Authentication of Medicine Blister Foils: Characterization of the Rotogravure Printing Process

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Abstract: Nowadays the number of medicine packaging counterfeits increases very quickly. The rotogravure printing technique is worldwide used for medicine blister foils production. However, the existing anti-counterfeiting solutions do not take into account this printing process. Additionally, it is not easy to apply conventional solutions while using blister foils instead of uncoated/coated paper. In this paper, we study some features of the rotogravure printing and identify the future paths to fight the increasing number of counterfeited medicine products. We present the result of a preliminary study of such a process, extended to foils, and discuss some promising solutions for blister foils authentication.

1 INTRODUCTION

The worldwide market is suffering from packaging counterfeiting. According to the Association for Packaging and Processing Technology [1], such a threat is predicted to increase three percent per year worldwide. Medical supplies represent one of the most sensitive markets: counterfeiting affects health of common people causing damage of brand reputation and market loss.

One of the first solutions for the authentication of printed surfaces was proposed by Goldman et al. (Goldman, 1983), making use of paper fibers and engraved dots as measurable but not duplicable physical characteristics. The use of individual printable glyph or character as a forensic mark were later investigated in a way consisting in the extraction of a profile of the printing: in (Pollard et al., 2010), a Model Based Signature Profile (MBSP) is extracted during the printing process, then stored in the database. The stored MBSP is compared with MBSP extracted from document during verification using the Shape Distortion Encoding Distance (SDED), a modified Hamming distance.

In (Kee and Farid, 2008), a profile of the legal printer is learnt on samples of a given character via principal component analysis during the registration step. At verification, this profile is used to assess the link of the current document with the printer by computing the error of the reconstruction of the new occurrences of the character. Investigation whether the document was printed using a particular device (Navarro et al., 2018) is a second approach of printings authentication.

Instead of using a model for legitimate prints or printings, another approach was suggested: the assessment of the degradation caused by printing an anti-copy pattern specially designed to protect the document or packaging (Picard, 2004). The so-called Copy Detection Patterns (CDPs) are maximum entropy images generated using a secret key and derived from the content, that takes full advantage of the principle of information loss during the printing process. A quality index is here considered to measure the non duplicable impact of the process.

A modular version was proposed for protecting QR codes against copy including error correction for keeping their reading robust at a second level (Tkachenko et al., 2016). The first level of these "2LQR" codes is accessible to all public and can be read by standard barcode reader. The second level is accessible only for authorized users and is sensitive to duplication process. The copy sensitivity is ensured by the use of specific textured patterns sensitive to Print&Scan impact. The second level increases the information density of the QR codes, adding a way to authenticate them.

Even if there exists several solutions for document

[1]PMMIs full 2016 Brand Protection and Product Traceability report https://www.pmmi.org

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and packaging authentication, the research and development of more efficient techniques or of the extension of their application domain is a hot topic in academia and industry. While developing the novel security elements to fight against packaging counterfeiting, the following requirements might be taken into account: 1) easy integration and generation processes, 2) low cost, 3) use of standard printing process, 4) fast and automatic verification process, 5) use of common devices for verification (office scanners, smartphones), 6) reliable verification by any user, 7) good level of global security and strong anti-fraud ability.

The development of copy sensitive graphical codes can satisfy all the items above. These codes are based on the use of measurable but not duplicable physical characteristics (Goldman, 1983). Today we can find numerous security elements that use measurable but not duplicable physical characteristics and that are sensitive to duplication attack. However, all these elements have been developed for packaging or documents that use the white uncoated/coated paper and high resolution printing (from 600 dpi till 2400 dpi). Additionally, the authentication process is provided using high resolution scanners (from 600 dpi till 4200 dpi).

We aim at developing security elements for protection of medicine packaging that are produced using rotogravure printing on aluminum foils. To our knowledge, there does not exist any tested solution for such printing process and such type of support. The well-understanding and characterization of the printing process is a crucial, preliminary step before developing efficient security elements. Therefore, the aim of this paper is to study the characteristics of rotogravure printing process and to identify several possible paths for authentication of such packaging.

