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Beyond Datasheets: A Comparative Evaluation of Standard and Technical Filaments in High-Speed FDM 3D Printing

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Abstract: This study presents a systematic comparative evaluation of the printing performance of both standard and technical filament types on a high-speed FDM 3D printer (Creality K1 Max). Unlike datasheet-based comparisons, this research experimentally investigates the real-world effects of nozzle temperature, bed temperature, print speed, volumetric flow rate, and cooling settings across nine widely available filament types, including PLA, ABS, PETG, TPU, ASA, PC, carbon-reinforced PLA, silk PLA and hyper PLA. Using standardized test geometries and consistent environmental controls, the study assesses dimensional accuracy, surface quality, and warping tendencies. The results demonstrate that while Hyper PLA enables printing speeds up to 300 mm/s with minimal surface defects, technical filaments like ABS and PC require strict temperature and cooling regulation to avoid warping and delamination. A correlation heatmap and optimization matrix were constructed to visualize key parameter interactions. This work contributes to the field by offering a consolidated, data-driven guide for tuning print parameters based on filament-specific behavior—extending beyond catalog data and enabling informed material selection and process control in high-speed 3D printing applications.

Keywords: 3D Printing, Additive Manufacturing, Comparative Analysis, Optimization

Öz: Bu çalışma, yüksek hızlı bir FDM 3D yazıcıda (Creality K1 Max) hem standart hem de teknik filament tiplerinin baskı performansının sistematik karşılaştırmalı değerlendirmesini sunmaktadır. Veri sayfası tabanlı karşılaştırmaların aksine, bu araştırma, PLA, ABS, PETG, TPU, ASA, PC, karbon takviyeli PLA, silk PLA ve hyper PLA dahil olmak üzere yaygın olarak bulunan sekiz filament tipinde nozul sıcaklığı, yatak sıcaklığı, baskı hızı, hacimsel akış hızı ve soğutma ayarlarının gerçek dünya etkilerini deneysel olarak araştırmaktadır. Standart test geometrileri ve tutarlı çevresel kontroller kullanılarak, çalışma boyutsal doğruluğu, yüzey kalitesini ve eğilme eğilimlerini değerlendirmektedir. Sonuçlar, Hyper PLA'nın minimum yüzey kusurlarıyla 300 mm/s'ye kadar baskı hızlarına olanak tanırken, ABS ve PC gibi teknik filamentlerin eğilme ve delaminasyonu önlemek için sıkı sıcaklık ve soğutma düzenlemesi gerektirdiğini göstermektedir. Temel parametre etkileşimlerini görselleştirmek için bir korelasyon ısı haritası ve optimizasyon matrisi oluşturulmuştur. Bu çalışma, filament-spesifik davranışa dayalı baskı parametrelerinin ayarlanması için konsolide edilmiş, veri odaklı bir kılavuz sunarak alana katkıda bulunmakta; katalog verilerinin ötesine geçerek yüksek hızlı 3B baskı uygulamalarında bilinçli malzeme seçimi ve süreç kontrolü sağlamaktadır.

Anahtar Kelimeler: 3B Yazıcı, Eklemeli İmalat, Kıyaslamalı Analiz, Optimizasyon

1. Introduction

Fused Filament Fabrication (FFF), as a prominent method among additive manufacturing (AM) technologies, allows the production of functional parts and prototypes by extruding thermoplastic materials layer by layer [1, 2]. Thanks to increasing printer capabilities and filament diversity, this technology has become accessible to both industry and individual users [3, 4]. However, print quality and product functionality largely depend on the correct optimization of process parameters. These parameters include nozzle temperature, table temperature, printing speed, layer height and cooling strategies; these variables directly affect mechanical properties, surface roughness, dimensional accuracy and thermal behavior [5-7].

Studies have shown that common Fused Deposition Method (FDM) materials such as Polylactic Acid (PLA), Acrylonitrile Butadiene Styrene (ABS), polyethylene terephthalate glycol (PETG) and Polyether ether ketone (PEEK) exhibit different levels of sensitivity to process parameters. In particular, Algarni and Ghazali [8] stated that PLA and Polyethylene Terephthalate Glycol (PETG) exhibit stable dimensional performance in certain settings, while ABS and PEEK are more prone to warpage and delamination. Andronov et al. [4] reported quality differences among PLA filaments commercially sold in Europe and emphasized the importance of standard testing protocols.

