Stimulation for High Quality, High Speed Ink-Jet Printers

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Abstract

Drop Generators for continuous ink-jet printers are designed to stimulate the jets to induce uniform drop formation. In printers having arrays of jets, the drops from each of the jets should break off almost synchrounously. This report will desribe the design of a drop generator for use in a high speed, high quality printer which meets these requirements.

Introduction

Since the late 1970's ink-jet systems have been used for direct mail, lottery tickets, and address printing. The DIJIT family of high-speed printers, which have evolved up to the present Kodak 3000 printer, have provided the highest print speeds and lowest cost per page of any non-impact printer. While the print quality of these printers was state of the art when they were introduced in the 1970's, it has not kept up with that of the competitive technologies. The recently introduced Kodak 3500 printer has demonstrated ink-jet print quality that is once again competitive with that of other high volume non-impact printing technologies.

The Kodak 3500 printer can print at speeds up to 500 feet per minute with a resolution of 240 dots per inch. The printer uses four (4) printheads of 4 ¼″ width each to print a 17″ wide swatch. The printheads are based on the binary continuous ink-jet technology originally developed for The Dijit I office printer.

Before focusing on the design of the drop generator, the basics of binary continuous ink-jet technology will be described. A printhead is illustrated in Figure 1.

In this technology, ink is supplied to the drop generator under pressure. The ink squirts continuously out of each of the orifices in an array of orifices, forming ink jets or streams. If left unperturbed each of these streams will break up randomly into drops. The ink jets however can be stimulated to break up into uniform drops by vibrating the orifices or perturbing the ink pressure at an appropriate frequency. As these drops break off from the stream in front of the charge plate they can be charged by induction. The charging is controlled by the voltage on the adjacent charging electrode at the time the drop breaks off from the jet. Charged drops are deflected so they strike the ink collecting catcher. Drops left uncharged are undeflected allowing them to strike the paper. Since the voltage on each charging electrode can be switched between the charging voltage and zero voltage on a drop-to-drop basis, it is possible to individually print or catch each drop.

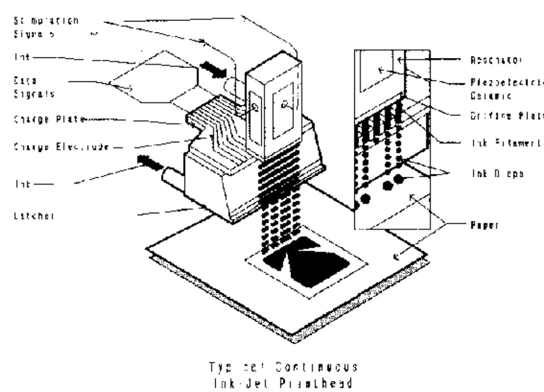

Figure 1. Continuous Ink-Jet Printhead

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It is however necessary to maintain the proper timing between drop break off and the switching of the charging electrode voltage between its two levels. If a drop were to break off during the switching interval, the drop charge and subsequent deflection would be intermediate between the normal print and catch levels. As such drops produce print defects, they must be avoided. Therefore the charging voltage switching interval must not include the time of drop break-off. Ink-jet printers therefore generally provide a means to set or adjust the phase between the drop break off and the switching interval for the charge voltage. For an array of jets, every jet in the array must have drop break off outside the charge voltage switching interval. The drop generator should therefore provide nearly synchronous drop break off for all the jets in the array. This requires very uniform vibration amplitude across the array.

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Drop Generator Design

The Kodak 3500 drop generator provides the necessary vibration uniformity across its array of over 1000 jets. The drop generator stimulates the jets by vibrating the orifices at 50 KHz. The drop generator shown in Figure 2 consists of the following features: a resonant body, an orifice plate, piezoelectric elements, and a fluid cavity.

