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A SURFACE TEXTURE EVALUATION METHODOLOGY FOR FUSED DEPOSITION MODELING (FDM) 3D PRINTED PARTS USING EXPERIMENTAL DATA AND STATISTICAL MODELING ALGORITHMS, WITH MATLAB

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Abstract: ***This paper presents, in a concise and practical manner, the results of a comprehensive study evaluating of surface texture characteristics for 3D printed parts using fused deposition modeling (FDM) technology. The results of a series of experiments coordinated by the authors were used, employing hybrid techniques and procedures, such as advanced statistical modeling techniques with advanced programming and implementation techniques in MATLAB, validated in numerical applications. Three types of engineering polymers (ABS+, PAHT, PC-FR) were investigated, considering two printing orientations (front and side), with a view to evaluating their influence (e.g., local sensitivity) on surface roughness parameters: Ra, Rz, and Rq. The implementation of the methodology, by incorporating these advanced ideas, techniques, and procedures, using Anova for factorial analysis, a Monte Carlo algorithm, a Pareto analysis, and finally generating a customized MATLAB program, has the stated objective of instantly issuing evaluated and verified recommendations for optimal combinations consisting of pairs of the following types: material orientation, characteristic parameters that play a role in minimizing deviation from target roughness values. The integrated approach of this methodology provides a robust framework to support engineers in selecting the optimal printing parameters to meet the stringent surface finish requirements in FDM applications***

Keywords: *Fused Deposition Modeling, Surface Roughness, Statistical Modeling, Monte Carlo Simulation, ANOVA, MATLAB, Print Orientation, Engineering Polymers).*

1. INTRODUCTION

In recent decades, additive manufacturing (AM) has impetous development, becoming an essential technology in fields such as the automotive, aerospace, biomedical, and electronics industries, [1], [2], [3].

In this context, and considering the impact of improvements in 3D printing processes, especially FDM (Fused Deposition Modeling) technology, it is essential to choose an optimal material that combines low cost with good mechanical strength and superior surface quality after printing. The end result is the manufacture of high-quality parts for applications in the fields highlighted above [4], [5].

A significant number of researchers are focusing their efforts on obtaining scientific results, focusing on solutions that generate superior surface quality. Equally important is the emphasis placed on the development of innovative predictive systems for estimating surface roughness, interactive techniques used during the turning of 3D-printed CFRP parts, with frequent use and advancement of machine learning techniques and dynamic data (including online monitoring and control through the exploitation of collected data, in particular vibration signal processing) [6], [7], [8].

With these premises as a basis for work and analysis, on the one hand, and on the other hand, considering their own findings regarding the quality and condition of the surfaces, which, compared to subtractive manufacturing, is visibly inferior, the authors of this study have focused their efforts on the development and implementation of methods by which additive technologies can be combined with subtractive ones, with the aim of achieving dimensional and mechanical properties, with a surface condition in accordance with the machining processes, with a significant reduction in manufacturing times and a more efficient use of materials. This creates the technological and economic conditions for optimizing production processes and developing this direction of high-tech machine tool construction, known as hybrid machines (additive technology combined with subtractive technology on the same machine), technological and cost efforts at least equal to, if not much lower than, traditional ones, resulting in high-quality parts, [9], [10], [11], [12].

The techniques for optimizing and studying capital markets in the field presented here highlight inhibitory reactions, taking into account only the price of such machines, which is quite high (downright prohibitive in the field of metal processing, as it reaches amounts exceeding €1,000,000), [13], [14]. As for plastics processing, the cost is also considerable, being significantly higher than the price of a 3D printer used in current production, [11], [15], [16].

Considering the above-mentioned and justified reasons, namely the need for certain properties and qualities in terms of versatility, low costs, and low material consumption, the authors of this study aimed to comparatively evaluate the roughness generated by 3D printing using the FDM process and using three technical polymers (ABS+, PAHT, and PC-FR) as printing materials. Ten samples were printed from these materials, and the condition of the front and vertical surfaces was analyzed (180 measurements).

In order to describe/analyze/evaluate what the authors set out to do in this study, the test samples were prepared in accordance with all relevant rules and standards: using sample printing technology, followed by well-defined, established procedures and study/ measurements, respectively analysis of the surface condition (Ra, Rz, Rq) using a profilometer, followed by processing of the collected data using techniques such as ANOVA, Monte Carlo, Pareto, and finally the development of a Matlab application. [17].

2. DESCRIPTION OF METHODOLOGY

Based on studies in reference databases, the global spread of 3D printing technology, supported by international collaborations, can be observed. Fig. 1 highlights the central role of the United States, China, and India, as well as the important contribution of European and Asian countries. This network demonstrates the international and collaborative nature of the field, confirming the strategic importance of 3D printing.

