4th International DAAAM Conference
"INDUSTRIAL ENGINEERING – INNOVATION AS COMPETITIVE EDGE FOR SME"
29 - 30th April 2004, Tallinn, Estonia

CHEMICAL AND ENZYMATIC DEINKING FLOTATION OF DIGITAL PRINTS

Bolanča, I. & Bolanča, Z.

Abstract: *The efficiency of ink separation in the process of waste paper recycling depends among other things on the ink properties, kind of the substrate, the printing techniques and the printing conditions. Chemical deinking flotation does not efficiently remove water based flexographic inks, UV ink and varnish, ElectroInk and some toners from digital printed paper. The use of enzymes could be an alternative to chemical deinking.*
The investigations results about the chemical and enzymatic deinking process the prints from digital printing with liquid and powder toner have been presented in this paper. The used enzyme is the product of fermentation of the fungus Humicola insolens. It was used with the addition of non ionic tenside based on ethoxylated fatty acids. The investigation results show that the application of enzymatic deinking causes the increase of brightness, improved dirt removal efficiency and the mechanical properties of handsheet are somewhat decreased.
Key words: *chemical deinking, enzimatic deinking, digital prints, factor influencing deinking, recycled fibre properties*.

1. INTRODUCTION

Recycled fibres have become an important source in the paper production. Deinking is a process for detaching and removing printing inks from recycled prints. On the other hand, the difficulties in the preparation of the secondary raw material, primarily in separation of ink from cellulose fibres and its removal are possible in chemical deinking process. The efficiency of this method depends on the technique and printing conditions, kind of ink and kind of printing substrate (Borchard, J. K., 1998, Bolanca. Z. et al. 2000; Bolanca Z. et al. 2003).
Each technology places different demands on the ink and particle size, and ink and toner chemistry determine effectiveness of deinking chemicals. The particle sizes of water based flexo inks are in the range from 0,2 -1,0 μm after repulping and they are too small for flotation. Because the ink is hydrophilic it cannot be agglomerated by collector chemicals (Skaar, T. F., 1994; Brochardt, J. K., et al. 1994). Water based rotogravure inks behave similarly to water based flexo inks (Hooper, C., et al. 1996).
Ultraviolet inks and varnishes form hard polymers, which are difficult to break up in the disintegrator, have particles which may be too big to flotate. Resins used in toner for laser printing and photocopying make them difficult to detach from the fibres. When the toner is removed from the substrate, during repulping, the toner fused film is detached in flat plate-like structures. These particles are too big to be removed successfully by flotation (Dorris, C. M. G., Sayegh, N. N., 1994).
From the presented, the problems of ink removal i.e. toner are evident, which is the main technical obstacle to greater usage of the recycled paper in printing. The investigations in the area of deinking technology are directed towards the study of the process and finding the additional chemicals in the sense of the decreasing the limited usage of heterogeneous mixture of the waste paper in the conventional recycling method. On the other hand, the conventional deinking processes require great quantities of chemicals which results in big costs for waste water treatment. Deinking processes are also considerable source of solid and liquid waste. The development in this area comprises some new technologies such as magnetic deinking (Marwah, N.; 1996), deinking using ultrasound (Scott, W. E. & Gerber P.; 1995) and enzymatic deinking.
The study of enzyme application in the deinking process is performed by many scientists. There are some patents from that area (Prasad, D. Y. et al. 1992; Cropsey, K. et al. 1994, Welt T., Dinus, R.J.,1995, Eom, T. J. & Ow S. S K.1990).
The enzymes used in deinking are: cellulases, hemicellulases, lipases, xylanases, pectinases, esterases, α amylase and lignolytic enzymes. Cellulases, xylanases or pectinases release ink from fibre surfaces and lypases and esterases hydrolyze soy based ink carriers. Except that α amylases influence the coatings on paper. Xylanases, pectinases and lignolytic enzymes have impact on fibre surface. Generaly, in enzymatic deinking there are different approaches available for enzymes: vegetable oil based binders of the printing inks can be hydrolysed, as it was said earlier, the fibre surface can be attacked by enzymes and the starch based coating can be solubilised by enzyme.
Welt and Dinus (1995) investigated the mechanism of enzyme activity. Enzymes can be active in one way or in combination of the following ways: they hydrolyse the cellulose to the water soluble sugars they partly hydrolyse and depolymerise the cellulose molecules on the fibre surface, by which the bonds among the fibres weaken; the bonds among the fibres weaken because of the removal of surface layers; cellulose causes piling on the fibre surface; hemicellulose destroys the complex lignin-cellulose; cellulose fibres are removed by the impact of enzymes on hairy particles which increases the hydrophobic ability of toner. Mechanical activity in defibering is the prerequisite for enzymatic activity.
In this work the prints of digital printing with powder and liquid toner are treated by alkaline chemical and enzymatic deinking process. The relevant optical parameters and the particle size distribution are observed on the handsheet before and after flotation. Parameters which determine deinkability in relation to the toner and substrate characteristics are discussed.
In scientific sense, the investigation results are the contribution to the explanation of the influence of digital printing on the mechanism of the enzymatic deinking. The investigation results application is particularly interesting for the production of the recycled papers in the usage of the waste papers from the digital printing techniques.

