Fundamental Configuration and Principles of a Stereolithography System Incorporating Magnetic Levitation Technique

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Abstract

Stereolithography apparatus (SLA), a standard 3D printing technology, has problems such as the postprocessing for burrs and the use of extra material for support legs. To solve these problems, we propose a novel SLA system that fabricates desired objects by photocuring and layering processes using a magnetically levitated special fluid. The key requirement for the fluid is its good responsiveness to magnetic fields while being curable under specific wavelengths of light. To fulfill the requirement, we developed and evaluated a new magnetic photocurable resin (mPCR) fluid with both magnetic responsiveness and photocurability. Additionally, we designed and implemented a prototype SLA system that incorporates the magnetic levitation technique.

1 Introduction

One of the additive manufacturing (AM) technologies is the stereolithography apparatus (SLA), which utilizes a photocurable resin (PCR) liquid. Figure 1 illustrates the basic principle of SLA. A container (reservoir) filled with the photocurable resin liquid and a Z-stage are installed. A mirror is used to scan a laser beam in the *x* and *y* directions, facilitating the curing of the resin liquid on the surface of the stage. Upon completion of the first layer, the Z-stage raises in the *z* direction to fabricate the subsequent layer. This layer-by-layer process enables the production of a modeled object [1]. Depending on the modeled object, not only the main body but also its support legs are printed at the same time. As a result, material wastage and extra printing time occur. Additionally, as depicted in Fig. 1, burrs can remain at specific locations, requiring time and effort to remove them.

On the other hand, we have researched applying magnetic levitation to magnetic fluids, specifically the behavior of magnetically levitated droplets and supported liquid cones [2]. On the basis of the acquired findings, we propose a novel stereolithography system using magnetic levitation technique. This system uses a magnetic photocurable resin fluid (mPCR fluid) as the modeling material. Throughout the modeling process, the mPCR fluid is continuously supplied from the reservoir, magnetically supported, and photocured with pinpoint accuracy. In this paper, we provide the specifications of the mPCR fluid, which serves as the primary material for 3D stereolithography, along with a description of the configuration of the prototype system, the 3D printing procedure, and the current status of printing experiments.

2 Prepared Magnetic Photocurable Resin (mPCR) Fluid and Prototype Overview

The mPCR fluid was prepared through a series of trial-and-error experiments. The prepared mPCR fluid was created by mixing 10 wt% triiron tetroxide (Fe_3O_4) powder, with an average particle size of approximately 1.0 μm, into an acrylate prepolymer resin solution with a viscosity of approximately 1900 mPa.s at 28°C. This mPCR fluid incorporates three essential elements: photocuring in response to a specific wavelength (405 nm), high sensitivity to magnetic fields, and uniform dispersion of the magnetic microparticles in the solution.

Figure 2 shows a prototype of the SLA system that integrates standard active magnetic levitation functionalities. The UV laser light passes through a central through-hole in the control electromagnet, which allows reliable irradiation of the apex of the mPCR fluid cone that is magnetically supported in the reservoir on the Z-stage.

3 Levitation and Photocuring Tests

Figure 3 illustrates the proposed printing procedure. Initially, the electromagnet generates an attractive force, causing the mPCR fluid to be drawn up from the reservoir and accumulate at the tip of the support jig (Fig. 3a). Subsequently, the upper section of the fluid cone, which is precisely controlled in position, is exposed to a laser beam for photocuring, thereby solidifying it onto the jig (Fig. 3b). As the reservoir is vertically displaced, the apex of the mPCR fluid emerges above the previously cured section due to the effect of precise positioning control (Fig. 3c). The next apex is then subjected to photocuring, completing the formation of the second layer (Fig. 3d). By repeating this process while also moving in the *x* and *y* directions, additive manufacturing will be achieved. Successful preliminary experiments have been conducted for stages 3a, 3b, and 3d, indicating a high potential for the realization of 3D stereolithography. Further experimental results will be presented in detail at the conference.

Acknowledgements

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References

[1] US Patent, No. 4575330, Apparatus for production of three-dimensional objects by stereo-lithography, 1986.
[2] T. Ohji et al., Magnetic Levitation of a Ferrofluid Droplet in Mid-Air, *AIP Advances*,10, Issue 1, 015037, 2020.

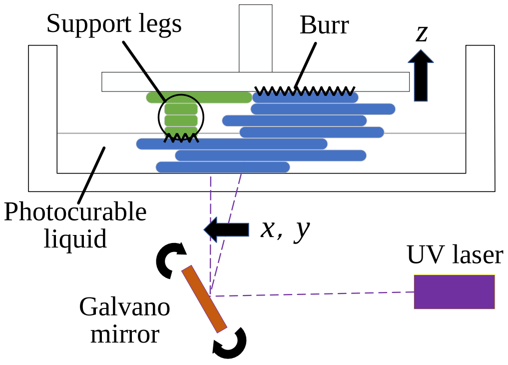

Figure 1: Basic principle of SLA.

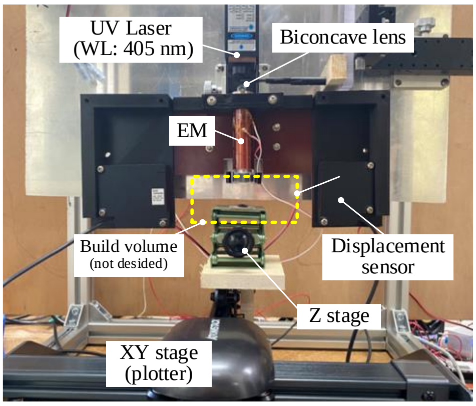

Figure 2: Prototype overview.

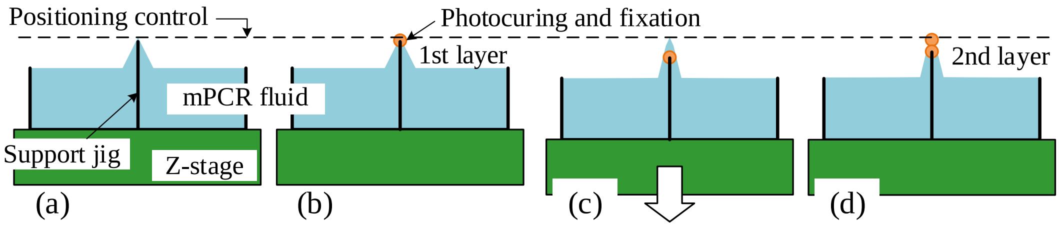

Figure 3: Printing procedure; (a) fluid cone formation, (b) photocuring and fixation, (c) lowering Z-stage, and (d) layer curing.