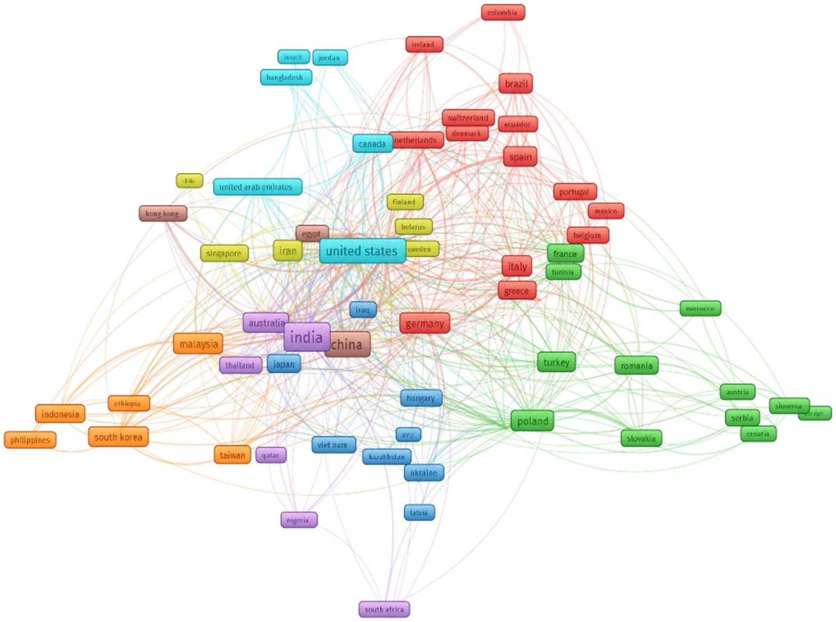


Fig. 1 Countries studying 3D printing

Continuing the analysis in the SCOPUS database with VOSviewer, it is evident that the application fields of 3D printing are highly diverse. Fig. **2** shows clusters ranging from engineering and materials science to pharmaceutics, chemistry, and natural sciences. This diversity confirms the interdisciplinary character of additive manufacturing and its impact in both industrial and medical fields.

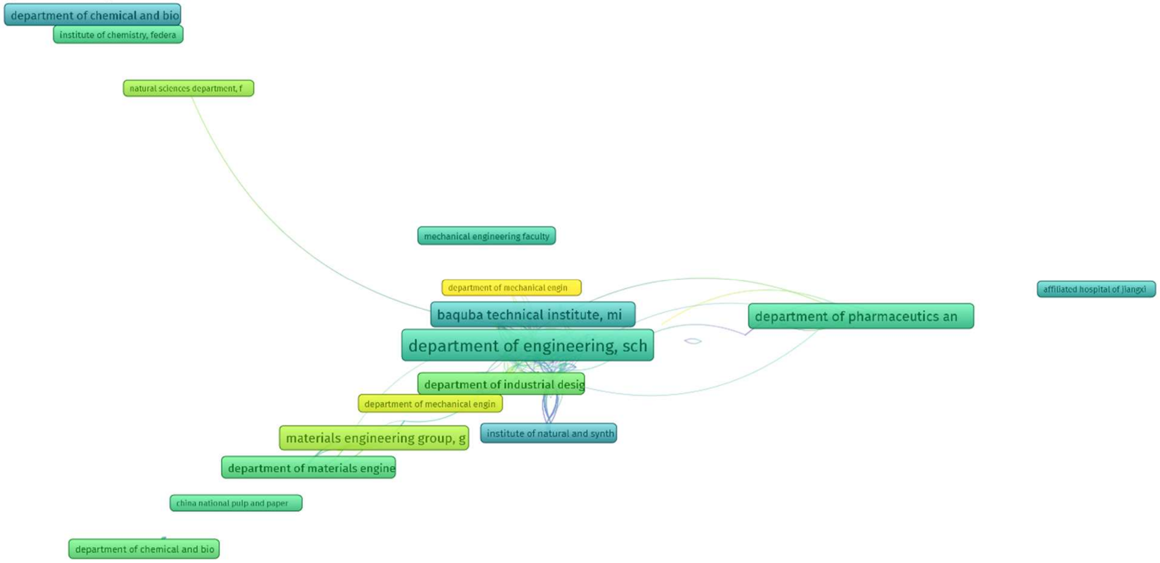


Fig. 2 Areas in which 3D printing is applied

2.1 Fabrication of test samples using 3D Printing

The samples, (Fig. **3**) were produced folowing materials: ABS+ (improved acrylonitrile-butadiene-styrene), PC-FR (Flame Retardant Polycarbonate) and PAHT (High-Temperature Polyamide), dedicated materials used for FDM 3D printing, suitable for engineering applications. [4].

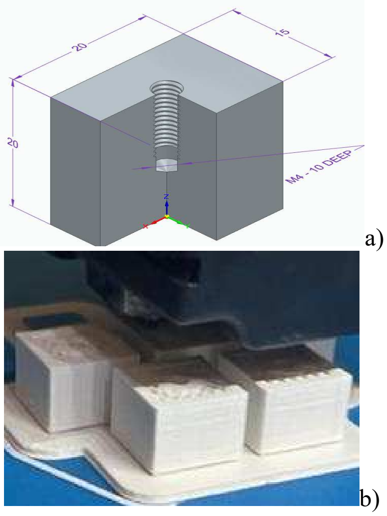


Fig. 3 Sample presentation:
a) Virtual dimensions, b) 3D printed manufacturing

The samples features:

- Were printed with a constant infill of 50%,
- Were printed with the same parameters of printed, to ensure identical conditions.

Dimensions 15×15×15 [mm] as rectangular blocks, alowable for measurements on both surfaces, (Fig. **3**a). Of course, we used the data obtained (Table 1), for various analyses regarding material consumption and manufacturing costs, which allows us to believe that the following analyses can bring conclusions and benefits in terms of economic efficiency,[18]:

Table 1

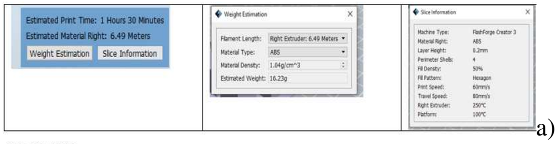
Material data

	ABS	**PC-FR**	**PAHT-CF**
Density [g/cm^3]	1,04	1,24	1,01
Sample weight [g]	16.23	19.44	16.76
Price material [eur]	1.06	1.09	1.81
Manufacturing time [min]	90	99	86
Filament [m]	6,49	6,52	6,90
Specific price [eur/kg]	65.33	55.89	107.8

These data are according to the material supplier [18], respectively using the printer's simulation software, we had access to the printing times and material consumption for 5 printed pieces/print (Fig. **4**).This allowed for a detailed comparison of production efficiency between the two manufacturing methods.

