Estimation of Toner Usage in Xerographic Printing

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Abstract

A method for estimation of toner usage in digital xerographic process is described. This method is used to create toner gas gauge by using both pixel count and pixel transition count obtained from different types of image. Using the ratio of transition count to pixel count , it can develop a more accurate estimation of toner consumption (more accurate toner gas gauge) than just using simple pixel count method. Due to fringe field development effect, different types of images (solid area, halftone and text) consume different toner mass for the same number of pixel counts. By monitoring the transition count (laser on/off or off/on) a determination can be made as to what type of image is being printed and what the corresponding toner mass per pixel should be used ,leading to a more accurate toner gas gauge.

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Introduction

In digital xerographic printers and copiers, the controller software is able to count the actual number of pixels in every image. Pixel counting has been used to estimate the amount of toner used in developing a given image. The estimated value representing the amount of toner consumed is used for controlling the addition of toner to the developer housing in a dual component development system, and to indicate the remaining toner left in the toner cartridge in both single and dual component development systems. In a dual component development system, for example, to maintain print quality throughout the entire printing operation, toner concentration has to be maintained. This involves adding toner to the developer housing in a controlled fashion during the entire processing sequence. In both single and dual component development systems, toner consumption is usually monitored and a warning signal is given to the user when the condition of " End of Life " is nearly approached. In a digital xerographic machine, the number of pixel printed can be roughly correlated to the amount of toner to be used. When using simple pixel counting, the area of pixels developed is taken as fully developed, that is, toner mass developed can be calculated according to the following equation :

$$M=N*A*DMA \qquad (1)$$

where : M is the mass of toner developed
N is the number of pixels developed
A is the area of each pixel
DMA is the maximum developed toner mass/area

This equation, however, fails to account for the different types of images such as text/line, halftone and solid area which will yield different toner mass consumption, and therefore the estimation generated from this equation may be inaccurate.

Experimental

Overview

Figure 1 is a schematic view and flow chart of a single component non-magnetic toner development system. Figure 2 represents a toner dispensing system in a dual component development system. Referring to Figure 1, the printer controller generates the image to be printed in an electronic pixel stream (video data) to the imager ROS (Raster Output Scanner or LSU (Laser Scanner Unit) as well as to a Field Programmable Gate Array (FPGA) unit where both pixel count and transition count per page are counted. The function of the Field Programmable Gate Array (FPGA) is to interface between the controller and the print engine. Video data being sent to the engine is also sent to the pixel counter in the FPGA and this pixel counter keeps track "On" pixel on the page. Another counter in the FPGA is the transition counter register which counts only "On/Off" or "Off/On" transition in horizontal scan direction. Next, the ratio of transition count to pixel count per page is calculated in the controller. This directly provides a corresponding toner consumption per pixel based on the ratio of transition counts to pixel counts, enabling a calculation of toner consumption per page. The calculation of toner consumption per page is in turn subtracted from the previous toner mass remaining, indicating a new percentage of toner remaining. In a dual development system represented by Figure 2, this calculated toner consumption will be converted to dispense time for replenishing toner to the developer housing from a dispensing unit.

Experimental Details

The toner consumption per pixel for different types of images is first determined experimentally to estimate the toner consumption per page and subsequently the remaining toner in the toner gas gauge. The toner mass consumption per pixel and ratio of transition counts/pixel counts for text, halftone and solid area images will vary with the particular printer and should be empirically determined by measuring toner usage for different types of images in a test machine under conditions of commonly used area coverage percentage (e.g. 5 %) and image density (e.g. 1.35). That is, the "fringe-field" effect will vary with different printers due to differences in the photoreceptor, its charge/discharge levels, the developer bias levels, the toner, etc.