The paper is organized as follows. We introduce the rotogravure printing technique which is worldwide used for medicine blister foils production in Section 2. Then we discuss some features of the rotogravure process in Section 2.2 that can be useful to fight the increasing number of counterfeit medicine products. We present the result of a preliminary study of such a process, extended to foils in Section 3, and discuss some promising outlooks for medicine authentication in Section 4. Finally, we conclude in Section 5.

2 ROTOGRAVURE PRINTING CHARACTERIZATION

Rotogravure printing produces high-quality images with intense rich colors using primary colors such as CMYK. Each primary color is printed by one pass through the press. Therefore, it is often used for high-volume printing such as advertising pieces, magazines, catalogs and packaging.

2.1 Printing Process

Rotogravure is an intaglio printing process, where the image is cut or etched below the surface. Rotogravure printing has its pros and cons. The positive points are long lifetime of printing cylinder ($>$ 1 million copies), variable printing formats, front- and backside printing on one time, different printing primary colors, different materials, high printing quality, simple printing principle. The negative points are costly cylinder engraving process and sloven based colors.

The rotogravure printing process uses a metal cylinders with an image engraved on it in the form of a pattern with enclosed 3D cells. The cylinder radius is determined by the final size of the page and repeat of the design.

The cylinders are covered by cooper as it is soft and pliable material easy to engrave. The copper layer is only 80 microns thick. Before engraving, the copper surface is automatically polished. It removes any imperfections and smoothed out the cylinder. Polishing also adds a roughness to the surface so it can retain the ink that will lubricate the cylinder.

An artwork needs to be created before engraving the cylinder. Digital data for text and images feed the engraving heads, that images the copper cylinder. Three the more popular types of engraving process are electromechanical engraving, chemical etching and laser engraving.

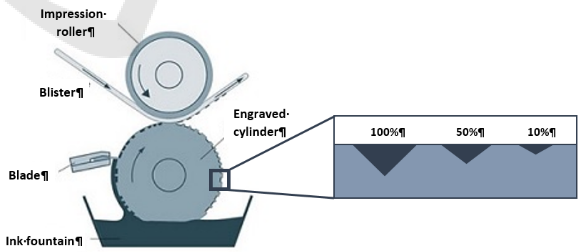


Figure 1: The printing process using rotogravure.

The printed image results from the ink transfer from the honeycomb shaped cells (see Fig. 1) engraved into the copper cylinder. The un-etched areas of the cylinder represent the non-image (unprinted) areas. The cell depth control the amount of ink to be transferred to the surface. The final size and shape of the printed dots depend on the ink and type of paper.

After engraving, the cylinder is polished for a consistent surface, and imperfections removal. The cylinder is electronically cleaned to remove all grease and oil from the surface. The engraved clean cylinder is coated with a final layer of chromium. The chrome-plated cylinder is polished once again to rough up the surface, making the ink act as a lubricant. Before go to press, the cylinder is inspected. Due to the printing principle, one engraved cylinder is dedicated to each primary ink.

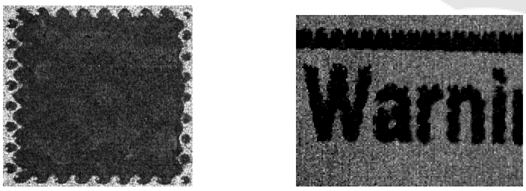
The general scheme of printing process is illustrated in Fig. 1. The cylinder rotates through an ink pan where the cells pick up ink. The non-image areas and over quantity of ink are scraped of the cylinder by a blade before the ink is transferred to a paper surface. The ink used are based on low viscosity solvents or water. After each ink unit, the ink is dried using high velocity air nozzle dryers.

