Digital Prints: A Survey of the Various Deinkability Behaviors

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Abstract

Digital printing is being used more and more. Several of these prints end up in the recovered paper collection from households, offices and industry, becoming part of the raw material to be recycled by papermakers. Most printing technologies are well accepted but pose some difficulties with respect to deinkability and paper recycling. Worldwide; approximately 50% of the paper is recycled; Digital printing should not be a determining factor in reducing or stabilizing this number.

The paper reviews the deinkability of various digital prints: dye and pigment based inkjet, normal toners (high speed B/W and colour, liquid and dry) and UV curable technologies (overcoats, inks and toner). During the last 3 years, a project performed by Centre Technique du Papier, sponsored by INGEDE (International Association of the Deinking Industry) and ADEME (French Agency for Energy & Environment) with some interested digital print actors allows to point out which prints lead to significant deinking difficulties.

Introduction

Nowadays, out of the nearly 340 Millions tons paper and board produced worldwide, more or less half of them are produced with recovered papers. Most of them are used to produce brown grades paper and board but since 10 - 15 years there is a drastic increase of the use of recovered papers to produce, through deinking, white grades such as newsprint, tissue, market pulp and also more recently magazine papers (Super Calendered & Light Weight Coated)… Deinking is indeed a sophisticated way of recycling, high grade papers can be produced by using this technique.

By using the deinking technology, white grade papers can be produced from post-consumer or post-industrial recovered papers. This means that the components which cause either visible in-homogeneities or a reduction of brightness - the inks - must be removed, as well as all the additives used during printing, converting and using the paper. From the recycling point of view these additives are contaminants. They include various grades of adhesives (such as binding materials, labels, tapes), staples, plastic films, inks, varnishes, and all the components of the pulp which cannot be used to produce paper.

Recycling means manufacturing papers using recovered papers as the raw material; two main steps have to be performed:

- Production of a (recycled) pulp, from recovered papers
- Manufacturing a paper by using this pulp alone or mixed with other pulps (virgin or recycled).

The second step is, in principle, not very different of the production of paper from virgin pulp but this is not the case for the first one. The production of deinked pulp is indeed carried out using techniques totally different of those used for the production of pulp from wood.

The recycling technology is the combination of the various treatments carried out to produce a pulp from recovered papers and to clean it for its use on a papermachine to produce paper.

The deinking technology includes all the main steps of the recycling technology, but special treatments are added in order to remove the ink.

The Main Steps of Deinking Technology

Repulping the recovered papers is always the first step. During pulping, fibres are separated and all the additives added to the paper during the printing and converting process are (or should be) separated from the fibres. Most often, medium consistency pulpers and drums are proposed by machinery suppliers. The choice of the type of pulper has to be made by considering various parameters including the efficiency of defibering and energy consumption but mainly with respect to:

- Defibering kinetic
- minimising the breaking up of contaminants in order to improve their removal efficiency.
- efficient ink detachment (however this objective is sometime contradictory with the previous one)

Chemicals (caustic soda, sodium silicate and soap) are most often used in the pulping stage in order to improve ink release from the fibres. Bleaching chemicals (hydrogen peroxide) is also often used in this stage.

Removal of Contaminants

The removal of contaminants is based on their different properties, compared with fibres, fines and fillers:

- differences in size: particles smaller than fibres can be removed by washing and contaminants larger than fibres can be removed by screening.
- differences in density: particles having a density other than 1 can be removed by centrifugal cleaning. Some cleaners are designed to remove high density (>1) contaminants and others to remove lightweight contaminants (density <1).
- differences in surface properties: flotation can remove hydrophobic particles, additives (synthetic surfactants or soaps) are generally used to collect ink particles which improves the flotation efficiency.