Additionally, the simulations provided insights into potential material waste and energy usage per print cycle, contributing to the overall sustainability assessment.

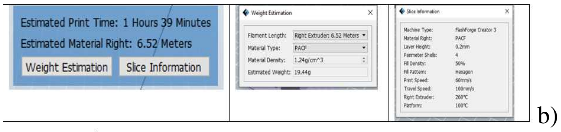
ABS 50%


Estimated Print Time: 1 Hours 30 Minutes
Estimated Material Right: 6.49 Meters

Weight Estimation
Filament Length: Right Extruder: 6.49 Meters
Material Type: ABS
Material Density: 1.04g/cm^3
Estimated Weight: 16.23g

Slice Information
Machine Type: FlashForge Creator 3
Material Right: ABS
Layer Height: 0.2mm
Perimeter Shells: 4
Fill Density: 50%
Fill Pattern: Hexagon
Print Speed: 60mm/s
Travel Speed: 80mm/s
Right Extruder: 250°C
Platform: 100°C

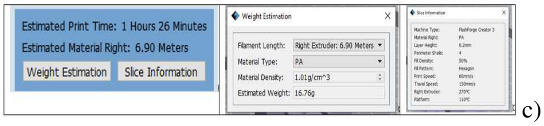
PC-FR 50%


Estimated Print Time: 1 Hours 39 Minutes
Estimated Material Right: 6.52 Meters

Weight Estimation
Filament Length: Right Extruder: 6.52 Meters
Material Type: PACF
Material Density: 1.24g/cm^3
Estimated Weight: 19.44g

Slice Information
Machine Type: FlashForge Creator 3
Material Right: PACF
Layer Height: 0.2mm
Perimeter Shells: 4
Fill Density: 50%
Fill Pattern: Hexagon
Print Speed: 60mm/s
Travel Speed: 100mm/s
Right Extruder: 260°C
Platform: 100°C

Paht··CF·50%¶


Estimated Print Time: 1 Hours 26 Minutes
Estimated Material Right: 6.90 Meters

Weight Estimation
Filament Length: Right Extruder: 6.90 Meters
Material Type: PA
Material Density: 1.01g/cm^3
Estimated Weight: 16.76g

Slice Information
Machine Type: FlashForge Creator 3
Material Right: PA
Layer Height: 0.2mm
Perimeter Shells: 4
Fill Density: 50%
Fill Pattern: Hexagon
Print Speed: 60mm/s
Travel Speed: 150mm/s
Right Extruder: 270°C
Platform: 110°C

Fig. 4 Modeling and simulation through 3D printing of samples: a) ABS, b) PC-FR, c) Paht-CF materials, 50% Infill

At the same time, the graph (Fig. **5**), highlights the price differences between various FDM materials, including the total cost and the final price with profit. Ideal for budget analysis in 3D printing

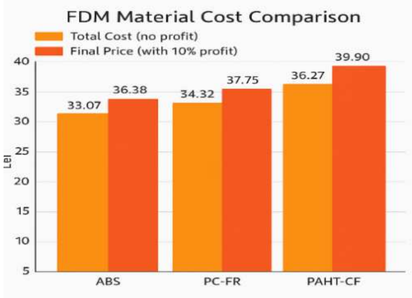


Fig. 5 Comparative price chart materials

2.2 Impact of material and orientation on roughness in FDM 3D printing

The purpose of this study is to evaluate the influence of material and surface orientation on the roughness of 3D printed parts using FDM technology, studies that can be performed using various numerical procedures, such as Matlab, Anova, [19] as follows:

The samples were measured in order to evaluate the following parameters: Ra – average roughness; Rz – maximum height of asperities; Rq – average square roughness

Directions of measurement: Frontal (horizontal) – the upper section of the sample; Lateral (vertical) – the side area, exhibiting a layered structure

This research aims to highlight how the material and orientation of the part influence roughness and, implicitly, the engineering applicability of printed parts. [20], [21].

Fig. 6 shows a measurement diagram and the practical measurements taken with a contact profilometer on both surfaces (front and side) for each material.

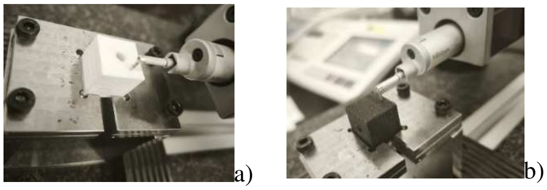


Fig. 6 Measurement basis, a)-frontal, b)- lateral

These values provided a preliminary overview of the surface quality obtained under different conditions. The tabular representation, (Table 2) facilitated the identification of trends and significant variations among materials and orientations, serving as the basis for further graphical and statistical analysis.

