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OPTIMIZING LASER FINISHING PARAMETERS TO IMPROVE SURFACE QUALITY OF FDM-PRINTED PLA AND ABS COMPONENTS

Radu Emanuil PETRUSE, Nicolae-Claudiu GRESOIU

Abstract: *Fused Deposition Modelling (FDM) is a widely adopted additive manufacturing technique but often produces parts with suboptimal surface finish and dimensional accuracy. This study explores laser finishing as a post-processing technique to enhance the surface quality of FDM components made from PLA, ABS, and PET-G. Using a Taguchi design of experiments, key laser parameters—power, scanning direction, feed rate, and pass spacing—were systematically optimized. Results showed significant reductions in surface roughness (R_a and R_z) for PLA and ABS under distinct conditions. PLA achieved the smoothest finish with 1200 mW laser power, 45° direction, 100 mm/min feed rate, and 0.2 mm pass spacing. ABS required higher laser power and perpendicular scanning for optimal results. PET-G could not be effectively finished under tested settings. Additionally, printing parameters such as nozzle diameter and speed were found to critically influence the initial roughness. This work provides a validated framework for selecting laser finishing conditions tailored to material behaviour, contributing to enhanced surface quality and functional performance in FDM-printed parts.*
Keywords: *Additive Manufacturing (AM), Laser Finishing, Fused Deposition Modelling (FDM), PLA, ABS, PET-G, Surface Roughness Optimization, Taguchi DOE.*

1. INTRODUCTION

Fused Deposition Modelling (FDM) is a widely used additive manufacturing (AM) technique recognized for its capacity to fabricate complex geometries directly from digital designs without the need for moulds or conventional tooling. This method operates by depositing successive layers of thermoplastic materials, allowing the efficient and cost-effective production of customized parts across various industries, including automotive, aerospace, biomedical, and consumer products. Despite these advantages, the inherent layer-by-layer deposition process typically results in pronounced surface roughness and dimensional inaccuracies[1], [2], [3]. Such surface imperfections can negatively impact both mechanical performance and aesthetic appeal, limiting the application of FDM-produced parts in precision-dependent sectors[4].

To mitigate these limitations, researchers and practitioners have explored several post-processing techniques such as mechanical machining, sanding, and chemical treatments like acetone vapor smoothing [5], [6]. Although these traditional methods can significantly improve surface finish, they often entail labour-intensive operations, exposure to hazardous chemicals, or limitations when processing intricate geometries[7], [8]. In this context, laser finishing has emerged as a promising, innovative, and non-contact post-processing approach that addresses these issues effectiv [9].

Laser finishing employs focused laser energy to selectively melt and subsequently re-solidify the surface layers of the printed parts, significantly smoothing out visible surface irregularities. Studies indicate that this method can dramatically improve the surface roughness of FDM parts by melting the topmost layers, effectively removing rough patterns, and enhancing overall surface quality [6], [10], [11]. Laser finishing's effectiveness, however, depends heavily on various parameters, including laser power, speed, and the material's optical absorption properties[12], [13], [14], [15]. Recent studies demonstrate that higher laser power combined with optimized speed settings can substantially reduce surface roughness. For instance, specific studies have reported surface roughness reductions of up to 96.4% when using laser powers around 15W on PLA parts [16].

Furthermore, the colour and composition of the thermoplastic materials significantly influence laser absorption, directly affecting the polishing outcomes. Differently coloured PLA materials absorb varying amounts of laser energy, thus affecting the final surface finish quality achieved through laser finishing [16].

Comparative analyses have highlighted the advantages and limitations of laser finishing relative to other post-processing techniques. Acetone vapor smoothing generally achieves the best surface finish but results in a glossy appearance and potential structural weakening. Conversely, mechanical processes such as shot blasting can aggressively alter the surface and dimensions of parts [10]. Laser finishing provides a balanced compromise, offering substantial improvement in surface quality without aggressive material removal or undesirable glossiness.

Despite its effectiveness, laser finishing presents several challenges that need addressing, such as optimizing laser parameters for diverse materials and complex geometries. Future research could focus on more precise control over laser parameters and explore laser finishing effects on various FDM materials, including advanced composites such as polyamide and carbon fibre-reinforced filaments.

