EVALUATING THE IMPACT OF SANDBLASTING AND SPRAY COATING ON SURFACE THICKNESS IN ABS 3D PRINTED PARTS

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ABSTRACT: In Fused Filament Fabrication (FFF) 3D printing, surface irregularities and roughness, often referred to as the "stair-stepping" effect, reduce part quality in terms of mechanical performance and visual appeal. Conversely, post-processing techniques can improve the surface finish, but their influence on the surface thickness is still not clear. It is related to the fact that this lack of knowledge impairs the optimization of these methods for increased quality of the surface of the part without impairing the dimensional accuracy. This study aims to investigate and compare the impacts of sandblasting and spray coating post processing methods on the surface thickness of ABS FFF 3D printed parts to improve surface quality. The sandblasting process and spray coating process were used to analyses the influence of both technique to the surface thickness of ABS printed parts. The result of sandblasting shows 1.64 μm of thickness when using with 106 μm of aluminum oxide abrasive size. The thickness reduced to 0.93μm with 29.5 μm of abrasive size. Then, spray coating provided higher surface thickness 6.79μm when using 100 kPa of pressure with three-layer of coating. The sample shows 8.55μm of surface thickness when the pressure was increased to 800 kPa with one-layer of coating. Therefore, this paper provides scientific knowledge and solutions to improve surface quality by focusing at surface thickness of ABS 3D printed parts.

KEYWORDS: *Surface Thickness; Fused Filament Fabrication (FFF); Post-Processing Process; Sandblasting; Spray Coating*

1.0 INTRODUCTION

There are various 3D printing technologies out there, but fused filament fabrication (FFF) is still the most popular. The recent rise in open-source 3D printers can be attributed to the simplicity and eco-friendly nature of FFF technology. [1]. 3D printing can be described as a layer-by-layer manufacturing method and directly from a CAD model using a variety of materials using an additive process. FFF is viewed as a significant enabler for current industry trends because of its potential to transform manufacturing by introducing new processes, materials, and applications. The FFF process enhances sustainability by consuming less energy and reducing material waste [2]. This will help to unleash the full potential of the technology and provide significant chances to implement smart resource-oriented production in the context of Industry Revolution 4.0. Considering the increasing concern for the environment, plastics are the preferred materials for prototyping using the FFF technology. In addition, plastics are used in a variety of products and industries due to their low cost, ease of manufacturing, flexibility, and water resistance. Acrylonitrile butadiene styrene (ABS) is one of the most often applied polymers in the production of various parts for engineering applications. This polymer frequently gets metalized to change the products surface qualities [3].

However, defects, inaccuracies, and other quality issues are common with FFF printing [4]. Since most concerns and “defects” of the FFF 3D printing technology are found on the product’s surface, finishing is required post-processing process to make the product more presentable. Post-processing is the various mechanical and chemical finishing techniques that can be directly applied to the surface of the printed part. The performance of surface characteristics usually increases by applying the post-processing method. Usually, properties are reported in term of surface roughness and dimension accuracy. These characteristics are important for reducing the 'stair stepping' effect to obtain a better surface finish and determining the dimensional change after post-processing methods. Many post-processing approaches have been studied and implemented to improve surface roughness in FFF parts [5]. The approaches may be divided into two categories namely chemical and mechanical methods [6][7]. However, most of studies did not highlight the effect of post processing technique on the surface thickness of 3D Printed part. Mechanical methods such as sandblasting utilize an abrasive technique that can potentially reduce the thickness of the surface. On the other hand, coating techniques involve adding an additional layer to the surface, thereby increasing its surface thickness. Despite these differences, both techniques share the common objective of improving the surface roughness of the part. The significance of both post-processing techniques on surface quality is vital, as it plays a critical role in determining the performance, longevity, and visual appeal of the part. In this study, post-processing process of experimental was conducted to analyses various parameters of the sandblasting and spray coating finishing process of ABS printed parts that effect on the surface thickness.

