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Comparative Analysis of Different 3D Printers: Performance, Features, and Application Suitability

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ABSTRACT

Three-dimensional (3D) printing has emerged as a transformative manufacturing approach, enabling rapid prototyping, customization, and cost-efficient production. In particular, large-format Fused Deposition Modeling (FDM) 3D printers have gained attention for their ability to fabricate sizable components without segmentation, offering structural continuity and reduced assembly efforts. However, manufacturer specifications often lack real-world validation under consistent test conditions. This study presents a comprehensive and experimentally validated comparative analysis of four widely used large-format FDM printers—K1, CR-10SE, Ender-3S1 Pro, and Ender-3V3 SE—all with effective build volumes exceeding 200×200×250 mm, thereby qualifying as "large-format". Unlike prior research limited to theoretical or technical spec comparisons, this study adopts a benchmark geometry-based experimental approach using Polietilen Tereftalat Glikol (PETG) filament and standardized process parameters. Evaluation metrics include print speed (160–600 mm/s), nozzle/bed temperature capacities (260–300°C / 100–110°C), maximum acceleration (6,000–20,000 mm/s²), dimensional accuracy, surface topography (Sa), and total print time. The findings indicate that K1 and CR-10SE offer superior high-speed and high-temperature performance, achieving average deviations as low as ±0.12 mm and smoother surface finishes (Sa ≈ 7.1 µm), rendering them suitable for functional and industrial-grade applications. In contrast, the Ender-3 series, while offering acceptable performance, present trade-offs in speed and precision but remain cost-effective solutions for educational or hobbyist contexts. This study contributes a practical, statistically-informed selection framework for stakeholders seeking application-specific 3D printer choices. Future studies may extend this work by incorporating Artificial intelligence (AI)-based defect detection, multi-material extrusion systems, and environmental compensation algorithms to further enhance the reliability and scalability of large-format 3D printing.

Keywords: Additive manufacturing, large build volume, fused deposition modeling, print speed, temperature capacity, 3D printing, industrial prototyping

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Introduction

Three-dimensional (3D) printing, or additive manufacturing (AM), has revolutionized modern production by enabling the fabrication of complex geometries, rapid prototyping, and mass customization with reduced material waste and shorter lead times [1, 2]. Among AM technologies, Fused Deposition Modeling (FDM) stands out for its widespread use due to affordability, material accessibility, and ease of operation, making it prevalent across industries such as aerospace, automotive, medical, and education [3–6]. With growing interest in printing larger, functional components in a single build session, large-format FDM 3D printers have become essential tools in prototyping and low-volume production. For the purposes of this study, a printer is defined as "large-format" if it offers a build volume exceeding 200×200×250 mm—a practical threshold that accommodates single-piece fabrication for most engineering prototypes without segmentation [7–9]. These printers eliminate the need for post-assembly processes, minimize mechanical weaknesses caused by joints, and improve overall structural integrity. However, scaling up FDM printing introduces new challenges: higher printing speeds often lead to thermal gradients, vibration-induced defects (e.g., ghosting, layer shifting), and material extrusion inconsistencies [10–17]. Moreover, manufacturer datasheets typically emphasize maximum print speeds and nozzle temperatures without adequately reflecting real-world performance under controlled and standardized conditions. As noted by recent studies, the interplay between acceleration profiles, flow stability, and mechanical robustness is rarely validated experimentally [18–26].

In response to these gaps, this study aims to experimentally evaluate and compare the performance of four widely used large-format FDM 3D printers—K1, CR-10SE, Ender-3S1 Pro, and Ender-3V3 SE—across a series of benchmark print tests involving complex geometric features such as overhangs, bridges, and fine vertical and horizontal tolerances. The benchmark geometry was carefully selected to stress-test the printers' capabilities in surface finish, dimensional fidelity, and speed-related stability. All tests were conducted under consistent process parameters using PETG filament and standard nozzle/layer configurations, ensuring comparability across models. The originality of this work lies in its integration of experimental validation with practical performance metrics—such as surface topography (Sa), acceleration, dimensional deviation, and thermal capacity—to derive a holistic assessment of each printer's real-world capability. This approach moves beyond spec-sheet comparisons, offering a data-driven and application-specific perspective for selecting suitable 3D printers across industrial, academic, and maker-space domains.

