Research and Analysis of Modern Printer and Printing Defects

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Abstract.
A printer is already crucial office equipment. However, when using any printer, it is normal to see defects in the printed contents. The research integrates the common defects that users will encounter and analyzes some feasible solutions. The paper focuses on the basic procedures of the laser printer and analyzes the common printing defects based on the procedures. After some analysis, the paper finds that most regular defects can result from malfunctioning charging units for the charging process, the laser path and its optical components, or the photosensitive drum. Afterward, the paper addressed some improvements to inhibit the defects, including enhancing craftsmanship to different units. The paper has left the common users some insights on solving the defects and has provided the manufacturers or the researchers with ideas for further improvement.
Keywords: Photosensitive drum, printing defects, improvements, analysis.

1. Introduction

A printer is already crucial office equipment. As was addressed in the Global Printer Market Shipment Report, for Q2 2023, the global printer shipments were 19.5 million units. (IDC, 2023). When using any printer, it is normal to see defects in the printed contents. However, it is impractical for most users to thoroughly understand the printer they are using, and the countermeasures to the troubles can be time-consuming. In addition, with the continuous updating and innovation of printing technology, introducing new printer products has brought new challenges and problems that warrant more profound research to improve their performance and reliability. To help common users find solutions more efficiently, it is necessary to analyze the common printed quality defects and encapsulate their commonalities.

Some papers have already discussed how the printer works and how to deal with image defects, but there are also some contradictions between those papers. Based on the basic principles of the steps for most printers, this paper analyzes the causes of the defects and the feasible solutions after the integration and the deductions into different related papers.

2. Procedures Happened Within the Printing

2.1 Charging

Charging is the process that uses electrostatic high voltage corona discharging, electrifying the photosensitive drum and raising its surface potential. In general, there are two types of charging methods.

The corona wire that connects with the conductive layer is connected to the output end of the high-voltage generator and moves parallel to the surface of the photosensitive drum while discharging the corona. Under the influence of electric field force, positively charged ionized air ions are propelled towards the photosensitive drum‘s surface, which has a dual effect: firstly, they interact favorably with the photosensitive drum‘s surface; secondly, they induce negative charges from the conductive layer to establish phase equilibrium. Since the photoconductive layer is not illuminated at this stage, it behaves as an insulator (with only weak leakage current), similar to an insulating medium between two plates of a flat capacitor. At its two interfaces (one being the air interface and another being the base interface), two charge layers with equal amounts but opposite polarities are formed, following principles akin to capacitor charging. The charge distributed on both sides of the photosensitive drum and air is positively polarized, resembling a positive plate in a capacitor. The higher amount of electricity forming this charged layer results in higher surface potential [1].

The conductive rod that connects with the end of the high-voltage generator will carry some charges. Through the small gaps between the rod and the surface of the photosensitive drum, the photosensitive drum will discharge to the surface. This is also the most frequently used method. However, the charge distribution induced by the method is not as uniform as the former one, and due to the small gaps between the two units, the inevitable friction between them will result in a shorter life expectancy of the machine.

Noticeably, due to the difference in the material of the photosensitive drum, some types of the drum will be charged negatively.

2.2 Illumination

Illumination is the process of eliminating the potential of some specific area on the surface. The process is based on the photosensitive characteristics of the photoconductive material on the surface of the photosensitive drum. When scanning the surface of the photosensitive drum with a laser beam carrying printed data, the part irradiated by the light is directly connected with the conductive layer of the photosensitive drum, and the charge quickly disappears. The part not irradiated by the light still maintains the insulation state. It only carries out the dark decay process (the process of natural potential reduction over time is called the dark decay process, which normally requires more time than the whole printing process), so the high potential is maintained. The part irradiated by the light becomes conductive due to the light, and the positive and negative charges neutralize each other through the photosensitive drum. Hence, the surface potential is greatly reduced, also called the bright decay process. The bright decay process is completed in an instant. At the end of the exposure, an electrostatic latent image is formed on the surface of the photosensitive drum.

Noticeably, the illumination process in the different printers can be different out of the variance of the photoconductive layer in the photosensitive drum. This essay focuses on the type that contains three effective layers, with the sequence from outside to inside. They are the charge transport layer (CTL), charge generation layer (CGL), and undercoat layer (UCL).

Assume that the surface of the photosensitive drum is charged with some potential after the charging process. In the illumination process, positive and negative charges will be generated in the CGL after exposure to the laser.

The part irradiated by light becomes electrically conductive. Subject to the electric force induced by the positive charges distributed on the surface and negative charges in the base interface, the newly generated negative charges will move upward through the CTL and neutralize the positive charges on the surface. Similarly, the positive charges will go downward through the UCL and neutralize the negative charges. Therefore, the potential on the surface will drop to a certain level.