Mechanical finishing includes material removal and cleaning, while chemical finishing uses material addition of chemical coating. These finishing techniques are used to achieve smoothness effects, good surface properties, and added durability. The mechanical finishing techniques mainly include manual sanding, abrasive flow machining, milling, barrel finishing, vibratory finishing, and sandblasting. Mechanical finishing typically used as surface preparation involves removing these particles and, in some cases, roughening up the substrate to increase the area available for adhesion. The simplest mechanical finishing is hand sanding and sandblasting [5]. But manual sanding techniques must be predictable, consistent, and under control in terms of parametric. Abrasive flow machining has increased the roughness of FFF printed parts with increasing extrusion pressure, abrasive concentration and finishing time [8]. Lavecchia et al., [9] stated employed CNC milling technique will solve the staircase problem using CNC milling machines. However, this approach to surface removal proved inefficient when complex surfaces or small details were to be machined. Rodríguez et al. [10] found that polishing shafts with ball burnishing not only increased the surface quality but also made the surface harder. Surface roughness (Ra) was found to be decreasing and rising with processing time for representative corroded samples of varied geometries when using barrel finishing techniques. The optimal finishing time was found to be between four to six hours [11]. Chohan, [12] observed that process with vibratory finishing provides longer hours and utilizing lower media weight resulted in higher dimensional stability for ABS products. Sandblasting or polishing usually used to reduce the product's surface roughness [13]. This technology has the characteristics of being appropriate for mass manufacturing, quick, and affordable [14]. Among the mechanical finishing methods, sandblasting process is preferable over manual sanding, abrasive flow machining, milling, and vibratory finishing ball because of its short processing time and low cost [15].

Another secondary post-processing method is chemical finishing or metallization, which is a coating process on a non-metallic material with a metal. The coating is typically applied to enhance a substrate property, allowing it to be used for additional purposes, such as improved conductivity, corrosion resistance, or aesthetics. The chemical coating can improve the surface quality of FFF printed products without reducing their dimensionality. Gap-filling, spray coating, plating, vapor smoothing, and water transfer printing are the types of chemical coating techniques considered under surface quality improvement methods in post-processing techniques [16]. Haidiezul et al., [17] examined surface finish effects from the application of gap filling with different coating layer numbers using XTC-3D coating developed by Smooth-on, USA on ABS products. These additional layers allow for increased quality of surface finishing which is also cost-effective. The staircase effect can be filled in with chemical coatings applied to a product. For example, chemically hardened resins and waxes can be used to overcome this issue [18]. In terms of the aesthetical factor for the coating spray, the visual appearance of the final product has complete flexibility, but for the electroplating, sanding the surface may be necessary to ensure a smooth surface finish [7]. The application of coating spray is considered a cheap and easily accessible tool.

This critical review of available literature reflects that, for all these analyses and studies, not much work has focused on the effect of post-processing techniques, such as sandblasting and spray coating, on the thickness of the surface of ABS Fused Filament Fabrication 3D printed parts. The work details the functioning and results of the optimization studies carried out on the post-processing variables to provide better surface qualities without compromising dimensional accuracies in the parts. The main aim of this study was to investigate the effect of these strategies on surface thickness and compare them, aiming at possible guidelines for improvement in post-processing practice. Significantly, it will help the manufacturing sector produce better additive-manufactured 3D components with an excellent surface finish and consistent dimensions, expanding the utility of the FFF technology into various industries.

3.0 METHODOLOGY

The methodology section thoroughly describes the system used in our research to assess how sandblasting and spray coating affect the surface thickness of ABS 3D-printed products. This paper presents novel findings on optimizing surface quality through post-processing operations, particularly concerning dimensional accuracy. We provide a detailed account of the procedures for sample fabrication, post-processing, and measurement and analysis to ensure the results are reliable and replicable. The experimental work was organized into several stages. It started with sample fabrication using Fused Filament Fabrication (FFF) with ABS material, followed by mechanical and chemical finishing processes. These stages concluded with tests for surface roughness and thickness. By using two approaches—mechanical finishing like sandblasting and chemical finishing like spray coating—a clearer and more detailed view of their effects on the surface thickness of FFF parts can be provided. The main flow of the experimental methodology is shown in Figure 1.

