Deinking of HP Digital Commercial Prints: Effect of Chemicals and Their Loadings on Deinkability

Hou T. Ng, Manoj K. Bhattacharyya, Laurie S. Mittelstadt, Eric G. Hanson
HP Labs, Hewlett-Packard Company, 1501 Page Mill Rd, Palo Alto, CA 94304, USA

Abstract

Here we show that the effect of chemicals and their specific loadings play a dominant role on the outcome of a deinking process. More specifically, we demonstrate that good deinkability of HP digital commercial prints (i.e. liquid-electrophotographic (LEP), dry-EP and inkjet (IJ) prints) can be achieved with our highly efficient neutral deinking chemistry (coded HPE6S4), which is based on readily available non-proprietary chemicals. We found a direct correlation of the chemical effects to the ink-particle speck contamination and its particle-size distribution. Our excellent results compared favorably to that obtained with the traditional deinking chemistry. Our approach can be readily scalable for adaption in the paper recycling mills.

Introduction

Recycling of paper products is important for fulfilling both environmental sustainability and economical returns. In Europe, ~ 85% of newspapers are printed on recycled paper while ~ 50% of printed media are recycled.[1] In North America, these numbers are somewhat lower but the trend is increasing rapidly.

An important factor that critically affects the overall yield of paper recycling is the efficiency of deinking process. As digital prints gain more market share, sustainable deinking of digital prints can positively impact the effectiveness and yields of paper recycling. Digital prints based on various digital printing technologies do not generally yield the same deinking outcome[2-4] which is influenced by a number of factors associated with the deinking processes. The recovered fiber must be free of residual inks if it is to be used for re-making high-grade office, graphics and writing papers. Hence, it is highly desirable to implement a 'universal' deinking process which is effective for a wide range of wastepaper mixes.

In this work, we show that deinking chemistry can be optimized to obtain good deinkability for various digital commercial print media, including LEP, DEP and inkjet ink-media. Our results indicate that with an appropriate choice of deinking methodology, all three of the above-mentioned prints can be deinked to either meet or surpass the deinking thresholds and criteria. Our approach is applicable to various offset print media and is readily scalable to be adapted in recycling paper mills.

Experimental

Figure 1 shows the major steps of the deinking processes adopted in our work. Briefly, for aging the print products, two-hundred grams each of test media were stored in a thermostat-controlled oven at T= 60°C for 3 days to simulate aging (~ 3-6 months of natural aging). All test media were cut on a paper-cutting machine to 2 cm squares. During the pulping stage, a Hobart pulper was used. The test media was mixed with the deinking chemicals and de-ionized water which was treated with calcium chloride dihydrate to achieve a water hardness of 128 mg Ca^{2+}/L. During storage, the stock was diluted with treated water to a pulp consistency of 5% and stored for 60 min in a water bath maintained at 45°C. Before the flotation stage, the stock was further diluted with 45°C warm water to a consistency of approximately 0.8% in the Voith Delta25 flotation cell. The flotation was allowed to proceed for 12 min, with extra warm water added during the process to ensure overflow. The rotor speed was set at 1470 rpm, with an airflow of 6 – 7 L/min. During the flotation stage, the overflow was collected and measured according to DIN ENISO 4119, including the consistency of the overflow by drying on a filter paper, to determine the yield.

To investigate the effect of chemicals on the deinking outcome, the key steps of the process flow are kept similar to that of INGEDE Method 11, except for the deinking chemicals (coded HPE6S4). In the case of the INGEDE Method 11, the traditional alkaline deinking chemicals were used, i.e. 0.6% caustic soda (NaOH), 1.8% sodium silicate, 0.7% hydrogen peroxide and 0.8% oleic acid.

Three different HP commercial print ink-media sets were used in this work: 1) HP Indigo ElectroInk on coated (Newpage Indigo)/uncoated (Cougar Opaque) media; 2) HP Edgeline inkjet inks/HP Multipurpose ColorLok (HMC) media and 3) HP Colorsphere toner/HMC.