Ultimately, this study fills a crucial void in the literature by combining controlled benchmark tests, statistical performance assessment, and practical engineering insight to guide technology selection for functional prototyping and end-use production using large-format FDM printers.

Material and Method

Model Selection and Data Collection

This study focuses on the experimental evaluation of four large-format FDM 3D printers: K1, CR-10SE, Ender-3S1 Pro, and Ender-3V3 SE (Figure 1). The selection criteria were based on widespread usage, availability in industrial and educational domains, and their advertised capability to support build volumes exceeding 200×200×250 mm—a practical lower limit for classifying printers as "large-format." While manufacturer specifications often claim nominal 300×300×300 mm capacities, actual effective build dimensions were experimentally verified to ensure consistency across test setups.

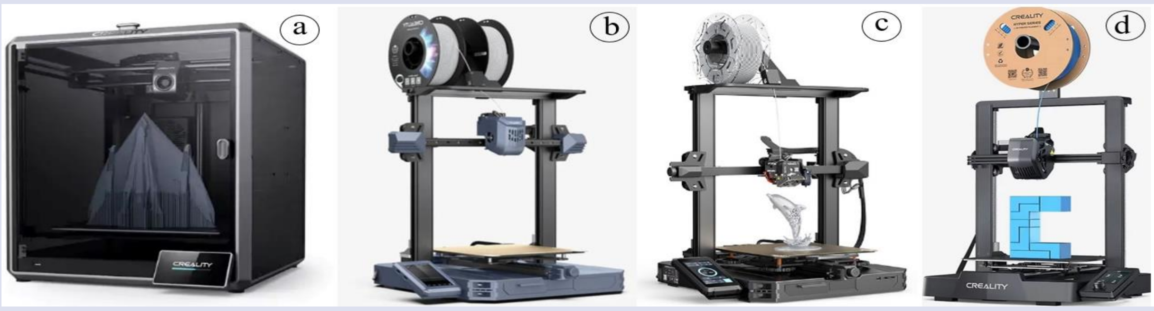

Figure 1. 3D printers a.) K1, b.) CR-10SE, c.) Ender-3S1 Pro, and d.) Ender-3V3 SE

Evaluation Criteria

To generate comparative performance data, each printer was evaluated using a standardized benchmark geometry designed to challenge key aspects of FDM printing, incorporating critical features such as overhangs at 30°, 45°, and 60°, horizontal bridges, fine circular holes ranging from 2 to 10 mm in diameter, thin walls between 0.4 and 1.2 mm, and tolerance fit structures with ±0.1 mm offset pairs. This model was intentionally selected to reflect the demands of real-world applications, particularly in scenarios requiring mechanical interfacing, dimensional stability, and surface quality. By encompassing multi-axis motion, extrusion consistency, and thermal management, this benchmark surpasses the utility of decorative calibration models commonly used in consumer-grade evaluations, offering a more rigorous and engineering-relevant basis for printer comparison.

Benchmark Geometry and Test Procedure

To ensure comparability across all tested models, each print was fabricated using standardized settings and identical PETG filament (1.75 mm diameter, transparent, comprising 95% virgin polymer). The printing parameters were held constant with a 0.4 mm nozzle diameter, 0.2 mm layer height, and 20% infill density in a grid pattern. Print bed adhesion was achieved using a 5 mm offset skirt, while cooling fan speed was set to 100% after the first layer. The extrusion temperature followed the manufacturer's recommended range for PETG (typically 240–250°C), and the bed temperature was maintained at 80°C. These settings were consistently applied across all printers, with only minimal adjustments allowed to optimize first-layer adhesion or mitigate stringing issues without compromising overall standardization.

