Deinking of Inkjet Prints

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Abstract

The study investigates the deinkability of inkjet printed products and shows the influence of printing paper and inkjet ink on deinkability. Test prints were produced on high-volume inkjet printing systems using different papers but the same image and print settings.

Tests included a standard laboratory deinking procedure for ink removal (INGEDE Method 11) as well as a VOITH test method of pulp bleaching, applying standard bleaching agents and chemical concentrations. Assessment of deinking results was based on the deinking scorecard promoted by the European Recovered Paper Council.

The tests showed good deinkability for 70 % of the test prints with pigment-based inkjet inks and their deinkability was clearly influenced by the printing paper. In contrast, deinking of dye-based inkjet prints was strongly influenced by both the type of paper and inkjet ink (only 20 % of the test prints showed good deinkability). All dyes, however, were capable of being bleached by common reductive bleaching agents. It was further shown that the deinkability of a recovered paper mix containing inkjet prints depends on the type and proportion of inkjet print products.

The study also identified paper properties (surface tension, paper components) that are responsible for good or poor deinkability.

Introduction

Most of the previous studies of inkjet printed products indicated a generally poor deinkability. This study was therefore designed to investigate how the printing paper and inkjet system (aqueous pigment and dye-based inkjet systems) influence deinkability and to identify product parameters that can help to improve the deinking performance. The study was funded by the German Federal Ministry of Economics and Technology [1].

Methodology

Papers and Inkjet systems

The methods applied in this study were intended to allow the production of comparable test samples and the evaluation of their deinking performance, with the condition that the effects of each parameter could be investigated separately. To this end, test prints were produced by commercially available, high-volume inkjet printing systems (HP T200, Info Print 5000, Kodak VL2000, Océ ColorStream 3000 and Océ JetStream 1400) on different papers, applying the same image and using identical print settings. Altogether 28 different test prints were produced, tested and assessed.

The printing papers selected for this study included 2 newsprints as well as 2 uncoated papers of different fibre qualities (virgin and recycled fibre) and 2 coated papers. They represent paper qualities designed for normal as well as specific inkjet printing applications. The printing papers within each group were from different manufacturers, each group included papers with comparable paper basis weight and all papers belonged to the same production batch. The print image and data processing were defined in such a way that print production was the same, regardless of the inkjet system used. For this reason print conditions were specified and all colour management settings, such as ICC profile "ISO-Coated V2", "Device Link Profiles" and GCR, were disabled.

Assessment of print products

Tests on print products included a standard laboratory deinking procedure for ink removal in flotation deinking (INGEDE Method 11) as well as a test method of pulp bleaching from the company VOITH. This method applies bleaching agents and chemical concentrations commonly used in paper mills processing recovered paper.

The analysis of the deinking tests was based on the 5 key parameters of the deinking scorecard (luminosity Y, colour coordinate a*, dirt particle areas A_{50} and A_{250}, ink elimination IE and filtrate darkening ΔY) promoted by the European Recovered Paper Council (ERPC) [2].

Deinking results are usually represented in the form of stacked bar graphs where each bar is comprised of six segments representing the parameters Y, a*, A_{50}, A_{250}, IE and ΔY. The height of each segment is equal to the value which the respective parameter scored in the assessment. As a result of this, the deinking performance is generally divided into four main categories: 'good', 'fair', 'poor' and 'not suitable for deinking' (Figure 1).