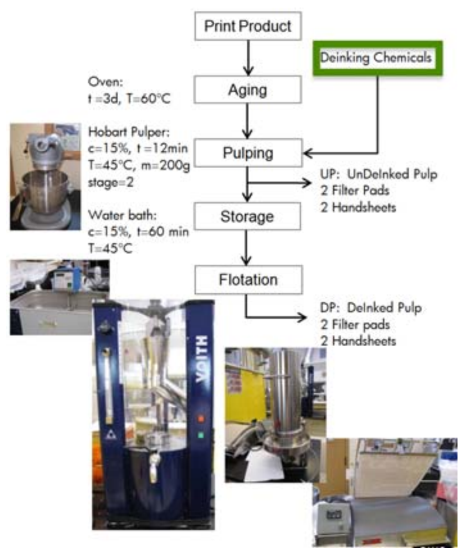

Figure 1*. A schematic showing the key steps of the deinking process adopted in this work. Except for the variations in deinking chemicals, conditions at various stages are similar to that as outlined in the INGEDE Method 11, 1 and 2.*

Results and Discussion

Figure 2 shows the typical deinking results for the three ink-media sets following INGEDE Method no. 11 protocols. While the deinking results of DEP print media are satisfactory (according to the deinkability score card), the other two are marginal. A comparatively higher ink residual speck contamination was observed for the LEP print media, while a lower ink elimination (IE) and higher filtrate darkening were noted for the IJ print media.

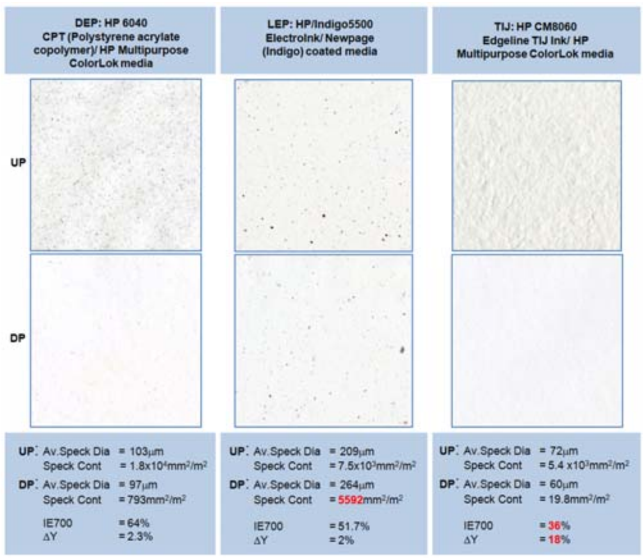

***Figure 2**. A summary of deinking results using INGEDE Method no. 11 for the three ink-media sets. Optical images of respective handsheets, made from the un-deinked pulp (UP) and deinked pulp (DP) are shown. The ink elimination (IE) data were measured from the filter pads while the filtrate darkening (ΔY) data were measured from membrane filters. Negative scores (according to the deinkability scorecard) are highlighted in red.*

With HPE6S4, which consists of a mixture of non-ionic ethoxylated fatty alcohols and anionic surfactants such as sodium dodecyl sulfate (SDS), excellent deinking results were achieved with all three representative commercial print media. It is noteworthy that these surfactants are widely used in numerous applications and are commercially available at relative low cost. For the current laboratory-scale deinking process, two major steps are involved – pulping and flotation. In the pulping step, the print media is swelled by the aqueous deinking chemicals and the ink particles are detached either from the fibers or the media coatings. Simultaneously, the detached ink particles are mechanically broken down and made hydrophobic by their interactions with the added surfactant. Ink particle removal occurs next during the flotation process. The formerly detached ink particles interact with the air-flow generated bubbles and float to the top of the flotation cell as foam and are removed by a scooping action. It is crucial that the bubbles provide the desired surface-interaction energy and hence sufficient buoyancy to carry the attached ink particles to the top of the flotation cell where they can be removed as overflow. Hence, the choice of surfactants and their individual roles as collector and dispersant in the pulping and flotation stages are critically important toward the outcome of a deinking process.[5,6]