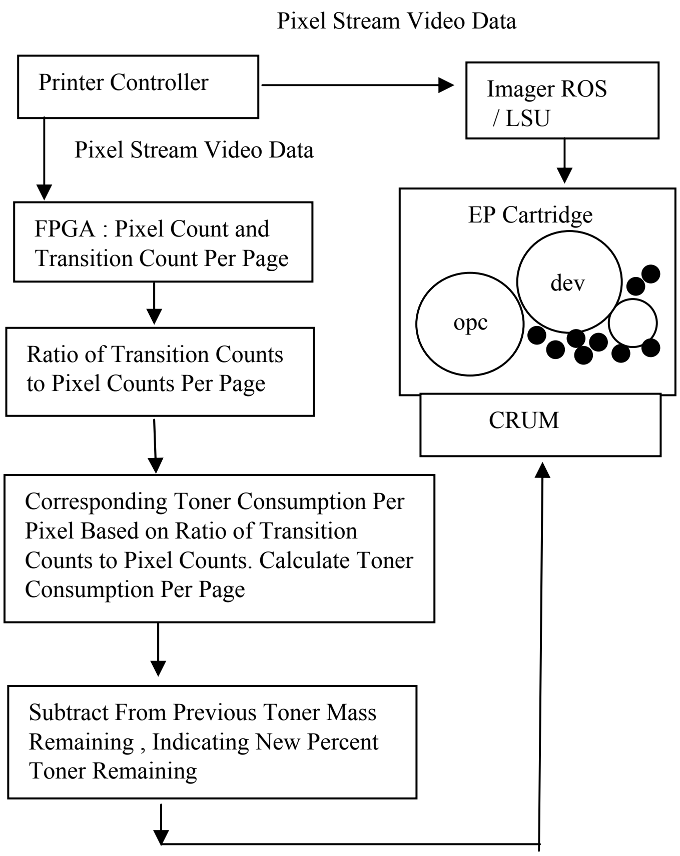


Figure 1 *Non Magnetic Single Component System*

Also, the transition counts and pixel counts for any given image may vary between printers due to differences in the imager spot size and spacing or resolution (number of pixels per inch) and the scan rate.

For a given printer, to obtain toner mass consumption per pixel and ratio of transition counts/pixel counts for pure text (text only) image, the following procedure (a) through (f) is used as an exemplary illustration :

For a print resolution of 600 dpi :

(1) "Pure Text" test pattern (text only). Test pattern can be the text portion taken out from ISO test pattern. Number of pixels =1.346 millions (About 4 % pixel area coverage .)

Procedure :

(a) Weigh the toner cartridge before running experiment (e.g. 2500 grams)

(b) Print 1000 prints on Letter / A4 size paper

(c) After the test, obtain the number of pixels and transition counts and determine the ratio of transition counts/pixel counts.

(d) Weigh the toner cartridge after finishing 1,000 prints.

(e) Obtain the toner mass consumption per page and then toner mass consumption per pixel (toner mass consumption per print divided by the number of pixels per print) expressed in Ng (Nano-gram : 10^{-9} grams).

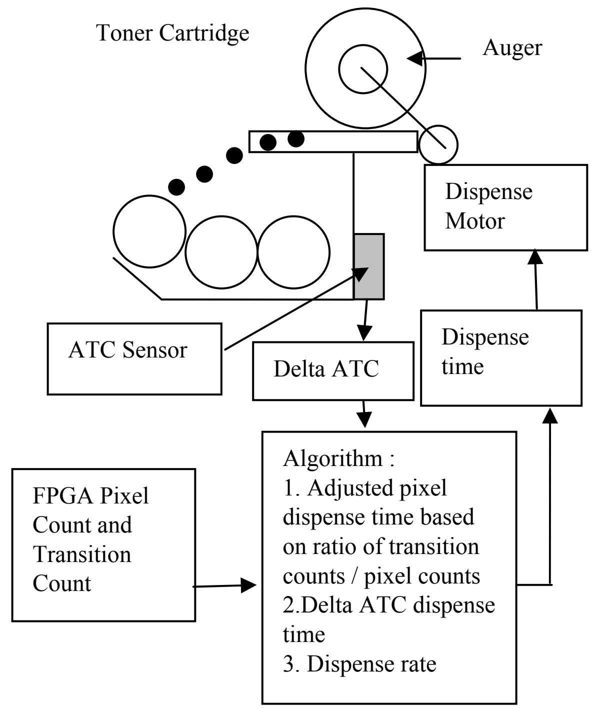


Figure 2 *Dispensing System for Dual Component Development*

(f) Repeat (a) through (e) five times and get the average toner mass consumption per pixel as M1 and get the average ratio of transition counts/pixel counts as R1.