Recent literature is not limited to conventional polymers; it also focuses on recycled, composite and nano-reinforced filaments. Ibrahim et al. [9] presented a systematic review on the technical performance and sustainability of recycled filaments, while Kristiawan et al. [1] addressed the roles of carbon fiber or graphene-doped functional filaments in printing processes. Furthermore, Lei et al. [10], Khan et al. [2, 11] have thoroughly investigated the effects of parameter-material interactions, especially on hybrid and ternary composite structures. However, most of the existing studies either focus on single materials only or have been conducted under controlled laboratory conditions, leaving limited direct comparative analyses of commercially available standard and technical filaments in realistic printing environments [12-14]. Moreover, since the parameter sets used in many studies are based on manufacturer recommendations, the data do not always reflect real application conditions [15-17]. In order to fill this gap, this research conducted a comparative experimental analysis on nine different filament types commonly available in the market (PLA, ABS, PETG, Termoplastik Poliüretan (TPU), Acrylonitrile Styrene Acrylate (ASA), Polycarbonate (PC), carbon-reinforced PLA, and Hyper PLA) in a high-speed FDM 3D printer. Important process parameters such as printing speed, nozzle temperature, and fan usage were systematically varied; performance criteria such as dimensional accuracy, surface quality, and print stability were evaluated [12, 18, 19]. Thus, going beyond the manufacturer's data, an experimental, applicable and repeatable roadmap is presented that provides solutions to the problems encountered by users in real printing scenarios [20,21]. In this context, the aim of the study is to guide the selection of materials that can be used in both functional and aesthetic applications and to contribute to the multi-material printing optimization specific to FFF technology by determining the optimum process parameters for different filament types [22, 23].

In this study a comprehensive comparative analysis was performed on high-speed FDM printers using nine different filament types (PLA, ABS, PETG, TPU, ASA, PC, carbon-reinforced PLA, and Hyper PLA) that are widely available in the market. Parameters such as printing speed, nozzle temperature, and fan usage were systematically varied and their effects on dimensional accuracy, surface quality, and print stability were experimentally evaluated. Thus, this study aims to provide a knowledge-based, applicable, and repeatable framework for application-oriented material selection and parameter optimization, going beyond manufacturer data.

2. Material and Method

2.1. Materials

This study evaluated the performance of several filament types commonly used in 3D printing. The selected filaments were categorized into two groups: standard and technical. Standard filaments included Hyper PLA, Silk-PLA, Generic PLA, Generic PETG, and Generic TPU. Hyper PLA was chosen for its high-speed printing capabilities, while Silk-PLA was selected for its aesthetic glossy finish, often used in decorative applications. Generic PLA, widely regarded as a user-friendly and biodegradable thermoplastic, was also included. PETG was chosen for its durability and impact resistance, and TPU was selected for its flexibility, ideal for functional parts requiring elasticity. In contrast, technical filaments, including Generic ABS, Generic ASA, Generic PC, and Generic PLA Carbon, were evaluated for their advanced mechanical and thermal properties. ABS, known for its high mechanical strength and heat resistance, was compared with ASA, which offers improved UV and weather resistance. PC was included due to its excellent heat resistance and strength, while PLA Carbon was chosen for its lightweight yet stiff properties, attributed to its carbon fiber reinforcement. All filaments were sourced from reliable manufacturers and stored in moisture-controlled environments to prevent degradation.

2.2. Equipment

The experiments were conducted using a Creality K1 max 3D printer (Figure 1), which is capable of high-speed printing and precise temperature control. The printer (Table 1) features an adjustable hotbed and nozzle, as well as customizable fan settings, ensuring compatibility with both standard and technical filaments. Supplementary tools included a digital caliper for dimensional accuracy measurements, an infrared thermometer for temperature validation, and a high-resolution camera for capturing surface details. To ensure filament quality, a filament dryer was employed to remove residual moisture, particularly for hygroscopic materials such as PETG, ABS, and PC.

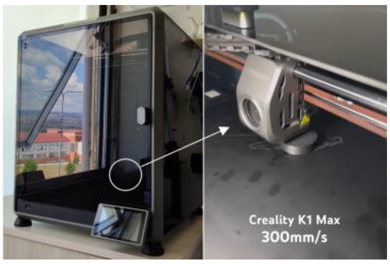

Figure 1. Creality K1 max 3D printer

Table 1. Technical specification of Creality K1 max 3D printer

Feature	Specification
Build Volume	300 x 300 x 400 mm
Printing Technology	Fused Deposition Modeling (FDM)
Nozzle Diameter	Standard: 0.4 mm (replaceable)
Nozzle Temperature	Max 300°C
Hotbed Temperature	Max 110°C
Filament Compatibility	PLA, ABS, PETG, TPU, ASA, PC, Carbon Fiber Reinforced PLA
Print Speed	Normal: 250 mm/s, Max: 300 mm/s
Layer Thickness	0.1 mm to 0.4 mm
Extrusion System	Direct Drive Extruder
File Format Support	STL, OBJ, G-code

2.3. Experimental Design

The experimental setup involved preparing the filaments, defining a standard test geometry, and systematically adjusting the print parameters. Filaments were dried at 50 °C for six hours prior to use, ensuring optimal performance. Each filament was loaded into the printer, and preliminary purges were performed to prevent clogging. A standardized calibration cube (20x20x20 mm) was selected as the test geometry to evaluate dimensional accuracy, surface finish, and layer adhesion. Additionally, tensile test bars (ASTM D638-14 Type IV) [24] were printed for future mechanical property analysis.

