PROPOSAL OF A 3-D STEREOLITHOGRAPHY SYSTEM INCORPORATING MAGNETIC LEVITATION TECHNIQUE

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Abstract. This paper proposes a novel stereolithography (SLA) system for forming designed models by photocuring and stacking magnetically levitated special fluid. A drawback of stereolithography, one of the 3-dimensional printing techniques, is the post-processing of burrs and wasted support materials. The proposed method repeats photocuring while magnetically levitating magnetic photocurable resin (mPCR) fluid. Therefore, burrs and support materials are unnecessary, saving both time and money. The system has two main structural requirements; one is to generate an upward attractive force so that the mPCR fluid and its formed object do not droop under gravity, and the other is to irradiate the laser beam while reliably tracking the apex of the mPCR fluid cone that is magnetically supported and manipulated. This paper briefly introduces the prototype machine, designed to align a laser beam path, the controlled electromagnet with a through-hole, and the apex of magnetically levitated mPCR fluid.

1. Introduction

One of the additive manufacturing (AM) technologies is the stereolithography apparatus (SLA) [1], which uses photocurable resin liquid. SLA is a higher-resolution fabrication method than fused deposition modeling (FDM) with filament materials. Figure 1 shows the basic principle of SLA. A Z stage exists in a container (reservoir) filled with photocurable resin liquid. A laser beam is scanned in the *x*- and *y*- directions using Galvano mirrors. The resin liquid on the Z stage surface is cured only where the beam is irradiated. In the stacking process, support legs other than the modeled object are also layered, and the portions are removed after completion. The support legs cause extra material, printing time, removal process, and deburring.

We have developed a magnetic levitation (maglev) device that is easy to use for levitating a magnetic fluid droplet at room temperature and in the atmosphere [2]. Figure 2 is a photo of a magnetic fluid cone with its apex position controlled. When the controlled electromagnet installed above moves in the *x*- and *y*- directions, it has been confirmed that the apex of the fluid cone follows while maintaining the positioning control state. Utilizing this know-how, we propose a new stereolithography incorporating a maglev technique that uses magnetic photocurable resin (mPCR) fluid and has no support leg and burr to the limit.

2. Concept

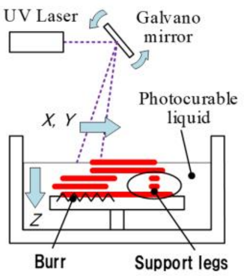

Fig. 1

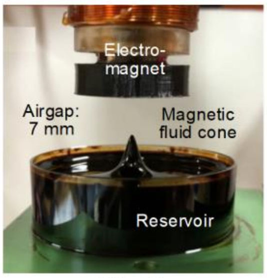

Fig. 2

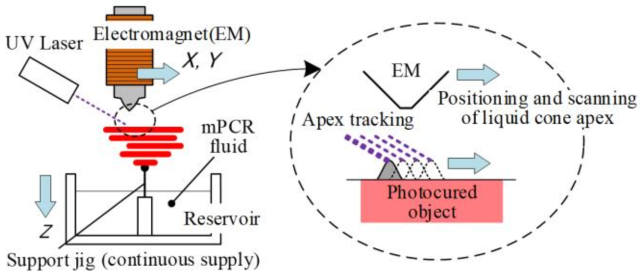

Fig. 3

Fig. 1. Basic principle of SLA. Fig. 2. Photo of a positioning-controlled magnetic fluid cone. Fig. 3. Conceptual diagram of a new SLA system with maglev functions

Figure 3 is a conceptual diagram of the proposed SLA system. The system consists of an electromagnet, a displacement sensor, control equipment, a laser light source, an mPCR fluid reservoir, and a support jig. The mPCR fluid belongs to suspensions. It consists of 10 wt% triiron tetroxide (Fe_3O_4) powder (average particle size is around 1.0 um) dispersed uniformly in an acrylate prepolymer resin solution. It responds well to magnetic fields and UV light with a wavelength of 405 nm. First, a controlled attractive force from the electromagnet pulls up the mPCR fluid from the reservoir to the tip of the support jig. Next, the laser beam photocures the top of magnetically levitated mPCR fluid. Furthermore, additive manufacturing would be possible by moving the electromagnet in the *x*- and *y*- directions and the reservoir in the *z*-direction, simultaneously scanning the laser beam to track the apex of the fluid cone.

3. Configuration of a prototype machine

Figure 4 shows a prototype machine based on the concept of Fig. 3. The main requirements for the proposed SLA system are as follows:

- The attractive force from the electromagnet can pull up mPCR fluid from the reservoir to a desired position along the surface of the support jig;
- The pulled-up mPCR fluid can be fixed with photocuring at the top of the support jig;
- The attractive force can move the mPCR fluid cone in the *x*-, *y*-, and *z*- directions while controlling the apex position of the cone;
- The laser beam can always track the apex of the cone; and
- Vibrations from moving parts should not affect forming quality.

When the electromagnet, suspended from a linear stage fixed to the aluminum frame, was moved left and right, housing vibration occurred due to the movement, and the laser beam could not track the apex of the fluid cone. To solve these issues of vibration and misalignment, in the prototype machine shown in Fig. 4, a laser beam path, the controlled electromagnet with a through-hole on the central axis, and the apex of a fluid cone are aligned center vertically, and the reservoir is placed on the XYZ stage. As a result, the tip of the support jig set in the reservoir moves three-dimensionally, thereby advancing the stereolithography process.

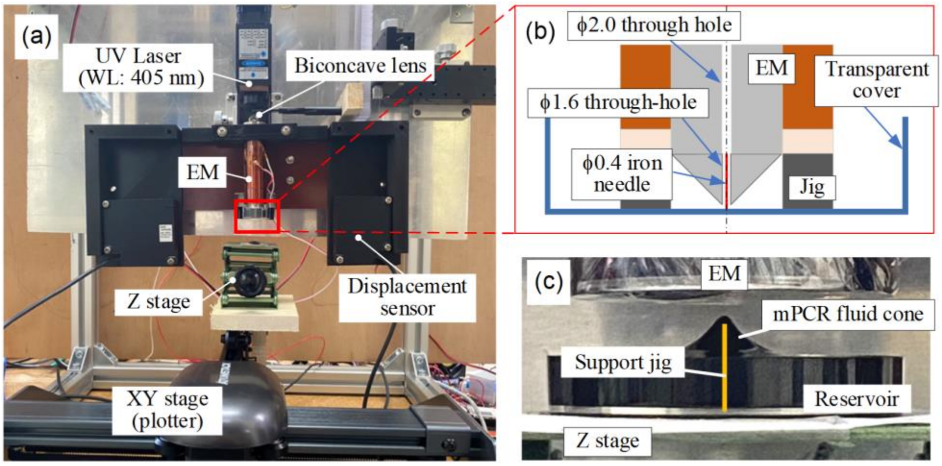

Fig. 4 A prototype machine of SLA with maglev functions: (a) overall structure; (b) cross section of the electromagnet tip; and (c) positioning control test for the apex of mPCR fluid cone

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Conclusions:

This research has just started to develop the 3-dimensional stereolithography system with maglev functions. Pulling up and positioning control of mPCR fluid (see Fig. 4c) and photocuring at the top of the support jig have been achieved.

References:

[1] US Patent, No. 4575330, Apparatus for production of three-dimensional objects by stereo-lithography, 1986.

[2] Ohji T., Yamaguchi S., Amei K., Kiyota K. Magnetic Levitation of a Ferrofluid Droplet in Mid-Air, AIP Advances (Vol.10, Issue 1), 015037, 2020.