The values above and throughout this paper were chosen for illustration purpose only and serve as examples. For example, 1,000 prints may be any large number of prints and the not limited to five times. Next, for the same printer, to obtain toner mass consumption per pixel and ratio of transition counts/pixel counts for pure halftone the following procedure is used :

(2) "Pure Halftone" test pattern (halftone only). Test pattern can be a combination of different grade levels (e.g. use those taken out from ISO test pattern). Number of pixels =1.346 millions.

Procedure :

Repeat procedures for pure text test to obtain the average toner mass consumption per pixel as M2 for pure halftone and the average ratio of transition counts/pixel counts as R2 for pure halftone. Similarly, to obtain toner mass per pixel and ratio of transition counts/pixel counts for pure solid areas the following procedures is used :

(3) "Pure Solid " test pattern (solid areas only). Test pattern can be a combination of several solid patches and those taken out from ISO test pattern. Number of pixels =1.346 millions.

Procedure :

Repeat procedures for pure text to obtain the average toner mass consumption per pixel as M3 for pure solid and the average ratio of transition counts/pixel counts as R3 for solid area.

To verify the accuracy of toner consumption per pixel for each type of images , an ISO standard test pattern is used in the following procedures :

By way of example and for purposes of illustration, the ISO standard test pattern contains :
(1) Number of pixels in the standard test pattern = 1.346 millions.
(2) 76.17 % of text image, number of pixels = 1.0252 millions.
(3) 5.28 % halftone image, number of pixels = 0.0710 millions.
(4) 18.55 % solid area image, number of pixels = 0.2497 millions.
Procedure :
(a) Weigh the toner cartridge before running experiment.
(b) Print 1,000 prints on Letter/A4 size paper.
(c) Weigh the toner cartridge after completing 1,000 prints.
(d) Obtain the tone consumption per one print of standard test pattern.

The actual toner consumption per print from the test should be equal or close to 1.0252 millions * M1 + 0.0710 millions * M2 + 0.2497 millions * M3.

Ratio of transition counts to pixel counts and the corresponding toner mass consumption per pixel from images containing various types of images and various percentages of each type of images can be determined experimentally by running the tests according to the different combinations as illustrated in the following tables.

Table 1 contains image patterns consisting of only one image type :

Table 1. Image pattern containing single image type

	Pure Text	Pure HT	Pure Solid
Ratio of transition counts to pixel counts	R1	R2	R3
Toner mass per pixel	M1	M2	M3

It is expected that for a given number of pixels for an image, there will be more transition counts (More On/Off and Off/On transitions) for halftone pattern and the ratio of transition counts to pixel counts would be larger than the other two types of images. Since there is less transition for solid area pattern, the ratio of transition counts to pixel counts for solid area is expected to be the smallest among the three types of images.

Table 2 contains image patterns consisting of two types of images (text and halftone) with different R values and M values obtained from different combinations of area coverage percentages. Other ratios of transition counts to pixel counts and toner mass per pixel for image pattern containing text and solid, solid and halftone with different area coverage percentages can also be obtained from other test designs.

Table 2 . Image pattern containing double image types

(For example, image pattern containing text and halftone)

	Area Coverage Percentage %								
Text	90	80	70	60	50	40	30	20	10
Halftone	10	20	30	40	50	60	70	80	90
Ratio of transition counts to pixel counts	R 11	R 12	R 13	R 14	R 15	R 16	R 17	R 18	R 19
Toner Mass per pixel	M 11	M 12	M 13	M 14	M 15	M 16	M 17	M 18	M 19

Table 3 contains image patterns consisting of three types of images (text, halftone and solid area) with different R and M values obtained from different combinations of area coverage percentages. Ratio and toner mass per pixel for other combinations of area coverage percentages can be obtained accordingly.

