Optimized Automatic Recovery of Nozzle Health in Inkjet Systems

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Abstract

During the new print head installation process, an inkjet printer carries out several servicing actions to set the print head in the optimum printing conditions. In inkjet systems using pigmented inks there are known issues such as pigment settling after long periods of storage that can clog nozzles and cause bad drop ejection. This paper summarizes a system that initializes print heads after long periods of storage and inactivity. The system measures the level of nozzle health degradation and adjusts the servicing routines correspondingly, thus minimizing the ink waste and time required to guarantee an optimum nozzle health status for printing.

Introduction

The usage of pigmented inks in HP thermal inkjet printers have been increasing during the past few years, particularly on those market segments requesting superior print quality with high durability. Compared to dye-based inks, pigmented inks offer a higher durability of the print quality over time. The image permanence and stability to high humidity/moisture is improved.

If a print head containing pigmented ink is not used for a long period of time, nozzle health may be degraded. Specific servicing actions that include spitting drops, wiping and priming the print head are required to recover nozzles.

Storage of Pigmented Inks

Print head nozzle health can degrade over time when pigment inks are stored either on the shelf before initial insertion into the printer or in the printer when it is sitting idle. Pigment particles in dispersion are influenced by gravity and can sink or settle and collect in the nozzle region. Some of the particles may also stick together to form larger clumps of pigment which then settle down in the nozzle region. Depending on the specific ink and pigment chemistry, these agglomerated particles may stick to different surfaces inside the body of the print head or to various features of the nozzle architecture. The flow of ink through the nozzles is then either restricted or completely blocked by the accumulation of solids in the nozzle region as shown in Figure 1.

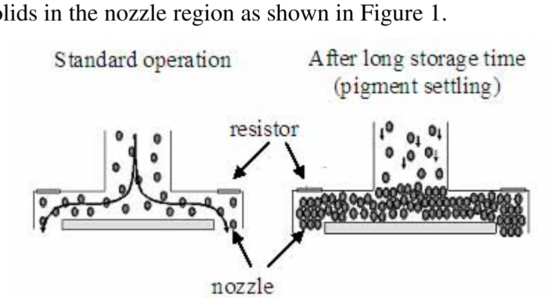

Figure 1 Schematic representation of blockage in the nozzles

Nozzle Health Measurement Systems

In order to be able to trigger the proper servicing actions to recover bad nozzle health caused by long periods of storage (or by any other causes that may induce nozzle failures), it is key to have a fast and reliable method to measure nozzle performance.

A nozzle check is done automatically by the print system when the print head is new or has not been used for a long time. In that case, the probability of nozzle health degradation is high due to pigment settling so a measurement of the nozzle health is required in case specific servicing actions are needed to set print heads back in proper condition for printing well. Nozzle checks are also regularly done by the printer during normal operation.

The nozzle health measurement system needs to check a large number of nozzles in a reduced amount of time to avoid or minimize the impact on unit time initialization. In the past 15 years there has been a huge increase in the number of nozzles present in a printer. Figure 2 shows the exponential evolution in the total number of nozzles per printer for HP large format printers from 1995 to the date.

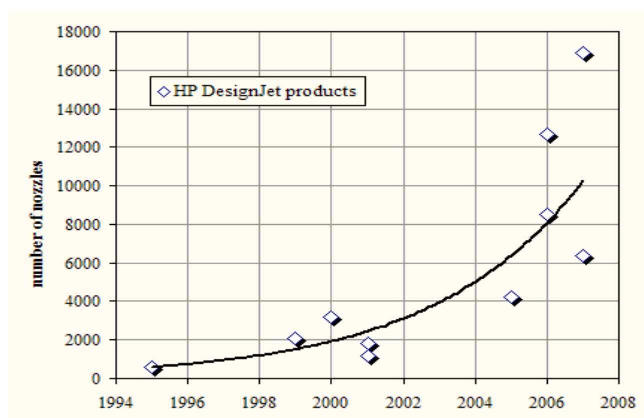

Figure 2 HP Large Format Printers number of nozzles trend

In some cases, the increase in the number of nozzles has been so high that common measurement concepts of having one sensor device to check all the print heads have evolved to parallel nozzle health measurement of several print heads at the same time. This is the case in HP CM8000 Color MFP series, having more than 10K nozzles per color.

Nozzle health measurement systems in HP products can be grouped in 2 families according to the technology, electrostatic and optical devices[1]. To the date, optical solutions have been much more used, mainly in products with extensive usage such as large format printers. Electrostatic solutions have been implemented in a few lower cost products with less printing life, examples are HP Photosmart Pro B9180 or HP Officejet Pro K550 Color Printer.

The basis of the nozzle health measurement algorithm is similar for the different hardware solutions implemented. A burst of drops that are fired from any given nozzle are detected. The output signal from the sensing device is analyzed to determine whether the nozzle is ejecting proper droplets. The process of checking nozzles is sequential by nozzle.