Print settings (Table 2) were carefully calibrated for each filament type. Nozzle temperatures ranged from 220°C to 260°C based on the filament's melting point, while hotbed temperatures varied between 45°C and 100°C to ensure proper adhesion. Print speeds were tested between 120 mm/s and 300 mm/s, and the maximum volumetric flow rates were recorded, ranging from 10 mm^3/s to 25 mm^3/s. Cooling fan settings were adjusted between 0% and 100% depending on the material's cooling requirements. PLA and TPU, which benefit from rapid cooling, were printed with higher fan speeds, while ABS and PC required minimal or no cooling to prevent warping or cracking.

Table 2. Creality K1 max 3D printer settings and some printing details

Aspect	Details
Printer Model	K1 Max 3D Printer
Filaments Tested	PLA (Hyper PLA, Silk-PLA, Generic PLA), PETG, ABS, TPU, ASA, PC, PLA Carbon
Test Geometry	Calibration cube (20x20x20 mm) for dimensional accuracy; tensile test bar (ASTM D638 Type IV)
Nozzle Diameter	0.4 mm
Nozzle Temperature Range	220°C to 260°C
Hotbed Temperature Range	45°C to 100°C
Print Speed Range	120 mm/s to 300 mm/s
Cooling Fan Settings	Model fan: 0% to 100%; Side fan: 0% to 80%
Layer Thickness	0.2 mm (fixed for all tests)
Bed Adhesion Aids	Adhesive glue stick, PEI sheet (used for high-warp materials like ABS and PC)
Environmental Conditions	Room temperature (22 ± 2°C) and humidity controlled (<40%)
Number of Samples	Three prints per filament type for repeatability
Data Collection Tools	Digital caliper (dimensional accuracy), high-resolution camera (surface analysis), microscope (layer bonding)
Key Evaluation Metrics	Dimensional accuracy, surface quality, layer adhesion, warping, and stringing behavior

2.4. Data Collection

Dimensional accuracy was assessed using a digital caliper, measuring critical points on the printed models. Surface quality was visually inspected and documented using high-resolution photographs, identifying issues such as stringing, roughness, or layer separation. Warping and adhesion were evaluated by observing the base layer's contact with the build plate and checking for deformations or cracks in the print. Each filament type was printed in triplicate to ensure repeatability and reliability of the results. A control sample using Generic PLA was printed under identical conditions for comparative purposes, normalizing the results across experiments.

3. Results

3.1. Nozzle and Hotbed Temperatures

The study revealed that filament types varied significantly in their thermal requirements. Standard filaments such as Hyper PLA, Silk-PLA, and Generic PLA demonstrated excellent printability at lower nozzle temperatures (220 °C–230 °C) and hotbed temperatures of 45 °C (Figure 2). These materials adhered well to the build plate and showed minimal warping. In contrast, technical filaments like Generic ABS, ASA, and PC required higher nozzle temperatures (250°C–260 °C) and hotbed settings of 100 °C to ensure proper layer adhesion and to prevent warping or cracking. PETG, a semi-technical filament, performed optimally at intermediate temperatures (nozzle: 250°C, hotbed: 70°C), balancing good adhesion with minimal warping.

