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PAPER

QUESTIONED DOCUMENTS; CRIMINALISTICS

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The Examination of Commercial Printing Defects to Assess Common Origin, Batch Variation, and Error Rate*

ABSTRACT: The examination of printing defects, or imperfections, found on printed or copied documents has been recognized as a generally accepted approach for linking questioned documents to a common source. This research paper will highlight the results from two mutually exclusive studies. The first involved the examination and characterization of printing defects found in a controlled production run of 500,000 envelopes bearing text and images. It was concluded that printing defects are random occurrences and that morphological differences can be used to identify variations within the same production batch. The second part incorporated a blind study to assess the error rate of associating randomly selected envelopes from different retail locations to a known source. The examination was based on the comparison of printing defects in the security patterns found in some envelopes. The results demonstrated that it is possible to associate envelopes to a common origin with a 0% error rate.

KEYWORDS: forensic science, questioned documents, forensic document examination, batch variation, common source, envelopes, error rate, flexography, printing defects, printing processes

Conducting forensic examinations of evidence for the presence of individual and class characteristics is a generally accepted procedure used in many forensic comparison sciences. An individual characteristic is defined by Saferstein (1) as "evidence that can be associated with a common source with an extremely high degree of probability." Saferstein makes the point that, "it is not possible to state with mathematical exactness the probability that the specimens are of common origin; it can only be concluded that the probability is so high as to defy mathematical calculations or human comprehension." Class characteristics can be described as common features between items within a group. These may include characteristics that are imparted during the manufacturing process of certain items (e.g., footwear). In contrast to individual defects, a single class characteristic does not allow a forensic examiner to link multiple items with a high degree of scientific certainty. However, the probability of associating items increases when additional mutually exclusive class characteristics are present.

The examination and evaluation of individual and class characteristics in questioned document examinations is a widely accepted methodology for linking documents to a common source (2–4). For example, photocopiers may transfer unique markings, or imperfections, onto a document due to scratches or debris on the glass platen, cuts on the delivery belt, dirt on the lens, scratches on the drum, or problems with the fuser system. Similarly, a rubber stamp may have a cut that results in a unique void area in the inked impression. In each case, a forensic document examiner (FDE) may be able to link the respective items because of the unique morphology and a repeated pattern of significant markings. The term that will be used to describe an unintentional marking or imperfection that is transferred onto a printed document is *printing defect*. Printing defects can often be visualized by means of a macroscopic or microscopic examination of the printed and nonprinted areas of the document.

Flexography is a form of relief printing, wherein a plate containing a raised image area is inked and transferred directly to the substrate via an impact process. The printing plates are typically composed of a flexible polymer material. This conventional printing process can be equated to the use of a stamp bearing an image that is impressed onto a document. This paper will focus on printing defects that occur when a flexographic process is employed, but the concept is applicable to any plate-based printing process. Defects in the artwork, scratches on the plate, and/or excess ink accumulation on the printing plate can result in the transfer of defects onto the printed substrate, which can be used to associate a document to a single printing plate. Printing plates do have a finite time period for use and are typically replaced on a regular schedule. In many circumstances, printing defect variations on a single plate may occur during the printing production because of random accumulation and dislodging of ink. Therefore, it is possible that printing defects may be transient or they may be present for the entire production batch. For the purpose of this writing, a production batch is defined as all of the printed items created during the lifetime of the plate(s) used.

The presence of printing defects found on various types of questioned documents, such as letterhead, bank checks, counterfeit documents, and preprinted envelopes, can be used to associate

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questioned and known items of evidence. FDEs commonly use this information to conclude that two or more items originated from a common source. Using this approach, Morton (5) was able to show that three groups of counterfeit documents were associated with each other and with a genuine model. This association methodology is especially valuable when attempting to link a document with known materials seized from a suspect. Horton (6) discusses two different cases where printing defects on three-ring notebook paper from a known source were linked to the questioned documents. Mazella and Taroni (7) conducted a study of printing defects found within security printing patterns on the inner surfaces of some envelopes. They concluded that a probability-based approach can be used when weighing features common to suspect envelopes and those originating from a known source.