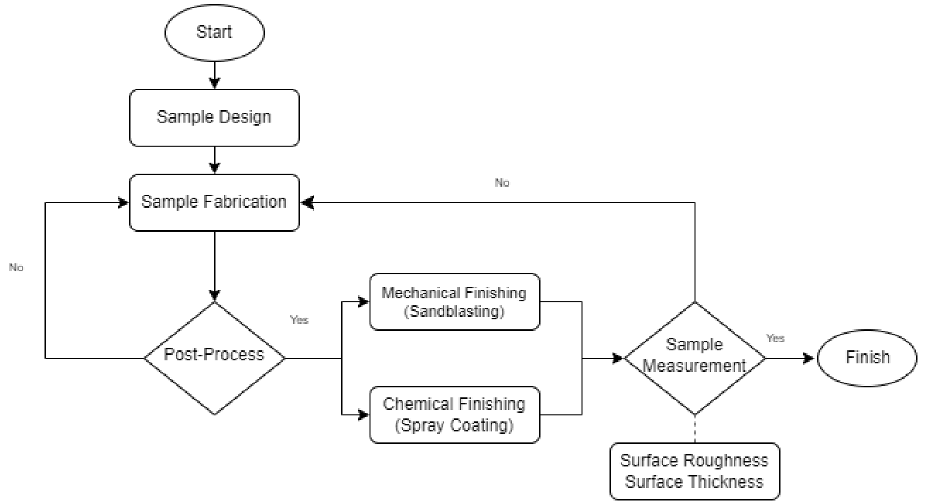


Figure 1: Flowchart of experimental work

3.1 Sample Preparation

Mechanical was used as the plastic material in production of all samples in this study. Table 1 provides the printing parameter of Polymaker PolyLite ABS with 1.75 mm of diameter. The samples were produced using FFF Creality 3D Ender 6 3D printer.

Table 1: Printing parameters for PolyLite ABS

Property	Value
Nozzle temperature	245°C - 265°C
Bed temperature	90°C - 105°C
Nozzle speed	30mm/s - 50mm/s
Cooling fan	OFF
Layer height	0.1
Infill	20%

3.2 Post Processing Process

Mechanical samples fabricated through the use of FFF 3D printing will be subjected to two types of post-processing methodologies, namely sandblasting and spray coating. The sandblasting procedure involves the employment of aluminum oxide as an abrasive material to flatten the surface irregularities on the sample. In the alternative post-processing technique, the sample surface is coated with 2K automotive paint. This paint is applied to fill the gaps between the printed layers, resulting in an enhancement of the surface quality and visual appearance. Table 2 presents the parameter setting of sandblasting and spray coating process. Before and after the post-processing process, the surface roughness of the sample was measured through an optical 3D microscopy imaging using digital microscope VHX 7000.

Table 2: Parameter setting for sandblasting and spray coating process

Sandblasting	Run 1	Run 2	Spray	Run 1	Run 2
Pressure (kPa)	100	100	Pressure	100	800
Time (s)	10	10	Time (s)	120	120
Distance (mm)	10	10	Distance	10	10
Grit size (μm)	106	29.5	Layer	3	1
Initial Ra (μm)	8.056	8.112	Initial Ra	8.175	8.223

A precision cutter was used to cut each sample at cross-sectional of 90 ˚ at Z-direction as shown in Figure 2. From the exposed cross-sectional area, the effect of coating thickness by sandblasting and spray coating process was analysed on the samples surface. A magnified image of each trial at 45X was captured using XOPTRON XST6 Stereo Microscope and were analyses using Solution Lite software. Initial surface roughness for all samples is 6.577 μm.

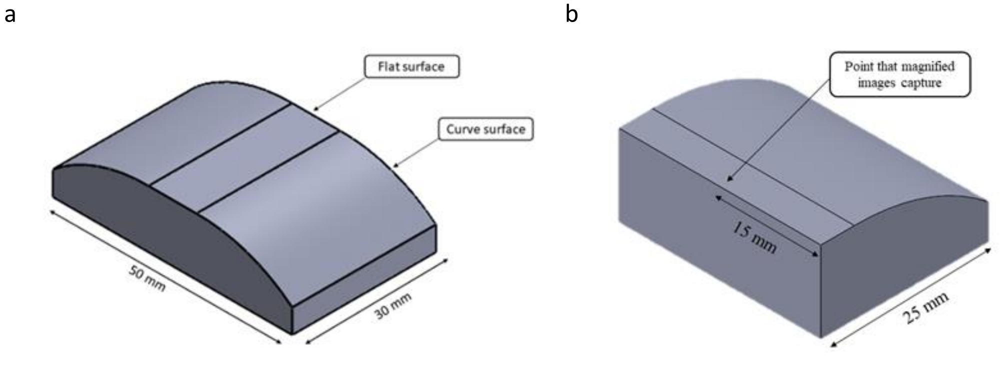


Figure 2: (a) 3D sample design created using Solidwork 2021 (b) cross-section of sample.