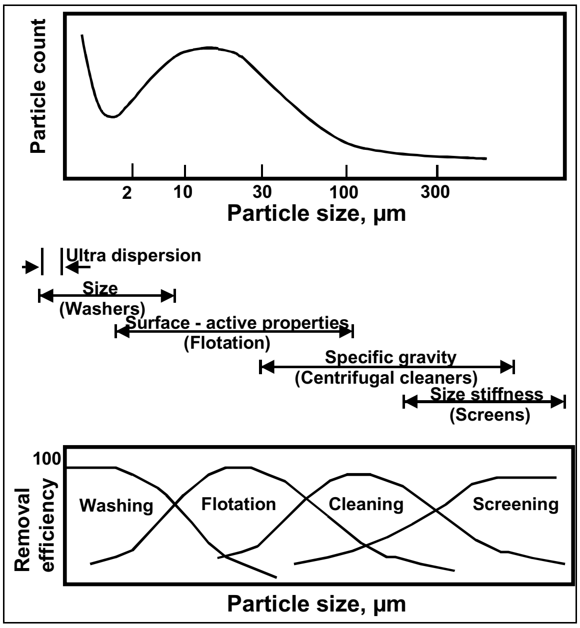

Figure 1. Particle size distribution in a recovered paper pulp suspension and unit operation removal efficiency. Mc Cool 19871

Results presented by McCool in 1987[1] (Figure 1) show that each technique is efficient for the removal of contaminants in a defined size range.

Screening consists in removing contaminants by keeping them on a screen while fibres go through the openings (slots from 200 to 100 µm or/and holes from 6 mm to 1.6 mm) of the screen.

At the beginning, the screening devices were open vibrating screens, today the screens are closed and pressurised to increase capacity.

Screening can remove large contaminants including plastic films, wet strength papers...

Cleaning is based on particle separation in a centrifugal flow field. A swirling motion is created by the tangential inlet flow. The vortex motion creates centrifugal forces which causes the particles heavier than the stock to migrate to the outside of the cleaner, while lightweight particles migrate toward the vortex core.

Cleaners can be designed to remove heavy or lightweight contaminants.

Cleaning (heavy contaminants) can remove metals, sand, and some varnish particles.

Cleaning (lightweight contaminants) can remove hot melt adhesives and various plastic particles.

Flotation consists in removing hydrophobic particles (particularly ink particles & toners), by floating them up to the surface with air bubbles. Flotation aids are used to improve the attachment of ink/toner particles to air bubbles.

Washing consists in removing all small particles with water through a screen, larger particles including fibres being retained on the screen. Washing can remove fillers and finely divided ink particles, as well as colloidal materials dispersed in water. Washing is used only when mineral fillers are not wanted such as in tissue paper. For other applications it is not used since the yield is too low.

Dispersion of Residual Contaminants

Another technique, which is not concerned with removal, is also widely used in deinking lines. The pulp suspension is submitted to “Hot dispersion”. This treatment is performed after thickening the pulp at high consistency (25-30%), usually around 70°C with a high energy input (70 kWh/T) in order to disperse residual contaminants such as hot-melt adhesives or specks from varnish particles and toner inks.

Deinking Process

Deinking processes are made up of a combination of the various techniques described before, alternating removal treatments followed by dispersion / removal treatments. The number of stages in the process depends on the grade of the furnish and the quality requirement of the deinked pulp to be produced, the higher the quality the more sophisticated the process.

Deinking of Various Digital Prints

Among the digital prints issued from the different markets, i.e.: large format market, large volume market, offset quality market & small office home office market, it was decided to focus the deinkability study on prints which will represent the largest volume of paper. These can be recovered mainly either through the household collection or through the office recovered paper collection. Instead of investigating the deinkability of the prints from the different markets, it was decided to study the corresponding deinkability according to the printing process, as represented in Table 1.

The deinkability of several commercial digital prints has been studied. Apart these evaluations, extensive Eco Design works have been performed with OCE, Xeikon and Agfa. These works allow to point out which printing conditions lead to a good or poor deinkability allowing to propose Eco Designed (from the recyclability point of view) prints. OCE work was focused on the high speed copier black & white prints, Xeikon work was focused on colored high speed copier prints whereas Agfa work was focused on ink jet photo prints.

Table 1. Main Printing Processes Involved in Digital Printing.

