The Mechanical Design Concerning for Multiple Print Heads in Ink-Jet Printing System

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Abstract

How to compromise the tunable resolution requirement and mechanical design is a big issue for ink-jet fabrication. The conflict comes from the innate characteristics of loose pitch resolution between nozzles for the piezoelectricity inkjet print head. This article disclosed a mechanical design methodology for multiple print heads, to use for large size panel in high resolution by ink-jet printing without mechanical inaccuracy, and the white omission in pixel or drops mis-landing could be eliminated. Four heads consisted as a basic module, and could be continuous tuning the nozzle pitch by micro-driver and optical magnifier assistant up to 200 dpi ± 1um, and the surface alignment of ink-jet heads for different modules can be controlled with ± 50um above substrate. Besides, the mechanical designs for reduction of the ink temperature fluctuation, the isolation of temperature transfer into motion stages, as well as a trimming design of air bubble within ink flow path to avoid deterioration in printing quality were also presented. Several important concept included the ink supply, piping, temperature consideration, isolation of head module, de-gas function etc. were discussed. This design proved a good design in mechanical design and its alignment methodology, and can be transferring heat in uniform to keep the temperature variation along the direction of nozzle in order within ± 4°C, and by simulation results, multi-stage heating design is preferred to avoid the temperature drop from main chamber to print head.

Introduction

In recent years, printed organic electronics have been intensively developing because of many advantages over conventional lithography and vacuum processes, such as low cost, easy and flexible processes, efficient usage of material and large size manufacturing [4]. Some non- photolithographic approaches had been proposal to manufacturing printed circuits boards (PCBs), such as micro contact printing (CP)[5], ink jet printing (IJP)[6] are corroborated to appropriate for process replace. Especially, the ink-jet printing enabled to offer the additional advantages of low capitalization, low pollution, very high materials efficiency, elimination of photolithography, and non-contact processing [7].

However, in consideration of the feasibility for mass production, the nozzle-to-nozzle (N2N) and head-to-head (H2H) variation are hard to well control at present. It results the defect on printed display pixel, shows mura, white omission and color mixing etc., or presents the inconsistence of line width quality on printed circuit, and deteriorates the electrical performance. Several approaches are considered to solve the variation issue, (a) design an electrical circuit to detect the electrical resistance of each nozzle, then module appropriate driving waveform for correcting the difference, (b) stabilize the temperature and pressure fluctuation for print head, especially for multi-heads operated, (c) high accuracy of mechanical design to reduce the misalignment, (d) pre-calibrated of print head, in a range of driving voltage.

Term (a)-(d) is the key design to promote the ink-jet printing fabrication toward to mass production. Multiple print heads design in an ink-jet platform can speed up the throughput, but it also causes the difficulty on maintenance issue and deteriorates the quality because of the variation between N2N and H2H. Therefore, a module design for print head with high accuracy is proposed in this article, and the temperature stability and its effect in jetting quality is also discussed. In this design, four heads consisted as a basic module, and could be continuous tuning the nozzle pitch by micro-driver and optical magnifier assistant up to 200 dpi ± 1 m, and the surface alignment of ink-jet heads for different modules can be controlled with ± 50 m above substrate. Detail will be described below.

Module Design & Alignment Methodology

Print Head Description

Diamtix's S-Class print head is a piezoelectric device operating in shear mode used for this design. The jets are driven by PZT (Lead Zirconate Titanate), a piezoelectric ceramic. There are 128 nozzles in a single line. The shear mode of PZT actuation allows individual jets defined on the same PZT to be fired without adversely affecting the simultaneous operation of adjacent jets.

Each head contains two electrically independent PZTs, with 64 addressable ink pumping channels per PZT. The resulting 128 fluid paths in the jetting assembly terminate at the nozzles which form a single line at 50 dpi spacing. Each PZT is controlled by two 32-bit serial-to-parallel converters, or driver chips, for selecting which jets to fire. A high-voltage fire pulse is applied, which actuates the PZT pumping chambers within each channel with controlled slew rates. All 128 channels can be fired simultaneously or individually, depending on an application's jetting uniformity requirements.