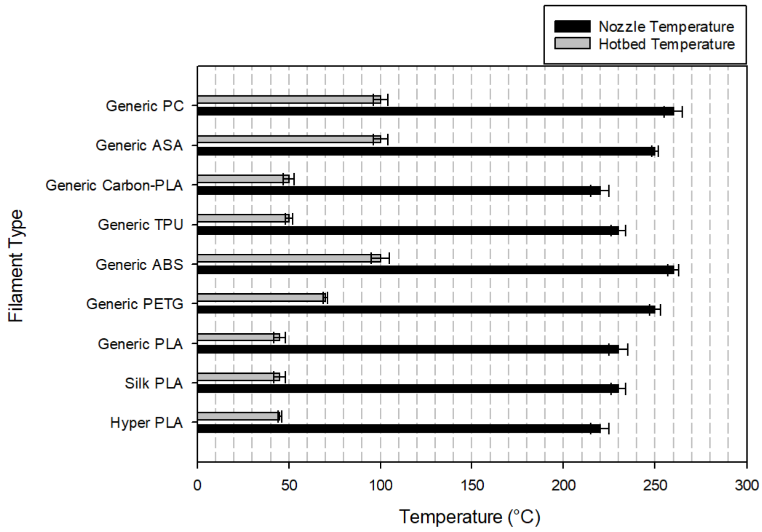

Figure 2. Nozzle and hotbed temperatures vs filament type

3.2. Print Speed and Volumetric Flow

Hyper PLA outperformed all other filaments in terms of print speed and volumetric flow rate, achieving a maximum speed of 300 mm/s and a volumetric flow rate of 25 mm³/s (Figure 3). These characteristics make Hyper PLA suitable for rapid prototyping without compromising surface quality. PLA Carbon also showed high-speed capabilities (150 mm/s), attributed to its low thermal expansion and rigidity due to carbon fiber reinforcement. On the other hand, technical filaments like ABS, ASA, and PC required slower speeds (120 mm/s) to maintain consistent extrusion and layer bonding. TPU demonstrated moderate speeds (250 mm/s) but exhibited stringing issues if the speed exceeded the recommended range.

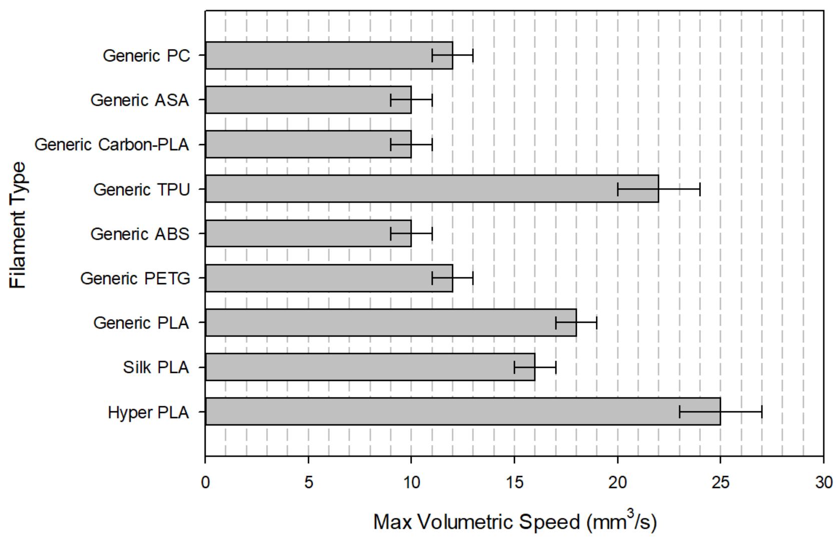

Figure 3. Max. volumetric speed by filament type

3.3. Cooling Fan Settings

Cooling fan settings played a critical role in determining print quality, especially for materials prone to warping. PLA-based filaments (Hyper PLA, Silk-PLA, Generic PLA) showed optimal results with high fan speeds (80%–100%), which enhanced layer cooling and surface smoothness (Figure 4). TPU also benefited from high fan settings (70%), improving its dimensional stability. Conversely, technical filaments such as ABS, ASA, and PC required minimal or no cooling (0%–10%) to prevent layer cracking and warping, particularly during larger prints. PETG displayed moderate behavior, requiring 0% side fan usage but benefitting from controlled cooling (80%) on the model fan for better surface quality.

