CHEMICAL ENGINEERING TRANSACTIONS, Volume 11, 2007
Edited by Sauro Pierucci

Optimization of felt life time in paper manufacture

Daniela M. Devienne Drummond[a]; Maria Teresa M. Rodrigues[b]; Reginaldo Guirardello[c]
UNICAMP, FEQ/DPQ, [1]dmdd@feq.unicamp.br, [2]maite@desq.feq.unicamp.br,
[3]guira@feq.unicamp.br

The process of manufacture of paper is essentially the removal mechanics of a fiber suspension, starting in the formation where relatively low level of force mechanics is used to remove the free water between staple fibers. The biggest force mechanics used for continuous removal of this water is in the sector of presses, where the located one between them in such a way involves the compression of the leaf for water withdrawal of the interior of staple fibers how much. The more compressed the leaf, greater the amount of water is removed. The pressing is made with the leaf in contact with one or two felts in nip (zone of contact between two coils). The press sector is an important part of the machine, affecting the properties of the paper, as the smoothness and the density, as well as intervening with the final cost of manufacture. Low efficiency of this sector causes inconvenience as to the rise of the number of in additions the leaf, for the reduction of the tensile strength; increase in the vapor consumption in the drying section of the machine, and in many cases, the reduction of the productivity due to reduction of the speed of the machine. A reduction of 1% of humidity in the leaf results in a reduction of vapor consumption in the order of 4.5%. The manufacture of papers to print and to write is the second category of paper more produced and consumed, participating, in 2003, with 29% of the total production of paper and 25% of the consumed total volume. Brazil is 13th bigger world-wide manufacturer of papers to print and to write, participating with 2.4% of the world-wide production. The programming and control of the production consist essentially of a set of interrelated functions that objectify to command the process productive and to co-ordinate it with the too much administrative sectors of the company. In this work we present the alternatives that we can have in the analyses of the data of the press sector, due to existence of a great amount of involved variable of control in this sector (approximately 20), was necessary the accomplishment of an analysis statistics through the study of Techniques Multivariates Statistics through the method of PCA (Principal Components Analysis), PCR (Principal Components Regression) and PLS (Partial Least Squares), with the one of the use of softwares Minitab14 and Statistica 7. This analysis will supply basement the development of the model for optimization of the useful life of the clothes of the sector of press in the manufacture of paper to print and to write.

1. Introduction

The press section is an important part of the machine, affecting the properties of the paper, as well as intervening with the final cost of manufacture. Low efficiency of this sector causes inconvenience as to the rise of the number of in additions the leaf, for the reduction of the tensile strength; increase in the vapor consumption in the drying

section of the machine, and in many cases, the reduction of the productivity due to reduction of the speed of the machine. The sheet of paper in the exit of the box of entrance of the paper machine has 1% of dry approximately. In the zone of formation and draining, we can remove water of the leaf, economically, until a text hard dry around 20%. In the last years, a sufficiently fast evolution of the concepts of presses was observed, searching an adequacy of the requirements such as economy in the operational process, increasing the water removal in this sector and at the same time keeping or improving the characteristics of the sheet of paper, still new demands of efficiencies demanded in the machines. The increase of 1% of humidity of the leaf can increase the steam consumption in the order of 4 to 5%.

2. Principle of Pressing

The humid pressing is based on the compression mechanics of the leaf of paper, in contact with felt between two press rolls, combined with the suction of the water, as (figure 1).

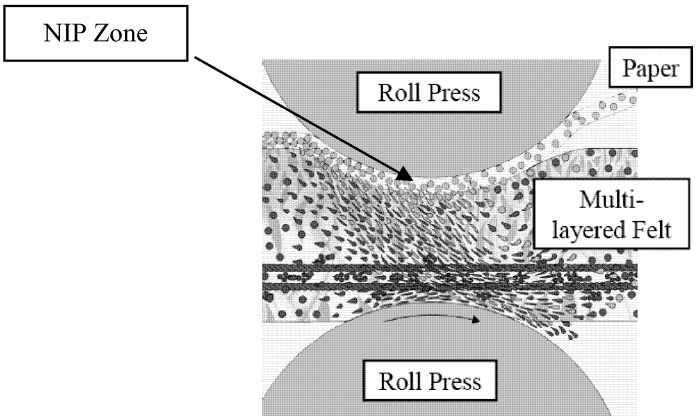


Figure 1: Press principle

The function of the presses is the water withdrawal of the felt structure, through the compression of the leaf. Bigger removal determines efficiency of the section better, leading in account the economic aspect of the operation, and the final quality of the production. The way with that the felt and the leaf enter in the NIP (contact zone enters the rolls) of pressing, both load obtain a restrained water film for the superficial tension of its respective fibers structures. The water extraction in the press is followed by a compression of the leaf, in the point between the two rolls. The felt beyond the transport of the leaf serves as a way of absorption of the water extracted for the related compression of the leaf. The extracted volume, for its turn, must in continuity, removed being of the felt, in order to condition it to a new pressing. The absorption is made by the action of the fibres of the felt and by the pores between the

