High-Quality Deinked Pulps via Alkaline-based HPMA Deinking Chemistry

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Abstract

In this paper we present an alkaline-based deinking chemistry (coded HPMA), which facilitates deinking of digital as well as conventional print media. The novel method presented here, HPMA, uses traditional alkaline deinking chemicals including sodium hydroxide and sodium silicate, but with the substitution of a readily-available emulsifier, a non-ionic surfactant, for the traditional fatty acid. The chemistry is based on methodical structural-physical understanding of properties of digital inks applied to deinking chemicals and deinking processes, to achieve high-quality deinked pulps at lab scale. The resultant chemical composition serves effectively as a release agent for the ink from the paper fibers and a collecting agent to agglomerate the particles to achieve ink particulates with the desired size range and provides the desired interfacial interaction with the foam for eventual removal during the flotation. High quality deinked pulps of HP-Indigo ElectroInks, HP Inkjet pigment/dye-based inks and HP dry toners were successfully obtained via HPMA. Similarly good results were obtained for traditional offset inks and mixed office waste with HPMA, suggesting the generic nature of our deinking chemistry.

Introduction

Three core technologies of digital printing are Inkjet, Dry Electrophotography (DEP), and Liquid Electrophotography (LEP). Of these, pigment-based thermal inkjet (TIJ),via the new HP Web Press, and LEP, via HP-Indigo, are scalable to longer run lengths approaching those of analog offset printing presses and are important in the commercial printing space.

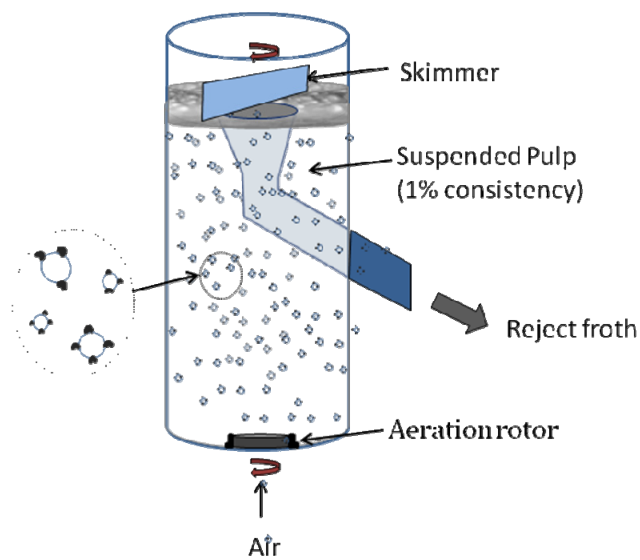
In general, for water-based pigment or dye TIJ inks, the colorants are either nanoparticles or molecules. For effective deinking, they need to be agglomerated to the desired size range for removal. For LEP prints, the ink particles are slightly larger, so it is advantageous to break them down prior to deinking.

As commercial inkjet printing and LEP printing technologies gain more market share in the global print market digital prints will become a larger part of the waste stream. It is therefore important that good recyclability of these various printed products be achievable. "Downcycling" paper for packaging materials and other uses is widely used and does not require good deinkability, but 50% or more of newsprint is made from recycled newspapers and magazines in Europe, so a very good deinkability is desirable. Some mills, especially in European's newsprint production, are adopting the more traditional alkaline deinking in legacy deinking plants.

Our objective was to devise an appropriate deinking chemistry, based on alkaline chemistry currently in use for deinking newspapers, to achieve good deinkability for HP digital commercial print media along with other types of printed media in the waste stream.

Experimental

Figure 1. Schematic of Voith Delta25 laboratory-scale flotation cell. An aerator rotor with a magnetic drive rotates, causing agitation of the suspended



pulp while infusing the cell with air. Hydrophobic ink particles and fines adhere to the air bubbles and are buoyed up to the top of the cell, where they are skimmed off as reject froth.