Table 2

Measured values of roughness

Material	ABS+						PAHT						PC-FR					
Infill	50%						50%						50%					
Rugozit	Ra		Rz		Rq		Ra		Rz		Rq		Ra		Rz		Rq	
Perete	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral	Frontal	Lateral
1	1.998	8.594	49.734	45.791	3.752	10.668	3.993	10.439	46.250	89.295	5.579	13.676	3.348	9.474	41.826	47.296	4.606	11.707
2	4.077	10.036	93.559	54.270	7.257	12.498	5.478	10.767	60.787	71.648	7.335	13.424	3.493	9.872	62.381	80.376	5.309	12.185
3	4.476	9.409	50.470	46.891	6.445	11.611	5.777	7.645	54.940	71.360	7.596	10.108	2.890	9.454	34.417	50.983	4.463	11.633
4	4.420	9.708	76.535	51.216	7.853	12.033	4.162	11.069	46.543	106.270	5.643	14.007	2.277	8.947	43.281	45.553	3.535	1.045
5	3.632	9.791	69.882	47.187	6.254	12.091	4.175	10.403	48.868	81.831	5.589	12.848	3.117	8.903	43.460	54.070	4.572	11.006
6	2.068	11.135	36.119	54.168	3.390	13.720	4.556	10.993	53.802	68.767	6.316	13.610	2.522	10.334	53.976	54.680	4.043	12.509
7	2.331	10.270	52.547	53.251	3.952	12.620	4.972	10.653	52.302	125.440	5.501	13.721	2.234	9.346	37.761	54.304	3.367	11.579
8	2.057	9.359	40.730	75.587	3.321	11.647	5.551	10.305	74.491	80.876	7.656	13.030	2.837	9.158	46.065	63.993	4.491	11.363
9	3.393	9.837	78.682	48.217	6.371	12.268	4.715	10.540	41.480	70.605	6.037	13.108	2.838	9.888	51.224	59.676	4.472	12.213
10	2.089	10.188	35.373	52.154	3.541	12.450	5.090	8.968	55.530	84.438	6.752	11.847	2.610	9.651	39.113	47.775	4.239	11.913

The graphical analysis of surface roughness (Ra, Rz, Rq) parameters highlighted significant differences among the three investigated materials and the two build orientations. These findings underline the combined effect of material type and orientation on the resulting surface quality, providing a solid basis for deeper comparative and statistical evaluation.

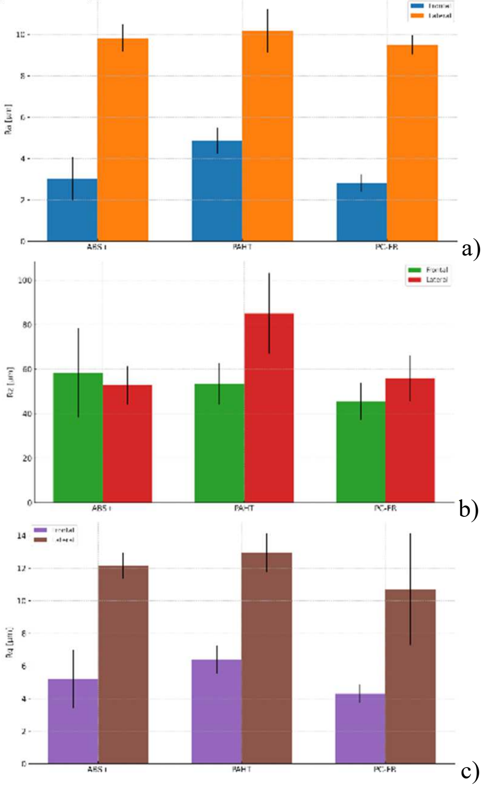


Fig. 7 Comparative chart with error bars:
(a) Ra, (b) Rz, (c) Rq- – Front Wall vs. Lateral Wall

Thus, based on Fig. 7, we can conclude that a clear visual summary of the three materials and the two orientations highlights the behavior of each material.

2.3 Evaluation of the surface condition

Although many studies have examined the effect of process parameters on surface roughness, only a few directly compare ABS+, PAHT, and PC-FR engineering materials under identical printing conditions with thorough statistical analysis. Furthermore, differences in roughness between front and side walls are not sufficiently explored, although these can have a major impact in functional or aesthetic applications.

Thus, this paper aims to fill this gap through a comparative experimental analysis with detailed measurements and statistical testing between materials and orientations.

Table 3

Statistic data

Material	Ra_F (mean ± std)	Ra_L	Rz_F	Rz_L	Rq_F	Rq_L
ABS+	3.05 ± 1.05	9.83 ± 0.67	58.36 ± 20.05	52.87 ± 8.58	5.21 ± 1.78	12.16 ± 0.79
PAHT	4.85 ± 0.63	10.18 ± 1.06	53.50 ± 9.24	85.05 ± 18.16	6.40 ± 0.87	12.94 ± 1.17
PC-FR	2.82 ± 0.42	9.50 ± 0.45	45.35 ± 8.40	55.87 ± 10.31	4.31 ± 0.56	10.72 ± 3.43

Based on the data in Table 3, comparative graphs were generated and presented in Fig. 8, highlighting the characteristics of each material.

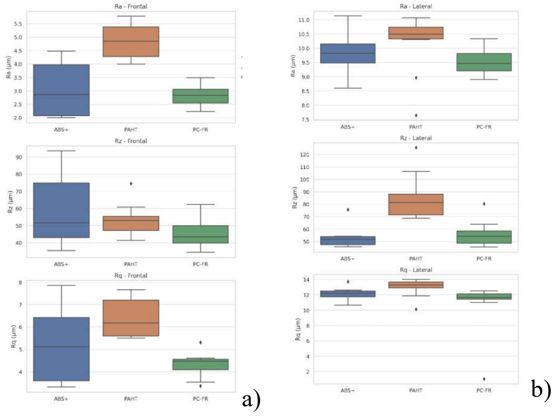
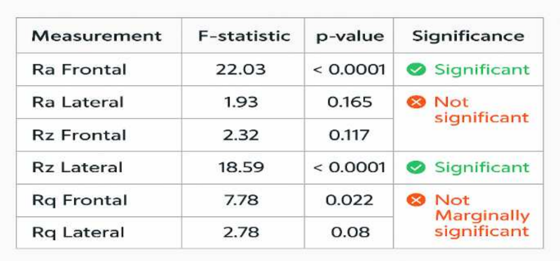


Fig. 8 Comparative graphical representation, a)Ra frontal, b) Ra lateral

A. Anova unifactorial

Continuing with a statistical test (one-way ANOVA), we checked whether the differences between materials for each metric are statistically significant, (Fig. 9).



