Pre-installation Assessment of Doctor Blade Quality in Electrophotographic Printers

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Abstract

The doctor blade is a steel blade installed in electrophotographic (EP) printers as one of the ways to control the toner flow. It meters the amount of toner on the developer roller surface to develop a uniformly distributed toner layer on the photoconductor (PC) drum surface. The blade straightness can affect the overall uniformity of the printed page. In this paper, we propose an approach for quantifying the blade straightness to help assess the quality of the doctor blade before its installation into the printer. A polynomial fitting approach is applied to the straightness data measured directly from the blade. The probability mass function of the polynomial slopes is derived. The probability of the straightness variation provides a measure of the blade's quality. The same approach is applied to scans from printed samples showing artifacts caused by the same blade. A pass/fail criterion is used for both measures to determine their consistency in assessing the quality of the blade. Our experimental results show that both measures agree, for 20 of the 24 blades tested. This high level of consistency verifies the validity of assessing the blade quality from direct measurements on the blade using the proposed approach.

Introduction

Measurements are usually performed on scanned images of printed pages to provide ways of quantifying print quality. The detection of any sort of non-uniformity in any printed pages of flat field imagery can indicate the existence of one or more printing artifacts or defects [1]. In addition, the defect characteristics can indicate the source of the defect. In this paper, we are concerned with artifacts caused by imperfections in doctor blade straightness. Two different approaches are presented to measure the straightness of the blade, by either direct measurements on the blade or indirect measurements on printed images.

The goal is to provide approaches that can be applied to the two types of measurements so that consistent decisions about blade quality can be taken. Figure 1 shows images having non-uniformities caused by defective blades. The defect can be characterized, in general, by low frequency signals [2]. Sharp transitions can add high frequency components to the fundamental low frequency signals.

A doctor blade is used in electrophotographic printers to meter and charge the toner on the developer roller, see Figure 2. This metering serves to provide a uniformly distributed toner layer on the developer roller and also charges the toner through triboelectric charging as a result of friction between toner particles. This charge helps with toner transfer between the developer roller and photoconductor drum. Toner which is improperly metered/charged can lead to artifacts such as banding, fade-to-color and other undesirable print defects.

The doctor blade in printers using non-magnetic toners is typically made from steel and is very rigid. The blades are charged and in direct contact with the surface of the developer roller. For printers using magnetic toner, the doctor blade has a compliant polymer surface. Either type may also be coated to prevent excessive wear.

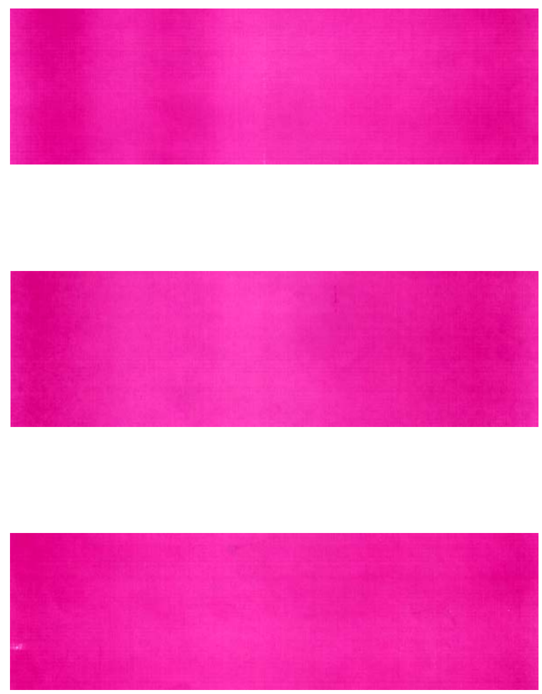

Figure 1. *Examples of printed pages with non-uniformities caused by imperfections in doctor blade straightness. The defect can be characterized by vertical bands of low frequencies with the possibility of including high frequencies due to sharp transitions.*

Improperly metered or charged toner can arise from various sources. These include defects in the coating on the blade, doctor blade surface roughness non-uniformity, and the overall straightness of the blade profile. Each defect can have a negative effect on the ability of the blade to provide uniform toner metering/charging which leads to a toner layer that may be either too thick or too thin on the developer roller.