2.2 Main Printing Characteristics

Several characteristics distinguish rotogravure printing from other well-known printing techniques as offset or flexographic.

Rotogravure can usually produce a richer black than other processes. Rotogravure's ability to lay down a thick three-dimensional ink film - altering not only the width of the dot but also the depth - produces brilliant colors (Keif and Goglio, 2005).

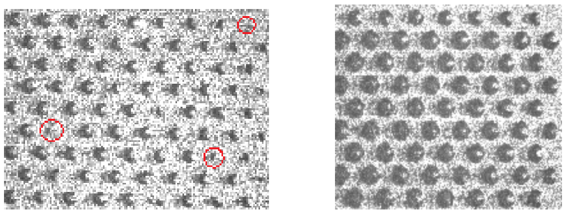
A typical characteristic of rotogravure is its serrated edges on type and line work when the cylinder is electromechanically engraved (Keif and Goglio, 2005). Such serrated edges, not visible to the naked eye, can be observed with a 5× magnification (Fig. 2).



(a) (b)

Figure 2: Example of serrated edges on a) the edges of a block pattern and b) letters observed by using a ZEISS microscope with 5× magnification.

The cylinder hardness demands a smooth surface to ensure best contact and ink transfer. The rotogravure method is sensitive to surface defects (blade lines and indentations). The bottom of the cell does not release the ink quickly during the rotogravure printing process. This phenomenon results in either ink transfer failure so some missing dots (Fig. 3.a) or in a non-uniform ink coverage, more precisely in ”doughnut”-shaped dots where dots have holes in the center or on a board of the targeted disk area (Fig. 3.b).



(a) (b)

Figure 3: Example of a) missing dots in a uniform patch printed with resolution 152 lpi and b) ”doughnuts” in a uniform patch printed with resolution 136 lpi. The images were captured using a ZEISS microscope with 5× magnification.

An additional characteristic of cylinder engraving process is the dot coverage rate (%) that is produced by variable depth and diameter of cells, but it always has a fixed aspect ratio. The dot coverage rate can vary between 10% and 100%. The images in Fig. 3 illustrate a dot coverage rate equal to 20% and 50%, respectively. The smaller dot coverage rate tends to produce more dot imperfections (like missing dots and closed or open ”doughnuts”) during the printing process.

Another important element of rotogravure printing process mentioned in (Lv et al., 2010) is the ink viscosity: the decrease of ink viscosity led to the decrease of the contrast of printed image, and the range of the reachable coverage rates. The author in (Kader, 2017) showed that the low viscosity eases ink transfer from the cells to the substrate and it results in a messy print having limited sharpness. In the same time, when the viscosity increases, the dots become rounder, sharper and darker.

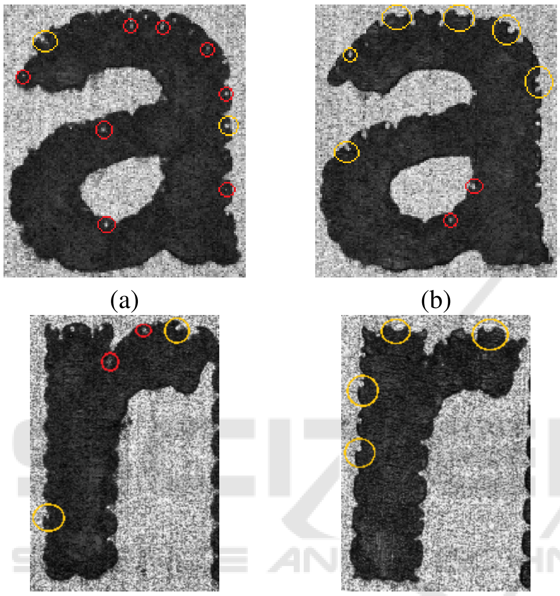
2.3 Main Production Steps

When talking about production of packaging using a rotogravure printing process, one needs to take into account a specific production setup. First, designing an artwork by taking into account the printer resolution in lpi is required. The cylinder is engraved accordingly. The selected engraving method is an important factor of the quality of printed images. At the end, the surface in contact with the engraved cylinder (upstream inked and scraped with a squeegee) will be more or less pressed by a roller.