Noticeably, the illumination process is divided into two types with two different types of electrostatic latent images: regular illumination and inverted illumination. Regular illumination uses the laser to irradiate the area surrounding the target latent image, while divert illumination uses the laser to directly create the target latent image. The machines that apply regular illumination are mostly photocopiers, in which the toner and the photosensitive drum surface will be electrified with opposite charges. The inverted illumination requires the same charge between the photosensitive drum surface and the toner. This type of illumination is applied mostly in printers.

2.3 Developing

Developing refers to the process that transforms the electrostatic latent image into the toner image that forms on the surface of the photosensitive drum.

The toner in the storage is attracted by the magnetic in the developing roller and electrified by the friction process with the blade (a special construction in the printer), carrying charges contrary to the charges on the surface induced by the charging process. The roller is spinning and carries the toner to the electric field induced by the electrostatic latent image. The toner is subjected to the electric force and will be absorbed into the surface of the photosensitive drum, forming an image.

2.4 Transfer

Transfer is transferring toner from the photosensitive drum to the printing paper.

Generally, a high voltage static electricity with the opposite polarity as the toner is moved along the back of the paper at the same time as corona discharge. A strong electric field causes the toner particles to be desorbed from the photosensitive drum surface and transferred to the printing paper.

Noticeably, in the process of transfer, due to the electrostatic latent image potential to the electric field intensity formed by the transfer of high voltage closer to the surface of the photosensitive drum, coupled with the effect of external gravity and toner particles in the transfer process of crowding phenomenon and other factors, in the transfer of high pressure in an instant, it is impossible to transfer all toner to the paper, there are always some toner remains on the photosensitive drum. Residual toners on the photosensitive drum are residual toners[2].

2.5 Photographic Fixing and Cleaning

The method frequently adopted in this process is heat fixing, which utilizes a heat source (usually a heating roller) to melt the toner. Melted toner will permeate the paper, forming a stable image[3].

After the whole process ends, there will be some residual charges and toners on the surface of the photosensitive drum. If not cleaned thoroughly, the residuals will jeopardize the printing quality next time[4]. Three methods are generally adopted to clean the surface: discharge exposure, scraper, and brush cleaning. Discharge exposure cleaning eliminates the residual charges through full exposure, led by AC high-voltage discharge. Scraper cleaning and brush cleaning are required to clean the

residual tonners.

3. Analysis of Common Imaging Faults and Causes

3.1 Failure in Printing

Malfunction in the discharge electrode in the photosensitive drum. The photosensitive drum fails in the dissipation process of charges after exposure in the illumination process, resulting in an insufficient drop of the potential on the surface. This is usually caused by the disconnection in the grounding circuit[5]. Malfunction of the laser path. Due to the malfunction, the printer will not complete the electrostatic dissipation. Hence, the electrostatic latent image does not complete its formation on the surface of the photoreceptor. Disconnection in the charging circuit that charges the paper in the transfer process.The disconnection of the electrode on the transfer unit. Based on the disconnection, there will not be any electric field between the photosensitive drum and the paper. The toners will not be transferred into the paper. Wholescale -fatigue of the photoconductive layer.The non-functional layer will not respond to the laser effectively; hence, the charges on the surface will not be neutralized. As a result, charges will be distributed wholesale, and no toners will be attracted due to the same charges. Run out of the toners. Short circuit in the charging units for the charging process. Due to the short circuit of the charging circuit, the surface of the photosensitive drum is excessively charged. As a result, the charge dissipation in the illumination process cannot drop the potential on the surface to an appropriate level. Hence, there is no valid formation of the electrostatic latent image. Disconnection in the charging unit for the charging process will result in all black on paper [6]. Due to the disconnection in the charging circuit, the surface of the photosensitive drum remains electroneutral. The toners will be attracted wholesale due to the electrostatic adsorption phenomenon. Driver error in scanning the driver circuit will result in a similar phenomenon.

3.2 Unwanted Images

Insufficient toner storage. Due to insufficient storage, the toner will be ununiformly distributed on the developer roller. If observing the paper, there will be a gradual dilution of the pattern. Beam reflectors contaminated with toner and other dirt will have the same defects. Obstruction of the optical path by a foreign object will cause local insufficiencies to discharge in the illumination process.

Additionally, they can be identified by observing whether the vertical direction of the blank pattern‘s verges is neat; if the edges are blurred, it may be lens contamination[6]. Otherwise, the optical path may be obstructed. Also, fatigue of the photoconductive layer means the absence of the response to the exposure to the laser. As a result, the potential of those specific areas will not drop to a sufficient level. Disconnections or poor contacts in the fixing roller may also cause this due to the toners not permeating the paper.

Surface damage on the photosensitive drum surface. Due to the damage, toners will accumulate in the wound, resulting in a local toner concentration zooming. Unstable rotation of the photosensitive drum will cause uneven transformation, leading to the same defect. Poor contact of the photosensitive drum elimination electrode. Due to unstable contact of the circuit, the intermittent malfunction in discharge will result in some local insufficient potential drop, obstructing the formation of an electrostatic latent image. Abnormal electrification of the toners. In case of failure in the electrification, toners will not be subjected to electric force and, hence, will not attach to the surface of the photosensitive drum.