4.0 RESULT AND DISCUSSION

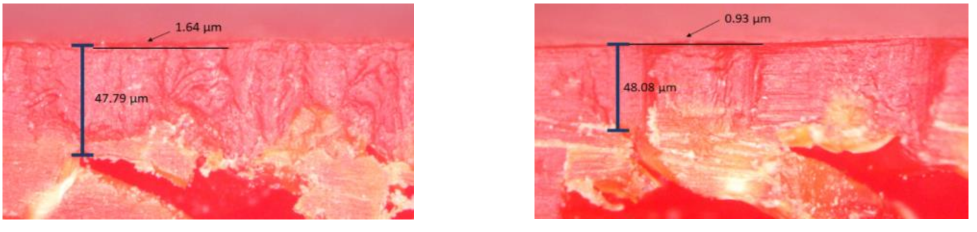
The Figures 3 and 4: In the cross-sectional images, it is evident that both sandblasting and spray coating techniques reduce the "stair-stepping" effect significantly, leading to an improved surface finish. This fact was supported by the improved changed surface roughness test results for sandblasting than for spray coating. The results themselves are, however, not sufficient to claim that the study has completely provided a solution for the same. Table 3 presents the results for surface roughness and changes in thickness. More specifically, sandblasting with a lower abrasive particle size of 29.5 µm resulted in the improvement of 4.869 mm toward the surface finish. In contrast, better surface quality was obtained with a higher pressure of 800 kPa of the Spray coating process with one layer of coating.

In addition, coinciding with these results are the findings by Chohan [6] and Minetola et al. [13], who found fine abrasives in sandblasting and high-pressure application in spray coating to improve the surface. Chohan commented on observing the fact that sandblasting with fine abrasives significantly contributed to reducing the surface roughness. In contrast, Minetola et al. further commented that quality in the surface was enhanced by spray coating having a high-pressure application. However, the following results contradict the studies by Wahab et al.[16], where it is suggested that the many coatings of the layers were necessary to get optimum performance. The inconsistency in our results could be due to differences in experimental setups, coating materials, and process parameters.

This study takes a close look at how sandblasting and spray coating influence the thickness and quality of ABS-FFF 3D-printed parts. It offers fresh insights on optimizing these post-processing methods, which could help improve the performance and usefulness of 3D-printed parts in the future.

Table 3: Results changes of surface roughness and coating thickness of sandblasting and spray coating process

Sandblasting	Run 1	Run 2	Spray coating	Run 1	Run 2
Changes Ra (µm)	1.081	4.869	Changes Ra	3.968	6.639
Result Thickness (µm)	1.64	0.93	Result Thickness	6.79	8.55



(a) (b)

Figure 3: Cross section images: (a) run 1 and (b) run 2 of sandblasting process

(a) (b)

Figure 4: Cross section images: (a) run 1 and (b) run 2 of spray coating process

Sandblasting is primarily employed for surface preparation in comparison to spray coating. Analysis of the data reveals that the thickness of the surface post-sandblasting can vary significantly, ranging from a few microns to several tens of microns. This variability is contingent upon several factors, including the size of the abrasive particles, the pressure applied to propel the abrasive from the nozzle, and the distance between the nozzle and the sample. A closer examination of Figure 3 (a) illustrates that when abrasive particles sized 106 μm were used in Run 1, there was a remaining surface thickness of 1.64 μm. Conversely, in Figure 3 (b), utilizing abrasive particles sized 29.5 μm resulted in a remaining surface thickness of 0.93 μm. As anticipated, the change in surface roughness was slightly more pronounced when larger abrasive particles were used, in contrast to the samples treated with finer abrasive particles. A higher surface thickness corresponds to a higher surface roughness in the printed samples. Conversely, a lower roughness indicates a better surface finish. Therefore, it is reasonable to infer that a lower surface thickness achieved through sandblasting techniques is indicative of better surface roughness, thereby reflecting superior surface quality.

