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Experimental Investigation of Fused Deposition Modelling 3D Printing Process on Propeller Blade Roughness Using PLA+

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***Abstract**. The manufacturing process now emphasizes producing high-quality products. Additive manufacturing, particularly Fused Deposition Modeling (FDM), fulfills these demands by enabling precise fabrication through filament layer extrusion. This study investigates the effects of process parameters, specifically layer thickness and infill density, on the surface roughness of PLA+ polymer material using FDM. Surface orientation plays a crucial role in determining the quality of printed components, such as propeller blades with complex geometries. Surface roughness was analyzed using the Gaussian Filter method with cutoffs of 800 µm and 25 µm at different surface points, namely top and bottom. The results indicate that layer thickness significantly impacts surface roughness. A layer thickness of 0.1 mm yielded smoother surfaces compared to 0.3 mm, as the smaller layer height reduces the formation of uneven surface lines and roughness. The higher layer thickness (0.3 mm) increased the distance between layers, resulting in a rougher texture. In conclusion, optimizing layer thickness, particularly at 0.1 mm, improves surface quality. These findings highlight the importance of parameter control in achieving high-quality 3D printed components, especially for intricate geometries like propeller blades.*

***Keywords:** FDM 3D Printing, PLA, Roughness, Layer Thickness, Cutoff.*

1. INTRODUCTION

Additive manufacturing, popularized as a rapid prototyping process that utilizes 3D digital model data, is now a breakthrough innovation in the industry introduced by Charles Hull in 1980 as stereolithography (Lengua 2017; Ngo et al. 2018), and commercialized by Stratasys in the 1990s by Scott Crump (Weng et al. 2016)developed AM manufacturing technique is Fused Deposition Modeling (Aslani et al. 2020; Barreno-Avila, Monar-Naranjo, and Barreno-Avila 2021; Galeta et al. 2016). Fused Deposition Modeling (FDM) is known as the extrusion of thermoplastic materials (Hartcher-O'Brien, Evers, and Tempelman 2019; Ngo et al. 2018; Wang, Zou, and Ding 2019), which undergoes melting through a nozzle where the process is horizontally layered to build model parts by using Computer-Aided Design 3D (Jaisingh Sheoran and Kumar 2020). In the FDM part of the object is created using a solid material known as a filament which is heated at the head of the nozzle (Doil and Kusiak 1994; Samykano et al. 2019). In the AM process, thermoplastic materials are very appropriate to be applied due to the flexibility of the material, and shape geometries (Galetto, Verna, and Genta 2021), such as PLA (Polylactic Acid) are the main materials used as deposition materials which can reach nozzle heat temperatures of around 300°C (Alsoufi and Elsayed 2017).

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Polylactic Acid is a semi-crystalline polymer (Peterson 2019) classified as biodegradable to the environment because it can be decomposed and the absence of chemical mixtures so that it is easy to mould because of the low melting point temperature (Suteja and Soesanti 2020) with a recommended temperature range between 190°C-230°C (Jaisingh Sheoran et al., 2020; Shenzhen Esun Industrial Co., Ltd., n.d.) causing the material's melting point to adhere tightly to the platform easily. FDM technology provides significant advantages in the fabrication of objects with complex and challenging geometries (Aslani et al. 2020; Galetto et al. 2021; Rayegani and Onwubolu 2014; Vidakis et al. 2022) over conventional manufacturing processes (Backeris and Borrello 2017; Townsend et al. 2016). Another advantage of FDM is that the materials are readily available and do not contain toxic substances, efficient production time capability, low maintenance costs (Alsoufi and Elsayed 2018), and the potential to reduce object deviation compared to other prototyping methods (Chaidas et al. 2016; Dwiyati et al. 2019).

This technology was developed to make it easier to visualize the product's simple design because the product's dimensional accuracy and functional performance play an important role in improving the quality value of product quality. However, it significantly affects the cost, design-to-production cycle time, and material selection (Gibson, Rosen, and Stucker 2015). This implementation of additive manufacturing is increasingly widespread, especially in the manufacturing, aerospace, and automotive industries (Aslani et al. 2020), architecture, medical devices, and aerospace (Aslani et al. 2020; Weng et al. 2016).

Now Fused Deposition Modeling is widely applied in rapid prototyping; apart from that, the FDM method has limitations in quality, including warping at the end of the raised part on the platform (Galantucci, Lavecchia, and Percoco 2009; Li et al. 2019), surface roughness due to deposition of molten material on the layer (Alsoufi and Elsayed 2018; Chen and Zhang 2019; Hartcher-O'Brien et al. 2019) extruded by a moving nozzle giving rise to a “stair-stepping” effect (Ahn et al. 2009; Lavecchia, Guerra, and Galantucci 2022; Vyavahare, Kumar, and Panghal 2020) limited geometry tolerance (Taşcıoğlu et al. 2022) produced by the FDM process due to the characteristics of fused material-based manufacturing so that it is less effective in meeting the competitiveness value of the industrial (Mendricky and Fris 2020; Webbe Kerekes et al. 2019). The quality review of printed parts is based on performance characteristics as a process scope which includes manufacturing process parameters, material and part geometry that impact the tribological treatment of surfaces in the FDM manufacturing process (Eladl et al. 2018; Shirmohammadi, Goushchi, and Keshtiban 2021; Vidakis et al. 2022).