In optical solutions, drop detection is performed by firing a burst of drops from any given nozzle through a light beam. An infra-red LED sources light onto a photodiode. The burst of drops provides, in effect, a shadow as they pass the photodiode, decreasing its output current. Firing parameters are chosen to ensure the change in signal (photodiode output) is large enough to indicate the presence of drops over noise present in system.[2]

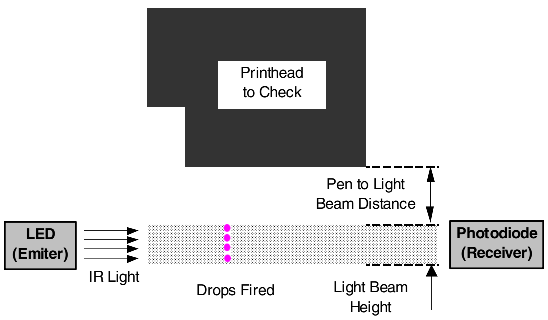

Figure 3 Schematic Diagram of Optical Drop Detection

Optical drop detectors in HP printers have been used to detect drops of different colors of a large variety of sizes, ranging from 4 pl to 18 pl. The maximum length covered to the date by an optical drop detector is around 1.7 inches. The detection time of the latest designs is approximately 1.8 ms per nozzle.

In most of the existing hardware implementations, the light beam is aligned with the column of nozzles. The print head carriage successively positions different print heads over the drop detector. However, there are a few implementations in which the print head is too large for the light beam to cover all its length. In those cases, the light beam is set orthogonal to the column of nozzles. Obviously, either the print head or the sensor needs to be moved to be able to scan the entire nozzle column. An example is the HP CM8000 Color MFP series, which incorporates print heads that span the width of a page, a technology known as HP Edgeline Technology, in which only the paper moves during the printing process, not the print head.

The amplitude of the drop detector output signal is compared to the sensor noise level to determine whether the nozzle is ejecting droplets or if the nozzle is completely clogged (no ink coming out of the nozzle). A finer analysis of the signal looks not only at the signal amplitude but also at the whole shape of the signal and is used to determine whether the drops being ejected have any specific problem such as wrong drop volume or trajectory, these are called weak or misdirected nozzles. The finer analysis does compare the signal resulting from one nozzle to its physical neighbor nozzles.[3]

Electrostatic drop detectors base the measurement on drop electrostatic charges. Previous designs, such as the one included in HP Color Inkjet Printer cp1160 are based on firing drops on the sensing plate (target). There is a potential difference between the sensing plate and the printhead. This difference forces a charge on the droplet as it is formed. As the droplet hits the target, the AC coupled amplifier detects the charge transferred. This detector has a slightly slower detection speed than the optical one described above (around 3ms) because detection requires more drops per nozzle, but on the other side it is cheaper. The ink deposited on the target by successive drop detection events ends up reducing the target sensitivity. A wiping system is required to remove the ink from the top of the target.[4]

An advanced design of electrostatic drop detectors do not spit on the sensing plate, but the drops flight through or parallel to the it[5]. An example is the drop detector included in HP PhotoSmart Pro B9100 series. The sensing plate is no longer a surface on which the print head spits but a surface parallel to the drop trajectory. The design ends up being much more robust in terms of waste management, there is no need for a wiping system to keep the sensor clean.

In order to identify nozzles not firing properly, similar signal analysis approaches described for optical drop detectors are applied to electrostatic sensors.

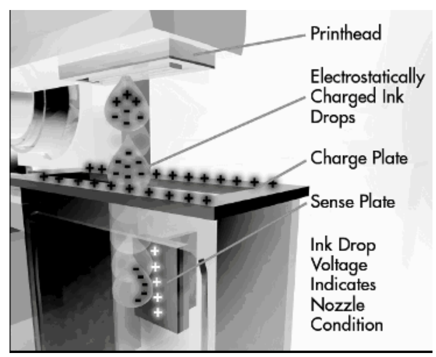

Figure 4 Schematic Drawing of Electrostatic Drop Detection

Other technologies to measure nozzle health have been investigated, such as acoustic devices to capture the disruption caused by a nozzle being fired, or indirect thermal measure of nozzle resistors to determine whether a drop was ejected, or even other optical approaches such as using a CCD to capture drops from several nozzles at the same time, but none of them has been implemented in any product to the date.

Blow and Suction Primer Systems

The priming action allows extracting a considerable amount of ink without heating the nozzle resistors. The nature of some nozzle health issues makes it difficult to unclog nozzles by heating resistors to eject droplets. Nozzle clogs caused by pigment settling due to long periods of non-usage is one of these cases. Priming is an alternative option to pull ink out from the print head.