This study aims to systematically investigate the effects of laser finishing on the surface roughness and dimensional accuracy of FDM-manufactured components. Employing the Taguchi method for experimental design, we analyse the influence of key laser processing parameters—such as laser power, scanning direction, feed rate, and pass spacing—on the post-processed quality of parts fabricated from commonly used thermoplastics, including Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), and Polyethylene Terephthalate Glycol (PETG). By identifying optimal laser finishing conditions, this research seeks to enhance the functional performance and broaden the application scope of FDM-produced parts in various industrial sectors.

2. EXPERIMENTAL METHODOLOGY

2.1 Design of experiments

A Taguchi orthogonal array (L27 3^5) was employed to assess the impact of laser finishing on surface roughness systematically. Multiple levels of experimental factors were tested, covering three common FDM materials—PLA, ABS, and PET_G—three nozzle diameters (0.4 mm, 0.6 mm, 0.8 mm), layer heights (0.1 mm, 0.2 mm, 0.3 mm), and printing speeds (30 mm/s, 60 mm/s, 120 mm/s).

Table 1 outlines the main influence variables (input factors) and their associated response functions (output variables). These variables were identified based on their potential impact on the quality and precision of the resulting components.

Table 1

Main influence variables and response functions

Code	**Type**	**Unit**	**Variation domain**	**Output variables**
x1	Nozzle diameter	[mm]	0.4-0.8	R_a [μm], R_z [μm]
x2	Layer height	[mm]	0.1-0.3	
x3	Materials	-	PLA, ABS, PETG	
x4	Printing speed	[mm/s]	30-120	
x5	Laser power	[mW]	80-100	
x6	Laser Speed	[mm/min]	100-300	
x7	Finishing direction		H-V-45^0	
X8	Distance between paths	[mm]	0.1-0.3	

The experimental design adopted three levels of variation for all parameters. These levels uniformly cover the domains defined previously and are detailed in Table 1.

The Taguchi methodology was selected for designing the experiments due to its efficacy in systematically analysing the influence of multiple independent variables on the response variables, particularly given the relatively high number of levels involved. The experimental design was created using Minitab 18 software, resulting in the Taguchi orthogonal array L27 for the samples fabrication and L9 for the finishing process.

2.2 Sample Preparation

The test specimens were produced using a Snapmaker A350 FDM printer, ensuring consistent environmental conditions, such as temperature and humidity. Specimens' dimensions are according to figure 1.

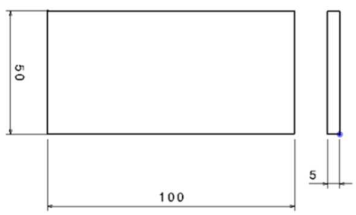


Fig. 1. Specimen's dimensions

Table 2 illustrates this matrix with 27 distinct experimental configurations, indicating the specific combination of factor levels.

Table 2

Taguchi Orthogonal Array L27(3^5) – Codes for Input Variables

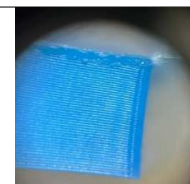
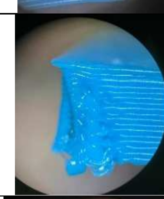
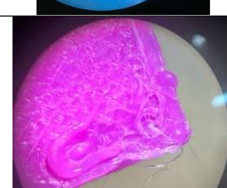
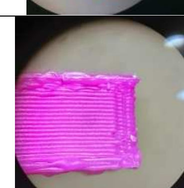
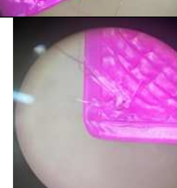
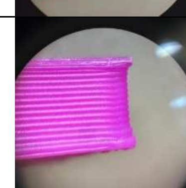
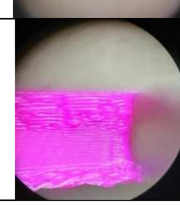
Code	Material	Nozzle diameter	Layer height	Printing speed
L1	PLA	0.4 mm	0.1 mm	30 mm/s
L2	PLA	0.4 mm	0.1 mm	30 mm/s
L3	PLA	0.4 mm	0.1 mm	30 mm/s
L4	PLA	0.6 mm	0.2 mm	60 mm/s
L5	PLA	0.6 mm	0.2 mm	60 mm/s
L6	PLA	0.6 mm	0.2 mm	60 mm/s
L7	PLA	0.8 mm	0.3 mm	120 mm/s
L8	PLA	0.8 mm	0.3 mm	120 mm/s
L9	PLA	0.8 mm	0.3 mm	120 mm/s
L10	ABS	0.4 mm	0.2 mm	120 mm/s
L11	ABS	0.4 mm	0.2 mm	120 mm/s
L12	ABS	0.4 mm	0.2 mm	120 mm/s
L13	ABS	0.6 mm	0.3 mm	30 mm/s
L14	ABS	0.6 mm	0.3 mm	30 mm/s
L15	ABS	0.6 mm	0.3 mm	30 mm/s
L16	ABS	0.8 mm	0.1 mm	60 mm/s
L17	ABS	0.8 mm	0.1 mm	60 mm/s
L18	ABS	0.8 mm	0.1 mm	60 mm/s
L19	PET_G	0.4 mm	0.3 mm	60 mm/s
L20	PET_G	0.4 mm	0.3 mm	60 mm/s
L21	PET_G	0.4 mm	0.3 mm	60 mm/s
L22	PET_G	0.6 mm	0.1 mm	120 mm/s
L23	PET_G	0.6 mm	0.1 mm	120 mm/s
L24	PET_G	0.6 mm	0.1 mm	120 mm/s
L25	PET_G	0.8 mm	0.2 mm	30 mm/s
L26	PET_G	0.8 mm	0.2 mm	30 mm/s
L27	PET_G	0.8 mm	0.2 mm	30 mm/s