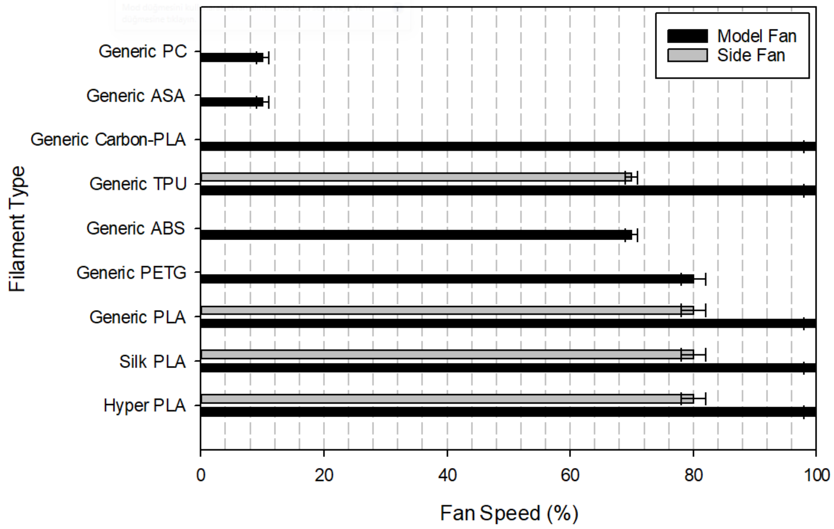

Figure 4. Cooling fan settings for each filament type

3.4. Surface Quality and Dimensional Accuracy

Hyper PLA produced the smoothest surface finishes among all tested filaments, with negligible stringing and excellent layer adhesion. Silk-PLA also exhibited a glossy surface finish, suitable for aesthetic applications (Figure 5). PLA Carbon, despite its rigidity, maintained good surface quality but required slower speeds to avoid layer inconsistencies. Technical filaments like ABS and PC showed minor surface roughness and occasional layer separation when printing conditions deviated from their optimal settings. Dimensional accuracy was highest in PLA-based materials, with deviations of less than ±0.2 mm. TPU exhibited slight deviations due to its flexibility, while ABS and PC occasionally exhibited warping, leading to dimensional inaccuracies in the range of ±0.5 mm.

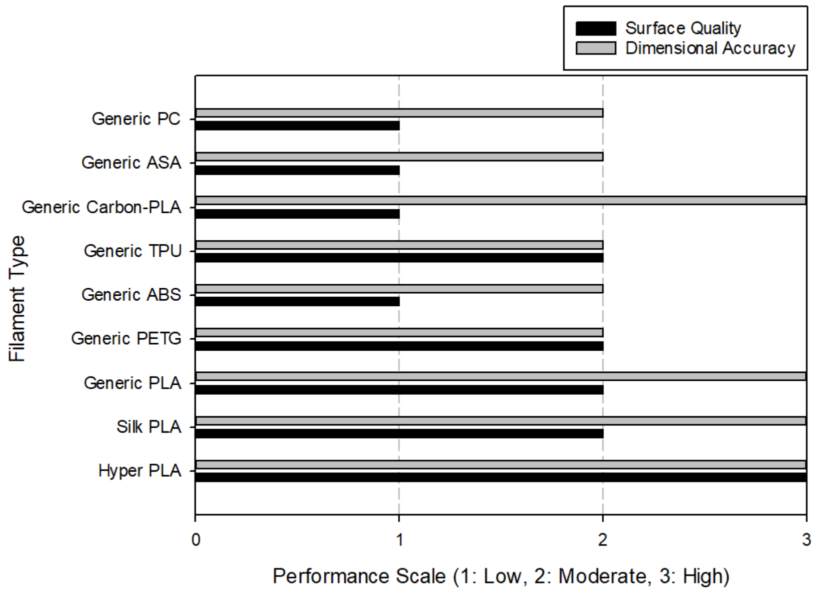

Figure 5. Surface quality and dimensional accuracy for each filament type

3.5. Warping and Layer Adhesion

Warping was most prevalent in ABS and PC when cooling was improperly managed or when the hotbed temperature was below 100°C (Figure 6). These materials exhibited improved adhesion when printed with a heated enclosure or adhesive aids like glue sticks or PEI sheets. PLA-based materials, in contrast, showed minimal warping under default conditions, with strong adhesion to the bed even at lower temperatures. TPU, although flexible, adhered well to the bed but showed minor stringing issues during layer transitions. ASA demonstrated improved performance compared to ABS, with reduced warping and better UV resistance, making it suitable for outdoor applications.

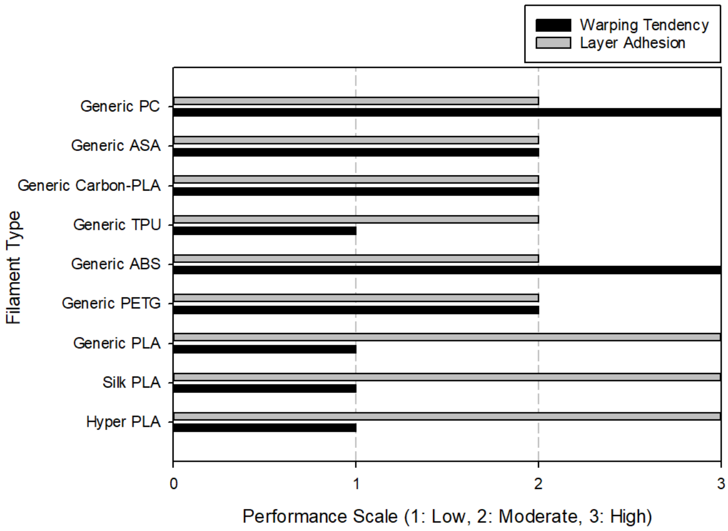

Figure 6. Warping tendency and layer adhesion for each filament type

The heatmap (Figure 7) illustrates the correlation between numerical variables related to 3D printer filament slicing parameters. The color scale ranges from red to blue, representing strong positive to strong negative correlations, respectively. Notable findings include a strong positive correlation (0.92) between nozzle temperature and hotbed temperature, suggesting a consistent relationship in optimal temperature settings across different filaments. Similarly, a robust positive correlation (0.89) between print speed and maximum volumetric speed indicates that higher printing speeds align with greater volumetric capacity. Negative correlations, such as those observed between nozzle temperature and print speed (-0.64), imply that certain parameters inversely affect each other, possibly due to material limitations or technical constraints. These insights can guide optimal parameter selection for efficient and precise 3D printing.