As shown evidently by the results in Figure 3, HPE6S4 has successfully served as a collector and a dispersant during the pulping and flotation stages to facilitate efficient detachment and removal of the ink particles from the media. Notably, we observed a dramatic improvement, at least an order of magnitude difference, in the ink speck contamination level for the LEP print media. Interestingly, that of the DEP print media was brought favorably to be within the targeted level ($< 600\ mm^2/m^2$). It is noteworthy that

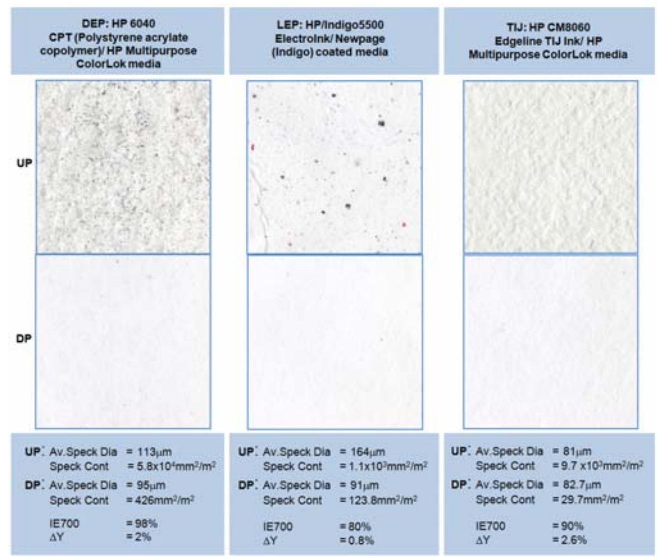

***Figure 3**. A summary of deinking results using the process steps as that of INGEDE Method no. 11, with HPE6S4 for the three ink-media sets. Optical images of respective handsheets, made from the un-deinked pulp (UP) and deinked pulp (DP) are shown. The ink elimination (IE) data were measured from respective filter pads while the filtrate darkening (ΔY) data were measured from respective membrane filters.*

the ink elimination (IE700) and filtrate darkening (ΔY) were also significantly improved for the IJ print media. A corresponding increase in the average speck diameter of IJ ink particles was observed, suggesting efficient agglomeration of the submicron size pigment particles using our HPE6S4 deinking chemistry. Through repetitive runs, we have found ink specks with sizes of between 50 and 150µm, which work well with the present neutral deinking chemistry. We have further confirmed the reproducibility of our approach by repetitive runs using the afore-mentioned ink-media sets. Optimization of our base formulation for HPE6S4 has also been performed to determine the operational compositional windows.

Further deinking experiments were performed on HP Indigo ElectroInk/uncoated media, where Cougar Opaque was used as an example. Figure 4 summarizes encouraging residual ink speck information obtained with the DP handsheets. Upon successful deinking, we observed no appreciable residual ink particle and extremely few large ink specks within a scanned area of 1.5” by 1.5”. Both speck contaminations of DP and UP handsheets of coated and uncoated papers are compared and found to be well within the target range. The slight difference in UP speck contamination between coated and uncoated paper could be attributed to the slightly higher ink-paper ratio of the uncoated ink-media set.