The piezoelectric plate has actuating electrodes on only one side of the plate and an electrode pattern conforming exactly in shape and position to the pattern of pressure chambers in the carbon plate. The formation of an array of closely adjacent pressure chambers for an ink jet head which have a long aspect ratio and require highly precise and uniform channel dimensions. The process for manufacturing a carbon plate component of an ink jet head is greatly simplified by shaping the carbon plate using a series of linear motions against the surface of the carbon plate with a shaping tool having the desired profile.

Print Head Module (PHM) Alignment Apparatus

An optical magnifier system combined with image analysis software to analyze the nozzle pitch, as a position reference in adjusting each print head in the multiple print heads module. The system includes an optical magnifier system, a single 2-D CCD camera, image analysis software and an adjustable mechanism system. The optical magnifier system equipped of a X-Y stage with high resolution optical ruler feedback (0.1um) to move the focus point relative to observe object, the print head module. An optical system with tunable magnification used for capturing nozzle image and recording its relative position analyzed by software, as shown in Fig.1.

Fig.1 The micro-driver and optical magnifier system

A multiple print heads module in order to have 200dpi ± 1um pitch accuracy, aligned four print heads in parallel and shifted in distance of nozzle pitch of 50dpi (508 um) each. The adjoin head at same nozzle number defined will be a shifting distance of 127 um along the direction of nozzle arrange in order, as shown in Fig.2.

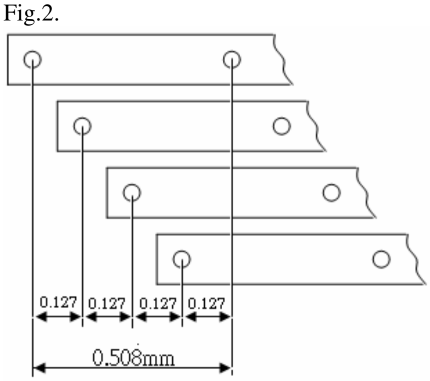

Fig.2 A multiple print heads module arranged

At tuning, the nozzle number #1 and the number #128 of reference head (called head # 1) are the reference nozzle along the arrangement of nozzle in order. Four heads are aligned their relative parallel direction first by referring the nozzle number # and number #128, then tuning their related shifting to the target of 127 um. The mechanism is with a pre-locking design for the print head module frame, to fix the module on the X-Y stage. If the operation confirmed the head shifting is within the acceptable range (in our case, ±1 m) by repeating the X-Y stage moving in observation, then applied a force to lock the head. Otherwise, keep continuing adjust the head shift by micro-screw relative the reference head, the head number #1. Following the same operation, Head #2-#4 can adjust their horizontal and nozzle shifting position relative to head #1. The detail description of head module construction and this alignment frame were shown in Fig.3.

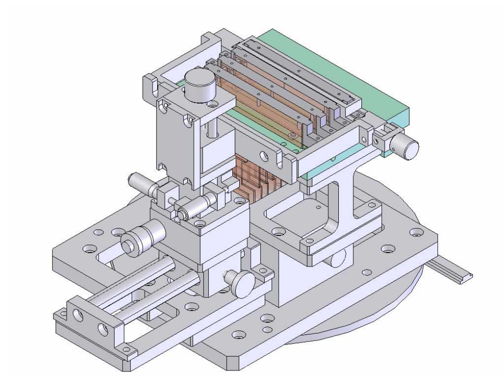

Fig.3 The adjustable mechanism system

Print Head Module (PHM) Design

In a print head module, several points need to be carefully considered. (a) The ink supply system. (b) The piping system for each head. (c) Temperature Control (d) Isolation of head module to avoid the heat transfer into stage on platform. (d) De-gas function. (e) High mechanical accuracy for mounting and demounting. We will discuss the concerning point below.

