

1.Fused Deposition Modelling (FDM) is one of the most widely used additive manufacturing techniques for producing thermoplastic components due to its low cost, ease of operation, and capability to manufacture complex geometries. However, the mechanical properties of FDM printed parts are often lower than those produced by conventional manufacturing methods.

2. The mechanical strength of FDM printed components is strongly influenced by several process parameters such as layer height, infill density, printing speed, nozzle temperature, and build orientation. Improper selection of these parameters can result in weak interlayer bonding, poor structural integrity, and reduced mechanical performance.

3. Many researchers have investigated the influence of individual parameters on the mechanical properties of FDM printed parts. However, the combined effect of multiple parameters and the identification of optimal parameter settings remain a challenge. Conducting a large number of experiments to determine the best parameter combination can be time-consuming and costly.

4. To address this issue, statistical optimization techniques such as the Taguchi Method can be applied. The Taguchi method uses orthogonal arrays and signal-to-noise ratio analysis to determine the optimal parameter settings with a minimum number of experiments.

5. Therefore, there is a need to systematically investigate the influence of important FDM process parameters and determine their optimal combination to improve the mechanical properties of 3D printed parts. This research aims to optimize selected FDM parameters using the Taguchi method and evaluate their effect on the mechanical strength of printed specimens through experimental testing.

#### **IV. OBJECTIVES**

1. To study the process of Fused Deposition Modelling and understand the effect of different printing parameters on the mechanical properties of printed parts.
2. To identify important FDM process parameters such as layer height, infill density, printing speed, and nozzle temperature that influence the strength of printed components.
3. To design experiments using the Taguchi Method in order to reduce the number of experiments and systematically study parameter effects.
4. To fabricate test specimens using an FDM 3D printer according to standard testing dimensions.
5. To evaluate the mechanical properties of printed specimens through tests such as tensile strength and compression strength.
6. To analyse experimental results using statistical tools such as Signal-to-Noise (S/N) ratio and ANOVA to determine the most influential parameters.
7. To determine the optimal combination of FDM process parameters that produces maximum mechanical strength.
8. To improve the overall performance and reliability of FDM printed parts for engineering applications.

#### **V. METHODOLOGY**

##### **A. Research design**

The research focuses on improving the mechanical strength of parts manufactured using Fused Deposition Modelling. In this process, thermoplastic filament is melted and deposited layer by layer to create three-dimensional objects.

First, a detailed study of previous research papers and technical literature will be conducted to understand how different printing parameters affect the mechanical properties of FDM printed parts. Based on this review, important process parameters such as layer height, infill density, and printing speed will be selected for investigation.

To systematically study the effect of these parameters, the Taguchi Method will be used. The Taguchi method allows researchers to design experiments efficiently using orthogonal arrays, which reduces the number of experimental trials while still providing reliable results.

Using the Taguchi L9 orthogonal array, different combinations of selected printing parameters will be defined. Test specimens will then be designed according to standard testing dimensions and fabricated using an FDM 3D printer.

After printing the specimens, mechanical testing will be carried out to evaluate the strength of the printed parts. Tensile tests will be performed according to ASTM D638, while compression tests will follow ASTM D695.

The results obtained from the mechanical tests will be analysed using statistical methods such as Signal-to-Noise (S/N) ratio analysis and ANOVA. These methods will help determine which process parameters have the most significant influence on mechanical strength.

Finally, the optimal combination of FDM process parameters that produces the highest mechanical strength will be identified. The results will be discussed and conclusions will be drawn regarding the best printing conditions for improving the mechanical properties of FDM printed parts.

#### **B. Tools Used in the Research**

##### 1. 3D Printer

A desktop FDM 3D printer will be used to fabricate test specimens.

##### 2. Printing Material

Thermoplastic filament such as PLA will be used for specimen fabrication.

##### 3. CAD Software

Software such as SolidWorks or Autodesk Fusion 360 will be used to design the test specimens.

##### 4. Slicing Software

Programs such as UltimakerCura or PrusaSlicer will be used to generate G-code and control printing parameters.

##### 5. Mechanical Testing Machine

A Universal Testing Machine (UTM) will be used to measure tensile and compression strength.

##### 6. Statistical Analysis Software

Software such as Minitab or Microsoft Excel will be used to analyse experimental results and perform Taguchi optimization.