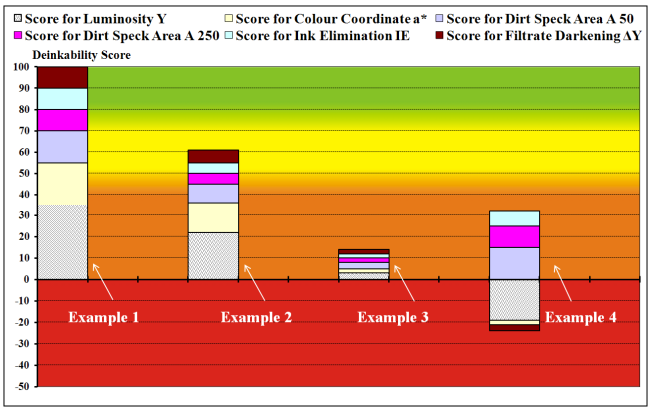

Figure 1. *Graphic representation of deinking results in which example 1 refers to 'good deinkability', example 2 to 'fair deinkability', example 3 to 'poor deinkability' and example 4 to a product that is 'not suitable for deinking'.*

In the assessment of bleaching tests, the deinked and bleached pulp was compared with pulp obtained from deinking tests (INGEDE Method 11) on unprinted paper.

Test results

Pigment-based inkjet prints

The deinking test results showed that 70 % of the test prints using pigment-based inkjet inks produced good deinking results, according to ERPC's deinking scorecard. The test results also showed that their deinking performance was mainly influenced by the type of printing paper and to a much lesser extent by the inkjet system and therefore by the type of inkjet ink (Figure 2).

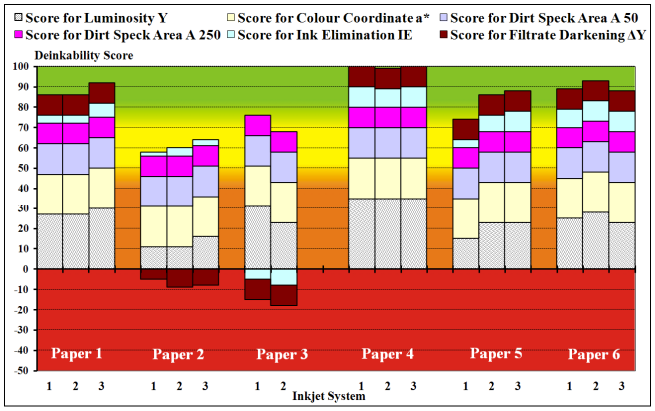

Figure 2. *Deinkability Scores of inkjet prints produced with pigment inks.*

To clarify why printing papers 2 and 3 produced negative deinking results, further investigations into the paper properties were performed. When studying the interaction between water and the paper surface it was found that papers 2 and 3 showed relatively high contact angles and consequently poor wettability. The corresponding property of the paper surface (i. e. surface energy) showed relatively low values for the polar component of the surface energy (Table 1). The measurements were performed with a contact angle tester OCA 20 of the company Dataphysics at 23 °C and 50 % relative humidity. Contact angles were measured using water as a test liquid.

Table 1: Contact angle and surface energy for printing papers

Printing paper	Contact angle (°)	Surface energy (mN/m)	Polar component (mN/m)
Paper 1	45.1	58.8 ± 0.5	25.5 ± 0.3
Paper 2	87.1	48.1 ± 0.7	1.7 ± 0.1
Paper 3	98.0	32.9 ± 0.4	0.8 ± 0.1
Paper 4	52.7	50.3 ± 0.8	22.4 ± 0.5
Paper 5	56.7	55.1 ± 0.4	15.0 ± 0.2
Paper 6	61.1	41.5 ± 0.8	18.5 ± 0.5

Dye-based inkjet prints

In contrast, only 20 % of the test prints using dye-based inkjet inks were deinkable according to ERPC's deinking scorecard. The newsprint samples failed on the deinking criteria for ink elimination, filtrate darkening (an indication of process water discolouration) and to some extent also on the colour coordinate a* of the deinked pulp. The print samples on uncoated and coated papers mainly failed on the criterion for the colour coordinate a* of the deinked pulp.

Compared to pigment-based inkjet products, the deinking performance of dye-based inkjet products were influenced by both the inkjet system (and subsequently inkjet ink) and printing paper (Figure 3).