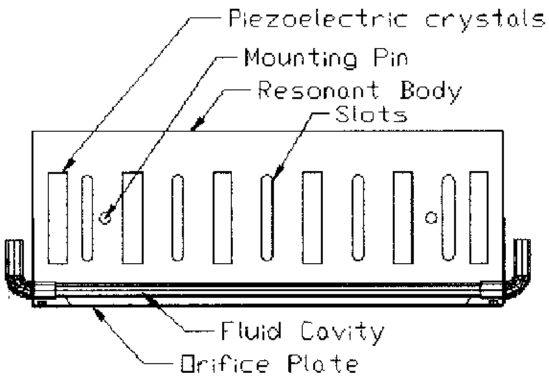

Figure 2. Kodak 3500 Drop Generator

The body of the drop generator is a one-piece block of steel, which is made to resonate. The vibrational mode employed is the longitudinal mode in the vertical direction. The resonant frequency of this mode is approximately given by $f = v/2h$; where v is the velocity of sound in steel and h is the height of the resonator. As the drop generator expands and contracts vertically, it vibrates the orifice plate that is rigidly bonded on the bottom face. This type of drop generator is called a resonant body drop generator, to differentiate it from travelling wave or moving piston drop generators. Resonant body drop generators were initially developed for use in the Dijit I office printer which required a ¼" array of holes. For that application, the drop generator was a simple rectangular block whose height was greater than its width or thickness. In that configuration, the vibration amplitude is quite uniform across the top and bottom faces of the drop generator. As the length of the array is lengthened, the vibration uniformity is degraded. To prevent the vibration uniformity from degrading unacceptably, the drop generator for the Kodak 3500 is segmented by means of slots through the drop generator. The segments between the slots are each narrower than their height so that their vibration uniformity remains quite uniform. The segments are coupled together by the solid material above and below the slots. The coupling insures that the drop generator vibrates at a common resonant frequency as opposed having separate resonant frequencies for each segment. The drop generator is mounted into the rest of the printhead by means of pins that are located on the nodal plane of the drop generator. This resonant body design provides sufficient vibrational uniformity to yield drop break-off phase variations of only about 180º.

To achieve these phase defects, the orifice plate must move with the end of the drop generator without having interfering plate bending modes. This requires a fairly narrow fluid cavity opening to the orifice plate, a .025" wide slot is used. Alignment features incorporated in the orifice plate and drop generator body insure that the orifices are properly aligned with the narrow fluid cavity slot. The orifice plate is bonded to the drop generator using a 1 mil thick layer of epoxy. This thin bond provides the bond rigidity required for good acoustic energy transfer. The use of a thin epoxy layer prevents the epoxy from flowing into or possibly bridging the fluid cavity. The low temperature cure of the epoxy minimizes the thermal stresses that can distort the orifice plate.

Ink is supplied to the orifices by means of a fluid cavity which is machined into the end of the drop generator. A hole drilled through the block from side to side serves as a plenum. The narrow fluid cavity slot connects the plenum to the orifices. Inlet and outlet fluid fittings are made from hypodermic tubing. The tubing is bent to form elbows to keep the overall length of the drop generator small.

Vibration of the drop generator is induced by piezoelectric crystals that are bonded on the front and back surfaces of the drop generator. One piezoelectric crystal is used on the front and back of each segment. The use of multiple crystals decreases the drive voltage requirements for the stimulation. Because of the strong coupling between the drop generator segments however, the use of just one piezoelectric crystal still produces proper stimulation uniformity, but at much higher drive voltages. In addition to the piezoelectric crystals used to drive the vibration of the drop generator, a piezoelectric crystal is used to monitor the vibration. This feedback crystal, which can be bonded on the sides, front, or back faces of the drop generator provides a signal that can be used by the stimulation control servo electronics. By servoing to maintain a constant amplitude from the sensing piezoelectric crystal, the stimulation amplitude and therefore drop break-off length can be properly controlled.

The drop generator outlined above is a key component in the Kodak 3500. Its simple construction provides the consistently high print quality and good reliability which are required in the high speed commercial printing markets.