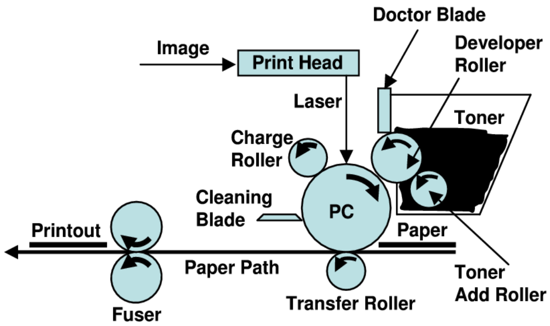

Figure 2. EP Print Toner Cartridge: The charge roller charges the surface of the PC to a certain voltage. The PC is then exposed to a modulated laser beam to generate the latent image on the surface of the PC. The charged toner particles on the developer roller are attracted to the regions on the PC exposed to the laser. The transfer roller transfers the toner particles from the PC onto the paper. The fuser then melts the toner onto the paper. The residual toner on the PC is removed by the cleaning blade.

The defects described in this paper stem from irregularities in the straightness of the blade. A camera system was used to measure the straightness of the doctor blade along its entire length, and this straightness data was correlated with the overall uniformity of printed pages. By quantifying this straightness to assess the quality of the blade prior to insertion into the printer cartridge, we hope to avoid the cost associated with obtaining the printed pages.

Issues related to the straightness of the doctor blade have received little attention in the literature. More commonly addressed problems are scoring and streaking [3, 4]. Excessive pressure against the developer roller can cause slivers or burrs of the doctor blade edge to break off and gouge the roller's surface, causing one form of streaking [5]. Toner particles can adhere onto the doctor blade, melting and accumulating until streaks appear [6]. Nevertheless, many recognize the importance of maintaining uniform, consistent flex across the entire length of the blade [7], even if the blade straightness is not mentioned explicitly.

Analysis of Doctor Blade Straightness and Printed Page Uniformity

Imperfection of the blade straightness results in a low frequency L^* variation across the page with possible high frequency components due to sharp transitions. To model straightness data measured directly by a camera system scanning the blade length, we use a polynomial fitting method with degree $n = 17$. Then we print a page after assembling this same blade into a printer. We scan this page and model the straightness with a polynomial of degree $n = 13$. To accommodate more for the sharp transitions, the direct straightness measurements are modeled by a polynomial of a higher degree.

Since analysis is similar except for the polynomial's degree selection, we will describe the proposed approach using image data. First, the $M \times N$ image $I(x,y)$ is collapsed from two dimensions into a one-dimensional profile, perpendicular to the artifact direction as:

$$f(x) = \frac{1}{M} \sum_{y=0}^{M-1} I(x,y) \tag{1}$$

A polynomial of degree n is used to fit the 1-D profile of the artifact as:

$$g(x) = p_n x^n + p_{n-1} x^{n-1} + \ \ldots \ + p_1 x + p_0. \tag{2}$$

For a given data record of size N, pairs $(x_0, f(x_0)), (x_1, f(x_1)), \ldots, (x_{N-1}, f(x_{N-1}))$ are used to solve for the polynomial coefficients $p_0,\ p_1, \ldots,\ p_n$ in a least squares sense as:

$$\begin{bmatrix} f(x_0) \\ f(x_1) \\ . \\ . \\ . \\ f(x_{N-1}) \end{bmatrix} = \begin{bmatrix} 1 & x_0 & . & . & x_0^n \\ 1 & x_1 & . & . & x_1^n \\ . & . & . & . & . \\ . & . & . & . & . \\ . & . & . & . & . \\ 1 & x_{N-1} & . & . & x_{N-1}^n \end{bmatrix} \begin{bmatrix} p_0 \\ p_1 \\ . \\ . \\ p_n \end{bmatrix} \tag{3}$$

The proposed measure is based on calculating the slope of the L^* variation in the direction of the artifact. We calculate the slopes at measured points using $s_x = g'(x)$, the first derivative of $g(x)$, to generate N data slopes pairs $(x_0, s_{x_0}),\ \ldots,\ (x_{N-2}, s_{x_{N-2}}), (x_{N-1}, s_{x_{N-1}})$. These slopes are assumed to be observations of a random variable S_x. Then we can get an empirical distribution, $P_i(S_x)$, by using the histogram of the slopes. An example of a histogram of the slopes of one test sample, is shown in Figure 3.