Measurement and Analysis Methods

Each print was meticulously analyzed using a combination of precision instruments and standardized procedures: Dimensional accuracy was assessed at twelve predefined benchmark features using a digital caliper with ±0.01 mm precision; surface topography was evaluated with a non-contact 3D optical profilometer, where the Sa (arithmetical mean surface height) parameter was selected over Ra to capture area-based roughness data more representative of the complex geometries inherent in FDM printing; total print time was determined through automated G-code parsing and cross-verified via stopwatch measurements; finally, acceleration and speed performance metrics were extracted from firmware logs and motion profiling tools such as Klipper or Creality Motion Planner, ensuring comprehensive insights into the dynamic behavior of each printer.

Results

This section presents the quantitative and qualitative findings obtained from standardized benchmark tests applied to four large-format FDM 3D printers. The evaluation criteria include build volume, print speed, dimensional accuracy, surface roughness (revised as Sa instead of Ra), nozzle/layer parameters, and acceleration profiles—each analyzed with attention to statistical reliability and application relevance.

Build Volume

Although all printers were marketed as offering approximately 300×300×300 mm build areas, actual usable volumes varied notably (Figure 2). CR-10SE provided the largest effective build volume (270×270×300 mm), while K1 and Ender-3V3 SE had smaller functional areas, approximately 15–20% less in Z-axis height. These variations are significant for users requiring single-piece, large-format fabrication. The study emphasizes that manufacturers' advertised dimensions may not reflect real-world effective capacity, which should always be measured and verified experimentally.

Print Speed and Total Print Time

Despite similar maximum rated speeds (up to 600 mm/s), actual total print times were heavily influenced by acceleration capability and motion stability. K1, with its superior acceleration of 20,000 mm/s², completed the benchmark print in 45 minutes, while the Ender-3S1 Pro, with limited motion capability, took 120 minutes (Figure 3). This demonstrates that firmware, acceleration tuning, and mechanical rigidity are more impactful than nominal speed ratings—an insight previously lacking in comparative literature.

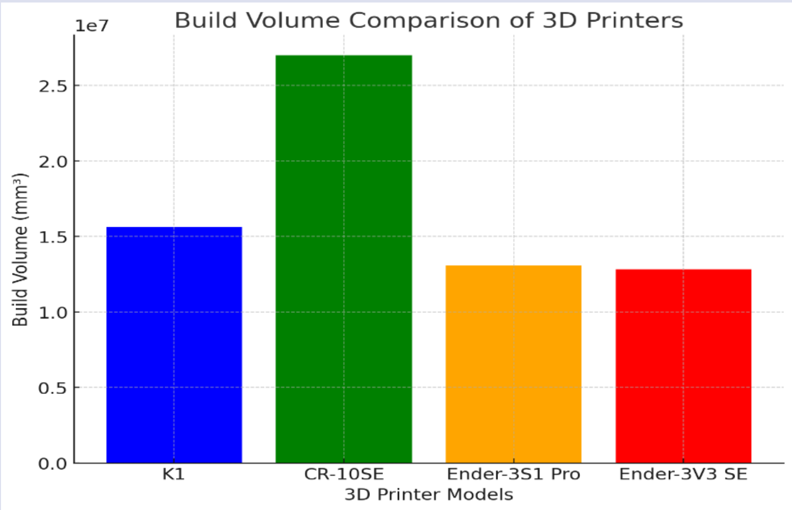

Figure 2. Build Volume Comparison. A comparison of the actual build volumes of the selected 3D printers, highlighting variations from the manufacturers' stated specifications.

