1

Overview of Pulp and Paper Technology

1.1 The Impact of Clothing

Why is the vendor selection process for Paper Machine Clothing (PMC) so notoriously emotional? The reason is simple. Paper machine clothing is mission critical. It has a profound impact on sheet properties, total cost of production, and paper machine efficiency:

- **On Sheet Properties**

Machine clothing has a significant impact on the quality of the finished sheet of paper. In the forming section, PMC must provide a stable, durable area for water to drain through the fibers and fillers to create the sheet. In the press section, fabrics must provide a uniform environment for mechanical, vacuum-based, and heat-driven dewatering. Dryer fabrics must provide consistent contact with the cylinders to provide efficient and even drying of the sheet. Inconsistencies in any of these areas can reduce the quality of the finished product. Sheet formation, smoothness, bulk and strength properties are some of the primary properties to be considered in the selection of specific paper machine fabrics.

- **On Total Cost of Production**

Efficient water removal is a primary objective of forming, press, and dryer fabrics. Therefore, energy cost is a key operating factor. Paper machine clothing impacts total cost in various ways:

- Chemical use
- Machine downtime
- Fiber use
- Tons of paper produced

- **On Paper Machine Efficiency**

Paper machine clothing, when properly designed and applied, allows the papermaker to run a machine faster with fewer sheet breaks. The life of clothing fabrics has increased through the years with newer raw materials and design improvements. This allows the papermaker to reduce downtime for clothing changes.

The quality and consistency of paper machine clothing will have a positive or negative impact on machine efficiency. Every fabric has to run consistently through its life, and new fabrics must run the same as the fabrics they replace. There must be "no surprises" coming out of the fabric shipping box.

1.2 Pulp Manufacturing

Eight-step Process for Producing Pulp as a Raw Material for Paper

Pulp is defined as "fibrous material produced either chemically or mechanically (or by some combination of chemical and mechanical means) from wood or other cellulosic raw material" [1]. The wood cell has a nonliving cell wall, made of cellulose fibers, hemicellulose, and lignin which gives strength and support to the cell wall. Cellulose is a carbohydrate, i.e., it is made of carbon, hydrogen, and oxygen. It does not dissolve in water and its surface is hydrophilic. Cellulose imparts high tensile strength and stiffness to the structure. The amount of cellulose in native wood fiber is less than 50%. Lignin holds the cellulose fibers together in the cell wall. Therefore, lignin must be removed to separate the individual cellulose fibers, which eventually become paper. Some of the hemicellulose, which has some properties of cellulose and lignin, is also removed during the pulp manufacturing process. "Virgin" pulp (i.e. pulp that is not produced from recovered fibers) is manufactured in mills where trees or annual plants are turned into pulp by separating the plants into individual fibers. This is done in several steps [2, 3, and 4]:

Step 1: Trees are cut into logs and showered with water to remove sand and soil.

Step 2: The bark and rotted parts in logs are removed in the debarker since they do not make high quality paper. There are various types of debarkers. A common type is a cylindrical drum with open ends (Figure 1.1). Logs enter from one end, rub against each other inside the drum until bark is removed with friction and shear, and leave the debarker on the other end. Bark falls down through the openings on the bottom of the debarker. It is collected and used for other purposes, most typically as a source of fuel for the mill (either in the boiler or gasified for use in the lime kiln).

Step 3: The next step depends on the method for separation of individual fibers i.e., the pulping method. Separation of fibers can be done in many ways including mechanical, chemical, and semichemical methods. Stone groundwood (SGW) and thermomechanical