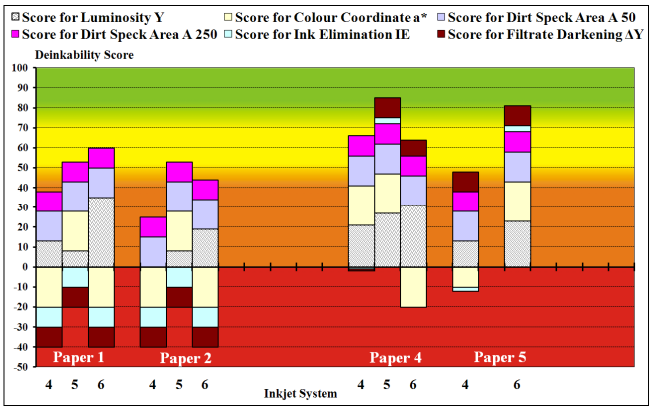

Figure 3. *Deinkability Scores of inkjet prints produced with dye inks.*

When investigating different pulp samples obtained from print products that were produced by one inkjet system (dye-based inkjet inks) on different printing papers, it was found that the colour of the filtrates varied, depending on the paper type (Figure 4).

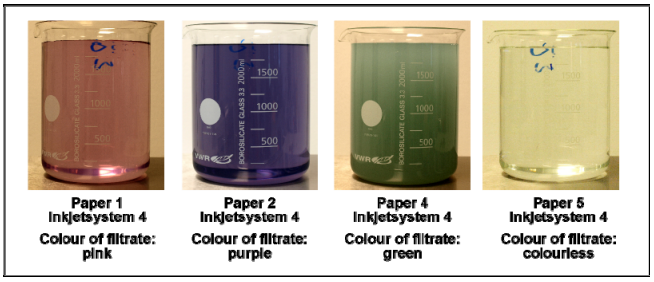

Figure 4. *Filtrates from pulp samples obtained from products that were printed on different papers but by the same inkjet system.*

This observation indicated that certain paper components interacted with the ink colorants and thereby produced different coloured filtrates. In order to verify this explanation, further tests applying cationic polyelectrolytes to the paper pulp, as well as to the printed paper surface, were conducted. Cationic polyelectrolytes are used in papermaking as retention aids, wet-strength additives and fixing agents [3].

Tests on a number of commercially available cationic polyelectrolytes showed that their presence in the fibre pulp eliminated the discolouration of the process water. The resulting filtrates were clear and transparent. Figure 5 illustrates the effect of different cationic polyelectrolytes in the fibre pulp on the process water. The concentration of the polyelectrolytes in this example was 1.3 % of the amount of oven-dry fibres present in the pulp.

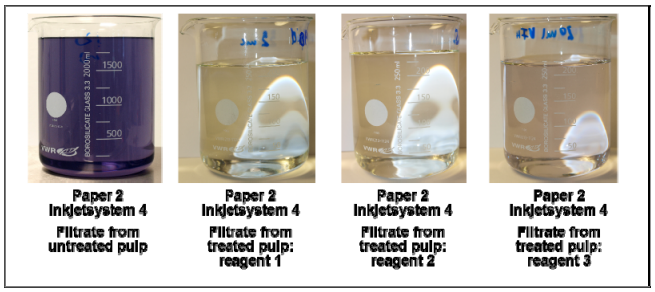

Figure 5. *Effect of different cationic polyelectrolytes (reagent 1, 2 and 3) on the filtrates obtained from fibre pulps containing dye-based inkjet products.*

In the second stage of the tests, a dye-based inkjet product was treated with a cationic polyelectrolyte by applying the reagent to the paper surface. A subsequent deinking test confirmed the effect of the reagent on the process water (no discolouration was observed). The test further showed that the presence of the polyelectrolyte did not have an adverse effect on the deinkability but improved the overall deinking performance. The treated print product showed better results for the colour coordinate a*, ink elimination IE and luminosity Y than the untreated sample.

