AUTOMATION AND CONTROL OF PULP AND PAPER PROCESSES

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Contents

Summary

This chapter describes pulp and papermaking fundamentals and the related control issues. Paper production begins with pulp making. Pulp is produced either chemically or mechanically. In chemical pulp making wood chips are cooked in liquor to separate fibers in wood from lignin. An important part of chemical pulp making is the recovery

cycle. The organic materials are burned and cooking chemicals are recovered in a recovery boiler.

Two major ways exist in mechanical pulp making: stone grinding or thermomechanical pulp making. In stone grinding, short, de-barked logs are fed with water between two huge grinding stones rotating in opposite directions. The grinding effect is able to separate fibers from wood lignin resulting in stone groundwood pulp.

In thermomechanical pulping, a refiner process is used. It consists of two grooved disks rotating in opposite directions. Water and wood chips, softened with heating, are fed into the gap between the disks. When the disks are pressed hard against each other, fibers are separated from lignin. The end result is thermomechanical pulp.

Mechanical pulps have better printing properties than chemical pulp. On the other hand, chemical pulp has better strength properties, but is also more expensive than chemical pulp. A pulp mixture made out of chemical pulp, mechanical pulp, deinked pulp, and broke, is prepared for papermaking. It is called stock. Further additives, like fillers and starch may be added to the stock.

The wet stock then enters the paper machine. The main purpose of the paper machine is to make a two-dimensional paper sheet out of the wet stock and remove the water out of it. Headbox is the process, which acts like a huge nozzle. It spreads the wet stock on the running wire. On the wire, most of the water is removed, because the wire is a mat full of holes. Paper sheet is also formed on the wire.

From this point on the main issue in papermaking is further water removal, first in the press section then in the drying section. Now the paper is ready for finishing, which means coating and calendaring. In coating, paper pigments are used to cover the uneven paper surface. In blade coating, the idea is the same as covering toasted bread with butter using a knife. Calendaring is like shoe polishing. Final touches are then made on the paper to achieve appropriate gloss, slickness, color, and brilliance.

The control issues in mechanical pulping, chemical pulping and papermaking are then discussed. The emphasis here is on the domain specific control issues like control of a TMP refiner, control of paper machine retention, and grade change automation.

1. Introduction

Paper is formed of fibers, which originate from tree wood. Wood consists of fibers with lignin in between. Fibers are quite small – about 30-40 micrometers in diameter and 2-4 mm long. A typical paper sheet (A4 or 8 ½ x11”) consists of millions of fibers, which are bound together with hydrogen bonds. Chinese Tsai Lun is considered to have invented papermaking around 105 A.D, while he served the Emperor. The first paper machine making paper continuously (web-like paper) was constructed in France in 1798.

Paper appears in many forms in everyday life, in daily newspapers, colorful magazines, white copying paper, glossy art paper, packages of many forms in supermarkets and cardboard boxes. It is not possible to make all paper grades with just one type of paper machine. Newsprint is ‘easy’ to make, art paper is ‘difficult’, because it contains 30% of clay. Due to clay it is difficult to burn magazines, but clay is also the reason why color pictures in magazines are of high quality. Modern paper manufacturing requires and uses a variety of today’s high-technology tools including Internet, wireless communication and virtual reality. A modern paper mill alone has several thousands of basic control loops controlling different flows, temperatures, levels in tanks, pH of stock, consistencies, etc. The basic control of these variables is handled with distributed control systems (DCS) (see *Supervisory Distributed Computer Control Systems*).

The papermaking logistics chain starts from a forest, where trees are cut into logs and transported to pulp mills. Wood handling in the mill consists of pre-processing the logs, cutting them to specific lengths and removing the bark. The wood is then cut into chips, except in groundwood pulping. Figure 1 shows the flow of raw material from wood handling to eventual finished paper product in an integrated pulp and paper mill.

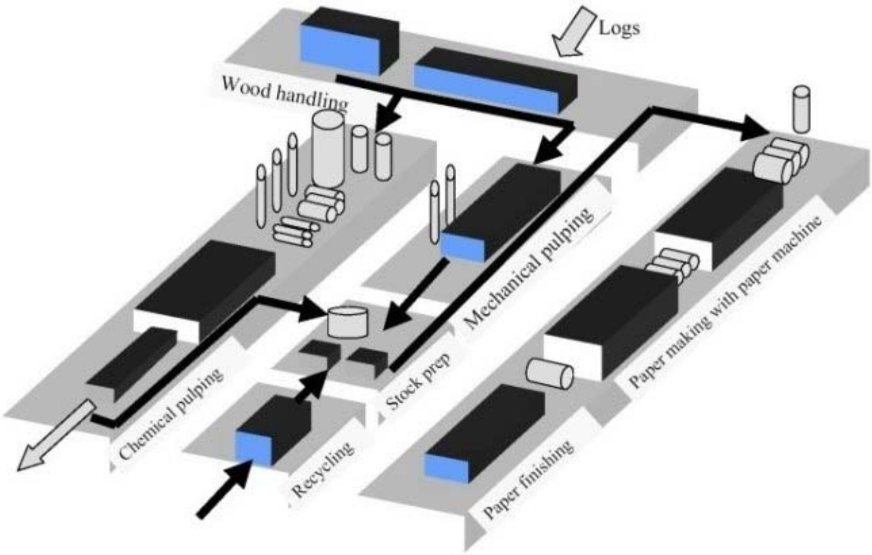

Figure 1. Scheme of an integrated paper mill. Logs from forest are entered into wood handling. They are debarked and made into wood chips. In chemical pulp making line, the wood chips are cooked in liquor to separate fibers from lignin resulting in chemical pulp. In mechanical pulping, fibers are separated mechanically from lignin resulting in mechanical pulp. Chemical pulp, mechanical pulp, and recycled pulp – e.g. deinked pulp and broke – are cleaned and mixed in stock preparation. Stock flow enters paper machine’s wet end. Paper web is produced in the paper machine by spreading stock on the wire and removing the water in it. In finishing, paper is coated with paper pigments and calendared to improve gloss, color, and brilliance.