Table 3. Image pattern containing triple image types

	Area Coverage Percentage %								
Text	90	80	70	60	50	40	30	20	10
Halftone	5	10	15	20	25	30	35	40	45
Solid area	5	10	15	20	25	30	35	40	45
Ratio of transition counts to pixel counts	R 21	R 22	R 23	R 24	R 25	R 26	R 27	R 28	R 29
Toner Mass per pixel	M 21	M 22	M 23	M 24	M 25	M 26	M 27	M 28	M 29

All these R and M values obtained experimentally from various patterns containing various image types and various area coverage percentages can be stored in the controller or other non-volatile memory (NVM) within the printer. They can be used in the algorithm for the calculation of toner consumption and gas gauge. Each R value is assigned for a range of interval so that no matter what ratio is obtained from the printed page, it falls into one of the R value range and the corresponding M value can be determined. For example, R11 covers values from 0.05 to 0.10, R12 covers from 0.11 to 0.15, etc. The corresponding M11 and M12 will be used based on the value range for the calculations of toner consumption for this page. The toner consumption of this page is obtained from multiplying the pixel counts of this page by the M value assigned. This toner consumption is subtracted from previous remaining toner mass and the new toner remaining % can be used for toner gas gauge. The gas gauge can also be expressed in the following equation:

Toner remaining % = 100 *(Toner capacity – Total of Current and Previous toner consumption)/Toner capacity

Getting all R and M values shown in the tables for double and triple image types with different combinations require conducting many experiments and consuming a lot of time. However, depending on the design of experiments, a few R and M values would also be able to provide adequate information for the construction of toner gas gauge as indicated in the examples in Results and Discussion section below.

For 1200 dpi resolution, similar experiments can be run to obtain various M values with respect to various ratio of transition counts to pixel counts. It is expected that the toner mass consumption per pixel for 1200 dpi will be roughly about a quarter of that of 600 dpi.

In every printer cartridge there is an initial amount of toner filled according to the toner life specified for this printer cartridge at a specified image pattern and area coverage. For example, using the ISO test pattern (Consists of different types of images with various percentage respectively for a given area coverage %), how many page this printer can print this ISO test page before toner is exhausted? In this case, an ISO test pattern is printed and the ratio of transition counts to pixel counts R_{ISO} and the corresponding toner mass per pixel M_{ISO} can be determined and stored as other R and M values in the controller code. Initial toner weight may be stored as a pixel count or as an actual toner weight in the controller. By way of example, for a 10 K (Ten thousands prints of ISO test pattern) cartridge, the toner to be loaded is about M_{ISO} *1.346 millions*10,000 grams plus pre-determined amount of unused toner (Assume 1.346 millions of pixels are printed in an ISO test pattern). A CRUM (Customer Replaceable Unit Monitor) is an EEPROM (Electrical Erasable Programmable Read Only Memory) and is installed in the toner cartridge. It receives the information about toner usage from the controller.

As each page is printed, the pixel counts and transition counts are monitored for that page in FPGA. These counts are read by the controller. From the ratio of transition counts to pixel counts for this page, the corresponding toner mass per pixel is obtained from the algorithm. The number of pixels for that page is then multiplied by the toner mass per pixel to determine the toner consumption for that page. This toner consumption amount is subtracted from the previous remaining balance of toner. This new toner remaining percentage value is saved and transmitted to and stored in the CRUM. After the pixel count and transition count are read by the controller, FPGA will reset for the next job. This process continues until the warning level for remaining toner is attained ("Low Toner" signal). The user is then alerted that toner is nearing its "End of Life" condition. The process continues until a calculated remaining toner percentage of zero is attained, which should coincide with the toner cartridge being empty. That is, continuously subtracting calculated toner usage this way from the known initial installed toner amount or previously calculated remaining amount until the balance amount reaches zero and automatically gives an "Out of Toner" indication, without ever actually sensing the toner by the toner low sensor. This method can provide substantial hardware cost saving as compared to other sensor system.

For a dual component development system as illustrated in Figure 2, toner in the cartridge is added to the developer housing to replenish the depleted toner during development process to maintain proper toner concentration in the developer. Toner dispensing algorithm receives inputs from three sources to determine the proper dispense time : (1) Pixel count multiplied by the ratio of transition count to pixel count. This value is then converted to dispense time or to auger rotation count. (2) Delta ATC (Automatic Toner Control).This is the difference in concentration between current toner concentration and target toner concentration (The toner concentration that can provide good print quality). This value is then converted to dispense time or auger rotation count. (3) Job length (Number of page per job). Due to over run of dispense motor after "On" signal is terminated, dispense rate should be adjusted to accommodate for different job lengths which may have different levels of over run.