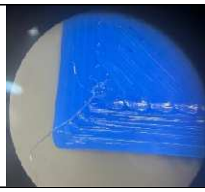
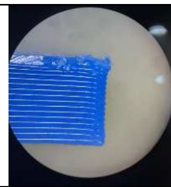
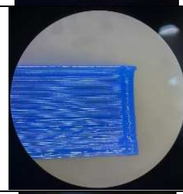
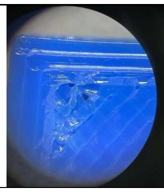
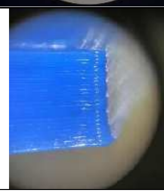
All samples were printed using the same 3D printer—Snapmaker A350 equipped with a closed enclosure. The materials utilized in the experiment were stored under controlled environmental conditions, maintaining consistent temperature and humidity levels throughout the printing process. Samples were printed horizontally (flat on the printing platform) with a uniform infill density of 15%, employing a triangular internal structure. The top, bottom, and wall thicknesses were uniformly set at 1.2 mm.

The printed specimens exhibited common FDM-induced defects, including dimensional deviations and various surface irregularities, as confirmed by microscopic analysis. Surface irregularities included layer delamination, edge irregularities, and localized melting due to improper thermal management (table 3).

Table 3

Manufacturing induced defects

Sample no.	Top surface defects	Edge defects
L1-L3		
L4-L6		
L7-L9		
L10-L12		
L13-L15		
L16-L18		

L19-L21		
L22-L24		
L25-L27		

As depicted in table 4, microscopic analysis of the FDM-printed specimens revealed several characteristic defects, including inadequate interlayer adhesion, visible surface cracks, delamination, irregular edges, and inconsistent extrusion, resulting in pronounced surface roughness, dimensional inaccuracies, and compromised geometric precision. Planar surfaces often presented protrusions, uneven textures, and edge irregularities, whereas edges of the samples showed notable layer separation, cracking, and uneven stacking patterns. These observations clearly underscore the necessity and importance of this research in optimizing printing parameters and subsequent post-processing methods to enhance the overall quality and functionality of additive manufactured components.

Initial roughness measurements are made with a MarSurf VD 140 roughness meter equipped with a BFW A 10-45-2 probe. These measurements are a reference for the laser finishing process.

Table 4

Initial Surface Roughness (R_a, R_z)

Code	**R_a [µm]**	**R_z [µm]**	**Code**	**R_a**	**R_z**
L1	4.2133	24.6299	L15	5.8132	52.3747
L2	3.5263	30.4045	L16	15.0612	123.2971
L3	4.0641	29.5668	L17	13.7533	115.7610
L4	3.7755	35.2976	L18	13.8529	116.9407
L5	4.6521	44.1339	L19	8.9133	66.9843
L6	5.9686	53.7608	L20	9.2417	64.3606
L7	20.0960	98.3372	L21	9.4564	70.1003
L8	19.1487	97.2242	L22	9.3007	101.4344
L9	18.6448	97.6270	L23	26.6551	174.3274
L10	6.7414	49.9479	L24	12.8611	135.3278
L11	8.1081	53.6389	L25	13.0817	64.0014
L12	7.9325	57.6846	L26	11.7619	57.6599
L13	4.6681	44.9580	L27	11.2721	54.9277
L14	4.5220	48.7769			

2.3 Laser finishing preparation

The laser finishing operations were conducted using a Snapmaker A350 modular 3-in-1 3D printer equipped with a laser module capable of a maximum power of 1600 mW.