2. LITERATURE REVIEW

Numerous studies have explored the quality indicators of extrusion-based moulded parts, where the moulding process involves stacking layers of material beads, resulting in surface roughness. Several researchers have investigated the process parameters that affect the quality of these moulded parts. Alsoufi and Elsayed (2017) investigated the surface roughness of printed parts using PLA material with process parameters of raster deposition angle, nozzle diameter, and layer thickness. They conducted experimental roughness measurements using a profilometer, understanding that the nozzle diameter and layer thickness parameters were the main factors affecting the surface roughness quality. At the same time, the raster deposition angle had no significant effect. Aslani et al. (2020) experimentally investigated the impact of two process parameters, wall thickness, and extraction temperature, using PLA as the sample moulding material and Taguchi's orthogonal array as the experimental design method. The researchers concluded that high extraction temperature and wall thickness did not significantly affect the dimensional accuracy of printed parts. However, the high temperature was exceptionally able to minimize surface roughness.

The literature of Sammaiah et al., (2020) analyzed the surface roughness of ABS material FDM printed samples against the impact of infill density parameters (20%, 40%, 60%, 80%, and 100%) and layer thickness (0.06 mm; 0.1mm; 0.14mm; 0.18mm; 0.22mm and 0.26mm). They found that the 20% infill density parameter with a layer thickness of 0.26 mm resulted in poor surface roughness. In comparison, 100% infill density with a layer thickness of 0.06 mm showed proper surface roughness. It was concluded that a high infill density parameter and low layer thickness showed optimal surface roughness.

Different printing parameters affect the surface roughness obtained, as Vyavahare et al., (2020) in their experiments, showed that the five process parameters are layer thickness, wall print speed, orientation, wall thickness, and extrusion temperature. Their study stated that the layer thickness and orientation parameters significantly affect the surface roughness. (Alsoufi and Elsayed 2018) observed that the printed parts of ABS polymer materials have high surface roughness values compared to PLA under the same process conditions due to the formation of high warping deformation.

In recent years, there has been widespread research on surface roughness quality. Now, some researchers are expanding on this by investigating the impact of the formation of defects in FDM printed samples. (Jang et al. 2021) analyzed the fabrication of FDM structures with four process parameters, namely printing speed, layer thickness, extrusion rate, and nozzle diameter, which affects the line arrangement of the layers and the resulting void space on the printed part. They concluded that the layer thickness, extrusion rate, and printing speed parameters affect the line width. Based on the literature, the author concludes in his paper that high printing speed parameters result in thin lines and formed gaps, but low printing speed results in thick lines. This will impact printed parts' dimensions, shape, and surface roughness indicators. Advances in FDM can now create modelling with diverse geometries such as cubes, ellipses, curves, etc.

Taşcıoğlu et al., (2022) in their study conducted experiments on printed samples with square prism geometry (20 mm x 20 mm x 15 mm) of PLA material considering two printing process parameters, ie, layer thickness and printing temperature by measuring surface roughness and topography on each sample, ie, side and top surface using Keyence digital optical microscopy. The paper confirms that the coating thickness parameter is the main parameter affecting the surface roughness in samples with square geometry. The printing temperature parameter does not affect roughness but can control the accuracy of the printed dimensions.

Other quality indicators have been analyzed by Buj-Corral et al., (2021) on the effects of layer thickness, printing speed, temperature, and flow rate with PLA material on surface roughness, and dimensional error. They observed that the roughness factor and dimensional error increased with higher layer thickness and flow rate. Since then, many works have utilized 3D FDM technology in various product applications due to its attractive features when designing highly complex product geometries, such as the formation of curved geometry profiles. Ahn et al., (2009) observed a product manufacturing study of 3D models of ABS material with elliptical or parabolic arch cross-sections at a non-uniform surface angle using layered manufacturing. The designed product model was measured for surface roughness using the Surftest Formtracer with a rotating plane angle on the model surface. In their study, the roughness value applied was the average roughness (Ra) from the measurement centerline to the surface profile, they concluded that the surface roughness distribution was significantly influenced by cross-sectional geometry, surface angle, and layer thickness factors.

Buj-Corral et al., (2021) analyzed the surface roughness of hemispherical cup products with hemispherical geometry of 32 mm internal diameter and 50 mm external diameter using PLA against the moulding process. Roughness measurements on the external and internal surface of the cup product using a Talysurf 2 contact roughness meter with Ra, Rz, Rku, and Rsk as roughness parameters concluded that the dominating roughness depends on the layer thickness and nozzle diameter.

