Features of laser printers in the context of identification studies

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Abstract

This paper is intended to provide an insight into the specific features found on printed documents and an attempt to attribute the structural elements from which they may have been applied in the printing process to expert witnesses providing opinions in cases involving technical examination of documents. The consequences of such findings can be as serious as a categorical identification of the device that was used to obtain a disputed document.

The process of printing documents using the electrophotographic method with colour and monochrome laser printers is briefly introduced. The main part of the paper provides a synthetic discussion of the role of each component and the types of identifiable features that can occur, with a presentation of some in the accompanying figures. The operation of individual codes in electrophotographic devices has also been mentioned, but this issue is not part of the specific subject of this paper. In the conclusions, the authors also focused on the rank of the traces visible on prints, noting the transient nature of some of them and the resulting possible errors of in opinions provided.

Keywords: technical examination of documents, laser printers, identification of printing equipment, identification features

Introduction

One of the numerous types of opinions provided in technical document examination laboratories of police forensic laboratories is the identification of printing devices using the electrophotographic printing method. Currently this primarily concerns colour laser printers, which perform the function of scanning, copying, faxing and even e-mailing at the same time, and monochrome printers mainly intended for office and home applications.

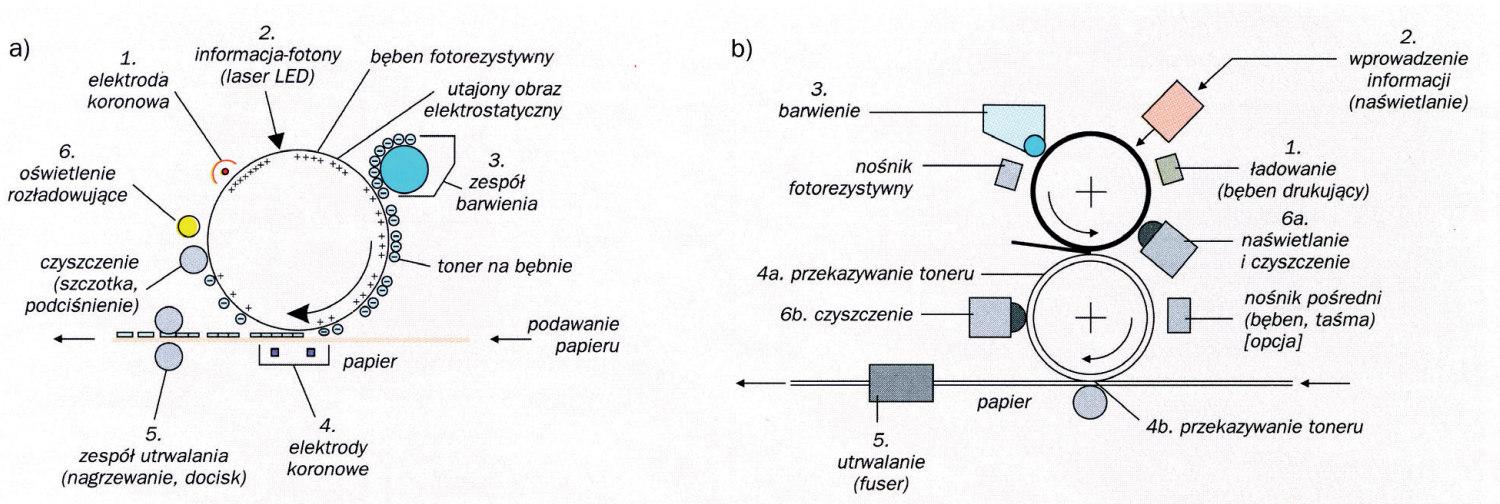
The essential task of an expert in cases of this type is to link the challenged document to the printing device sent for examination as comparative material or the printouts obtained from such a device, and to answer the question of whether the challenged document was printed using the printer sent for examination. It is obvious that to carry out the entire examination process as reliably as possible, it is better to have a printer, and not just the printouts made. Having a printer available makes it possible to become thoroughly familiar with its design, technical parameters and modes of operation, and to obtain comparative material with characteristics as close as possible to those of the evidence. Another extremely important aspect in favour of carrying out the commissioned examinations with the use of the device itself is the fact that it allows the content of the internal memory to be checked, where already at this stage the challenged document may be revealed, even before the expert has made the comparison printouts. A complementary examination material is then available, which is a combination of the graphic design together with any features applied in the printing process.

Electrophotographic printing technology used in laser printing devices

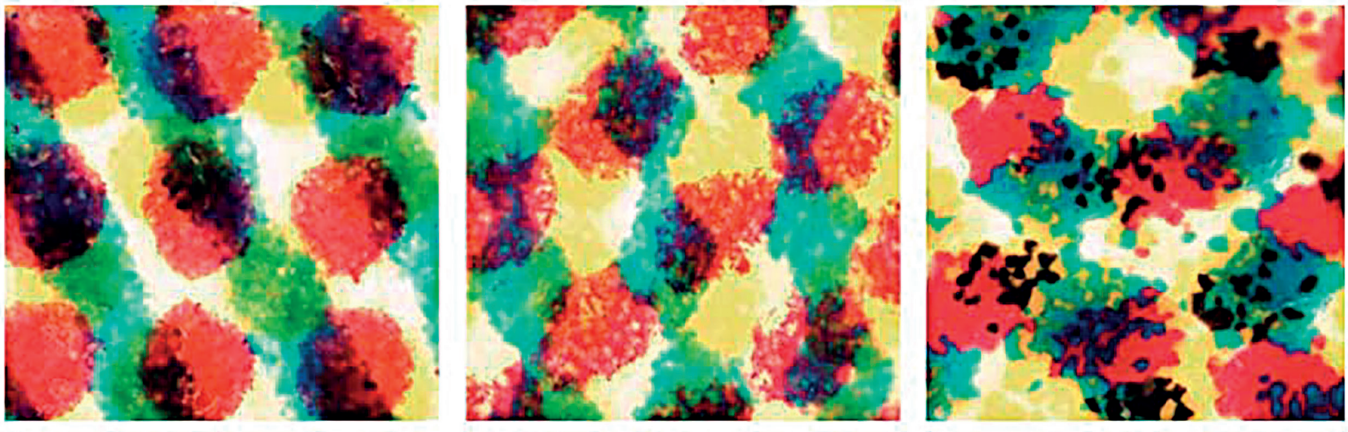
The basis of electrophotographic printing technology is considered to be xerography (Greek xero - dry and graphein - writing), which is used to multiply documents without the need for classic print forms. The first print using this technique was made on 22 October 19381, but it was only nine years later that the company later known as the Xerox Corporation perfected the method for copying documents. The first machine that made satisfactory quality copies while achieving reasonable running costs appeared in 19852 ('Colour One') and worked using the optical-photochemical technology. Currently, analogue and digital electrophotographic devices are the most common. The difference between the two types occurs at the exposure stage of the image. In digital printing, the original is a digital file, instead of a physical document/image (as in the analogue technique), which undergoes reproduction, where a pixel-by-pixel conductive layer is exposed using, for example, a laser beam instead of an optical system exposing

