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THE EFFECT OF LAYER HEIGHT ON THE LIGHTING CHARACTERISTICS OF THE 3D-PRINTED KALARUPA BEDSIDE LAMP

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Abstract

Additive Manufacturing (AM) has increasingly been adopted in product design due to its flexibility in producing complex geometries and customized products. Among various AM technologies, Fused Deposition Modeling (FDM) is widely used because of its accessibility and ease of operation. While layer height is commonly associated with surface quality and production efficiency, its influence on the visual performance of illuminated products remains relatively unexplored. This study investigates the effect of layer height on the light distribution characteristics of the 3D-printed Kalarupa bedside lamp. A qualitative case study approach was employed using three layer height variations: 0.12 mm, 0.20 mm, and 0.32 mm. The lamp prototypes were fabricated using PLA filament and evaluated through visual observation under identical lighting conditions. The results indicate that lower layer heights produce smoother surfaces and more uniform light distribution, resulting in a brighter and cleaner visual appearance. In contrast, higher layer heights generate more visible layer structures that increase light diffusion and create softer illumination effects. Although the differences in lighting characteristics were relatively subtle, each variation produced a distinct visual atmosphere that contributed to the aesthetic quality of the product. These findings suggest that layer height can function not only as a manufacturing parameter but also as a design parameter capable of influencing the visual characteristics of 3D-printed lighting products.

Keywords: *3D Printing; Layer Height; Light Diffusion*

INTRODUCTION

The rapid advancement of digital fabrication technologies has expanded the possibilities for product development across manufacturing, design, and creative industries. Among these technologies, Additive Manufacturing (AM), commonly referred to as three-dimensional (3D) printing, has gained significant attention due to its ability to produce objects directly from digital models through a layer-by-layer fabrication process. Compared with conventional manufacturing methods that rely on material removal or molding processes, AM offers greater flexibility in producing complex geometries while reducing tooling requirements and material waste (Gibson et al., 2015; Thompson et al., 2016).

Fused Deposition Modeling (FDM) is one of the most accessible and widely adopted AM technologies. The process involves melting thermoplastic filament and depositing it sequentially through a nozzle to create a three-dimensional object. Because the object is formed through successive material layers, the quality and appearance of the final product are highly influenced by printing parameters. Among these parameters, layer height plays a crucial role in determining surface characteristics, production time, and material deposition patterns (Hague et al., 2003).

Previous studies have extensively examined the influence of layer height on dimensional accuracy, surface roughness, mechanical performance, and printing efficiency. In general, smaller layer heights tend to produce smoother surfaces and finer details, whereas larger layer heights reduce printing time but generate more visible layer structures (Boschetto & Bottini, 2014; Gibson et al., 2021). As a result, layer height is commonly treated as a manufacturing parameter used to optimize product quality and productivity.

Beyond its technical implications, layer height also influences the visual properties of printed objects. The layered structure created during the FDM process affects how light interacts with the surface and passes through printed materials. This phenomenon becomes particularly relevant in decorative lighting products, where the visual experience is shaped not only by the form of the object but also by the way light is diffused, transmitted, and distributed. Despite the growing application of 3D printing in lighting design, research investigating the relationship between layer height and lighting performance remains limited. Existing studies largely focus on surface quality and structural properties, while the optical effects generated by layer variations have received comparatively less attention.

The emergence of Design for Additive Manufacturing (DfAM) has encouraged designers to consider manufacturing parameters as integral components of the design process rather than merely technical constraints. Within this perspective, layer height can be viewed as a controllable design variable capable of influencing the visual character of illuminated products. By adjusting layer height, designers may create different lighting atmospheres and aesthetic effects without modifying material composition or product geometry. Such an approach provides opportunities to integrate manufacturing efficiency with experiential design considerations.

This study focuses on the Kalarupa bedside lamp, a decorative lighting product developed using FDM technology. The product was selected because its lampshade geometry allows clear observation of light diffusion and distribution patterns generated by different printing parameters. Three layer height variations, namely 0.12 mm, 0.20 mm, and 0.32 mm, were applied to investigate their influence on the visual characteristics of emitted light. Through visual observation and user evaluation, the study examines how variations in layer height affect perceived light distribution and aesthetic qualities.

The objective of this research is to evaluate layer height as a design parameter that contributes not only to manufacturing outcomes but also to the visual performance of 3D-printed lighting products. The findings are expected to provide insights for designers and manufacturers seeking to optimize both production efficiency and lighting aesthetics in additive manufacturing applications.

RESEARCH METHOD

This study adopts a qualitative case study approach to investigate the influence of layer height on the light distribution characteristics of a 3D-printed bedside lamp. The approach is considered appropriate for examining how variations in printing parameters affect the visual qualities of illuminated products and how these differences are perceived by users. The study focuses on the Kalarupa bedside lamp as a case study, aiming to explore the relationship between layer height, light diffusion patterns, and the resulting aesthetic experience. Through visual observation and user evaluation, the research seeks to understand how different layer height settings contribute to distinct lighting characteristics and influence users' perceptions of visual comfort and aesthetic quality.

