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Comparison of Dimensional Accuracy and Surface Quality of 3D Printed Parts from Various Slicing Software and Infill Patterns

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ABSTRACT

Fused Filament Fabrication (FFF) is a subcategory of Additive Manufacturing (AM). FFF is also widely used in 3D printing technology with the globally known AM. To accommodate the rapid growth, numerous research studies and developments have contributed to the significant achievement of FFF. For example, many slicing software applications are available to provide better-quality printed parts. The purpose of slicing software is to instruct the 3D printer to perform operations. Therefore, selecting the best slicing software among various options is crucial. In this article, a comparative study of dimensional accuracy and surface quality of 3D printed parts from various slicing software (Ultimaker Cura, PrusaSlicer, and CraftWare Pro) and infill patterns (line, grid, and gyroid) was conducted. Dimensional accuracy was measured based on the dimensional error recorded by the printed parts to the designed dimension. Meanwhile, the surface quality was measured based on the surface roughness value recorded from the printed parts. The lowest surface roughness was suggested as a better surface quality product. From the study conducted, it can be concluded that Ultimaker Cura produced better dimensional accuracy compared to PrusaSlicer and CraftWare Pro. In addition, the infill pattern did not affect the dimensional accuracy of the produced part. In contrast, the infill pattern affected the slicing software selection for surface quality. A line pattern using CraftWare Pro is recommended to produce better surface quality. Meanwhile, Ultimaker Cura is ideal for generating grid infill patterns, whereas PrusaSlicer is recommended for gyroid infill patterns.

INTRODUCTION

Additive Manufacturing (AM) is widely used nowadays. Due to its high flexibility and simple process, AM has been employed to manufacture complex and customized products. Fused Filament Fabrication (FFF) is a subcategory of AM, which is simple, cost-effective, and easy to operate [1]. FFF is

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a process of extruding a melted polymer through a nozzle that moves according to a pre-determined slicing program by slicing software. The product is built layer by layer until it is complete [2]. Nowadays, many FFF 3D printer brands are available in the market [3,4]. Slicing software plays an important role in supporting processing using a 3D printer. Slicing software is required to set printing parameters and slice the 3D Model into a pre-determined layer before loading the program into the 3D printer. Many printing parameters can be customized for a product, such as infill pattern, bed temperature, nozzle temperature, printing speed, assigned material, type of support, and infill density. Many research studies have published optimization parameters for the process [5-7].

However, there are still other opportunities to explore further. For example, many slicing software are available in the market, such as MatterControl, Ultimaker Cura, KISSlicer, PrusaSlicer, CraftWare Pro, and Simplify 3D. Each slicing software is bound to have slight differences. Sljivic et al. [8] emphasized the importance of slicing software, concluding that Simplify 3D slicer is better than Cura and Slicer 3D. Other slicing software can also be used by 3D printer users apart from the slicing software that comes with the 3D printer. Since performance and characteristics studies on various slicing software to produce products are still scarce, this study was conducted to compare the dimensional accuracy and surface quality of printed parts produced from various slicing software programs/settings, namely Ultimaker Cura, PrusaSlicer, and CraftWare Pro. The findings of this study are expected to provide insight into the characteristics of slicing software, which can lead to the selection of the most suitable slicing software for 3D printers.

METHODOLOGY

Three main processes were involved in this study, commencing with the development of a 3D Model using Solidwork software and slicing software (Ultimaker Cura, CraftWare Pro, and PrusaSlicer), 3D printing parts, and measurement of dimensional accuracy and surface quality of 3D printed parts.

3-Dimensional Model

In this study, the geometry of the 3D Model was selected according to ASTM D638 Type 1. The Model was developed using Solidwork software and saved in STL file format.

Slicing Software

From the 3D Model previously developed and saved in the STL file, the Model was opened, and printing parameters were set in each slicing software. In this study, the slicing software selected were Ultimaker Cura, PrusaSlicer, and CraftWare Pro. Each slicing software used printing parameters similar to those tabulated in Table 1. All parameters were constant except the infill patterns, which were varied into line, gyroid, and grid patterns. These infill patterns were selected based on the strength characteristics of the Model after the printing process, as described by Jay [9]. The line was categorized as low strength pattern, the gyroid was medium strength, while the grid represented high strength (Fig. 2). The set parameters were then sliced and saved before printing.

Table 1: 3D printing parameters.