The key parameters considered for the laser finishing process included: laser power [% of maximum], scanning direction (horizontal, vertical, 45°), feed rate [mm/min] and the distance between successive laser passes [mm]

All parameters were systematically input into Minitab software, and the Taguchi method was utilized to generate structured experimental designs for subsequent analysis (tables presented in the Results and Discussion sections).

The finishing process required careful initial parameter setting tailored to each specific thermoplastic material.

For PLA (Polylactic Acid), due to its relatively low melting temperature and ease of laser absorption, the parameter settings (Table 5) were optimized to effectively smooth the surface without causing excessive melting or damage.

Table 5

Taguchi Orthogonal Array L9 – PLA Laser Finishing

Code	**Laser power [mW]**	**Direction**	**Speed [mm/min]**	**Radial path distance [mm]**
1	1200	H	50	0.1
2	1200	V	80	0.2
3	1200	45	100	0.3
4	1360	H	80	0.3
5	1360	V	100	0.1
6	1360	45	50	0.2
7	1600	H	100	0.2
8	1600	V	50	0.3
9	1600	45	80	0.1

Switching to ABS (Acrylonitrile Butadiene Styrene) necessitated parameter adjustments (Table 6) due to its higher melting point and thermal conductivity. These changes ensured optimal heat input, avoiding excessive melting and ensuring uniform surface smoothing.

PET-G (Polyethylene Terephthalate Glycol) posed distinct challenges due to its unique thermal behaviour.

Table 6

Taguchi Orthogonal Array L9 – ABS Laser Finishing

Code	Laser power [mW]	Direction	Speed [mm/min]	Radial path distance [mm]
1	1280	H	100	0.1
2	1280	V	200	0.2
3	1280	45	300	0.3
4	1440	H	200	0.3
5	1440	V	300	0.1
6	1440	45	100	0.2
7	1600	H	300	0.2
8	1600	V	100	0.3
9	1600	45	200	0.1

Specific adjustments were necessary (Table 7) to minimize overheating, material degradation, and potential surface carbonization. Despite these adjustments, PET-G was particularly challenging to process with standard parameters, indicating a need for further optimization.

Table 7

Taguchi orthogonal array L9 – PET-G laser finishing

Code	Laser power [mW]	Direction	Speed [mm/min]	Radial path distance [mm]
1	1280	H	10	0.1
2	1280	V	20	0.2
3	1280	45	30	0.3
4	1440	H	20	0.3
5	1440	V	30	0.1
6	1440	45	10	0.2
7	1600	H	30	0.2
8	1600	V	10	0.3
9	1600	45	20	0.1

To design and execute the laser finishing process, Luban software was employed. The first step in Luban involved defining the working area within the test specimen surface, set at 100 mm x 50 mm. Subsequently, nine distinct rectangular areas were created on the defined workspace, as shown in Figure 2. Each rectangular area was processed individually using different sets of parameters derived from Taguchi methodology. For each type of material (PLA, ABS, PET_G), nine distinct laser finishing parameter combinations were tested, defined by the Taguchi L9 orthogonal array. Each sample group, defined by the printing parameters (nozzle diameter, layer height, printing speed), consisted of three replicates. After laser finishing, roughness parameters R_a (average roughness) and R_z (peak-to-valley roughness) were measured.

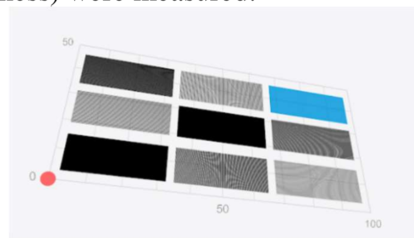


Fig. 2. Preparation of laser finishing workspace

3. RESULTS AND DISCUSSION

3.1 3D printing parameters and their influence on surface roughness

To assess the roughness parameters obtained from the FDM printing process, the Taguchi method was applied using the "Smaller is better" criterion for objective analysis. The experimental factors analysed were: Material, Nozzle Diameter, Layer Height, and Printing Speed.