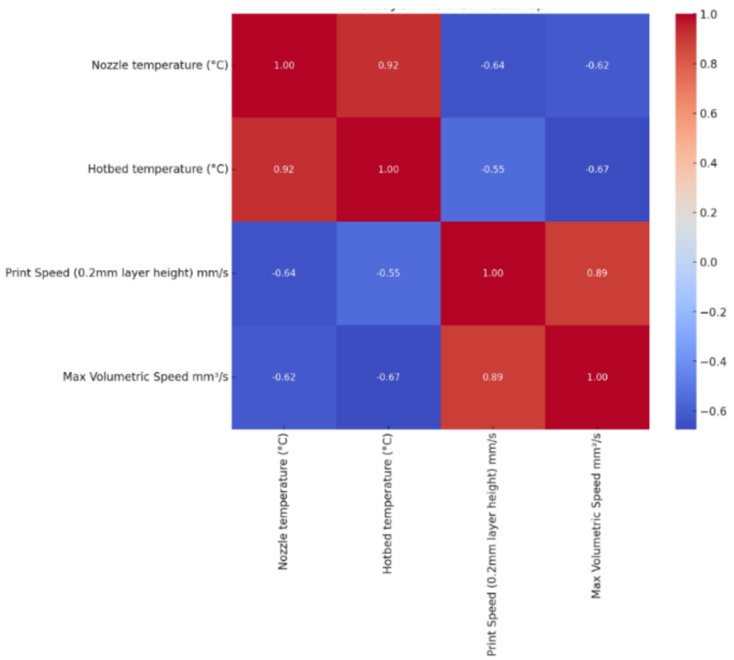

Figure 7. Correlation matrix headmap

3.6. Optimization Factors for Each Filament Type

The graph (Figure 8) highlights the optimization factors for various filament types, comparing temperature sensitivity, cooling sensitivity, and print speed tolerance, offering practical insights for parameter tuning and filament selection. High temperature sensitivity is observed in technical filaments like Generic ABS, ASA, and PC, necessitating precise control over nozzle and bed temperatures to prevent warping or adhesion issues, whereas PLA-based filaments (Hyper PLA, Silk-PLA, and Generic PLA) display low sensitivity, providing a broader temperature tolerance. Cooling sensitivity follows a similar pattern, with ABS, ASA, and PC requiring controlled cooling to avoid delamination, while PLA-based filaments handle high cooling fan settings with ease; PETG and TPU lie in a moderate range, balancing cooling needs with quality. In terms of print speed tolerance, PLA variants excel at high speeds, ideal for rapid prototyping, whereas ABS, ASA, and PC require slower speeds to ensure structural integrity; PETG and PLA Carbon offer moderate speed tolerance for balanced applications. Overall, PLA-based filaments are user-friendly and suitable for general use, technical filaments cater to advanced functional needs, and intermediate options like PETG and TPU provide flexibility for specialized applications, making this analysis a practical guide for optimizing 3D printing processes.