Measurement	F-statistic	p-value	Significance
Ra Frontal	22.03	< 0.0001	✓ Significant
Ra Lateral	1.93	0.165	☒ Not significant
Rz Frontal	2.32	0.117	
Rz Lateral	18.59	< 0.0001	✓ Significant
Rq Frontal	7.78	0.022	☒ Not Marginally significant
Rq Lateral	2.78	0.08	

Fig. 9 Anova test measurement

Based on the analysis, the following opinions were generated, formulated, and then consolidated:

- ABS+, has moderate average values, but large variations for Rz.
- PAHT, has the highest average roughness (both Ra, Rz, and Rq), especially on the sides.

- PC-FR, has the best values for finish – Ra and Rq are the lowest in both directions.

As preliminary conclusions:

- Roughness depends significantly on the material and wall orientation.
- For applications where front surface quality is important, material selection is critical (e.g., PC-FR is the finest).
- PAHT tends to have higher roughness values, especially on the sides, which can affect precision applications.

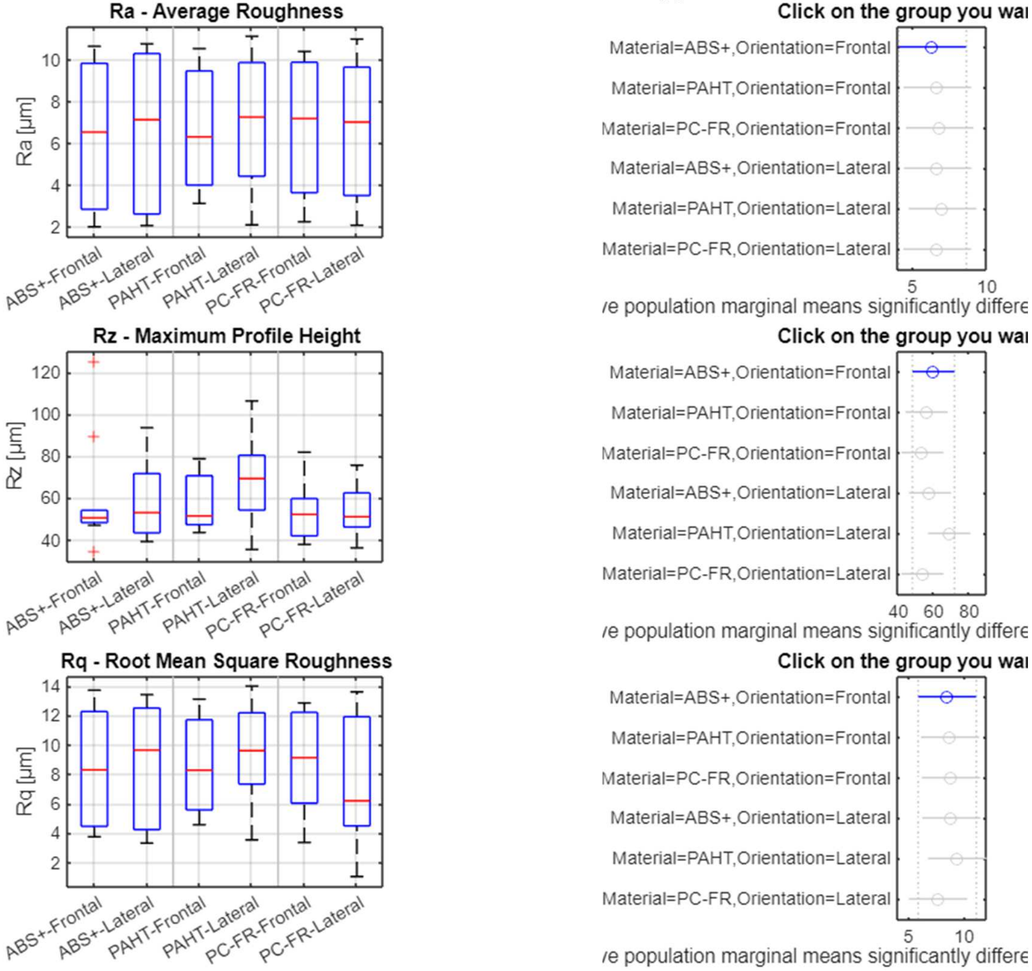


Fig. 10 Diagrams
(Boxplot_Ra; Boxplot_Rq; Boxplot_Rz /
Multcompare_Ra; Multcompare_Rq; Multcompare_Rz)

The findings (Fig. **10**) show that material type and wall orientation significantly affect surface quality, guiding the optimization of 3D printing parameters. For Ra, lateral walls generally exhibit higher values compared to frontal walls, confirming the staircase effect. Regarding Rz, ABS+ in frontal orientation achieves the lowest variability, while PAHT and PC-FR present larger dispersion, especially laterally. For Rq, differences between materials are less pronounced, but orientation still influences the results, with frontal walls yielding smoother surfaces overall.

