CHEMICAL ENGINEERING RESEARCH AND DESIGN 90 (2012) 1045–1051

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

Deinking in bubble column and airlift reactors: Influence of wastewater of Merox unit as pulping liquor

*J. Behin**

Department of Chemical Engineering, Faculty of Engineering, Razi University, Baghe Abrisham, Kermanshah, Iran

ABSTRACT

Deinking efficiency of recycled fibers was investigated in bubble column reactor (BCR) and in internal loop airlift reactor (ALR). The brightness and intensity of ink spot of deinked fibers were reported as deinking efficiencies. A four-step process involving pulping, washing, flotation, and secondary washing was used. Employing ALR instead of BCR resulted in an increase of 1–4% in brightness, and a decrease of 3–14% in number of ink spot. Subsequently, in separate experiment the wastewater obtained from a Merox unit was used in pulping step instead of sodium hydroxide solution as pulping liquor. Compared to sodium hydroxide, industrial wastewater rendered more brightness gain. Comparison of both experiments suggests that using industrial wastewater in the pulping step and ALR in flotation step gives satisfactory results for industrial applications, yields a quality product with reduced capital investment and operation costs while considerably preserving the environment.

Keywords: Airlift reactor; Bubble column reactor; Flotation deinking; Paper recycling; Wastewater

1. Introduction

The deinking of fibers is an important stage in wastepaper recycling. Flotation deinking is one of the principal deinking systems adopted by the paper industry (Ecomonides et al., 1998; Julian Saint Amand, 1999; Theander and Pugh, 2004; Zhu et al., 2005; Beneventi et al., 2006; Cho et al., 2009). Prior to flotation step, pulping is carried out where the ink is initially detached from the fibers. The detachment of the printing ink from the fibers of the disintegrated recycled pulp needs a combination of chemical and mechanical conditions (Borchardt, 1993; van de Ven et al., 2001). Due to the influence of the surface active chemicals (e.g. NaOH, H_2O_2, and chelating agent) and the mechanical shear forces in the pulper, ink particles of different sizes are released to the aqueous phase. The brightness of recovered paper is about 40–45% ISO after pulping (Lassus, 2000). Flotation, the most common method used, provides a high yield of fibers, i.e. a low amount of rejects, and less effort to purify the white water produced. It is a selective separation method using the different surface properties of particles. Air is introduced into a diluted fiber suspension of low consistency. Consistency defined as the mass in grams of oven-dry fiber in 100 g of pulp–water mixture. The water-repelling ink particles attach to the air bubbles and rise to the surface. The hydrophilic fibers remain in the water phase. The froth that contains the ink particles can be removed mechanically, by overflow (McKinney, 1995; Renner, 2000). Flotation deinking is usually more effective in removing large particles (10–100 μm) from newsprints (Julian Saint Amand, 1999; Johansson et al., 2000; Theander and Pugh, 2004). Many researchers described the factors that affect flotation deinking. They recommended optimum values of consistency 0.5–2%, temperature 40–55 °C, pH 8–11, water hardness 110–130 ppm Ca^{2+}, sodium hydroxide 0.25–1.0%, hydrogen peroxide 0.5–1.0%, and soap 0.25–1.0 wt% based on dry newspaper (Borchardt, 1993; McKinney, 1995; Ecomonides et al., 1998; van de Ven et al., 2001; Lassus, 2000).

Some conventional mechanical flotation devices used in the deinking of wastepaper are simple stirred tank reactors with air bubbles sparged continuously into the recycled pulp slurry. In the recent past, the use of column flotation as an effective technology for the deinking of wastepaper has been suggested. Column flotation is a novel technology being introduced into the mineral processing industry since it offers significant cost and process advantages over conventional flotation cells. Among the benefits of column flotation are a

* Tel.: +98 831 8250167; fax: +98 831 8250167.
E-mail addresses: Behin@razi.ac.ir, Jamshid_Behin@yahoo.com
Received 12 April 2011; Received in revised form 8 October 2011; Accepted 30 October 2011
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doi:10.1016/j.cherd.2011.10.021

Nomenclature

A_d	downcomer cross-sectional area (m^2)
A_r	riser cross-sectional area (m^2)
C	normalized dimensionless concentration of tracer
C_{final}	final concentration of tracer ($mol\,cm^{-3}$)
$C_{initial}$	initial concentration of tracer ($mol\,cm^{-3}$)
$C_{instantaneous}$	instantaneous concentration of tracer ($mol\,cm^{-3}$)
t_m	liquid mixing time (s)
U_g	superficial gas velocity ($cm\,s^{-1}$)

simpler mechanical design, higher selectivity, less floor space requirement, reduced capital cost and reduced operating and maintenance costs. It has been reported that the operating cost can be reduced by up to 80% compared to conventional cells. Furthermore, power savings result since agitator requirements are eliminated and savings in reagent consumption of up to 30% have also been reported (Dessureault et al., 1974; Gomez et al., 1994; Chaiarrekij et al., 2000). Among pneumatically agitated reactors, the bubble column reactor (BCR) and airlift loop reactor (ALR) are more attractive compared to others as the gas phase serves the dual function of aeration and agitation. Bubble columns are multiphase reactors in which a gas phase is dispersed in form of small bubbles into a continuous liquid phase. An internal loop airlift reactor (IL-ALR) is a simple bubble column divided into four distinct sections by an internal draft tube: riser, downcomer, top and bottom. The fluid circulates along a well defined path: up-flow in the riser, down-flow in the downcomer (Lu and Hwang, 1994; Muthukumar and Velan, 2005; Lin and Chen, 2005; Kantarci et al., 2005; Zhang et al., 2005; Gourich et al., 2008).

