INVESTIGATION OF THE EFFECT ON PRINTED PAPER RECYCLING OF TONERS USED IN ELECTROPHOTOGRAPHIC PRINTING SYSTEM

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Abstract

The printing sector is gaining new dimensions with developments in printing systems. Especially, innovations in electrophotographic printing system are moved to different dimensions of the printing sector. In terms of preference, electrophotographic printing have not passed in front of the offset printing yet, new use areas and the integration with other printing systems have been expanded the fields of use of electrophotographic printing systems. Recently, it has become fast continues studies intended for reducing the cost of both substrates and toner and other raw materials in electrophotographic printing system, which is more and more preferred in less printing circulation.

Although, electrophotographic printing has many advantages, the difficulties of recycling of printed digital papers is a major disadvantage. While printing inks used in offset printing or gravure printing during printed paper recycling can easily be remove from paper, toner used in electrophotographic printing can not be completely separated from the paper. Because of the fact that they stick on the paper surface, the quality of paper obtained after recycling are decreased.

The primary purpose of this study is to understand the structure of the toners used in digital printing. The study will be examined in two parts. In the first part, the recycling conditions of printed papers will be explained. In the second part, the impact on recycling of toners used in electrophotographic printing will be considered.

Keywords: *Electrophotography, Printing, Toner, Recycling*

Introduction

Today and in the near future, the trend in print technology is shaped as digital printing. Digital printing is the most talked about printing technology. According to Smithers Pira's estimate of digital commercial printing, electrophotography (EP) and ink-jet are the most popular digital printing technologies. They are a strong potential for the future. Between 2013-2018, the use of inkjet printing will increase by 2/3 and it is estimated that this will reach 23% by electrophotography.

Today, offset lithography, gravure, flexography, inkjet, electrophotography and printing techniques such as screen printing are used. The print quality and process are influenced by the type of ink. Also, resolution and the kind of the substrates have a strong influence on the process.

Although Electrographic printing of our study' subject, also known as "xerography" or "laser" printing, is the second basic digital printing process, there are not many applications in printing electronics. There are two main reasons:

1. The "toner" (which may be in the form of powder or liquid dispersion) used as printing ink can cause problems during electrostatic charging and transfer due to conductive elements.

2. Transferred toner may then adhere to the lower layer, which may cause problems in some applications (Anne Blayo and Bernard Pineaux, 2005)

Electrophotography or EP is the oldest of non-impact printing technologies invented by Chester Carlson in the mid-1930s. Electrophotographic printing often Xerography (which means dry writing) and / or is referred to as laser printing. Technically, "laser" as used herein refers to specific light exposure technology used in the process, but more often the laser printer is used to identify any electrophotographic printing system (e.g., independent of exposure technology, such as an LED printer).

Electrophotography is the most complex digital printing technology with two critical materials and five process steps.

Figure 1: basic stages for this print format

Source: http://www.canon.com/technology/canon_tech/explanation/lp.html http://archive.is/fhnBP

The main advantages of electrophotography (EP) over other non-impact printing or digital printing technologies are:

- Excellent print quality for text, graphics and picture
- Large speed range - from 4 PPM to 1,000 PPM

(http://www.tpr.com/electrophotography.htm)

Electrophotography process

Electrostatic charges are used to create a charged light image in the drum. First, Toner is drawn and then paper.

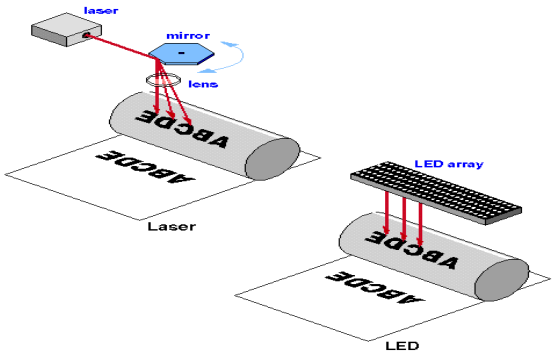


Figure 2: Electrophotography Process

(https://www.pcmag.com/encyclopedia/term/42509/electrophotographic)

