Rapid Drying and Low Feathering in a Plain Paper Ink-jet Printer

Masao Mitani, Kazuo Shimizu, and Katsunori Kawasumi

Katsuta Research Lab., Hitachi Koki Co. Ltd., 1060, Takeda, Hitachinaka City, Ibaraki, 312, Japan

A new method for high speed drying of wet ink on media, essential for the operation of a high-speed full-color ink-jet printer, is proposed and studied experimentally. Immediately prior to jetting of ink drops, a medium is heated to a very dry condition by bringing it into contact with a moving-belt-type preheater. Experimental results show a clear print quality with low feathering, for such paper as plain paper for laser printers and recycled paper. Also, features such as high-speed drying, short warmup times, low power consumption, compactness, and safety, all inherent in the proposed drying method, are confirmed.

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Introduction

Until recently the idea of applying a drying method to an ink-jet printer has not been implemented. Hewlett-Packard's Desk Jet 1200C[1] will be the first product to actually adopt it. There are very few examples of practical use of this method because the printing speed has been very slow, so that no drying method was necessary. The printing speed of the Desk Jet 1200C is 0.5 ppm in the full-color, entire-surface scanning mode. However, when a large-scale, high-integration printhead is developed, a full-color printer that can exceed 100 ppm will be realized, and drying will become necessary. In fact, the performance of the drying method will determine the maximum printing speed of the printer.

We studied a very efficient drying system with a moving-belt-type preheater, in which a medium is heated to a very dry condition immediately prior to the jetting of ink drops. We found that this system results in less feathering and achieves clear color printing without being affected by moisture conditions during storage, even for plain paper for laser printers and recycled paper. It also has the benefits of high-speed drying, short warmup times, low power consumption, safety, and compactness.

This article reports the results of an experiment in which full-color printing was simulated with only a black ink. We also discuss future possibilities for this drying method.

Experimental Simulation Method

Figure 1 shows an outline of the experimental unit. The printhead is fixed at the downstream side, 40 mm away

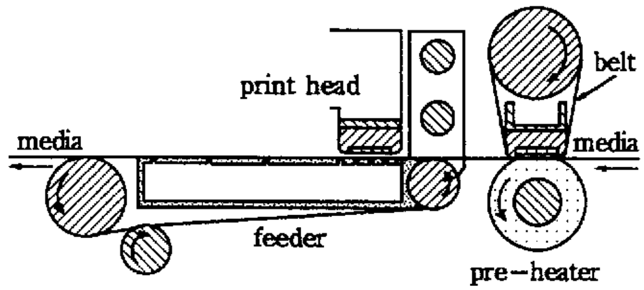

Figure 1. Belt-type preheated printing system.

from the preheater, and the medium is transferred by a belt-type preheater at a constant speed of 25 mm/s. The distance between the media surface and the orifice plate of the print head is 1 mm. The media surface temperature at a side point, which corresponds to an area directly below the printhead, is simultaneously measured by an infrared radiation thermometer. A 360-dpi printhead was used. Except for the print samples of Fig. 2, which were printed in the normal printing mode, ink drops were simultaneously jetted out from three neighboring nozzles while jet-out repetition frequencies of 250, 500, and 1000 Hz were used to evaluate the influence of the overlaying of print dots. The printed dots are independent at 250 Hz but are solid at 500 Hz (100% coverage) and are overlaid (equivalent to full-color printing) at 1000 Hz. Plain paper (55 kg paper from Nippon Paper Industries Co., Ltd.) and recycled paper (55 kg paper from Daio Paper Corp.) were used after being retained for 12 hours at 27°C (room temperature) in atmospheres with humidity levels of 30, 60, and 80%, respectively. The main items evaluated were drying time and feathering. Drying time was measured by pressing a sheet of white paper onto a printed sheet within 3 s after completion of printing in order to allow any undried ink to be transferred to the white paper. Feathering was checked visually in relative terms by aligning print character samples and then enlarging them.

Experimental Results

Bleeding and Feathering. Figure 2 shows an enlarged photo of representative print samples. The storage humidity of the media shown in this figure is 80%, and the preheated temperature is approximately 75°C. The printed dots correspond to 100% coverage. We observed that preheating drastically reduced feathering. Feathering of the recycled paper is minimal, presumably due to the paper fiber being cut during the recycling process and shortened. This tendency of recycled paper is also related to the low drying rate of ink, described later in this report.