Table 8

Manufacturing factors influencing R_a

Level	Material	Nozzle size	Layer height	Printing speed
1	9,343	6,911	11,476	6,991
2	8,939	8,691	8,144	9,408
3	12,505	15,186	11,167	14,488
Delta	3,566	8,275	3,333	7,396
Rank	3	1	4	2

The nozzle diameter is identified as the most influential parameter (Rank 1) affecting R_a, with smaller diameters significantly improving surface smoothness. Specifically, a 0.4 mm nozzle diameter provides optimal conditions for the lowest roughness. The printing speed also considerably impacts surface roughness, ranked second in influence, with the best surface finish observed at the lowest speed (30 mm/s). Lower printing speeds enable more precise material deposition and better cooling. Material type and layer height have relatively less influence on R_a. However, ABS generally performs better, achieving lower roughness values due to its thermal and mechanical properties compared to PLA and PET-G.

The figure above visualizes how the four key printing parameters influence the average surface roughness (R_a) across all test specimens. The following observations were made:

- Material Type: ABS generated the lowest R_a values on average, followed by PLA. PET-G displayed the highest roughness, indicating its poor print quality in terms of surface texture when using the tested settings. This suggests that ABS is inherently more favourable for applications requiring smoother surfaces straight off the printer.
- Nozzle Diameter: A clear trend is observed: increasing nozzle diameter correlates with increased surface roughness. The smallest diameter (0.4 mm) provided the smoothest surfaces. This is consistent with theoretical expectations, as smaller nozzles produce finer layers and allow more precise material deposition.
- Layer Height: The lowest R_a was observed at a 0.2 mm layer height, which appeared to offer a balanced trade-off between print resolution and printing time. Although smaller heights (0.1 mm) typically produce better finishes, the benefit was less pronounced here, likely due to imperfections caused by heat accumulation and nozzle retraction.
- Printing Speed: Lower printing speeds (30 mm/s) consistently produced lower R_a values. As speed increases to 60 mm/s and 120 mm/s, the surface finish deteriorates due to inadequate material bonding, poorer layer adhesion, and thermal gradients.

The Taguchi results confirm that to minimize surface roughness R_a during FDM printing, the following configuration is optimal for minimizing R_a roughness are: material: ABS, nozzle diameter: 0.4 mm, layer height: 0.2 mm, printing speed: 30 mm/s.

3.2 Laser Finishing Results and Optimal Parameters

This section presents the analysis of surface roughness values (R_a and R_z) obtained after laser finishing for both PLA and ABS samples. Using the Taguchi experimental method (L9 orthogonal array), key laser parameters—power, scanning direction, feed rate, and radial pass distance—were varied. Each combination was applied to three specimens, and the resulting average roughness (R_a) and peak-to-valley roughness (R_z) were measured to evaluate surface quality improvements.

PLA – Analysis of roughness values and Taguchi optimization

PLA samples (L1–L9) were processed using nine unique finishing parameter sets derived from the Taguchi L9 array. The best surface finish (minimum R_a and R_z) was observed in sample set L4–L6 using parameter set no. 3 (1200 mW, 45° direction, 100 mm/min feed rate, 0.3 mm pass distance), achieving: R_a = 1.7362 µm and R_z = 13.9459 µm

Higher laser powers (e.g., 1600 mW) and lower feed rates (50 mm/min) generally resulted in surface deterioration due to localized overheating and possible carbonization.

The Taguchi analysis shown in Figure 3 and Table 9 highlights the influence of laser finishing parameters on the average surface roughness (R_a) for PLA samples. The graph illustrates the response of R_a to each parameter variation, reinforcing the following insights:

- Laser Power: Optimal roughness (lowest R_a) was achieved at 75% (1200 mW), confirming that moderate power provides sufficient thermal energy to smooth the surface without causing damage or excessive melting.
- Laser Direction: The scanning direction at 45° resulted in the lowest R_a values. This direction aligns effectively with the layer structure, enhancing uniform heat distribution and smoothing efficiency.
- Feed Rate: The highest feed rate (100 mm/min) clearly produced the lowest R_a, indicating reduced heat exposure minimizes surface imperfections by providing a quick and consistent melting action.
- Radial Pass Distance: A radial distance of 0.2 mm offered the lowest R_a values. This spacing provided the optimal overlap between successive laser paths, enabling consistent surface smoothing.