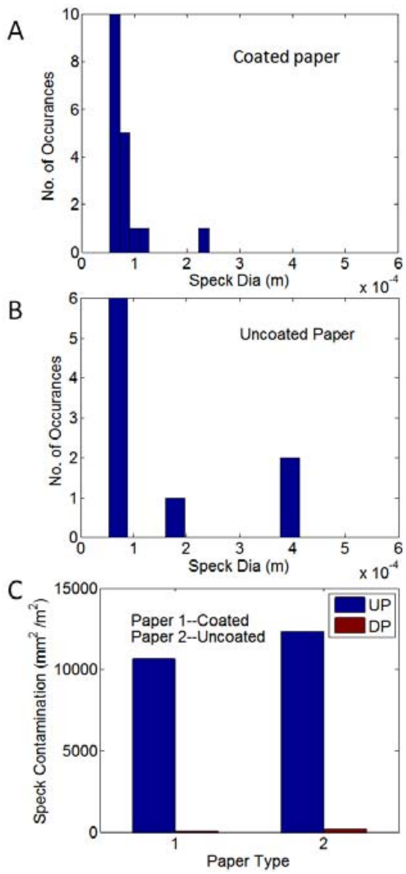

***Figure 4**. Ink speck size distributions within a 1.5" by 1.5" scanned area of the post-flotation handsheets for HP Indigo ElectroInk/Newpage Indigo (coated paper) (A) and Cougar Opaque (uncoated paper) (B). C, Speck contamination comparison for the UP and DP handsheets.*

Print Type/Media	Average Fiber Yield (%)	
	HPE6S4	INGEDE Method 11
LEP/ Newpage Indigo	81	90*
LEP/Cougar Opaque	86	90*
DEP/HP Multipurpose ColorLok	82	83*
IJ/HP Multipurpose ColorLok	85	86*

***Table 1**. Average fiber yields for the various ink-media test sets. * indicates presence of noticeable amount of filler materials besides the fibers in the recovered pulps.*

Flotation deinking could potentially lead to undesirable loss of high quality fibers in the overflow.[7] Further structural analysis of the recovered pulps was performed by scanning electron microscopy (SEM). As shown in Figure 5, the undeinked pulp shows the presence of fibers, mineral pigments, filler materials and ink particles while the mineral pigments are predominantly found in the flotation overflow waste, with a small amount of fiber. Deinked pulps, on the other hand, mainly consist of fibers, with a noticeably small amount of residual mineral pigments. Typical fiber yields for the ink-media sets used in our present work are summarized in Table 1.

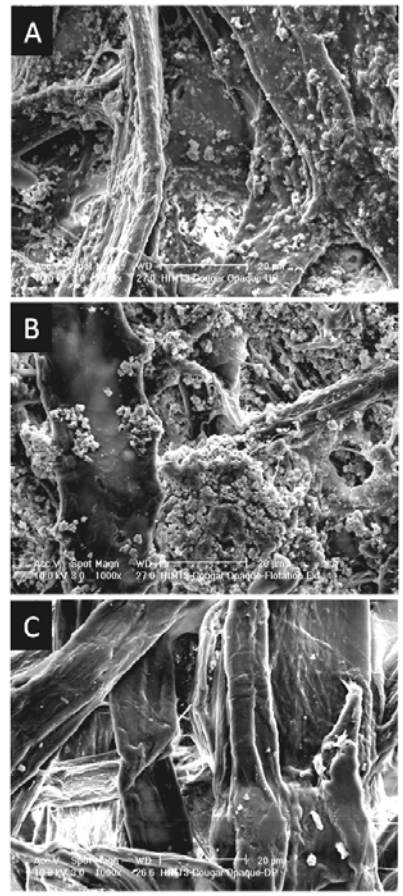

***Figure 5**. Scanning electron microscopy of the undeinked pulp (A), flotation overflow (B) and deinked pulp (C) for the HP Indigo ElectroInk/Cougar Opaque (uncoated) media. Respective scale bar is shown in each panel.*

Besides the ink speck contamination level, optical properties of the recycled fibers play a deterministic role in the grade of the recycled paper. For achieving high quality recycled media for graphics, office and writing applications, stringent optical characteristics have to be met. Table 2 lists the key optical measurements of the three ink-media sets. Strikingly, these are well within the targeted range according to the Deinkability Score card proposed by the European Recovered Paper Council (ERPC).[8]

Print Type/Media	Y (Brightness)	L*	a*	b*
LEP/ Newpage Indigo	92.7	96.9	1.53	-2.18
DEP/HP Multipurpose ColorLok	94.1	98	1.42	-4.44
TIJ/HP Multipurpose ColorLok	99.0	100	1.12	-4.34

***Table 2**. Optical measurements of the deinked-pulp (DP) filter pads for the three ink-media sets.*

Measuring against the targeted values for ‘toner prints on woodfree papers’, all three ink-media sets met or exceeded the five key parameters – speck area A, filtrate darkening ΔY, color a^*, luminosity Y, and ink elimination – and achieved good deinkability. Figure 6 shows the tabulated plots.

