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Implementation of A Photo-Curable 3D Additive Manufacturing Technology with Coloring Gray Capability by Using Piezo Ink-Jet

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***Abstract*—**The 3D printing is a combination of digital technology, material science, intelligent manufacturing and control of opto-mechatronics systems. It is called the third industrial revolution from the view of the Economist Journal. A color 3D printing machine may provide the necessary support for high value-added industrial and commercial design, architectural design, personal boutique, and 3D artist's creation. The main goal of this paper is to develop photo-curable color 3D manufacturing technology and system implementation. The key technologies include (1) Photo-curable color 3D additive manufacturing processes development and materials research (2) Piezo type ink-jet head control and Opto-mechatronics integration technique of the photo-curable color 3D laminated manufacturing system. The proposed system is integrated with single Piezo type ink-jet head with two individual channels for two primary UV light curable color resins which can provide for future colorful 3D printing solutions. The main research results are 16 grey levels and grey resolution of 75 dpi.

***Keywords*—**3d printing, additive manufacturing, color, photo-curable, Piezo type ink-jet, UV Resin.

I. Introduction

THE hasty movement of the market change is an important factor that affects the fabrication technology from traditional approaches to Time-Compression Technologies (TCT). TCT always make use of Rapid Prototyping (RP) systems by taking the advantage of reducing production development cycle. The combination of RP and the Rapid Tooling (RT) into Rapid Manufacturing (RM) gradually replace traditional molding process as well.

Recently, 3D printing has become more and more popular and getting common in many fields. With its' superposing property, particular work process is unnecessary. ABS plastics are diffusely used in FDM (fused deposition modeling) techniques [1]. However, low precision in small-scale products, weaknesses between sections, low speed prototyping, etc. Have always been big problems to FDM techniques. Therefore, a piezoelectric ink-jet head is used, due to its' quick reaction and printing speed [2].

J. Th. Lambrecht et al. used 3D printing on cone beam computed tomography (CBCT). They transferred the data to the 3D printing machine to generate the models. Nowadays individual medical models are routinely generated by rapid prototyping. Physical models are produced by selectively solidifying UV-sensitive liquid resin by using a laser beam [3]. Inkjet technology has recently emerged as one of the most powerful tools for patterning electronic devices [4]. Thermal and Piezoelectric techniques are widely used in business applications [5]. Ink spilling problems may occur while printing using thermal technique [6]. With all different scales, viscosity, and materials from traditional 2D printing, it is also hard to handle the direction and the size of the material on 3D printing aspect. High-precision and high-lifetime of piezoelectric technique matches high specification 3D applications. By getting the piezoelectric head fixed, and jet the ink on the shifting plane to study on droplets' features and the interactions between droplets and plane by tuning printing frequency and plane shifting velocity. Then define the drop's geometry shape and surface roughness [7]. In 1992 [8] and 1999 [9], 3D SYSTEMS proposed a technique on the operation system to jet phase-changing ink and the variation of phase-changing composition after solidify under normal temperature.

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II. Piezoelectric Head Control and System Integration

This study presents piezoelectric head control and axial control for 3D printing system. On head controlling, piezoelectric head is used due to its' small size, quick reaction speed, high mechatronic converting efficiency, and small heat generation. Then the signal of printing graphics is sent to the head via head control card and driver during printing. Process axial control, on the other hand, step and servo motors are used to control XYZ axis movement as shown in Fig. 1.

The piezoelectric driving waveform is designed to match the resin which is used in this study. It is necessary to make the head jet out the ink in right amount. This study keeps tracking the interaction between the time, amplitude, ink-jet amount when the piezoelectric sheet vibrates, material viscosity and temperature. Therefore, the preliminary head ink-jet printing and axis control can be worked properly as show in Fig. 2.

A designed Human Machine interface (HMI) for such a 3D printing system is shown as Fig. 3. There are three available printing modes: (1) return to the machine home, (2) manual axis control (x axis & y axis) testing, and (3) automated printing mode. Because the study goal is to achieve bi-color grey level mixed printing, it is necessary to know that if even holes or odd holes are now printing according to the encoder feedback signal under printing mode. The status column shows current axial motion, the velocity (rps) and acceleration (rps/s) in target parameter column. The instant direction of each axis is shown in print status window.