2. EXPERIMENTAL

The samples of multicolour prints were obtained by the direct digital Xerox printing (DocuColour 2045 printing machine) with powder toner and digital offset printing with liquid toner (Indigo E-Print 1000+ printing machine). The unique test form was used in printing. The prints were made on the coated and uncoated substrate.
The recycling process of prints is presented schematically in figure 1.

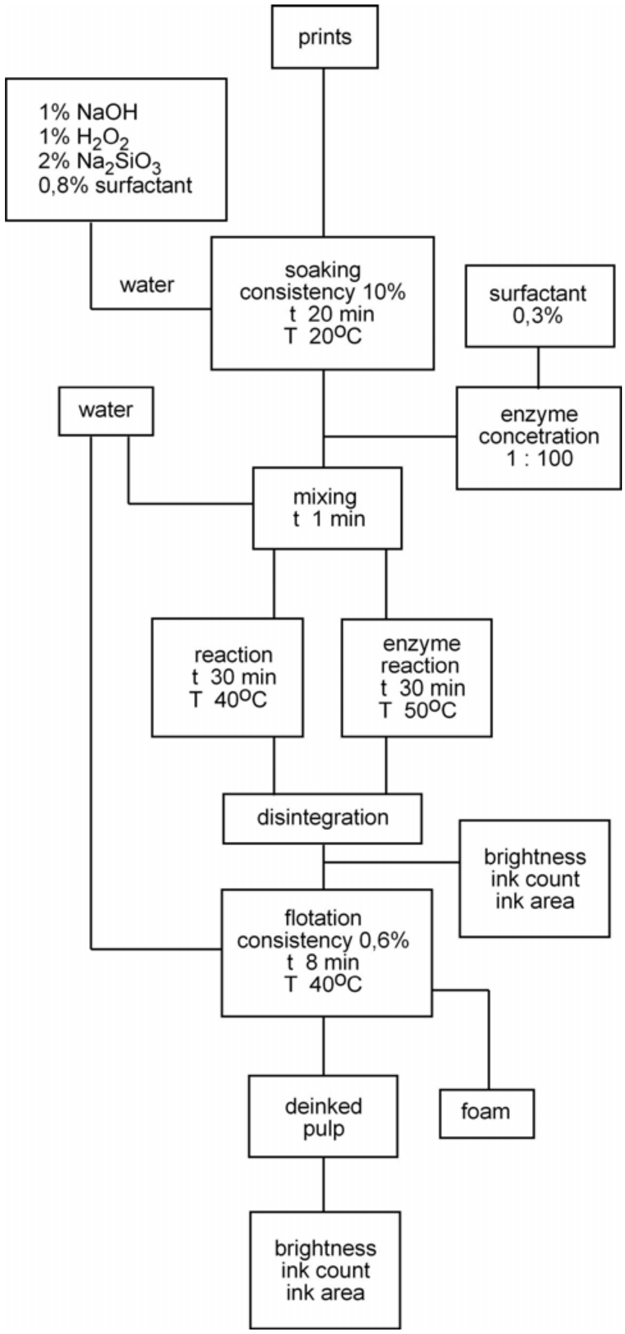


Figure 1 Schematic presentation of the alkaline chemical and enzymatic deinking flotation process

