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Analysis and evaluation of magnetism of black toners on documents printed by electrophotographic systems

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ABSTRACT

This paper reports on a study to assess the potential of measurements of magnetism, using a proprietary magnetic analysis system, for the routine analysis of toners on documents printed by black and white electrophotographic systems. Magnetic properties of black toners on documents printed by a number of different devices were measured and compared. Our results indicate that the analysis of magnetism is complementary to traditional methods for analysing black toners, such as FTIR. Further, we find that the analysis of magnetism is realistically applicable in closed set cases, that is when the number of potential printing devices can be clearly defined.

1. Introduction

Due to the wide distribution and availability of business printing machines over the past 40 years, forensic document examiners now commonly face the need to analyze documents produced by electrophotographic printing processes using a dry toner. Black and white electrophotographic printing systems, that is laser printers and/or photocopiers, are part of this class of technology. Nowadays, forensic document examiners routinely examine documents printed by such systems by means of a stereomicroscope, by organic and inorganic chemical analyses or by using image analysis systems. They use these methods when they are requested to help, for example, with the issue of whether or not two or more documents were printed with the same laser printer or the same cartridge unit.

Analyses of toners and electrophotographic printing systems are well documented in forensic literature [1,2]. Herlaar et al. [3], for example, extensively explored a fast method based on magnetic analysis, providing quantitative measurements. In this paper, we study the complementarity of this technique and traditional methods of analysis, such as FTIR, in view of routine examinations of magnetism of black toners on printed documents.

In order to assess the extent to which measurements of magnetic flux may be used in operational forensic casework, it is necessary to gain an understanding of several aspects related to magnetism of black toners and the measurement of this property. On the one hand, it is necessary to assess whether magnetism can be consistently measured by different operators using a commercially available measuring device. Such understanding is important to decide, for example, if part of the items (e.g., known and questioned) may be analysed by different operators. On the other hand, it is necessary to investigate magnetic properties of printed documents produced by the same and different printing devices (i.e., toner type, brand and model). In this paper, we approach these topics as follows. Section 2 explains the collection of reference documents produced under controlled conditions, that is the model and make of the printing device as well as the toner type (and FTIR properties) known from previous research [5,6]. This section also introduces the measuring device for magnetism used in the experimental part of the study and the preliminary testing of this device. The results of the analyses of magnetism are presented in Section 3, including a study of prototype evaluative case examples, using established probabilistic interpretation

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schemes [e.g., 4]. Discussion and conclusions are presented in Section 4.

2. Materials and methods

2.1. Collection of documents printed by black and white electrophotographic systems

This study used photocopied documents from 61 different multifunction black and white electrophotographic printing systems, which all use magnetic toner (Table 1). These photocopy printouts were collected earlier in 2009 for other research purposes (as part of a field study), not specifically related to the study reported in this paper. Among the 61 printing systems, only two main brands are encountered, that is Canon and Kyocera Mita. Table 1 summarises the different brand and models available, their original toners and FTIR group (named generically by a number), determined as part of previous research [5,6]. Some combinations of brand/model and toner type were encountered several times. With each device listed in Table 1, the same standard text was photocopied and printed. For various reference purposes, additional documents were printed with a Canon SmartBase PC 1230D copier (see also Sections 2.4.2 and 2.4.3).

2.2. Methods and instrumental techniques used

2.2.1. Fourier Transform Infrared spectroscopy (FTIR)

Fourier Transform Infrared spectroscopy is a suitable method for the analysis of organic binders present in toners. Analyses of toners were performed, as part of previous research (see Tables 1 and 2), by microscopic Attenuated Total Reflectance (ATR) with an Internal Reflection Element (Germanium crystal) using a Digilab® Excalibur spectrometer, Canton, USA. FTIR spectra were acquired from 4000 to 650 cm^{-1} with a resolution of 4 cm^{-1} and 64 scans were co-added for each spectrum. For shortness of notation, we summarise FITR group assignments generically by a single number.

2.2.2. Analysis of magnetic properties using a magneto-optical visualizer

Single-component toner powders, which contain magnetic material, incorporated into the toner particles when fixed onto the paper, exhibit magnetic properties similar to other forms of magnetic printing. The magnetic properties, particularly the magnetic flux (nWb), were measured using the Regula Magmouse Model 4197. All the measurements with this magneto-optical visualizer were carried out under standardized and stable conditions, on the same position on a wooden table covered with

Table 1
Summary of the brand and model, the toner type, and number of distinct printing devices from which photocopied documents were collected for analysis of magnetism. The column on the far right-hand side indicates the FTIR properties as determined in previous research [5,6].