Once the algorithm receives threes inputs and use the information to generate required dispense time, toner concentration can be maintained during operation of the printer. At the same time, a toner gas gauge can be constructed and the toner remaining % can be obtained. To generate a toner gas gauge showing toner remaining percentage, the following equation can be used :

Toner remaining % = 100 – (Dispense rate*Dispense time *100/Toner capacity)

where Dispense time (Auger rotation count) is obtained from the algorithm based on three inputs and toner capacity is the initial toner amount in the cartridge.

The delta ATC source can be eliminated from the algorithm if the adjusted pixel count (Adjusted by ratio of transition count to pixel count) and the dispense rate (Selected from different job lengths) together can provide a good print quality and accurate toner gas gauge. In this case, the TC sensor is not required and saving on hardware cost can be achieved.

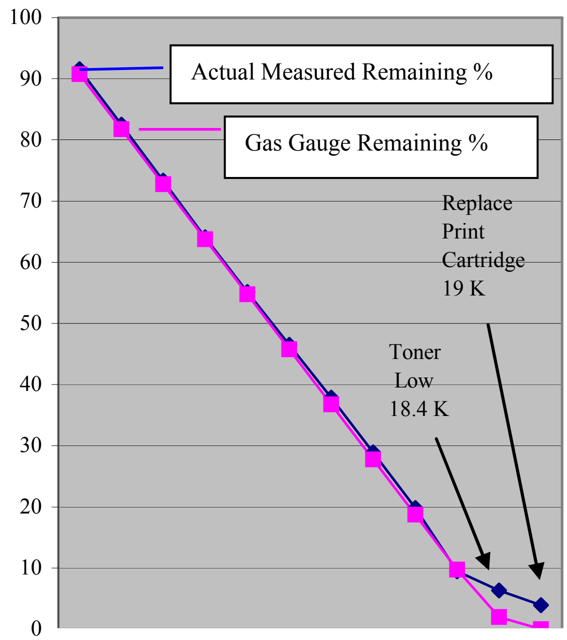
Results and Discussion

This method of estimation of toner usage and construction of toner gas gauge was applied to a single component development system. The toner cartridge was a 18.5 K life CRU (Customer Replace Unit) installed with a low toner sensor just for verification purpose . Both the ISO test pattern and a combination of mixed jobs consisting of different types of images with different percentages were used in the test. In this test, only 6 R values and 6 M values were used for the sake of simplicity. Figure 3 illustrates the test results from running the ISO test pattern only.

As indicated from the graph, the toner remaining % from gas gauge was almost identical to actually measured toner remaining % throughout the entire cartridge life. Towards the end of the toner life, the "Toner Low" and "Replace Print Cartridge" between the gas gauge and toner low sensor was within 5 %.

When this method was applied to a 10.5 K CRU testing on the ISO test pattern, similar result was obtained as illustrated in Figure 4 below.

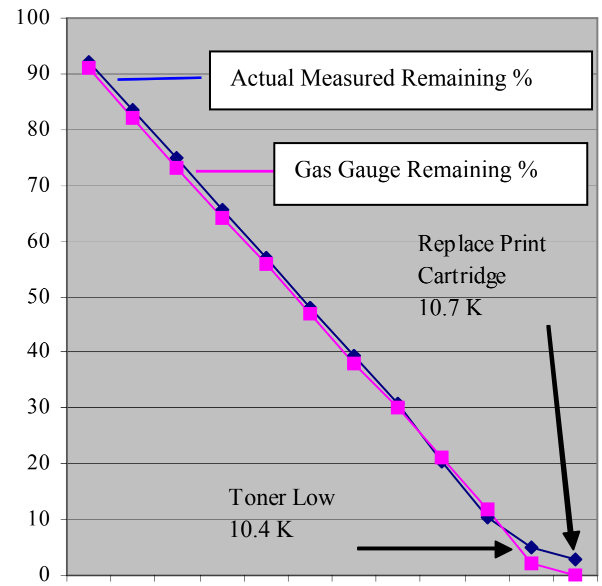
Toner Remaining % : Toner Gas Gauge VS Actual Toner Remaining 18.5 K Toner Cartridge



Print Volume (Page) on ISO Test Page

Figure 3

Toner Remaining % : Toner Gas Gauge VS Actual Toner Remaining 10.5 K CRU



Print Volume (Pages) on ISO Test Page

Figure 4

Next, mixed jobs which consisted of various types of patterns with different percentages of text, halftone and solid area and with various area coverage % were tested on a 18.5 K CRU using the same algorithm. The area coverage % among the mixed jobs were between 3.11 % to 10.16 % (Pixel input %). They represent the normal print jobs customers would use. Due to a larger than 4 % pixel area coverage , the print volume was reduced to about 17.6 K prints.