Parameter	Value
Filament material/diameter	PLA/1.75mm
Extruder /bed temperature	220°C/ 60°C
Infill percentage/layer thickness	40%/ 0.3mm
Printing speed	40mm/s
Infill pattern	lines, gyroid, grid

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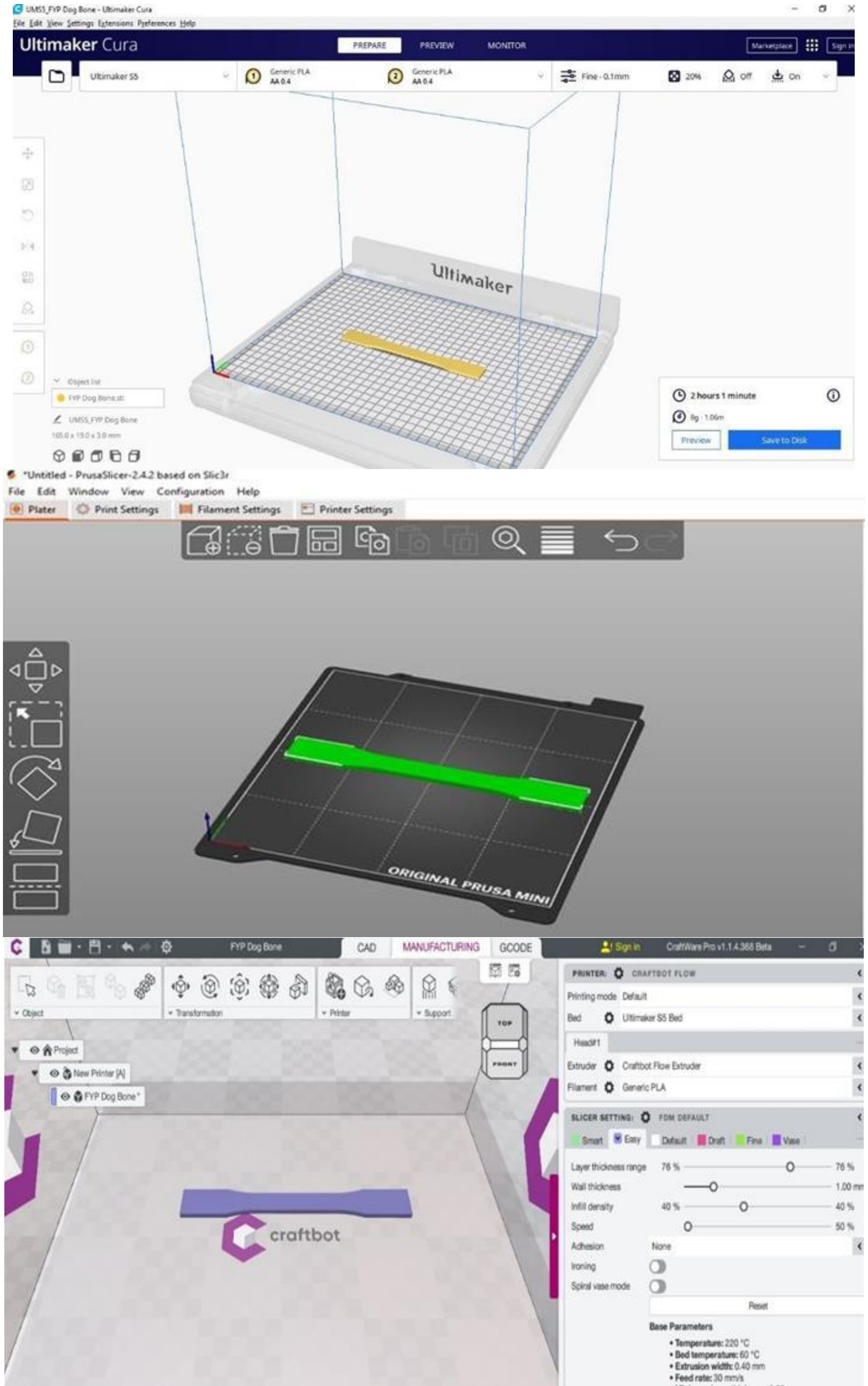

Fig. 1: Slicing software interfaces: Ultimaker Cura (top), PrusaSlicer (centre), and CraftWare Pro (right)