Figure 3 shows the degree of feathering when plain paper is used under various conditions. According to Fig. 3, feathering is greatly reduced when the paper temperature

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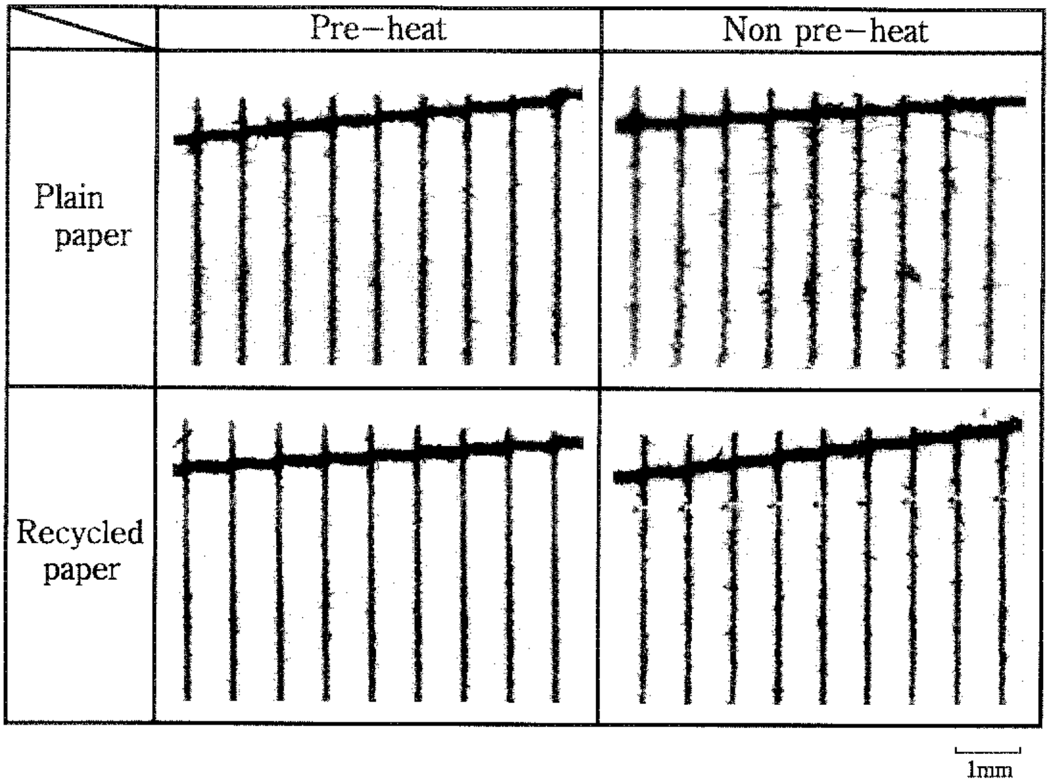

Figure 2. Representative samples of feathering.