Research Objects and Materials

The research object in this study is the Kalarupa bedside lamp, a decorative lighting product designed and manufactured using Fused Deposition Modeling (FDM) technology. The lamp was selected because its lampshade geometry enables the observation of light diffusion and distribution patterns generated by different printing parameters. As light passes through the 3D-printed structure, variations in layer height can influence the visual characteristics of the emitted illumination, making the product suitable for investigating the relationship between manufacturing parameters and lighting performance.

The prototypes were fabricated using a Bambu Lab A1 Mini FDM 3D printer. Polylactic Acid (PLA) filament was selected as the printing material due to its widespread use in additive manufacturing and its suitability for decorative lighting applications. All printing parameters were prepared and controlled using Bambu Studio slicing software. To ensure consistency throughout the experiment, parameters other than layer height were kept constant, allowing the study to isolate and evaluate the specific influence of layer height on light distribution characteristics.

Experimental Procedure and Technical Variables

This study uses variations in layer height to examine differences in visual appearance. Three variations were applied:

Table 1. Layer Height and Visual Classification of Samples

Sample Code	Visual Classification	Layer Height
Sample A	Smooth	0.12 mm
Sample B	Moderate	0.20 mm
Sample C	Rough	0.32 mm

Thompson et al. (2016) explain that parameters such as layer height not only affect technical performance but also influence the visual quality and design of a product. The selection of layer height variations in this study is based on the optimal FDM printing range, which is generally between 25% and 80% of a 0.4 mm nozzle diameter. These three values represent commonly used categories of print quality.

To ensure that the observed differences in results are solely caused by variations in layer height, all other printing parameters were kept constant using the following configuration:

Table 2. Printing Parameters and Configuration

Parameter	Configuration
Nozzle Diameter	0.4 mm
Nozzle Temperature	200–210°C
Bed Temperature	60°C
Print Speed	200 mm/s
Wall Speed	300 mm/s
Sparse Infill Density	1%
Cooling Fan	100% (after the first layer)
Flow Rate	100%
Slicing Mode	Spiral (Vase Mode / Spiralize Outer Contour)

These settings were selected as they represent a stable and commonly used configuration for PLA material, ensuring consistent and comparable print results. All other parameters were controlled to ensure that any observed differences in visual appearance were solely influenced by variations in layer height.

RESULT AND DISCUSSION

The The visual observation results of the Kalarupa bedside lamp printed with different layer height settings are presented in Table 3 Variations in layer height produced noticeable differences in both surface appearance and lighting characteristics when the lamp was illuminated.

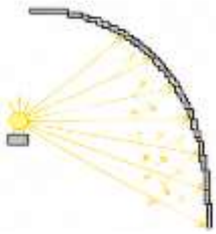
Table 3. Lighting Character Analysis

Layer Height	Picture	Surface Character to Light	Lighting Characters
00,12 mm		The smoother surface makes the seam lines almost invisible so that the light can be seen more clearly on the surface of the lampshade.	Surface appears brighter and cleaner, Light distribution is even, Layer lines hardly affect light output
00,20 mm		Layer lines are starting to appear on the surface, but the texture is still quite smooth.	The light display is still similar to the 0.12 mm variation.
00,32 mm		The layer line texture looks the most dominant and forms a visually rougher surface.	The light appears softer and slightly dimmer visually. The light spread is more scattered by the layer line texture. The layer line texture is most dominant

Source: Author's documentation

To further examine the influence of layer height on lighting performance, schematic illustrations of the light distribution patterns for each specimen are presented in the following table. The illustrations serve as a visual analytical tool to identify the relationship between layer-induced surface textures and the resulting light diffusion characteristics. Furthermore, they support the evaluation of the visual atmosphere and aesthetic qualities produced by each layer height variation, enabling a deeper understanding of how manufacturing parameters contribute to the experiential qualities of 3D-printed lighting products.

Table 4. Lighting Character Analysis

Layer Height	Picture	Surface Character to Light	The Aesthetic Effect of Lighting
0,12 mm		The light spreads evenly and comes out more clearly	The light looks clean clearly because the surface is
0,20 mm		Light spreads evenly with a slight scattering by the texture of the coating	Starts to show a layered texture that gives a slight softness to the light
0,32 mm		The light spreads inside the hood more, as it is blocked by the rough texture of the coating.	The texture of the thicker layers creates a slightly softer light impression.

