# DIGITAL PRINTS: A SURVEY OF THE VARIOUS DEINKABILITY BEHAVIOURS

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# Digital prints : a survey of the various deinkability behaviours


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**Abstract**

Digital printing technologies are gaining more and more market shares. In a near future, several of these prints will end up in the recovered paper collection from both households and offices, becoming part of the raw material to be recycled by papermakers. But the **deinkability** of several digital prints could turn out to become a threat for paper recycling systems of today. Some of these prints deink rather easily while some others lead to **severe problems**, which may endanger all the deinking process.

Problems are especially created when recycling waterbased, **pigment based ink-jet inks** more and more used by all the major office inkjet printers (HP, Epson, Canon, Lexmark and others) all around the world. The resulting prints are not only **undeinkable –** when present in quantities as small as 10 per cent among the other recovered paper to recycle, they also **spoil the deinkability of the whole mixture**. It is therefore of prime importance for the deinking paper mills to cooperate with ink jet ink and printer manufacturers in order to find solutions to this problem.

In this paper, more attention will be paid on deinkability of toner based prints. Deinkability of various high speed copiers prints has been studied extensively : among all parameters, the influence of the toner fusing system is the major parameter affecting deinkability. Moreover, correlation between toner adhesion and deinkability has been drawn : a good new is that high toner adhesion does not always lead to a poor deinkability : a compromise between printers and deinkers may thus be found !!


**INTRODUCTION**

The CEPI European Declaration on Paper Recovery of 2000[1] has fixed an optimistic objective of 56 % recycling rate in Europe for 2005, which meant, according to Lombard 2003[2] and Kibat 2004[3], an additional usage of roughly 10 millions tons of recovered papers. In order to succeed to this objective, Europe has still to (i) recover more used paper & board, (ii) secure the actual high recycling rate of recovered papers, (iii) introduce recovered paper & board pulp in new grades or in increasing proportion in grades already incorporating some.

Among the nowadays collected paper & board, the main sources of used paper & board which have still a development potential are graphic papers, Krauthauf 2003[4], collected by the household collection and the office collection, the trade and industry collection being already well developed.

If household collection is well developed in some EU countries, some of them (Italy, UK, France, Spain…) have still a large progression potential representing a significant volume of recovered papers. However, the largest progression potential may be issued from the office collection as it is overall poorly developed in EU and large volumes of paper are available.

Finally, the grade of paper & board which incorporate the lowest amount of recovered paper is fine paper and it has the largest growing potential since some papermakers are already able to produce fine paper, copy paper and even coated offset with 100 % of deinked pulp.

It is therefore of prime importance to focus on paper prints that can be found in the office collection (type of paper, printing process used - **Table 1**) and on the deinkability of the corresponding papers since an increasing number of them are said to be digital prints.

| Office collected papers | Printing process involved |
|---|---|
| Copy papers, Computer print out | • mainly xerography **(laser prints, low speed copiers & sometimes high speed printers)**,<br>• ink jet (especially for colour prints) |
| Mailing letters, business forms, | • offset heat-set,<br>• sheet fed offset<br>• xerography<br>• ink jet |

**Table 1 : Printing processes for the various office collected papers**

What means "digital prints" ? Since the last 10 to 15 years, the printing industry changes very rapidly, concurrently to the large progresses made by the computer industry. The increase of transmission speed of datafiles and of information storage capacities lead printers to radically modify their printing processes. As a matter of fact, the trend, mainly for the low run length (inferior to 5000 copies), is the use of so-called digital printing processes. Information to be printed comes directly from the computer to the base paper without passing through intermediary phases such as plate manufacturing, development and setting (offset's case), cylinder or rubber plate engraving (cases of traditional rotogravure or flexo)…

Digital printing is therefore used with most of the traditional printing processes, the only difference being that information is transferred either directly to the plate (computer to plate) or to the paper (computer to paper). The main actors and processes involved in digital printing are reported in **Table 2**.

As far as office collected papers are concerned, it is therefore of prime importance to focus more on the deinkability of toner printed (xerography) and ink jet printed papers. This is the main topic of this paper.

| Processes | Industrialists |
|---|---|
| Dry toner electrophotography prints (high speed copiers and laser office printers) | HP, Canon, Xerox, Xeikon, Oce… |
| Small Office Home Office ink jet printing | HP, Canon, Epson, Lexmark, … |
| Continuous ink jet prints | Scitex, Barco, … |
| Liquid toner electrophotography printing | HP Indigo |
| New processes (electrocoagulation) | Elcorsy |
| Conventional printing (offset …) | Heidelberg, KBA, Man Roland … |

**Table 2 : Main actors involved in digital printing.**

**DEINKABILITY OF INK JET PRINTS**

As well described in the Printing Ink Manual, Leach and Pierce 1993[5], ink jet, unlike traditional printing processes, is relatively young. Its market, mainly concentrated until now to the said S.O.H.O. (Small Office, Home Office) market, is still growing very rapidly. According to some recent statistics, around 170 Millions of office ink jet printers have been sold world wide within the last 20 years (HP Canada 2002) with a growing rate between 20 & 30 %.

As far as the deinkability of the corresponding prints is concerned, very few works have been performed : Cathie et al. 1994[6] mentioned that ink jet inks were mainly composed of dyes which were not floated and not entirely washed during deinking (brightness of 56 %). In order to remove the resulting color, bleaching treatments had to be performed such as hydrosulfite, FAS or peroxide (Final brightness after hydrosulfite bleaching around 75 %). Krauthauf 1996[7] as well as Hsu et al. 1996[8] mentioned that inks used for ink jet printing are waterbased inks and as such did not lead to good deinkability.

Since these works, a number of new printing machines have been proposed on the market, with new inks associated and deinkability behaviour changed accordingly. More recently, Carré 2001[9], Carré & Magnin 2002[10] reported that there is a marked introduction of pigments in the formulation of waterbased ink-jet ink as substitutes to dyes. This change seems to be already done for most of the black inks of the recent ink-jet printers whereas this substitution is on the way for coloured inks. This induce deinking difficulties : first of all in the deinking of wood free grades for the production of tissue, fine paper and market pulp, secondly in the deinking of wood containing grades such as for newsprint. The probability to find these prints in significant proportion in household collection is however lower than in office paper collection.