All these steps are important and can influence to the final quality of printed image. That is why the image resolution in artwork (in ppi), the cylinder engraving resolution as the printer resolution (in lpi) are important parameters in the production setup.

3 EXPERIMENTS

In our experiments, we have used foils printed by a rotogravure process equipped with a chemically engraved cylinder. The screen ruling of the cylinder was 70 lines per cm (i.e. 178 lines per inch). Blister foil and liquid ink (foil ink) were used for the production of samples. 780×880 images were captured with a ZEISS microscope with $5\times$ magnification (Fig. 4). Here we imaged samples representing letter 'a' (72 samples) and letter 'r' (162 samples) to construct our database.



(a) (b) (c) (d)

Figure 4: Several samples of our database: a,b) glyphes 'a' with some visible enclosed "doughnuts" (red circles), and some "open" doughnuts on the boundary (yellow circles), c,d) idem but for glyphes 'r' with more (d) or less (c) "open" doughnuts (yellow circles) on the vertical left side.

In these images, we remark several of the characteristics of rotogravure printing as missing dots and "doughnuts", in particular "open" ones (yellow circles) on a part of the border of a glyph.

3.1 Distribution of Black Dots after Printing

After masking the acquired and registered images with a binary mask of the ideal pattern (letter a), we obtained the histogram depicted in Fig. 5. It shows the distribution of gray level pixels after digital printing and scanning. This distribution looks very approximately like a log-normal distribution (see Fig. 5).
In comparison with laser and inkjet printing processes, it is important to mention the strong asymmetry

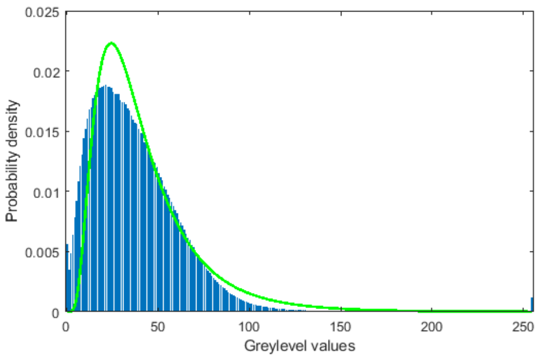


Figure 5: The distribution of gray levels after electromechanical rotogravure printing and microscope capturing process compared with log-normal distribution. The green curve represents here a log-normal distribution with parameters $\mu = 3.57$ and $\sigma = 0.61$, hypothesis which does not accurately models the distribution (the hypothesis was rejected by the χ^2 goodness-of-fit test at a significance level of 0.05).

of the histogram: 74.5% of the gray levels are in the range of 0 to 50 (Fig. 5). This reflects the fact that rotogravure printing process can produce a richer black.

3.2 Uniqueness of Printed Glyph

Due to the specific impact of rotogravure printing process, the first possible solution for authentication is to use the uniqueness of printed glyph as proposed in (Pollard et al., 2010). However, our aim is not to define the specific profile of the current printing, but to show that given a character (or a glyph), each printed pattern (e.g. printed samples representing the letter 'a') has the same "signature" as any other pattern or "brother" printed from the same cells in the cylinder, while its signature differs from the patterns or ("cousins") printed from cells located elsewhere on the cylinder. Fig. 4.a-b shows prints resulting from two different cylinder locations ("cousins"). To compare two printed patterns we propose to analyze the correlation rate that exists given a reference sample (representing letter 'a' then letter 'r') with its "brothers", and its "cousins" respectively.