#### Requirements for the Project

The following resources are required to successfully complete the research work.

##### 1. 3D Printing Material

Thermoplastic filament material such as PLA or ABS will be required for printing the test specimens.

##### 2. FDM 3D Printer

A desktop FDM 3D printer is required to fabricate specimens with different printing parameters.

##### 3. Test Specimen Design

Standard specimen models must be designed according to ASTM standards for tensile and compression testing.

##### 4. Mechanical Testing Equipment

A Universal Testing Machine (UTM) is required to measure tensile strength and compression strength of printed specimens.

##### 5. Measurement Tools

Basic measuring instruments such as:

Verniercalliper

Digital weighing machine

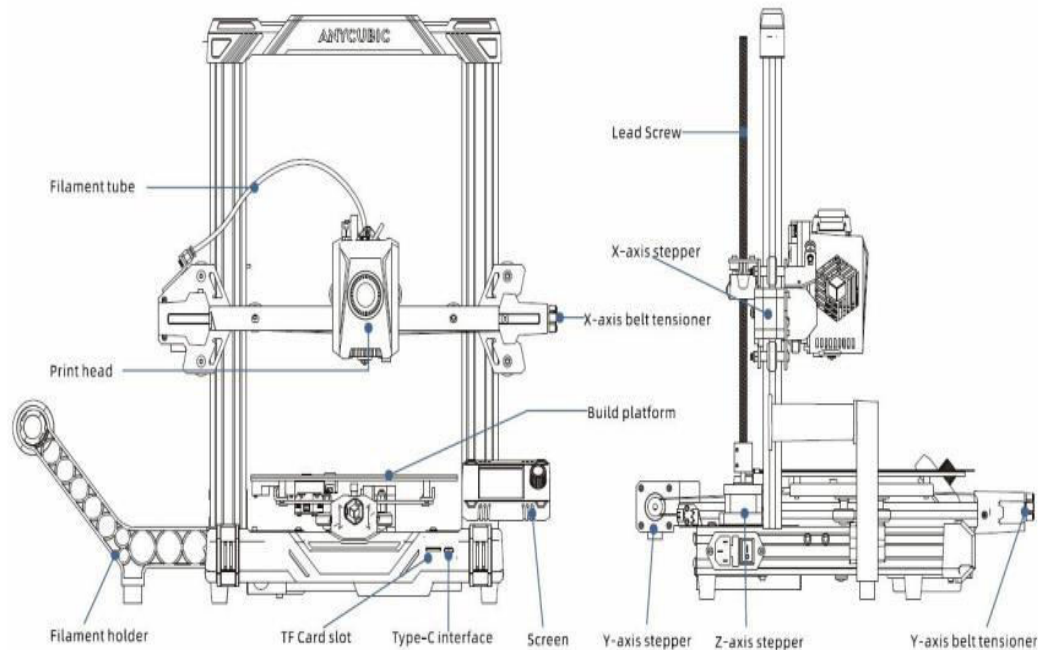
Scale or micrometre

These tools will help measure specimen dimensions accurately.

##### 6. Data Analysis Tools

Software tools for statistical analysis and Taguchi method calculations will be required to analyse the experimental results and determine optimal parameter settings.

### C.3D printer details:-



## VI. TECHNICAL SPECIFICATION

### TECHNICAL SPECIFICATION PRINTING

- Technology: FDM (Fused Deposition Modelling)
- Build Size: 220 mm (L) × 220 mm (W) × 250mm (H)
- Layer Thickness: 0.05 – 0.3 mm
- Positioning Accuracy: X / Y / Z 0.0125 / 0.0125 / 0.0025 mm
- Extruder Quantity: Single
- Nozzle Diameter: 0.4 mm
- Supported Materials: PLA/TPU/PETG/ABS etc.

### TEMPERATURE

- Ambient Operating Temperature: 8 °C – 40 °C
- Operational Extruder Temperature: Max 260 °C
- Operational Print Bed Temperature: Max 110 °C

### SOFTWARE

- software Output Formats: GCode
- Connectivity: Memory card;
- Type-c cable Electrical Power Input: 110V / 220 V AC, 50 / 60 Hz
- Rated Power: 400 W
- Physical Dimensions Printer Dimensions: 444mm (L) × 440 mm (W) × 485 mm (H)
- Net Weight: ~7.3 kg

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