Electrophotography Technology

Electrophotographic printing was invented by Chester Carlson in the 1930s. In the late 1950's, electrophotography (also known as xerography after Xerox Corporation) is the most common office copying machine. Originals were placed face down on a glass plate and a sufficient copies could be produced immediately. In the mid-1970s, the process was adapted to be used as a printed output method for computers. Instead of using light reflected from an original document, such as in old copiers, a laser (sometimes an LED) was used to turn computer data into light waves that would produce a light-sensitive, photoconductive drum or belt (Figure 3). In the 1980s, laser printing was reduced to be produced on a desktop sized printer. Below, an example and a description of the six basic stages for this print format are:

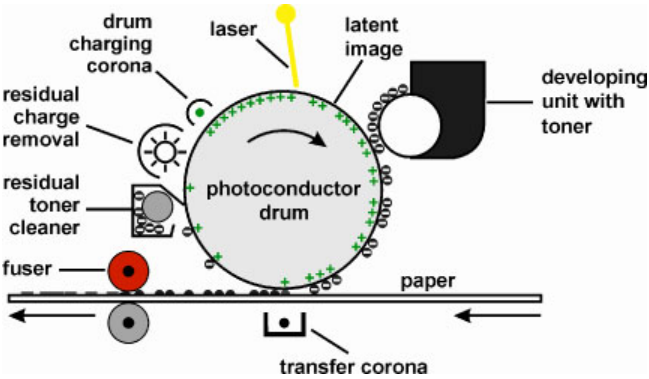


Figure 3: Electrophotographic printing

1. Charging the Photoconductor: A photoconductive drum or belt is charged by a corona (electric discharge).

2. Exposure: Charge is neutralized when light, charged drum or belt is exposed. In a laser printer, the laser is turned on and off by digital data in the computer. Laser, document or image to white space "open" and is neutralized the charge on these areas of the drum. Black areas of the document or image are invisible to the laser, for this reason the drum areas are charged.

3. Development: In this step, the toner is applied to the open drum surface. The toner carries an opposite charge from the drum, so toner sticks only to charged, unexposed areas.

4. Transfer: The toner is now transferred to the drum paper. A second corona is placed behind the paper and the photo creates a larger load than the beam. This, the toner is pulled from the drum to the paper.

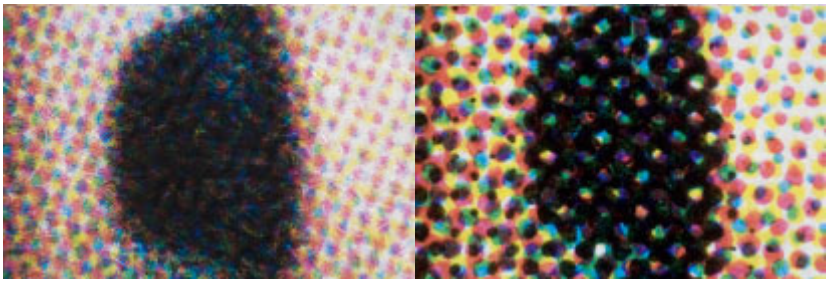
5. Fusing: At this point, the toner only stays on the surface of the paper and can easily infect. Various techniques can be used to correct the image. For dry toner systems, fixing is the combination of heat and pressure. For liquid toner systems, evaporation of the solvent dries the image.

6. Cleaning: Both the remaining toner and de-charged must be removed in order to reuse the photographic drum or belt for subsequent printing. The toner is peeled off mechanically. The drum is then charged with a light that neutralizes the charge remaining. Thus, the system becomes ready to restart.

Image Structure

Because electrophotographic printers can produce only one dark tone for each color (monochrome black or four-color CMYK), they need to produce color tones using the paper's whiteness. Dark colors, light colors by placing

close together forming point is formed by placing close to each other toner. This process is similar to the scanning technique used in offset printing, known as halftoning.



Dry toner image pattern *Liquid toner image pattern*

Figure 4: Dry and Liquid Toner Image Pattern

Individual image points consist of multiple toner particles. Dry toner prints provide a typical dusty appearance produced by toner particles outside the intended spot area. Liquid toner, instead, can provide thin toner particles, but it can always be in the dot area.

