Review of Patented Electric Field Technology with Application to Non-Impact Printing

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Abstract

Office waste papers with non-impact printing are difficult to deink. It contains dye, pigment, binders dispersed in solvent which was not responding to conventional flotation cell treatment very well. To focus on green and sustainability of printing industry, deinking of recycled paper containing these inks by using patented technology in a flotation cell with anode and cathode is described. The deinking of non-impact printed inks vs. traditional printed inks is reviewed. The deinking efficiency of non-impact printed inks can be improved substantially by introducing an electric field to the conventional flotation process. The electric field exerts a force on the charged ink particles and it also generates fine bubbles due to the electrolysis of water. Electric field could improve the efficiency of convention flotation deinking process in detaching ink from fiber surface and network. This is because physiochemical and hydrodynamic forces do not provide enough detachment force in the flotation process. Using a combined electrolytic and flotation cell has the advantage of removing the ink from both surface and network based on charge difference between ink and fiber.

Introduction

Office waste papers with non-impact printing are difficult to deink. It contains dye, pigment, binders dispersed in solvent which was not responding to conventional flotation cell treatment very well. Collection and Deinking are two major reasons why very little office waste is recycled back into printing and writing paper. Most office paper collected are consumed by tissue, boxboard and more than 2/3 are landfilled in municipal solid waste. The resource required to separate, collect, and grade usable office waste is not adequate to supply larger paper mill production. Also, the technology to deink xerographic toner and laser printed materials is not readily available. The added complication of "sticky" contamination from envelope adhesives, pressure sensitive labels, the document bindings hot melts makes non impact printing office waste difficult to be used.

All non-impact printing methods, including copier machines and laser printers, are using dry ink plastic toners. This dry fine powder is coloured thermoplastic polymer based on pigment. Electronic charges triggered by light are used to transfer the dry ink to paper. The light used include visible, ultraviolet light and laser. The plastic toners are permanently fused to paper by heat, which is very difficult to be removed by conventional chemical and flotation method. Less than 10 micron in size, fused through high temperature melt, wetting and adhere to the pulp. They will not float nor sink because of large number of fibers are sticked together. Combined flotation and washing procedures are used to deink the toner, but additional multiple cleaning and screening stages are required, which contributes to weak quality and low yield recycled pulp. Poor deinking efficiency from the chemical and energy costs plus lower yield makes the process too expensive to be considered practical. The left over toner particles can contribute to holes or dirt count in deinked paper. The substantial amount of deinked pulp containing toner is becoming unusable and rejected to produce sludge. This will create solid waste landfill problem down the road.

A survery of the various deinkability behaviours of digital prints [1] pointed out that the deinkablility of several digital prints could turn out to become a threat for paper recycling systems. The resulting prints are not only undeinkable and it will spoil the deinkability of the whole mixture with 10% content.

Effort was made to deink non-impact printed paper [2]. Deinking of impact and nonimpact printed paper is accomplished by repulping and defibering the printed paper in an alkali aqueous medium containing a deinking chemical to form an ink pulp medium. The presence of the deinking chemical causes separation of ink particles from the printed paper fibers. Removal of the ink particles from the ink pulp medium is accomplished by screening, flotation, forward cleaning, reverse cleaning, washing and mechanical dispersion procedures to produce a substantially ink free pulp medium. This substantially ink free pulp medium has a speck removal and brightness level sufficient to produce a high-grade recyclable grade paper product. The invention provides a deinking composition comprised of a mixture of one or more solvents, and nonionic and anionic surfactants, capable of high ink removal from all types of impact and nonimpact printed paper.

The mixed office waste (MOW) portion of presently under-utilized mixed recovered paper grade contains more than 70% uncoated free sheet, mainly printed with difficult-to-deink toners [3]. Both the cost and difficulty of removing toners from MOW have limited upgrading MOV into printing and writing grades. This paper presents the results of an industrial-scale investigation exploring the benefits of enzyme-enhanced deinking. Since residual toner inks are the primary contaminant remaining in deinked marked pulp, 100% laser-printed white office postconsumer waste was used for these trials. The results of three deinking trials-two enzyme trials and a control-are presented. The control was similar to the enzyme trials with the exception that a heat-killed enzyme preparation was substituted for the active enzyme. Results showed increased ink removal is achieved at a low level of a commercially available enzyme preparation in combination with a surfactant. The enzyme-enhanced trials also displayed improved drainage and comparable strength when compared with the control. There were no significant differences in the quality and treatability of the process water from the various trials. Effluent samples from these trials were lower in oxygen demand and toxicity than effluents from the control.