Chemical deinking was performed so that the results could be compared with the efficiency of the enzymatic deinking with the aim of obtaining the recycled fibres which could satisfy the demands in the production of printing papers. The procedure was the same in both cases. In the enzymatic deinking process the following chemicals were used: 2% sodium silicate, 1% sodium hydroxide,1 % hydrogen peroxide, 0,3% DTPA and 0,3% non ionic surfactant. Percentages are on dry weight fibres. In enzymatic process the enzyme was added together with the flotation agent before the disintegration process. In this case the used enzyme is the product of fermentation of the fungi Humicola insolens and the mixture is cellulase and hemicellulase. Before enzyme addition the pH value was measured and adjusted as much as it was necessary. Optimal temperature and pH value for the enzymatic preparation were used in the investigations.

Handsheet was made before and after flotation in accordance with TAPPI standard T 205. The brightness of the handsheet was measured according of ISO standard method.

Image analysis system is useful for recording optical inhomogeneities of the deinked pulp. Dirt particle analysis procedure included: image acquisition, digitalization, image enhancement, segmentation, binary image processing, measurement of dirts and data output.

3. RESULTS AND DISCUSSION

Relevant factors which influence the properties and the look of handsheet made before and after flotation, chosen in the context of impact on cellulose hydrolysis and defined in the frame of experiment are: concentration and the kind of enzymes, concentration of the surfactant and the time of disintegration. The influence of these factors was observed in relation to some optical and mechanical properties of handsheet.

Figure 2 presents the particle size distribution of toner and ElectroInk before flotation

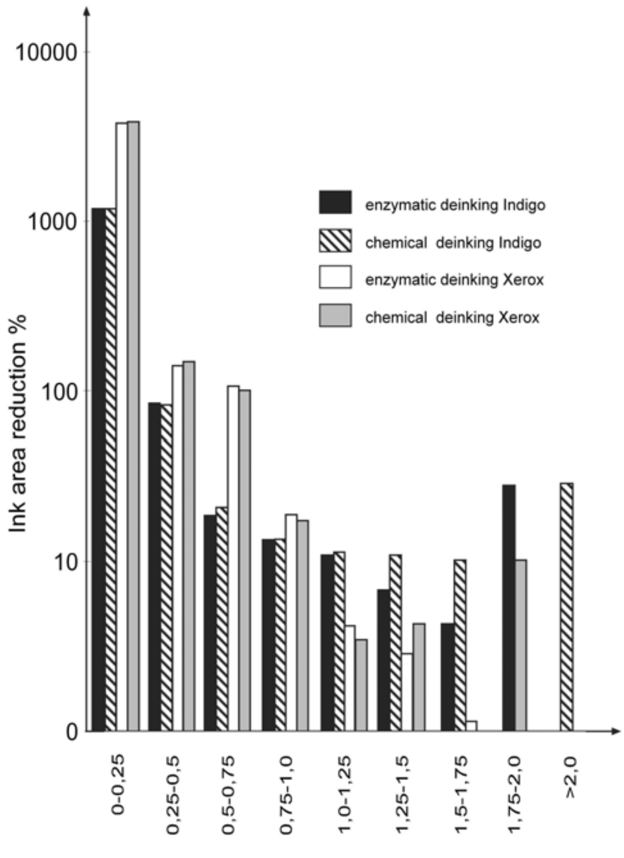


Figure 2. The particle size distribution

As it is visible from the presentation, the process of suspension with the addition of chemicals in one case and in another case with addition of enzymes does not influence much the particle size distribution. In relation to the chemical and enzymatic process the difference is much more striking when two techniques of digital printing are compared together. Handsheet made from deinked pulp from digital offset prints has less number of small particles and greater number of large particles in relation to Xerox.