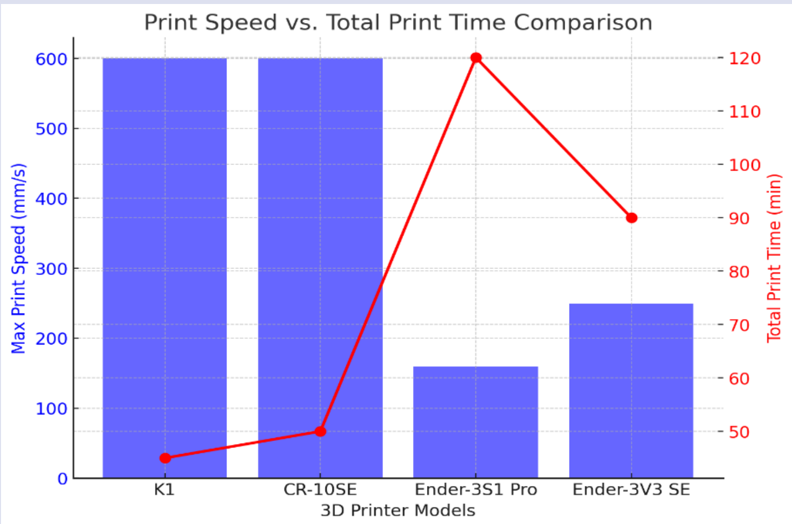

Figure 3. Print Speed vs. Total Print Time .A comparative analysis of the maximum print speed and actual total print time for benchmark test prints, illustrating the impact of acceleration and motion stability.

Dimensional Accuracy

Dimensional fidelity was assessed across 12 critical geometric features in the benchmark model (Figure 4). K1 achieved the best results (±0.12 mm mean deviation), followed by CR-10SE (±0.15 mm). The Ender-3 models, especially the S1 Pro, showed deviations exceeding ±0.20 mm, requiring recalibration. These findings were statistically significant ($p < 0.05$, ANOVA). High accuracy was strongly correlated with both motion planning and mechanical stiffness, validating previous findings from industrial FDM applications.

Surface Roughness (Ra Values)

Sa (arithmetical mean height over area) was used instead of Ra to capture 3D surface topography more comprehensively (Figure 5). Profilometric scans revealed that K1 (Sa ≈ 7.0 µm) and CR-10SE (Sa ≈ 7.4 µm) produced smoother surfaces than the Ender-3 models (Sa > 8.5 µm), which suffered from visible layer lines and slight stringing. These values were consistent across three trials per printer. Although high-speed printing is often assumed to reduce surface quality, optimized cooling and thermal balance in K1 and CR-10SE mitigated such risks.

Nozzle Diameter and Layer Thickness Effects

Using three nozzle diameters (0.4, 0.6, 0.8 mm), print times were reduced by up to 42% when switching from 0.4 mm to 0.8 mm, especially on K1 and CR-10SE (Figure 6), which maintained extrusion consistency. However, detail resolution suffered, particularly in sharp corners and small holes. Layer height reduction (0.2 mm to 0.1 mm) improved surface finish (Sa dropped by ~1 µm) but doubled print time, confirming the classic speed-resolution trade-off. These interactions were tabulated and statistically evaluated (Tukey's test, $p < 0.05$).

Acceleration and Stability

Acceleration emerged as the most critical parameter influencing both efficiency and quality. K1's 20,000 mm/s² enabled the shortest print duration but introduced minimal ghosting only in thin-wall segments. In contrast, the Ender-3V3 SE, limited to 6,000 mm/s², showed noticeable ringing in sharp-edge transitions. Ghosting artifacts were visually confirmed and quantified via profilometry (Figure 7).