Radhwan et al., (2020) observed the results of arch products with an internal radius of 15 mm and external radius of 25 mm against printing parameters with different levels (layer, outline speed, and extruder temperature) which have an impact on product surface quality indicators, namely roughness surface product by FDM process, they confirmed that the main factor that plays a role in the quality of surface roughness is the layer thickness parameter. However, researchers Wang et al., (2019) said that low or high printing speed process parameters with low layer thickness result in poor surface morphology quality of complex geometry products even though the product roughness value is smoother. Galetto et al., (2021) investigated curved and square geometry products with six process parameters: layer thickness, bulk density, extruder temperature, number of shells, print speed, and retraction speed on PLA filament with a response of print time, surface quality, and dimensional accuracy.

The authors found that low printing efficiency was affected by thick layer thickness but reduced surface roughness depending on different product geometry and structure with dimensional accuracy; consideration of design features is needed because the overhang geometry of the product is more accurate with low print speed. Based on the literature review, many researchers have focused on investigating the surface roughness quality of FDM products. However, there needs to be more information related to the surface roughness produced in the FDM 3D printing process with more curved geometry. Work has not been found to create a propeller blade model product with an inhomogeneous corner curve. Considering this problem, this study focuses on the analysis of the surface roughness of the propeller blade product through the FDM 3D Printing fabrication process.

3. METHODS

Based on the literature review, the phenomenon of the FDM process has caused deviations in the quality of printed parts produced, but this section applies the FDM process with more complex geometry modelling experiments that will have an impact on the quality indicators surface roughness of the product.

1.1 Material

The raw material used in this work is a thermoplastic-grade polymer, PLA. A low-temperature FDM technology process fabricates the material, becoming solid when cooled to the glass transition temperature and returning to the initial properties of the material. The PLA filament material used for quality observation of propeller printed products is produced by Shenzhen Esun Industrial, Nanshan District, Shenzhen, China, with a filament diameter of 1.75

mm, weight of 1 kg, and white colour. The specifications of the properties of the filament material applied in 3D printing obtained from the manufacturer are presented in Table 1.

Table 1. Properties of PLA+ filament

Properties	Units	Value
Grade	-	Semi-crystalline
Density	g/cm³.	1.25
Glass transition temperature	ºC	57-60
Heat conductivity coefficient	W /(mK)	0.13
Heat capacity	J/(kg.K)	1700
Rockwell hardness	-	82-88
Elongation at break	%	12
Melt flow index	g/10min	4(190ºC/2.16kg)
Notched Izod impact	kJ/m²	8.5
Tensile strength	MPa	65
Flexural strength	MPa	75
Flexural modulus	MPa	2102
Print temperature	ºC	205-225
Bed temperature (platform)	ºC	60-80
Shrink rate	in/in	0.0037-0.0041

Shenzhen Esun Industrial Co., Ltd.

1.2 Description Process

Fused deposition modelling is becoming an additive manufacturing fabrication technology by deposition of thermoplastic filaments to build 3D parts by feeding the filaments into the liquefier chamber, Figure 1. The process begins with a computer-aided design with very complex arch-shaped propeller dimensions are 40 mm inner diameter and 110 mm outer diameter, designed using Dassault's Solidwork System, then changing the format. stl (stereolithography), loading the file into the Ultimaker Cura 5.2.1 slicer. Ultimaker Cura software loads slicing on the design file by entering the 3D printer machine printing process parameters set for the printed part. Table 2 shows the constant parameters used in the production process of printing the product. Then the design file generates a g.code program that will be read on the 3D printer through the SD Card containing the geometry of the part to be printed. Setting the process parameters affects the production time and properties of the print. Experiments were conducted using Anycubic i3 Mega Drucker 3D Printer technology, Shenzhen, Guangdong, China, with a build size of 210 mm x 210 mm x 205 mm.

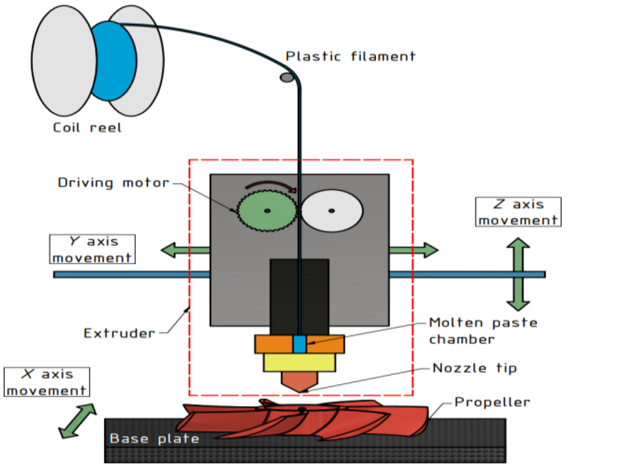

Figure. 1 Schematic of the FDM process

Table 2. Printing process parameters of FDM for PLA+

Factors	Units	Value
Printing temperature	ºC	210
Bed temperature	ºC	70
Nozzle diameter	mm	0.4
Print speed	mm/s	50
Reaction speed	mm/s	50
Fan speed	%	100
Infill pattern	Lines	-
Road width	mm	0.4
Orientation build	degree	90
Extrusion rate	%	100

