MACH for Pigment Ink

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Abstract

Color inkjet printers are boasting overwhelming popularity due to their low costs, high speed and high quality print. A high quality imaging technology has been developed for color inkjet printers using a piezoelectric print head. We have worked toward inkjet printers that use pigment ink with light-resistance and water-resistance because requirements for fast color have recently risen. That is a new MACH (Multi Layer Actuator Head) which is most important to produce those characteristics.

I'd like to introduce you to the MACH technology for pigment ink.

1. The structure of MACH
2. The technology to achieve high speed color print and high quality print by MACH
   - The increased number of nozzles
   - The meniscus control
   - The prevention of clogging by quivering meniscus

1. Introduction

Recently, color printers have attracted a great deal of attention as a medium for printing rapidly spreading color digital images. Especially, color inkjet printers are in extremely widespread use because they have achieved not only low cost and high speed but also high quality print, the basic requirements for color printers. Our success in bringing about the high performance of color inkjet printers is thanks in large measure to integrating our whole technology to exercise the capabilities to the full as well as improving the core technologies such as:

1. inkjet head and its control,
2. ink and print media,
3. super precise feed of paper, and
4. image processing and print control.

We have worked toward inkjet printers that use pigment ink with light-resistance and water-resistance because requirements for fast color have recently risen. We have succeeded in developing Stylus C80/82 which uses DuraBrite ink optimized for plain paper and Stylus Photo 2200 which uses UltraChrome ink optimized for photos.

In this paper, I'd like to discuss inkjet heads focusing on our MACH which has been used in Stylus series for high speed and quality print. Inkjet heads play a crucial role in using any pigment ink.

2. The Structure of MACH

Photo 1 shows MACH loaded into Stylus C80/82 which uses DuraBrite ink. Photo 2 shows MACH loaded into Stylus Photo 2200 which uses UltraChrome ink.

Photo 1. MACH (Stylus C80/82)

Photo 2. MACH (Stylus Photo 2200)

To realize high speed and quality print, inkjet heads must be able to:

1. generate undistorted ink droplets and land them precisely at the target,
2. minimize the volume of an ink droplet,
3. fire ink droplets in a high frequency, and
4. deal with any ink.

To meet these requirements, we have developed new products each with a different type of MACH carrying piezo elements. The two types of MACH are as follows: One is MLP (Multi Layer Piezo), which uses the longitudinal oscillation mode with multi layer piezo elements. And the other is MLCHIPS (Multi Layer Ceramic with Hyper Integrated Piezo Segment), which uses the flexural oscillation mode with the integral multi layered sintered-ceramics. MACH that we have recently developed uses MLP. Fig. 1 shows the structure of MLP MACH.

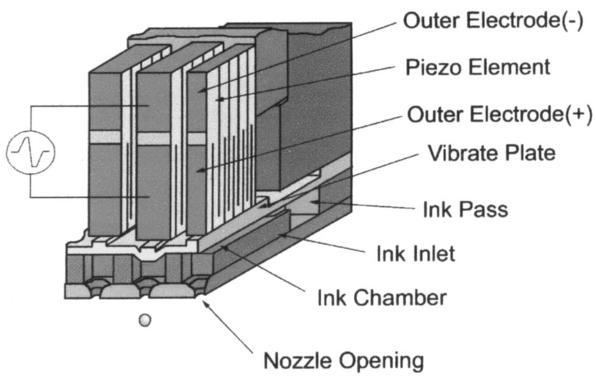


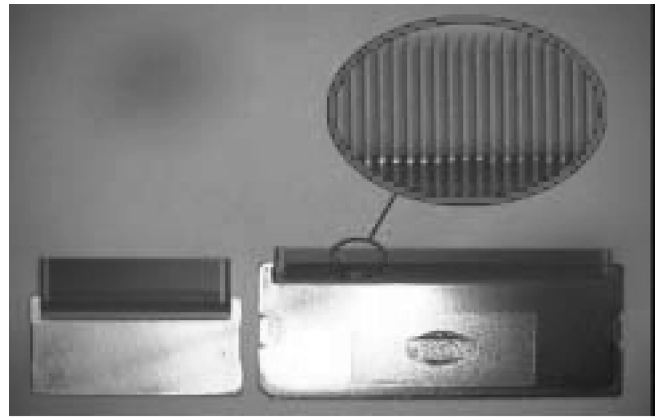
Figure 1. Structure of MLP MACH

The principle of operation for MLP is the longitudinal oscillation caused by the driving signal applied between the positive and negative outer electrodes. The signal, when applied, causes the piezo element to expand and contract, which causes the ink chamber volume to increase and decrease, and consequently ink droplets to fire from the nozzle. The piezo element follows the driving signal well enough to control the meniscus perfectly, which we will discuss later.