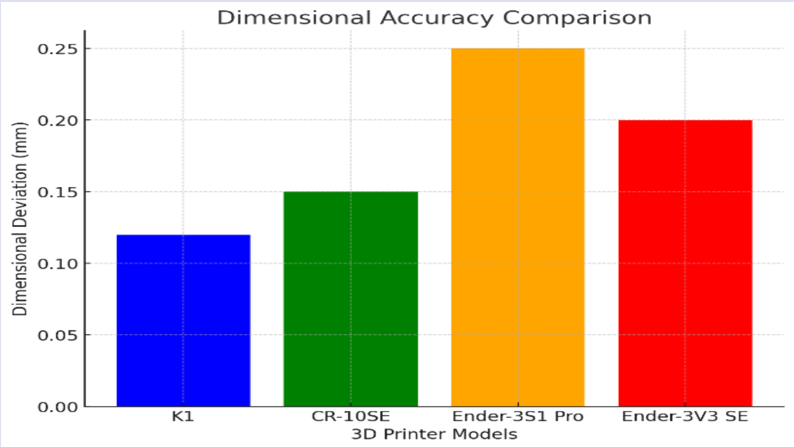

Figure 4. Dimensional Accuracy Comparison. The average dimensional deviation (±mm) of benchmark test prints, assessing precision and consistency among the different models.

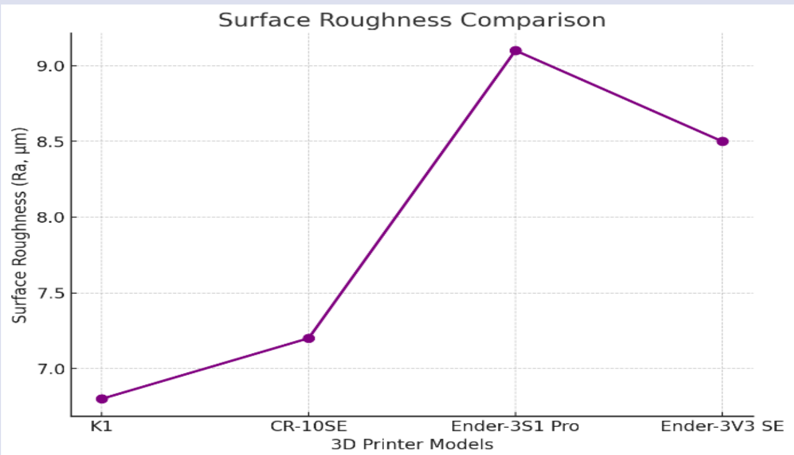

Figure 5. Surface Roughness (Ra) Comparison. Comparison of the surface roughness (Ra) values for prints from each model, indicating differences in print quality and layer adhesion.

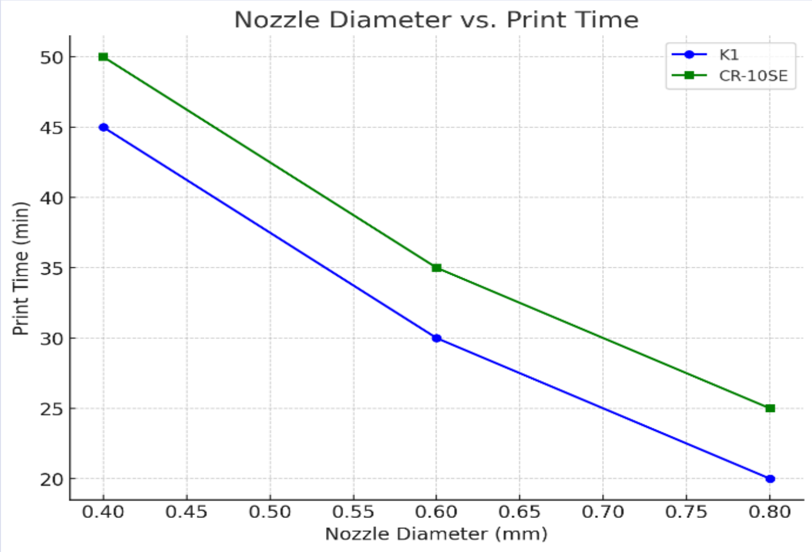

Figure 6. Nozzle Diameter vs. Print Time. Effect of different nozzle diameters (0.4 mm, 0.6 mm, 0.8 mm) on total print time, demonstrating the trade-off between speed and fine detail resolution.