Fused deposition modelling technology in the manufacture of propeller parts makes 2 types of techniques in one material, namely the primary material as a printed product and the support material as a support for the object when printed. During moulding, the material is heated to the melting point and then extruded through a nozzle tip that moves in horizontal and vertical directions to build layers on the bed/platform. The nozzle moves to the next layer and hardens to form the arch geometry model. The model is formed with multiple stacks and layers deposited from bottom to top. Figure 1. Schematic of the FDM fabrication process for printing propeller components into physical products. Meanwhile, Figure 2 shows an illustration of the stages of the FDM 3D printing process into more complex products.

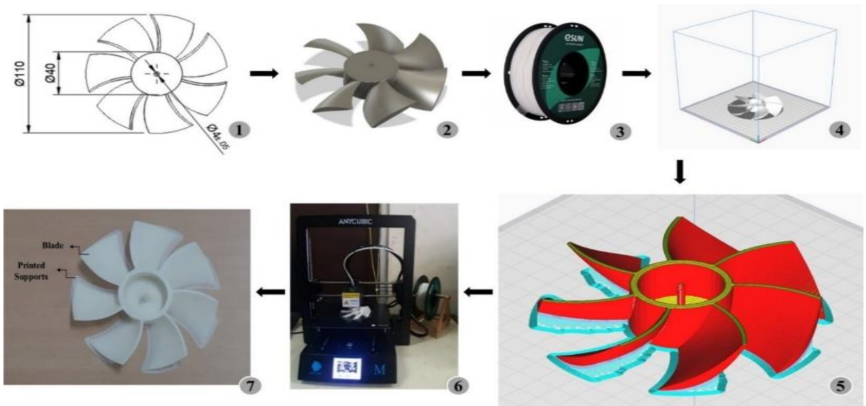

Figure. 2 The steps to produce propeller (Dimensional 3D, STL, Material PLA, Transfer file to slicer Ultimaker Cura, Parameters setup, Build product geometry; Printed product)

1.3 Parameter Selection

Many parameters impact surface roughness quality, but little information incorporates the correlation between surface roughness quality and defects formed. In this observation, trying to observe the quality indicators of the product produced, the two process parameters or control factors used are layer thickness and infill density. These control parameters consist of a scale of each process parameter's minimum, middle and maximum values (Table. 3).

Table 3. Factors and their level parameters

Factor process parameters	Units	Low	Medium	High
Layer Thickness (LT)	mm	0.1	0.2	0.3
Infill Density (ID)	%	60	80	100

1.4 Material Characterization

FDM product quality indicators of surface roughness and void space defects were observed using a laser-scanning confocal digital microscope (LEXT OLS4100 from Olympus Corporation, Tokyo, Japan), Figure 3. Measurements were taken using an objective magnification of 20X. Surface roughness was recommended using the ISO 4288 standard Gaussian Filter, which some researchers use with a cut-off value of 80 µm (Buj-Corral, Sánchez-Casas, and Luis-Pérez 2021; Chen and Zhang 2019). The roughness measured on the propeller is the blade section with three surface points, namely the top and bottom points, Figure 4.

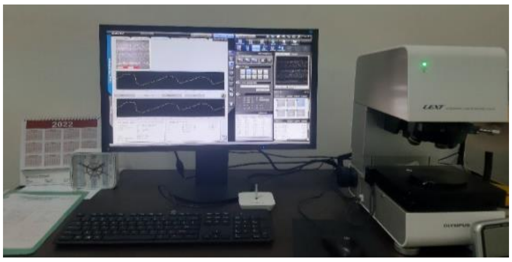

Figure 3. Laser-scanning confocal digital microscope (LEXT OLS4100)