fibers. If the felt will not be able to absorb the removed water of the leaf, after nip, in a short space of time, for permit it high speed in the machine and if the half ones for removal of the water absorbed for the felt will not be efficient, the hydraulic pressure servant, will promote the crushing of the leaf.

2.1 Presses of Paper Machine

The stages of water removal of the leaf in the paper machine can be simplified in the following way:

1- Draining through foils in the formation table;
2- Vacuum applied for the boxes and rolls of suction;
3- Pressure of contact in the presses;
4- Evaporation by the drying cylinders.

3. Factors that influence the efficiency of pressing

Taking as base the theory of pressing defined for Wahlstrom for one nip of vertical flow, and other studies developed for the refinement of the same mathematical model, can be defined some basic rules to increase the pressing efficiency: Applied pressure. Since the increase of water removal in nip directly is related to the increase of the compression of the leaf in nip, the pressure applied in respective nips of the presses must be adequate to the concept of pressing, produced paper and speed of the machine. Time of residence in nip: the increase of the time where the leaf is compressed of also results in the increase of the water removal, mainly in leafs of controlled flow. Joint pressure x correctly projected time will mean dry text profits and operational efficiency. Reduction of the passage of the water: to optimize the vertical flow through ventilated presses, felts with the maximum of empty spaces, and low resistance to the flow. The passage of the water will be reduced by the half in presses with double felt. Distribution of pressure in nip: the application of the appropriate for the formation of bridges preventing the shading of the leaf for rolls of suction and ventilated felts, maximizing the points of contact with the leaf in nip. Temperature of the leaf: the increase of the temperature of the leaf results in dry text increment, due to reduction of the viscosity of the water, increase of the compressibility of staple fibers and reduction of the superficial tension of the fluid diminishing the re-moisturing of the leaf. Efficient draining of the felt: the felt must return to nip with empty spaces enough to absorb all the removed water of the leaf in nip. Therefore it has that to be kept clean and with efficient draining, fact this obtained through the correct project of the conditioning elements. Other factors: not of lesser importance, it can still be included the geometry and arrangement of the presses, type of rolls and covering and correct application of felts, adjusting these and the other described factors previously to the concept of pressing substance cousin and speed of the machine.

4. Case Study

The object of study of case considered in this work was the sector of pressing of a machine of paper of an industry of paper to print and to write. This sector is

responsible for 45% to 50% of the drying of the paper (figure 3). This part of machine cheaper as the next section, the dry section.

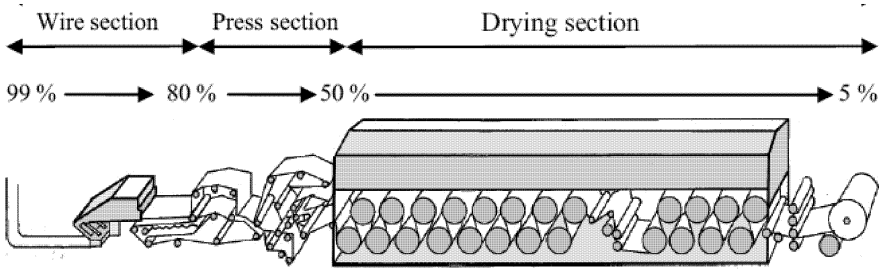


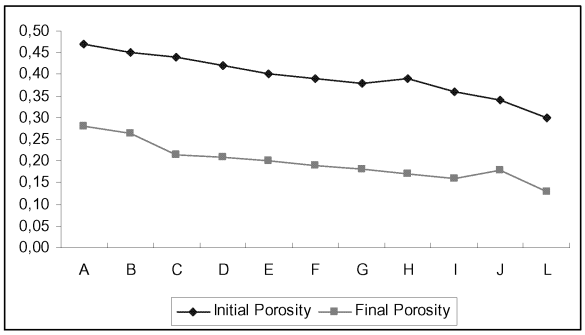
Figure 3: Division of Paper Machine

4.1. Analysis of the variables

The partial components analysis (PCA) was applied in order to find the most important variables that influence the process of pressing. It was found that the porosity and thickness of the felt were strongly influenced by speed of the machine and pressure applied in the nip. The capacity of removing of water in the pressing section depends on the porosity, which decreases with time.