<u>Deinking of 100 % of black ink-jet prints</u> :

- Pigments are now introduced in the formulation of most black ink jet inks. These are thus waterbased inks, which means that pigments are released to a very small size during alkaline pulping, such as for waterbased flexo inks for newsprint. Their removal by flotation is therefore very poor (brightness after flotation between 30 and 50 % depending on prints for an unprinted paper with 84 % ISO brightness). Their removal by hyper-washing is better, but because of their small size, some inks are irreversibly redeposited onto or/and into fibres during pulping.
- For the few black ink-jet inks still containing dyes, these are not removed by flotation, nor by washing, however some dyes can be efficiently discoloured, especially with reductive bleaching such as hydrosulfite.
- Contrary to conventional waterbased flexo prints for newsprint, the deinkability of the black pigment based waterbased inks is also very poor in neutral conditions. Since, contrary to flexo inks, they do not include any binder, ink particles are also dispersed in very small particles during neutral repulping which avoid an efficient flotation removal.

<u>Deinking of mixtures including black pigment based ink-jet prints</u> :

- The introduction of 10 % of black pigment based ink-jet prints into a wood free furnish (mixture of photocopies and laser prints) induces a large brightness reduction after flotation (-10 % ISO) from 85 to 74,5 % with an associated large increase of flotation losses (from 8 to 20 %).
- Introduced into a wood containing furnish (newsprint / magazine), 10 % black pigment based ink-jet prints induces a lower but still pronounced brightness loss (- 3 %) from 57 to 54 % for a similar yield.

In both cases, ink-jet inks will be concentrated into the process waters which will make them dirtier and increase the coagulant cost to get an efficient clarification.

As ink jet printing is especially used in offices to print coloured documents, the deinkability / bleachability of various coloured ink jet prints has been studied and is reported hereafter.

## Experimental

### Characteristic of prints

The following drop on demand (DOD) ink jet printers, representative of the coloured printers on the market, were used to print the papers to deink :

- HP 815 C (office, thermal ink jet)
- HP 2000C (office, thermal ink jet)
- Epson Stylus 740 (office, piezoelectric ink jet)
- Epson stylus C70 (office, piezoelectric ink jet)
- Canon BJC 6000 (office, thermal ink jet)
- Lexmark Z43 (office, thermal ink jet)

The same test form was used for all the prints (one for each primary colour, i.e. cyan, magenta & yellow), consisting of text. 100 % of each of these prints were used as raw material to deink.

### Deinking and postbleaching operating conditions

- <u>Deinking</u>

Flotation deinking was performed after a conventional alkaline repulping with a chemistry used for wood-free papers

Pulping (laboratory Helico pulper)
Pulping time : 15 min (pulping) + 30 min (storage time)
Temperature: 45 °C
Concentration: 12 %
Chemistry: 0.5 % NaOH, 0.5 % $H_2O_2$, 1.5 % silicate, 0.75 % soap (SERFAX MT 90)
Flotation: 7 minutes in Voith cell at 1 %, 40 °C – 200 % of air

Dilution water (pulping and flotation ) was fresh water from the CTP. Calcium content was adjusted to 150 mg/l $Ca^{2+}$ with $CaCl_2$.

- <u>Post-bleaching conditions</u>

After flotation, pulp was thickened on a Büchner funnel. The thickened pulp was submitted to post bleaching with :

- Hydrogen peroxide : 15 % consistency, 1 % $H_2O_2$, 1 % soda, 2.5 % silicate, 0.5 % DTPA, 90 min at 60°C
- Hydrosulfite : 3 % consistency, 1 % hydrosulfite, 60 min at 80°C, no pH adjustment
- Ozone : 3 % consistency, ambient temperature, ozone introduction stopped as soon as pulp is decolourised or until 1 % ozone was consumed, no pH adjustment

### Deinking efficiency characterisation

For coloured prints, the ERIC value is unfortunately unsuitable since this measurement is based on reflectance measurement in the infra red of carbon black pigment.

In order to evaluate deinking of coloured prints, brightness but more importantly colour coordinates L*, a*, b* are useful.

In order to examine if coloured prints are correctly deinked, the total colour difference (ΔE) versus unprinted paper were measured on pads of pulp :

$\Delta E^2 = (L_2^*-L_0^*)^2 + (a_2^*-a_0^*)^2 + (b_2^*-b_0^*)^2$
Unprinted paper : $(L_0^*, a_0^*, b_0^*)$
Printed paper after deinking or post-bleaching : $(L_2^*, a_2^*, b_2^*)$

For magenta print, it is considered that below $\Delta E_{limit}$ and $a^*_{limit}$, printed paper is correctly deinked or decolourised.
For cyan print, it is considered that below $\Delta E_{limit}$ and $|b^*_{limit}|$ printed paper is correctly deinked or decolourised.
For yellow print, it is considered that below $\Delta E_{limit}$ and $b^*_{limit}$, printed paper is correctly deinked or decolourised.

## Results and discussion

Deinkability results are reported in **Figure 1** to **Figure 3**.