Fig. 6 shows experimental results about 6 occurrences of letter 'a' printed during three rotations of the cylinder: two series of 18 values of the Pearson correlation coefficient measured with respect to a given reference image, item 4, arbitrarly chosen in series 2. The correlation is close to 0.62 for "cousins" while it stays close to 0.83 (1. resp.) for "brothers" (items numbered 5 and 6) in series 1 (series 2 resp.).

That results tend to show some uniqueness of the patterns (e.g. letters) coming from a given spatial location on the cylinder of a chemical rotogravure prin-

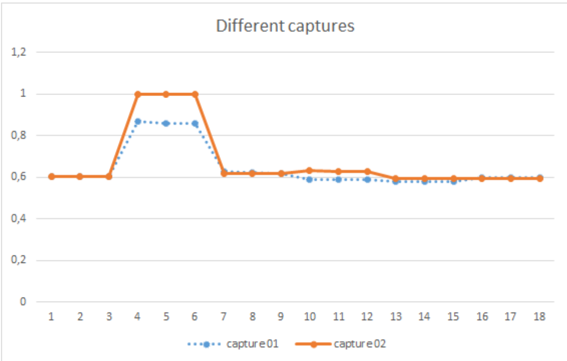
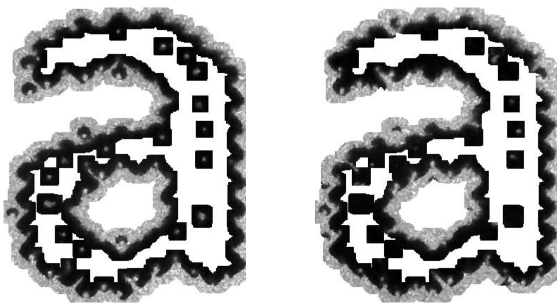


Figure 6: The changes of correlation values for different captures. Samples 4, 5, 6 correspond to prints coming from the same cylinder location meanwhile other samples correspond to prints of the same letter but coming from other cylinder locations.

ting device.

The laboratory microscope such as used is well-suited for forensic purposes, but cannot be deployed in practice for authentication on place on market. Thus, we used an USB-microscope for constructing a new database. In this database, we look at the patterns representing a same letter ('a' then 'r') that were printed using one cylinder engraved by chemical process, and one cylinder engraved by electromechanical process respectively. Images of samples representing letter 'a' are shown in Fig. 10. As the USB-microscope images are less resolved, features are less well captured and the values of the correlation with respect to a reference have a lower gap between the populations of "cousins", and "brothers" respectively.

In order to increase this gap, we only extracted the edges of the letter (see example in Fig. 7).



(a) (b)

Figure 7: a) An edge of reference image sample of letter 'a', b) an edge of another sample of letter 'a' placed in a different area on of the same cylinder.

The correlation with respect to the reference edge computed with all the samples have higher values with an increased but small gap in both chemical (Fig. 8) and electromechanical (Fig. 9) rotogravure printings.

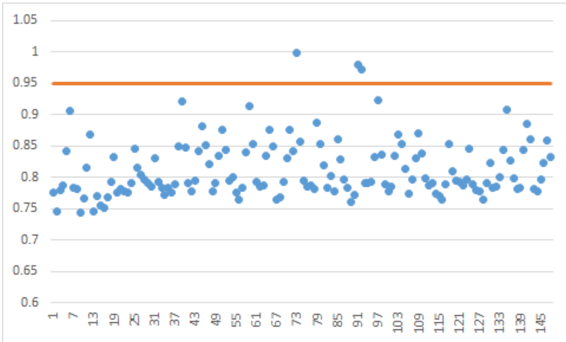


Figure 8: The correlation values with respect to the edges of a reference image for all the images in the database obtained from 'a'-patterns and 'r'-patterns printed using a chemically engraved cylinder.