Figure 4 presents more typical results from the spray coating process. The measured thickness ranges widely, from a few to hundreds of micrometers, influenced by parameters like the number of coating layers, the force applied in the flow, and the viscosity of the coating material. As illustrated in Figure 4(a) for Run 1, the coating thickness was 6.79 μm with a single-layer 2K primer coating applied at 100 kPa pressure. In the second run, shown in Figure 4(b), with a single-layer 2K primer application at 800 kPa, the coating thickness increased to 8.55 μm. This suggests that higher application pressure, even with a single coating layer, significantly impacts surface roughness. Interestingly, although Run 1 in figure 4 (a) had additional coating layers, its lower coating thickness did not significantly affect the surface roughness compared to Run 2 in figure 4 (b). These observations highlight that pressure is the most influential factor on the surface roughness of the sprayed coating. These findings offer valuable insights into how different process parameters affect coating thickness and surface roughness in spray-coating applications. By understanding this relationship, we can optimize the process to achieve desired surface characteristics for specific applications.

The importance of this study lies in demonstrating how spray-coating parameters, particularly pressure, affect surface properties. It reveals that pressure is more critical than the number of coating layers, guiding future efforts to optimize spray coating for high surface quality. From a theoretical standpoint, this study underscores fundamental principles of fluidics and material science—specifically Bernoulli's principle and the Hagen-Poiseuille equation. Bernoulli's principle explains that a fluid's speed increases as pressure or potential energy decreases, accounting for thicker coatings at higher pressures. The Hagen-Poiseuille equation relates pressure drop in laminar flow to flow velocity and fluid viscosity, supporting observations about the impact of viscosity and pressure on coating thickness.

Micallef et al. [19] found similar results, noting that fine abrasives significantly reduce surface roughness in sandblasting. Nguyen et al. [20] also demonstrated that high-pressure spray coating improves surface quality. However, these findings contradict those of Tan et al. [21] and Liu et al. [22], who concluded that multiple coating layers are necessary for better results. These discrepancies may stem from differences in experimental setups, coating materials, and process parameters. Further research is needed to understand how these parameters interact to achieve optimal surface properties in spray coating processes. This study lays the groundwork for future research on critical parameter optimization in advancing 3D printing post-processing techniques. Understanding these fundamental aspects advances the field of materials science and engineering, enhancing both practical applications and theoretical insights into surface modification techniques.

5.0 CONCLUSION

The research aimed to show how post-processing techniques, especially sandblasting and spray coating, affect the surface thickness of 3D printed ABS parts that initially lack surface finish, all while maintaining dimensional accuracy. The findings demonstrate that the objective has been achieved. For sandblasting technique, using smaller abrasive particles (29.5 μm) in sandblasting resulted in smoother surfaces with lower roughness (0.93 μm) compared to the coarser particles (106 μm), which resulted in a rougher surface thickness (1.64 μm). This indicates that finer abrasives lead to a much better surface finish, meeting our goal of optimizing post-processing techniques for superior surface quality. For spray coating method, it showed that higher application pressure (800 kPa with one layer) creates a thicker surface (8.55 μm) than lower pressure (100 kPa with three layers), which results in a thinner surface (6.79 μm). This suggests that pressure plays a more crucial role than the number of coatings in achieving the desired surface characteristics, thus meeting the study's objective.

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AUTHOR CONTRIBUTIONS

A.H.M Haidiezul: Conceptualization, Methodology, Software, Writing- Original Draft Preparation; M.S.Dolah: Data Curation, Validation, Supervision; M. Khalid: Software, Validation; N.A. Shuaib: Writing, Editing; N.A. Omar: Validation ; A. Mahmud: Reviewing and Editing.

CONFLICTS OF INTEREST

The manuscript has not been published elsewhere and is not under consideration by other journals. All authors have approved the review, agree with its submission and declare no conflict of interest on the manuscript.

REFERENCES

[1] F. Ramli, M. Nazan, M. Alkahari, M. Abdullah, M. Sudin, and S. Herawan, "Dimensional Accuracy Of Fused Filament Fabrication By Cassava Adhesion On Printing Platform", *Journal of Advanced Manufacturing Technology*, vol. 14, no. 2, no. 1, pp.149-158, 2020.

[2] N. Shahrubudin, T. C. Lee, and R. Ramlan, "An Overview On 3D Printing Technology: Technological, Materials, and Applications", *Procedia Manufacturing*, vol 35, pp. 1286–1296, 2019.

[3] Y. F Chen, Y.H Wang, and J. Tsai, "Enhancement of surface reflectivity of fused deposition modeling parts by post-processing", *Optics Communications*, vol. 430, pp. 479–485, 2019.

[4] A. Elkaseer, S. Schneider, and S. G. Scholz, "Experiment-Based Process Modeling and Optimization for High-Quality and Resource-Efficient FFF 3D Printing", *Applied Sciences*, vol. 10, no. 8, pp. 1-18, 2020.

