Chapter 2
Pulp and Paper Making Process

Some excerpts taken from Bajpai (2012a). Biotechnology for Pulp and Paper Processing with kind permission from Springer Science+Business Media.

The paper manufacturing process has several stages—Raw material preparation and handling, Pulp manufacturing, Pulp Washing, and Screening, Chemical recovery, Bleaching, and finally Stock Preparation and Papermaking.

2.1 Pulp Making Process

Manufacturing of pulp starts with raw material preparation (Smook 1992; Biermann 1996). This includes debarking (when wood is used as raw material), chipping, and other processes such as depithing (for example, when bagasse is used as the raw material). Cellulosic pulp is manufactured from the raw materials, using chemical and mechanical means (Bajpai 2012a). The manufacture of pulp for paper and board employs mechanical (including thermomechanical), chemi-mechanical, and chemical methods. Each pulping process has its advantages and disadvantages (Smook 1992; Biermann 1996). The major advantage of mechanical pulping is its high yield of fibers—up to 90 %. Chemical pulping yields approximately 50 % but offers higher strength properties.

Mechanical pulping separates fibers from each other by mechanical energy applied to the wood matrix causing the bonds between the fibers to break gradually and fiber bundles, single fibers, and fiber fragments to be released. It is the mixture of fibers and fiber fragments that gives mechanical pulp its favorable printing properties. In mechanical pulping, the objective is to maintain the main part of the lignin in order to achieve high yield with acceptable strength properties and brightness. Mechanical pulps have a low resistance to ageing which results in a tendency to discolor. Mechanical pulps are weaker than chemical pulps, but cheaper to produce and are generally obtained in the yield range of 85–95 %. Currently, mechanical pulps account for 20 % of all virgin fiber material. The main processes are stone groundwood pulping (SGW), pressure groundwood pulping (PGW), thermo-mechanical pulping (TMP), or chemi-thermo-mechanical pulping (CTMP).

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Chemical pulping is used for most paper produced commercially in the world (Smook 1992; Biermann 1996). Chemical pulps are made by cooking the raw materials, using the Kraft (sulfate) and sulfite processes. The Kraft process is the dominant chemical pulping process. In the Kraft process the active cooking chemicals are sodium hydroxide and sodium sulphide. The Kraft process is applicable to all types of wood but its chemistry carries with it the inherent potential for malodorous compounds. Kraft pulp possesses superior pulp strength properties in comparison to sulfite pulp. Kraft processes produce a variety of pulps used mainly for packaging and high-strength papers and board.

Chemical recovery is an essential part of the pulp production process (Tran 2007; Vakkilainen 2000; Bajpai 2008; Biermann 1996). Half of the wood raw material is utilized as chemical pulp fiber. The other half is utilized as fuel for electricity and heat generation. In fact, a pulp mill has two main lines. Wood is turned into pulp on the fiber line. Energy is produced on the chemical recovery line from the wood material cooked in the liquor; the cooking chemicals are recovered for reuse. In the chemical recovery line, black liquor is evaporated and combusted in a recovery boiler, and the energy content of the dissolved wood material is recovered as steam and electricity. The chemical pulping process generates more energy than it uses. A pulp mill generates energy for its own use and energy to sell.

The sulfite process uses different chemicals to attack and remove lignin. The sulfite process is characterized by its high flexibility compared to the Kraft process. In principle, the entire pH range can be used for sulfite pulping by changing the dosage and composition of the chemicals (Smook 1992; Biermann 1996). The use of sulfite pulping permits the production of many different types and qualities of pulps for a broad range of applications.

After pulp production, pulp is processed in wide variety of ways to remove impurities, and any residual cooking liquor is recycled via the process. Some pulp processing steps that remove pulp impurities are screening, defibering, and deknotting. Residual spent cooking liquor from chemical pulping is washed from the pulp using brown stock washers for Kraft and red stock washers for sulfite. Efficient washing is critical to maximize return of cooking liquor and to minimize carryover of cooking liquor into the bleach plant.

Mechanical pulp can be used without bleaching to make printing papers for applications in which low brightness is acceptable—primarily, newsprint. However, for most printing, for copying, and for some packaging grades, the pulp has to be bleached (Smook 1992). For mechanical pulps, most of the original lignin in the raw pulp is retained but is bleached with peroxides and hydrosulfites. In the case of chemical pulps, the objective of bleaching is to remove the small fraction of the lignin remaining after cooking (Smook 1992; Reeve 1996a, b). Oxygen, hydrogen peroxide, ozone, peracetic acid, sodium hypochlorite, chlorine dioxide, chlorine, and other chemicals are used to transform lignin into an alkali-soluble form (Reeve 1989). An alkali is necessary in the bleaching process to extract the alkali-soluble form of lignin.

