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# 3D Print Parameter Optimization: A Literature Review

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## Abstract

*3D printing technology is developing very fast. One of the technologies that are often encountered is Fused Deposition Modeling (FDM). FDM technology has many advantages, such as easy maintenance, not easily damaged, easy to operate, relatively safer, and relatively cheaper. Much researches on the optimization of the FDM process have been carried out. There is a need to map research results regarding process optimization and the results of FDM technology so that it can provide research opportunities for other researchers to develop this technology. For this reason, this study aims to map the results of research that has been carried out regarding the optimization of the 3D printing process, especially FDM technology. This study uses a qualitative method, namely, a literature review. According to technology and year of publication, some literature is selected to provide relevant and up-to-date results. Based on the literature review that has been done, some process parameters are used along with the desired response variables.*

Keywords: 3D Print, FDM, Parameter, Optimization

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# I. INTRODUCTION

3D printing technology is a technology that is growing rapidly nowadays. The high need for a production process that is fast, flexible, easy to use is the factors that influence this increase. It is the reason that makes this technology used in various industries, such as the food industry, cars, planes, buildings, and also health (Petrovic *et al.*, 2011).

3D printing technology itself is a technology based on the layer by layer manufacturing of products. Unlike the existing manufacturing processes, where the material is formed by reducing the original material, this technology actually adds material. Therefore, 3D printing is also called layer manufacturing and also additive manufacturing.

3D printing technology is based on the material used. The material used can be powder, liquid, or solid (filament). For liquid materials, usually, the 3D print process is done by shooting a laser at the surface of the material. The surface of the material that is hit by the laser will harden and form a layer. The process will repeat itself so that it becomes a 3-dimensional product. The same concept applies to powder materials. Laser firing on this powder material will cause a bond between one molecule to another molecule. When a laser-firing process is complete, you will get a layer that will repeat itself into a product.

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In contrast to the powder and liquid materials, the concept of 3D printing technology using solid material (filament) does not use a laser but the nozzle. The filament passing through the nozzle is heated so that the material melts. This nozzle moves following the instructions or shapes that have been previously inputted so that it will form a layer. These layers will be stacked and become a 3-dimensional product. This technology using filament material is better known as Fused Disposition Modeling (FDM).

FDM technology has many advantages, such as easy maintenance, not easily damaged, easy to operate, relatively safer, and relatively cheaper. That is why FDM technology is more widely used. With the many uses of FDM technology, there is also more and more research on this technology. Various studies were conducted to optimize the process and also the results of FDM technology (Rinanto *et al.*, 2018; Radhwan *et al.*, 2019; Saad *et al.*, 2019; Sharma, Sharma and Kala, 2019; Wankhede *et al.*, 2019; Yang *et al.*, 2019; Zaman *et al.*, 2019; Camposeco-Negrete, 2020; Dey, Hoffman and Yodo, 2020; Yadav *et al.*, 2020). Optimization is carried out for various parameters so that better results are obtained in terms of time, cost, product strength, etc.

However, it is often the case that the research process carried out by a research team has been carried out in advance by other researchers at almost the same time. There is a need to map research results regarding process optimization and the results of FDM technology so that it can provide research opportunities for other researchers to develop this technology. For this reason, this study aims to map the results of research that has been carried out regarding the optimization of the 3D printing process, especially FDM technology, so that it can provide an overview of technology and opportunities for further research development.

## II. RESEARCH METHODOLOGY

This research is qualitative research. The data used is research data that specifically discusses process optimization and 3d printing results, especially FDM technology. This technology was chosen because it is easier to find, lower costs, a large number of users, and a large amount of research on process optimization and also the results of FDM that has been done. The span of years of research data used in this study literature is limited to the last three years. This is determined in order to capture up to date potential research. Sources of data used in this study are from journals and proceedings as well as some relevant literature books.

## III. RESULT AND DISCUSSION

There are some parameters used in this study, such as layer thickness, infill percentage, print speed, temperature, and infill pattern.

### III.1. Layer Thickness

Layer thickness or layer height is the thickness level of a layer when the material in the FDM process is melted. Layer thickness can directly affect the processing time and also the level of surface smoothness. The thicker the layer, the faster the process, but the resulting surface will be rougher. In contrast, the thinner a layer, the longer the process, but the resulting surface will be smoother (Nancharaiah *et al.*, 2010; Chohan and Singh, 2017). Usually, to save time and money, the 3D print process is done using a thick layer thickness. After the product is finished, it is mashed manually by a refining processor with the help of chemicals. However, this only applies if the printed product does not have geometric shapes with a high level of complexity. If the product has a geometric shape with a high level of complexity, then the refining process will actually take longer and cost more. In addition to affecting the processing time and also the level of surface smoothness, many studies have stated that layer thickness also affects the strength of the results.