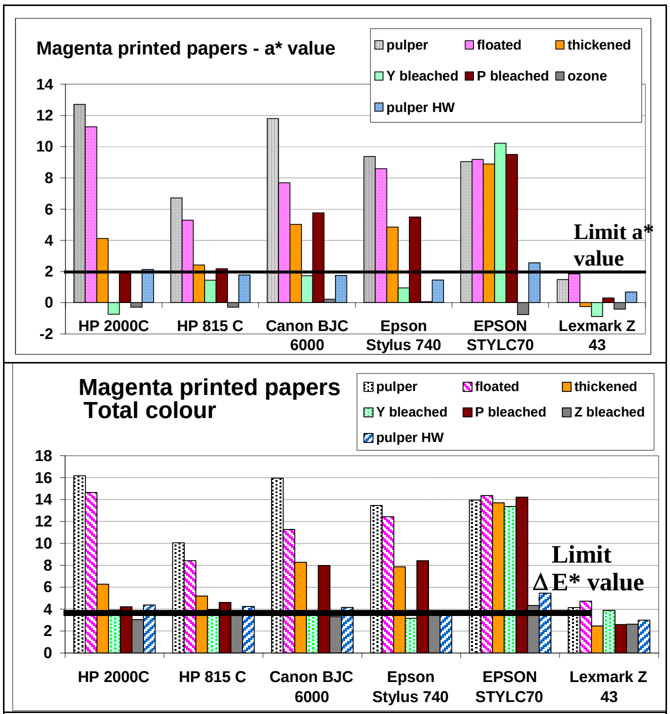
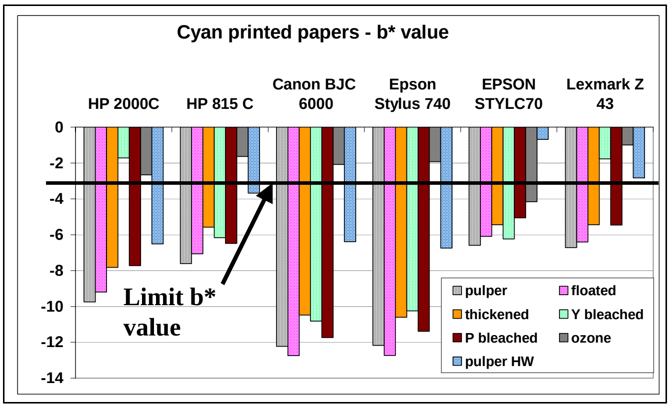



**Figure 1**: a* and ΔE* values for the various magenta prints after pulping, deinking, thickening and post-bleaching

After deinking by flotation and thickening, only Lexmark Z43 printed paper gives acceptable results : red is removed at pulping thanks to peroxide and further removed by post-bleaching. All the prints can be colour stripped by ozone despite such bleaching sequence is not realistic industrially for wood free grades. All the prints excepted Epson stylus C70 printed paper can be colour stripped by hydrosulfite, peroxide being, overall less efficient.



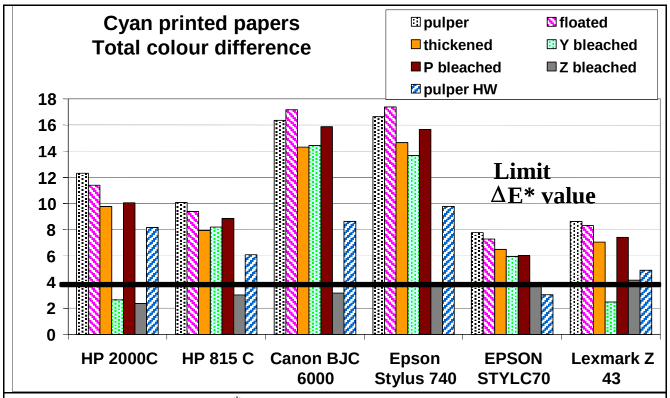



**Figure 2**: a* and ΔE* values for the various cyan prints after pulping, deinking, thickening and post-bleaching

After deinking by flotation and thickening, none of the cyan printed paper leads to acceptable results.

Ozone can efficiently colour-strip all cyan printed papers except Epson Styl C70, hydrosulfite is efficient only on two of them and hydrogen peroxide is not efficient at all.

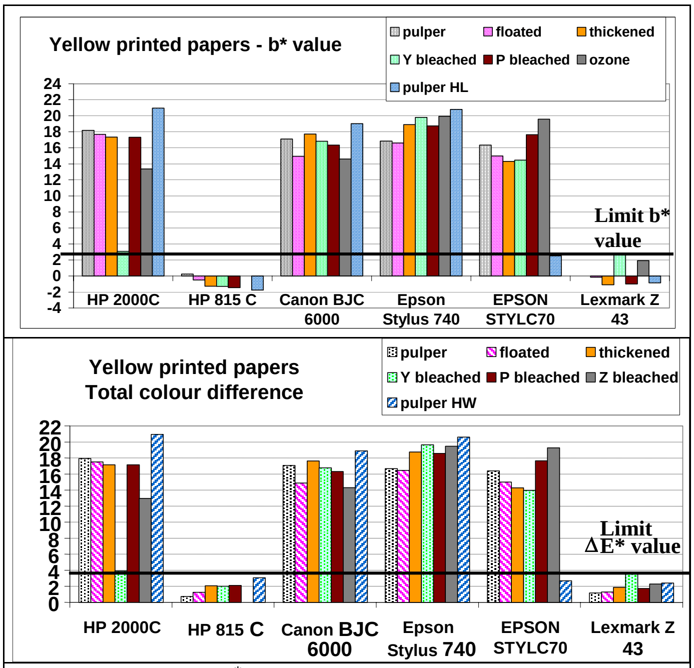



**Figure 3**: a* and ΔE* values for the various yellow prints after pulping, deinking, thickening and post-bleaching

After pulping, yellow shade of HP815C and Lexmark Z43 printed papers is removed directly by hydrogen peroxide in the pulper.

On the other hand, the yellow shade of practically all the printed papers (except HP2000 with Y) can not be removed by any bleaching agent (Y, P or Z).

Among the different coloured ink jet prints, a large diversity of deinking / bleaching behaviour is observed. Some colour are directly colour stripped during alkaline repulping with peroxide (yellow for HP2000 C, yellow and magenta for Lexmark Z 43 ), some others required conventional reductive bleaching (all magenta except Epson Styl C70 – cyan for HP 2000 C & Lexmark Z 43 – yellow for HP2000 C) whereas ozone (usually not employed in deinking lines) is the only treatment to destroy the magenta issued from Epson Styl C70, the cyan shade issued from HP815 C, Canon BJC 6000, Epson Stylus 740 & Epson Styl C70. Ozone is however not efficient to destroy the yellow shade of all prints which was not destroyed during pulping.

Overall only HP2000 C & Lexemark Z 43 can be completely colour stripped by conventional bleaching (P & Y). The worse being both Epson & Canon tested printers.