Processes	Market
Dry toner electro-photography printing	SOHO, Offset quality & Large volume markets, including: • High speed copiers • Office printing (laser printers), • Copying market
Ink jet printing	• Small Office Home Office printing • Continuous ink jet printing market • Photo printing market
Liquid toner electro-photography printing	Offset quality market
Conventional printing (offset …)	Offset quality market

Deinking Evaluation: Methodology

Deinkability has been evaluated thanks to repulping & flotation experiments described hereafter:

Pulping (Laboratory Helico Pulper)

Temperature: 45 °C; Concentration: 11%.

Chemistry: 0.5% NaOH, 0.5% H_2O_2, 1.5% sodium silicate, 0.75% soap (SERFAX MT 90: mixture of oleate & stearate).

Flotation

7 minutes in a laboratory Voith cell at 1%, 35 -40 °C – 7 litre air/min, i.e. 200% air ratio.

Dilution water (pulping and flotation) is tap water. Calcium content is adjusted to 150 mg/l Ca^{2+} with $CaCl_2$.

Deinkability is then characterized by optical measurements on the floated pulp: brightness, residual ink, optical in-homogeneities relatively to the unprinted paper, and by flotation yield.

Deinking Evaluation: Results

All the deinking results are gathered in

Table 2 which report the deinkability behaviour of most of the digital prints which may be found in the various recovered paper collections.

These, compared to the brightness & cleanliness of the unprinted paper target to recover (two right columns), show the main important following points:

Significant deinkability problems are observed with:

- UV inks: when they are used either for dry toner or ink jet inks, they lead to unacceptable **speck** contamination. Their mechanical dispersion will not be sufficient to hide their presence.
- Liquid toner: large visible inked film **specks** are observed which can not be removed by flotation nor screening since they are too soft and pass through screens. Their mechanical dispersion will not be sufficient to hide their presence.
- Hot melt based ink jet prints since even if optical properties are more or less recovered, residual toner will fuse during drying leading to **sticky** deposits which are very detrimental.
- Waterbased pigment based inks such as those used for home & office inkjet printing and those used with the electrocoagulation printing process. Hydrophilic inks can not be floated from the suspension and **very low brightness** is obtained compromising the use of the whole furnish.

Deinkability problems are also observed with:

- UV coating: visible **speck** contamination is observed. Their mechanical dispersion may be sufficient to hide them. Waterbased varnishs do not lead to such problem.
- Water based dye based prints (home & office inkjet printers, Scitex): a **low brightness** or/and **pronounced colour shade** is most often seen. Colour stripping treatments, mainly by reductive bleaching, may discolour some of them. This treatment is unfortunately not always part of the deinking process. Moreover, a selection of bleachable dyes should be done

Speck contamination is also observed with most dry toners prints, however some printing parameters (fusing technology, toner formulation…) lead to a significantly reduced contamination after a single flotation deinking loop. As an example with toner formulation, the use of **polyester** seems to really lead to a reduced speck contamination compared to polyether, **fusing** system leads also to large differences. Compared to the target, the still high specks values obtained after a single deinking loop with most dry toners prints will be reduced with industrial deinking processes, combining two flotation with an intermediate dispersion; acceptable cleanliness (close to 5 mm²/m²) should then be obtained.

Conclusion

This large overview of the different digital prints deinkability problems point out the major difficulties which have to be solved in order that some digital prints do not jeopardize the recycling/deinking of recovered papers. Efforts should be made to solve the deinking of (i) UV inks, liquid toner & UV coating leading to large resistant visible speck particles, (ii) waterbased pigment based inks leading to an unacceptable very low brightness (iii) dye based waterbased prints (selection of bleachable dyes). The use of hot melt inkjet inks will lead to more difficult problems: sticky particles. Finally, the identification of printing conditions giving both a good printability & a good deinkability remain to be done for all the inks giving problems as referred before but also for all the office & copier printers using dry toner. Common work done with OCE, XEIKON & AGFA, allowed to find a suitable "printability – deinkability" compromise. Previous work[2] has even shown that both toner adhesion and good deinkability can be found.