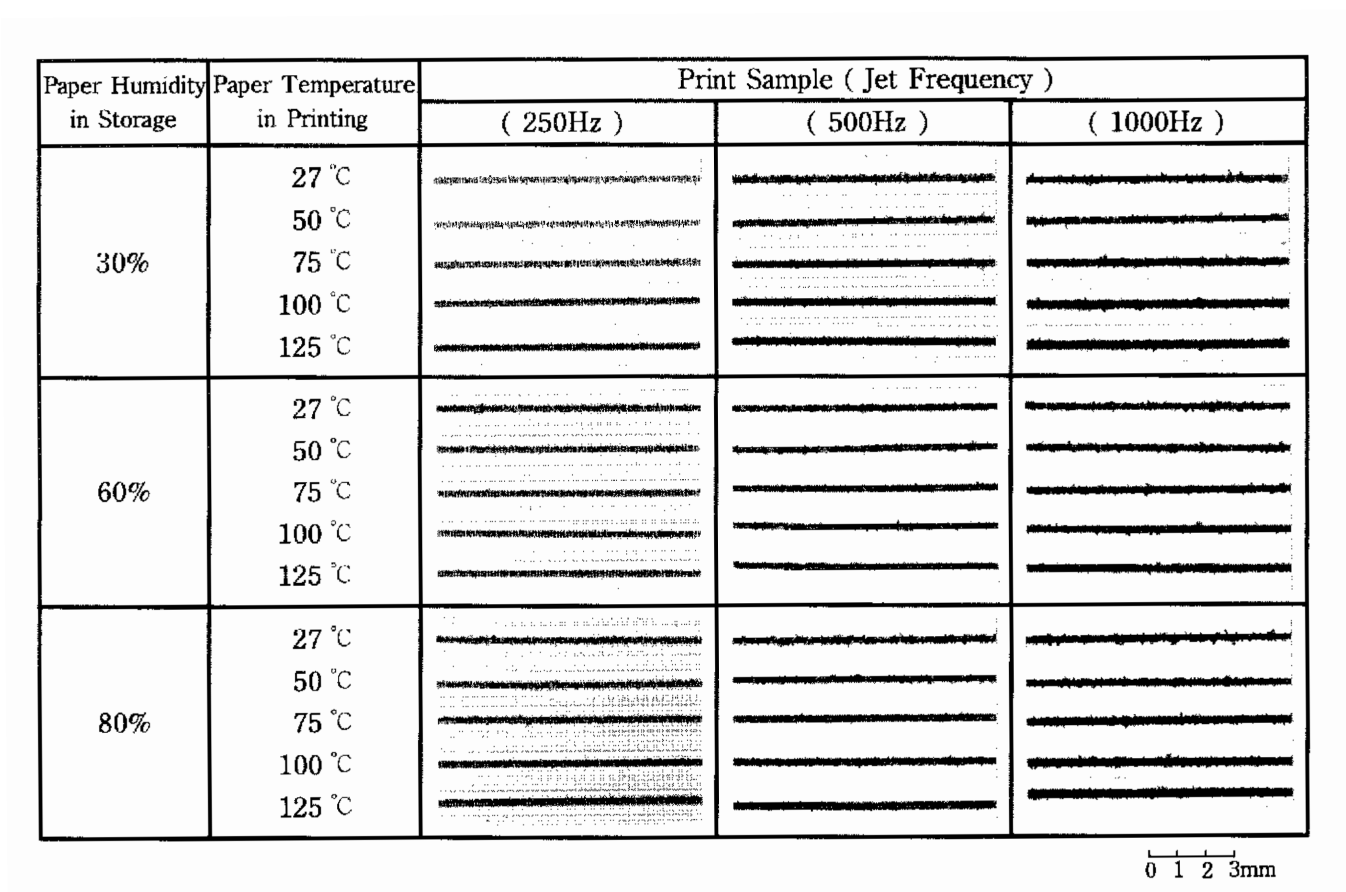

Figure 3. Feathering and thickening with preheated plain paper.

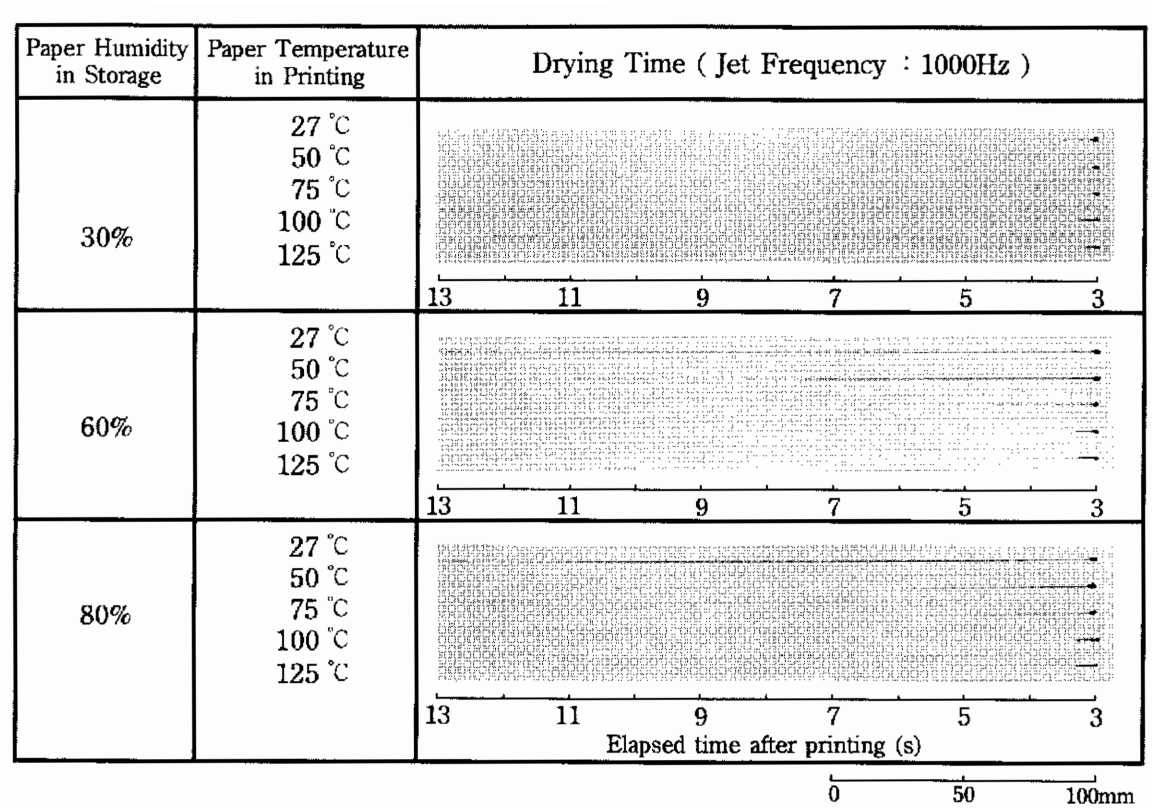

Figure 4. Drying time of preheated recycled paper. After printing left to right, a piece of white paper is pressed onto the printed paper within 3 s. These traces on the white paper show the existence of the undried inks.

is between 75 and 100°C. However, when the paper temperature is increased to higher than 100°C, no further improvement on feathering is noted, but remarkable thickening (due to the rapid boiling of ink) is observed. These results suggest that heating the paper to 100 to 110°C so that it will dry quickly and then reducing its temperature to 70 to 90°C to prevent the orifice surface of the head from being subjected to radiation heating produces the best results.