The obtained results could be explained by some specific characteristics of the mentioned printing techniques. In the Xerox printing process when an invisible latent image from the original is formed the remaining charged spots on the photoconductor will transfer the toner. Now the image is visible. The positively charged toner particles are transferred to the paper in the electric field. The tones is fused onto the paper. The fixing of toner onto the paper occurs with heat and pressure. (Fenton, H. M.; Romano, F. J. 1999.). In drying process ElectroInk is laminated into an ink-plastic film. The ink and film are peeled off the blanket and applied to the paper with the help of the transfer oil. The ElectroInk does not penetrate into the paper.
The influence of the pre-treatment of prints on the efficiency of flotation is presented by the brightness increment in figure 3.

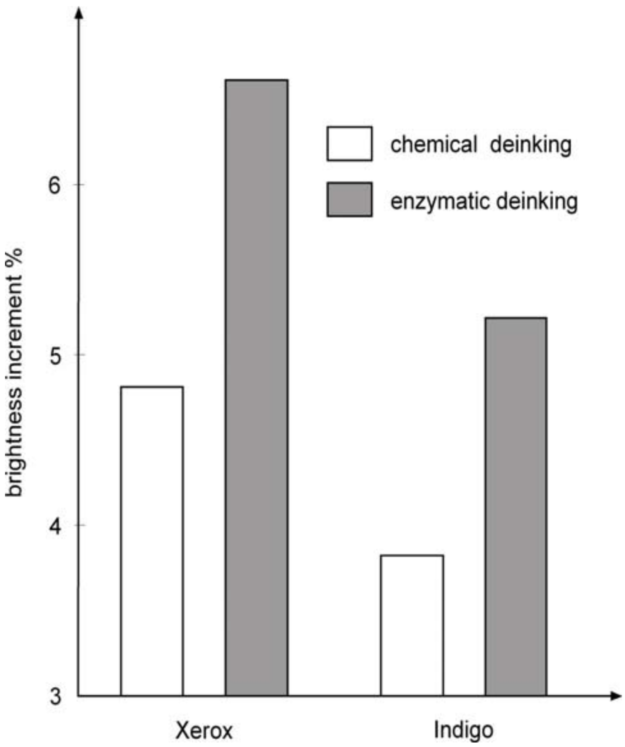
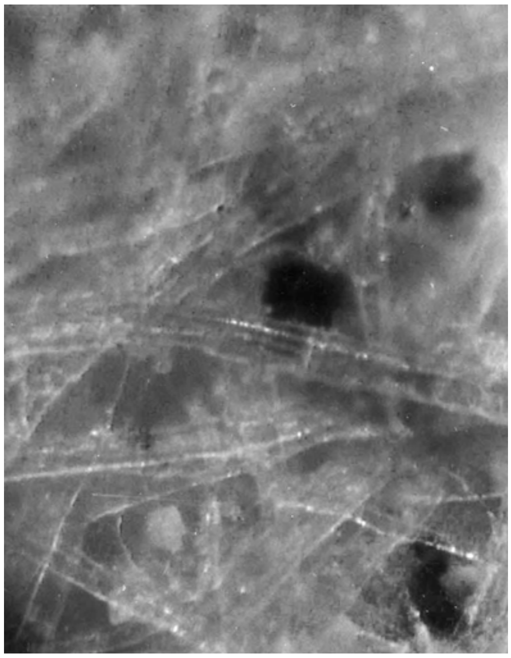


Figure 3 Brightness increment of the recycled fibres

As it is visible from the presentation, greater increment of brightness is achieved by the enzyme usage in the recycling process in relation to the alkaline chemical deinking process. Somewhat greater difference in handsheet brightness before and after flotation is achieved by treatment of prints of Xerox printing in relation to Indigo. Indigo handsheet after flotation has somewhat greater brightness, which can be explained by the fact that the presence of greater particles less influences the mentioned value. On the other hand just the presence of the greater number of bigger particles in such a sample is the reason of its worse flotation knowing that the removal efficiency of particles is the biggest one in the interval from 50 – 150 μm (Thompson B. 1998).
Except the particle size, their shape and surface characteristics influence the efficiency of the flotation process.