The bleaching efficiency of all colours can unfortunately not be related to the use of pigment or dye in the ink formulation since these information are not delivered by the corresponding companies. Since these trials, new printers are on the market and the use of pigment may has been expended widely, decreasing possible bleachability.

A large dialogue is therefore necessary with the ink jet inks manufacturers in order that they take into account this aspect of the life cycle of their products. Due to this wide diversity of bleaching behaviour, a compromise may be found.

## DEINKABILITY OF TONER PRINTS

Toner prints deinkability has been largely studied in North America maybe because a number of Greenfield mills using office recovered papers were implemented there. The main research results obtained in North America have been synthesised and reported by L. Magnin and B. Carré, 2003[11]. These results show that, generally speaking, the toner prints generate only few deinkability problems in terms of pulp whiteness. But on the other hand, they can give a high contamination in residual black impurities (> 100 µm) generating important energy dissipation (up to 180 kWh/T) to fragment them so that they become not visible anymore.

The cleanliness levels required by the paper mills manufacturing wood-free deinked pulp are about 2 to 5 mm²/m², corresponding to a very low contamination, explaining why they need these levels of energy.

This insufficient cleanliness result mainly from a very bad toner particle detachment from fibre surfaces, a detachment which will depend on a great number of parameters, among which:

- Printing conditions (toner thickness (fixed by contrast), toner attachment (toner chemical formulation, temperature and mode of fusion, applied pressure during and after the fusion, printing speed)…
- Repulping conditions of printed papers (concentration, temperature, type of pulper, pulping duration, surfactant used …)

Few has been done to show the incidence of printing parameters. However, we can cite Snyder and Berg 1993[12] who have shown the incidence of the copying speed on the deinkability: the higher the speed, the lower the quantity of toners attached. Dorris 1999[13], has also shown the incidence of the toner particle thickness and compared the effect of a laser printer in relation to a copier on toner's detachment and removal: the lower the thickness, the more difficult the toner detachment and then removal. Likewise, the detachment of toners applied by a laser printer is more difficult than with a copier maybe for printing speed reasons.

Generally speaking, more work, in particular, in North of America, has been done on the pulping parameters incidence on the detachment and removal of these toner particles. Berg et al. 1996[14] have shown the incidences of concentration, temperature and chemistry during pulping on the toner fragmentation and detachment. It appears that the fragmentation and the detachment are all the more better when pulping is carried out at elevated concentration and temperature. Little difference on the incidence of tested chemistries have been observed. On optimal concentration and temperature conditions, about 40 % of toner remain attached on the fibres after disintegration.

Dorris and Sayegh 1994[15] previously had demonstrated the incidence of pulping kinetics and pulping concentration on toner fragmentation and removal by flotation. A good removal needs a high concentration and a long pulping time.

Works have been done at CTP in order to better understand the incidence of both process parameters and printing parameters on toner deinking. The present paper reports the incidence of a key parameter on deinkability : toner fusion technology, better investigated after a first set of experiments.

## *Preliminary approach for studying the effect of printing parameters on deinkability*

First rough experiments consisted in studying the deinkability of the same base paper (XEROX EXCLUSIVE 80 g/m²) printed with the same printing form (page of “a” character), on various copier & laser printers available at CTP.

## Experimental

### Characteristic of prints tested

The characteristic of each copier or laser printer used were the following, reported in **Table 3**.

| | Printing speed, A4 / min | Fusion technology | Toner Particle size | Resin type | Glass transition temperature |
|---|---|---|---|---|---|
| OCE2465 | 65 | undirect | 14 µm | PE | 69°C |
| XEROX 5343C | 50 | nip | 9 µm | SA | 65 °C |
| OCE2050 | 50 | nip | 11 µm | SA | 63 °C |
| OCE PS 75 | 75 | nip | ? | PE | ? |
| HP laser jet 4000 PCL6 | 16 | nip | 5 | SA | 64 °C |

**Table 3** : characteristics of the various printers and copiers used (PE : poly ester – SA : styrene acrylate)**.**

### Operating conditions

Deinking was performed in conventional alkaline conditions for wood-free papers

Pulping (laboratory Hélico pulper)
Temperature : 45 °C ; Concentration : 11 %
Chemistry : 0.5 % NaOH, 0.5 % $H_2O_2$, 1.5 % silicate, 0.75 % soap (SERFAX MT 90)

Flotation : 7 minutes in lab Voith cell at 1 %, 35 -40 °C – 200 % of air.
Dilution water (pulping and flotation) is tap water. Calcium content is adjusted to 150 mg/l $Ca^{2+}$ with $CaCl_2$

### Deinking efficiency characterisation

Deinking efficiency was characterised thanks to measurements of brightness & residual ink (ERIC) on pads of entire & hyperwashed pulps. As the major problem of toner prints is specks, these were controlled by image analysis (Simpatic, CTP – Techpap) on handsheets of hyperwashed pulp as hyperwashing allows to remove all the small ink particles which otherwise give handsheets with different grey levels, affecting then specks count.

## Results and discussion

Deinkability results are reported in **Figure 4** and **Figure 5**.

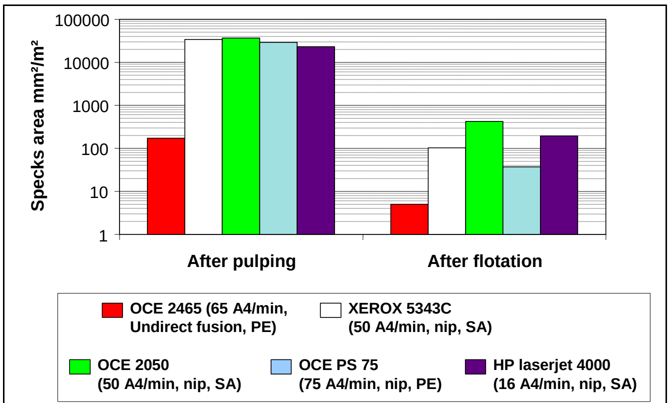



**Figure 4**: Specks contamination(∅ > 100 µm) after pulping and flotation for various toner prints (measured on hyperwashed pulp handsheets).