This analysis further confirms that careful optimization of laser finishing parameters significantly improves the surface quality of PLA components, identifying the combination of moderate laser power (75%), 45° scanning direction, high feed rate (100 mm/min), and intermediate radial pass spacing (0.2 mm) as optimal.

Table 9

Factors influencing R_a (average roughness) for PLA

Level	Laser power	Direction	Speed	Radial path distance
1	5,351	6,693	6,372	7,404
2	8,476	5,515	8,569	5,806
3	7,114	7,846	5,319	7,023
Delta	3,125	2,332	3,250	1,598
Rank	2	3	1	4

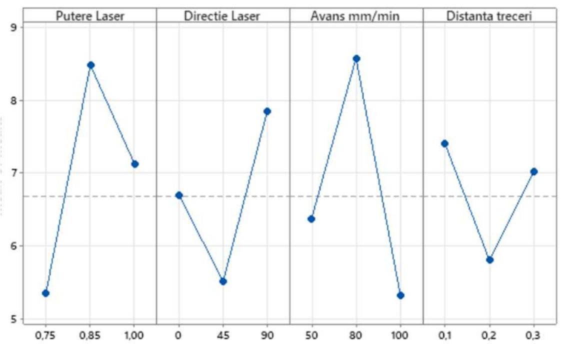


Fig. 3. Optimal Parameters Influence on R_a for PLA (Taguchi Analysis)

The Taguchi analysis presented in Figure 4 and Table 10 provides insight into the influence of laser finishing parameters on the peak-to-valley roughness (R_z) for PLA samples.

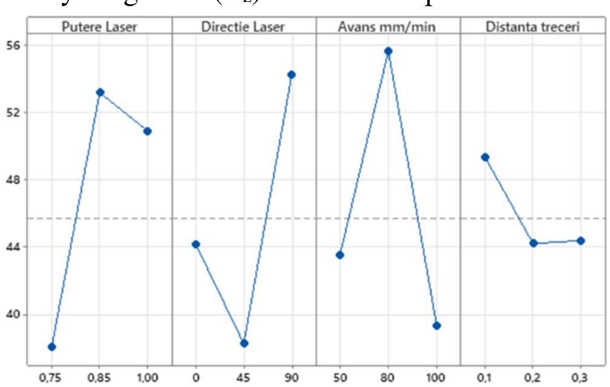


Fig. 4. Optimal Parameters Influence on R_z for PLA (Taguchi Analysis)

Table 10

Factors influencing R_z (average roughness) for PLA

Level	Laser Power	Direction	Speed	Radial path distance
1	38,06	44,18	43,53	49,37
2	53,19	38,28	55,65	44,22
3	50,91	54,23	39,33	44,40
Delta	15,13	15,95	16,32	5,15
Rank	3	2	1	4

This detailed analysis solidifies the optimal parameter set identified for PLA—75% laser power, 45° scanning direction, 100 mm/min feed rate, and a 0.2 mm radial pass distance—as the best conditions to minimize surface roughness (both R_a and R_z), thereby significantly enhancing the final quality of laser-finished PLA components.

ABS – Analysis of roughness values and Taguchi optimization

The Taguchi method was also applied to systematically analyse surface roughness improvements for ABS samples.

For ABS (L10–L18), the best results were recorded in sample set L13–L15 using parameter set no. 1 (1280 mW, horizontal, 100 mm/min, 0.1 mm), with: $R_a = 2.3089$ µm and $R_z = 9.5165$ µm. Higher power levels (1440–1600 mW) improved smoothing due to ABS's higher thermal conductivity, but only when paired with high feed rates and tight pass distances. The Taguchi analysis depicted in Figure 5 and Table 11 illustrates the effect of laser finishing parameters on the average surface roughness (R_a) for ABS samples. Key insights derived from this analysis are as follows:

- Laser Power: The optimal R_a was achieved at the maximum tested power (100%, 1600 mW). This higher power level is required due to ABS's higher melting point and improved thermal conductivity, allowing efficient surface smoothing without inducing excessive damage.
- Laser Direction: The optimal direction for achieving the lowest R_a was vertical (90°). This perpendicular orientation provided the most effective interaction with deposited layers, uniformly redistributing the melted ABS surface and enhancing smoothing effects.
- Feed Rate: The highest feed rate (300 mm/min) resulted in the lowest R_a values, highlighting that rapid scanning effectively reduces localized heat exposure, thus preventing overheating and ensuring a consistent, smooth finish.
- Radial Pass Distance: A radial pass distance of 0.2 mm showed optimal R_a reduction, providing adequate overlap between passes, facilitating uniform surface treatment without causing thermal degradation or excessive melting.