On the other hand, feathering on recycled paper is essentially minimal, as shown in Fig. 2, unless the paper temperature goes over 100˚C while printing.

Drying Speed. Plain paper could be dried within 3 to 4 s under all of the experimental conditions. However, the drying speed of the recycled paper was slower, as shown in Fig. 4. This figure shows the drying time when the printed dot density is set for 200% coverage, which is equivalent to full-color overlaid printing with four-color inks. A drying time of 6 to 7 s was required for the recycled paper when the paper temperature was 75°C at a storage humidity of 60 to 80%.

Figure 5 shows the relationship between the overlaying of dots and the paper temperature for drying times of 3 to 4 s. A-PPC80 refers to the data obtained when the ink of Canon Inc.'s BJ cartridge (BC-01) was printed on plain paper at a storage humidity of 80%. B refers to the ink of Seiko Epson Corp.'s MJIC1, and the drying speed in this case did not depend on the storage humidity of the paper. The drying speed of ink B is extremely slow because not only is the ink composition different, but the amount of ink per dot is also larger.

Discussion

Specifications for Ink. In conventional ink-jet printers, the ink and media have mainly been responsible for the printing quality and drying speed. However, as explained here, reduced feathering and rapid drying depends entirely on the preheat printing method, and it is not necessary for the ink and media to possess rapid-drying characteristics. This fact will contribute enormously to the practical application of a pigment-type ink, which has tended to clog in the past.

The A and B inks used in this experiment are rapid-drying inks. Therefore, assuming that full-color printing is performed on plain paper and monochrome printing is performed on recycled paper with a slow-drying-type ink, we estimate that a paper temperature of 70 to 90°C will be satisfactory. Using this approach, we believe that high-quality printing can be achieved on both plain paper and

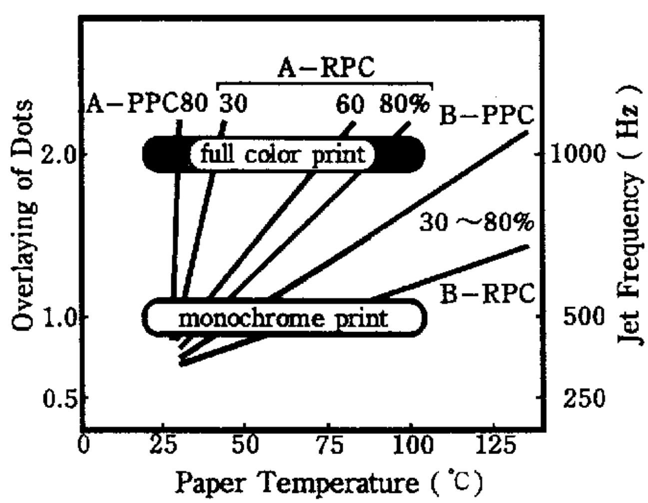

Figure 5. Relationship between overlaying of the dots and paper temperature for drying times of 3 to 4 s.

Table I. Comparison of Performance Between a Belt-type Preheated Printing System and a Radiation Heat Printing System

Item	Belt-type preheated printing system	Radiation heat printing system
Warmup time	(10s)	(55s)
Maximum power consumption	(300W)	(250W)
Temperature control	Unnecessary (PTC thermistor heater)	Necessary
Safety protection	Unnecessary	Necessary
Printing (drying) speed	20 ppm	~1 ppm
Feathering	O	×
Humidity dependence	Independent	Dependent
Clearness	O	×
Envelope, card	O	×

recycled paper at a drying speed of 20 to 30 ppm, even if a slow-drying-type ink is used.

Clear Full-Color Printing Method. From the above experimental results, we understand that the bleeding and feathering of the first dot printed on heated dry paper is small, but that bleeding and feathering of the subsequent dot to be printed, which overlaps the first dot, tends to be large. To take advantage of this phenomenon to achieve clear color printing, nozzle arrays must be set in order from dark colors, especially black, to light colors.

Features of Belt-Type Preheating. Belt-type heaters are used as fusers for laser beam printers.[2,3] The preheater in this report uses a further simplified belt-type heater. Table I shows performance comparisons between this system and the radiation heat printing system.

Conclusion

We found that the preheat printing method with a belt-type heater not only drastically improves the drying speed of ink-jet printers but may also allow high-quality full-color printing on plain paper and recycled paper.

References

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