As indicated from the Figure 5, the gas gauge worked very well and was coincided with the actually measured toner remaining %, showing excellent performance of the gas gauge when monitoring the toner usage when printing a mixture of different jobs .

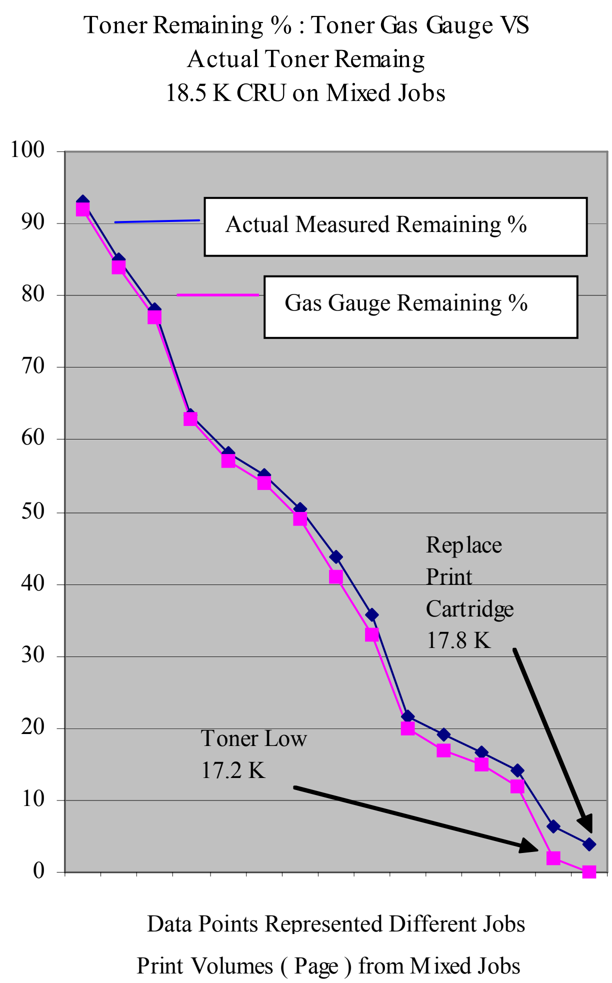


Figure 5

Conclusion

The method of estimation of toner usage for laser printer technology described in this paper presents a more accurate way of estimation of toner consumption than just using pixel count as the only tool for the calculation. Due to "Fringe field" development effect, toner consumption per pixel will be different depending on various types of images such as text, halftone and solid area. Using the ratio of transition counts to pixel counts in the estimation algorithm, toner consumption per pixel for different types of image can be more accurately determined. This estimation method can be applied to both single component and dual component development systems to produce a more accurate toner gas gauge and to better maintain toner concentration in the developer in dual component development system. It is important that the toner gas gauge should be accurate so that it can provide the user a correct warning signal that toner is getting low and a new cartridge should be prepared before toner is running out. It should not give the users a surprise that the images they are printing suddenly get deleted when the gas gauge is showing plenty of toner is still left. If more tests are conducted in developing the gas gauge, an accurate gas gauge can be produced and toner sensor may not be required in both single and dual component systems. Saving on hardware cost (toner sensor)can be achieved.

Reference

1. Kaiser Wong . et al, "Estimation of Toner Usage" , US Paten 6,810,218. Oct.26, 2004.

Author Biography

Kaiser Wong worked for Xerox in El Segundo in development of thermal ink jet, acoustic ink jet and laser mono and color printers for twenty years. The latest works were focused on laser engine development and reliability test. After leaving Xerox, he worked for the Printing Division of Samsung Electronics in Korea and now works as a consultant. He received his MS from the University of Massachusetts at Amherst.