Colorants

Colorants used in electrophotographic systems are called toner. Toners are in two forms, dry and liquid. Dry toner is used in all desktop and office printer / copier systems. It is used both dry and liquid toner systems in electrophotographic digital print.

Dry toners consist of pigments or dyes embedded in polymer beads. In addition to the colorants in the polymer beads, the "charge materials" feature allows the toner to be charged to the photoconductor drum. Without this charge, the toner will not stick to the drum (or strap) or be transferred to paper. The toners also contain small "lubrication" particles between them to prevent them sticking together. In black-and-white printers, the coloring is carbon black, which is usually very stable. For this reason, black and white electrophotographic prints made on high quality alkaline paper should be very durable.

Papers

Electrophotographic paper can be uncoated or coated. Most of the desktop or office printer papers, which are often referred to as office paper or photocopy paper, are uncoated. A major disadvantage of plain paper for photographs is that they can easily bend or tear during processing.

This is usually the type of paper that we see in glossy magazines. They are also used in brochures, booklets and posters. Coated papers are sometimes used for desktop or office electrophotographic printing and at the same time is the preferred paper for digital printing machines. The following pictures show cross-sections of printing on each paper type. Fused toner particles can be clearly seen on the paper.

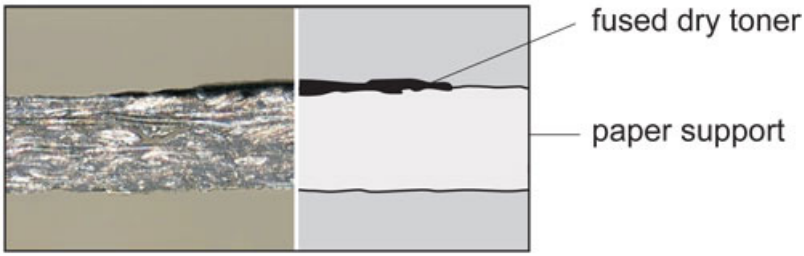


Figure 5: Dry toner on plain paper

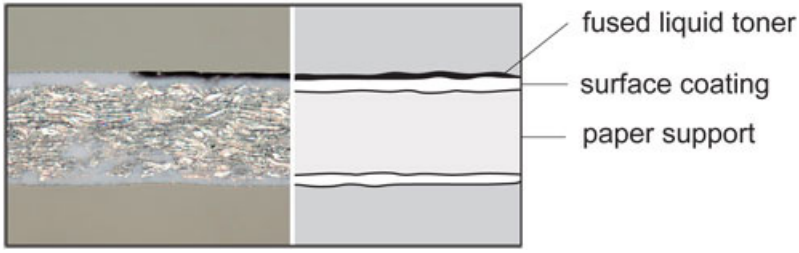


Figure 6: Liquid toner on coated paper

Source: http://www.dp3project.org/technologies/digital-printing/electrophotographic

Waste papers in the recycling process

Almost all types of paper are used for recycled paper. While some papers are easy to recycle, some are difficult and hard. Such that some paper cannot be used for recycling.

The data obtained from statistical data related to the printing industry of the Confederation of European Paper Industries (CEPI) are shown in table 1 and table 2.

Table 1: Paper for recycling

	1991	2000	2005	2010	2015	2016	%Change 2016/2015	%Change 2016/2000
Paper for Recycling ('000 Tonnes)								
Collection	25,452	43,658	53,100	55,917	55,829	56,406	1.0	29.2
Utilisation	25,360	40,922	46,745	48,122	47,751	47,792	0.1	16.8
Exports to Outside CEPI	n.a.	3,751	7,698	9,592	10,086	10,655	5.6	184.1
Imports from Outside CEPI	n.a.	1,015	1,343	1,796	2,008	2,041	1.7	101.1
Trade Balance with Outside CEPI	n.a.	2,736	6,355	7,795	8,078	8,614	6.6	214.8
Utilisation Rate	39.0%	45.1%	47.6%	50.6%	52.5%	52.6%	0.1	7.5
Exports/ Collection	n.a.	8.6%	14.5%	17.2%	18.1%	18.9%	0.8	10.3
Imports/ Utilisation	n.a.	2.5%	2.9%	3.7%	4.2%	4.3%	0.1	1.8
Recycling Rate in Europe[4]								
Recycling Rate	40.3%	51.8%	61.8%	68.5%	71.9%	72.5%	0.7	20.8