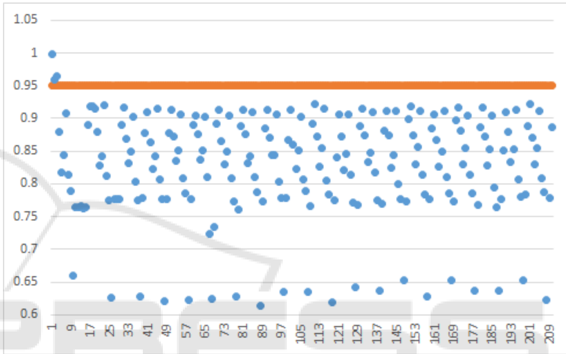


Figure 9: The correlation values with respect to the edges of a reference image for all the images in the database obtained from 'a'-patterns and 'r'-patterns printed using an electromechanically engraved cylinder.

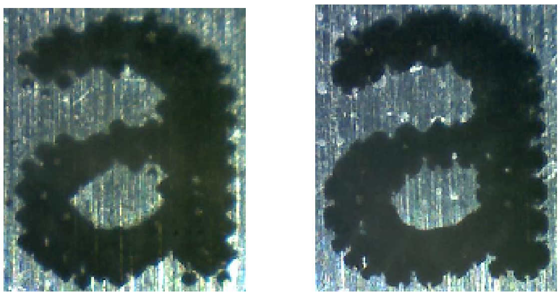
We fixed at both cases the authentication threshold at $Th = 0.95$ which separates the population of "cousins" from that of "brothers". These results show the existence of a signature of the native glyphs in the cylinder.

4 DISCUSSION

Exploitation of the uniqueness of printed glyphs would mean a storage of the image captured with a high resolution device, or a representation, in order to allow a later comparison. In the case of the protection of medicine foils it is not an optimal solution due to the huge production.

4.1 Printer and Cylinder Signatures

We suppose that the authentic artwork is kept in a secret. In the same time, we can suppose that each cylinder has its own signature when cylinders are engraved using mechanical or chemical processes. Additionally, the dot shape is different for each engraving process. Fig. 10 illustrates the differences in the shape of letter ’a’ printed using an electronically engraved cylinder (Fig. 10.a) and using a chemically engraved cylinder (Fig. 10.b).



(a) (b)

Figure 10: A sample of letter ’a’ printed using a cylinder engraved a) electronically and b) chemically. Both cylinders were engraved using the same artwork.

We spotted that the engraved cylinder of a specific rotogravure printing system may transmit its own spatial ”signature” measured by image correlation. In the same time, we can assume that the patterns printed with the same engraved part might have higher correlation values than the patterns printed using another engraved part.

And finally, as in laser and inkjet printers, each printed character contains the printer signature. The only thing we need to study is the impact of each signature. That means we need to test either the characters differ more from printer to printer (we fix the cylinder and we change the printer used) or the characters differ more from cylinder to cylinder (we fix the printer and we use some cylinders engraved using the same method).

Table 1: Different combinations of cylinder and printer in order to understand whose signature is more important during authentication.

Cylinder	Printer
Fixed	Variable
Variable	Fixed
Variable	Variable

In order to understand which signature is more important, we need to analyze different combinations of printer and cylinder that are presented in Table 1.

4.2 Authentication System based on Cylinder Signature

However when we talk about the counterfeiting of packages that were printed using rotogravure process, we need to take into account the necessity to produce new engraved cylinder as a counterfeiter do not have access to the original cylinder. That is why the printer forensic investigation or more precisely the cylinder forensics can be a good alternative for detection of counterfeits.

Let $\mathbf{W}$ be the original artwork image after cylinder engraving and printing process this image will be $\mathbf{I}_a = \mathbf{W} + \mathbf{N}_a$, where $\mathbf{N}_a$ is a noise added by the rotogravure printing. We suppose, that all images $\mathbf{I}_a$ that were printed using authentic cylinder C_a have some specific characteristics added by the cylinder signature. That is why, we can tell that all these images belong to one class C_a ($\forall \mathbf{I}_a \in C_a$).