B. Pareto

For a clear comparative assessment of the influence of material and wall orientation on roughness, Pareto charts were created for the average Ra, Rz, and Rq values. These charts highlight the contribution of each material–orientation combination that contributes most to the high roughness values (Fig. **11**).

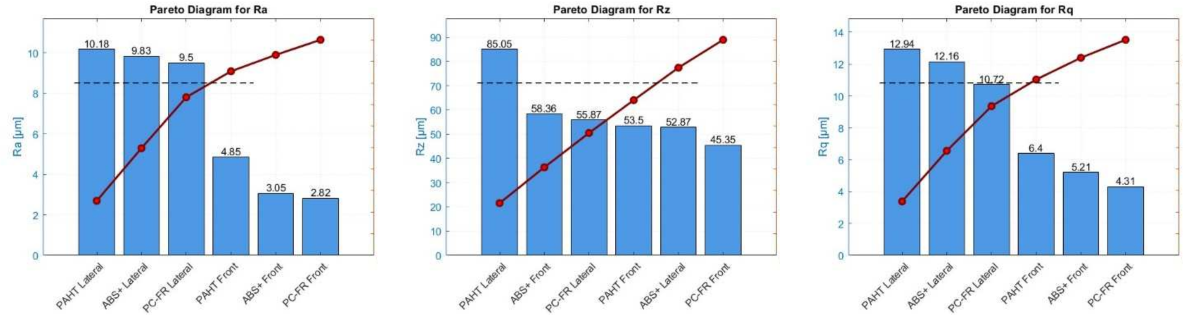


Fig. 11 Pareto charts for mean values Ra, Rz, and Rq

Thus, it can be quickly observed that lateral orientation has a significantly greater impact on roughness increase, especially for PAHT and ABS+ materials. The use of these diagrams facilitates the prioritization of critical factors affecting surface quality and supports the decision-making process in optimizing printing parameters.

C. Monte Carlo Algorithm

A third method for evaluating the results regarding the surface condition is a Monte Carlo simulation to assess the robustness of the roughness values. Ra=3.2[µm], was proposed as the target roughness.

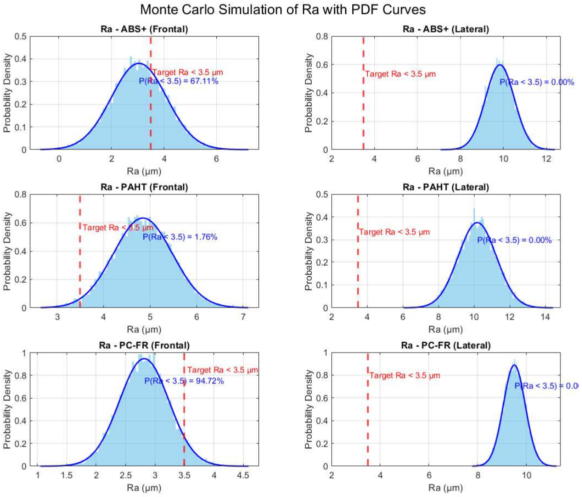


Fig. 12 Monte Carlo histograms

After applying this method, the data obtained in Fig. 12, show the following:

- PC-FR Frontal – is the only combination that has a high probability of achieving the Ra < 3.5 µm requirement.
- ABS+ Frontal – a significant part of the distribution is below 3.5 µm.
- PAHT Frontal – only a small part of the distribution reaches the target.
- The lateral orientations for all three materials clearly exceed 3.5 µm.

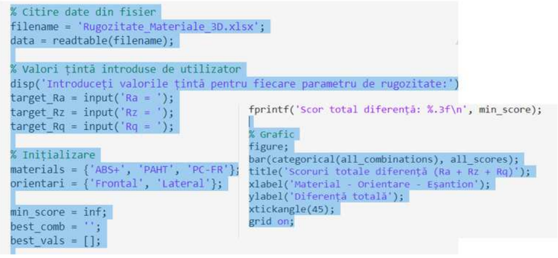
In addition to the experimental findings, the proposed methodology demonstrates strong potential for industrial applications, [7]. In the automotive sector, it can be employed to evaluate and optimize FDM-printed jigs, fixtures, and prototype housings, ensuring both dimensional accuracy and durability, [22]. In the biomedical field, the methodology supports the development of customized medical devices and implants with controlled surface finish, enhancing both performance and patient comfort, [23]. Furthermore, in aerospace and electronics, where strict tolerances and surface integrity are crucial, this approach enables engineers to select materials and orientations that minimize deviations from target roughness values, [1], [24].

3. MATLAB ALGORITHMS FOR OPTIMIZING MATERIAL SELECTION AND ORIENTATION BASED ON SURFACE ROUGHNESS

Although all ten samples were manufactured using constant, previously established printing parameters (extrusion speed, printing temperature, layer height, infill pattern, etc. depending on the material used), the results presented in CHAPTER 2 show that analyzing the values obtained for surface roughness (Ra, Rz, Rq) revealed significant variability between samples.

This discrepancy can be explained by factors intrinsic to the FDM process, such as micro-variations in room temperature, uneven wear of the nozzle, positioning of parts on the print bed, or irregularities in filament feeding, [25], [26],[27].