[4] *Europe means EU-28 countries plus Norway and Switzerland.*

Source: CEPI Key Statistics 2016 EUROPEAN PULP&PAPER INDUSTRY

Table 2: Grades of Paper for Recycling

	A Mixed Grades	B Corruga-ted and Kraft	C Newspapers & Magazi-nes	D Other Grades	E Total Use of Paper for Recycling	F Utilisation by Sector[1] %	G Total P&B Produc-tion	E:G Utilisation Rate[2] %
Paper Sector ('000 Tonnes)								
Newsprint	22	0	5,732	131	5,885	12.3	6,549	89.9
Other Graphic Papers	129	27	2,986	667	3,809	8.0	27,360	13.9
Total Newsprint + O.G.P.	151	27	8,719	797	9,694	20.3	33,909	28.6
Case Materials	4,571	20,254	231	944	26,000	54.5	27,733	93.8
Carton Board	1,865	581	90	850	3,386	7.1	9,049	37.4
Wrappings, Other Pack	1,914	1,707	170	454	4,246	8.9	8,888	47.8
Total Packaging Papers	8,351	22,541	492	2,248	33,632	70.4	45,671	73.6
Sanitary and Household	269	126	535	1,882	2,813	5.9	7,301	38.5

	A Mixed Grades	B Corruga-ted and Kraft	C Newspapers & Magazi-nes	D Other Grades	E Total Use of Paper for Recycling	F Utilisation by Sector[1] %	G Total P&B Produc-tion	E:G Utilisation Rate[2] %
Other Paper & Board	245	1,044	190	132	1,611	3.4	4,050	39.8
Total Paper & Board	9,016	23,738	9,936	5,060	47,751	100.0	90,931	52.5
Share of Total	18.9%	49.7%	20.8%	10.6%	100.0%			
De-inked Market Pulp	0	0	1	40	41			

[1] Utilisation by sector: total use of paper for recycling in a sector as a percentage of the total amount of paper for recycling used by the industry

[2] Utilisation rate: use of paper for recycling in a sector as a percentage of total paper & board production in that sector

Source: CEPI Key Statistics 2016 EUROPEAN PULP&PAPER INDUSTRY

Figure 7 also shows European countries' recycling rates.

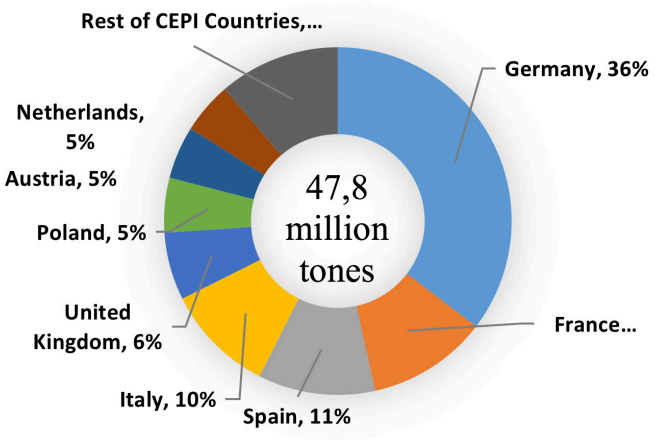


Figure 7: European countries' recycling rates.
Source: CEPI Key Statistics 2016 EUROPEAN PULP&PAPER INDUSTRY

Table 3. The top grade is again coated gloss, identified by 32% of respondents. About 15% selected premium bond, and about 12% selected uncoated and uncalendered. The top three grades in this question accounted for 58% of the "most often used" responses, and the top six grades accounted for 80%.

Table 3: Frequency of use of paper grades for digital printing.