In the same time, even if the counterfeiter produce the same artwork $\mathbf{W}$ for production of counterfeiter cylinder C_c, the images printed using this cylinder will be different $\mathbf{I}_c = \mathbf{W} + \mathbf{N}_c \in C_c$ due to the signature of counterfeiter cylinder C_c.

Thus, the authentication test for a new captured image $\mathbf{I}'$ can be formulated as a hypothesis test:

$$H_0 : \mathbf{I}' \in C_a,$$

$$H_1 : \mathbf{I}' \notin C_a,$$

where the image $\mathbf{I}'$ is authentic when the hypothesis H_0 is accepted, otherwise the image $\mathbf{I}'$ cannot be considered as authentic.

4.3 Possible Attacks

In this section, we want to list the possible counterfeiter strategies while faking the blister foils.

1. Photo-printing (scan-and-engraving) attack. This attack consists on scanning the blister foil of authentic medicine and using this scanning image as an artwork for engraving a cylinder. This attack is not realistic, as the image after scanning is noisy and cannot be used for cylinder engraving without pre-pocessing step.
2. Scan-Processing-Engraving attack. Here an opponent tries to estimate the original artwork (that was used for authentic cylinder engraving) using the scanned image.
3. Artwork counterfeiting-and-engraving attack. In this case, an opponent creates his/her own artwork, that must be close to authentic artwork. If the authentic artwork is simple, the recreation process can be very simple. That is why the smart construction of authentic artwork with non-trivial security elements is a very important process.

5 CONCLUSIONS

The protection of medicine blister foils is an important issue these days. There exists a big amount of security elements that were developed for document and packaging protection, and anti-copy authentication. However, all the operational solutions have been developed for laser and inkjet printers and used with the uncoated/coated paper substrate.

In this paper, we are focusing on rotogravure printing techniques and blister foil substrates that are used for production of medicine packaging. We have listed the main characteristics of these production process and we have presented the preliminary study of this process. We have done the experiments in order to show the distribution of black color after printing and capturing process. We have shown the uniqueness of patterns printed by rotogravure. Finally, we have discussed the future path where we want to understand the impact of cylinder and printer signature in this uniqueness. Based on this study, we will construct a new security element for rotogravure printing on blister foils.

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REFERENCES

Goldman, R. N. (1983). Non-counterfeitable document system. US Patent 4,423,415.

Kader, M. E. A. (2017). The impact of ink viscosity on the enhancement of rotogravure optical print quality. *International Design Journal*.

Kee, E. and Farid, H. (2008). Printer profiling for forensics and ballistics. In *ACM workshop on Multimedia and security*, pages 3–10. ACM.

Keif, M. G. and Goglio, T. (2005). Identifying high-volume printing processes. *Visual Communications Journal*, pages 35–42.

Lv, X., Liu, C., Wu, Y., and Ipsen, H. (2010). Variation of gravure printing characteristic curves. In *17th IAPRI World Conference on Packaging*.

Navarro, L. C., Navarro, A. K., Rocha, A., and Dahab, R. (2018). Connecting the dots: Toward accountable machine-learning printer attribution methods. *Journal of Visual Communication and Image Representation*, 53:257–272.

Picard, J. (2004). Digital authentication with copy-detection patterns. In *Electronic Imaging 2004*, pages 176–183. International Society for Optics and Photonics.

Pollard, S. B., Simske, S. J., and Adams, G. B. (2010). Model based print signature profile extraction for forensic analysis of individual text glyphs. In *Information Forensics and Security (WIFS), 2010 IEEE International Workshop on*, pages 1–6. IEEE.

Tkachenko, I., Puech, W., Destruel, C., Strauss, O., Gaudin, J.-M., and Guichard, C. (2016). Two-level QR code for private message sharing and document authentication. *IEEE Transactions on Information Forensics and Security*, 11(3):571–583.