Thus, considering that in all manufacturing fields (regardless of their nature), performance, speed, and quality are required according to the requirements imposed by the documentation, we have designed and written three Matlab codes (Fig. **13**) which, based on the results collected from the 10 types of 3D printed samples made from three different types of material, provide the user with a quick and accurate response, resulting in the selection of the appropriate type of material and its orientation, so as to obtain a part with the desired surface condition.



```
% Citire date din fisier
filename = 'Rugozitate_Materiale_3D.xlsx';
data = readtable(filename);

% Valori țintă introduse de utilizator
disp('Introduceți valorile țintă pentru fiecare parametru de rugozitate:')
target_Ra = input('Ra = ');
target_Rz = input('Rz = ');
target_Rq = input('Rq = ');

% Inițializare
materials = {'ABS+', 'PAHT', 'PC-FR'};
orientari = {'Frontal', 'Lateral'};

min_score = inf;
best_comb = '';
best_vals = [];
```

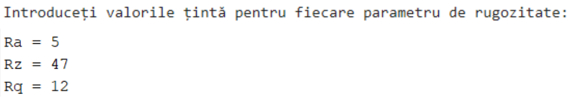
```
fprintf('Scor total diferență: %.3f\n', min_score);

% Grafic
figure;
bar(categorical(all_combinations), all_scores);
title('Scoruri totale diferență (Ra + Rz + Rq)');
xlabel('Material - Orientare - Eșantion');
ylabel('Diferență totală');
xtickangle(45);
grid on;
```

Fig. 13 Sequences from the Matlab programs

A. Run program 1 - which automatically identifies the optimal material-orientation combination that most closely approximates the target values of Ra, Rz, and Rq roughness introduced by the user:

Step 1 – User input

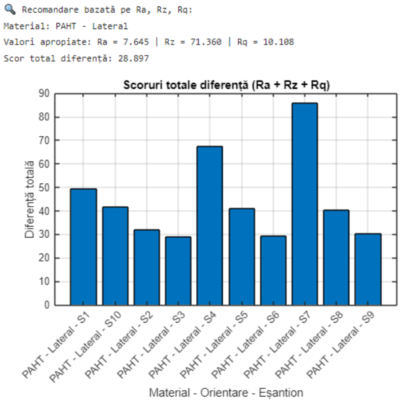


```
Introduceți valorile țintă pentru fiecare parametru de rugozitate:

Ra = 5
Rz = 47
Rq = 12
```

Fig. 14 Data entered by the user

Step 2 – Answer given by the program



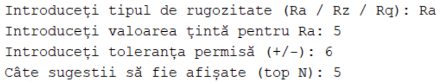
```
🔍 Recomandare bazată pe Ra, Rz, Rq:
Material: PAHT - Lateral
Valori apropiate: Ra = 7.645 | Rz = 71.360 | Rq = 10.108
Scor total diferență: 28.897
```

Fig. 15 Data provided after running the program

In conclusion, based on the data provided in Step 1 (Fig. **14**), it appears that the best material to use is PAHT and LATERAL orientation (Fig. **15**).

B. Run Program 2 - which allows quick identification of material–orientation–sample combinations that fall within a tolerance range for a target roughness value (Ra, Rz, or Rq), providing top N relevant suggestions, (Fig. 16 and Fig. 17):

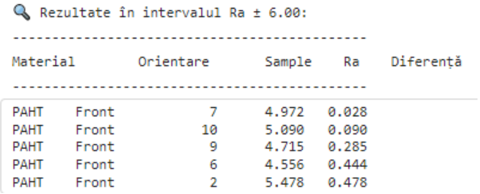
Step 1 – User input



```
Introduceți tipul de rugozitate (Ra / Rz / Rq): Ra
Introduceți valoarea țintă pentru Ra: 5
Introduceți toleranța permisă (+/-): 6
Câte sugestii să fie afișate (top N): 5
```

Fig. 16 Data entered by the user

Step 2 – Answer given by the program



```
🔍 Rezultate în intervalul Ra ± 6.00:
--------------------------------------------
Material        Orientare        Sample    Ra      Diferență
--------------------------------------------
PAHT     Front             7     4.972   0.028
PAHT     Front            10     5.090   0.090
PAHT     Front             9     4.715   0.285
PAHT     Front             6     4.556   0.444
PAHT     Front             2     5.478   0.478
```

Fig. 17 Data provided after running the program

C. Run Program 3 –

The third version of the program is a new full extended MATLAB program.

The images presented in Fig. 18 represent the results of the ongoing study and constitute an extension of the comparative analysis and optimization process applied to the data set obtained through experimental measurements.

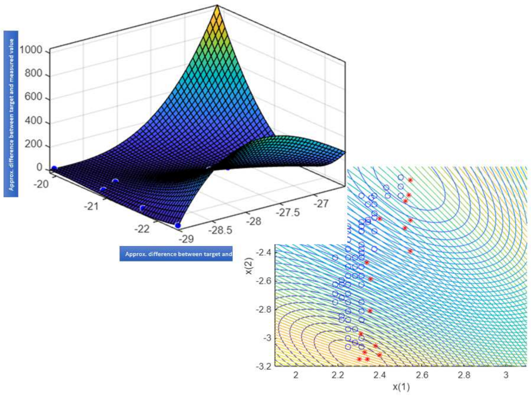


Fig. 18 Inverse diferences aproximation/ Contour Representation of a Generic Multi-Objective Optimization Algorithm

The algorithms used are Genetc multi-objective algorithm, Pareto search, and Front Pareto Experimental. The results clearly show that the trends observed in this research are consistent with the conclusions of the first stage of the previous study, thus confirming the robustness and consistency of the proposed approach.

The labels on the response surface graph represent the differences calculated between the target values and the maximum values on each column of the matrix of measured values (these differences were determined in the analysis of the matrices of two columns, the first column being the target column, and the second column representing a column from the original matrix of measurements, resulting in 18 pairs, 10 rows each, 10 rows = 10 samples). These differences are approximated by fourth-degree polynomial functions, and the approximation functions obtained are used as objective functions (it is obvious that the most efficient results are obtained for a set of at least two variables, which is why we chose matrices of two columns each) in each of the optimization algorithms, both in this paper and in subsequent research.