Most of inkjet printing system, the ink is supplied directly to a chamber or passage connected to an orifice, the nozzle of print head. The ink is jetting drop-by-drop in continuous cycles and the pressure in chamber will be fluctuating and get balancing back, depends on the chamber space and piping length. For traditional office printer, generally is an ink cassette mounted and can fast response the pressure balancing. However, for industrial application, it needs a continuous ink supply system so that a batch production is possible, in less maintenance consideration. It caused a serious problem, the lower response of pressure balancing due to the long piping from main chamber to print head, and presented in the deterioration of printing quality at high frequency operation. In this design, a two- -chamber architecture is proposed. The main chamber functions only deliver ink to head chamber (combined with the head module), and then will be shot off the pipe flowing by electrical valve, to avoid the pressure oscillation between the head chamber and main chamber, and a fast response of pressure balancing can be realized.

For a print head module, to keep from the jetting variation create, the electrical wiring and ink piping should need carefully arrange for each head in same situation. Especially, the piping length and the cascading should calculate its pressure drop, to avoid the different at the ink flow into head. Besides, the cross section area of piping flow channel must be larger than the total area of nozzles for all heads, to keep off the chock occurs at ink supply system. Here we adopt a factor 2 of cross section area of piping compared with total area of nozzles for all heads.

As for the air bubble in ink, generally is the ink introduced into the passage contains dissolved air. The air bubble will affect the jetting directionality, aggravate nozzle-to-nozzle variation and absorb mechanic impact force and obstacle to operate at higher firing frequency. These influences will result mis-landing, than the white omission in pixel will occur..

To make sure the completed air / ink separation, three procedures to reduce the effect from the air bubble in the inkjet printing. By positive pressure purge, is helpful to drive the bubble out of nozzle. If the situation is still abominable, a vacuum suction nozzle by nozzle is operated. Besides, within the head chamber, we have design a air / ink separation device, to abstract the air bubble flow into head. Every multiple print heads module consists of four heads of 128 nozzles, two symmetry flow channel are located at both sides of the module, de-gas device and head chamber is above the module. In order to control the different modules position above substrate, there are four tapers respectively in the back corner of the multiple print heads module. By adjusting four tapers of the multiple print heads module, the module to module alignment can be gotten. (see Fig.4).

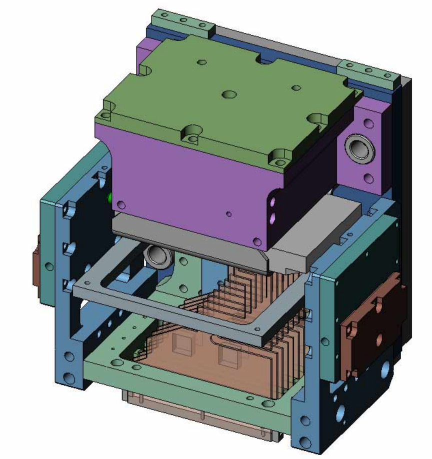

Fig.4 The multiple print heads module

Ink Viscosity Concerning

The viscosity of the ink is more concern while operated at temperature higher than room temperature. For most of ink, the viscosity will decrease with temperature increase. It implies, the ink viscosity in the main chamber, will be different with near the print head, for thermal dissipation change the ink temperature. Fig.5 indicated a typical example, the cholesterol liquid crystal of red, green and blue color. The operation window is about 50-80°C, follow the criteria of Dimatix S-series. Ink temperature is a critical factor affecting the viscosity. Sometime, some special ink like the legend in used for printed circuit board, the flowing of ink will be difficult under 60°C, if all the flow channel can't keep above 60°C , then the transportation will be blocked. Above ink characteristics indicated the importance of how to maintain the ink temperature during ink transportation. In this design, three stage of heaters and thermal-couples as feedback in the multiple print heads module to control the temperature, where one inserts in the ink reservoir, and the others are located on both sides of the module.