### III.2. Infill Percentage

Similarly, the layer thickness, infill percentage is also one factor in influencing the outcome of 3D print products. This percentage infill is the content percentage of the product form that will be made. Infill percentage 100% means making a solid object, while 0% infill percentage means only making a cover without any content in it. To create a product, we can choose how much the infill percentage will be used. The bigger the infill percentage, the longer it will take, the more material is used, the heavier the product will be. Meanwhile, the smaller the infill percentage, the faster the processing time, the less material used, and the lighter the product. The infill percentage also affects the strength level of the 3D print products.

### III.3. Print Speed

Print speed also affects the results of the 3D print. The faster the print speed, the less processing time will be, whereas the slower the processing time will also increase. The print speed needs to be adjusted so that it is neither too slow nor too fast. It is adjusted to the nozzle temperature and nozzle thickness.

### III.3. Temperature

Temperature is the condition at the nozzle when heating the filament. Temperature settings need to be considered in order to remain stable. The temperature that is too hot can cause the material to melt more than it should. Meanwhile, temperatures that are too low can cause the print process not to run smoothly. With a stable temperature, the melted filament material will have a uniform shape. It will make the 3D printed product stronger. Temperature settings also affect the use of power used.

### III.4. Infill Pattern

The infill pattern is a pattern used in making a product for 3D printing. There are several types of infill patterns, including diamond, cross, honeycomb, and linear infill patterns. This infill pattern affects the strength of the 3D print product. Apart from that, the infill pattern is also directly related to the infill percentage. The size of the infill pattern is based on the infill percentage. The bigger the infill percentage, the smaller the infill pattern will be, and the number will be a lot smaller. In contrast, if the infill percentage gets smaller, the size of this infill pattern will get bigger, and the number will get smaller.

Apart from these parameters, there are other parameters that can be used when doing the 3D printing process. These parameters are then used as input in doing the 3D print process. There are many methods that can be used, such as Taguchi, response surface method, and others to perform the optimization process of these parameters to get the desired result characteristics, lower cost, and more efficient time. Several studies related to the optimization of 3D printing parameters can be seen in Table 1.

Table 1. FDM Optimization

| Author | Process Parameter | Method | Response Variable |
|---|---|---|---|
| (Saad *et al.*, 2019) | Layer thickness<br>Print speed<br>Print temperature<br>Outer shell speed | RSM, particle swarm optimization (PSO), and symbiotic organism search (SOS) | Surface roughness |
| (Camposeco-Negrete, 2020) | layer thickness, filling pattern, orientation angle, printing plane, and position of the piece on the printing table's surface | Taguchi | processing time, the energy consumption of the 3D printer, and dimensional accuracy of parts manufactured by the FDM process, using ASA as the model material |
| (Wankhede *et al.*, 2019) | infill density, layer thickness, and support style | Taguchi | build time of part and Surface roughness on Acrylonitrile Butadiene Styrene (ABS) polymer |
| (Zaman *et al.*, 2019) | layer thickness, shells, infill pattern, and infill percentage | Taguchi | compressive strength |
| (Yang *et al.*, 2019) | nozzle diameter, liquefier temperature, extrusion velocity, filling velocity, and layer thickness | Response surface methodology combined with nondominated sorting genetic algorithm II | tensile strength (TS), surface roughness (SR), and build time (BT) |
| (Yadav *et al.*, 2020) | material density, infill density, and extrusion temperature | Artificial neural network (ANN) and genetic algorithm-artificial neural network (GA-ANN) hybrid | tensile strength of Acrylonitrile Butadiene Styrene (ABS), Polyethylene Terephthalate Glycol (PETG), and Multi-material test pieces |
| (Sharma, Sharma and Kala, 2019) | layer thickness, infill percentage, and print speed | DOE and optimization techniques | Tensile and compressive strength of ABS |
| (Rinanto *et al.*, 2018) | Temperature, density, and fill angle. | Taguchi and PCR-TOPSIS | High tensile strength with low energy consumption and processing time |
| (Radhwan *et al.*, 2019) | layer thickness, print speed, and fill density | Response Surface Methodology | surface roughness |
| (Dey, Hoffman and Yodo, 2020) | layer thickness, build orientation, infill density, and extrusion temperature | Particle swarm optimization | higher compressive strength and lower build time |

## IV. CONCLUSION AND FURTHER RESEARCH

Based on the study result that has been conducted, it is found that the parameters used in doing 3D printing include layer thickness, infill percentage, print speed, temperature, and infill pattern. These parameters are used in experiments using Taguchi, response surface method, PSO, etc. The desired yield characteristics are roughness, cost, strength, and processing time.

This research only focuses on optimizing the FDM parameters to be a reference in optimizing other parameters. However, because it only focuses on optimizing the FDM parameters, there are still many further explored parts. The sections that can be investigated further include design, materials, marketing, usability, etc. In addition, this study also mentions several methods used in the optimization process—most of the Taguchi methods, response surface method, and genetic algorithms such as PSO and ANN. Research on parameter optimization can be carried out by applying other methods so that it can have an impact on novelty research.

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