During standard operation, the pressure in the nozzles is lower than the atmospheric pressure, which avoids the ink flowing out of the print head due to gravity.

During priming, a positive delta of pressure between the ink inside the print head, in contact with the nozzles, and the external environment surrounding the nozzle plate is created. The pressure difference forces the ink to flow outside the print head through the nozzles.

Priming systems have been implemented in different HP printers to the date. Hardware concepts can be grouped in two main families, blow and suction primers. Since priming is not a frequent action in the print system operation, priming systems are usually not designed to be able to prime all print heads at the same time, but only one or a few of them.

Blow primers increase the pressure of ink inside the print head. Pressurized air is forced into plastic bags inside the print head, which are in contact with the ink, thus incrementing the ink pressure, for this reason some time they are called also push primer. The primer in HP DesignJet 1000 and HP DesignJet 5000 includes a small axial pump that is pushed against the vent that connects the internal air bags to the atmosphere, forcing a controlled volume of air into the print head. The volume of displaced air can be tuned by the magnitude of the pump axial displacement; 0.2cc's are displaced per mm of stroke. The primer is fixed to the service station and can only prime one print head at a time. To allow for priming several print heads, the print head carriage successively positions the selected print heads under the primer.[6]

The blow primer in HP DesignJet Z-6100 allows priming two print heads at the same time and uses the already pressurized air from other parts of the print system. In all cases, the integration of the primer in the system is done so that the ink coming out from the print head directly drops in the service station waste container. An ink puddle may be formed on the nozzle plate of the print head during priming, therefore some wiping and spitting is usually done after priming.

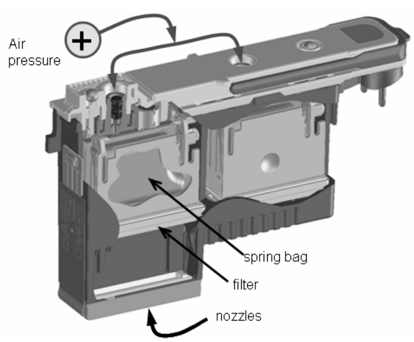

Figure 5 Schematic Drawing of Blow Priming Principle

Suction primers reduce the pressure of the external air surrounding the nozzle plate. For that purpose, in HP Photosmart Pro B9180 or HP DesignJet Z-2100, the print heads are kept in capping position and air is extracted from the capping system to create vacuum around the nozzle plate. The same tubes used to extract air from the capping system are also used to conduct the primed ink to a waste container. In order to keep the suction pressure constant while priming, an accumulator is placed between the pump that generates the vacuum and the capping system. When priming is triggered, the connection between the capping system and the accumulator is established. Not all print heads are primed at the same time, but the print system can select pairs of print heads to be primed.

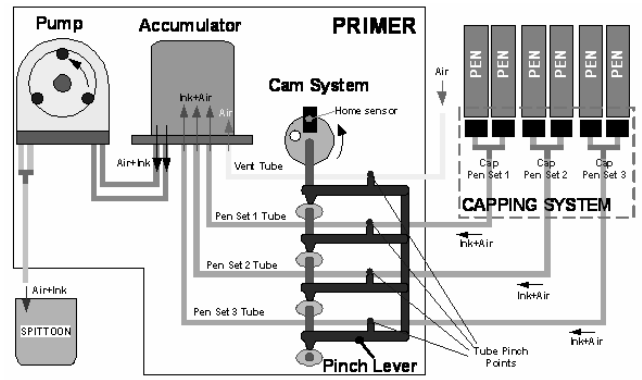

Figure 6 Schematic Drawing of Suction Priming System in HP DesignJet Z-3100

Both for the blow and suction primers, the amount of ink extracted in a prime is roughly proportional to

$$\int_{t_{start}}^{t_{end}} \Delta P dt, \text{ for } P_{inside} > P_{outside}$$

In the existing designs previously mentioned, the pressure is kept approximately constant during the whole priming action. Also both systems are able to get similar performance.

As previously stated, priming can solve nozzle health problems caused by long periods of print head inactivity. Other print head problems can be solved or alleviated by performing a priming operation, for example dry or crusting ink, air bubbles or foreign particles may be removed from a nozzle or its associated firing chamber. The primed ink on the nozzle plate has an additional washing effect that could act as a dissolvent.

Automatic Nozzle Health Recovery

The storage time and conditions are different for every new print head inserted in the print system. Therefore, there is a high variability in the type and amount of servicing required to recover nozzle health. If the servicing algorithms were designed so that all cases are covered, including worse storage cases, then in most of the cases the servicing waste and time for the new pen initialization would be far over dimensioned. The automatic nozzle health recovery algorithms adjust the type and amount of servicing to the level of nozzle health degradation. As a reference, the amount of servicing time required for print head initialization in HP DesignJet Z-6100 with an automatic servicing adjustment can be cut by half compared to the time required by a fixed servicing strategy.

