Contents lists available at ScienceDirect

Chemical Engineering Research and Design

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

Equipment performance analysis of a Canadian Kraft mill. Part II: Diagnostics and identification of improvement projects

Radia Ammara, Louis Fradette, Jean Paris*

Department of Chemical Engineering, Polytechnique Montreal, Canada

ARTICLE INFO

Article history:
Received 25 September 2015
Received in revised form 26 May 2016
Accepted 8 September 2016
Available online 19 September 2016

Keywords:
Kraft process
Equipment performance analysis
Dimensionless key performance indicators
Energy efficiency
Systems performance

ABSTRACT

The Kraft process is an intensive user of capital, energy, water, and chemicals, and is particularly vulnerable in the present precarious economic situation. Therefore, Canadian Kraft pulp mills offer good potential for improvement, especially if the equipment and unit operations are diagnosed in details by means of specific key performance indicators (KPI). The characterization and performance analysis of equipment is a prerequisite to optimization. A thorough evaluation of the equipment performance must be done to assess the actual vs. the expected performance before proceeding to any kind of energy improvement project. A systematic methodology for equipment performance evaluation through key performance indicators (KPIs) is presented in Part I. New key performance indicators (KPIs) based on dimensional analysis as well as other conventional key performance indicators are used to efficiently analyze and diagnose the causes of inefficiencies of the equipment, and propose adequate remedial actions. The methodology has been applied to an Eastern Canadian Kraft mill and several improvement projects leading to 30% of energy savings are proposed, entailing a low investment cost and a payback of 1.1 a.

1. Introduction

The Canadian pulp and paper industry has been going through a difficult phase for the last decades because of many reasons, the emergence of new competitors from emerging countries, the decrease of commodity papers, the increase of energy prices, and strict environmental regulations (Mateos-Espejel et al., 2011a,b). The pulp and paper industry is among the largest industrial consumers of energy and water, and is forced to increase its energy efficiency to face the precarious economic situation (Francis et al., 2002). As a result, various methodologies and technologies have been developed to address the energy efficiency challenges and have produced significant energy savings (Kermani et al., 2014). However, these energy savings often imply high capital costs for major modifications in the plant, and are difficult to justify in front of mill management (Browne et al., 2001). Major capital investment are often required when several causes are combined, for instance, when improvement to product quality and increase in production rate are sought simultaneously (Browne et al., 2001). However, cost-effective improvement projects are possible through proper process performance and efficiency evaluations (Keshtkar, 2013).

Conventional optimization or energy enhancement methodologies such as Pinch analysis, do not address process issues, such as whether wash stages could be operated with less water. They are applied with the assumption that all equipment and unit operations are working efficiently or as intended, which is not always the case in operating pulp and paper mills. Hence, results need to be considered in the light of in-depth process knowledge, and equipment performance evaluation. This is especially the case for the aging Canadian Kraft mills (Francis et al., 2006). Older equipment often uses more water, chemicals or energy than necessary. Such equipment may also present a bottleneck to future production increase (Browne et al., 2001). Thus, a structured equipment performance evaluation is a pre-requisite step to any energy optimization procedure and implementation projects, to avoid unnecessary commitment of expenditures in the long term.

Evaluating the individual equipment and unit operations of a mill will help channelling efforts to address points of concern in an efficient

* *Corresponding author.*
E-mail address: Louis.fradette@polymtl.ca (L. Fradette).
http://dx.doi.org/10.1016/j.cherd.2016.09.018

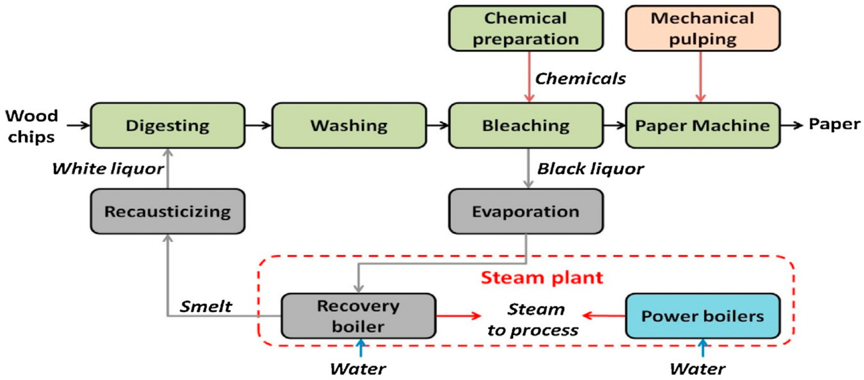

Fig. 1 – Simplified diagram of the Kraft pulp mill.

manner, and understanding fundamental mechanisms of process systems will lead to an easier identification of inefficiencies (Kamal, 2011). This type of equipment performance analysis can lead to low capital costs projects generating gains in the long term (Keshtkar, 2013). Low capital cost solutions begin with careful housekeeping; close monitoring and efficient operating equipment (Browne et al., 2001).