Brand and Model	Toner type	No. of devices	FTIR group
Canon iR 2000	Canon Toner C - EXV 5	1	1
Canon iR 2200	Canon Toner C - EXV 3	3	2
Canon iR 2800	Canon Toner C - EXV 3	4	2
Canon iR 3300	Canon Toner C - EXV 3	3	2
Canon iR 2230	Canon Toner C - EXV 11	15	3
Canon iR 2270	Canon Toner C - EXV 11	1	3
Canon iR 2870	Canon Toner C - EXV 11	5	3
Canon iR 3025 N	Canon Toner C - EXV 11	6	3
Canon iR 3225 N	Canon Toner C - EXV 11	1	3
Canon iR 3035 N	Canon Toner C - EXV 12	8	3
Canon iR 3045 N	Canon Toner C - EXV 12	1	3
Canon iR 3530	Canon Toner C - EXV 12	8	3
Canon iR 5000	Canon Toner C - EXV 1	2	4
Kyocera Mita KM 2530	Kyocera/Mita Toner 5PLPXLMAPKX	2	4
Kyocera Mita KM 3530	Kyocera/Mita Toner 5PLPXLMAPKX	1	4

Table 2
Mean and standard deviation (SD) of measured magnetic flux by three different operators on each of 61 documents printed under controlled conditions. Each operator performed three measurements per document. Note that the measuring device only gives integer numbers as an output reading. The column on the far right-hand side indicates the toner type as determined in previous research [5,6].

No.	Operator 1		Operator 2		Operator 3		FTIR type
	Mean	SD	Mean	SD	Mean	SD	
1	13.7	0.6	16.0	0.0	14.0	0.0	3
2	19.0	0.0	21.3	0.6	21.7	0.6	3
3	22.0	0.0	22.7	0.6	26.0	0.0	3
4	16.7	0.6	15.3	0.6	16.0	0.0	3
5	26.0	0.0	25.0	0.0	27.0	0.0	2
6	15.7	0.6	15.7	0.6	16.0	0.0	3
7	16.3	0.6	16.0	0.0	17.0	0.0	3
8	27.7	0.6	28.7	0.6	29.3	0.6	2
9	17.0	0.0	16.7	0.6	18.0	0.0	3
10	12.7	0.6	12.0	0.0	14.0	0.0	3
11	16.0	0.0	15.0	0.0	16.3	0.6	3
12	15.0	0.0	14.7	0.6	16.0	0.0	3
13	15.3	0.6	16.0	0.0	17.0	0.0	4
14	18.0	0.0	18.0	0.0	19.0	0.0	4
15	17.0	0.0	17.3	0.6	19.0	0.0	3
16	20.0	0.0	19.3	0.6	20.3	0.6	3
17	17.7	0.6	17.0	0.0	18.0	0.0	3
18	15.0	0.0	15.0	0.0	16.0	0.0	3
19	14.0	0.0	15.0	0.0	16.7	0.6	3
20	30.0	0.0	29.0	0.0	32.3	0.6	2
21	19.7	0.6	19.0	0.0	21.0	0.0	3
22	21.7	0.6	21.0	0.0	22.0	0.0	3
23	23.0	0.0	23.0	0.0	26.0	0.0	2
24	20.7	0.6	20.3	0.6	22.0	0.0	2
25	21.7	0.6	21.0	0.0	24.0	0.0	2
26	13.3	0.6	13.0	0.0	13.3	0.6	4
27	16.3	0.6	17.0	0.0	18.0	0.0	4
28	14.7	0.6	14.7	0.6	15.0	0.0	3
29	18.0	0.0	18.0	0.0	20.0	0.0	3
30	18.0	0.0	17.0	0.0	19.0	0.0	3
31	13.0	0.0	13.0	0.0	14.0	0.0	3
32	13.7	0.6	15.3	0.6	16.0	0.0	4
33	17.0	0.0	16.3	0.6	18.0	0.0	3
34	25.0	0.0	24.0	1.0	26.7	0.6	2
35	18.3	0.6	18.0	0.0	20.0	0.0	3
36	19.0	0.0	19.0	1.0	20.0	0.0	3
37	13.3	0.6	13.0	0.0	15.3	0.6	3
38	17.0	0.0	15.0	0.0	17.3	0.6	3
39	16.0	0.0	16.7	0.6	19.0	0.0	3
40	11.0	0.0	11.0	0.0	13.0	0.0	3
41	16.3	0.6	16.0	0.0	16.3	0.6	3
42	15.0	0.0	13.3	0.6	15.7	0.6	3
43	19.7	0.6	19.0	1.0	20.0	0.0	3
44	23.3	0.6	24.3	0.6	28.3	0.6	2
45	19.3	0.6	19.0	0.0	22.0	0.0	2
46	15.7	0.6	14.3	0.6	17.3	0.6	3
47	14.3	0.6	15.0	0.0	16.0	0.0	3
48	20.0	0.0	19.3	0.6	20.7	0.6	3
49	11.7	0.6	13.3	0.6	14.0	0.0	3
50	14.7	0.6	16.0	0.0	18.0	0.0	3
51	14.0	0.0	14.7	0.6	17.7	0.6	3
52	16.0	0.0	17.0	0.0	17.3	0.6	3
53	18.3	0.6	18.0	0.0	19.7	0.6	3
54	18.0	0.0	18.0	0.0	21.0	0.0	3
55	19.3	0.6	18.0	0.0	20.3	0.6	1
56	15.3	0.6	15.0	0.0	16.7	0.6	3
57	23.0	0.0	22.3	0.6	24.0	0.0	2
58	11.0	0.0	11.0	0.0	13.7	0.6	3
59	16.0	0.0	15.0	0.0	17.3	0.6	3
60	20.7	0.6	19.3	0.6	21.0	1.0	3
61	17.0	0.0	17.0	0.0	18.3	0.6	3