As described previously [1], we have set up a complete deinking laboratory compatible with international standards and tested numerous ink/media systems. Filter pads and handsheets are formed before and after flotation to provide accurate color and reflectance measurements to determine the ink elimination, assessed using standard benchmarking techniques. Deinkability scores are determined using the European Recycling Paper Council (ERPC) scorecard as well as ISO and TAPPI standards.

All test media were cut on a paper-cutting machine to 2 cm squares. The pulping chemicals were mixed with deionized water (~ 45°C) treated with calcium chloride to achieve a water hardness of 128 mg Ca^{2+}/L to achieve a consistency (solid content by weight) of 15%. A Hobart pulper was used at Speed 2 for 20 minutes to pulp the printed test media.

Before the flotation stage, the stock was further diluted with 45°C warm water to a consistency of 0.8% in the Voith Delta25 flotation cell. The flotation cell is shown schematically in Figure 1. Air flow and agitation from the rotor in the bottom of the cell cause bubbles to rise within the cell. Hydrophobic ink particles and other fines from the paper or paper coating attach to the bubbles and float to the top where they form a froth, which is skimmed off. The flotation was allowed to proceed for 12 minutes, with extra warm water added during the process to ensure overflow. The rotor speed was set at 1470 rpm, with an airflow of 6 to 7 L/min. During the flotation stage, the overflow was collected and measured according to DIN ENISO 4119 by drying on a filter paper in order to determine the yield.

Traditional alkaline deinking chemicals, i.e. up to 0.6% caustic soda (NaOH), and 1.8% sodium silicate were used. The dosing of these chemicals was adjusted so that the pH of the pulp suspension was between 9 and 10 after pulping. To investigate the effect of chemicals on key deinking parameters, , the traditional oleic acid was replaced with a non-ionic surfactants such as polyoxyethylene(8) stearate, MYRJ45, during pulping and more MYRJ 45 plus an anionic surfactant such as sodium dodecyl sulfate (SDS) during flotation. The typical chemical dosage is shown in Table 1.

Table 1. Chemical Dosage

Chemical	Dosage (related to oven-dry paper)
Pulping:	
NaOH	0.35 %
Na_2SiO_3	0.60 %
MYRJ45	0.35 %
Flotation:	
MYRJ45	0.8 %
SDS	0.2 %

Six different ink-media sets were used in this work:

- HP DeskJet dye-based inks/HP Multipurpose ColorLok media (TIJ dye)
- HP Edgeline pigment-based inkjet inks/HP Multipurpose ColorLok media (TIJ pigment),
- HP Color Laserjet dry toner/HP Multipurpose ColorLok media (DEP)
- HP Indigo ElectroInk/commercial coated paper (LEP)
- Heatset Offset prints/commercial matt paper (Offset)
- Mixed Office Waste (MOW)

Optical measurements of handsheets and filter pads were performed using an Elrepho spectrophotometer. Deinking was evaluated using the European Recycling Paper Council (ERPC) deinking scorecard [2]. Individual scores summing up to 100 points were calculated for luminosity (L), color shade (a*), dirt particle area (A), ink elimination (IE) and process water darkening (ΔY). Target and threshold values are specified, and if any result is outside of the threshold the product is rated “not suitable for deinking. A score above 70 is considered to show “Good Deinkability”.

Results and Discussion

With HPMA, excellent deinking results were achieved with all six print media. Figure 2 shows the individual scores that go into the ERPC Deinkability Score. According to the Deinkability Scorecard, all have passed on the five measures and are rated as having “Good Deinkability”. LEP shows the highest luminosity, which is likely to be attributable to the quality of the original paper.