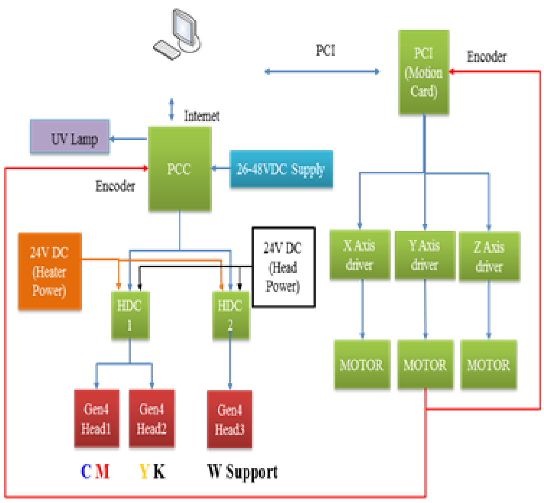


Fig. 1 System structure

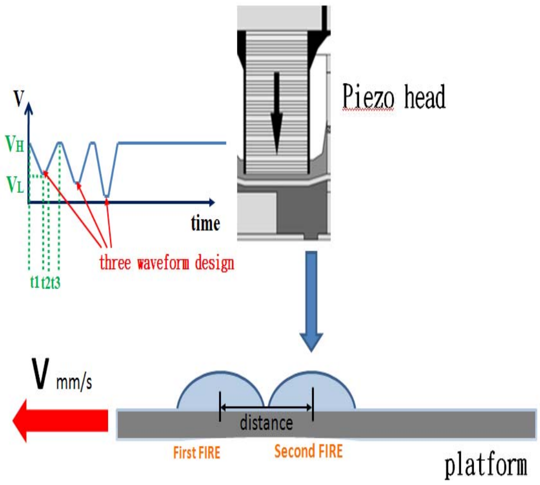


Fig. 2 Piezoelectric waveform designing

III. Photo-Curable Manufacturing and Grey Level Designing

Photo-curable resin may result a high quality surface. Using the solvent to break up supporting in processing has advantages of color displaying and material diversity which can be applied in medical, aerospace, vehicles and other mechanical components.

In this study, twin colors (Cyan & Magenta) resins are fed into the odd and even holes a single piezo head. The color resins are jetted out in dot matrices and blended into as grey level in each layer, shown in Fig. 4 [10]. First, the piezoelectric head jets out the resin in dot matrices, then making lines by dots, and making plane after line by line scanning, as show in Fig.5. Each layer is stacked complementarily to form a 3D object.

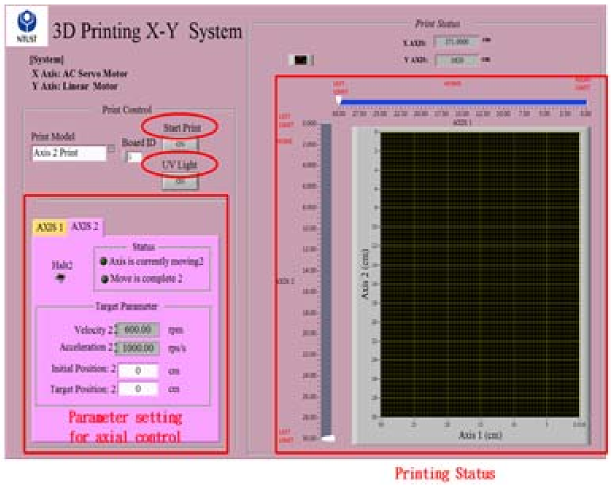


Fig. 3 A HMI for grey level based 3D printing system

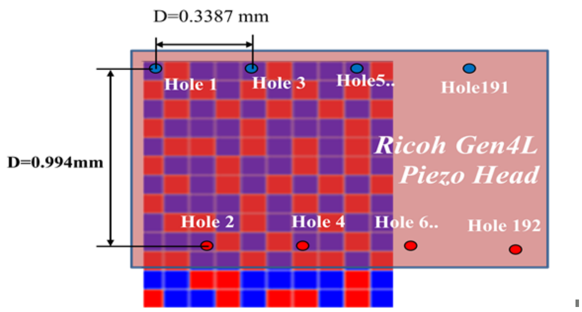
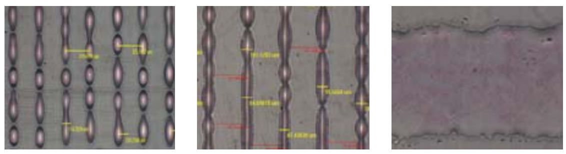


Fig. 4 Bicolor dot matrices



(a) (b) (c)

Fig. 5 (a) Arrays of dots (b) Line by dots (c) Plane by lines

The printing process can be arranged into four steps. First, y axis platform shifts forwardly to desired location along predesigned route. Meanwhile, x axis (head) shifts right a little as predesigned, y axis platform shifts backwardly to the starting point, then x axis shifts right again a little. Repeat these 4 steps until a layer printing is done, as shown in Fig. 6.

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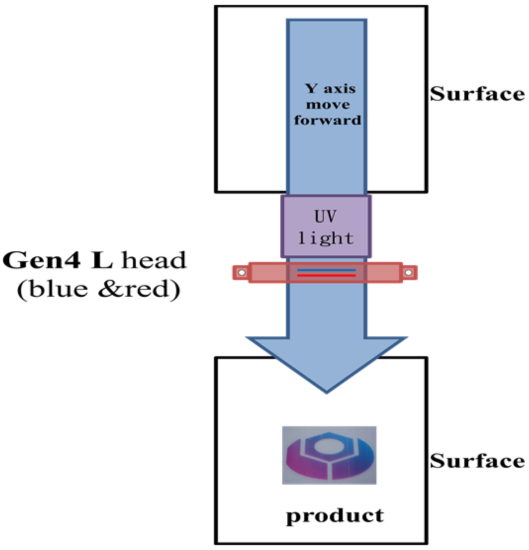