Conclusions derived from the analysis, comparison, and evaluation of printing defects on multiple documents can provide significant insight to a case examination. If feasible, further information regarding the manufacturing, production parameters, and distribution channels will likely provide additional evidentiary and investigative value. In 1977, a methodology for associating envelopes by means of manufacturing characteristics was described in the scientific literature by Bertocchi (8). Fletcher (9) also discusses techniques that can be used to match envelopes and concluded that "information from the factory could be used in terms of our examinations to establish links between envelopes." Furthermore, the author concluded that methods "… can be used to physically link envelopes which were manufactured at a similar time in a production run …"

Two mutually exclusive research studies will be reported in this paper. The first was to assess printing defect morphology in a batch of 500,000 envelopes to determine if changes within a single production sequence could be used to demonstrate batch variation. The second was to ascertain the accuracy of using a comparative methodology in the examination of printing defects. A blind study using randomly purchased envelopes from multiple retail locations was administered to a trained FDE. The results were reported and evaluated to determine the error rate when requested to associate multiple items with a common source.

Materials and Methods

Controlled Production Run

A total of 500,000 envelopes bearing printed text and graphics were produced at a manufacturing facility in the United States. Two flexographic printing plates installed on the same plate cylinder of a printing press were used during the production run (see Fig. 1). Using this configuration, alternating envelopes were printed using the same printing plate.

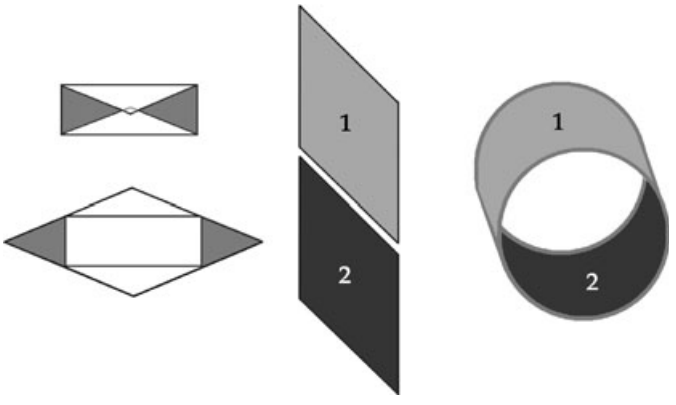

FIG. 1—*An illustration to depict the positioning of the two printing plates and how they were positioned on the plate cylinder. Each flexography plate incurs random printing flaws during the manufacturing process.*

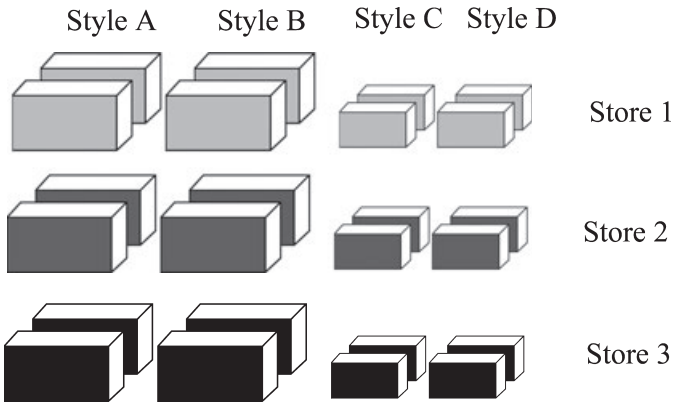

FIG. 2—*A diagram to depict the different styles of envelopes that were purchased from different retail locations throughout the same region. The different styles are designated A through D and the different retailers are designated 1 through 3.*

Once printed, the envelopes were packaged by placing 500 envelopes in every box. The boxes were then placed in cases containing 10 boxes each. The production run consisted of 100 cases or 500,000 envelopes. During the packaging process, every box and case were marked to indicate the order in which they were produced. Because of the large number of envelopes that were produced, envelopes were randomly selected for further study. Envelopes from the same box were initially examined to determine if there were any significant variations within the course of 500 envelopes. Subsequently, representative envelopes from different boxes and different cases were selected for inspection. A microscopic examination of the imperfections on the selected envelopes was documented by charting the defects onto an envelope replica. Images of the defects from various printed areas were captured.