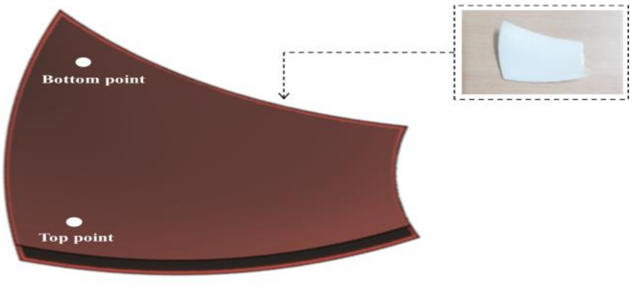

Figure 4. Roughness measurement points on the propeller blade

Analysis of roughness testing on the propeller blade part of the blade top point surface point is the area where the printing process is completed, while the bottom point is the start of the printing process when the nozzle tip ejects the filament that sticks to the printer platform /bed due to pressing. Investigation of product surface roughness indicators is recommended using the Gaussian Filter method measurement with a cutoff value of 800 µm by ISO 4288 to measure roughness on filament coating beads, a large cutoff measurement method to measure a wider roughness texture on a large scale (Aslani et al., 2020; Buj-Corral, Bagheri, et al., 2021; ISO 4288:1996 Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture, n.d.). Meanwhile, measuring the effect of the surface roughness of the filament coming out of the nozzle tip using a cutoff value of 25µm with ISO 4287, is a method that uses a small scale so that the measurement of roughness samples is more accurate.

4. RESULTS

Based on Measurements on propeller blade samples using the FDM 3D Printing process were carried out replication measurement as many as 5 times to get mark accurate roughness using Gaussian Filter measurements at 800 µm and 25 µm cutoffs. Table 4 shows a representation of the result data measurement rudeness at each surface point at the 800 µm cutoff. The table presented shows a significant difference even though replication testing at the point blade sample.

Table 4. Data Roughness measurement using Gaussian Filter cutoff 800 µm

Exp No.	Parameter process		Mean Roughness-Ra (µm)	
	Layer thickness (LT)	Infill density (ID)	Top point	Bottom point
1	0.1 mm	60%	28.945	22.639
2	0.2 mm	60%	30.463	19.249
3	0.3 mm	60%	40.307	24.689
4	0.1 mm	80%	23.290	23.013
5	0.2 mm	80%	24.531	32.623
6	0.3 mm	80%	39.183	23.336
7	0.1 mm	100%	20.269	20.792
8	0.2 mm	100%	22.108	30.623
9	0.3 mm	100%	39.870	21.145

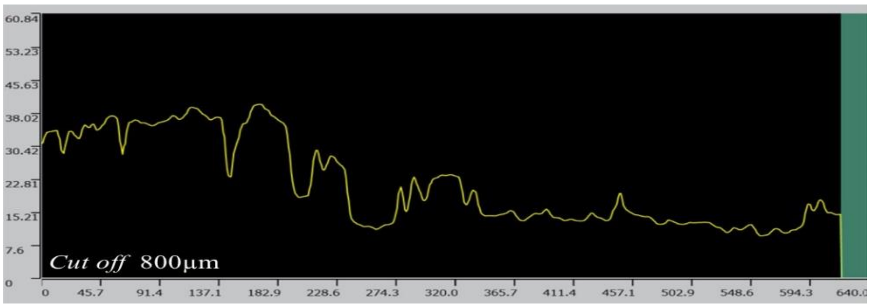

Figure 5. Representation measurement roughness-Ra using cutoff 800 µm

Figure 5 presents representation measurement on the profile measured surface using a cutoff of 800 µm. The illustration picture indicates Peak and valley heights describe level unevenness or rudeness measured surface. Figure 4 shows the characteristics of the rudeness surface from the blade to point surface namely the top point and bottom point are formed by curve fluctuations indicating that some points obtained mark amplitude big It means the level rudeness surface more rougher and vice versa. Based on a curve and result data measurement a laser-scanning confocal digital microscope (LEXT OLS4100 from Olympus Corporation, Tokyo, Japan) is presented in the chart For know difference mark significant roughness different, Figure 6 shows the average value measurement roughness in the top point area (finishing process) against the FDM 3D Printing process parameters, namely layer thickness and infill density with different parameter values. Figure 7 shows the graph in the bottom point area which is the location of The beginning of the propeller blade printing process when the 3D Printing nozzle tip releases filament as a material attached to the printer bed.