Bleaching tests on dye-based inkjet products

Paper mills processing recovered paper and applying bleaching stages in their process, typically use hydrogen peroxide (H_2O_2) as an oxidative bleaching agent, sodium dithionite ($Na_2S_2O_2$) or formamidine sulphinic acid ($CH_4N_2O_2S$) as reductive bleaching agents [4]. Hydrogen peroxide is mainly used to prevent mechanical pulp from yellowing, whereas the reductive bleaching agents are more suitable for bleaching colorants used in dye-based inks. Table 2 summarises the main bleaching conditions that were adopted by the laboratory test method.

Table 2: Bleaching conditions (concentration of bleaching agents refer to the amount of oven-dry fibres)

	H_2O_2	$Na_2S_2O_4$	$CH_4N_2O_2S$
Pulp concentration	10 %	5 %	10 %
Concentration of bleaching agents	1.5 %	1 %	0.5 %
pH value - paper pulp	10.5	no adjustment of pH	use as an activated alkaline solution
Bleaching temperature	80 °C	80 °C	80 °C
Bleaching time	60 min	30 min	30 min

Although sodium dithionite is most effective at initial pH values of about 6, the presence of calcium carbonate in the pulp makes it difficult to adjust and keep the pH value for longer periods.

It was found that all colorants used in the dye-based inkjet prints of this study were removable by bleaching. Lightfastness tests on bleached pulp samples showed that the bleaching of the colorants was an irreversible reaction.

Bleaching tests on the deinked pulp confirmed that reductive bleaching agents (sodium dithionite or formamidine sulphinic acid) are more effective than oxidative bleaching agents (hydrogen peroxide). Reductive bleaching agents improve the luminosity of the deinked pulp by between 10 and 25 points, depending on the printing paper and inkjet ink, and thereby give the pulp a final luminosity of about 90 % to 95 % of the unprinted, deinked pulp. Compared to this, hydrogen peroxide only improves the luminosity by 3 to 8 points, which results in a luminosity of the treated pulp that is between 70 % and 80 % of the unprinted, deinked pulp.

Deinking tests on a recovered paper mix

Tests on a standard recovered paper mix were performed in order to assess the effects of different amounts of inkjet prints on the deinkability of the paper mix. The standard recovered paper mix consisted of 50 % newsprint (uncoated recycled paper), 30 % magazines (improved, uncoated paper) and 20 % gravure prints (LWC paper) [5]. The initial share of 50 % offset newsprint was replaced, step by step, with 10 %, 20 % and 30 % inkjet print product.

Three test runs were performed using both pigment and dye-based printing systems on newsprint. The following print samples were selected:

1. Pigment ink: Inkjet system 1, Paper 2 (Figure 2)
2. Pigment ink : Inkjet system 1, Paper 3 (Figure 2)
3. Dye ink: Inkjet system 4, Paper 2 (Figure 3)

The above mentioned individual inkjet products showed poor deinking results when tested as single print products. It was therefore expected that they would negatively affect the overall deinkability of the paper mix. The deinkability of the paper mix was tested according to INGEDE Method 11 and assessed by the parameters of brightness, colour coordinate a*, ink elimination and filtrate darkening (Figure 6).

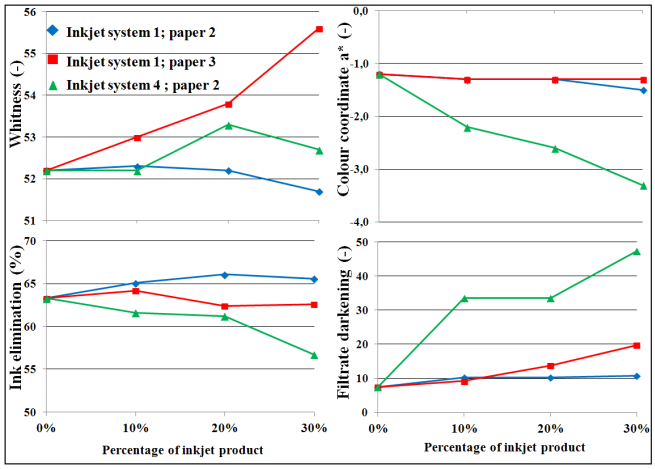

Figure 6. *Influence of the share of inkjet products in a recovered paper mixture, using inkjet products with poor deinking results for the respective parameter.*