Recycling of office waste paper (photocopy, inkjet and laser prints) is a major problem due to difficulty in removal of non-impact ink [4]. Biological deinking of office waste paper is reported using several microorganisms and their enzymes. We report here deinking and decolorization of the dislodged ink particles from inkjet printed paper pulp by a marine bacterium Vibrio alginolyticus, isolate # NIO/DI/32 obtained from marine sediments. Decolorization of this pulp was achieved within 72 h by growing the bacterium in the pulp of 3-6 % consistency suspended in sea water. Immobilized bacterial cells in sodium alginate beads also were able to decolorize this pulp within 72 h. The cell-free culture supernatant of the bacterium grown in nutrient broth was not effective in deinking. However, when the culture was grown in nutrient broth supplemented with starch or Tween 80, the cell-free culture supernatant could effectively deink and decolorize inkjetprinted paper pulp within 72 h at 30oC. The culture supernatant of V. alginolyticus grown in the presence of starch or Tween 80 showed 49 and 33 U ml-1 amylase and lipase activities respectively. Dialysis of these culture supernatants through10 kDa cut-off membrane resulted in a 35-40% reduction in their efficiency in decolorizing the pulp. It appears that amylase and lipase effectively help in dislodging the ink particles from the inkjet printed-paper pulp. We hypothesize that the bacterium might be inducing formation of low molecular weight free radicals in the culture medium, which might be responsible for decolorization of the pulp.

A method for the deinking of recycled fibers, in which the macerated fibers are slurried with water [5]; introduced to a deinking cell which has a central anode and a perimetal cathode; subjected to a direct current electric field applied between the anode and the cathode, causing the ink to be attracted away from the fibers and to electrocoagulate the ink then floating to the surface of the slurry with the aid of gas bubbles generated during the application of the electric field and washed to recover a cleaner, brighter pulp of recycled fibers.

Preliminary experiments suggest that electric field could enhance the efficiency of convention flotation deinking process in detaching ink from fiber surface and network [6]. This is because physiochemical and hydrodynamic forces do not provide enough detachment force in the flotation process. Using a combined electrolytic and flotation cell has the advantage of removing the ink from both surface and network based on charge difference between ink and fiber. We study the mechanism of interaction among aforementioned forces on the ink detachment. The electric field doubled the brightness gain of flotation deinking process.

Inkjet printing is one of the simplest digital printing methods and is a non-impact printing technology that does not require an intermediate carrier as in electrophotography [7]. The ink is usually liquid and is transferred directly onto the paper slowly. As far as the deinkability of the ink jet printing, it is mainly composed of dyes, which were not float and not entirely washed during deinking. In order to remove the resulting color, bleaching treatments had to be performed on this water based inks. Now the introduction of pigments in the formulation of waterbased ink-jet as substitutes to dyes. It is changing from black ink pigment to coloured ink pigment. The small size pigrment particles in water based ink-jet is similar to flexographic inks from newsprint. Their removal by flotation is very poor because some inks are irreversibly redeposited into fibers, which can only improved by hypo-washing.

Experiments

Flotation Deinking

Ink removal from recycled fiber is called deinking. There are two types of deinking, washing and flotation. Flotation deinking involves the following simple steps, first the recycle paper (e.g. non-impact digital printing) is soaked in water and deinking chemicals are added, thereafter the paper is pulped to dislodge ink from the paper, the air bubbles are introduce to stock to remove dislodge ink. The air bubbles and ink mixtures accumulates as froth.

Smaller ink particles however are difficult to de-ink, because of ink re-deposition and entrapment in the paper fiber matrix [8]. Electric field energy can be introduced as an alternative source of energy to aid in ink removal.

By introducing electric field to the conventional flotation process the ink particle removal efficiency can be improved. (See figure 1) Ink particle are considered charge particle. The electric field force would exert an electric force on the charge ink particle in a process called electrophoresis.

Electric Field Technology

Electric field technology has been used in electrostatic precipitator. Electrostatic precipitators are composed of two sections, a charging and a collection section. The charging section uses ionizer to impart a positive charge to the incoming smoke or dust particles. The charge particles are then drawn into a secondary electric field where they are collected on oppositely charged metal plates.

An analogy could be drawn between electric field precipitator and the use of electric field in flotation deinking. In deinking, the medium is water, air and solid fiber. When electric field is applied across the anode and cathode, the charged ink particles in the fiber matrix begin to migrate.

There are three mechanisms by which ink is removed to the froth when electric field is incorporated into deinking.

1. The electric field force yanks the charged ink particles from the interstitial regions of the fiber matrix, these loose ink are easily intercepted by rising dissolved air bubble and taken to the froth

2. Finer bubbles than regular dissolved air bubbles which regenerated by electrolysis of water can reach ink particles embedded in the fiber matrix where regular bubbles cannot reach [5,9]. Once the fine bubbles are attached to the ink, the fine bubble and ink agglomerate can migrate to the outer regions of the fiber matrix where they can be attached to dissolve air bubble.

3. Fine ink particles which cannot attach to dissolved air bubble because of hydrodynamic limitation can attached to the fine bubble [10]. The fine ink particle-fine bubble agglomerate then attaches to the dissolve air bubbles.