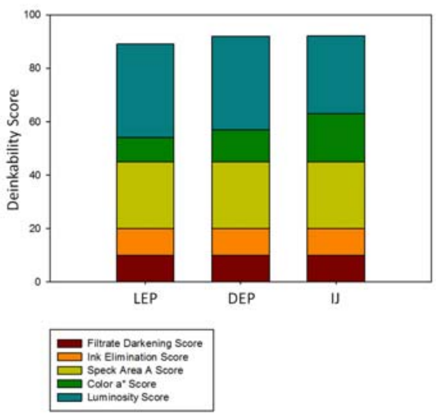

Figure 6*. Deinkability scores, graded according to the specifications as spelt out in reference 8, of the three ink-media sets (obtained with three different commercial digital printing technologies).*

Conclusion

In conclusion, we show that good deinkability of various print media, derived from various digital printing technologies, can be achieved with appropriate selection of deinking chemistry. Through this work, we demonstrate the genericalness of neutral deinking chemistry, based on non-proprietary commercially readily available chemicals, which can cater to the three common digital commercial print products. Due to the simplicity of our present approach, scalability to industrial paper mill operation can be realized. In addition, the usage of neutral deinking chemistry is a step in the right direction towards realization of a greener solution for recycling of paper products.

References

[1] A. Tribute and R. Schlozer, InfoTrends Report (2009).
[2] A. Fischer, 22nd International Conference on Digital Printing Technologies Final Program and Proceeding (2006), 514-516.
[3] C. Craft, Paper 360°, January/February (2009), 10-13.
[4] B. Carre, L. Magnin, C. Ayala, International Conference on Digital Production Printing and Applications, May 2005, Amsterdam, the Netherlands.
[5] D. Beneventi, B. Carre, A. Gandini, Colloids and Surfaces A, 189 (2001), 65-71.
[6] Y. Zhao, Y. Deng, J.Y. Zhu, Progress in Paper Recycling", 14, No 1 (2004), 41-45.
[7] J. Y. Zhu, F. Tan, The Canadian Journal of Chemical Engineering, 83 (2005), 377-381.
[8]http://www.wrr.icodat.com/resources/reports/erpc%20deinkability%20scorecard.pdf.

Acknowledgment

The authors would like to acknowledge fruitful discussions with Doris Chun, Howard Tom, Nathan Moroney, Minedys Macias, Gregg Lane, Nils Miller, Jeffrey Belson, Marc Aronhime, Yossi Rosen, Pinni Perlmutter, Greg Smith, Sandeep Bangaru, Kelly Ronk, William Houle, Glen Hopkins, and Frank Drogo.

Author Biography

Hou T. Ng is a research manager/technical lead from the Commercial Print Engine Lab of HP Labs, Hewlett-Packard Company. His team is responsible for advanced research and development revolving around the chemistry, materials science, physics and printing processes of next-generation inkjet and liquid electrophotographic printing technologies. Hou T. received his Ph.D. in Chemistry from the National University of Singapore in 2001. He joined HP Labs in 2004 from NASA Ames to focus on R&D projects related to digital commercial printing technology.

Manoj K. Bhattacharyya received his Ph.D in Electrical and Computer Engineering from Carnegie Mellon University in 1984. He has been with the Hewlett-Packard Laboratories since his graduation and works in a variety of fields including magnetics, magnetic recording and digital commercial printing.

Laurie S. Mittelstadt is a Materials Scientist at Hewlett-Packard Laboratories. Ms. Mittelstadt received her M.S. in Materials Science from Stanford University and an M.S. in Physics and Astronomy from San Francisco State University Her research includes innovations and advanced R&D in printing processes and materials for digital commercial printing technology. Ms. Mittelstadt has worked on a variety of projects at HP Labs including excimer-laser micromachining of inkjet printheads and miniature planar capillaries, optical fiber fabrication and portable fuel cell technology.

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.