The last image (Fig. 18 -right) demonstrate the validity of the proposed method for the analyzed field, as it is based on actual measurements rather than artificially generated data. The labels in this image correspond to variables x(1) and x(2), and to Objectives 1 and 2, respectively. The data is integrated into the programming blocks through script file loops, demonstrating the practical applicability and reproducibility of the method.

Although the proposed approach relies on statistical foundations, it has been formalized as an original algorithm. The present study constitutes a starting point, and future investigations will focus on its refinement and broader validation.

4. CONCLUSION

In conclusion, based on the data provided in Step 1, as can be seen in Fig. 16, we chose the same value for Ra roughness, namely = 5, and due to a tolerance of 6 units (+/-), we obtain the same result as in the first program, namely that the PAHT material (Fig. 17). is the one that meets these requirements. The difference between the first two programs is that the first requires three parameters, while the second requires only one parameter, which can lead to different results if other values are chosen for the Ra, Rz, and Rq parameters.

Although the proposed methodology provided reliable results, several limitations should be acknowledged.

Additive manufacturing (AM) is one of the most remarkable manufacturing technologies in terms of growth and development, eliminating many limitations in producing parts with no common geometries. The complexity of geometries often imposes limitations due to their unique design features. While the advantages of AM have been extensively discussed in research, challenges remain, including the need for support structures and the generally poor surface quality of printed parts, [28].

In all layer-based systems, overhanging surfaces require additional support, which must later be removed through post-processing, leading to increased time, cost, and material waste.

New approaches, such as topology optimization with support-reduction constraints, are being developed to minimize these drawbacks, [29]. Nevertheless, due to current manufacturing and control constraints, complex geometries produced through topology optimization continue to face practical challenges, [28],[30]. Addressing these issues is essential to ensure that AM can achieve its full potential in industrial applications, [31].

This study systematically investigated and applied the influence of material type and printing orientation on surface roughness parameters (Ra, Rz, and Rq) in engineering polymers manufactured by FDM. The combined use of statistical modeling, ANOVA, Monte Carlo simulations, and customized MATLAB programming enabled the development of a reliable decision-making tool for optimizing roughness performance.

The main conclusions are as follows:

- It is well known that surface roughness depends significantly on the type of material and the direction of movement of the print head, with lateral orientation generating more pronounced roughness.
- Among the materials analyzed, PAHT demonstrated the most balanced performance in

terms of minimizing deviations from target roughness values.

- The developed MATLAB tools provide real-time recommendations on material–orientation pairs, based on user-defined target values and roughness tolerances, significantly improving the decision-making process in practical applications.
- The integrated methodology provides a scalable framework for future investigations involving other additive manufacturing parameters (e.g., layer height, printing speed) and can be extended to multi-objective optimization tasks.
- It is not difficult to recognize that the results obtained complement the ongoing efforts to increase the accuracy and reliability of FDM technology in the context of industrial and functional prototyping, where surface quality is essential.

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Metodologie de evaluare a texturii suprafeței pentru piese imprimate 3D prin depunere de material topit (FDM) utilizând date experimentale și algoritmi de modelare statistică, cu MATLAB

Această lucrare prezintă, concis şi aplicat, rezultatele unui studiu complet cu o evaluare cuprinzătoare a caracteristicilor texturii suprafeței pentru piesele imprimate 3D prin tehnologia depunerii de material topit (FDM). Având la dispoziţie rezultatele unor seturi de experimente coordonate de autori, folosind tehnici şi proceduri hibride, precum tehnica modelării statistice avansate, cu tehnici avansate de programare şi implementare în MATLAB, bineînţeles validate în aplicaţii numerice. Au fost investigate trei tipuri de polimeri tehnici (ABS+, PAHT, PC-FR), considerând două orientări de imprimare (direcţie frontală, respectiv laterală), avându-se în vedere, o etapă de evaluare a influenței (de exemplu, a sensibilităţii locale) acestora asupra parametrilor rugozităţii suprafeței: Ra, Rz și Rq. Materializarea metodologiei, prin cooptarea acestor idei, tehnici şi proceduri avansate, generatoare a unui program MATLAB personalizat, are scopul declarat de a emite instant, recomandări, evaluate şi verificate, de asociert optime constituite din binoame de tipul: material ⇋ orientare, parametri caracteristici cu rol in minimizarea abaterii de la valorile țintă ale rugozității. Diversitatea aplicaţiilor şi rezultatele încurajatoare ale optimizării parametrizate au impus, o analiză ANOVA factorială. Prin aceasta, rezultatele analizei, au permis evidențierea efectelor de interacțiune a cuantificării şi validării semnificației statistice a tipului de material și influenţa abaterii orientării asupra rugozității suprafeței. De remarcat că, o altă procedură, constituită ca model de abordare, este algoritmul Monte Carlo prin care, s-au modelat, evaluat şi validat distribuțiile probabilistice ale parametrilor de rugozitate, consfinţită prin valorile elementelor matricei de conformitate. O analiză Pareto a identificat factorii critici, care generează abateri ale valorilor obţinute experimental, ceea ce are ca efect modificarea vizibilă, uneori, necontrolabilă, a calităţii suprafeței, oferind informații utile pentru optimizarea procesului. Abordarea integrată a acestei metodologii oferă un cadru robust pentru a sprijini inginerii în selectarea parametrilor optimi de imprimare pentru a îndeplini cerințele stricte de finisare a suprafețelor în aplicațiile FDM.

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