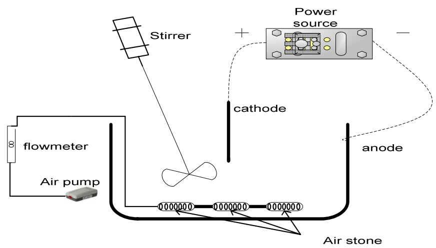

Figure 1. *A Schematic of Batch Electric Field System*

Results and Discussion

A presoaking step and stage can be added to the deinking method and apparatus to initiate the loosening and dislodging of the ink particles from the fibers. Typically, the pulp is presoaked for approximately ten minutes at approximately room temperature, 20" C.-55"C., and atmospheric pressure. The pulp is kept at approximately 7% consistency and may contain approximately 1%-3%, and preferably 2.5%, sodium hydroxide and approximately 0.5%-I%, fiber. Although many different surfactants are acceptable, ethoxylate surfactants are acceptable and found to give adequate results. After presoaking, the pulp is disintegrated using a conventional disintegrator means. A first disintegration takes place for approximately twenty (20) minutes at approximately 7% pulp consistency. After the first disintegration stage, the pulp is subjected to a flotation stage at approximately 1% consistency for approximately 10 minutes to remove the bulk ink products. The pulp is then subjected to a second disintegration stage for approximately 10 minutes also at approximately consistency. After the second disintegration stage, the pulp is subjected to the instant deinking process. For this particular set up, the pulp is deinked at approximately 1% consistency for approximately 10 minutes. Subsequent to deinking, the pulp is washed and further processed. The main purpose of this method and apparatus is to provide adequate process and equipment designs for more efficient continuous deinking process. The method and apparatus are designed to accommodate a DC electric field application in the deinking cells and to provide adequate but economical electrode area. Additionally, it is desirable to minimize the anode area so as to keep the cost of the anode material low. The present method and apparatus facilitate an easy and continuous removal of the ink from the pulp and the removed ink from the deinking system. The instant method and apparatus is suitable for retrofitting to existing mills and also for use as a new installation. The pulp resulting from the intant method and apparatus is superior to the pulp obtained from the prior art methods and apparatuses. The following tables show the superior characteristics of the pulp obtained from the present invention. Table 1 gives values for the brightness, Table 2 gives values for the ink speck count, Table 3 gives values for the tear index, Table 4 gives values for the tensile index, and Table 5 gives results for the burst index of paper produced from the pulp deinked by the present method and apparatus.

TABLE 1

GE Brightness

Waste Type	GE Brightness Increase (Points)
Old Newsprint (ONP)	2–3
Old Directory yellow pages	3–6
Old Catalog	
Offset printing	4–6
Gravure printing	2–3

TABLE 2

Visual Count of Specks

Waste Type	Number of Specks Per Handsheet: Control	GT	% Change
Old Newsprint	36	26	28
Old Directory			
Yellow Pages	24	18	25
White Pages	21	18	14
Old Catalog	42	23	45
Office Waste	62	8	87

TABLE 3

Tear Index ($mN\text{-}m^2/g$)

Waste Type	Control	GT
Old Newsprint	6.9	6.5
Old Directory		
Yellow Pages	6.5	7.5
White Pages	6.1	7.2
Old Catalog	9.9	10.9
Office Waste	6.5	6.8

TABLE 4

Tensile Index (N-m/g)

Waste Type	Control	GT
Old Newsprint	30.1	30.0
Old Directory		
Yellow Pages	32.8	37.7
White Pages	37.9	38.8
Old Catalog	48.6	47.0
Office Waste	29.9	34.0

TABLE 5

Burst Index ($kPa\text{-}m^2/g$)

Waste Type	Control	GT
Old Newsprint	1.5	1.4
Old Directory		
Yellow Pages	1.4	1.9
White Pages	1.9	1.6
Old Catalog	2.5	2.5
Office Waste	1.6	1.7

The present method and apparatus, by utilizing less chemicals and mechanical steps, also is more economical. A reduction in the chemical consumption of the deinking process by using the present method and apparatus. As can be seen, the fewer chemicals used, the brighter the resulting paper over the control paper. Additionally, paper produced from recycled pulp deinked by the present method and apparatus shows a significant improvement in brightness and ink removal over prior art. The brightness increases are indicated in Table 6.

TABLE 6

	Brightness Values			
	Prior to DC Field	After DC Field	Change	% Increase
Krodel				
Control 1	46.0	46.2	0.2	0.435
Control 2	50.9	51.8	0.9	1.77
Present				
Control 1	54.0	55.6	1.6	2.96
Control 2	53.2	55.2	2.0	3.76

Conclusion

We demonstrated experimentally that deinking of office waste with non-impact printing can be improved when electric field is incorporated into flotation deinking. The greater amount of ink dirt removed, the greater brightness gain and the greater ERIC reduction support the claim that electric field technology helps to improve deinking. However, deinking of the inkjet printing is much more complicated. The dye has to be bleached white from the fiber and the pigmented ink can be handled like small particle flexographic ink. Electric field deinking technology had success in removing water based hydrophilic flexographic ink from paper. Future study is needed to further investigate the deinking of non-impact ink jet printing by taking advantage of this emerging technology.

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