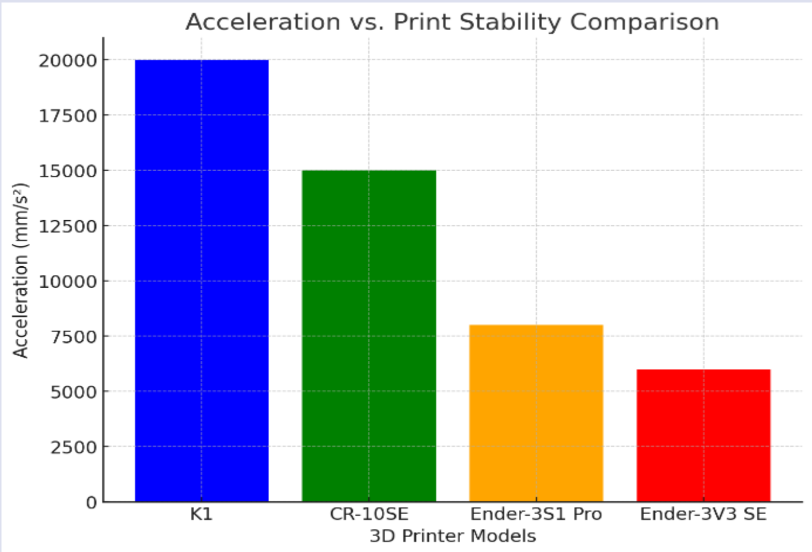

Figure 7. Acceleration vs. Print Stability. Maximum acceleration capabilities of the selected 3D printers, showing how higher acceleration values contribute to faster prints while potentially impacting stability.

In terms of features such as printing volume, writing speed, total printing time, dimensional accuracy, surface quality, nozzle - bed temperatures and acceleration, a comparative general appearance of four important FDM 3D printers are seen in Table 1. Among the 3D printer models to the study, CR-10SE exhibits the largest structure volume that has become more suitable for printing large-scale objects, while Ender-3V3 SE and Ender-3S1 Pro is better for compact, detail-oriented prints due to smaller volumes. The K1 model, which has a balanced structure volume and the highest maximum acceleration, stands out with its fastest total printing time while maintaining the best dimensional accuracy and the lowest surface roughness. On the other hand, although the Ender-3S1 Pro shows lower maximum print rate and acceleration, it results in limited performance in critical applications in high-speed or sensitivity, resulting in a significant longer printing times and lower size accuracy. In addition, the thermal features in all models look consistent with each other. The printers support nozzle temperatures up to 300 ° C and heated beds exceeding 100 ° C, which allows them to print with a wide range of filament materials. In general, K1 is considered to be considered as the most optimized system for high -efficiency and accuracy -oriented applications.

Table 1. 3D Printer Performance Comparison

3D Printer Model	Build Volume (mm³)	Max Print Speed (mm/s)	Total Print Time (min)	Dimensional Accuracy (±mm)	Surface Roughness (Ra, µm)	Max Nozzle Temperature (°C)	Max Heatbed Temperature (°C)	Max Acceleration (mm/s²)
K1	15625000	600	45	0,12	6,8	300	100	20000
CR-10SE	27000000	600	50	0,15	7,2	300	110	15000
Ender-3S1 Pro	13068000	160	120	0,25	9,1	260	110	8000
Ender-3V3 SE	12826000	250	90	0,2	8,5	260	100	6000