Figure 4 presents the toner and ElectroInk particles after the disintegration of prints



a) Xerox

b) Indigo

Figure 4 Toner and ElectroInk particles after disintegration

The shape of the toner and ElectroInk particles as well as the characteristics of their position on the fibres can bee seen in the presentation. The particles are flat, some of them are completely separated from the fibres, which gives them a certain hydrophilic character and which additionally decreases the possibility of good detachment and removal in the flotation process.
Except observing the factors such as brightness and residual ink count, a good valorisation of the influential factors of the system can be obtained by comparison of residual ink area as it is presented in figure 5.

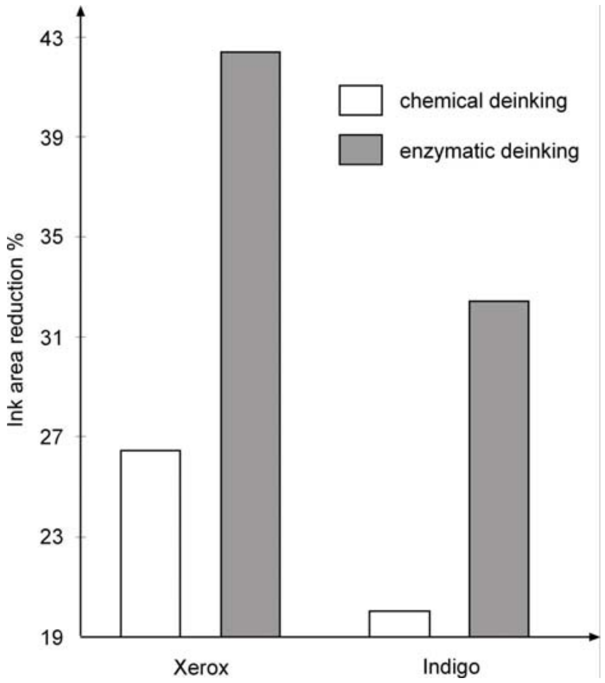


Figure 5 Reduction if residual ink area with flotation

As it is visible from the presentation, the usage of enzymes in pre-treatment increases the particle removal efficiency from 45-55% in relation to the chemical deinking process.. Brightness and ink count reduction by flotation increased while residual ink areas after flotation decreased.
The influence of deinking kinds on some mechanical properties of handsheet is presented in table 1.

Table 1. Mechanical properties of handsheet

	chemical deinking	enzymatic deinking
Tensile index, kNm/g	0.0222	0.0209
Burst index, kPam^2/g	1,11	0,98
Tear index, mNm^2/g	4,78	4,56

Tensile, burst and tear index are insignificantly decreased in handsheet produced after enzymatic deinking flotation in comparison with the chemical deinking process. Generally speaking weaker mechanical properties were noticed in handsheet obtained by the treatment of Indigo prints (table 1). The strength of fibres is not enough to ensure good mechanical properties. Their interconnectedness and interwoven conditions are necessary for that. The weakening of bonds between the fibres has decisive influence on mechanical properties of paper. Residual ElectroInk particles probably disturb the bonds among the fibres by their size and shape more than smaller residual particles of some other printing technique. This can be the reason in this case for worse mechanical properties of handsheet obtained from both processes.

4. CONCLUSION

On the basis of the obtained results one could conclude that by enzymatic deinking of prints of Xerox and digital offset printing the pulp brightness is increased, the toner and ElectroInk removal is facilitated, residual ink area is decreased and a somewhat worse mechanical properties of handsheet are obtained. In the investigations the influence of the principle of the digital printing technique and the characteristics of toner is recognizable.
The obtained results justify the further investigations. The continuation should comprise synergetic effects of different enzymes as well as the study of interactions of enzymes and fibre surface in relation to the substrate composition and the characteristics of the printing technique. The method of experimental design will be used in investigations.