Specks contamination results show that a wide variety of speck contamination is observed after both pulping & flotation showing that (i) toner fragmentation differs largely depending on toner printing machine (ii) for similar toner fragmentation during pulping, large differences in flotation removal are observed.

Among the different tested prints, print done with an undirect fusion (fusion of the toner on a belt before being applied on the sheet) of the toner seems to behave completely differently with a very low contamination after both pulping & then flotation (5 mm²/m²). Higher speed copier (75 A4 pages/min) then gives better results (40 mm²/m²) than the other prints with the worse result given by OCE2050 (400 mm²/m²). This level is higher than that observed on an industrial deinking line with 3 loops and 2 dispersion stages (5 to 10 mm²/m²). Yet the contamination is lower than that observed with a single industrial loop for mixed office recovered papers (around 1000 mm²/m² depending on the raw material) .

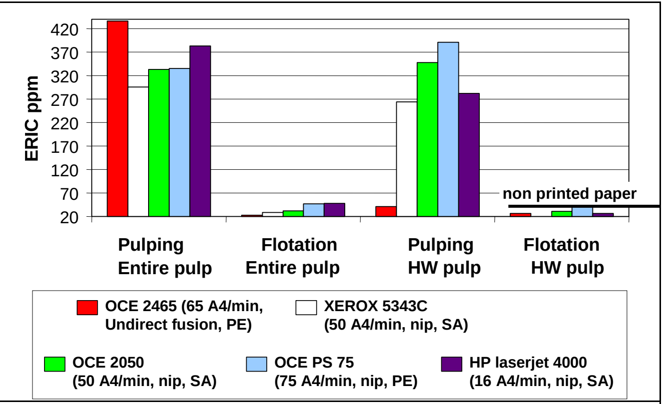



**Figure 5**: Residual ink after pulping and flotation for various toner prints (measured on entire pulp pads).

As far as residual ink is concerned, toner are known to give a low amount of small residual ink after flotation. Values reported in **Figure 5** confirm this trend.

Overall, when examining the characteristics of the various printers and copiers, it can be observed that the OCE 2465 print for which toner is firstly fused on a belt before being transferred on the paper gives much better deinkability than all the other prints, for which toner is directly fused on the paper in the nip. Fusion technology appears to be an important factor affecting deinkability.

In order to study the influence of toner type, we need to compare prints with different toners but with other identical printing parameters. Among the various tested prints, XEROX 5343C print (styrene acrylate, 50 A4/min, nip fusion) deinkability could be compared to OCE PS75 (type polyester, 75 A4/min, nip fusion) deinkability but there are too many non controllable parameters in order to obtain reliable conclusions (printing speed are different, pressure and fusion temperature are not controllable). It can be yet observed that the behaviours of the two prints are similar enough in comparison to the behaviour of the print OCE 2465 confirming that fusion technology appears as one of the most important factor affecting deinkability. This parameter has then been widely studied during the second approach.

## *Second approach for studying the effect of printing parameters on deinkability*

As a second step, a work was performed together with the OCE company in order to better control and study the incidence of the toner fusing technology, as well as of the printing speed on deinkability. To fuse a toner on the paper, several technologies are used in the different copiers and printers. These are summarised in **Figure 6**, all of them were investigated in regards to both deinkability and toner adhesion.

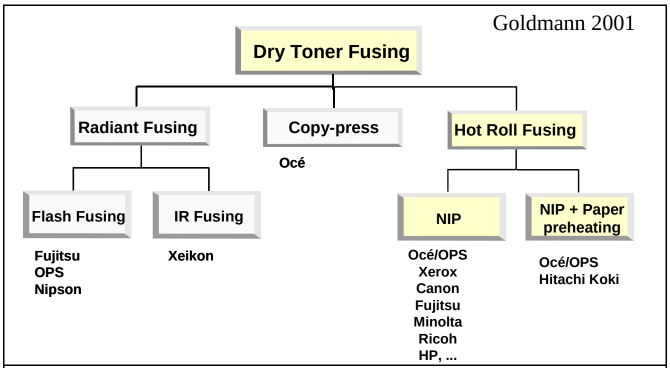



**Figure 6**: The different dry toner fusing technologies used in copiers & printers (Goldmann 2001[16]).

From **Figure 6** it can be seen that three major technologies are used to fused the toner on the paper surface, (i) hot roll fusing which is used for most of the copiers and printers, with or without preheating of the paper depending on the copying/ printing speed, (ii) copy press or belt fusing which consist in fusing the toner on a belt before its transfer on the paper surface, (iii) radiant fusing which comprises either flash fusing or Infra Red fusing, toner is heated by absorption of electromagnetic radiation such that it softens.

## Experimental

### Characteristic of prints tested

The characteristic of each copier / printer used are the following, reported in **Table 4**.

| Printer | Speed Pages/min (simplex print) | Heating saddle T°C and/or fusing roll T°C | Fusing roll surface | Toner type |
|---|---|---|---|---|
| OCE 8465 Copy press | 65 | 102°C | | polyester |
| PS 75 Nip fusion | 75 | 185<br>190<br>205<br>190<br>205<br>220 | Soft<br><br><br>Hard | B 2.6 (polyester)<br><br>B 2.6 (polyester) |
| DS 8090 Nip fusion + Preheating of paper | 175 | 70/180<br>82/180<br>100/200<br>80/180<br>90/200<br>100/220 | Soft<br><br><br>Hard | A 2.6 (polyester)<br><br>A 2.6 (polyester) |
| IR fusion | 200 | 120<br>130<br>145 | | Polyester |
| PS 88 Flash fusion | 43 | | | Polyester |

**Table 4** : characteristics of the various printers and copiers used (PE : poly ester – SA : styrene acrylate).

The cut sheet printer PS 75, 75 pages /min, the continuous feed printer DS 8090 (twin), 175 pages /min and the OCE 8465 printers are based on heat fusing process. Heat energy is transferred to the paper by contact heat.