Specific servicing actions triggered to recover nozzle health after long periods of storage are adjusted based on the nozzle health measured by the drop detector.

When inserting a new print head, the print system performs a mild servicing, which is a compound of spitting and wiping events. This is enough to for short periods of time without the print head being used or for inks not having storage issues. A nozzle health measurement is done just after this initial servicing. In the case of long storage times, for some of the inks the mild servicing is not enough to set nozzles in proper condition for printing. On those cases, the drop detector identifies a large number of missing nozzles and servicing recovery routines are triggered. Such routines include the priming action, which is much more efficient in recovering nozzles than spitting and wiping the print head.

The recovery routines consist of a sequence of servicing steps, at the end of each one a nozzle health measurement is performed. Based on the nozzle health measured, it is decided whether extra servicing is required or the print head is ready to print. There is a maximum number of recovery steps that a print head may undergo. This is a safety measure to avoid an endless servicing loop in case the print head being installed is damaged by any unexpected means that cause a large amount of non-recoverable nozzles.

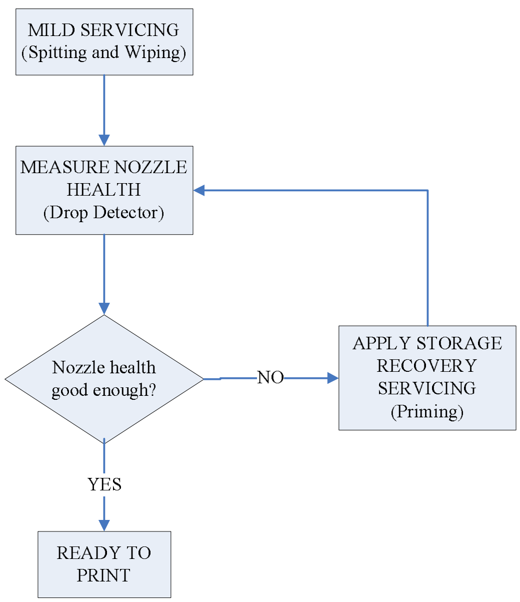

Figure 7 Automatic nozzle health recovery flowchart

The amount of servicing is adjusted for every print head independently. Inks showing worse storage issues will go under more extensive servicing. Those inks showing good nozzle health will not go under a servicing recovery action that includes priming, even if other print heads require extra servicing. Again, the overall servicing waste and time for new print head initialization is optimized.

A very similar process to the one described for new print head initialization is applied after the print system has been powered off for a large period of time (several weeks or months).

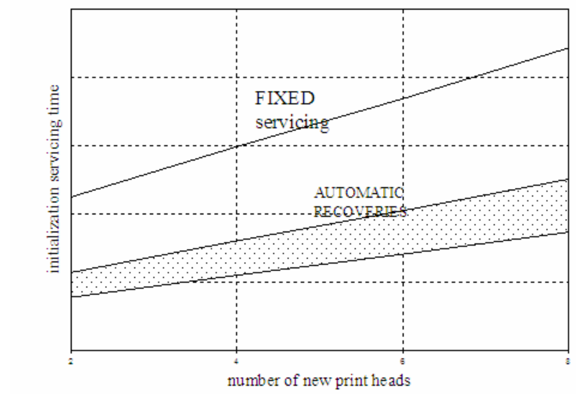

Figure 8 New print head servicing time optimization in HP DesignJet Z-6100

Conclusion

This paper summarizes the nature of pigmented ink print head problems after long periods of inactivity and how the print system manages to optimize the amount of ink and time spent in setting them back in proper printing condition. Nozzle health measurement and priming systems are key players in this process.

The paper describes different nozzle health measurement systems used in the past few years, such as optical and electrostatic sensor solutions. It also shows how these sensor solutions have evolved to respond to the exponential increase in the number of nozzles in the printer over the past few years.

The priming action is an efficient solution for recovering nozzle health after long periods of print head inactivity. The paper provides an overview of different priming hardware solutions used in the past few years, differentiating between blow and suction primers.

The algorithms that operate the print system guarantee that the servicing actions are adjusted to the actual level of nozzle health degradation of each print head. Servicing ink and time are minimized.

Acknowledgement

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Biography

Jose Luis Valero received his M.S in Mechanical Engineering from Escola Tècnica Superior d'Enginyers Industrials de Barcelona (UPC) in

1999. He joined Hewlett-Packard in 2000, working in the area of writing system reliability of inkjet large format printers. He has published several patents on this field.

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Cynthia Jarom received her BS in Chemical Engineering from Cornell University in 1998. She joined Hewlett-Packard in 2000, and is working in the area of writing system reliability of inkjet print heads. She has several patents pending in the areas of servicing and reliability.