Table 11

Factors influencing R_a (average roughness) for ABS

Level	Laser Power	Direction	Speed	Radial path distance
1	7,874	8,670	7,049	7,775
2	9,850	8,184	9,411	7,404
3	7,119	7,990	8,384	9,664
Delta	2,732	0,681	2,362	2,260
Rank	1	4	2	3

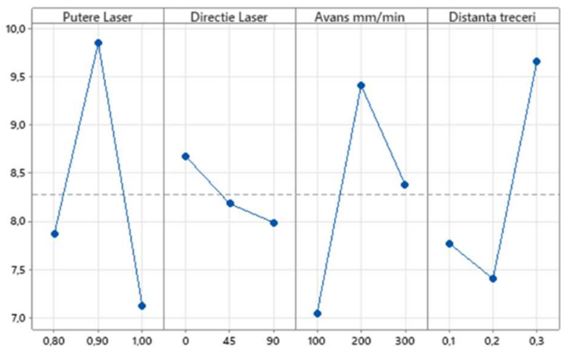


Fig. 5. Optimal Parameters Influence on R_a for ABS (Taguchi Analysis)

The Taguchi analysis depicted in Figure 6 and Table 12 provides insight into how laser finishing parameters influence the peak-to-valley roughness (R_z) values for ABS samples.

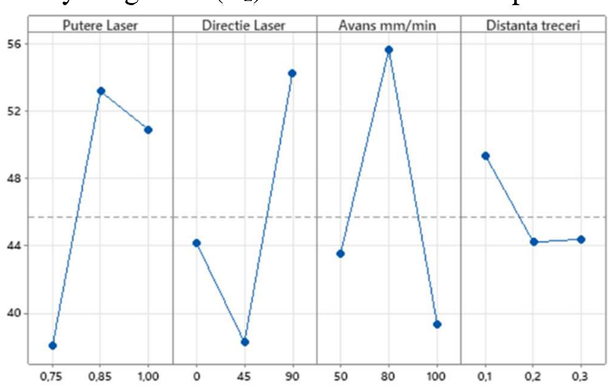


Fig. 6. Optimal Parameters Influence on R_z for ABS (Taguchi Analysis)

Table 12

Factors influencing R_z (average roughness) for ABS

Level	Laser Power	Direction	Speed (mm/min)	Radial path distance (mm)
1	38,06	44,18	43,53	49,37
2	53,19	38,28	55,65	44,22
3	50,91	54,23	39,33	44,40
Delta	15,13	15,95	16,32	5,15
Rank	3	2	1	4

The analysis clearly identifies the ideal laser finishing parameters for minimizing R_z in ABS as maximum laser power (1600 mW), vertical scanning direction (90°), highest feed rate (300 mm/min), and minimal radial pass distance (0.1 mm). These optimized parameters demonstrate superior capability in reducing the magnitude of surface peaks and valleys, thereby substantially enhancing the surface quality of ABS components finished by laser.

3.3 Encountered problems during printing and laser finishing

Although the experimental setup was carefully designed and executed, several technical challenges were encountered throughout the 3D printing and laser finishing processes. These issues emphasise the sensitivity of both techniques to process parameters and material characteristics. Several challenges arose during the laser finishing stage:

- Colour sensitivity of the material - Light-coloured parts reflected a considerable amount of laser radiation, reducing energy absorption. Consequently, in certain regions of the surface, finishing effects were minimal or inconsistent. In contrast, areas marked with black permanent markers where laser absorption was higher showed a noticeably better finish, confirming the influence of surface optical properties.
- Feed rate adjustment - Initially, a high feed rate (1500 mm/min) was applied, which proved ineffective for PLA. Gradual reduction to the optimal range of 50–100 mm/min yielded the desired results but significantly extended the overall processing time. For ABS, the initial feed rate caused excessive surface melting. Increasing the feed rate remedied this, balancing energy input and material response.
- PET-G finishing failure - PET-G presented a critical limitation. None of the tested parameter combinations (power, direction, feed rate, path distance) produced satisfactory surface quality. Even at minimal feed rates, surfaces became charred and thermally degraded, as shown in Fig. 7. The laser's thermal effect could not be

adequately controlled for this material within safe processing margins.