Blind Study

A total of 23 boxes of one manufacturer's envelopes were purchased from a retailer at three different Northern Virginia locations. Duplicate boxes of each style were collected in all cases with one exception due to limited availability. Figure 2 depicts the various styles, locations, and duplicates comprising the 23 boxes of envelopes in the study.

Three envelopes from each box ($n = 69$) were numbered using the Microsoft Office Excel® (Microsoft Corp., Redmond, WA) random number generator. Each box was also randomly numbered using the same software. The removal of envelopes from each box was not completely randomized. The first and last envelope from every box was chosen; a third envelope was arbitrarily selected from the middle of the box. The 69 envelopes were shuffled to avoid bias. The selected envelopes, along with the 23 boxes from which they were taken, were given to a trained FDE to determine if each envelope could be matched with its originating box.

Results and Discussion

Controlled Production Run

Printing defects were identified on the envelopes in various positions of the printed text and image areas. After witnessing the

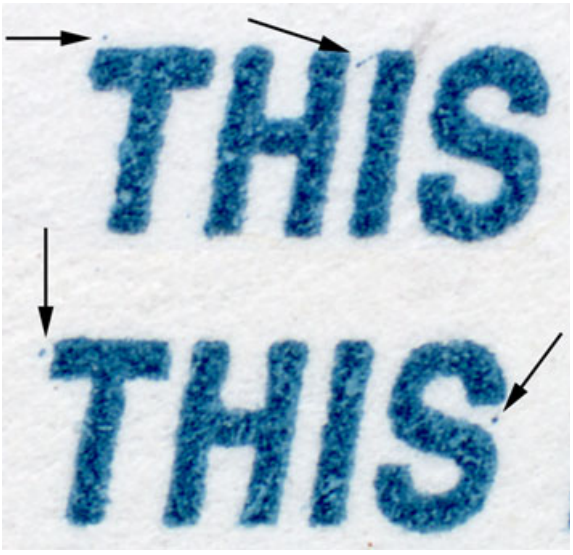

FIG. 3—*Images to demonstrate the differences in printing defects in the same areas on two envelopes produced consecutively during the manufacturing process. The printing plates used to print the top and bottom images were designated printing plates 1 and 2, respectively.*

entire manufacturing process, from the formation of the flexography plates to the packaging of the envelopes, it was determined that no printing defect sources were introduced during the preproduction period. Both the negatives and printing plates were examined prior to envelope production and determined to be free of defects (e.g. cuts, pits). As a result, it was concluded that excess or stray ink was the most likely source of printing defects. The defects on the envelopes printed with plate 1 were significantly different (e.g., positioning, morphology, and quantity) than those found on the envelopes printed with plate 2. In other words, the odd numbered envelopes created by plate 1 shared class characteristics different from those present on the even numbered envelopes created by plate 2. Given the absence of preproduction defects and the lack of variability in the production process, the noncorrelation between defects of the two envelope groups can only be attributed to random and unpredictable events. Figure 3 depicts differences in printing defects found on two envelopes that were produced consecutively during the same production run using different printing plates on the same cylinder.

Although identifying the positions of printing defects is one of the most important steps in the analysis process, comparing and evaluating the morphological characteristics should not be overlooked. Differences in morphology can indicate that two or more items were produced in the same production run but at different times. The morphological characteristics of numerous printing defects did change throughout the production sequence. Figure 4 demonstrates the change in the dimensions and placement of a single printing defect over the course of 115 boxes.