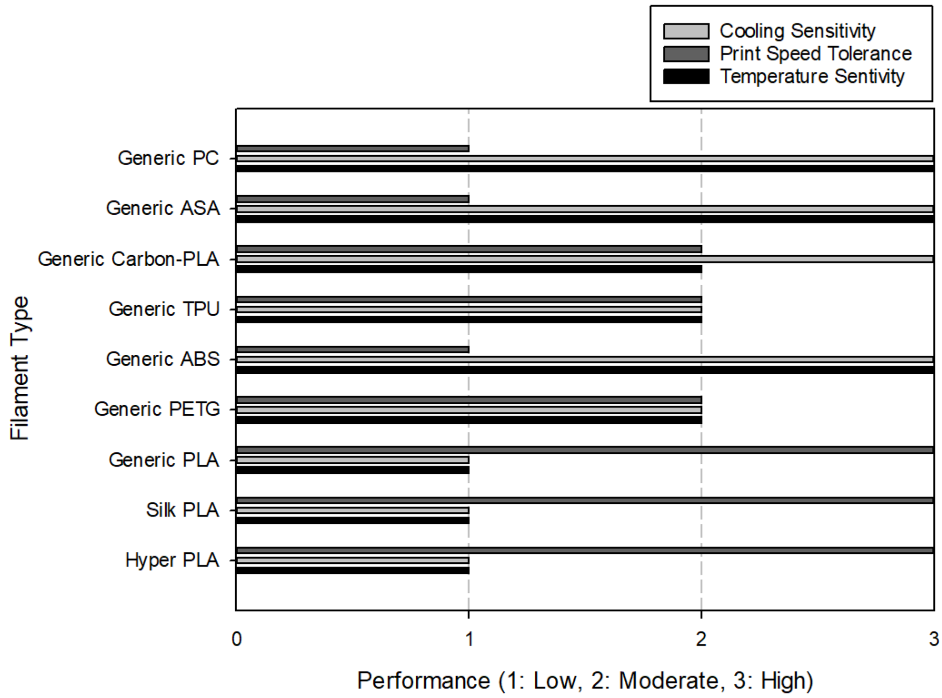

Figure 8. Optimization factors for each filament type

The results (Table 3) underscore the importance of tailoring 3D printing parameters to filament-specific requirements. Standard filaments like PLA are well-suited for high-speed, general-purpose printing, while technical filaments like ABS and PC are better for functional applications requiring strength and heat resistance. Cooling and temperature control were identified as critical factors in achieving optimal print quality and reducing defects such as warping and layer separation.

Table 3. Experimental results by filament type

Filament Type	Ease of Printing	Surface Quality	Dimensional Accuracy	Warping Tendency	Best Applications
Hyper PLA	High	Excellent	High	Low	Rapid Prototyping
Silk-PLA	High	Glossy	High	Low	Aesthetic Prints
Generic PLA	High	Good	High	Low	General Use
Generic PETG	Moderate	Good	Moderate	Moderate	Durable Parts
Generic ABS	Low	Fair	Moderate	High	Mechanical Components
Generic TPU	Moderate	Good	Moderate	Low	Flexible Parts
Generic PLA Carbon	Moderate	Fair	High	Moderate	Stiff Components
Generic ASA	Low	Fair	Moderate	Moderate	Outdoor Applications
Generic PC	Low	Fair	Moderate	High	Heat-Resistant Parts

4. Discussion

The findings of this study reaffirm the central role of filament-specific parameter optimization in achieving high-quality, defect-free prints in FDM 3D printing. As filament types vary significantly in their thermal behavior, mechanical resilience, and processability, uniform settings across all materials inevitably result in suboptimal outcomes. This section discusses the observed behaviors of standard versus technical filaments under high-speed conditions, aligns them with findings from the literature, and outlines practical implications for process refinement.

4.1. Comparison of Standard and Technical Filaments

Standard filaments-particularly Hyper PLA, Silk-PLA, and Generic PLA-exhibited excellent printability under low to moderate thermal settings. Hyper PLA's ability to sustain high-speed printing (up to 300 mm/s) with minimal deformation aligns with prior studies emphasizing PLA’s low thermal expansion and ease of extrusion [1,8]. Silk-PLA, while aesthetically pleasing, showed comparatively lower mechanical robustness due to its altered polymer composition for surface gloss.

Technical filaments such as ABS, ASA, and PC, in contrast, required elevated nozzle and bed temperatures (typically above 250°C and 100°C, respectively) and demonstrated high sensitivity to cooling fluctuations. These observations are consistent with research by Algarni and Ghazali [8] and Hsueh et al. [6], which emphasize the necessity of tight thermal control to mitigate warping and inter-layer delamination in engineering-grade polymers.

4.2. Influence of Print Speed and Volumetric Flow

The print speed capabilities of filaments diverged sharply across material classes. Hyper PLA stood out for its ability to maintain both dimensional fidelity and surface integrity at 300 mm/s and 25 mm^3/s volumetric flow. This makes it a highly efficient choice for rapid prototyping applications. Conversely, carbon-filled PLA, while mechanically robust, displayed increased resistance to flow, necessitating slower speeds to avoid nozzle clogging-a common issue reported in carbon fiber-reinforced filaments [1, 13].

ABS and PC, being more viscous and thermally demanding, were found to perform optimally at slower speeds (~120 mm/s), which corresponds well with empirical studies advocating reduced print velocities to enhance inter-layer fusion and avoid internal stresses [2,9].

4.3. Cooling Strategy and Surface Quality Outcomes

The effect of cooling fan settings on print quality varied notably by material. PLA-based filaments benefited from aggressive cooling (80-100%), resulting in smooth surface finishes and minimal stringing-consistent with conclusions drawn by Bakhtiari et al. [5]. On the other hand, technical filaments required restricted cooling (0-10%) to prevent micro-cracking, suggesting a need for careful thermal gradient control. PETG demonstrated intermediate behavior, confirming its status as a semi-technical material balancing adhesion, durability, and surface finish [10].