One tool that is mentioned in the literature for process performance evaluation is the comparison of energy, water, and electricity consumption of a mill with the Canadian average and best practice mills, using key performance indicators (Francis et al., 2006). This comparison leads to a preliminary appraisal and identification of inefficient departments in the mill. Calculating and comparing key performance indicators of a mill with a Canadian average was reported to be helpful in identifying general inefficiencies (Keshtkar et al., 2015). Further analysis is however required to pinpoint the exact location and unit operations of inefficiencies.

Lang and Gerry (2005) proposed indicators to monitor process control systems and identify periods where control loops are outside the normal mode or when they oscillate. These indicators identify areas with significant deviations from target points (energy or material consumption) but do not provide information on what is causing these deviations. Similarly, Buckbee (2007) defined indicators as the ratio between the setpoint and the actual targets achieved. The challenges that are associated with wide variations in energy savings led the industries to an intensive monitoring. Van Gorp (2005) proposed a strategic method for utility distribution and energy management based on metrics for energy consumption per unit of production. The metrics are compared to the goals set for the energy reduction projects and a mathematical relationship is used to monitor the consumption compared to the targets. Retsina (2004) proposed a similar methodology by adding a real-time monitoring of these indicators. Sivill and Ahtila (2009) proposed the use of performance indicators that take into consideration the logistic and productivity time periods of the mill based on their business strategy. Retsina (2004, 2006) developed a software to control various processes indicators. Sivill and Ahtila (2009) proposed the use of an indicator that connects paper production, economic parameters and the energy consumption for the overall performance evaluation of the mill. However, no work has been published on a complete structured and systematic approach for equipment performance analysis of a Kraft pulp process, by means of key performance indicators (KPIs) that have been specifically tailored for the process.

The objective of this work is to present the application of a structured and systematic equipment performance analysis to an Eastern Canadian Kraft pulp mill, in order to assess the current performance of the process unit operations, identify areas of inefficiencies, diagnose their causes, and propose low cost improvement projects. The work is presented in two parts. Part I described the development of new key performance indicators based on dimensional analysis of the specific Kraft process main equipment, and the present Part II, concerns the application of the equipment performance analysis using key performance indicators (KPIs). It should be mentioned that not all the dimensionless KPIs developed in Part I have been used in this study, because some of them required the computation of variables for which measurements are not available in the mill. However, a sufficient number of KPIs were used to complete a complete equipment performance analysis of the Kraft pulp mill.

1.1. *Case study*

The study is based on an operating Eastern Canadian pulp mill manufacturing newsprint (Goyal, 2015)[1] using a mixture of ground pulp (60%) and Kraft pulp (40%) from softwood biomass. Only the Kraft pulping plant of the mill was simulated and evaluated in this study. Due to the large variations in instrumentation level of the various sections of the plant linked to their construction period, the measurements of the mechanical pulping plant, necessary for the construction of the process simulation, were lacking. A prorated fraction of steam and water consumption by the paper machine was therefore used in the performance evaluation to account for the extra pulp fed to the paper machine coming from the mechanical part of the mill. CADSIM Plus® software (Aurel Systems Inc.) was used for the simulation of the Kraft process of the mill. CADSIM Plus is a commercially available chemical engineering software that has been widely used in the pulp and paper sector to simulate process models. The process simulation was built with the purpose of obtaining a reliable representation of a long term average steady-state of the mill, as data source for performance evaluations, and to assess the impact of the improvement projects on the overall performance of the process.

The average pulp production rate of the Kraft plant is 280 adt[2]/d. The core of the Kraft process was built in the 1930's but process upgrades were implemented later, the last major modification being the addition of a paper machine in the 1990's. A simple schematic of the Kraft process is given in Fig. 1.

The Kraft process is the worldwide prevalent pulp manufacturing process (Grahs, 1974) by which a wide spectrum of finished or semi-fished paper products is made. It consists of two main parts: a pulp line and a chemical recovery loop. The pulp line is composed of four main departments; the digesting department where lignin is separated from the cellulosic fibers (pulp) under the action of the delignification agent (white liquor), a solution of sodium hydroxide (NaOH) and sodium sulfide (Na_2S), the washing department where lignin is removed from the pulp, the bleaching department where the remaining lignin and dissolved solids are removed from the pulp, and the paper making department where the pulp is drained, pressed, and thermally dried to produce the final product (bleached paper).

The chemical recovery loop consists of three main departments: the evaporation plant where the spent delignification liquor (black liquor) separated from the fibers in the washing step is concentrated in the multi-effect evaporator, the power plant where the concentrated black liquor is burnt in the recovery boiler to produce the steam required for the process and to recover the spent chemicals, and finally the recausti-

[1] Newsprint is a type of paper weighting between 40 g/m^2 and 57 g/m^2 generally used in newspapers.
[2] Adt: air dry ton of pulp.