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A COMPARATIVE STUDY OF STEREOLITHOGRAPHY AND FUSED DEPOSITION MODELING: ADVANCEMENTS, CHALLENGES, AND FUTURE DIRECTIONS IN ADDITIVE MANUFACTURING

Additive manufacturing has transformed design and production across many industries. This review compares two prominent 3D printing methods—stereolithography (SLA) and fused deposition modeling (FDM). SLA uses a UV laser to cure liquid resin for high-resolution parts with smooth surfaces, while FDM extrudes thermoplastic filaments, offering cost-effectiveness and material versatility. Both techniques are finding innovative applications in medicine, aerospace, automotive, consumer products, and even architecture. Despite their benefits, challenges such as high material costs, post-processing requirements, surface quality issues, and mechanical anisotropy persist. Ongoing research is focused on sustainable materials, process optimization, and even hybrid systems that combine the strengths of both methods. The continued evolution of these technologies is expected to enhance further personalized production, lightweight structural design, and sustainable manufacturing practices [1, p. 5; 6].

Recent advances in additive manufacturing have enabled designers and engineers to break away from traditional, subtractive methods. SLA and FDM are at the forefront of this transformation. SLA employs a UV laser to selectively cure resin layer by layer, achieving exceptional detail and finish. In contrast, FDM extrudes melted thermoplastics such as PLA or ABS to build parts layer by layer, making it a practical and accessible option for rapid prototyping and low-volume production [1, p. 5; 6]. These complementary techniques offer varied benefits that are increasingly exploited across several fields [2, p. 7; 8].

Overview of SLA and FDM Technologies

Stereolithography (SLA) builds parts by curing layers of liquid photopolymer resin using a UV laser (or LCD), and it is renowned for its ability to produce components with extremely fine details and smooth surfaces—ideal for applications such as dental models, surgical guides, and microfluidic devices. However, the high-quality finishes come at the cost of expensive resins and additional post-processing, including cleaning and secondary curing, as well as concerns about resin waste, with recent trends focusing on improving curing speeds and reducing waste without compromising on quality [7, p. 2; 3].

Fused Deposition Modeling (FDM) constructs objects by extruding thermoplastic filaments (e.g., PLA, ABS, PETG) through a heated nozzle and is known for its low material costs, ease of use, and flexibility—including the use of biodegradable materials—which makes it widely adopted for rapid prototyping, tooling, and even limited production runs. Although the layer-by-layer process can leave visible striations and lead to anisotropic mechanical properties, meaning that strength may vary by direction, research is focused on developing composite filaments and optimizing printing parameters to enhance both surface quality and mechanical properties [4, p. 10; 11].

Both SLA and FDM have significant roles in the medical sector; SLA's precision is critical for fabricating detailed dental restorations, surgical guides, and orthopedic devices, while FDM offers a cost-effective approach to producing patient-specific prosthetics, anatomical models, and tissue scaffolds, with emerging hybrid techniques and biocompatible materials further pushing the boundaries of personalized medicine [3, p. 12; 13]. In the aerospace and automotive sectors, SLA's precision supports the production of complex, lightweight components with tight tolerances, and FDM is extensively used for rapid prototyping and tooling, enabling faster design iterations and the customization of components to reduce lead times and costs, which is crucial for achieving optimized strength-to-weight ratios in high-performance applications [7, p. 2; 3].

FDM also facilitates on-demand production and customization in consumer products, making it ideal for wearable accessories and personalized household items, while large-scale 3D printing using these methods is being explored in architecture to build complex, environmentally friendly structures with minimal waste, driving innovation through a combination of customization, material efficiency, and cost-effectiveness [9, p. 6; 7].

Despite these advances, technical challenges remain for both processes; SLA faces issues such as high material and equipment costs, intensive post-processing steps, and environmental concerns related to resin waste, whereas FDM must contend with visible layer lines, mechanical anisotropy, and the potential for part warping. Addressing these issues through improvements in material science and process control is critical [6, p. 9; 10]. Research is expected to focus on innovations in sustainable resins for SLA and enhanced composite filaments for FDM, the exploration of hybrid systems that combine the precision of SLA with the cost-effectiveness of FDM, and the integration of digital design tools and automation to further optimize printing processes and expand applications in personalized manufacturing and sustainable construction [10, p. 5; 6].

SLA and FDM are reshaping modern manufacturing by providing unique advantages in resolution, cost, and material versatility. While SLA is unmatched in delivering fine details and smooth finishes, FDM remains a go-to method for rapid, cost-effective prototyping. Despite their current challenges—such as high post-processing demands for SLA and anisotropic properties for FDM—ongoing innovations in material science and process engineering are paving the way for broader industrial applications. As these technologies mature, they are set to play an even greater role in personalized medicine, aerospace design, automotive manufacturing, and sustainable consumer products [2, p. 7; 8].

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