[5] T. K. Nguyen and B. K. Lee, "Post-Processing of FDM Parts To Improve Surface and Thermal Properties", *Rapid Prototype Journal*, vol. 24, no. 7, pp. 1091–1100, 2018.

[6] J. S. Chohan, "Pre and Post Processing Techniques to Improve Surface Characteristics Of FDM Parts: A State Of Art Review and Future Applications", *Rapid Prototyping Journal*, vol. 3, no. 3, pp. 495–513, 2016.

[7] J. R. C. Dizon, C. C. L. Gache, H. M. S. Cascolan, L. T. Cancino, and R. C. Advincula, "Post-Processing of 3D-Printed Polymers", *Journal of Technologies,* vol. 9, no. 3, pp. 1-37, 2021.

[8] H. S. Mali, B. Prajwal, D. Gupta, and J. Kishan "Abrasive flow finishing of FDM printed parts using a sustainable media", *Rapid Prototyping Journal,* vol. 24, no. 3, pp. 593–606, 2018.

[9] F. Lavecchia, G. Percoco, E. Pei, and L. M. Galantucci, "Computer

numerical controlled grinding and physical vapor deposition for fused deposition modelled workpieces", *Journal of Advances in Materials Science and Engineering,* vol. 2018, no. 1, pp. 1-7, 2018.

[10] A. Rodríguez, L. N. López de Lacalle, A. Celaya, A. Lamikiz, and J. Albizuri, "Surface improvement of shafts by the deep ball-burnishing technique". *Surface and Coatings Technology,* vol. 206, no. 11–12, pp. 2817–2824, 2022.

[11] M. S. Khan and S. B. Mishra, "Proceedings Minimizing surface roughness of ABS-FDM build parts: An experimental approach" *Material Today Proceedings,* vol. 26, pp. 1557–1566, 2020.

[12] J. S. Chohan, "Thermal and surface characterization of ABS replicas made by FDM for rapid tooling applications", *Rapid Prototyping Journal,* vol. 24, no. 1, pp. 28–36, 2018.

[13] P. Minetola, F. Calignano, and M. Galati, "Comparing geometric tolerance capabilities of additive manufacturing systems for polymers", *Additive Manufacturing Journal,* vol. 32, pp. 101-103, 2020.

[14] G. Q. V. dos S. Kaneko, "Surface treatment and tensile strength analysis of fused filament", in *International Symposium on Flexible Automation*, Kanazawa, Japan, 2018, pp. 1-4.

[15] S. Wan, Y. C. Liu, and K. S. Woon, "A simple general process model for vibratory finishing", *The International Journal of Advanced Manufacturing Technology*, vol. 86, pp. 2393-2400, 2016.

[16] A. Wahab Hashmi, H. Singh Mali, and A. Meena, "Improving the surface characteristics of additively manufactured parts: A review". *Material Today Proceeding,* vol. 81, no. 2, pp. 723-738, 2021.

[17] A. H. M. Haidiezul, A. F. Aiman, and B. Bakar, "Surface Finish Effects Using Coating Method on 3D Printing (FDM) Parts", *IOP Conference Series Material Science Engineering,* vol. 318, no. 1, pp. 1-9, 2018.

[18] W. Kuczko, F. Górski, R. Wichniarek, and P. Buń, "Influence of Post-Processing on accuracy of FDM products", *Advances in Science and Technology Research Journal,* vol. 11, no. 2, pp. 172–179, 2017.

[19] J. S. Micallef, M. H. Cheong, and W. M. Cheung, "Improving the surface quality of 3D printed parts by fine abrasives in sandblasting", *Journal of*

Manufacturing Processes, vol. 58, pp. 22-29, 2021.

[20] T. K. Nguyen and B. K. Lee, "Enhancing surface properties of FDM 3D printed parts using high-pressure spray coating", *Surface and Coatings Technology*, vol. 385, pp. 123-130, 2020.

[21] C. Tan, J. Zhang, and L. Li, "The necessity of multiple coating layers for optimal surface quality in 3D printed parts", *Additive Manufacturing*, vol. 36, pp. 201-210, 2020.

[22] Y. Liu, X. Zhang, and Q. Wang, "Layer-by-layer coating strategies to improve surface properties of 3D printed parts", *Materials Today Communications*, vol. 27, pp. 102-109, 2022.