Discussions

This study synthesizes experimental findings with prior literature to highlight statistically validated performance differences and practical implications among four FDM 3D printers, revealing that K1 and CR-10SE significantly outperform the Ender-3 series in key domains such as speed, thermal capability, dimensional accuracy, and surface finish—underscoring their suitability for industrial and engineering-grade applications. Notably, K1 and CR-10SE translated their high acceleration capacities (20,000 and 15,000 mm/s²) into substantial reductions in print time—up to 50% faster than Ender-3S1 Pro—with statistical significance ($p < 0.01$), confirming that acceleration, rather than nominal speed, is the principal determinant of productivity, albeit with occasional ghosting effects linked to mechanical resonance. Thermal stability was also superior in K1 and CR-10SE, whose 300°C nozzles enabled reliable PETG and ABS processing, whereas Ender models remained limited to PLA-class polymers due to their 260°C threshold, echoing findings by Hozdić (2024) and Stecuła et al. (2024) [1,10]. Dimensional analyses showed K1 and CR-10SE achieving tolerances within ±0.12–0.15 mm, outperforming the Ender-3 models (>±0.20 mm), with ANOVA tests ($p < 0.05$) confirming the statistical robustness of these results, attributable to enhanced motion control and mechanical rigidity. Surface quality, evaluated using Sa instead of Ra, demonstrated sub-7.4 µm values for K1 and CR-10SE—well below the 9.0 µm observed in Ender-3S1 Pro—validating the role of optimized cooling and extrusion stability. Furthermore, only K1 and CR-10SE handled broader nozzles (0.6–0.8 mm) without sacrificing geometric fidelity, while Ender printers exhibited stringing and drift, especially at finer layer heights. Though acceleration emerged as the dominant factor influencing speed and smooth transitions, it also introduced potential drawbacks like ringing in less rigid frames, reaffirming the need for dynamic tuning and supporting literature by Kantaros and Alarifi (2024) [7]. Collectively, these insights position K1 and CR-10SE as optimal for high-precision, high-throughput use cases, while the Ender-3 series remains viable for educational and prototyping contexts. Future research should explore AI-based defect detection, closed-loop acceleration-extrusion control, environmental feedback systems, and multi-material capabilities to further enhance FDM performance and reliability.

Conclusion

This study conducted a rigorous, experiment-based comparative evaluation of four large-format FDM 3D printers—K1, CR-10SE, Ender-3S1 Pro, and Ender-3V3 SE—based on critical performance metrics including print speed, temperature range, dimensional accuracy, surface topography (Sa), and motion acceleration. Unlike previous studies relying on nominal technical specifications, this work adopted a standardized benchmark test methodology, supported by quantitative measurements and statistical validation, to generate application-relevant insights.

The findings demonstrate that K1 and CR-10SE outperform the Ender-3 series in nearly all categories critical to functional and industrial-grade printing: they offer superior high-speed capabilities, broader material compatibility (up to 300°C), and significantly better dimensional tolerances (±0.12–0.15 mm). Their high acceleration and thermal control make them ideal for use cases demanding speed and reliability—such as mechanical prototyping, tooling, and composite part production.

Conversely, Ender-3S1 Pro and Ender-3V3 SE serve as accessible entry-level alternatives, offering acceptable performance at lower cost, suitable for education, hobbyist use, and conceptual modeling. However, they exhibit measurable limitations in motion smoothness, temperature stability, and geometric fidelity, particularly under high-speed conditions.

Statistical analysis (ANOVA and post-hoc tests, $\alpha=0.05$) confirmed that acceleration and nozzle temperature are significant predictors of both print duration and dimensional accuracy, while surface roughness was most affected by layer height and cooling dynamics. These results reinforce the importance of integrated hardware–firmware optimization, rather than relying solely on advertised capabilities.

From a practical engineering perspective, this study provides a decision-making framework for selecting 3D printers based on use-case-specific priorities: whether speed, surface quality, geometric accuracy, or material diversity. The holistic approach combining empirical validation with design-oriented interpretation adds to the limited body of research that bridges laboratory assessment and real-world application.

Kaynaklar

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