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Statistical experimental design of a novel deinking reactor based on centrifugal force under electric field concept

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ABSTRACT

The aim of this research was to study a new invention concept of ink removal processes by a combined effect of centrifugal force and electrical force. After deinking treatment with different voltage conditions, the effective residual ink concentration (ERIC) index from the test samples were lower than the operation without voltage input, indicating the applied electric force promotes deinking. With a certain operating time and ink coverage, the percentage weight loss of the pulp yield after deinking treatment has been lower by applying electrostatic force. From an analysis of variance (ANOVA), the optimum point of the process was obtained with low ink coverage of used paper, medium operating time and high voltage supply. This novel electrostatic separation is proved to be an effective method for paper recycling process since it has no chemical usage; thus, no requirement for further chemical separation.

1. Introduction

In the early 21st century, the demand for paper in Thailand had been decreasing slightly from 3.56 to 3.38 million metric tons due to the role of electronic media. Until the year of 2009 to 2012, the demand for paper or writing material began to rise to 4.24 million metric tons and tend to increase continuously (The Thai Pulp and Paper Industries Association, n.d.). On the other hand, while the paper supply was increasing, the amount of paper waste would also mount up. The recycling of waste paper would be the leading role to diminish environmental pollution since recycling could reduce forest destruction and also give less water and air pollution than making virgin paper (Recycle on the Go, n.d.; Petzold & Schwarz, 2015).

In conventional paper recycling process, the waste paper was converted into small pulp in a large vessel called pulper and passed through separation processes to remove ink, plastics and other contaminants. Miscellaneous contaminants such as staples, paper clips, plastics, etc. could be eliminated by simple separation process on the basis of size or density. However, the homogenous contaminants like print toner, inks, and dyes require certain techniques to obtain the high purity pulp and yield (Petzold & Schwarz, 2015; Misman et al., 2008; Lee et al., 2013). Sometimes the process needed both recycled and virgin fiber depending on which type of paper is being produced. The important part of the recycling process is therefore the deinking. Froth flotation are often used for deinking, in which chemicals such as sodium hydroxide, sodium silicate, soap, hydrogen peroxide and calcium chloride are added (Beneventi et al., 2006; Rahman et al., 2012). After the froth flotation, the process requires further treatment due to a lot of chemical usage, which would have an effect on the environment (Körkkö et al., 2008). In addition, the limitation of conventional paper recycling process was the energy consumption that is sometimes higher in operating costs than virgin paper (Vashisth et al., 2011; Lou et al., 2012). An alternative deinking process is thus required.

Currently, there are interesting studies on deinking process including chemical processes, biotechnological processes and mechanical processes. The ink removal by chemical processes has been introduced as shown in Petzold's study using polymer particle as the adsorbent

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(Petzold & Schwarz, 2015). The advantage of adsorption processes is the used particle can be regenerated by washing with a surfactant solution. The ink removal by biotechnological processes, which apply enzymes to the process, has been highly performed recently as shown in many literatures such as decolorizing and deinking flexographic inks using laccase-mediator (Fillat et al., 2012; Fillat et al., 2015), deinking of various types of wasted paper using cellulase and hemicellulose enzyme (Lee et al., 2013), and ink removal from school waste paper using xylano-pectinolytic enzymes (Singh et al., 2012). Ink removal by mechanical processes can remove ink particles from the pulp by suitable physical means and avoid chemical usage such as adhesion technique in Minolta's patent, which applied the recycled paper into a curvature instrument to detach the bonds between the fibers and ink particles by shear forces (Taniguchi & Yoshie, 2000). Westvaco Corporation's patent shared another alternative way to deinking which claimed to produce high quality pulp by subjecting a slurry of the fibers and magnetic carrier to a magnetic field (Mahwah & Allen, 1996). Some patents which could increase the capacity of the process suggested to apply the adhesive to the geometric apparatus to press against the printed paper continuously (Saitoh et al., 2000). These mechanical processes have some limitations about pulp purity and yield. However, the processes that could operate without the need of chemicals provide lower environmental pollution and may, in some cases, have lower total energy consumptions. Though chemical and biochemical processes that seem to utilize lower power, they require additional processes such as waste treatment, solvent separation and even the power requirements along the upstream chemical production. Therefore, a mechanical deinking using an ink removal reactor by a combination of cutting and centrifuge in electrical field is investigated in this study, as an alternative model to handle those observed limitations.

