Drop Placement Errors In A Thermal Ink Jet Printer

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Abstract

Ink droplets ejected from a Thermal Ink Jet printhead are made to form small spots at specific locations on the paper in order to produce the final printed image. Print quality degradation may occur when the printed spots are not precisely located. Thus, it is important to understand the factors which contribute to drop placement errors, how these errors can be minimized, and the effect such errors can have on image quality. This paper describes the problem and discusses several of the causes of drop placement errors.

Causes of Drop Placement Errors

One of the major causes of misdirected drops being ejected from a Thermal Ink-Jet printhead is the presence of dirt or particulates in the ink. In a Thermal Ink-Jet printhead, a drop is generated when ink is forced through a narrow orifice. Typically, this orifice is only 2-3 mils in diameter. Thus, even particles as small as 1 mil can cause a substantial disturbance or asymmetry in the fluid flow through the orifice. Any asymmetries or blockages of the flow going through the orifice will cause the ejected drop to be mis-directed as it heads toward the paper. In severe cases, dirt may actually cause a small drop or even no drop at all to be ejected from the orifice.

Sources of dirt are abundant. Even when properly filtered ink is supplied to a Thermal Ink-Jet printhead, particulates may pass near or through the orifice. The materials package comprising the ink supply to the printhead may itself be dirty or shed particles. Algae and other organisms may also grow in the ink. Dirt may even be introduced at various stages in the manufacturing process. Drop placement errors due to dirt can be minimized by establishing clean manufacturing environments and procedures, adding filters in the ink supply system which feeds the printhead, and adding biocides to the ink in order to control the growth of living organisms. Generally, only particles whose sizes are much smaller than the orifice or narrowest constriction in the printhead are allowable in the system. Thus, for example, one can determine the maximum acceptable pore size for filters, criteria for "clean" manufacturing environments, and the adequacy of other materials used in packaging the printhead and forming the ink supply system.

The design of the printhead may also play an important role in determining drop placement accuracy. The velocity of the ejected drops is often observed to be correlated with the accuracy with which drops hit their intended targets on the paper. Faster moving drops are generally associated with better jet directionality than are slowly moving drops. As a drop is being ejected, it will experience small lateral forces due to asymmetries both in the fluid flow and conditions at the exit of the orifice or front face of the jet. These lateral forces in turn add a small lateral velocity component to the ejected drop. The ratio of the lateral and forward velocities of the drop will be directly proportional to the amount by which the drop misses its intended target on the paper. thus, the larger the velocity of the ejected drop, the more quickly it will hit the paper, allowing less time for the drop to move laterally from its intended target. A good printhead design, then, will try to maximize the drop velocity without compromising other performance requirements.

The manufacturing procedures used in making printheads may also affect the consistency of the drop ejection process. As discussed previously, any asymmetries produced in the fluid flow in and near the orifice during the drop ejection process, or any non-uniformities of the orifice itself will cause some lateral momentum to be imparted to the drop being ejected. Thus, manufacturing procedures that tend to produce spatial variations or non-uniformities in the fluidic structures will also be prone to producing mis-directed drops. Some printhead designs, for example, make use of an etched glass to define the walls of the channels of each jet in a printhead. Such an etching process is difficult to control accurately, and produces jets that are not completely symmetrical or uniform in size. Printheads of this design have been observed to suffer from poor drop placement characteristics. On the other hand, orientation-dependent etching of silicon is a very stable and repeatable manufacturing process that has been used to make very regular and well-defined channel structures. Symmetrical and relatively uniform structures can also be made from electro-formed nickel.

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Another important factor in determining drop placement accuracy is the condition of the front face of the printhead, or the region immediately surrounding the exit of the orifice. As a drop is ejected from the orifice, some of the fluid which comprises the drop will come in contact with the front face of the printhead. Thus, the wettability of the printhead and the surface tension of the ink will be important in determining how the drop interacts with the front face of the printhead. If, for example, there is ink on the front face near the orifice while the drop is being ejected, surface tension forces will steer the drop in the direction of the ink on the front face. Similarly, any non-uniformity in the wettability of the front face can cause drops to be mis-directed as they leave the orifice. Other mechanical non-uniformities of the front face such as chipping and/or cracking can also pull the drops one way or another as they leave the orifice. Undesirable interactions between the front face of the printhead and the ejected drops are usually minimized when the front face is hydrophobic and repels ink. In this case, surface tension forces are unable to pull the drop laterally from its intended trajectory. The front face of the printhead can be made hydrophobic either through the proper choice of materials, or by application of a uniform hydrophobic coating. Manufacturing techniques and designs that will produce few irregularities or defects on the front face should also be implemented.

Lastly, the printer itself should be designed so that the distance between the printhead and the paper is minimized. When a drop is mis-directed as it leaves the orifice, its lateral velocity will carry it sideways until it impacts the paper. Minimizing the time of flight of the drop will correspondingly minimize the distance by which the drop can move laterally away from its target. Thus, it is desirable to keep the distance between the printhead and the paper as small as possible (consistent with other machine tolerances) in order to obtain good drop placement accuracy.

Summary

Drop placement errors can lead to degraded print quality in a Thermal Ink-Jet printer. Several factors have been discus-sed that can effect the drop placement accuracy. These include dirt or the presence of particulates in the ink in and near the orifice, the design of the printhead, the manufacturing procedures and methods used in making printheads, the condition of the front face, and the distance of the printhead from the paper. A number of steps can be taken to overcome the drop placement errors introduced by these effects. Filters in the ink supply system, along with the establishment of clean manufacturing environments and procedures can effectively minimize the detrimental effects of dirt. Printheads designed to produce fast drops and whose front faces are uniformly hydrophobic will also minimize placement errors. The materials used in packaging the printhead as well as the mechanical design of the printer itself can also be important in controlling drop placement errors. Careful attention to these ideas will minimize drop placement errors in a Thermal Ink-Jet printer and, thus, lead to improved print quality.