Design and Development of a Post-Processing Automation System to Improve Quality Consistency in Additive Manufacturing

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***Abstract*—The field of 3D printing has experienced remarkable growth in recent years, leading to its widespread adoption across diverse industrial sectors. Among the various additive manufacturing technologies, Digital Light Processing (DLP) stands out for its high resolution, fast printing speed, and material versatility. Despite these advantages, the use of photopolymer resin in DLP often results in unwanted surface residues on printed parts, causing tackiness and a loss of structural integrity. To mitigate these drawbacks, post-processing steps such as washing, drying, and curing are essential. However, these procedures are typically carried out manually, which introduces variability and makes it difficult to maintain consistent product quality. Ensuring uniformity requires the minimization of human intervention through process automation, along with precise control tailored to the specific characteristics of each printed component. This study presents an automated post-processing system capable of dynamically adjusting washing parameters according to the type of printed object. By integrating intelligent control into the washing stage, the proposed system improves the consistency and overall reliability of DLP-based 3D printed products.**

Keywords*— *Post-Processing, Automation Operation System, Smart Manufacturing, Additive Manufacturing

I. Introduction

3D printing technology has undergone rapid advancements in recent years and is increasingly being recognized as a core manufacturing technology across various industrial sectors. Depending on the application area, a range of printing methods has been adopted. These include Fused Deposition Modeling (FDM)[1], which melts and deposits thermoplastic materials layer by layer; Stereolithography (SLA) and Digital Light Processing (DLP)[2], which cure photopolymer resins using light exposure; and Direct Metal Laser Sintering (DMLS)[3], which sinters metal powders to form solid parts.

Among these techniques, DLP-based 3D printing has gained particular traction due to its high resolution, fast printing speed, and compatibility with a variety of materials. As a result, it has seen widespread use in industries such as dentistry and medical devices, jewelry manufacturing, character and figure production in the content sector, and prototype development for product design verification across multiple fields [4]. Despite its advantages, the DLP-based 3D printing method also presents certain limitations. Since DLP printers utilize photopolymer resins, printed objects immediately after fabrication tend to retain uncured residual material on their surfaces due to the inherent characteristics of the resin. As a result, the printed surfaces often exhibit stickiness, lack full curing, and show inconsistent surface roughness, which leads to softness and insufficient mechanical strength in the final product.[5]

To overcome these issues, post-processing procedures—including washing, drying, and curing—are essential components of the DLP printing workflow [6]. However, these post-processing steps are typically performed manually and rely heavily on the operator's experience. Consequently, it becomes challenging to ensure consistent product quality, and any defects in surface finish or mechanical integrity may necessitate reprinting. This not only results in material waste and increased production costs but also extends the overall fabrication time, leading to reduced efficiency and potential economic loss [7]. To ensure the consistency of printed part quality, it is essential to control various process parameters, including washing time and intensity, drying time and temperature, as well as curing time and light intensity.

In this paper, we present a fully automated post-processing system designed to dynamically adjust these parameters according to the characteristics of the printed objects—such as their shape and size. By enabling precise parameter control for each post-processing stage, the proposed system aims to achieve uniform quality and improved reliability in DLP-based 3D printed.

II. Post-Processing Automation System

The automated post-processing system for optimizing the quality of printed products is structured as shown in Figure 1. The system comprises several key components: a DLP-type 3D printer capable of fabricating various types of products; a washing unit that removes uncured resin remaining on the surface of printed parts to eliminate stickiness and glossiness; a drying unit that ensures complete removal of residual cleaning solvents or moisture after washing; and a curing unit that performs final polymerization to fully harden the photopolymer-based printed objects.

In addition, a transfer mechanism is employed to move printed parts sequentially through each post-processing stage. The entire workflow is coordinated by post-processing control software, which governs the operation of the 3D printer and post-processing units in the correct sequence.