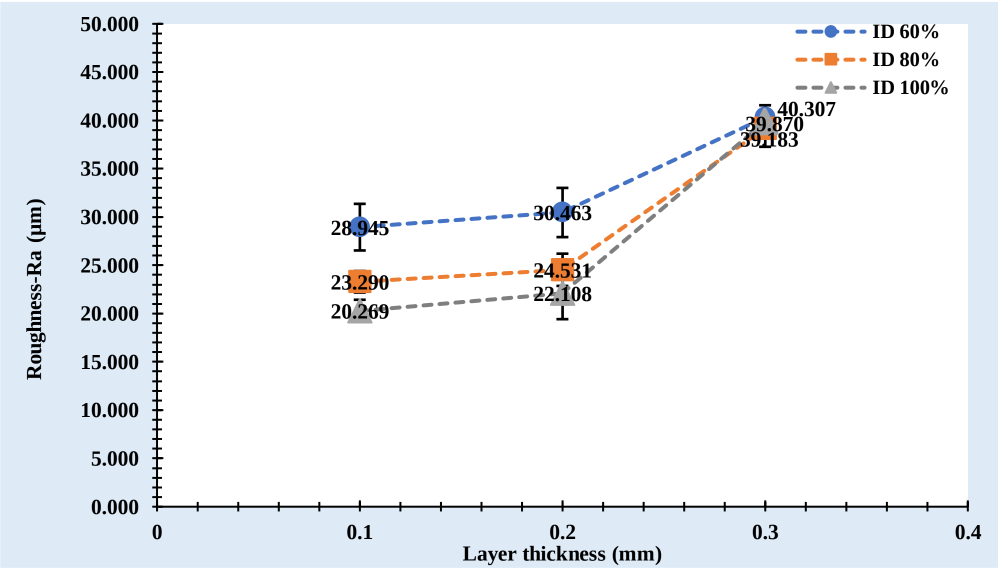

Figure 6. Graph of the results of the average roughness measurement-Ra at the top point surface using a cutoff of 800 µm

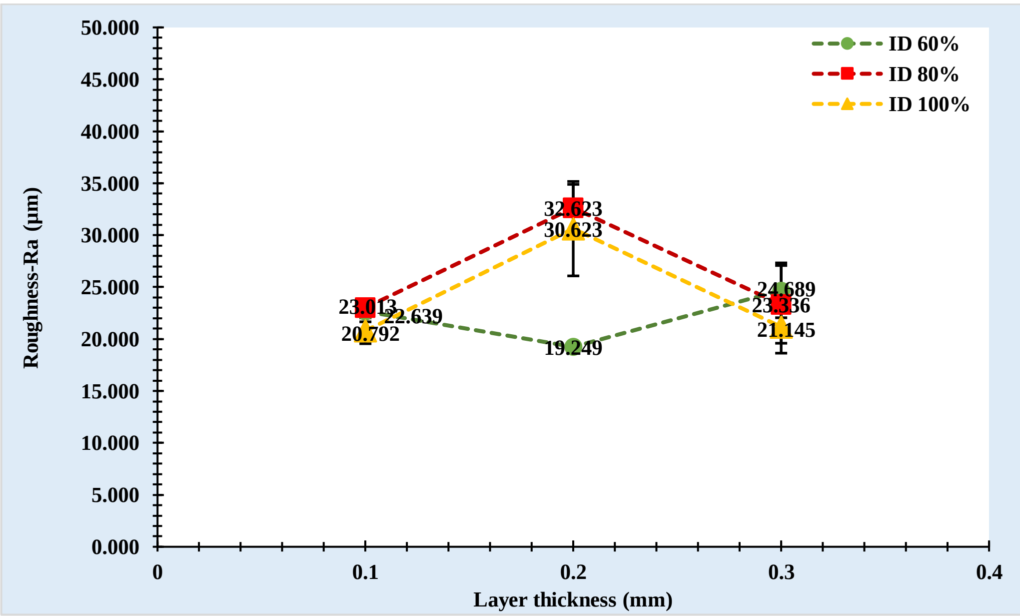

Figure 7. Graph of the results of the average roughness measurement-Ra at the bottom point surface using a cutoff of 800 µm

Testing rudeness with Gaussian Filter cut off method ƛc 25 µm; ƛs None; ƛf None ISO 4728 performed measurement on sample blade propeller with two point areas surface namely top point and bottom point. Measurement with a cut-off of 25µm was performed To measure the texture rudeness of surface filament coming out from the nozzle by removing noise for quality of the roughness that is obtained more accurately and detailed, using a low cut-off capable reduce waves formed. Table 5 presents the results of the measurement data at a cutoff of 25 µm carried out in the point area surface with as many as 5 times replication on the layer thickness and infill density parameters.

Table 5. Data Roughness measurement using Gaussian Filter cutoff 25 µm

Exp No.	Parameter process		*Mean Roughness*-Ra (µm)	
	Layer thickness (LT)	*Infill density* (ID)	Top point	Bottom point
1	0.1 mm	60%	1.652	1.260
2	0.2 mm	60%	1.566	1.186
3	0.3 mm	60%	1.397	0.796
4	0.1 mm	80%	1.383	1.143
5	0.2 mm	80%	1.480	0.927
6	0.3 mm	80%	1.330	2.484
7	0.1 mm	100%	1.219	1.214
8	0.2 mm	100%	1.447	1.969
9	0.3 mm	100%	1.094	1.298