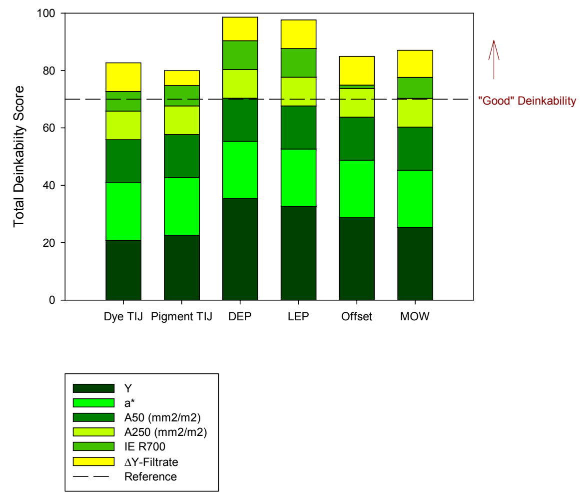


Figure 2. *Overall ERPC Total Deinkability Scores of the six ink/media sets tested. All scores are above 70, classified as “Good Deinkability”.*

Figure 3 shows scanned images from handsheets of each ink/media type. The DEP, LEP, and MOW handsheets are particularly distinctive, as they start out with a large number of visible specks before flotation, and virtually none are apparent after flotation. The replacement of the oleic acid with MYRJ45 and the subsequent addition of SDS allows for even the larger LEP and DEP ink particles to detach from fibers and floatable.

Figure 4 focuses in on the Dirt Particle Area measurement of the Deinkability Scorecard. Both the speck area before and after flotation are shown. After flotation, all are not only well below the 2000 mm^2/m^2 tolerable threshold of this parameter (600 for particles less than 250 µm) but also well within the desirable target value of 600 mm^2/m^2 (180 for particles less than 250 µm).

For the TIJ Dye and the TIJ Pigment, dirt particles and speck counts are usually not a challenging issue, because the pigment and dye particles are generally too small to be observed visually. Here the important issue is whether they can be collected together to float out of the suspension. First, during pulping, the print media fibers swell and the pigment or dye are presumably detached from the fibers. The alkaline conditions are believed to be favorable for this step. Depending on the particular dyes or pigments involved, typically the pulp becomes one color while a different color is separated out into the aqueous solution. Then, in flotation, when more surfactants are added, the particles are agglomerated and floated out as rejects.

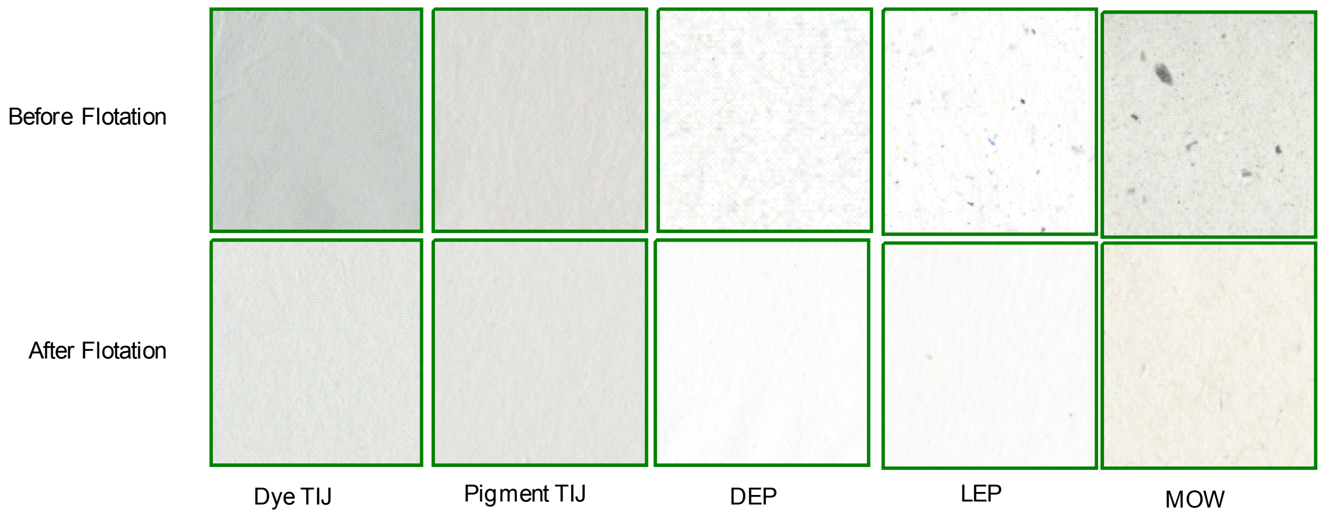


Figure 3. *Optical images of handsheets made from the un-deinked pulp (top) and deinked pulp (bottom).*