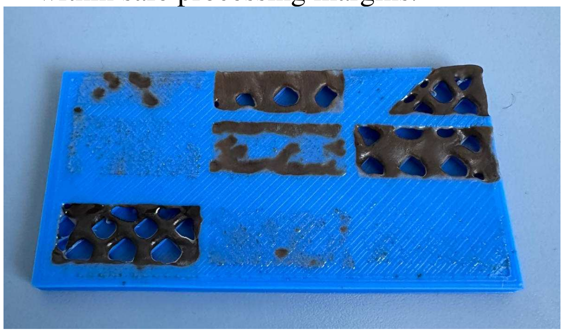


Fig. 7. PET-G sample after finishing failure

- Measurement limitations - On two samples - Sample 22 (PLA) and Sample 31 (ABS)- roughness could not be measured due to excessive surface deformation. The surface profile was outside the probe's detection range, likely caused by localized over-melting or warping.

4. CONCLUSION

This study investigated the effectiveness of laser finishing in improving the surface quality of FDM-printed components made from PLA, ABS, and PET-G. Using Taguchi experimental design, both printing and finishing parameters were systematically varied and analysed for their impact on surface roughness.

Results showed that surface quality is strongly influenced by initial printing conditions, with nozzle diameter and printing speed being the most critical factors. ABS generally exhibited better as-printed surface quality than PLA and PET-G. Laser finishing significantly reduced surface roughness for PLA and ABS, provided the parameters were optimized to suit each material's thermal behaviour. For PLA, the best finishing results were achieved using 1200 mW laser power, 45° scanning direction, 100 mm/min feed rate, and 0.2 mm pass spacing. ABS required higher energy input, with 1600 mW laser power, vertical scanning, 300 mm/min feed rate, and a 0.1 mm pass spacing yielding the lowest roughness values. In contrast, PET-G could not be effectively processed using laser finishing, showing thermal damage and surface carbonization under all tested conditions.

Challenges such as sensitivity to part colour, feed rate, and local overheating were encountered and addressed through parameter refinement. These findings highlight the importance of material-specific optimization and confirm that, when properly configured, laser finishing is an effective, non-contact post-processing method for improving the surface quality of FDM-printed parts.

Although this study provides a replicable parameter matrix and surface response analysis that can serve as a reference for researchers and engineers implementing post-processing workflows in additive manufacturing, further investigations are recommended to expand the applicability of this method to a broader range of materials and to evaluate the functional performance of the treated surfaces in service conditions.

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Optimizarea parametrilor de finisare cu laser pentru îmbunătățirea calității suprafeței componentelor fabricate prin tehnologia FDM din PLA și ABS

Fabricarea aditivă (AM), în special tehnica FDM, este o tehnologie de fabricație aditivă larg utilizată, însă produce frecvent piese cu o calitate suboptimală a suprafeței și cu abateri dimensionale semnificative. Acest studiu investighează finisarea cu laser ca metodă de post-procesare pentru îmbunătățirea calității suprafeței componentelor realizate prin FDM din materiale precum PLA, ABS și PET-G. Utilizând un design experimental de tip Taguchi, parametrii esențiali ai procesului laser – puterea, direcția de finisare, viteza de avans și distanța între treceri – au fost optimizați sistematic. Rezultatele au evidențiat reduceri semnificative ale rugozității suprafeței (R_a și R_z) pentru PLA și ABS în condiții specifice. PLA a obținut cea mai bună finisare cu o putere laser de 1200 mW, direcție de 45°, viteză de avans de 100 mm/min și o distanță între treceri de 0,2 mm. Pentru ABS au fost necesare o putere mai mare pentru a obține rezultate optime. În cazul PET-G, finisarea cu laser nu a fost eficientă în parametrii testați. De asemenea, s-a constatat că parametrii de fabricație, precum diametrul duzei și viteza de depunere, influențează semnificativ rugozitatea inițială a suprafeței. Acest studiu oferă un cadru validat pentru selectarea condițiilor de finisare cu laser adaptate comportamentului materialelor, contribuind la îmbunătățirea calității suprafeței și a performanței funcționale a pieselor realizate prin FDM.

Radu Emanuil PETRUSE, Dr. Eng, Lecturer, Lucian Blaga University of Sibiu, Industrial Engineering and Management, radu.petruse@ulbsibiu.ro, +40740304595

Nicolae-Claudiu GRESOIU, Eng, 550024 Sibiu, Romania