3. MACH Realizes High Speed and Quality Print

3-1 An Outline of High Performance MLP

While MACH with MLP has so far been loaded into Stylus Color 900, new MACH for Stylus C80/82 has more nozzles per line than that, and the one for Stylus Photo 2200 has more lines with the same number of nozzles per line. As shown in Photo 3, the number of oscillators per line for MLP for Stylus C80/82 is 180, which is nearly twice that for Stylus Photo 2200, 96. While the number of oscillators per line for MLP for Stylus Photo 2200 is the same as before, the number of lines has been increased from 5 to 7 to realize multicolor.



Stylus Photo2200 Stylus C80/82

Photo 3. Photo of MLP

3-2 Precise Control of Meniscus

Accurate and precise control of meniscus is indispensable for the realization of high speed and quality print. We have succeeded in realizing it by using AMC (Advanced Meniscus Control) particular to MACH, which includes the following two technologies:

One is PPP (Pull Push Pull), which controls the meniscus precisely over the following three stages of ink firing: before and after the firing as well as the firing moment. The following is the outline of PPP.

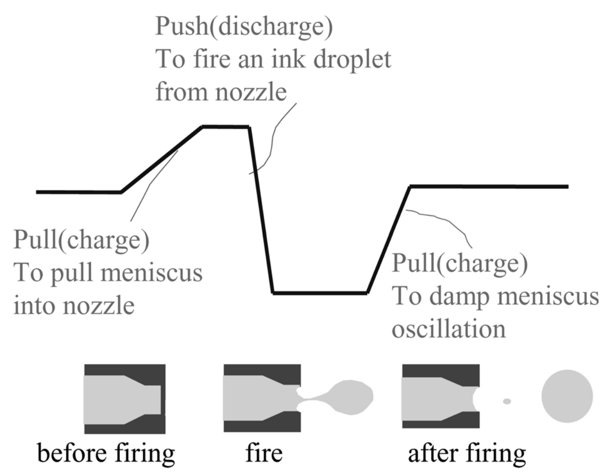


Figure 2. PPP Meniscus Control

Figure 2 shows the concept of PPP. First, for the first pull, it pulls the meniscus slowly into the nozzles before firing to obtain the uniform meniscus in all the nozzles. Second, it rapidly boosts the pressure in the ink chamber to fire an ink droplet by push. Third, for the second pull, it pulls the meniscus to rapidly damp the meniscus oscillation after firing an ink droplet. A series of this meniscus control operation performs pinpoint landing of uniform ink droplets on a sheet of paper and in a high frequency.

Figure 3 shows the meniscus behavior without the pull operations before and after ink firing. Without the pull before firing, the meniscus takes various forms influenced by the previous firing. This influences the flight speed, the flight direction, and the size of an ink droplet. For example, if a droplet is fired with the meniscus protruding from the nozzle, the droplet gets a flat head and a slow speed of firing. Besides, protruded extra ink soils the nozzle periphery, which disturbs the flight direction of the droplet. And without the meniscus control after firing, mist satellites generate due to long lasting piezo element oscillation. These troublesome phenomena not just deteriorate print quality, but also limit the firing frequency because the next droplet has to be fired after the meniscus oscillation has damped to a certain degree. It is, hence, crucial to solve these problems in order to obtain high speed and quality print.

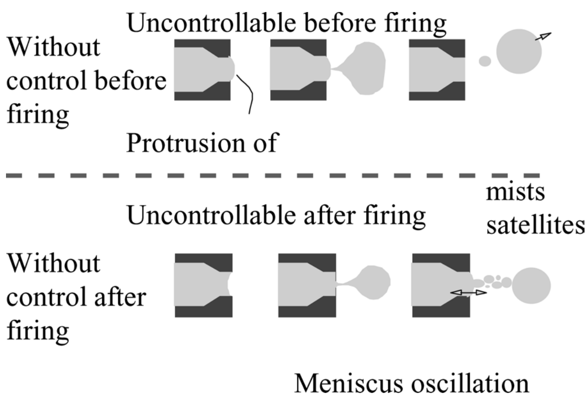


Figure 3. without PPP

Just after a droplet is fired, the meniscus is once drawn back towards the ink chamber, and thereafter the following two types of oscillation occur at the same time until they damp:

The meniscus oscillation due to:

1. the capillary attraction that acts on the ink returning to the nozzle, and
2. restoration movement of contracted ink chamber to the original condition.

Without our PPP control, the coexisting above mentioned two types of meniscus oscillation damp as time goes on. In the past, to quickly damp the oscillation, we used a smaller ink-feed opening because large resistance caused by a smaller opening helped quicken the damping of meniscus oscillation. A large resistance to ink feed, however, limited the firing frequency because it decreased the speed of ink feed. To quickly damp the meniscus oscillation without lowering the speed of ink feed, we give the meniscus the inverse phase oscillation to counteract the above mentioned oscillation, which we call the second pull. To damp thus forcibly the oscillation, the start and end point and the control of the strength for the second pull must be optimum. Our MACH responds well enough to realize a high firing frequency as well as quick damping of the meniscus oscillation.