Unregular black patterns will be caused by the shaking of the photosensitive drum and the poor contact of the charging roller or charging electrodes in the charging process. Due to the shaking, the toner will not be transformed evenly. Due to the unstable charging process, some areas that are supposed to be electrified remain electroneutral, eventually preventing the toner from attaching to the photosensitive drum.

The virtual image (Ghosting) is a phenomenon in which the image from the first cycle (photoreceptor cycle) has an effect on the print image from the second cycle [7].

The portion with the deeper color of the image is affected by the toner attached to the photosensitive drum, which causes the charge to move in patches, and the electrifying process is suppressed relative to the surrounding area. In the following process, the influence of this potential difference on the surface continues, resulting in an insufficient potential difference in the formation of the electrostatic latent image. Consequently, there will be a low concentration of toners in the darker area of the first cycle, which is also the ghost of the former image.

Usually, the foreign objects attached to the paper will obstruct the attachment of the toner, causing a white dot.

3.3 Uneven Color Distribution

Dropping color depths. The toner will run out soon, causing the concentration of the toner to gradually decrease on the photosensitive drum, resulting in the concentration decrease. Fluctuating color depths. Deterioration of the optical properties of the reflector and poor contact on the charging circuit for the transfer unit

(especially charging electrodes) might lead to fluctuation of color [8].

Sudden disappearance in color concentration. Usually refers to the phenomenon that when the concentration of color becomes significantly higher, the pattern‘s center occurs a white-out. Sometimes, it will be ignored when a complete pattern is separated into two seemingly patterns due to the white-out. Usually, due to the quality defects of the paper or the inherent defects of the developing roller, which cannot induce an ideal magnetic field or does not obtain an even surface to transform the toners uniformly. Surface wear of the fixing roller. The worn area will sometimes lead to the uneven pressing of powder, including some sudden disappearance of the toner.

4. Improvements

Improvements based on photosensitive drum. Adopt some methods to extend the life expectancy of the photosensitive drum. Lenovo has innovated a kind of longevity photosensitive drum, which contains more protective layers on its surface in the special design ‘Long life for all printer Engine Element’ (LLE) [9]. Adopt some new materials for the photosensitive drum to enhance the optical performance. Similarly, it enhances the magnetic property of the developing roller. Adopting the design will induce a more even magnetic field, which can result in a more even distribution of the toners on the developer roller [10]. Meanwhile, there are also some avenues to enhance the performance of the developing roller by lifting the surface‘s craftsmanship, which can ensure a uniform amount of toner is delivered to the photoreceptor drum for development [11].

Use of suitable 5μm insulating coatings, which is shown to perform best within the scope of the expedition. Also, regular the size of the toners. The requirements of the particle size of the toner are less than 3μm, and the volume fraction is not less than 2%; otherwise, a large number of particle clusters will be generated, resulting in poor printing quality [12]. Settle the printer in a cleaner environment, which can help avoid the contamination of the laser path. In the future, consider Investing more resources in the research and development of printing technology and promoting the introduction of more advanced printers to reduce defects and improve print quality.

Meanwhile, introducing advanced sensor technology, automatic calibration systems, etc., are feasible methods to improve the degree of automation of the printer, which will consequently reduce the possibility of human error. Optimize the quality control and manufacturing process, and strengthen the quality control of the printer manufacturing process toto ensure high-quality standards for each printer. Manufacturers can fix known hardware and software compatibility issues by regularly releasing firmware and driver updates to improve the system‘s stability. Designing more durable, easy-to-service printers reduces equipment obsolescence due to hardware failure. These improvements can help reduce printer defects and improve the printer‘s performance, reliability, and user experience.

5. Conclusion

The paper introduced the general printing procedures for most printers. It analyzed three major defects based on the procedures, including failure in printing, unwanted images, and uneven color distributions. The improvements based on those defects are mostly the enhancement of the craftsmanship of the different units. The common users can use the printing machine more easily with the assistance of this paper. Meanwhile, the paper also addressed some improvements based on the common defects for related researchers or manufacturers to consider. To encapsulate, most of the regular defects can result from malfunctioning charging units for the charging process, the laser path and its optical components, or the photosensitive drum. When facing the defacts, users can check these units as a priority.

This paper also has a shortcoming, which refers to a lack of discussions on color and ink-jet printers, which are not less in usage than the laser printer. Future research can be based on those two types of printers, and more profound research can be conducted. In the future, various printing defects can be systematically investigated and analyzed. Their generating mechanisms can be detected, and corresponding improvement and optimization schemes can be proposed to facilitate printing technology‘s continuous improvement and innovation.

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