Roll fusing systems comprise a heat roller (the fuser roller) that gets into contact with the un-fused toner image and a counter roller (the pressure roller) that normally is not heated. One of the two features a weak surface that deforms while operating together with the other roller, thus producing the nip. In the case of the printer PS75, the paper is not preheated. In the case of the printer DS8090, paper is preheated on a heated saddle. In both printers, polyester based toner is used with a glass transition temperature of about 58°C. For the two printers, the effect of fuser roll temperature was examined as well as the effect of the surface of fusing roller (hard or soft roll).

The OCE 8465 printer is based on the so called copy press : the toner is first melted on a transfer belt before being transferred on the paper. Fusion temperature is 102°C, toner is of polyester type and printing speed is 65 pages /min.

Two radiation based process prints were also tested : A printer with IR fusion (200 pages /min) and PS 88 printer (43 pages /min) with flash fusion (type polyester). The effect of fusion temperature was studied in the case of IR system.

The test form used for all prints except that for IR fusion was the same : it was composed of a large ink film (used for pick resistance tests) coupled with a page of “a” characters. The test form used for IR fusion process had the same toner coverage.

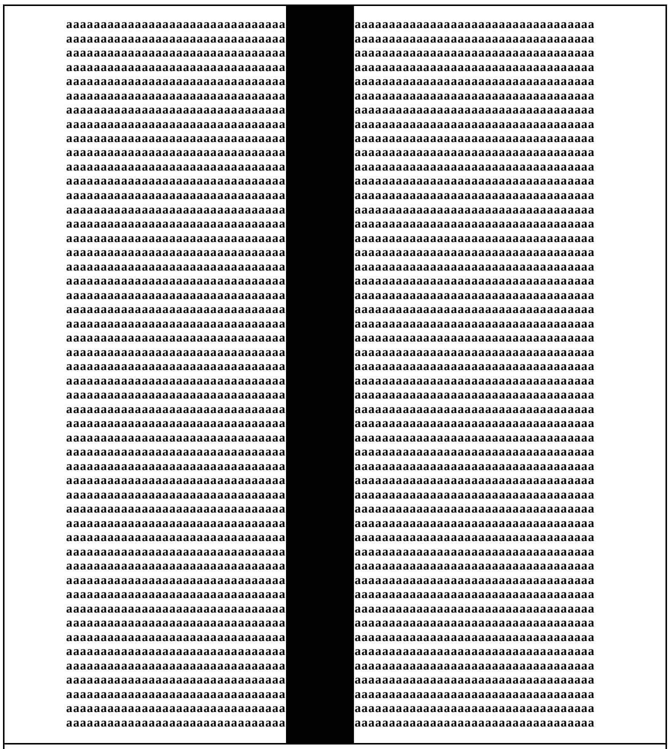


**Figure 7**: printing form used for the study (except for IR).

**Operating conditions & deinking efficiency characterisation**

Deinking operating conditions (pulping & flotation) as well as deinking efficiency characterisation were identical as those described previously for the preliminary work.

**Toner adhesion measurement**

The IGT picking test used in ENV 12283 was adjusted to assess adhesion : a black solid area is printed. A picking test in accelerating speed allows to determine the speed to pick up toner particles. The higher the pick resistance value, the better the adhesion[17,18].

## Results and discussion

Deinkability results are discussed hereafter first of all for Nip fusion, then for Infra Red fusion and then a general comparison is performed.

**Deinkability of nip fusion based prints**

Deinkability results are reported in **Figure 8** and **Figure 9**.

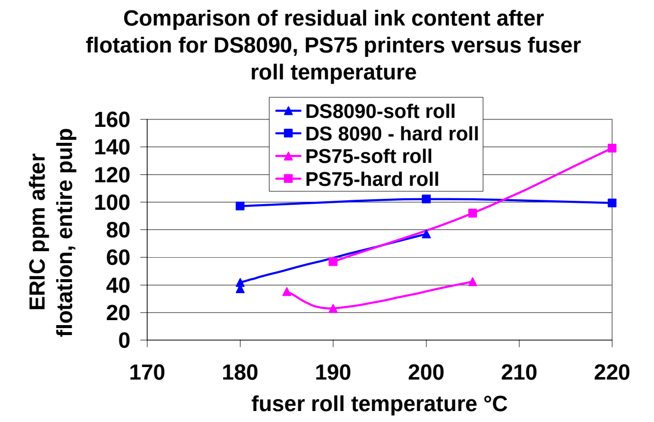
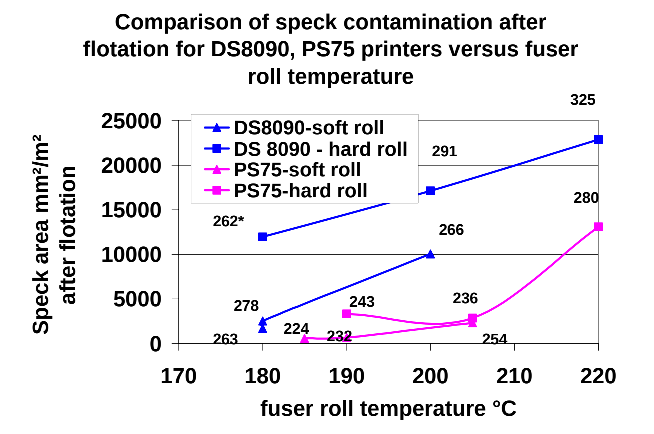



**Figure 8**: Deinking of Nip fused toner prints, incidence of fusing roll surface and fusing temperature & copying speed – Residual ink after flotation.




* : average diameter of specks (µm)

**Figure 9**: Deinking of Nip fused toner prints, incidence of fusing roll surface and fusing temperature & copying speed – Specks contamination (on hyperwashed pulp handsheets) after flotation.