The other meniscus control technology, DPE (Drastic Pull Ejection), which is a development from PPP, offers smaller ink droplets. You may think of various means of achieving smaller droplets such as smaller nozzle diameters and lower voltage for driving the head. The former, however, may result in nozzle clogging, and the latter failure of pinpoint landing of droplets due to a slow firing speed. Especially pigment ink is liable to cause nozzle clogging though it has higher fastness than conventional dye ink. With the DPE technology, we can obtain smaller droplets for pigment ink without decreasing the firing speed with the conventional nozzle diameter. As shown in Fig. 4, before firing, pulling deeper and more rapidly the meniscus and then pushing the ink stronger realizes ultra small droplets.

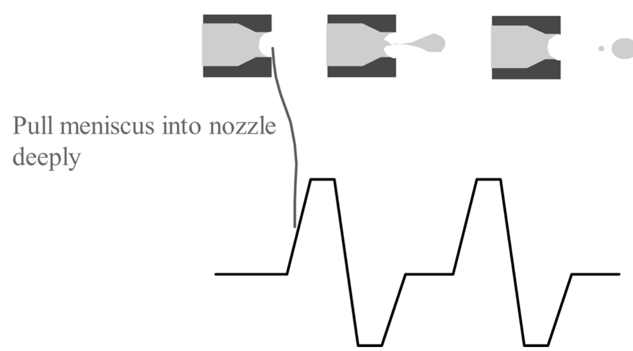


Figure 4. Drastic Pull Ejection

3-3 Break and Diffusion of High Viscosity Layer By Quivering Meniscus

To obtain dense, vivid and highly fast print, you must use a high concentration of pigment. Low pigment-concentrated ink gives poorer quality print than dye ink. Increasing the concentration of pigment may cause troubles in firing ink due to formation of a high viscosity layer in the interface between the nozzle and meniscus, which has been a problem in using pigment ink for achieving print quality equal to or higher than by dye ink. To use highly pigment-concentrated ink, MACH quivers the meniscus to avoid generation of a high viscosity layer in the surface of the meniscus which disturbs the smooth firing of droplets.

As shown in Fig. 5, a high viscosity layer forms on the surface of the meniscus. In the interface between the nozzle and meniscus, especially high viscous filmy layer grows.

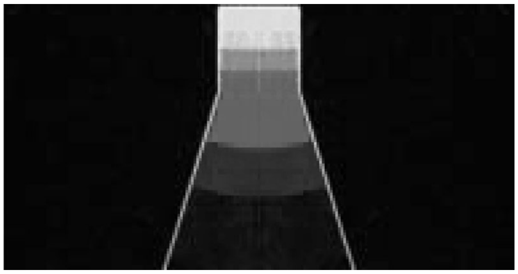


Figure 5. Viscosity Simulation of a nozzle (cross-section)

When the high viscosity layer is thin enough, there is no problem because firing ink breaks the layer quickly. The layer that has grown thick, however, disturbs normal firing.

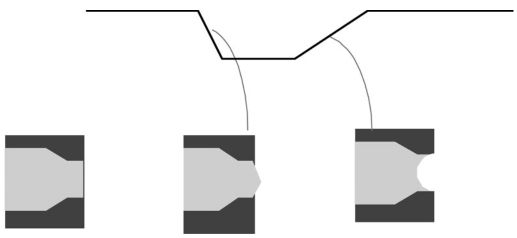


Figure 6. Driving wave to quiver meniscus

As shown in Fig. 6, to avoid firing troubles, MACH breaks the layer; for that purpose. It applies a driving wave to push the meniscus slightly enough for the droplets not to fire. Next, it pulls the meniscus into the nozzle to diffuse the broken high viscosity layer into the inner part of the ink. Repeating these operations on printing each line prevents the thickening of a high viscosity layer on the ink surface. MACH easily breaks and diffuses the high viscosity layer because it responds well to the driving wave as I mentioned earlier. Figure 7 shows the simulation of the behavior of the meniscus by quivering.

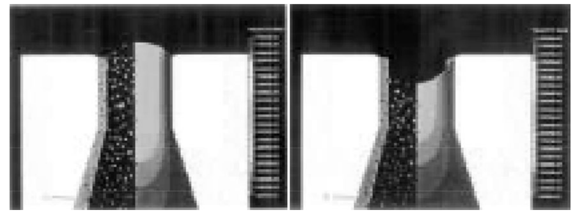


Figure 7. Behavior of meniscus

4. Conclusion

In this paper, I have summarized how we have developed high speed and quality print by inkjet, focusing on MACH. MACH has realized high quality print equal to photos. With digital machines such as digital cameras having come into wide use, MACH is widening its use for a new market beyond output from personal computers. Because of its mechanism, ie., landing ink droplets directly on print media, inkjet is expected to be used for a variety of purpose in various industries making the most of its characteristics that in principle it can print on any object. In the future, we will further enhance high speed and quality with our MACH to meet the demands in various markets.

5. References

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