1 S. Khadzhynova, S. Jakucewicz. Sposoby drukowania cyfrowego [Digital printing methods], Wydawnictwo Politechniki Łódzkiej 2016, p. 23. M. Borowski.

2 Barwne urządzenia kopiujące – możliwości identyfikacji kryminalistycznej [Colour copying devices - possibility of forensic identification]. Zeszyty Metodyczne nr 16, Badania dokumentów. Możliwości Badawcze dokumentów wytwarzanych technicznie [Document examinations. Possibilities to examine documents produced using technical methods]. Wydawnictwo Centralnego Laboratorium Kryminalistycznego Komendy Głównej Policji. Warsaw 2002, p. 9.



ryc. 1. Diagram showing digital electrophotographic printing: (a) direct, (b) with intermediate media - multi-colour printing. Source: Buczyński, L. (2003). Tonery w druku elektrostatycznym – proces barwienia, właściwości i wpływ na jakość druku. Część I [Toners in electrostatic printing - the colouring process, the characteristics and the impact on print quality. Part I]. Świat Druku 4/2003.



ryc. 2. A printout made using various printing technologies: ElectroInk HP Indigo with a liquid toner (left), offset (centre) and electrophotographic using dry toner (right). Source: S. Khadzhynova, S. Jakucewicz. Sposoby drukowania cyfrowego [Digital printing methods], Wydawnictwo Politechniki Łódzkiej 2016, p. 81.

the charged photoconductive layer with light reflected from the original, which characterises the analogue method3.

The electrophotographic printing process is divided into several stages. In the first stage, the surface of the photoconductive layer is covered uniformly with electrical charges and then exposed to a laser beam or light from light-emitting diodes (LEDs). The areas that have been exposed are discharged, while in the non-exposed areas the remaining charges form a so-called electrostatic latent image, which is then developed with a charged toner, usually in the form of a fine powder consisting mainly of thermoplastic resins, e.g. polyester, polypropylene wax, and colouring substances: technical carbon black for black, copper 3-phthalocyanine for blue, quinacridone red present in magenta and pigment 180, referred to as diaryl yellow, present in the yellow toner. In addition, there are glass (silicon dioxide) microparticles that counteract excessive friction and particle adhesion inside the cartridge, and magnetic agents that control electrical charges (positive in the form of nigrosine and negative in the form of, e.g., zinc, chromium, iron complex compounds). The transfer of dye between the photoresistive drum and the substrate depends mainly on the adhesion of the toner and the dimensions of its particles. Colour printing additionally uses intermediate media in the form of an image drum or collective ribbon.

The resulting print is then fused using thermal or pressure-thermal methods. The fusing unit (fuser) consists of two rollers pressed against each other, one of which is heated to the appropriate temperature, which causes the toner to melt, causing it to migrate into the pores of the paper and arrange its particles on the substrate. Parameters such as the viscosity of the toner, the pressure of the fusing system and the thickness of the toner layer on the paper affect its ability to penetrate the substrate. There are two types of toner currently in use - dry and liquid. Dry toners are in powder form and have a one- or two-component structure. Microscopically, a dry toner printout is convex and shiny, and it is possible to see its individual particles. Liquid toners, on the other hand, contain a solvent in which the toner particles are suspended, allowing a thinner print layer to be achieved while increasing the resolution of the printed image, as the use of a suspension allows particles with a much smaller diameter to be used than in a dry toner. The liquid toner colours the individual fibres of the paper, looking somewhat like printing ink4.

The fusing process takes place at a temperature of 160-200 °C and a pressure in the fusing zone of about 1 MPa. At the same time, the photoconductive layer is cleaned of toner residue and subjected to regenerative exposure to neutralise the charges on its surface, so that the cylinder with the photoconductive layer is prepared for the next production cycle.