4.2. Influence in the absorbing capacity of the felts

After several analyses relating the useful life of felts on press section, we got the graph below and we observed that, during the useful life of different felts (graphic 1), the decline of the porosity of a felt can be roughly correlated by an exponential function with time. We used this information to develop the model to minimize the changes of the felts and to program the production.



Graphic 1: Decrease of porosity in different life time

4.3. Proposed Model

In accordance with the previous analysis, the model was formulated in order to account for the decreasing capacity of water removal by the felt. The function tested was given by:

$$m_k = m_k^e - m_k^s - m_k^p$$

$$m_k^e = \sum_{i=1}^{N} \left[U_i^e \cdot A_i \right] \cdot x_{ik}$$

$$m_k^s = \sum_{i=1}^{N} \left[U_i^s \cdot A_i \right] \cdot x_{ik}$$

$$m_k^p = \sum_{j=1}^{4} m_{jk} \qquad k = 1, \ldots, N$$

$$m_{jk} = m_j^0 \cdot \exp(-\alpha_j \cdot \tau_{jk}) \qquad k = 1, \ldots, N$$

where α_j depends on the pressure and the speed of the machine (parameters in the model). The objective function that needs to be minimized is:

$$\min z = \sum_{k=1}^{N} \sum_{j=1}^{4} CF_j \cdot y_{jk} + \sum_{k=1}^{N} \sum_{i=1}^{N} CP_{i,k} \cdot x_{ik} + \sum_{k=1}^{N} cs_k \cdot m_k \quad (1)$$

Where:

$$\sum_{k=1}^{N} x_{ik} = 1 \qquad i = 1, \ldots, N$$

$$\sum_{i=1}^{N} x_{ik} = 1 \qquad k = 1, \ldots, N$$

$$cs_k = \sum_{i=1}^{N} CS_{i,k} \cdot x_{ik}$$

$$t_k = \sum_{i=1}^{N} T_i \cdot x_{ik} \qquad k = 1, \ldots, N$$

$$\theta_{j1} = 0$$

$$0 \le \theta_{jk} \le M \cdot \left(1 - y_{jk}\right)$$

$$\tau_{j,k-1} - M \cdot y_{jk} \le \theta_{jk} \le \tau_{j,k-1}$$

$$cs_k \cdot m_k = cs_k \cdot \left(m_k^s - m_k^e\right) - cs_k \cdot m_k^p$$

5. Results

The first results of this work in the sample that the model developed in entire and linear mixing programming, implemented in GAMS/CPLEX7.5, demonstrates that the objective function if holds very well indicating which the real necessity of exchange of felts by means of the programming of production, making that with this it has economy of energy in the machine of paper and with this increasing the useful life of the felts and production.

6. Notation

CF_j	costs of the felts
$CS_{i,k}$	costs of the steam in the dry section($/mass of water) in interval k
$CP_{i,k}$	costs of energy in press section i ($/rolls) in interval k
mk	mass of water evaporated in interval k

7. References

ADANUR S; “Paper Machine Clothing”. Published by Technomic Publishing.

BROOKE, A., KENDRICK, D. and MEERAUS, A. GAMS: A user’s guide. San Francisco: The Scientific Press, 1988.

BLAZEWICZ,J.;ECKER,K.H.;PESCH,E.SCHIDT,G.;WEGLARZ,J,J. – “Scheduling Computer and Manufacturing Process” – Springer – Verlag, Berlim, 1996.491p Company,INC.; Lancaster, Pensylvania, USA, 1997.

FURIBONDO, N.; “Pulp & Paper – Wire, Felt Cleaning Programs Can Improve Paper Machine Runability”. August, 1987.

NEUM, J.A. “Paper Machine Showers and Fabric Dewatering: Theory and Application”, AES Engineered Systems, Queensbury, New York, USA.

SLÄTTEKE,O - Modeling and Control of the Paper Machine Drying Section – PhD.

PAULAPURO, H, “Papermaking Science and Technology – Book 8 - Papermaking Part 1, Stock Preparation and Wet End”. Printed by Gummerus Printing, Jyväskylä, Finland 2000.

RENDER,B.& STAIR,R.M. – Quantitative Analysis for Management” –Prentice – Hall Inc.New Jersey sixth edition, 1997,769p.