5. REFERENCES

Borchard, J. K. (1997). Ink Types: The Role of Ink in Deinking, In: Paper Recycling Challenge-Deinking & Bleaching, Doschi M.R.; Dyer J. M.; (Ed), pp. 13-17 Doschi & Associates Inc. ISBN 0-9657447-1-X Appleton

Bolanca Z.; Agić D. & Bolanca I. (2000). Influence of the Offset Ink Formulation on the Paper Recycling Efficiency, Proceedings of the 11th International DAAAM Symposium, Katalinic B. (Ed.), pp. 37-39, ISBN 3-901509-29-1, Opatija, October 2000, DAAAM International, Vienna

Bolanca Z.; Bolanca I. & Hladnik A. (2003). The Influence of Digital Printing Conditions on the Characteristic of the Recycled Fiber, Proceedings on 28th EUCEPA Conference, Loureiro A. (Ed.), 356-357, Lisbon, April 2003, Techicelpa, Tomar

Skaar, T. F. (1994). Deinking Flexo Printed ONP in the Flotation Stage, Proceedings on TAPPI Pulping Conference, pp. 885-904, TAPPI Press, Atlanta,

Brochardt, J. K.; Raney, K. H.; Shpakoff, P. G.; Matalamaki. D. W. & Denley, D. R., (1994). Insights into Flexographic Newsprint Deinking: Laboratory and Pilot Scale Deiking Studies, Proceedings on TAPPI Pulping Conference, 1067-1103, TAPPI press, Atlanta,

Hooper, C.; Daneault, C. & Dorris, G. M., (1996), Deinking of New Water Based Gravure Inks, Pulp and Paper Canada, 97 (8), 28-31

Dorris, G. M., Sayegh, N. N., (1994). The Role of Print Thickness and Cohesiveness on Deinking of Toner Printed Papers, Proceedings on TAPPI Pulping Conference, 1273-1289, TAPPI Press, Atlanta,

Marwah, N. (1997). High Efficiency of Magnetic Deinking, In Recycling –A TAPPI Press Anthology of Published Papers, Abubakr S. (Ed.), 633-645, TAPPI Press, ISBN 0-89852-339-7, Atlanta

Scot, W. E.; Gerber, P. (1995). Using Ultrasound to Deink Xerographic Waste, Tappi J. 77(3), 125-130

Rutledge - Cropsey, K., Klungness, J., H., Abubakr S., M. (1998). Performance of Enzymaticaly Deinked Recovered Paper on Paper Machine Runnability , Tappi J. 81(2), 148-152

Prasad, D. Y.; Heitmann J. A.; Joyce T. W., (1992). Enzyme Deinking of Black and White Letterpress Printed Newsprint Waste, Prog. in Paper Recycl.1(3), 21-30

Cropsey, K., Klungness, J. H., Jeffries, T., Sykes, M.S.,(1994) Preliminary Results of Effect of Sizings on Enzyme Enhanced Deinking, Proceedings on. TAPPI Recycling Symposium, 61-65 TAPPI Press, Atlanta,

Welt, T., Dinus, R.J.,(1995) Enzymatic Deinking- A Review, Prog.in Paper Recycl. 4(2) 1995 36-47

Eom T.J & Ow S.S.K.; German Pat.3934772 (1990)

Fenton, H. M.; Romano F. J. (1999). On Demand Printing, GATF, ISBN 0883621940, Chicago

Thompson B.Printing Materials: Science and Technology, 236, Pira International ISBN 1 85802 150 2, Leatherhead

6. ABOUT THE AUTHORS

Ivana Bolanča, Bsc., Faculty of Graphic Arts, Getaldićeva 2, 10000 Zagreb, Croatia, grfibolanca@yahoo.com;
Zdenka Bolanča, Prof. PhD., Faculty of Graphic Arts, Getaldićeva 2, 10000 Zagreb, Croatia, zbolanca@yahoo.com