Fig. 6 Integration of Axial motion, UV light and Head control

The system separates the bicolor image into two primary color images by using a color splitting software. The two separated images which contain only one primary color. Then, according to the selected primary color resin, the prearranged piezoelectric waveform and the printing parameters are loaded into the host computer and the printing process can be automatically operated layer by layer, as shown in Fig. 7. The principle to achieve the bi-color image printing can be summarized into the following five steps:

1. Load bi-color blended layer image from 3D object.
2. Split the blended layer image twin-primary colors such as Red and Blue by using Color-splitting technique.
3. Load generated piezoelectric waveform and planning mask generation according to two primary colors.
4. Load grey level cured manufacturing parameter.
5. Digital motion control and Photo curable 3D printing head control

IV. Results

By using single piezo head, several bi-color gray level curing manufacturing images are tested in this study, The LabVIEW is used to design HMI system to realize the gray level control system of photo-curable 3D printing manufacturing. To achieve over 75dpi bi-color gray level pattern, the droplets must be smaller than 338.6μm. Displacement of the piezoelectric head is so far controlled between 120-145μm. As in color displaying, diameter of droplets is smaller than 100μm. Gray level printing can be worked above 75dpi, as shown in Fig. 8. Some experimental samples of bi-color gray level printing results are shown in Fig. 8. A Photo-curable 3D Additive Manufacturing Technology with Coloring Gray capability by using single Piezo Ink-jet head with twin individual channels is achieved in this paper.

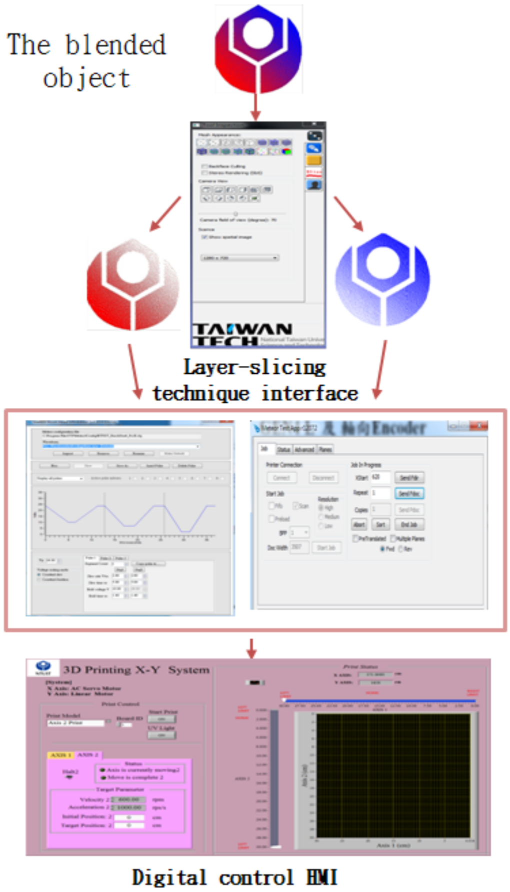

Fig. 7 3D printing stages for bi-color process Units

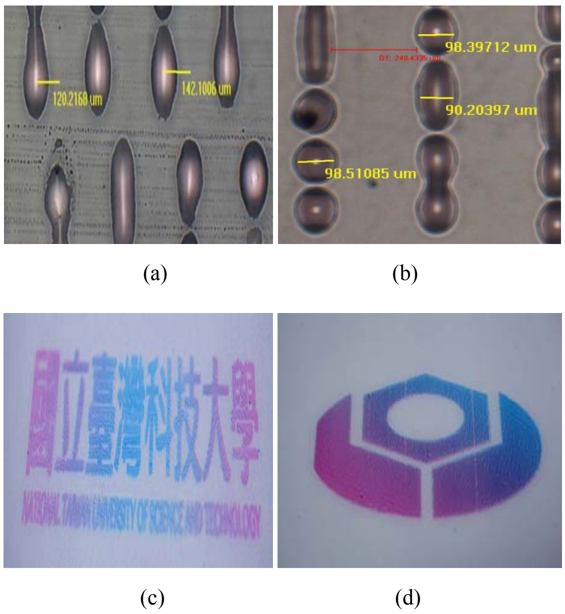

Fig. 8 (a) Axial displacement scale test of printed droplets (b) The diameter measurement of printed droplets (c) The experimental print for NTUST Chinese words with bi-color gray level (d) The experimental print for NTUST logo with bi-color gray level

V. Conclusion

This paper presents a Photo-curable 3D Additive Manufacturing Technology with Coloring Gray capability by using Piezo Ink-jet. The experimental results show that 75dpi and 16 grey level displaying capabilities are achieved on plane layering by using single inkjet head in this study. On the other hand, uneven size of droplets affects plane array and flatness which leads to the inaccuracy when multi-layers are printed. This problem can be solved by designing a proper waveform to control the size and stableness of droplets in the future study. It is expected that a colorful three-dimensional object with CMYK and supporting material can be achieved by involving multiple piezoelectric heads in the near future.

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