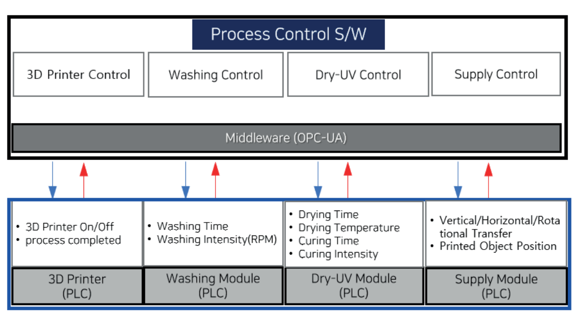

Fig. 1. Post-Processing Automation System Architecture

In addition, as summarized in **Table 1**, key controllable parameters were identified for each post-processing device to support quality uniformity of printed products. Based on these parameters, a system was developed to optimize the quality of post-processed outputs through precise control.

TABLE I. CONTROLLABLE PARAMETERS OF POST-PROCESSING

Equipment	Controllable Parameters
Washing Module	- Washing Time - Washing Intensity (RPM)
Drying Module	- Drying Time - Drying Temperature
Curing Module	- Curing Time - Curing Intensity

Fig. 2 presents the complete layout of the automated post-processing system designed for 3D printed products. The setup integrates a 3D printer along with dedicated washing, drying, and curing units. Each of these components is controlled in sequence by a centralized post-processing control software, ensuring coordinated system operation.

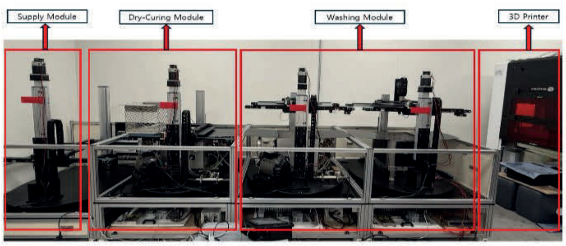

Fig. 2. Post-Processing Automation System

III. EXPERIMENT USING WASHING EQUIPMENT

In this paper, we conducted a series of experiments using the washing equipment to evaluate the impact of washing parameters on the quality uniformity of printed products. The washing process employed isopropyl alcohol (IPA) as the cleaning agent. Various printed parts were subjected to different washing durations and fluid agitation intensities (RPM) within the washing unit to investigate optimal post-processing conditions. The objective was to determine whether defects or inconsistencies would arise under varying parameter settings and to identify conditions that support consistent product quality.

Figure 3 shows the printed parts after the washing process, following the experimental procedure described above. The test specimens were categorized by thickness, ranging from 0.1 mm to 1.0 mm in 0.1 mm increments. The washing time was fixed at 10 minutes, and the fluid agitation intensity within the washing unit was set to 0, 5000, and 10000 RPM for comparison across different conditions.

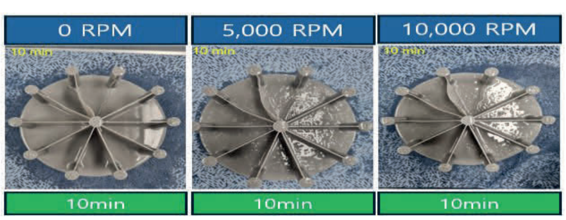

Fig. 3. Washed Results

Table 2 presents the results obtained from the above experiment, illustrating how variations in washing time and fluid agitation intensity affected the quality of the printed products. Samples exhibiting defects are marked with an "X", while those without any visible defects are marked with an "O".

TABLE II. WASHING EXPERIMENT RESULTS

Product Thickness (mm)	Washing Time (min)	Washing Intensity		
		0	5000	10000
0.1	10	X	X	X
0.2	10	X	X	X
0.3	10	X	X	X
0.4	10	O	O	X
0.5	10	O	O	O
0.6	10	O	O	O
0.7	10	O	O	O
0.8	10	O	O	O
0.9	10	O	O	O
1.0	10	O	O	O

IV. CONCUSION

In this paper, an automated system was developed to ensure the quality uniformity of printed products by controlling the process parameters of the washing equipment used in the post-processing stage of DLP-based 3D printing. Future work will focus on extending the system to include parameter control for drying and curing equipment, with the goal of optimizing product quality based on the characteristics of each printed object. This advancement is expected to contribute to reducing production costs and processing time in additive manufacturing.

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