Acknowledgement

The authors wish to thank Paul Piette and Christophe Trehoult, CTP printing specialists for their involvement in deinking aspects as well as Marie Christine Angelier, Alain Balme, Gilbert Chatel, Frédérique Entressangle & Pierre Crémon for having performing all the practical experiments.

The authors wish also to thank ADEME (conventions n° 01.02.019 and 00.02.023), INGEDE and CTP members for their financial support, and a special thank to the "Digideink" task force members among which OCE, XEIKON and AGFA's involvement was greatly appreciated.

Table 2. Deinkability Behavior of various Digital Prints.

Printing process	Deinked floated pulp: Brightness, %	Deinked floated pulp: Specks, mm²/m²	Unprinted paper target: Brightness, %	Unprinted paper target: Specks, mm²/m²
Dry toner				
High speed copier B & W (OCE)	80 to 85	200 to 12 000 mm²/m² according to printing conditions (fusing technology, fusing temperature, speed…) with **polyester toners** - ☺	85	5
High speed copier Color (Xeikon)	74 to 84	2000 to 10 000 mm²/m² according to printing conditions (fusing technology, fusing temperature, speed…) with **polyester toners** - ☺ / 15 000 to 20 000 mm²/m² according to printing conditions (fusing technology, fusing temperature, speed…) with **polyether toners** - 😐	85	5
High speed copier Color (Xerox - Igen 3)	72 to 85	40 to 4000 mm²/m² with **polyester toners** - ☺	85	5
Office printers	Apparently, only a few problems but remained to be studied more in detail		85	5
Office copiers			85	5
Digitally printed Newspapers (OCE & Xerox)	59	250 mm²/m² - ☺	58	100
UV Cured Toner prints	76	60 000 mm²/m² **!!!** - ☹	85	5
UV Coated prints	85	2000 mm²/m² (underestimated since cyan toner) **!** - ☹	85	5
Liquid toner				
HP Indigo prints	85	80 000 mm²/m² **!!!** - ☹	85	5
Magnetic toner				
Nipson prints	85	700 mm²/m² - ☺	85	5
Inkjet prints				
DOD - Office printers - water based pigment based	30 to 50 according to various prints **!!!** - ☹	no specks	85	5
DOD - Office printers - water based dye based ink	35 to 60 according to various prints but some are bleachable with a reductive treatment **!!** - ☹ or 😐	no specks	85	5
Continous ink jet (Scitex - dye based ink)	35 to 60 according to various prints but most are bleachable with a reductive treatment **!** - 😐	no specks	85	5
DOD - Office printers - hot melt based (Phaser Xerox)	83	1000 mm²/m² but forming sticky deposits **!!** - ☹	85	5
UV curable ink jet inks	more or less recovered	15 000 - 20 000 mm²/m² very large (400 µm) **!!!** - ☹	85	5
Photo ink jet	more or less recovered	1800 mm²/m² - ☺	85	5
Elcography prints				
Newspaper : Water based pigment based ink	39 **!!!** - ☹	100 mm²/m²	58	100
Offset water less ink				
Quickmaster prints : with conventional oil based ink	76	300 mm²/m² (a bit large : 400 µm)	79	5

References

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Biography

Bruno Carré studied at the Ecole Française de Papeterie (Grenoble - France) where he received an engineering license in papermaking. After a PhD on colloidal chemistry with EKA NOBEL in Sweden, he joined the "Recycled Fibres Group" of the Centre Technique du Papier in 1993. After having led several deinking projects, he is since 1999 responsible of the Deinking activities at CTP. His activities have been devoted to the improvement of recovered paper treatments and upgrading of recovered papers. He has carried out specific works in the field of ink formulation and ink detachment, dispersion mechanisms, fundamentals of pulping and flotation, deinking process water circuit design. He has published more than 50 papers. He runs projects for Ingede, the International Association of the Deinking Industry and is also teaching "Deinking technology" at the EFPG.