A measure describing the probability of the defect can be derived as:

$$D_i = 1 - P_i(s^- \leq S_x \leq s^+) = 1 - \sum_{S_x = s^-}^{s^+} H_n(S_x) \tag{4}$$

where s^- and s^+ are thresholds for acceptable negative and positive slopes, respectively and $H_n(S_x)$ is the normalized histogram of slopes. A similar expression can be derived for the measure D_s from the straightness data.

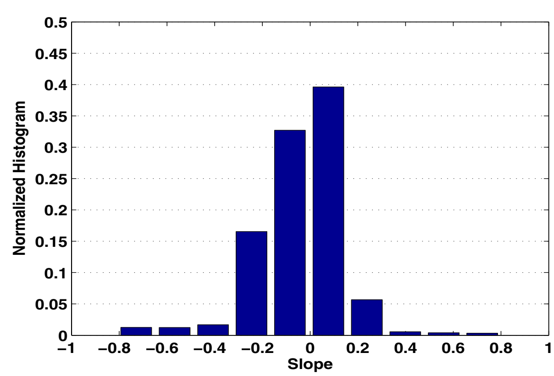

Figure 3. Distribution of slopes of a defect signal measured from a printed image.

Table 1. Probability measures for doctor blade quality based on straightness data and printed images.

Blade No.	1	2	3	4	5	6	7	8	9	10	11	12
D_s	0.41	0.32	0.31	0.34	0.45	0.21	0.21	0.21	0.38	0.45	0.52	0.42
D_i	0.43	0.35	0.36	0.28	0.33	0.34	0.27	0.39	0.58	0.44	0.51	0.59
Decision	FF	PP	PP	PP	FP	PP	PP	PP	FF	FF	FF	FF
Blade No.	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
D_s	0.23	0.45	0.32	0.35	0.28	0.45	0.41	0.45	0.49	0.35	0.54	0.36
D_i	0.55	0.40	0.56	0.51	0.46	0.47	0.44	0.59	0.51	0.63	0.47	0.46
Decision	PF	FF	PF	FF	PF	FF	FF	FF	FF	FF	FF	FF

Experimental Results

The objective of this experiment is to show the correspondence between two measurements of blade straightness. One measurement is obtained directly from the blade, using a camera system. The second measurement is obtained indirectly, from print samples measured after installing the blade into a printer. This correspondence can lead to assessing the quality of the blade directly without the need of printing test samples.

The experiment was performed on 24 blades. Measurements of blade straightness were then used by the proposed approach (using a polynomial of degree $n = 17$ for data fitting). Then a probability measure, D_s, was used to quantify the straightness imperfections of each blade. The blades were then installed, and the printed samples associated with each blade were analyzed by applying a polynomial fitting of degree 13. The printed pages had four constant coverage (flat field) areas, typically at 10%, 30%, 70%, and 100%. The probability measures, D_i, from these areas were then averaged to generate a single measure.

A pass/fail criterion was used to exclude the defective blades based on the measure D_s from direct straightness measurements and indirect measure D_i from the images separately. In this experiment, we chose a threshold $P_s = 0.35$ to exclude blades having $D_s \geq P_s$ based on straightness measurements and a threshold $P_i = 0.4$ to exclude blades having $D_i \geq P_i$ based on measurements from images.

A letter "F" was used to indicate blade failure, while the letter "P" was used to indicate blade success (pass). Table 1 summarizes the results of these experiments, where the first letter indicates the decision from the straightness measurements and the second letter indicates the decision from the image measurements. Thus, a decision of FF or PP means both measures agreed, which occurred for 20 of the 24 blades tested. Figure 4 shows profiles from images (left column), and blade straightness (right column), and their corresponding polynomial fit.

By comparing the left and right graphs, one can notice the correspondence between measurements from straightness data and printed images.

Conclusions

In this paper, we present two approaches to quantify the quality of the doctor blade in EP printers. Both approaches are based on the polynomial fitting of straightness measurements, either of the blade before installation or the L^* profile from printouts after installation. We then used a probability measure to quantify the blade before and after installation based on the distribution of the polynomial slopes at each measurement of straightness or the across the printed page (in the scan direction). Our experiment on 24 blades shows high correlation between the assessment of blade quality from both blade measurement (before installation) and from printed samples (after installation). These results show the possibility of measuring the quality of the blade from simple measurement before installation.