When looking at both residual ink and specks after flotation, the first obvious result is that low speed copier leads always to lower contamination than the high speed copier. This is somewhat surprising since previous result in the literature[12] show the reverse, however there is here a large difference : apart the toner type (however same chemical family) paper is preheated for the high speed copier to fasten the fusing step and this certainly improves the adhesion of the toner to the paper surface. As far as fusing roll surface is concerned, results are quite clear whatever the printing speed : the harder the fusing roll surface, the more difficult the deinking, for both residual ink & specks. A hard roll instead of a soft roll certainly induces a different toner penetration in the sheet thickness, especially when the toner is more melted. The toner detachment becomes then not easy since a thin layer of toner has been shown to be more difficult to remove (Dorris 1999[13]).

As expected, the different fusing conditions have a large incidence on the speck contamination since variations between 600 & 23 000 mm²/m² are observed, the effect on residual ink is lower (between 20 & 140 ppm) even if 140 ppm of residual ink could avoid to get high brightness DIP pulp.

From the deinkability point of view, low speed (without preheating of the paper), soft fusing roll & low temperature (180°C) could be recommended. Are these conditions compatible with a good toner adhesion ? This question will be answered in the last part of this paper.

**Deinkability of Infra red fused toner prints**

With the infra red fusing system, it was also possible to study the incidence of fusing temperature, the latter is reported in **Figure 10** to **Figure 12**.

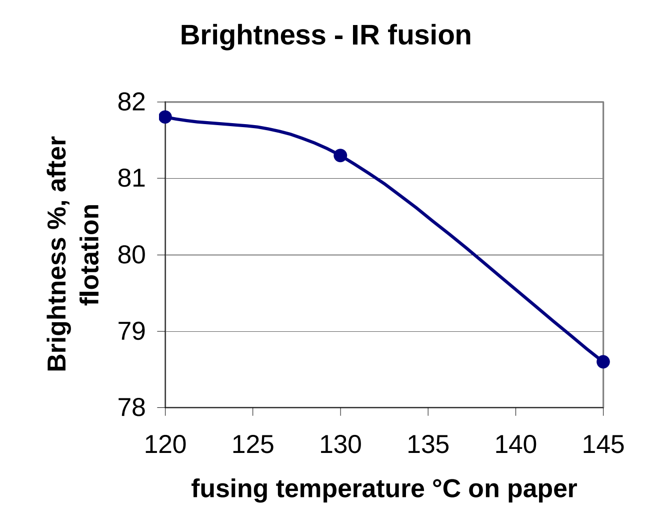



**Figure 10**: Deinking of Infra Red fused toner prints, incidence of fusing temperature – Brightness after flotation.

Results clearly show that an increase in fusion temperature decreases deinkability : the effect is obvious in terms of specks contamination and brightness.

The decrease in brightness after flotation when increasing temperature could be related to a residual ink content increase with temperature (not reported here, but increase from roughly 80 to 160 ppm).

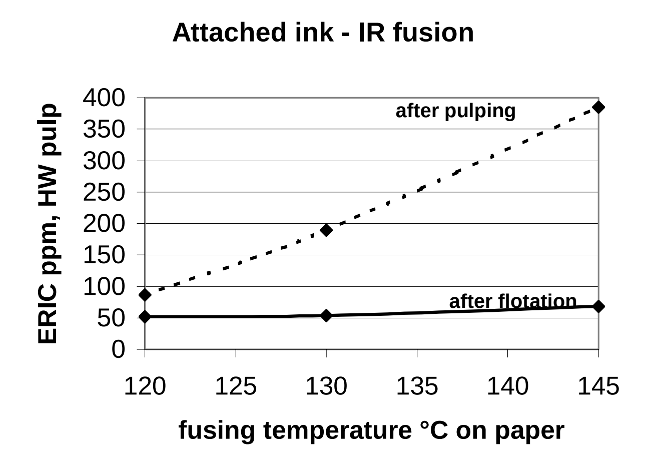
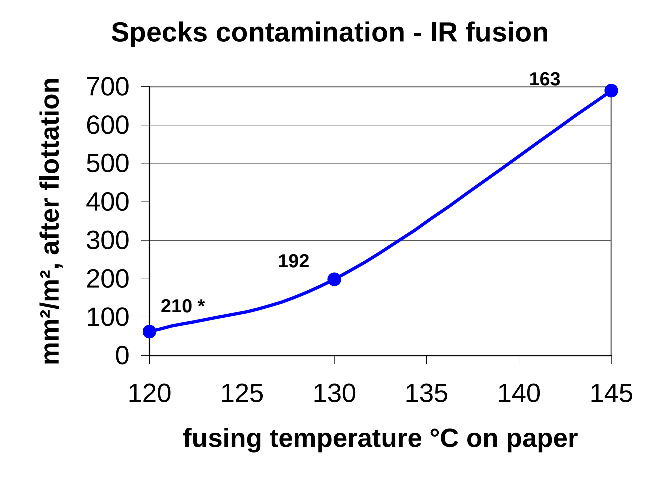



**Figure 11**: Deinking of Infra Red fused toner prints, incidence of fusing temperature – Residual attached ink on fibres (ERIC – HW (Hyper Washed) pulp pad)

Residual attached ink on fibres measurements show that after pulping, the fusing temperature effect is really obvious with a very large increase in ERIC from roughly 80 to 400 ppm, however after flotation, the temperature effect becomes much less visible, there was either a selective flotation of inked fibres or / and a detachment of these toners during flotation.




* : average diameter of specks (µm)

**Figure 12**: Deinking of Infra Red fused toner prints, incidence of fusing temperature – Specks contamination (on hyperwashed pulp handsheets) after flotation.

The speck contamination after deinking of IR fused printed paper is clearly lower than that observed after deinking of Nip fused printed paper. Particularly, at 120 and 130°C, the contamination is about 100 – 200 mm²/m² which is very low after a single deinking loop without any dispersion. It can be observed that specks are more fragmented since average diameter is around 160 – 210 µm though for Nip fused toners, average diameter was between 220 and 320 µm. Increasing fusing temperature with Infra Red also induces then smaller specks, the latter may be more brittle after this high temperature treatment.