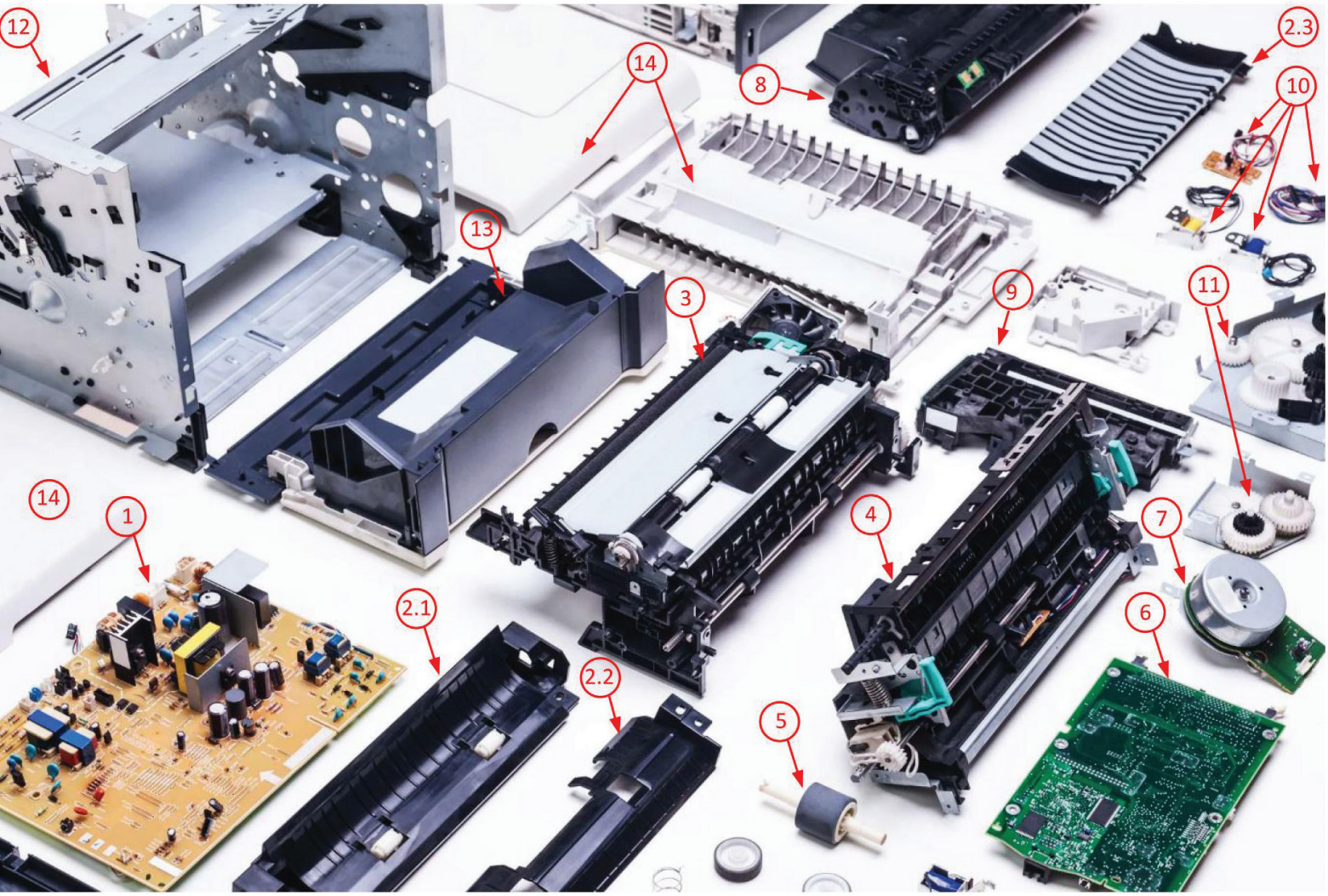
Commonly used are both monochrome and colour printing devices, the vast majority of the latter using the four primary colours - cyan, magenta, yellow and black (CMYK), with some devices using black toner to print text, and when copying graphic elements, the black colour is made up of the three primary colours (CMY)5.

With regard to printing mechanisms, different design solutions are used, where, alongside multi-pass devices,

3 S. Khadzhynova, S. Jakucewicz, ibidem, p. 24.

4 S. Khadzhynova, S. Jakucewicz, ibidem, p. 57. M. Hryciuk. Kryminalistyczna identyfikacja wybranych urządzeń kopiujących, tj. komputerowych drukarek laserowych i kserokopiarek [Forensic identification of selected copying devices, i.e. laser computer printers and photocopy machines]. Problemy Kryminalistyki 208, p. 22.

5 M. Borowski, 2002, ibidem, p. 9.



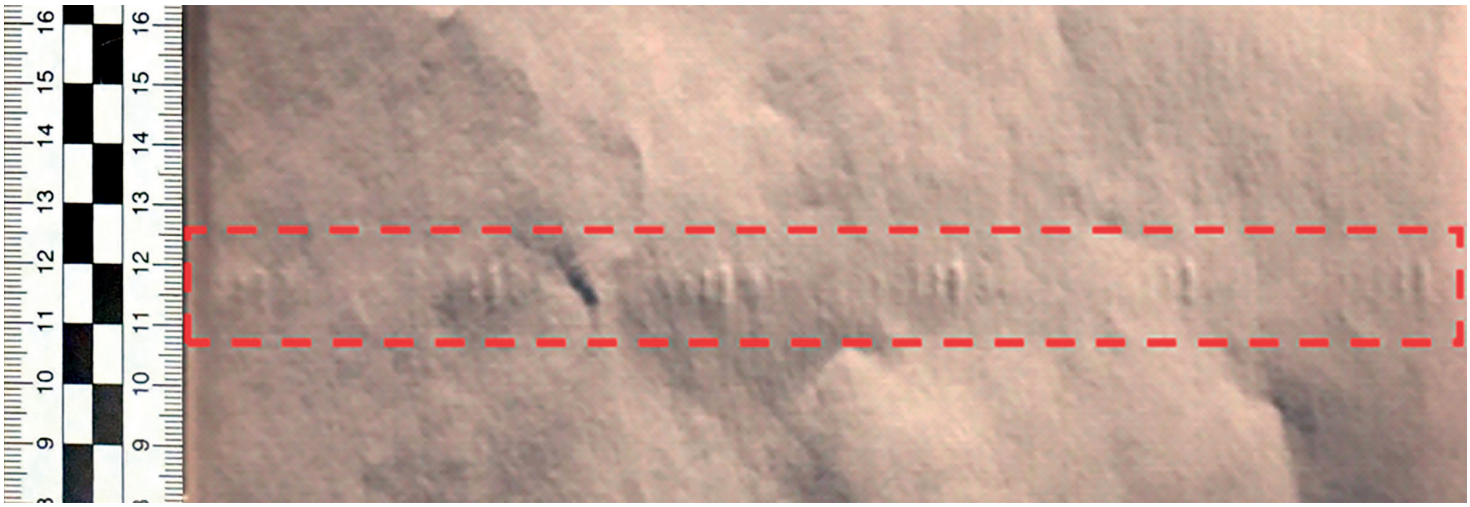
ryc. 3. Components of a monochrome laser printer. The figure indicates the main components of the device, where successive numbers denote: 1 - a power supply board, 2 - paper guide components (drawer exit 2.1, paper separator 2.2, paper guide 2.3), 3 - a duplex unit for paper guiding and page turning, 4 - a heating unit (fuser), 5 - a main roller, 6 - a main board, 7 - a main motor, 8 - a toner cartridge and a photoconductor drum, 9 - a laser unit, 10 - sensors and electromagnets, 11 - roller drive gears, 12 - a printer frame, 13 - a front flap, 14 - an enclosure. Source: https://forbot.pl/blog/jak-dziala-drukarka-laserowa-czym-jest-beben-swiatloczuly-id47000, downloaded on 26 January 2023, authors (descriptions).