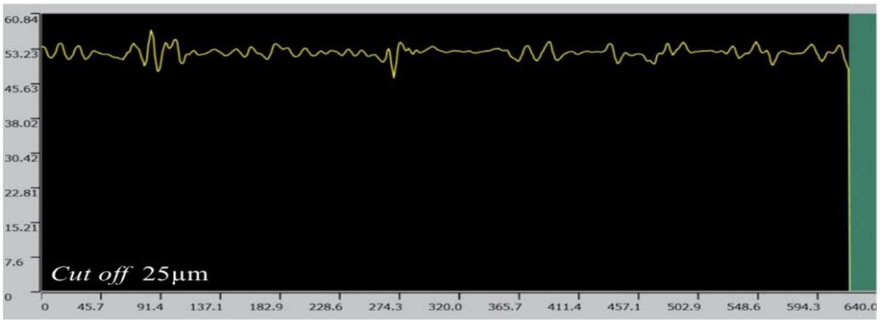

Figure 8. Representation measurement roughness-Ra using cutoff 25 µm

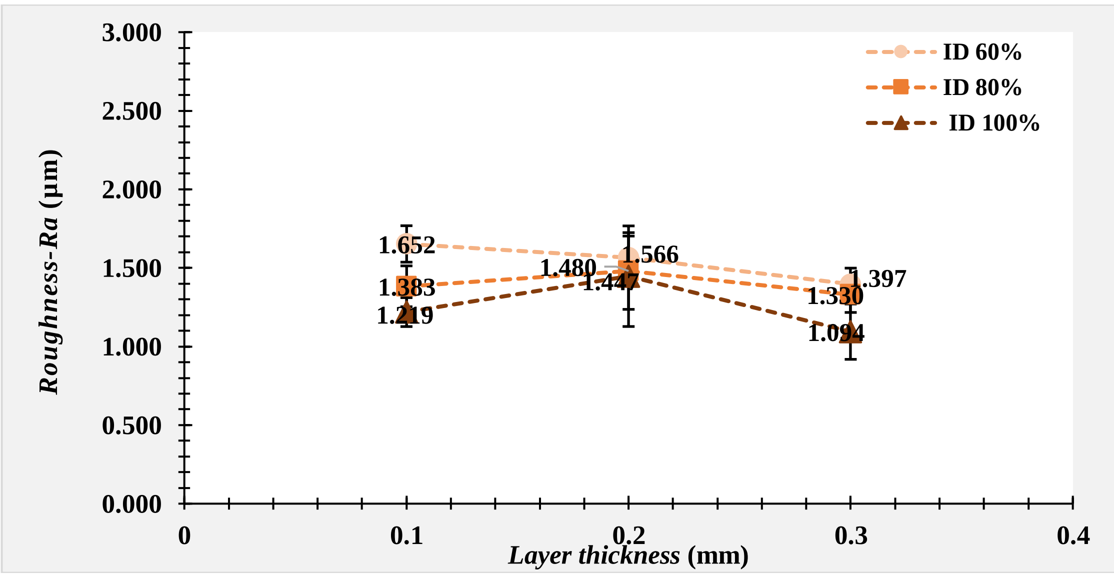

Figure 9. Graph of the results of the average roughness measurement-Ra at the top point surface using a cutoff of 25 µm

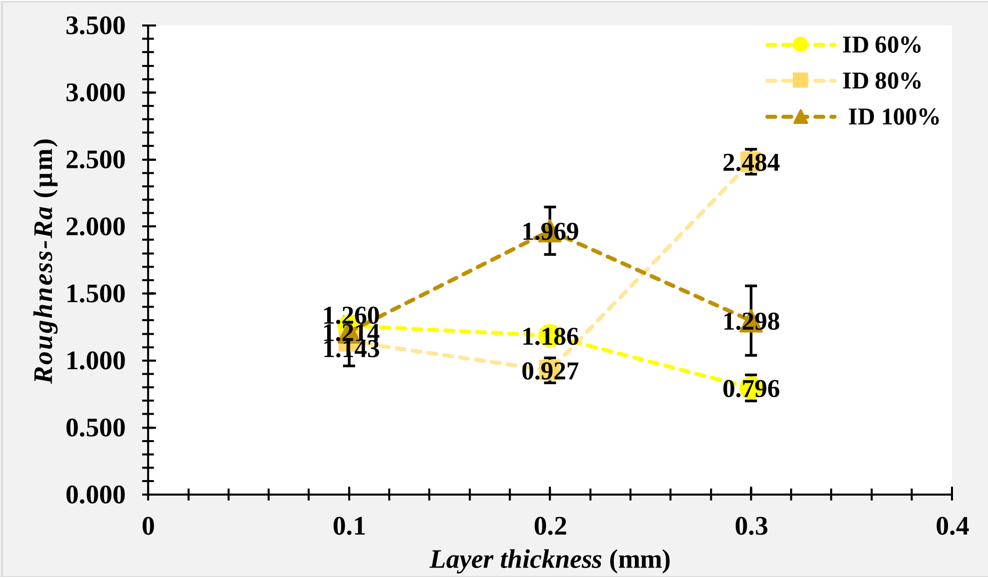

Figure 10. Graph of the results of the average roughness measurement-Ra at the bottom point surface using a cutoff of 25 µm

