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High-energy electron irradiation of annual plants (bagasse) for an efficient production of chemi-mechanical pulp fibers

Shailesh Pathak [a,*], A.K. Ray [a], Harald Großmann [b], Rene Kleinert [b]

[a] Department of Paper Technology, IIT Roorkee Saharanpur Campus, Saharanpur 247001, UP, India
[b] Institut für Holz und Papiertechnik, Technische Universität Dresden, Germany

HIGHLIGHTS

- The energy savings potential of bagasse chemi-mechanical pulp after irradiation pretreatment was studied.
- The effects of high energy electron irradiation pre-treatment on bagasse were determined.
- Irradiation pretreatment has the potential for reducing specific energy consumption.
- More than 50% energy saving potential of bagasse after irradiation pre-treatment was achieved.

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ABSTRACT

The paper industry is one of the largest consumers of energy and energy consumption has been increased several times in last few decades. Bagasse chemical pulping has very low yield about 45–55% and also generates high pollution load in the effluent as compared to mechanical pulping, e.g. thermo-mechanical pulp (TMP). On the other hand, the specific energy consumption is very high for TMP pulps. ETMP (Energy efficient Thermo-Mechanical Pulping) or ECTMP (Energy efficient Chemi-Thermo Mechanical Pulping) is an innovative idea for reducing the energy demand in TMP refining. In the present investigation, energy efficient mechanical pulping potential of bagasse was studied using TMP, CTMP and ECTMP pulping methodology with electron irradiation pretreatment. It is evident from the results that more than 50% energy saving potential of irradiation pre-treatment was achieved.

1. Introduction

In India about 5.8 million tonnes of wood is required for production of paper every year, which results in an increase in deforestation. So it is necessary to search other raw materials for paper making, such as agro-residues. Sugar industries are agro-based industries and produce bagasse in large quantity which will be available in large quantity for paper production (Rajesh and Rao Mohan, 1998). Bagasse fiber resembles hardwood in terms of fiber characteristics (Roger et al., 1997). The literature shows bagasse has the cell wall thickness of approximately 8.4 μm that makes it flexible, ability to collapse and to form inter fiber bonding easily (Marcela et al., 2014). Conventional methods of bagasse pulping are resulting in high pollution load in effluent and very low yield (Adriaanse and Morsink, 2007; Carrasco et al., 1992). This requires the search for new pulping methodology for higher yield, lower pollution load and energy consumption.

Thermo-mechanical pulping is a better option for increasing pulp yield, but has higher energy consumption. Mechanical pulp as an admixture with chemical pulp is very suitable for writing and printing paper due to its high opacity. Bagasse TMP (Thermo-mechanical pulping) fibers have very low strength properties and high CSF (Canadian Standard Freeness) value, but it can be used in furnishing to increase the bulk and bending stiffness of various grades of paper such as newsprint, folding boxboard and etc. An additional chemical pretreatment, so called CTMP (Chemi–thermo-mechanical pulping), results in increasing longer fiber portion in pulp while simultaneously decreasing shives & fines content.

The concept of electron irradiation is introduced to reduce the specific energy consumption in TMP (Thermo-mechanical pulping). ETMP (Energy efficient Thermo-Mechanical Pulping) or ECTMP (Energy efficient Chemi-Thermo Mechanical Pulping) is an innovative idea for reducing the energy demand in TMP refining. It has been investigated that the electron pre-treatment of fibers for paper making have been used with wood chips. High energy electron irradiation pre-treatment of wood chips such as spruce,

* Corresponding author.
E-mail address: shaileshpathak2009@gmail.com (S. Pathak).

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pines has been proven to enhance the yield and to reduce energy consumption. It has been found that the irradiation can modify the lignin, cellulose and hemicellulose structure (David Free, 1974). It has been found that the irradiation of wood chips with irradiation dose of 30 kGy significantly exceeds the chemical bonding energy and the ionization potential of molecules while saving 30% energy in TMP refining (Handke et al., 2011; Gailat et al., 2011).

2. Material and methods

Depithed Iranian bagasse was collected from University of Humberg Germany. 1.40 kg of bagasse sample was irradiated with electron irradiation facility TT 300 accelerator operated by Synergy Health Radeberg GmbH, Germany. This device is capable of accelerating electrons up to 10 MeV. The bagasse was supplied in batches on trays and was irradiated continuously at 15 and 30 kGy in the irradiation zone. Alanine dosimetry is used to measure the irradiation during the operation batch wise. The optimum energy consumption of electron beam irradiation under conditions of continuous supply for wood chips was found of the order of 60 kWh/t for 30 kGy irradiation dose (Bäurich et al., 2012).