Chaiarrekij et al. (2000) investigated the applicability of a new flotation cell based on a column without an agitator present to accomplish the deinking of typical wastepaper feedstocks. The flotation column volume was 10 l, operated with pulp consistency of 0.8% at temperature of 40 °C. Air flow rate was variable between 6 and 8 l min^{-1}. The brightness of handsheets made from deinked pulps for time intervals of up to 15 min showed an improvement of approximately 5.5 points in brightness. They concluded that it is possible to achieve typical deinking performance using the flotation column in a similar manner to conventional agitated cells. They found that the agitator can be eliminated by using the column flotation design which could yield significant electrical energy savings in addition to savings in capital costs and other operational and maintenance costs.

Pala et al. (2004) examined enzymatic versus chemical deinking for mixed office waste and photocopy prints. Several enzymatic preparations and two fiber/ink particle separation methods tested. The flotation device was based on an airlift reactor, operated with 4.5 l of sludge (0.6% consistency) for 20 min at room temperature and air flow rate of 1.14 l min^{-1}. It was observed that the airlift reactor removed ink more efficiently, and furthermore it allowed a more controlled and reproducible flotation, and a lower fiber loss.

2. Our approach to flotation deinking

The first objective of this work was to investigate the effect of using internal loop airlift reactor in flotation step on deinking efficiency, as well as to compare the results with bubble column reactor. The second objective was to produce deinked pulp by using the wastewater of the Merox unit (refinery spent caustic) instead of sodium hydroxide solution. One of the important units of the refining oil company, Merox, desulfurizes thousands of barrels of light gasoline daily. It removes the sulfur-containing components, such as mercaptans (organic sulfur compounds), hydrogen sulfide, and thiophenol, from light gasoline with a sodium hydroxide solution (caustic) in a reactive liquid–liquid extraction column. In the extraction column, the caustic soda solution converts mercaptans into sodium mercaptides (R-SNa) that is regenerated by aeration (oxidizing) in the regeneration column. When the concentration of the caustic soda solution in the closed loop decreases to about 2%, the solution with the produced disulfide (R–S–S–R) and other sulfur-containing components is withdrawn as wastewater (waste oil–disulfide mixture). This wastewater has strong and repulsive odors and is sent to the wastewater treatment unit, where it is finally disposed of in a pond. The treatment of this wastewater is the biggest concern from an environmental point of view. This approach is an environmentally friendly and cost effective process with the advantages of using wastepaper, as well as using the Merox unit waste.

3. Experimental methods

Among the different wastepapers available in Iran, newspaper "JOMHURI" with Ortho Printing black ink (11201133.NG20 & B/N = T50611727) was chosen. Four-step process involving pulping, washing, froth flotation, and secondary washing was employed.

3.1. *Pulping*

Recovered paper was disintegrated in water-based solution at a consistency of 7%. Recommended consistency is 5–18% depending on the type of pulper used (Chaiarrekij et al., 2000; Pala et al., 2004; Costa and Rubio, 2005; Zhu et al., 2005; Beneventi et al., 2006). 25 g of dry paper was added to a 14 speed Blendmaster (Hamilton Beach, USA) blender which served as the pulper. The principal chemicals used in the pulper were sodium hydroxide and hydrogen peroxide. The contents including different chemicals were pulped together for a total of 5 min in blender. The water temperature (40–45 °C) did not change appreciably during pulping, even though there was no heating element connected to the blender. The pH was adjusted to about 9–10 with NaOH in this step (Chaiarrekij et al., 2000; Costa and Rubio, 2005). Pulp obtained from pulping step was subjected to one washing step with 1 l tap water to eliminate residual chemical and ink separated from fibers.

3.2. *Flotation*

Flotation device was based on a bubble column reactor or an internal loop airlift reactor. The bubble column reactor consists of a glass cylindrical column 11 cm in internal diameter and 50 cm in height as shown in Fig. 1a. The internal loop airlift reactor consists of a glass cylindrical column identical to bubble column reactor with a concentric draft tube of 6.8 cm in internal diameter and 40 cm in height as shown in Fig. 1b. A vertical space of 5 cm was provided between the bottom of the column and the draft tube to allow pulp circulation. The riser to downcomer cross-sectional area ratio (A_r/A_d) was chosen