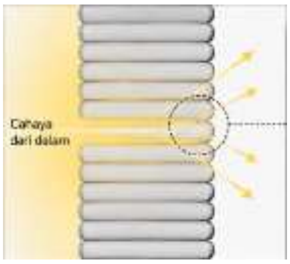
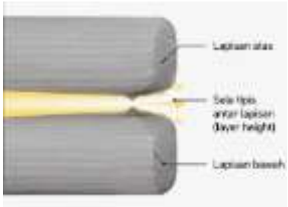
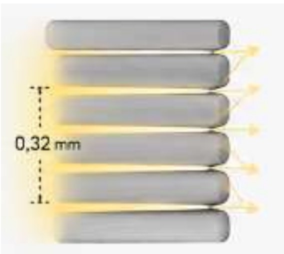
Source: Author's documentation

The aesthetic differences in lighting among the various layer height settings were not highly pronounced; however, each variation exhibited distinct tendencies in visual atmosphere through the relationship between surface texture and the resulting light characteristics. In this context, the lighting output of the 3D-printed lampshade was influenced by the layered structure generated by different layer height settings. Variations in the spacing between deposited layers produced different surface texture characteristics, which in turn affected the way light was transmitted and diffused through the lampshade material.

This study examined the relationship between layer structure, light diffusion behavior, and the visual characteristics of the emitted light across different layer height variations. Table 5 illustrates how changes in layer height influenced the lighting characteristics of the Kalarupa lampshade, highlighting the interaction between manufacturing parameters and the visual performance of the illuminated product.

Table 5. Lighting Character Analysis

No	Picture	Remarks

1		The light spreads in several directions after being held in the hood. Which causes it to be scattered evenly throughout the interior
2		The light that comes out through the thin gap between the layers (*layer height*) is more visible than the light that passes through the filament layer.
3		*The layer height* of 0.12 mm results in a large array of layers so that light comes out more directly through the gaps between layers. The light appears more focused and the spread is more controlled because the distance between layers is smaller.
4		*A layer height* of 0.20 mm results in a thicker layer of filament so that more light is retained and less comes out through the gaps.
5		*The layer height* of 0.32 mm results in a very thick layer of filament so that most of the light is trapped inside and only a small amount of light escapes through the interlayers. As a result, the light that comes out appears dimmer, less even, and the spread is more limited than *the smaller* layer height.

Source: Author's documentation

Analysis/Discussion

The results indicate that variations in layer height influence the visual characteristics of light emitted through the Kalarupa lampshade. Although the differences in illumination were not highly pronounced, each layer height produced distinct interactions between the layered structure and transmitted light. The 0.12 mm specimen generated a brighter and more uniform lighting effect due to its smoother surface and less visible layer lines, allowing light to pass through the lampshade with minimal visual interference. As the layer height increased to 0.20 mm and 0.32 mm, the deposited filament layers became more prominent, creating stronger surface textures that affected light diffusion. The visual observations suggest that thicker layer structures promote greater light diffusion, resulting in softer illumination effects, resulting in softer illumination and slightly reduced visual brightness, particularly in the 0.32 mm specimen. These findings suggest that the layered morphology produced during the FDM process plays a role in shaping the optical behavior of the lampshade by influencing how light is transmitted and dispersed through the material. From a design perspective, this demonstrates that layer height should not be regarded solely as a manufacturing parameter related to print quality and production efficiency, but also as an optical-design parameter capable of controlling the visual atmosphere of 3D-printed lighting products. Lower layer heights are more suitable for achieving clean and uniform illumination, whereas higher layer heights can be intentionally utilized to create distinctive lighting textures and enhance the aesthetic character of decorative lampshades. Consequently, layer height offers designers a practical means of balancing manufacturing efficiency and visual performance without modifying the product geometry or material composition.

CONCLUSION

This study evaluated the influence of layer height on the light distribution characteristics of the 3D-printed Kalarupa bedside lamp manufactured using Fused Deposition Modeling (FDM). The results show that variations in layer height affect both the surface appearance of the lampshade and the visual characteristics of the emitted light. A layer height of 0.12 mm produced the smoothest surface and the most uniform light distribution, resulting in a brighter and cleaner visual appearance. In contrast, increasing the layer height to 0.20 mm and 0.32 mm enhanced the visibility of layer structures, which contributed to greater light scattering and softer illumination effects. Although the differences in lighting performance were relatively subtle, the variations consistently influenced the visual atmosphere created by the lampshade.

The findings demonstrate that layer height functions not only as a manufacturing parameter associated with print quality and production efficiency but also as a design parameter that affects the optical and aesthetic performance of 3D-printed lighting products. Lower layer heights are suitable for achieving uniform illumination, while higher layer heights can be utilized to create distinctive lighting textures and decorative visual effects. Therefore, designers can strategically adjust layer height to balance production efficiency and desired lighting characteristics without modifying the geometry or material of the product. This study contributes to the understanding of how additive manufacturing parameters can be integrated into the design process to enhance the experiential qualities of 3D-printed lighting products.

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