single-pass printers and devices are used. The former have a single printing unit that applies each primary colour in a separate print run. Devices of this type are equipped with an intermediate collective carrier of toner particles of the individual colours, which is a collective drum or ribbon. They have one photosensitive print drum and as many colour units as the number of primary colours they use, which operate according to the principle of linear shifting or rotation, as carousel (turret) units. In single-pass devices, on the other hand, the toner is transferred to the substrate in a single cycle, where the dye from the intermediate carrier (intermediate drum or ribbon) is transferred directly to the paper. In this system, there is a single, mostly rectilinear movement of the paper, which significantly increases the printing speed.

Types of identification features applied by laser printing devices

The key to correct determination of equipment, is the presence of identifying features on the printed documents. As the entire printing process is made up of many stages, interference can occur at any of them, generating such features if they are not working correctly. The correct interpretation of the deficiencies found in the printouts, combined with the determination of their provenance, is the basis of the correct formulation of conclusions.

In document examination, as in other forensic disciplines, it is possible to speak of group and individual fea-



ryc. 4. A piece of paper with visible grooves caused by damage to the pressure roller. Source: the authors.

tures, and the presence of only the latter makes it possible to categorically attribute a device, which is usually provided as comparative material, to a document usually in the form of a paper printout.

The existence on the market of various types and models of colour and monochrome laser printers means that identification features can be applied by malfunctioning components or arise at the image formation stage, given that more and more devices are combining several functions rather than one, as was the case in the early 1980s. Therefore, the features applied by the devices may have different locations, related to the design and operating principle of each device.

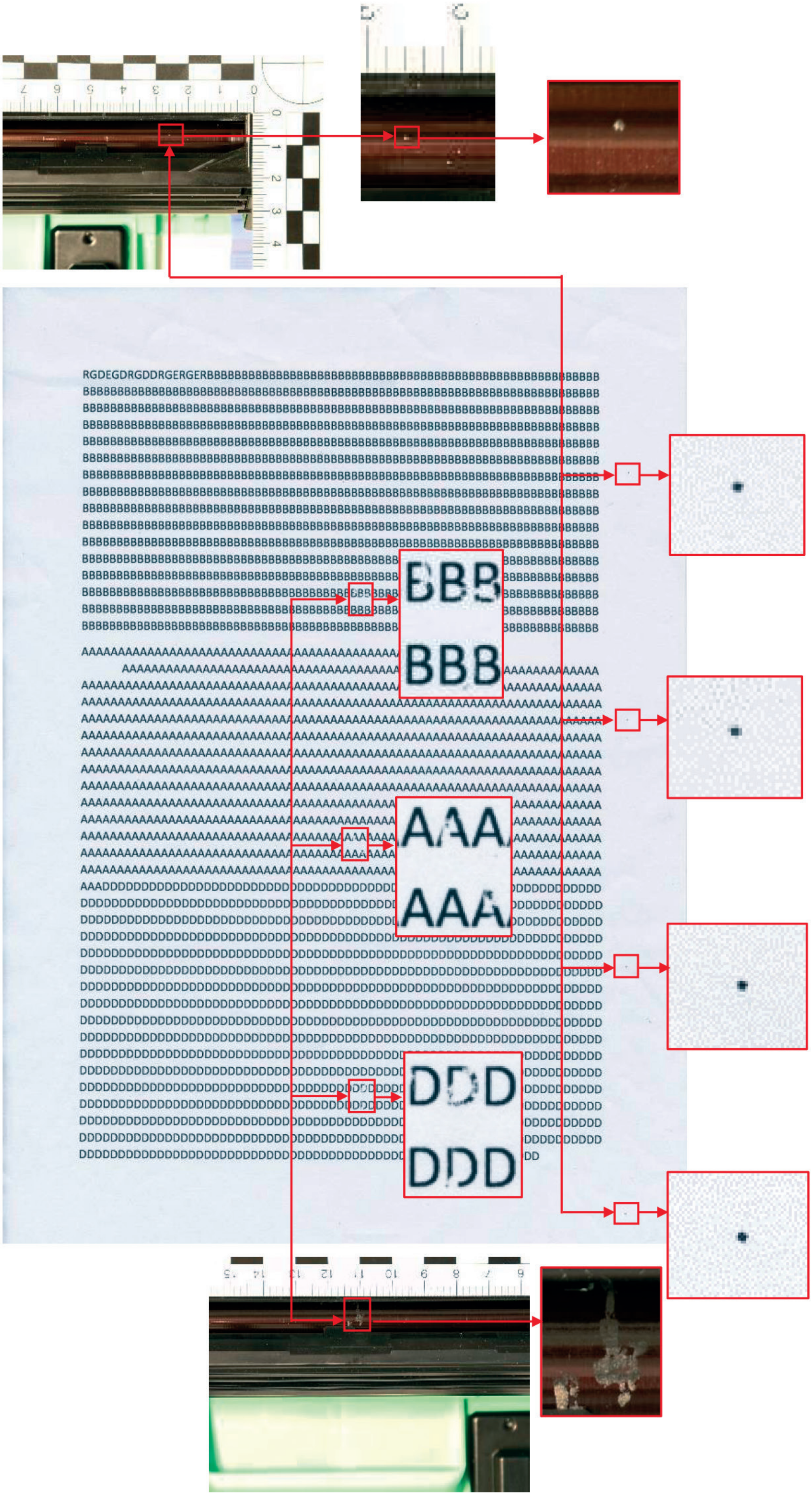
Nevertheless, it is possible to identify features whose emergence is common to a larger group of printing devices. These are concentrated around parts such as the paper tray, the guide rollers, the heating unit (fuser), the exposure glass and the cover in multi-function devices. Any of these components that do not function properly, whether through natural wear and tear, damage or simply a lack of maintenance and care for cleanliness, can generate unique features that are useful for in identification examinations.