Rendering a conclusion that two or more items originated from a common source based on repeating printing defects is feasible, but it should be emphasized that these imperfections can be class characteristics. Therefore, there are limitations to the conclusions rendered. If viable, collecting information about the manufacturing process can prove to be beneficial. For example, the manufacturer in this study typically utilizes the printing plates for approximately 1 day of production before disposing of them. This may not always be the case for other manufacturers; however, flexography plates are frequently replaced as the image areas wear down after extended use. Furthermore, the production of this particular product simultaneously employed two different printing plates within the same production run. Therefore, more definitive conclusions could be reached if alternating printing defects found on questioned envelopes matched alternating defects in the exemplars. Finally, having knowledge about the distribution channels such as the locations of where the envelopes are shipped and the retailers that sell them can prove to be valuable. With knowledge of the manufacturing process, adequate exemplars, and a variety of printing defects, it may be possible to elucidate the sequence of printed material based on morphological changes in the printing defects.

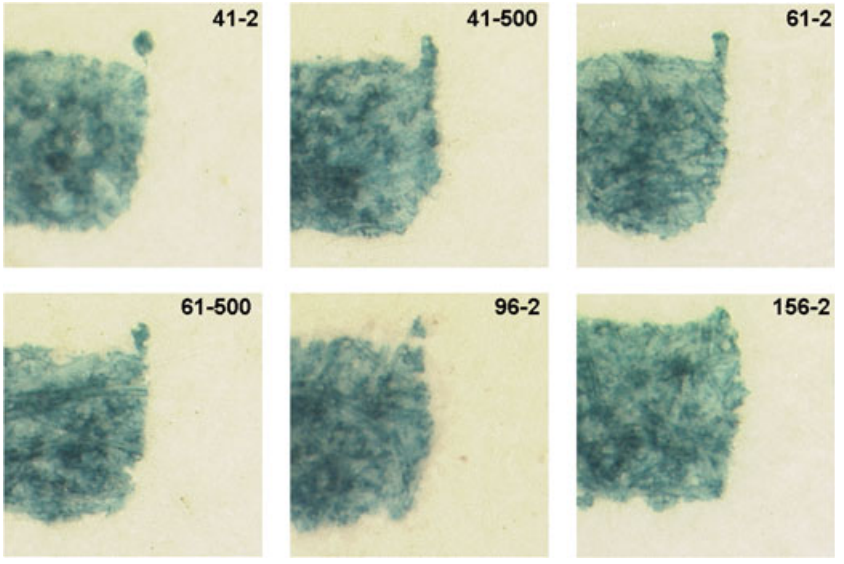

FIG. 4—*Morphological changes in printing defects were evident in various printing areas. The following is a series of photomicrographs of the top right portion of the letter "E" in a series of envelopes. The first and second hyphenated numbers represent the sequential number of the box and the position of the envelope within the box, respectively.*

TABLE 1—*A summary of results from the blind study.*

Box#	Envelope #'s	Style	Store #	Exclusive Association	Nonexclusive Association
1	199, 337, 552	A	1		Group 1
2	119, 355, 950	A	1		Group 1
3	17, 95, 624	B	1		Group 2
4	245, 531, 966	B	1		Group 2
5	66, 232, 863	C	1	X	
6	28, 744, 996	C	1	X	
7	71, 161, 572	D	1		Group 3
8	116, 579, 788	D	1		Group 3
9	76, 120, 686	A	2	X	
10	173, 412, 730	A	2	X	
11	220, 380, 493	B	2	X	
12	70, 679, 790	B	2	X	
13	112, 383, 979	C	2		Group 4
14	78, 853, 909	C	2		Group 4
15	554, 714, 875	D	2	X	
16	587, 778, 808	D	2	X	
17	495, 740, 828	A	3	X	
18	131, 483, 802	A	3	X	
19	405, 836, 988	B	3	X	
20	183, 377, 422	B	3	X	
21	427, 795, 912	C	3	X	
22	45, 96, 227	C	3	X	
23	142, 214, 779	D	3	X	

Four different styles of envelopes (designated A through D) were purchased from the same retailer at three different locations in the Northern Virginia area (designated 1 through 3). After removing three envelopes from each of 23 boxes ($n = 69$), a trained FDE was requested to determine if the removed envelopes could be matched with their originating boxes. An error rate of 0% was attained.