2. Materials and methods

2.1. Preparation of used paper

The used paper samples were prepared by printing black boxes, using a laser printer on plain A4 paper, with 10, 20 and 30% ink coverage.

2.2. Novel ink removal reactor design

Fig. 1 shows the design of the novel reactor, which includes two main parts: a dust collector and a blender for chopping paper into small pieces and extracting ink particles from paper surface. The blender section was the 500 mL volume with a copper plate, as an electrode, attached under the blender blade. The second part, the dust collector, was connected to the blender lid of the first part. This part was made of a circle ring and cylindrical acrylic fused to an opera hat shape. At the top of this part, the square acrylic plate was drilled four holes for four long bolts and five holes for air exits. The bolts were hanging down from the top plate. One side of the four bolts was attached to the holes at the corners of the acrylic and the bolt heads were attached to the copper plate as the other electrode. The other holes were left for air outflow. These outlets were necessary to prevent overpressure since there was air feeding at the bottom of the reactor. Besides, a sieve was attached to this part by wrapping around the bolts to reduce particle loss. The air blower was used to generate flow for separating pulps and ink particles, whilst helping to cool down the reactor during the process. After mounting all parts, an electric field was supplied to the reactor by connecting the cathode (negative electrode) to the top copper plate electrode and the anode (positive electrode) to the bottom copper

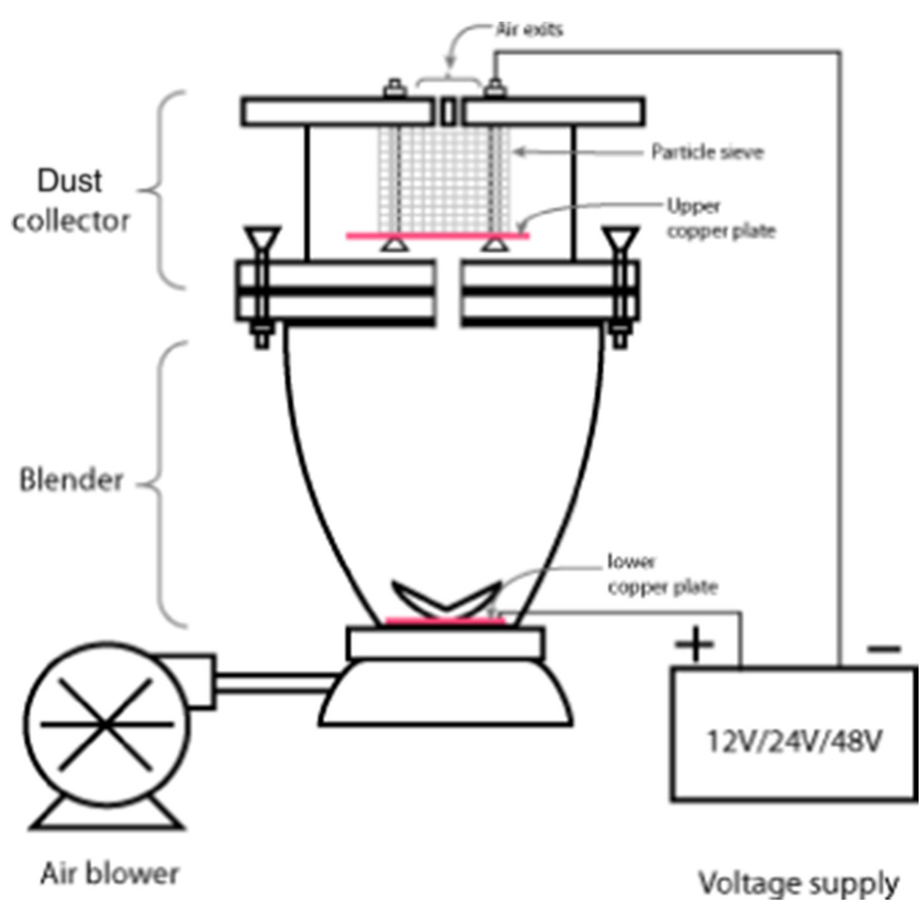

Fig. 1. Model of ink removal reactor by centrifugal force in electrical field.