### Deinkability of the various prints versus fusion technology and versus adhesion values

In **Table 5**, the various optical properties obtained after deinking of the various prints are summarized. For IR fusion and direct fusion in the nip, only values obtained with printing parameters giving the best deinkability are reported. For flash fusion and copy press, only one print was available.

| | Printer | | | | |
|---|---|---|---|---|---|
| | DS 8090 | PS 75 | OCE 8465 | | PS 88 |
| Printing speed (simplex print) | 175 pages / min | 75 pages / min | 65 pages / min | 200 pages / min | 43 pages/ min |
| Toner Fusing System | Nip fusion + preheating of the paper | Nip fusion No preheating of the paper | Undirect fusion Copy press | IR fusion | Flash fusion |
| | Floated pulp characteristics | | | | |
| ERIC entire pulp | 37 | 35 | 75 | 76 | 93.5 |
| Specks > 100 µm Surface mm²/m² Average ∅, µm | 1719<br>263 µm | 603<br>224 µm | 278<br>145 µm | 62<br>210 µm | 1404<br>183 µm |
| Specks > 200 µm Surface mm²/m² Average ∅, µm | 1347<br>348 µm | 383<br>321 µm | 21<br>424 µm | 39<br>304 µm | 540<br>297 µm |

**Table 5** : Comparison of deinkability for various fusion process based prints, ERIC & specks measurements reported correspond to floated pulp

**Table 5** confirms that best direct fusion conditions in the nip (from a deinking point of view) give a higher specks contamination than un-direct belt fusion (copy press).

As far as comparison are done at rather identical printing speed, flash fusion, compared with nip fusion & un-direct belt fusion, gives the worse deinkability for both the specks and residual ink contamination. When comparing higher speed copiers (nip fusion with pre heating and infra red fusion), it appears clearly that infra red fusion gives a better deinkability than nip fusion with pre-heating (even with the printing conditions giving the best deinkability).

Finding the best printing conditions to obtain a good deinkability is certainly of interest for the deinker, however this should not be obtained at the expense of the printing quality. In order to check this aspect, printing quality has been assessed by toner adhesion measurements (through pick resistance values), these are reported correlated with speck contamination in **Figure 13**.

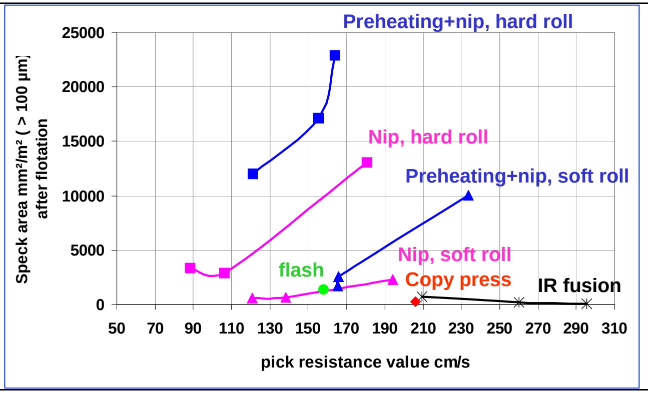



**Figure 13**: Correlation speck contamination after flotation deinking versus toner adhesion (through pick resistance values).

A high adhesion corresponding to a high pick resistance value, it becomes clear that a good deinkability is not obtained at the expense of a good toner adhesion which is a good new for both printers and deinkers as a compromise can be found quite easily.

More precisely, it can be seen that for low speed copier (flash fusion, nip and belt fusion), good adhesion (200 cm/s) are obtained for belt fusion (copy press) and nip fusion (soft roll high temperature) whereas for high speed copier, infra red fusion gives clearly a high adhesion with an excellent deinkability. Worse results (from both deinkability and adhesion) are clearly obtained with nip fusion (hard roll) & pre heating of the paper.

The expected correlation between adhesion and deinkability is only observed with nip fusion, the deinkability being deteriorated when adhesion increases (adhesion also increases with temperature) but for identical adhesion values, large deinkability differences can be observed.

There is therefore no direct relation between adhesion and deinkability. Some fusing systems can thus be promoted in order to try to favour deinkability without affecting toner adhesion.

## CONCLUSION

The use of recovered papers from the office collection will certainly rise in the near future as it is the only large source of recovered papers with a huge collection potential. After deinking, these will be mainly introduced in wood free grades: tissue paper, fine paper & DIP market pulp. However to obtain this target a very efficient deinking is required since high brightness high cleanliness need to be recovered. The deinkability of these recovered papers, among which a number of digital prints, needs therefore to be optimised and results presented in this paper give some inputs on deinking problems which may arise when treating these papers.

The largest deinking problem will be observed with pigment based waterbased ink jet prints :

- pigment based black ink jet inks are not only not deinkable, 10 % of them in a mixture of recovered papers deteriorate the deinking of the whole mixture (in both wood free and wood containing mixtures).
- Neutral deinking of these prints, contrary to waterbased flexo does not help to reduce the problem, ink particle in neutral condition being still completely dispersed.
- Coloured ink jet inks are not removed by flotation, however some of them (certainly those who still contain dyes) can be discoloured by conventional peroxide or most often by hydrosulfite reductive bleaching. According to the colour and mainly to the printer (and ink formulation) very different results are obtained which show that a collaboration with ink manufacturer should allow to develop coloured ink jet inks which can be colour stripped.

As far as toner based prints are concerned, results obtained have shown that :

- Speck contamination issued from toner prints depend first of all on how the toner was fused on the paper. Large differences are indeed obtained giving speck contamination after a single flotation deinking loop varying from 60 to 23 000 mm²/m².
- For low speed black & white copier, undirect fusion or belt fusion can be promoted as well as nip fusion if the fusing roll is soft.
- For high speed black & white copier, infra red fusion can be promoted. If nip fusion with pre heating of the paper should be used instead, then a soft fusing roll should be used.
- The interesting result is that good deinkability has been obtained without altering the toner adhesion, no correlation were found between these two parameters except for nip fusion.

Some digital prints, mainly inkjet prints, may disrupt recycling. Therefore the question of deinkability must be integrated in the ink designing in the same way as the printing quality, the printing speeds … However this question should be integrated in the approach of ink and press manufacturers. Some have already understood that it is their interest and have succeed to find a good compromise, however this approach should also be done in the area of ink jet inks, it is more and more urgent.

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