2. Pulping Processes

Two kinds of processes can be used to separate wood fibers from the tree lignin: mechanical and chemical pulp making.

Mechanical pulp is produced either by grinding or refining (Figure 2). These processes require large amounts of electrical energy.

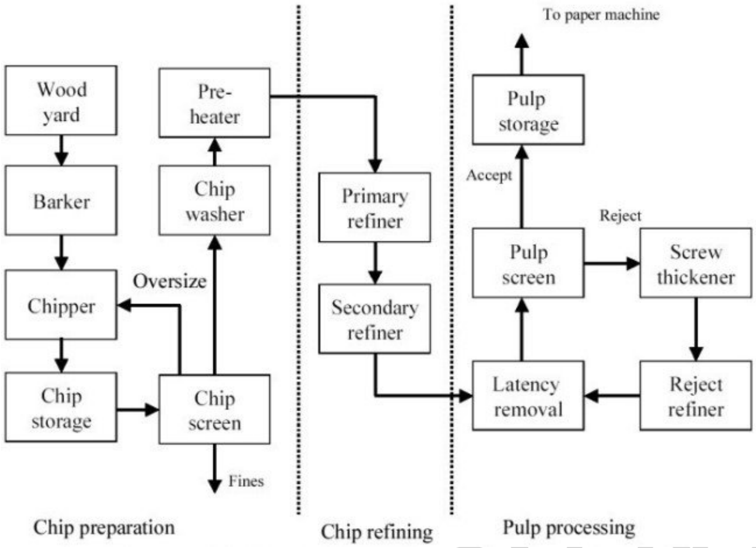

Figure 2. Thermomechanical pulp (TMP) refining process is separated into chip preparation, chip refining, and pulp processing.

In chemical pulp making wood chips are cooked in liquor in a digester. Chemical pulp requires mechanical refining at the paper mill - mechanical pulp does not. Currently, recycled paper is increasingly used as a third important source of paper fiber. Since the fibers in the recycled pulp become shorter after each cycle, recycling can be applied at most seven times.

Mechanical pulping is used to produce printing papers, which require good opacity and printability at low basis weights. Strength properties of mechanical pulp are not as good as those of chemical pulp.

By mixing mechanical and chemical pulp strength properties pulp may be improved. Pulp is further processed by bleaching and then transported to the paper mill. It should be mentioned that mechanical pulping is cheaper than chemical pulping and gives a higher yield.

3. Paper Mill

A paper mill is composed of stock preparation and a paper machine. In a paper mill, the first phase of papermaking process is stock preparation. It guarantees that stock entering the paper machine is clean, well mixed and combined with additives.

A paper machine (Figure 3) consists of a wet-end, a headbox, a wire, a press and a dryer section (Figure 4). Other subprocesses not discussed here include water treatment, filler preparation, starch cooking and broke handling.

Figure 3. Typical modern paper machine (Courtesy Metso Paper, Inc).

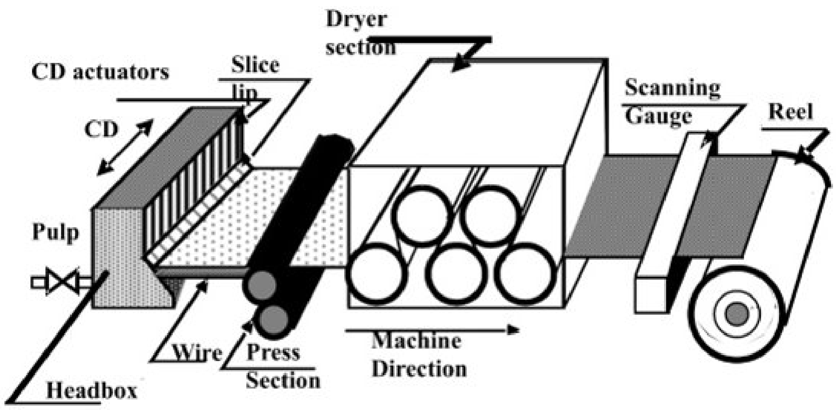

Figure 4. Scheme of a paper machine. Wet end, preceding the headbox, is excluded.

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Biographical Sketch

H. N. Koivo is a Professor of Control Engineering at the Helsinki University of Technology (HUT). He received his BSEE degree from Purdue University, Indiana, the MS degree in Electrical Engineering and the Ph.D. degree in Control Sciences from University of Minnesota. Before joining HUT in 1995, he has served in various academic positions at the University of Toronto and at Tampere University of Technology, Finland.

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Dr. Koivo is a member of the Editorial Board *Journal of Intelligent and Fuzzy Systems*, *Intelligent Automation and Soft Computing*, and *Journal of Systems and Control Engineering*. He was Associate Editor of *IEEE Transactions on Robotics and Automation* and a member of the Administrative Council of the *IEEE Robotics and Automation Society*. He is a Fellow of the Finnish Academy of Technology.