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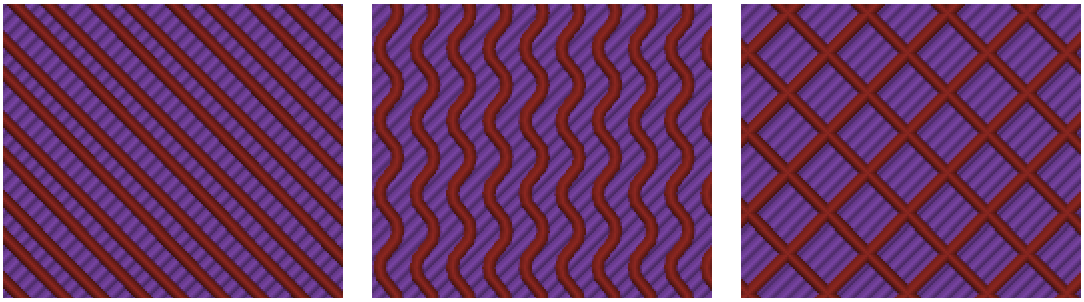

Fig. 2: Infill patterns: line (left), gyroid (centre), and grid (right)

3D Printing and Measurement

From the saved slicing program, the parts were then printed using a 3D Espresso F220 machine (Fig. 3). Two factors were considered when comparing each slicing software. The first factor was dimensional accuracy, measured based on a percentage of dimensional error (Equation 1). The lower the percentage, the more accurate the dimensions of the printed part to the designed dimensions. Three dimensions were measured, namely width, height, and thickness for each part. The dimension of each part was measured using a vernier caliper, and the average values from three sets (three replicates for each variable) of the printed samples were recorded. The second factor was surface quality measured based on the surface roughness value for each printed part, and each value obtained from each slicing software was compared. The best surface quality of the printed part was indicated by the lowest surface roughness value as measured by SURFTEST SJ-210.

$$\text{Dimensional error} = \text{ABS}\left((D_d - D_p / D_d) \times 100\right) \quad (1)$$

Where:
ABS: Absolute number
D_d: Design dimension
D_p: Printed dimension

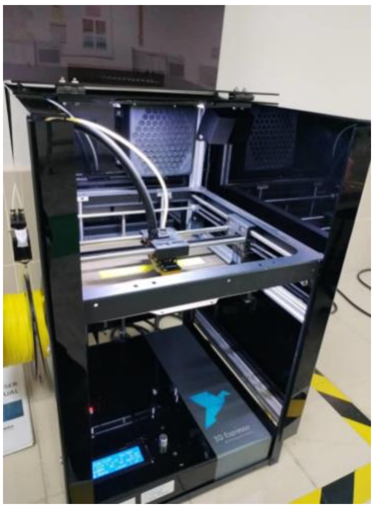

Fig. 3: 3D Espresso F220 machine

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RESULTS AND DISCUSSION

Dimensional Accuracy

Table 2 shows the average values of dimensional measurements of 3D printed parts. At the same time, Fig. 4 depicts the bar chart of dimensional errors of three types of infill patterns (line, grid, and gyroid) obtained from various slicing software (Ultimaker Cura, PrusaSlicer, and CraftWare Pro). The dimensional error bar charts were calculated using Equation 1 based on the data in Table 2. From the graph, it was explicit that the Ultimaker Cura software's slicing program generated a product closer to the designed dimension. At any dimension (width, height, and thickness) and infill pattern, the part produced from the Ultimaker Cura software indicated the lowest dimensional error among other software.

Meanwhile, Craftware Pro was the second software capable of generating accurate dimensions even though the height dimension exceeded the performance of line and gyroid infill patterns. Based on the results, PrusaSlicer needed help securing its program's consistent height dimension. Therefore, the height error was greater for all types of infill patterns. It was also discovered that slicing software affected the dimensional accuracy of the printed parts and infill pattern according to the trend. However, a comparison of individual slicing software demonstrated that the infill patterns did not affect the dimensional accuracy of the printed parts.

Table 2. Data measurement of 3D printed parts

Line pattern				
Measurement	Designed dimension	Ultimaker Cura	PrusaSlicer	CraftWare Pro
Length	165.00	163.90	164.33	163.81
Width	19.00	18.96	19.13	19.25
Height	3.20	3.19	3.68	3.45
Grid pattern				
Measurement	Designed dimension	Ultimaker Cura	PrusaSlicer	CraftWare Pro
Length	165.00	163.67	164.16	163.90
Width	19.00	19.03	19.30	18.95
Height	3.20	3.27	3.56	3.21
Gyroid pattern				
Measurement	Designed dimension	Ultimaker Cura	PrusaSlicer	CraftWare Pro
Length	165.00	164.08	164.67	164.60
Width	19.00	19.17	19.03	19.14
Height	3.20	3.20	3.55	3.56