Irradiated bagasse was soaked for 24 h to reduce the dust content because initial bagasse sample had 91% dry content which causes easier temperature rise during steaming stage and prevent burning of fiber during defibration. After 24 h soaking, soaked bagasse was dewatered to approximately 30–40% dryness. This bagasse was impregnated with 5% SO_2 bisulfite solution. Bagasse sample in a bag is dipped into the bisulfite solution for 5 min in order to impregnate the bagasse. It has been seen that the effect of impregnating more than 5 min had not produced much effect (Sundholm and Yhdistys, 1999). After dipping, the filled bag was taken out from the solution and pressed against the hand or by hanging for few minutes to remove the excess solution from the bagasse which now had 18–22% dry content.

Finally, thermo mechanical refining was carried out and hand sheets were made from pulp tested to evaluate the properties according to ISO standard.

3. Results and discussion

From plethora of data various parametric effects are determined. Data is plotted in graphs to interpret the correlation among the parameters. These are discussed in detail in the following paragraphs.

3.1. Effect of electron irradiation on SEC (specific energy consumption)

Canadian Standard Freeness, abbreviated as CSF is a measure of drainage rate, which is influenced by surface conditions, fines content, swelling and other properties of the fibers. In this study, CSF was measured according to the ISO method 5267-2; 2001. The power required during the refining of fibers from the raw material is defined in terms of specific energy consumption in kWh/t. It is the measure of power input to the refiner motor per tonne of pulp processed. Alternatively, specific energy consumption can be explained as the energy required for cutting and fibrillation of pulp fibers.

The Fig. 1 illustrates the CSF as a function of specific energy required to refine bagasse fiber. It is evident from the figure that specific energy consumption increases with decreasing CSF level. It is also reveals that the electron irradiation pretreatment leads to a decrease in the specific energy consumption for all kind of pulps namely, TMP (Thermo-mechanical pulping) reference, CTMP with 5%, bisufite, ECTMP 15 kGy and ECTMP 30 kGy pulps. The specific energy consumption of electron irradiation pre-treated bagasse is found significantly lower throughout all CSF levels. The irradiation dose of 30 kGy leads to higher energy savings than that at 15 kGy. From the trials in this study, energy savings amount of 52.61% at a CSF level ranging between ranging between 500 and 550, was achieved which is very significant. Thus the main aim of this present investigation to achieve energy benefits out of electron irradiation pretreatment, to reduce the specific energy consumption of pulping (Gailat et al., 2011) was fulfilled. Literature on irradiation indicates that the high energy irradiation causes a loosening of micro structure of fibrous raw material, breakdown of larger molecules such as lignin, depolymerization and modification of polymers in fibrous raw material and hence less effort or energy is required to make pulp.

3.2. Effect of electron irradiation on fiber properties and WRV

Fibrillation is the process of generating fibrils and microfibrils from raw fibers by mechanical action in refiners or beaters. By fibrillation, fibers become more flexible and conformable and be able to produce fiber network for paper formation in the wet end. The equipment, Kajaani fiber lab developed by Metso Automation was used in this analysis. The Fig. 2 shows the percentage of fibrillation as a function of CSF value. It is evident that chemical pretreatment in CTMP has no significant change on fibrillation when compared to TMP reference and both have almost the

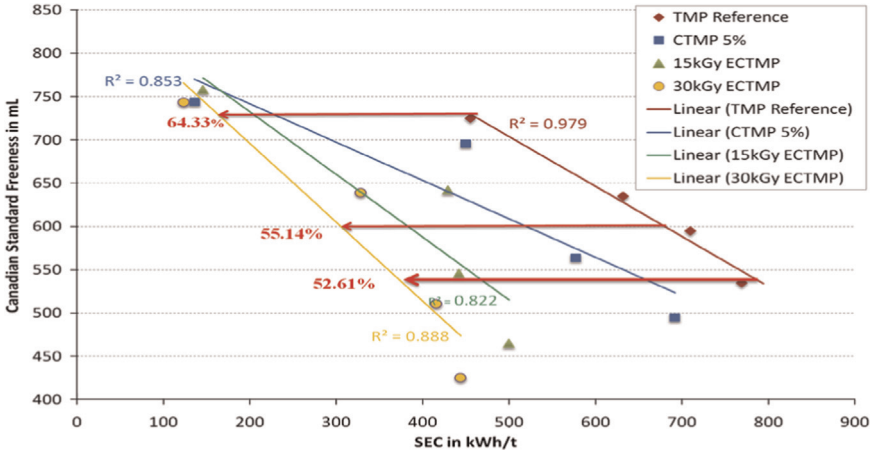

Fig. 1. CSF in ml as a function of SEC (specific energy consumption) in kWh/t for TMP reference, CTMP 5% bisulfite, ECTMP 15 kGy and ECTMP 30 kGy pulps.