The increase in whiteness, especially for inkjet system 1 / paper 3, can be explained by the relatively low whiteness of the pulp mixture and the high whiteness of the inkjet print product that

was added to the paper mix and subsequently increased the whiteness of the pulp mixture.

The dye-based inkjet product shows the greatest effect on the mixture. The most noticeable parameters were the colour coordinate a* and filtrate darkening ΔY which were already affected by shares of 10 % of inkjet prints in the paper mixture. The two pigment-based inkjet products, by contrast, did not have such an effect on the deinkability of the mixture.

Summary

The study showed that the deinking performance of print products produced by inkjet systems using aqueous pigment or dye-based inks can be influenced by the right choice of substrate or by the right paper/inkjet combination. The influence of the printing paper on the deinkability, especially in the case of pigment-based inkjet products, has not been reported on before and represents a distinctive feature of this investigation. However, deinking tests will still be necessary to identify suitable substrate or paper/inkjet combinations.

Outlook

Printers and print customers are becoming more and more sensitised to the environmental impact of their print products. Their environmental awareness presents a challenge which is to provide printers and print customers with a solution, enabling them to produce and buy products that pose no risk to paper recycling.

This is why Fogra promotes the use of 'compatibility lists' already used by the digital printing press manufacturers and that contain information about which printing papers can be printed by their printing presses. Such lists can be complemented by an additional category 'recyclability / deinkability', indicating which printing paper or paper-press combination leads to deinkable print products.

As a result, customers could easily opt for a 'deinkable print product' and printers could use such information as an effective tool for winning and keeping customers. This approach is also intended to help print customers apply for various environmental labels – so called eco-labels – for printing, which increasingly include criteria for the deinkability or recyclability as part of the product's lifecycle evaluation.

One further reason for promoting such an approach lies in the fact that some countries are concretely thinking about imposing taxes on print products. Depending on the product's deinkability, certain tax reductions will be granted.

Fogra's service in this area includes:

1. Production of print samples on the chosen paper-press combination according to Fogra's above-mentioned print specifications. This ensures that the print product can be reproduced and that the information on the 'compatibility list' refers to a standardised print product.
2. Deinking tests on the print sample according to the standard test method: INGEDE Method 11, and evaluation of the test results according to the deinking scorecard promoted by the European Recovered Paper Council.
3. If the test results are positive, a test certificate will be given showing that the print product can be deinked and fulfils the deinking criteria laid down by the European Recovered Paper Council. The test certificate can be used as documentation for 'compatibility lists', applications for certain eco-labels or when applying for tax reductions on print products.

References

[1] The project was supported within the programme of the Federal Ministry of Economics and Technology for the support of "Industrielle Gemeinschaftsforschung (IGF)" via the German Federation of Industrial Research Associations (AiF, no. 16730 N). The complete research report under the title of 'Deinking von Inkjet-Druckerzeugnissen' (Fogra no. 45.001) is available in German language as a PDF file.

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Author Biography

Alexander Schiller studied Physical Chemistry and graduated in 1996 from the Munich University of Applied Sciences, doing his final year at the Nottingham Trent University in England. He has been with Fogra Graphic Technology Research Association since 1997 in the department for Materials and Environment, where he is jointly responsible for research projects and approval tests on press room chemicals. Since 2002 he has been involved in various projects on paper recycling.