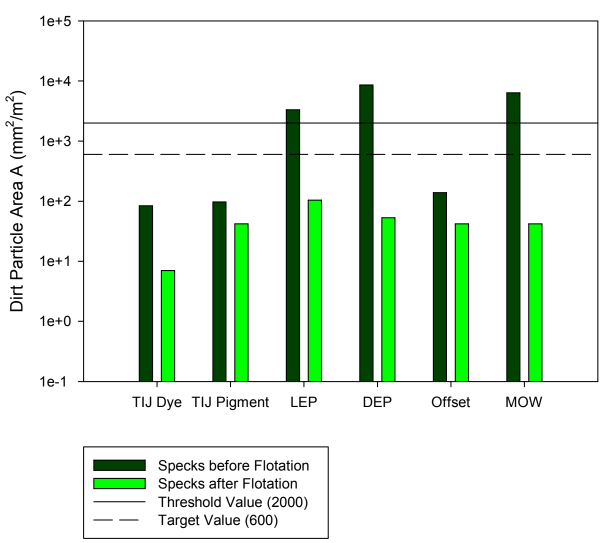


Figure 4*. Dirt Particle Area (ink specks) in a 1.5 inch by 1.5 inch scanned area from a handsheet made after flotation. These scores reflect the sum of both particles below 250 mm in diameter as well as above, but the majority of particles are small and both thresholds are well met after flotation.*

Our HPMA has overcome the challenging filtrate darkening issue with inkjet inks. Membrane filter specimens are made from the filter pad filtrate to measure ink contents in the process water during deinking. The results for TIJ specimens are shown below in Figure 6. The pigment-based TIJ had a score of +5, while the dye-based TIJ received a perfect score of 10 of 10 for very mild filtrate darkening (the luminosity change was only 5%).

Figure 6. *Membrane filter specimens from deinking of pigment-based TIJ (left) and dye-based TIJ (left).*

In traditional deinking processes using fatty acids, they react with the sodium hydroxide (caustic soda) to form an anionic sodium salt soap. The sodium silicate aids in the saponification, and also may help sequester the calcium ions in hard water, leading to an increase in the surfactant concentration [3]. The alkaline environment has also been shown to play a role in the swelling of the cellulose fibers and release of the binder materials in the paper [4]. However, in HPMA since there is no fatty acid, there is no need for saponification but rather synthetic non-ionic surfactants, which we have found to be more effective for ink detachment and small particle agglomeration. These surfactants are effective in an alkaline environment, although the sodium hydroxide and sodium silicate is not necessary for the ink removal as shown by our HPES studies [1].

Conclusion

Alkaline deinking chemistry can be optimized to obtain good deinkability for digital commercial print media, including liquid electrophotography, dry electrophotography inkjet prints.

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Author Biographies

Laurie S. Mittelstadt is a Materials Scientist at Hewlett-Packard Laboratories. In addition to advanced printing technology, she has worked on a variety of projects at HP Lab including excimer-laser micromachining, optical fiber fabrication and portable fuel cell technology. She received her M.S. in Materials Science from Stanford University and an M.S. in Physics and Astronomy from San Francisco State University

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Eric Hanson is the Director of the Commercial Print Engine Laboratory of Hewlett Packard Laboratories, in Palo Alto, California, where he has managed research investigating advanced digital printing since 1984. He is currently the Immediate Past President of IS&T, the Society for Imaging Science and Technology. He received a Ph.D. in physics in 1976 from the University of California at Berkeley and has been awarded 18 US patents.