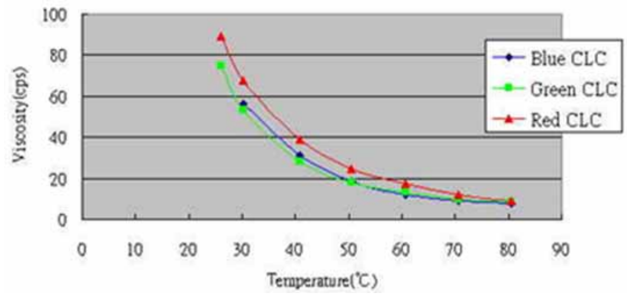

Fig.5 The curvature of viscosity varies with temperature for cholesterol liquid crystal.

Temperature Distribution

Fig.6 is a simulation results by COSMOS software for the print head module, to examine the temperature distribution and verify the material characteristic effect. In this case, the main chamber is setting at temperature 80°C, with fluctuation of ± 3°C. It is obvious that the temperature drop from main chamber to the side of module, the second heating location, the temperature will drop down to 60°C-65°C, and the temperature around the head is return to about 70°C-80°C, if the second heating system was operated in assistant. In our experience, module made of stainless material is hard to transfer heat to print head, and it takes longer time to achieve balance temperature, and larger temperature drop occurred than made of Alumni alloy.

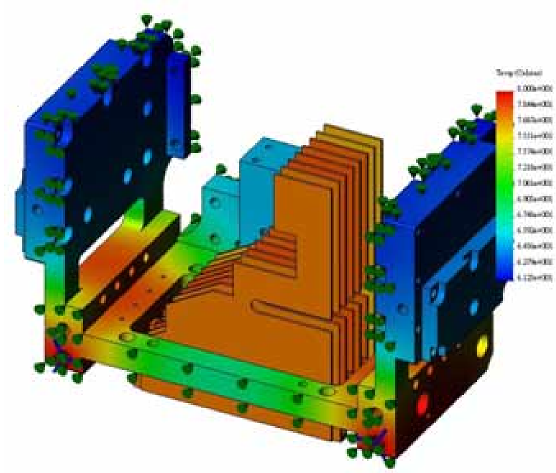

Fig.6 Simulation results by COSMOS software for the print head module

Table.1 is a measurement data at position A-D (Fig.7), to verification its uniformity for this print head module design. At different setting temperature at main chamber, without the second and third heating operated, the temperature drop was observed also. The results indicated the temperature is about 30°C drop without extra heating assistance, but the uniformity along the direction of nozzle in order is acceptable in a range about ± 4°C. Further study will analyze the temperature stability if all three heating sources are adopted.

Table.1 Measurement data at position A-D

Setting Temp (°C)	A	B	C	D
80	52	52	52	52
80	57	57	57	57
80	52	49	49	48
80	52	52	52	52
80	59	59	59	59
80	52	51	50	50

Fig.7 Picture of print head module and measured point.

Conclusion

Using the micro-driver and optical magnifier system to assemble a multiple print heads module with high accuracy was proposed in this article. Several important concept included the ink supply, piping, temperature consideration, isolation of head module, de-gas function etc. were discussed. This design proved a good design in mechanical design and its alignment methodology, and can be transferring heat in uniform to keep the temperature variation along the direction of nozzle in order within ± 4°C, and by simulation results, multi-stage heating design is preferred to avoid the temperature drop from main chamber to print head.

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Biography

Cheng-Yi Wang received her Master degree in Mechanical Engineering from National Chung Hsing University in 2001. She is now a system integration engineer in the Printable Science Department Display Process Integration Technology Division, Display Technology Center of Industrial Technology Research Institute at Taiwan. Her work has primarily focused on the mechanical design. In the inkjet printing engineering experience including cartridge design, mechanical design manufacturing support and testing.