4.4. Warping and Bed Adhesion Characteristics

Warping was particularly problematic for ABS and PC under inadequate thermal management, often manifesting as edge lifting and interlayer gaps. These findings echo those of Rodríguez-Reyna et al. [13], who emphasized the necessity of enclosed printing environments for thermal-sensitive polymers. The addition of adhesion aids such as PEI sheets and glue sticks significantly reduced warping tendencies. ASA exhibited improved UV stability and lower warping than ABS, supporting its suitability for outdoor functional parts [6]. PLA-based filaments, by contrast, showed minimal deformation, allowing for reliable open-frame printing.

4.5. Practical Implications for Additive Manufacturing Practitioners

Based on the experimental results, the following key guidelines can be drawn for effective 3D printing process planning:

- Material Selection: PLA variants are preferred for rapid prototyping and visual models due to their ease of use and high-speed compatibility. ABS, PC, and PLA Carbon are better suited for applications requiring enhanced strength, heat resistance, or rigidity.

- Parameter Optimization: Tailoring nozzle and bed temperatures to each filament's thermal profile is essential to avoid layer separation and dimensional inaccuracies. Cooling settings must also be adjusted accordingly to balance solidification and stress accumulation.

- Process Refinement: For challenging materials like ABS and PC, environmental controls (e.g., heated enclosures) and adhesive enhancements improve bed adhesion and minimize defects. Choosing optimal layer height and extrusion width further contributes to performance stability.

4.6. Limitations and Directions for Future Work

Although this study provides a controlled, empirical comparison of standard and technical filaments on a high-speed FDM platform, it is limited to the Creality K1 Max printer configuration and a fixed set of geometries. Broader insights could be gained by:

Including additional material brands and recycled filaments;

Conducting mechanical tests (e.g., tensile strength, impact resistance);

Exploring multi-material printing and advanced slicing strategies (e.g., variable layer height, adaptive cooling);

Measuring surface roughness using quantitative parameters (Ra, Rq, Rz), which would strengthen the objectivity of surface quality assessment—currently conducted visually.

5. Conclusions

This study systematically examined the performance of various standard and technical filament types on a high-speed FDM 3D printer, providing a comparative framework for understanding how print parameters must be adjusted to optimize dimensional accuracy, surface quality, and overall process reliability. The following conclusions can be drawn based on empirical findings:

- Hyper PLA exhibited superior performance at high printing speeds (up to 300 mm/s) and high volumetric flow rates (25 mm^3/s), with minimal warping and stringing, making it well-suited for rapid prototyping. Similarly, Silk-PLA and Generic PLA demonstrated excellent surface finish and dimensional consistency under high cooling conditions, affirming their suitability for general-purpose and aesthetic applications.

- Technical materials such as ABS, ASA, PC, and PLA Carbon required elevated nozzle (250–260°C) and bed temperatures (70–100°C), restricted cooling, and lower print speeds (~120 mm/s) to maintain layer adhesion and reduce warping. These materials are recommended for applications where structural strength, thermal resistance, and durability are prioritized. Notably, ASA outperformed ABS in terms of environmental resistance, reinforcing its suitability for outdoor functional components.

- The cooling fan settings significantly influenced print outcomes. PLA-based filaments benefited from aggressive cooling (80–100%), enhancing surface quality and layer definition. In contrast, materials like ABS and PC required minimal cooling (0–10%) to avoid thermal gradients that could cause cracking or delamination. PETG exhibited a balanced behavior, with moderate fan speeds (around 80%) yielding optimal results.

- Technical filaments were more prone to warping and poor bed adhesion, especially in the absence of adequate thermal regulation or when printed in open-frame setups. The use of adhesive aids (e.g., glue stick, PEI sheet) and enclosed chambers was essential in mitigating these defects, particularly for ABS and PC. PLA variants maintained reliable adhesion with minimal post-processing support.

- PLA-based filaments are ideal for educational, hobbyist, and visual prototyping contexts due to their forgiving nature, print stability, and compatibility with open-frame printers. Conversely, technical filaments demand precise parameter control, enclosed environments, and additional preparation steps, making them more appropriate for industrial and engineering-grade applications.

In conclusion, this study highlights the need for material-specific process tuning in FDM 3D printing, especially when operating under high-speed conditions. By offering a detailed empirical comparison of commercially available filaments beyond catalog specifications, this research provides a valuable reference for practitioners seeking to improve print reliability, part quality, and application-specific performance.

Conflict of Interest

The authors declare that they have no competing interests.

Ethics Committee Approval

Ethics committee approval is not required.

Author Contribution

We declare that all Authors equally contribute.

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