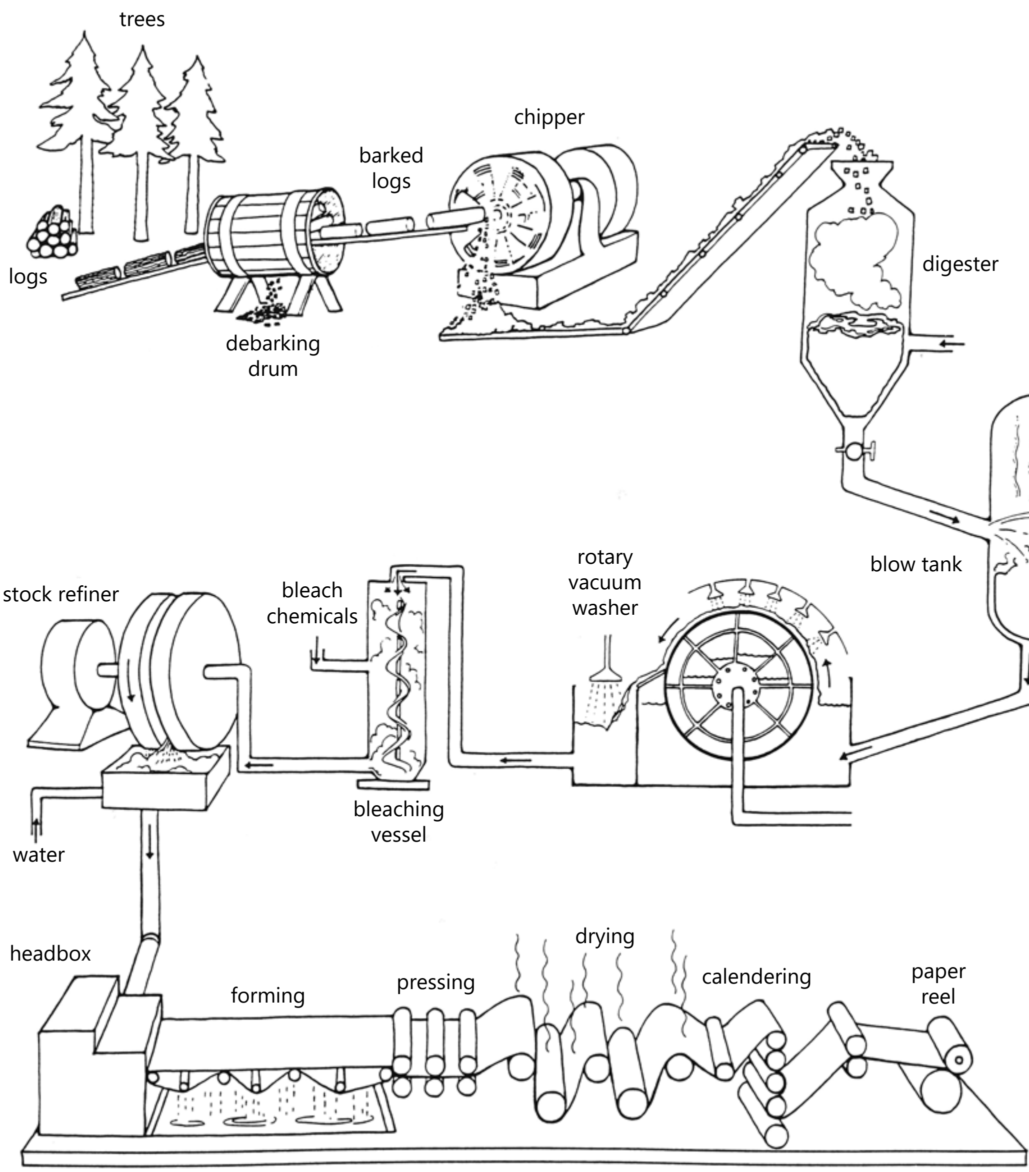

FIGURE 1.1. Schematic of wood pulp (chemical) and paper manufacturing (TAPPI, [2]).