Blind Study

The 69 questioned envelopes were compared with representative envelopes from the 23 boxes and conclusions were rendered based on an evaluation of common print defects. The examiner made no errors in the association of the questioned documents to the originating boxes. The examiner was able to match 45 (65%) of the envelopes to the originating boxes to the exclusion of all others. Of the remaining 24 envelopes, the examiner correctly separated them into four groups of six envelopes. The six envelopes in each group were successfully traced back to one of two boxes of the same style from the same retailer. Therefore, the same style of envelopes, obtained from the same retail location, could not be differentiated 35% of the time. Lastly, it was established that all of the envelopes purchased were associated to boxes from the correct retail location. The results are summarized in Table 1 and demonstrated in Fig. 5.

To demonstrate some of the findings, Fig. 6*a* depicts envelopes of the same style obtained from two different locations. Significantly different printing defects were found on each of the envelopes. Figure 6*b* shows differences in the printed areas between the same styles of envelopes obtained from the same retail location. These characteristics may be the result of the envelopes being printed using different plates or variations on the same plate. However, the emphasis is that significant differences were identified on two different envelopes of the same style obtained from the same shelf at the same time. Figure 6*c* illustrates two envelopes removed from two different boxes purchased at the same retail location that could not be discriminated. As noted previously, all of the envelopes from a group of six that could not be sourced to their respective boxes were purchased from the same retail location.

The results from the blind study confirm the generally accepted principle that a trained FDE can evaluate commercial printing defects and successfully determine that two or more items originated from a common source. The results also indicate that it is possible to differentiate the same style of envelopes purchased from the same retailer. Indeed, the evidence for this is empirical and should not be interpreted as dogmatic. Nevertheless, even if one million envelopes are printed using the same printing plate in a single day by one manufacturer, this is a relatively small percentage of all the envelopes produced nationally over a period of weeks or months.

The reasons that all envelopes from different locations could be distinguished are likely dependent on the distribution channels used by the manufacturer and/or the inventory methods implemented by the retailer. For example, one retailer may have distributed envelopes with the same printing defects to multiple locations; however, indistinguishable envelopes from different locations were not located in this study. While there are numerous reasons why indistinguishable envelopes were not seen at different locations, one reason may have been that the number of retail locations sampled was small. In order to formulate more statistical-based interpretations regarding the likelihood that a questioned item originated from a particular source, it will be necessary to obtain more specific information such

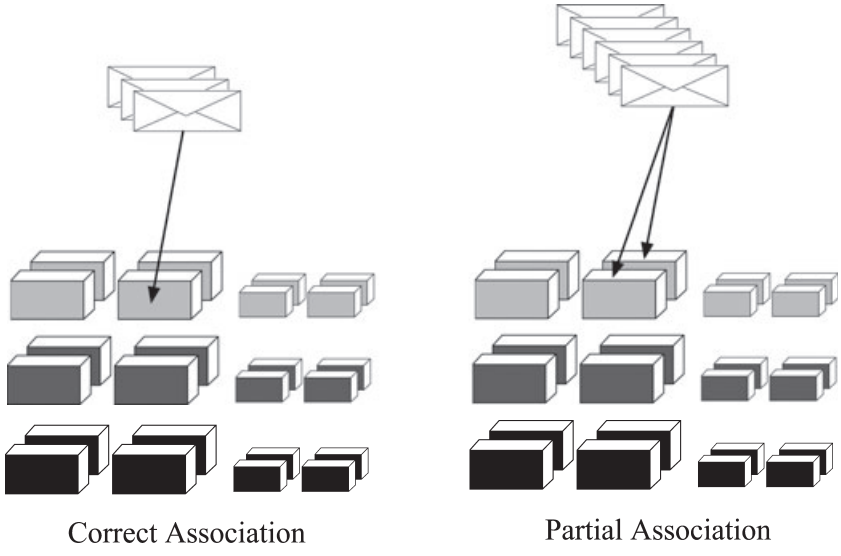

FIG. 5—*An illustration of the exclusive and nonexclusive association results from a blind study.*