5. DISCUSSION

Based on data and graphs generated from measurements of propeller blade samples experimentally with geometry the product is more complex Where a more radius or curved shape is done. Measurements at different point areas (top point and bottom point) with the same material, PLA+, against the FDM 3D Printing process parameters, namely layer thickness levels values of 0.1 mm; 0.2 mm and 0.3 mm with a certain infill density mark different namely 60%, 80% and 100%. Table 4 obtained results roughness-Ra using a Gaussian Filter with a cutoff of 800 µm that will listed in the form chart roughness -Ra. Figure 6 shows the surface area top point it can be seen that the performance parameter layer thickness 0.1 mm obtained average roughness -Ra 24.168 µm; on the 0.2 mm layer it is 25.700 µm and experiences improvement large on the 0.3 mm layer with roughness -Ra obtained 39.786 µm. While with the same process parameters and cutoff, the point area is different Where The bottom point surface presented in Figure 7 shows that the surface roughness-Ra is at a layer thickness parameter of 0.1 mm with roughness-Ra obtained 22,148 µm; temporary For layer thickness 0.2 mm experienced improvement roughness -Ra to be 27.498 µm as Likewise, at a layer thickness of 0.3 mm, the roughness-Ra was obtained as 23.056 µm. the three roughness results based on the graphs displayed are done to get the final average value. This is done to get a more accurate roughness sign. The data shows that the parameters have a significant effect on increasing surface roughness, while the infill density does not have a significant effect on the roughness of the indicator. This research is in line with a study conducted by Sammaiah et al., (2020) in which study that the variation in infill density does not significantly influential big on rough surfaces but the layer thickness becomes part main influencing factor quality rudeness surface in the FDM 3D printing method.

The best optimal roughness performance -Ra from two points surface between the top point and bottom point is a layer thickness of 0.1 mm in the bottom point area with mark optimum roughness is only 22.148 µm, this occurs Because low layer thickness with condition filament molten experience emphasis on the nozzle with the platform during the printing process in progress so that happen to widen elongated beads create a bond area between filament glue with good. While the maximum layer thickness of 0.3 mm produces texture rudeness become bad. Election low layer thickness is capable reduce the formation of layer lines filament that will lower texture rudeness surface Alsoufi et al., (2017). Concluded, that to reach more surfaces the focus lies on the layer thickness, but need known thickness of extruded filament will speed up the printing process time.

Temporary For Gaussian Filter method at cutoff 25 µm, average roughness value surface Based on Figures 9 and 10, the roughness graph (Ra) is in the range of 0.8 µm to 2 µm at both surface points. The Bottom of Form deviation that occurs due to the high layer thickness of 0.3 mm results in a low print resolution resulting in the appearance of layer lines on the surface of the printed product so that a larger layer of beads is formed. Chohan, Singh, and Boparai (2016) in his studies do measurement texture rudeness surface by taking mark rudeness using a Gaussian filter cutoff of 25 µm obtained results mark -Ra roughness is minimum 0.2154 µm and maximum roughness -Ra is 2.5023 µm. This can be it is assumed that the use of cut-off parameters is less capable of measuring texture and more roughness specifically with reduced noise that is formed.

6. CONCLUSION

a. Process parameters Layer thickness is identified as a significant parameter that influences the rudeness surface. Using layer thickness 0.1 mm produces a mark rudeness higher surface (Ra) low compared to with layer thickness 0.3 mm, both at the point top point and also the bottom point from the propeller blade. This shows that the reduction in layer thickness correlated with the improved quality of the surface.
b. Gaussian Filter Method with a cut-off of 800 µm was used To measure roughness on a larger scale, describing the general rudeness surface. On the other hand, the measurement with a cut-off of 25 µm capable of revealing texture in more detailed and specific roughness, allowing deeper analysis deep into the characteristics surface.

c. In the study it was found that the layer thickness is higher tall will lower the quality surface. This decrease is caused by the formation of layer lines more filaments bigger and more rough, which directly contributes to the improvement mark's rudeness surface.

LIMITATION

Based on research that has been done Still a need to develop more specific coverage related to the parameters of the Fused Deposition Modelling 3D Printing process, for example, position parameters printing appropriate objects To produce quality far away products more superior, especially in design object print that does not uniform like level radius object more varies. And this research still needs to be developed Again For more delve into other parameters that play a role connect relatedness quality rudeness with age-use products produced by the FDM 3D Printing process. This research will also be developed with characterization results in more 3D printing deep for example in structure morphology surface with objective observation of direct level density (porosity) of each layer filament material that affects strength from product print said, this is still become problem problem-based on references obtained until this year not yet There are researchers who do analysis investigation rudeness connecting surface density more products complex.

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