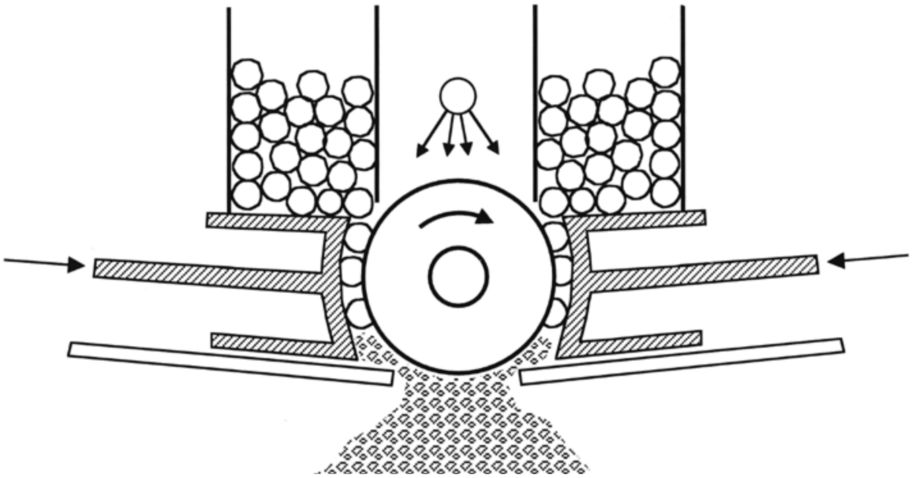

FIGURE 1.2. Schematic of mechanical grinder.

pulping (TMP) are mechanical pulping methods. In the historical but now obsolete stone grinding method, barked logs are pressed sideways against a rotating grinding stone (Figure 1.2).

The TMP process employs thermal and/or chemical pre-softening of the chips. Heat is utilized instead of chemicals to improve the simple mechanical pulping. Temperature should be carefully controlled to prevent melting of lignin. Melted lignin will reduce good bonding in the sheet by covering up the exposed cellulose. Other mechanical pulping methods include other forms of energy and/or chemicals to ease the pulping process. Chemi-mechanical pulping (CMP) combines chemical and mechanical methods. The chips are partially softened with chemicals before the final mechanical method of pulping. For the chemical pulping method, the debarked logs are cut and sent to the chipper on a conveyor belt. The logs are cut into small pieces (chips) with the shear action of steel knives (Figure 1.1). Then the chips are sorted out in screening trays according to their sizes. The ideal size chips are approximately 20-25 mm square and 2-3 mm thick. Oversized chips are rechipped and undersized chips are used for fuel generation.

In the chemical pulping method, the chips are cooked with water and chemicals in a large pressure vessel called a digester, which removes lignin and other impurities from the wood (Figure 1.1). In this process, the wood structure is chemically changed. More lignin is removed than in mechanical pulping, however cellulose degradation and fibrillation are increased. Chemical pulping produces collapsed, flexible and hydrophilic fibers. Crystallinity is increased and microfibril orientation is decreased. Paper made with chemical pulp is generally whiter and stronger than purely mechanical pulps. The alkaline kraft (sulfate) process is the major method of chemical pulping. The acidic sulfite process is still in use in a few locations around the world, primarily for the production of dissolving pulp. In the kraft process, a solution of sodium sulfide (Na_2S) and sodium hydroxide ($NaOH$, caustic soda), which is called white liquor, is used. The chips are cooked under pressure around 170° C in white liquor for one to two hours, after which most of the lignin and approximately half of the hemicellulose are removed from the chips. The white liquor turns black due to impurities. After cooking, the softened pulp is sent to the blow tank by opening the valve under the digester (Figure 1.1). The softened chips are smashed against the walls of the blow tank under high velocity and separate into individual fibers. The heat generated in this process is re-used. In the kraft process, approximately half of the wood is turned into fibers and the rest becomes part of the black liquor. The cooking chemicals in the black liquor are recycled. The lignins, etc., are burned.

In the sulfite process, a mixture of sulfurous acid and bisulfite ion is used to remove lignin. The sulfite process produces bright pulp that is easy to bleach and refine but with less strength than kraft pulp.