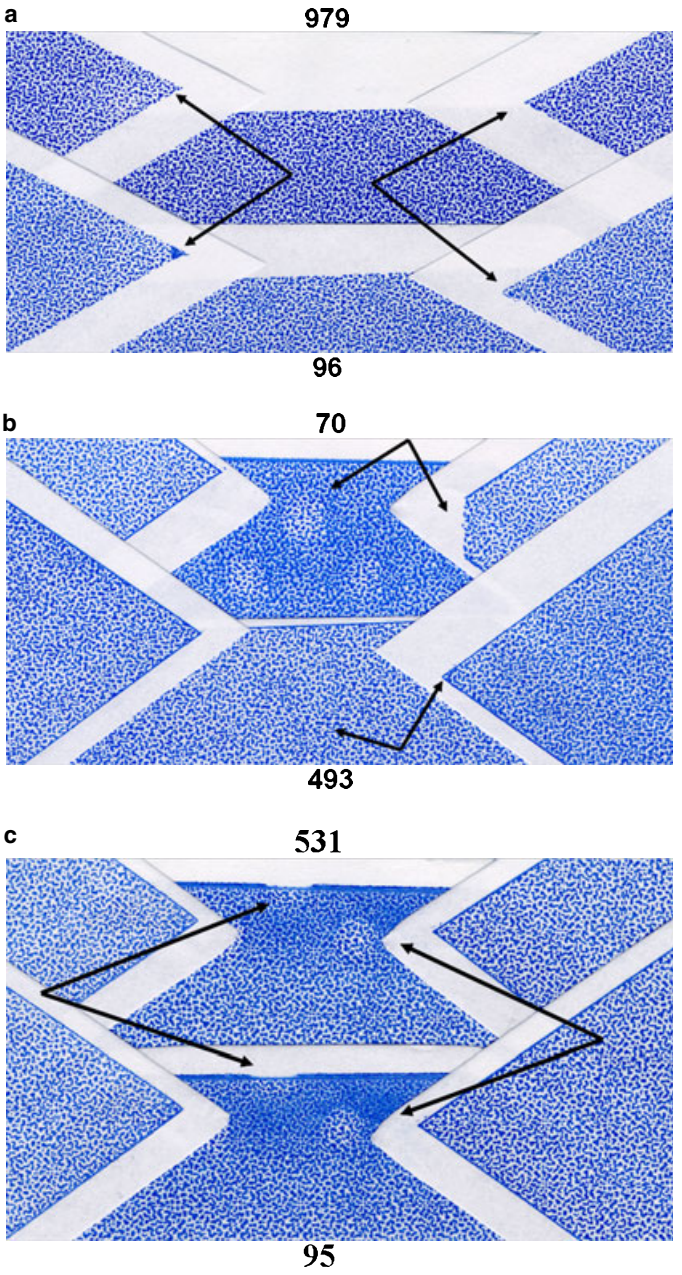

FIG. 6—*Images of (a) the same types of envelopes from different retail locations that could be discriminated (envelopes 96 and 979); (b) the same types of envelopes purchased from the same retail location that could be discriminated (envelopes 70 and 493); and (c) the same types of envelopes from the same retail location that could not be discriminated (envelopes 95 and 531).*

as the number of items produced, the distribution volumes to each location, and possibly the number of envelopes sold at that location. For example, the likelihood of someone randomly having an envelope that matches a specific box is greatly reduced if the production volume or regional distribution was low.

Conclusions

The results from the controlled production run and the blind study corroborate previous assertions that FDEs can make assessments regarding whether two or more items have a common origin based on the evaluation of printing defects. Moreover, variations within a single batch can occur in commercially printed documents. If information from the manufacturer is available regarding the distribution and production process, more accurate and decisive conclusions can be reached. The general principle of utilizing a scientific method to compare and evaluate printing defects found on questioned documents can be applied to other processes that utilize printing plates or involve the physical transfer of an image to a substrate. It is imperative to recognize that the 0% error rate obtained in the blind study was the result of a trained FDE conducting evaluations based on methodical and judicious consideration.

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