The features that the device applies can be of two types: non-permanent (temporary) or permanent (stable). Temporary features are usually the result of easily removable soiling of various kinds occurring, for example, on the scanner glass and, as such, can be the basis for linking printouts to the device or printouts to each other in a particular unit of time. They disappear after cleaning or maintenance of the equipment. Others, which are considered permanent, are associated with damage to the image drum, the image drum cleaning elements, the paper transport elements or the fusing rollers. They are considered to be permanent because the replacement of the aforementioned components takes place far less frequently, primarily during equipment repair or periodic maintenance6.

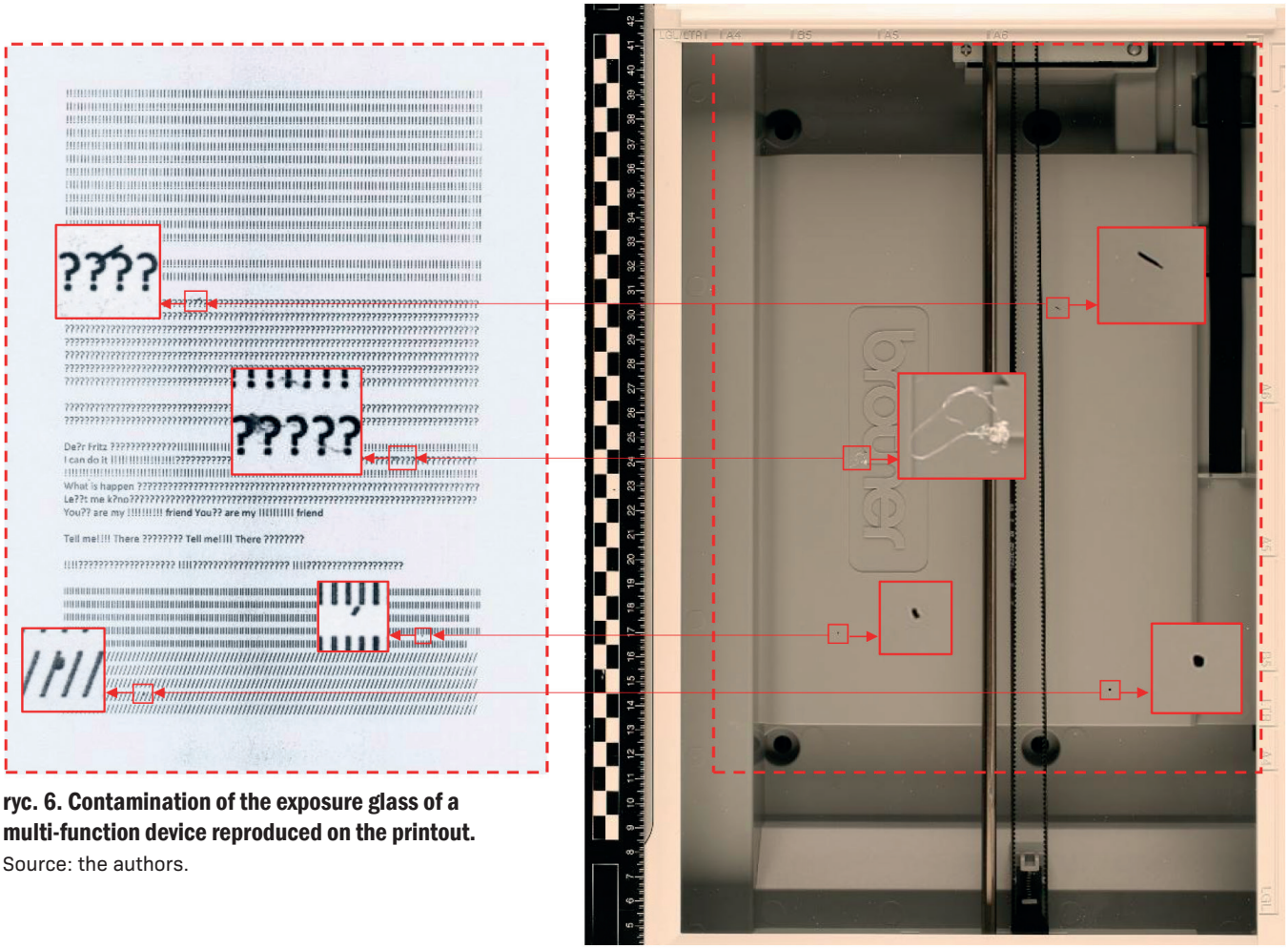
At the very beginning of the printing process, damage to the tray or feeder, e.g. plastic fragments breaking off or the paper feed roller falling off, results in uneven guidance, which is reflected, for example, in the slanted position of the text in relation to the sheet of paper. Deformations of the rubber or plastic paper guide rollers caused by wear or mechanical damage, often occurring when the paper is jammed and forcibly removed, result in indentations (grooves) or dirty streaks running along the sheet, with their location correlated with the defective component.