References

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Author Biography

Ahmed Eid received both his BS and MS in Electronics and Communications Engineering from Mansoura University (1994) and (1999) respectively. He received his PhD in Electrical Engineering from the University of Louisville (2004). He joined Lexmark International Inc. in 2005. His work focuses on image and print quality. His other research interests include 3-D data modeling, image registration, segmentation, and fusion. He is a member of IEEE and its computer and signal processing societies, IS&T, SPIE, and ACM.

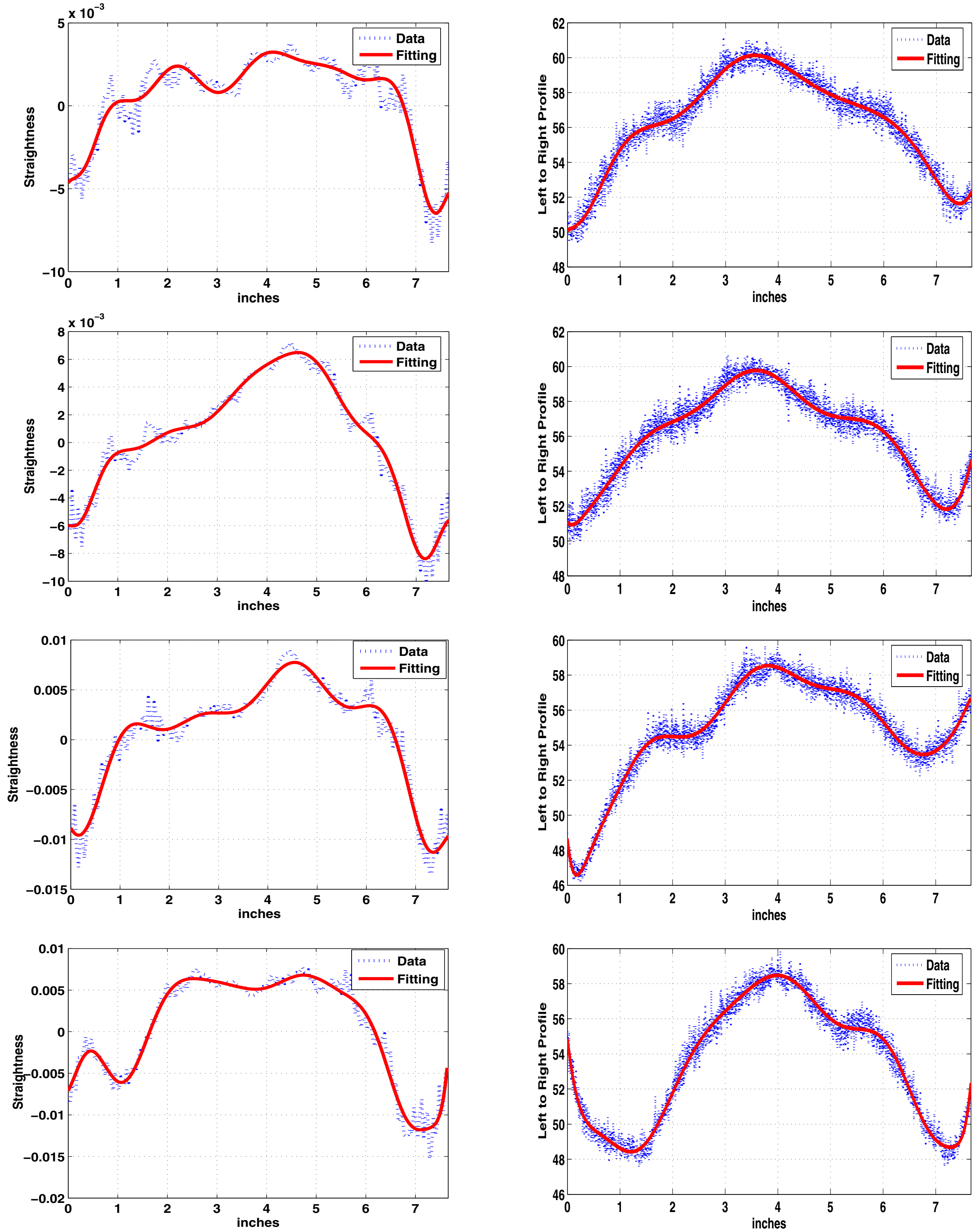

Figure 4. *Doctor blade quality assessment: direct measurements on the blade (left column), and indirect measurements from printed images (right column).*