Pulp is washed with water in the bleaching process. In modern mills, oxygen is normally used in the first stage of bleaching (Bajpai 2012b). The trend is to avoid the use of any kind of chlorine chemicals and employ “total chlorine-free” (TCF) bleaching. TCF processes allow the bleaching effluents to be fed to the recovery boiler for steam generation; the steam is then used to generate electricity thereby reducing the amount of pollutants discharged. Elemental chlorine-free (ECF) processes, which use chlorine dioxide, are required for bleaching certain grades of pulp. The use of elemental chlorine for bleaching is not recommended. Only ECF processes are acceptable, and, from an environmental perspective, TCF processes are preferred. The soluble organic substances removed from the pulp in bleaching stages that use chlorine or chlorine compounds, as well as the substances removed in the subsequent alkaline stages, are chlorinated. Some of these chlorinated organic substances are toxic.

2.2 Stock Preparation and Paper Making Process

Stock preparation is conducted to convert raw stock into finished stock for the paper machine. The pulp is prepared for the paper machine by blending different pulps, dilution, and the addition of chemicals. The raw stocks used are the various types of chemical pulp, mechanical pulp, and recovered paper, and their mixtures. The quality of the finished stock essentially determines the properties of the paper produced. Stock preparation consists of several steps that are adapted to one another: fiber disintegration, cleaning, fiber modification, and storage and mixing. These systems differ considerably depending on the raw stock used and on the quality of furnish required. For instance, in the case of pulp being pumped directly from the pulp mill, the slushing and deflaking stages are omitted. The operations practiced in the paper mills are: dispersion, beating/refining, metering, and blending of fiber and additives.

Pulpers are used to disperse dry pulp into water to form a slurry. Refining is one of the most important operations when preparing papermaking fibers (Baker 2000). The term beating is applied to the batch treatment of stock in a Hollander beater or one of its modifications. The term refining is used when the pulps are passed continuously through one or more refiners, whether in series or in parallel. Refining develops different fiber properties in different ways for specific grades of paper. Usually, it aims to develop the bonding ability of the fibers without reducing their individual strength by damaging them too much, while minimizing the development of drainage resistance. So the refining process is determined by the properties required in the final paper.

The furnish can also be treated with chemical additives. These include resins to improve the wet strength of the paper, dyes, and pigments to affect the color of the sheet, fillers such as talc and clay to improve optical qualities and sizing agents to control penetration of liquids and to improve printing properties. After stock preparation, the next step is to form the slurry into the desired type of paper at the wet end of the paper machine.

The pulp is pumped into the head box of the paper machine at this point (Smook 1992; Biermann 1996). The slurry consists of approximately 99.5 % water and

0.5 % pulp fiber. The exit point for the slurry is the "slice" or head box opening. The fibrous mixture pours onto a traveling wire mesh in the Fourdrinier process, or onto a rotating cylinder in the cylinder machine (Biermann 1996). The Fourdrinier machine is essentially a table over which the wire moves. Greater quantities of slurry released from the head box result in thicker paper. As the wire moves along the machine path, water drains through the mesh. Fibers align in the direction of the wire travel and interlace to improve sheet formation. After the web forms on the wire, the remaining task of the paper machine is to remove additional water. Vacuum boxes located under the wire aid in this drainage.

The next stop for the paper is the pressing and drying section where additional dewatering occurs (Smook 1992; Biermann 1996). The newly created web enters the press section and then the dryers. The extent of water removal from the forming and press sections depends greatly on the design of the machine and the running speed. When the paper leaves the press section, the sheet usually has about 65 % moisture content. The paper web continues to thread its way through the steam heated dryers loosing moisture each step of the way. The process evaporates many tons of water.

Paper will sometimes undergo a sizing or coating process. The web in these cases continues into a second drying operation before entering the calendaring stacks that are part of the finishing operation. Moisture content should be about 4–6 % as predetermined by the mill. If the paper is too dry, it may become too brittle. About 90 % of the cost of removing water from the sheet occurs during the pressing and drying operations. Most of the cost is for the energy required for drying.

At the end of the paper machine, paper continues onto a reel for winding to the desired roll diameter. For grades of paper used in the manufacture of corrugated paperboard, the process is now complete. For those papers used for other purposes, finishing and converting operations will now occur, typically off line from the paper machine. These operations can include coating, calendaring, or super calendaring and winding.

Other operations may include cutting, sorting, counting, and packaging. For some products such as tissue and copy paper, the typical paper mill will conduct all of these operations. In most cases, however, the rolls are wrapped and readied for shipment to their final destination.

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