Another design element of a printer that influences the emergence of characteristics on the printouts are the LED matrices, used in Oki printers, or the laser used by most manufacturers, one of whose main elements is a rotating polygon lined with mirrors. It performs high-speed rotations in one direction, and turning the laser on or off results in illuminating (or not) a selected point on the image drum. Such a 'latent image' is created line by line with very high precision. Operating the printing device in unfavourable conditions, especially in high humidity, causes dust particles to stick to the glass surface or the build-up of toner spilled from the cartridge. Then the beam does not reflect properly and hits the image drum with less power. Dirt can also appear on the lenses. The effects of these phenomena include, for example, a change in the tonality of printouts from parts with the correct degree of saturation to lighter colours, producing a kind of colour gradient effect in colour printouts, and a gradual transition from areas with the correct blacking up to those showing shades of grey in documents printed on a monochrome printer.

6 M. Borowski, 2002, ibidem, p. 27.



ryc. 5. Dirt on the image drum reproduced on the printout. Source: the authors.



ryc. 6. Contamination of the exposure glass of a multi-function device reproduced on the printout.
Source: the authors.

The next vitally important part is the image drum itself, which is the component that transfers the digital image from the computer to paper. Its photosensitive surface is susceptible to damage, which directly affects the quality of the printouts. Drum life is estimated at around a few thousand pages for printers with an integrated drum and toner unit, or around 20-30 thousand pages in devices when they are separate components. One of the factors resulting in the weakening of the properties of the photosensitive layer is contact with the

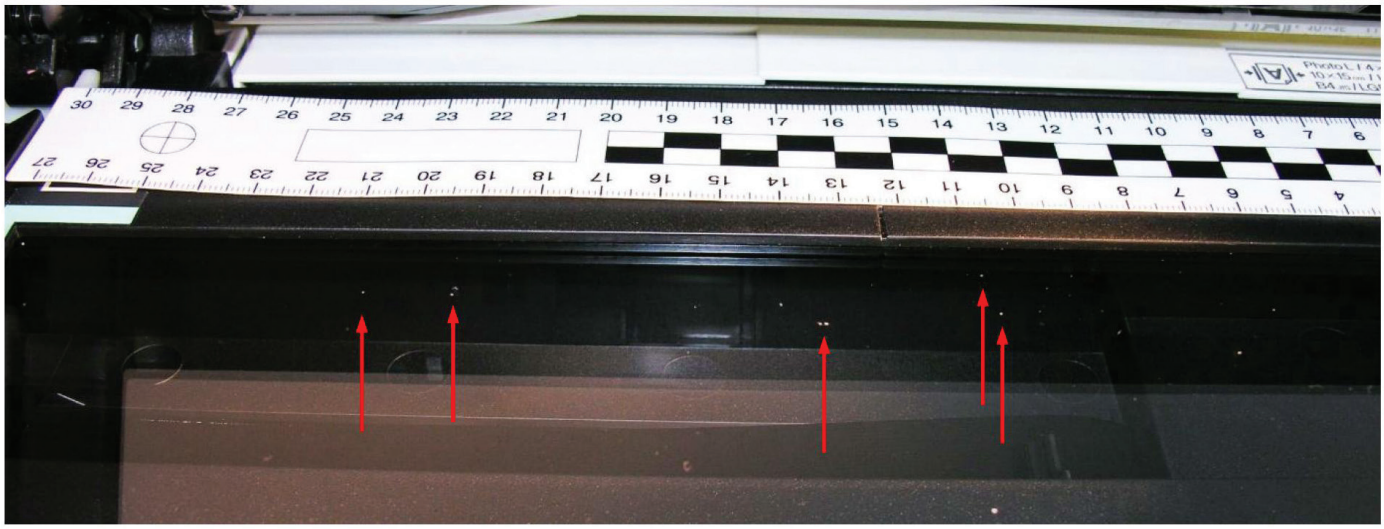
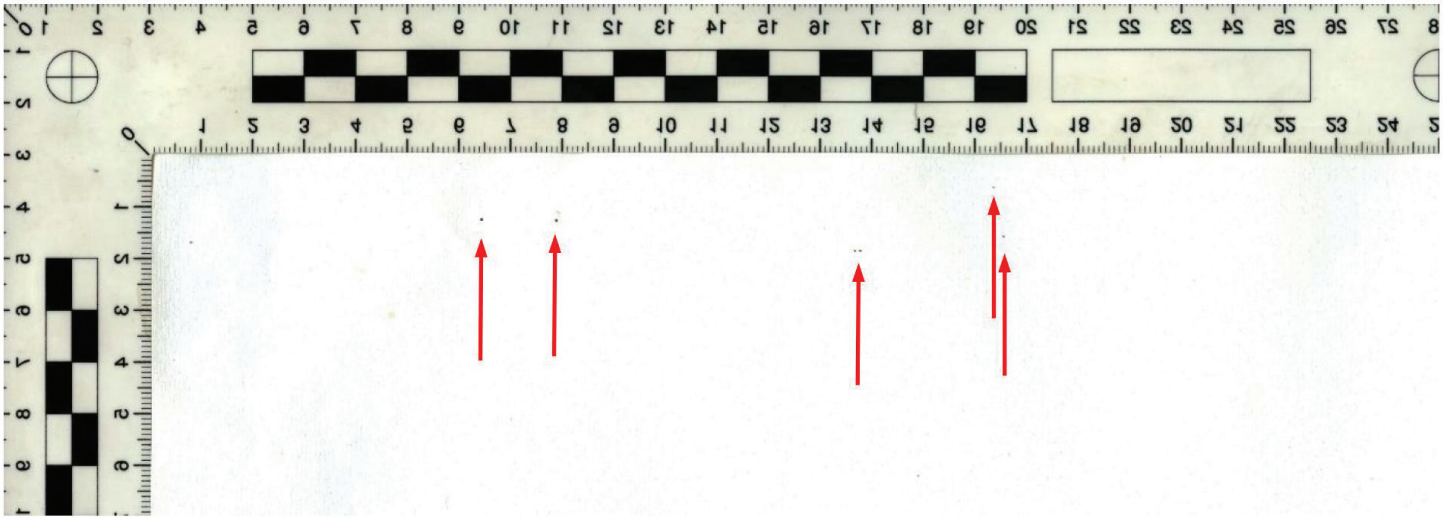
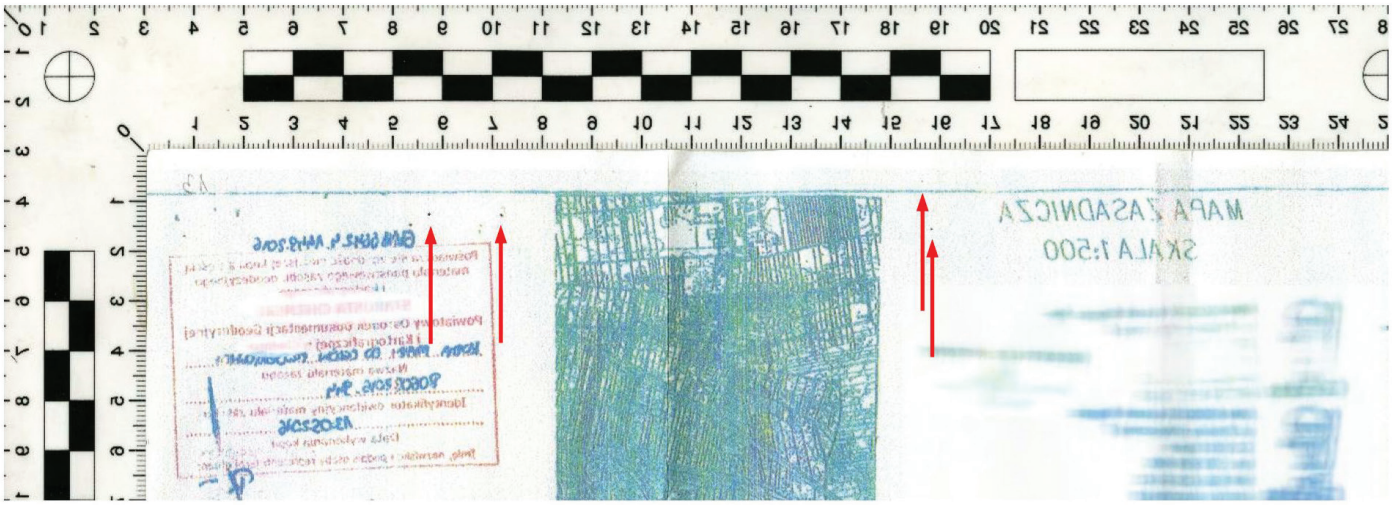