Grade	Very Frequently	Somewhat Frequently	Very and Somewhat Frequently**	Most Used*	% Most Used*
Coated Gloss	62	20	82	31	32.29
Premium uncoated	36	35	71	7	7.29
Uncoated calendered	30	38	68	6	6.25
Coated matte	30	36	66	8	8.3
Uncoated uncalendered	28	35	63	11	11.46
Premium bond	35	25	60	14	14.58
Coated high-gloss	24	35	59	5	5.21
Coated satin	21	28	49	3	3.1
Tinted/ colored	15	31	46	3	3.1
Coated enamel	14	24	38	3	3.1
Recycled	8	28	36	2	2.08
Uncoated su-percalendered	12	18	30	2	2.08
Textured	4	18	22	0	0.00
Synthetic grades	4	12	16	1	1.04

** The "most used" ranking was constructed from separate questions which allowed only one grade selection.*

*** The "very and somewhat frequently" category is a summation of the previous two categories.*

Source: Mary Anne Evans, Bernice A. LeMaire., 2006

Recycling

The basic process in recycling is to remove ink from the printed paper surface. This process is known as deinking. It is the flotation method which is used predominantly in the traditional deinking technology, depending on the composition of the classical inks. This method is the most used. (Rossitza Sardjeva, Enitsa Koeva 2015). Flotation mechanism is in figure 8.

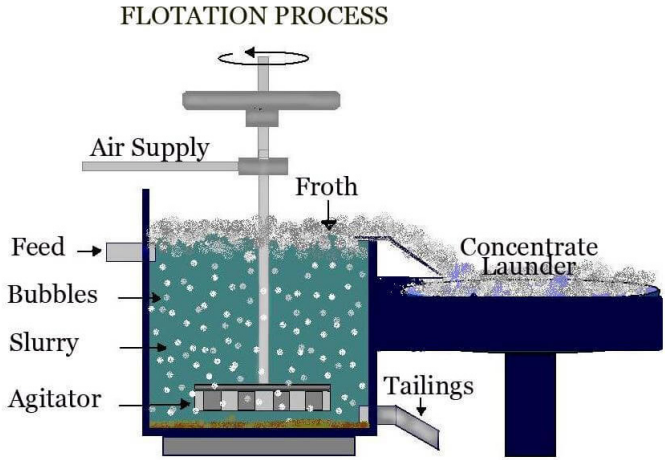


Figure 8: Flotation cell for deinking

Source: https://www.911metallurgist.com/blog/froth-flotation-process

Today, new techniques are developed to dispense "power ink removal" inks, such as photocopiers, UV cured ink films, and liquid toner suspensions or toners from electro-ink, as well as conventional ink removal processes. One of them uses ultrasound to remove ink. This method is also very effective in the development of the flotation method. The most efficient and effective method of ink removal on such printed papers is the flotation method. Printing inks are removed from the media using the flotation method for recycling the paper. While, the hydrophilic particles of the ink adhere to the air bubbles and are transported by floatation, the hydrophilic cellulose fibers remain in the water phase. Foam is formed at the liquid / air boundary containing ink particles, fillers, paint pigments, stickies and binders.

In the ink removal process; there are many effective parameters such as filler type, pH, temperature, ink particles and surface chemistry. Another effective factor is the type of printing. Letterpress inks can be separated from the prints without major problems. The ink of rotogravure prints us-

ing toluene-based ink can be more easily separated from the ink of offset printed papers. Conventional water-based inks can be separated less than toluene-based rotogravure prints. Similar hydrophilic character is considered for water-based rotogravure inks characterized by small particles. The separation of ink from coated paper is more successful than uncoated paper.

Toner from some digital prints (prints produced by laser printers and photocopiers) are too large to be removed by flotation of flat plate-like structures. Removal of plastics, removal of binders, contact adhesives and hot melts during recycling is important, as they can cause paper problems during production and subsequent printing.

Counclusions

As a result, we can say that taking ink from printed paper is the most important problem in recycling. The use of different printing methods is effective in this. Because it uses different inks for different types of printing and techniques. For this reason, the commonly used ink removal process is not always sufficient and the need for different ink removal techniques is required. The INGEDE technique is adequate for dry toners and dry inkjet inks, but not for wet ink. Therefore, new methods, which consist of Ultrasound, Flotation and Washing, have been started to be used and improved for eliminate the ink of the electronic printed paper.

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