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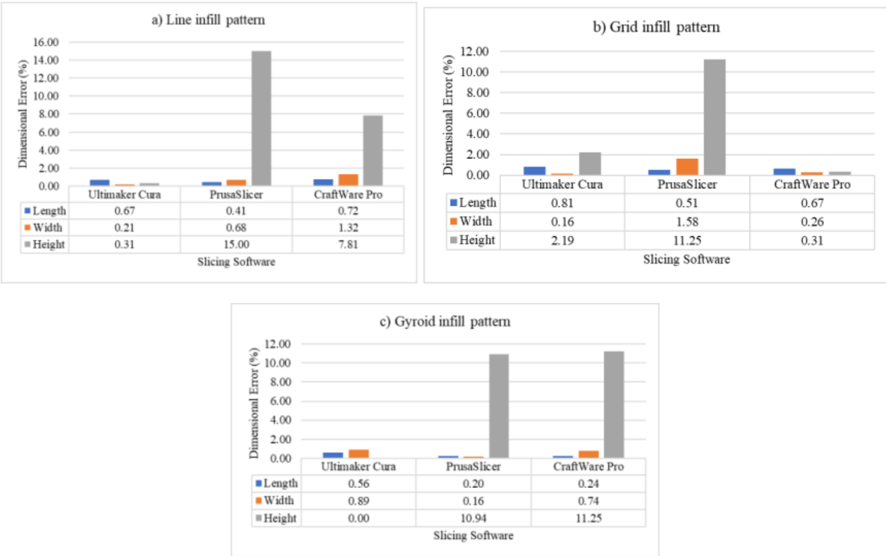

Fig. 4. Dimensional errors of 3D printed parts obtained from various slicing software and infill patterns: a) line, b) grid, and c) gyroid.

Surface Quality

Fig. 5 shows the surface roughness values obtained from various slicing software. The results showed that the roughest surface was generated by CraftWare Pro slicing software and gyroid infill pattern. On the other hand, the lowest surface roughness part was generated by Craftware Pro slicing software and line infill pattern. This trend was similar to those of Ultimaker Cura and PrusaSlicer slicing software, where part of the line infill pattern has a smoother surface than part of the gyroid infill pattern. Thus, the infill pattern affected the surface quality of the printed part. The line infill pattern was better than grid and gyroid infill patterns to produce a smoother surface. In deciding which slicing software could produce a smoother surface, it was suggested that the infill patterns be determined beforehand. The reason was that CraftWare Pro is the best slicing software for line infill patterns. Meanwhile, Ultimaker Cura should be chosen for the grid infill pattern, and PrusaSlicer slicing software is recommended for the gyroid infill pattern.

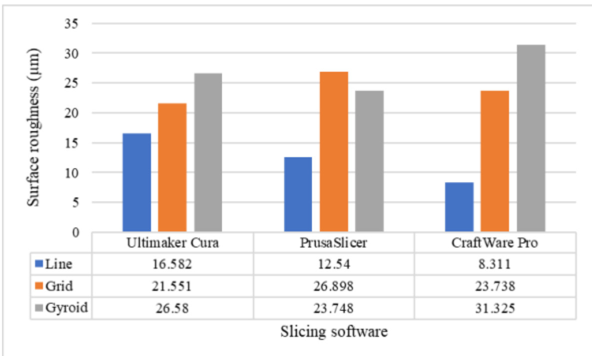

Fig. 5. Surface roughness values obtained from various slicing software for different infill patterns

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CONCLUSION

The manufacturing performance of 3D printed parts using various slicing software and different types of infill patterns was evaluated. By comparing manufacturing performance based on dimensional accuracy and surface quality, several conclusions can be drawn as follows:

1) Ultimaker Cura slicing software produced more consistent dimensional accuracy than PrusaSlicer and CraftWare Pro.
2) The infill pattern did not affect the dimensional accuracy of the printed parts. However, it affected surface quality.
3) Line infill patterns produced better surface quality (smoother surface) than grid and gyroid infill patterns.
4) To choose the best slicing software for better surface quality, the type of infill pattern should be considered. Ultimaker Cura is ideal for grid infill patterns, while CraftWare Pro is the most suitable for line infill patterns, and PrusaSlicer should be used for gyroid infill patterns.

This study's findings align with Sljivic et al. (2019), where slicing software affected the performance and quality of the printed parts. Thus, selecting the best slicing software is crucial and significant.

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CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted without any self-benefits or commercial or financial conflicts and declare the absence of conflicting interests with the funders.

AUTHORS' CONTRIBUTIONS

Normariah carried out the research and wrote and revised the article. Lyvanrick collected the data. Koay, Hamid, and Shuib advised on the paper's content, review, and structure. Nor Azirah and Nor Suhada reviewed and revised the article submission.

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