Fig. 7. A section of the exposure glass of a multi-function device with visible dirt spots. Source: the authors.



ryc. 8. A fragment of a printed sheet of paper made using the 'Copy' command in the colour mode in the normal option with visible dirt spots. Source: the authors.

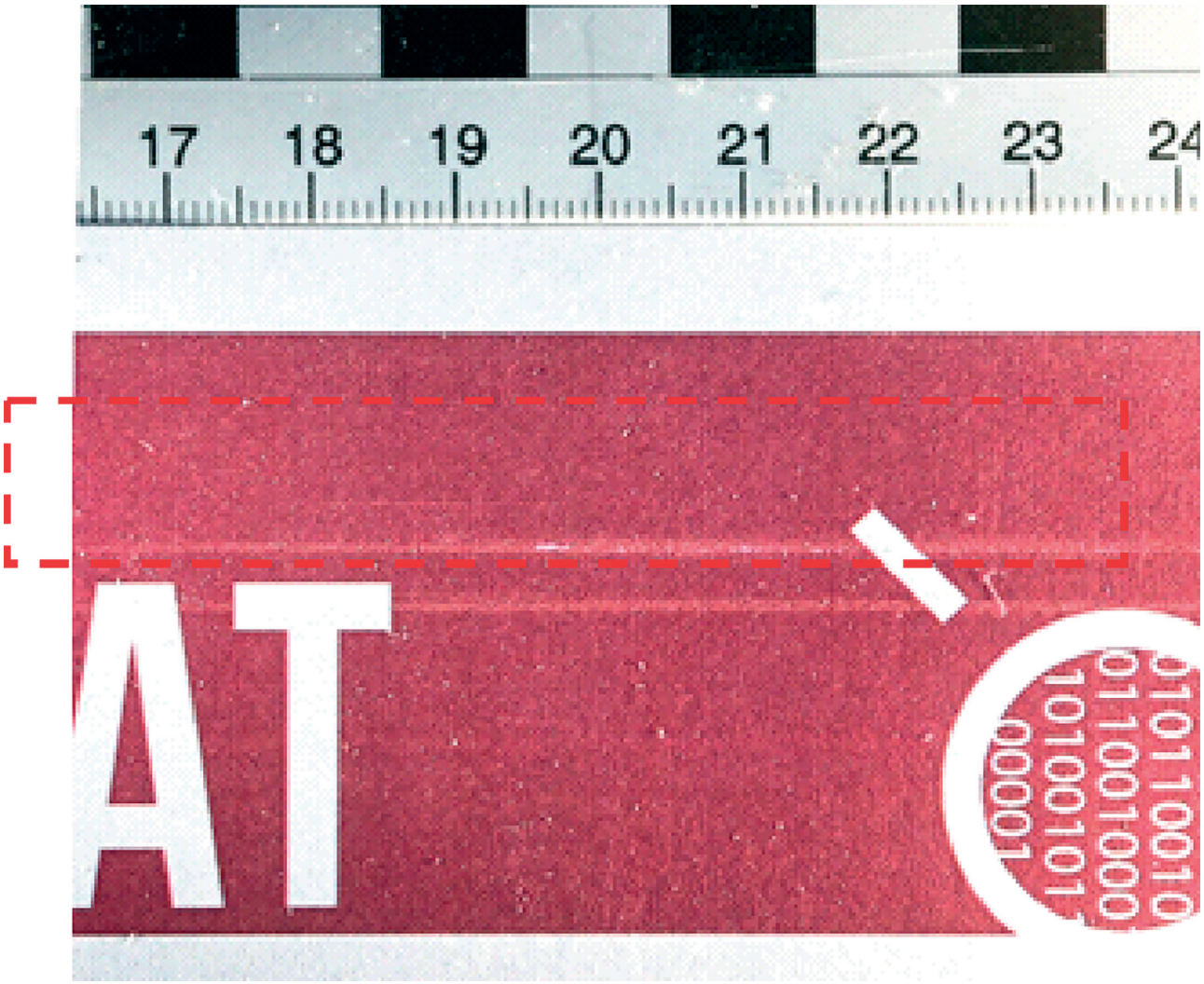


ryc. 9. A fragment of a survey map with visible dirt spots. Source: the authors.

cleaning bar and brush, which each time collect from the roller surface any toner residue that has not been transferred to the paper. If a lot of toner residue, dust or paper dust collects on the brush or bars, lines or imprinted parts of the printed document appear on the printout. Another phenomenon is toner particles stuck to the drum in the form of individual dots, larger clusters or irregularly shaped multiple layers. This results in dot-like artefacts on the paper and, with greater contamination, inadequate toner coverage of the printouts. Importantly, not only the shape of the artefacts usually corresponds to those on the drum, but also their repetition on the printout at intervals equal to the circumference of the image drum.

In colour printing devices, artefacts can also appear on the intermediate ribbon, which collects exposed images from individual image drums corresponding to the primary colours (CMYK).

In multi-function devices, one more element produces features that form the basis for identification, not in relation to the printout itself, but to the image acquired through it in scanning mode. This element is the presence of dirt on the exposure glass or the inside of the lid. Of course, it can be assumed that the entire print cycle was made on the same machine on which the image was acquired, although in the absence of individual features this would be difficult or impossible to establish. A document with the artefact applied could just as well have been printed on a completely different printer. However, if a multi-function device is treated as an integral object, it is possible to conclude that the contested document is produced using that device.



ryc. 10. Traces on the printout applied by a malfunctioning paper tear-off device. Source: the authors.

The identification feature described above was the basis for the identification, in one of the opinions prepared, of the multi-function device, provided as comparative material, for printing a survey map. Dirt on the exposure glass, presumably with an office correction fluid, was reflected in the printout. The conformance of their placement and shape provided sufficient grounds to categorically conclude that the map image was obtained using the device in question. The apparent shift in the distribution of dirt between that found on the unprinted sheet and that seen on the map is due to the fact that the document was moved away from the stops of the exposure glass.

Another type of distinction arises within the heating unit, acting as a thermal fuser, usually consisting of a rubber roller and a heating roller. The role of the first roller is to press the paper against the heating roller, which has the form of a metal cylinder covered with Teflon - in devices from the majority of manufacturers, or with heating foil - e.g. in HP LaserJet printers of M and P models. The appearance of specific images can be related to a foreign object such as a paper clip or a staple, which interferes with the image of the resulting printout. In addition, damaged elements result in creases and wrinkling of the paper, as well as the presence of additional letter images or a fragmentary lack of toner fixation on the paper - smudging. Within the fusing unit, which influences the final process of creating an image on paper and achieving the right quality, it is worth looking at another component: the tear-off devices. These are plastic elements in the shape of vertically seated 'teeth' spaced at equal intervals, whose function is to lift the paper after it has passed through the heating roller or strip.

The malfunction of the above-mentioned element manifests itself in the presence of scratches and dents in the paper, the appearance of which, also on the comparative prints, contributes to the potential determination of the printing device.

Due to the steadily increasing quality of printouts, in the printing or copying processes, and thus the increasing frequency of copier/printer use for counterfeiting or document alteration, manufacturers of colour machines affiliated to the Japan Business Machine Markers Association (JBMA) have used a special code introduced in the form of a repetitive pattern of yellow dots.When the controller of a printer equipped with such a system recognises that a colour image is being printed, the dot pattern is automatically applied to the paper. Their layout is characteristic of each print unit manufacturer and, in addition, carries a range of other data that makes it possible to identify the individual device. It is virtually impossible for the person making the printout to remove such a code. Such marking provides a basis for quickly determining the 'identity' of the printing device used for criminal purposes and linking it to the questionable documents produced. The code is applied by the majority of electrophotographic devices operating in colour mode.

Conclusions

Each time, before proceeding with analyses aimed at identifying a printing device, an in-depth verification of the characteristics found on the printed documents, should be carried out, as only the presence of unique ones will allow categorical conclusions to be drawn. It should also be borne in mind that some characteristics may seem unique only on the surface, but in fact are not, as they result, for example, from a manufacturing defect in the device or become apparent after a short period of use and are typical of a whole batch of the product. Many such characteristics may be temporary due to the replacement of a faulty component or maintenance of the device, or may even disappear naturally. Therefore, in order to eliminate false premises, it is also reasonable to send, if possible, other printouts produced on the printer in question secured in the course of the investigation as comparative material, each time seeking the closest possible temporal correlation, whether through the dating of the documents or the circumstances surrounding their creation. In addition, it is also important to include with the materials submitted information on the extent of repairs, servicing and toner replacements carried out, supplemented if possible by the dates on which they were carried out. Only then will the experts have all the necessary data at their disposal, allowing them to comprehensively address the issue under investigation and the correct formulation of conclusions from the identification and comparison examinations carried out.

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