WOOD FIBRE

Historical Background

The French physicist Reaumur first suggested Wood as a possible fibre for papermaking, in the early 1700's, following the example of the "Mechanical Wood" structure of a wasp's nest. There were various attempts at extracting fibre from wood shavings in the early 1800's, but it was not until the mid 1800's that wood fibre extracted by mechanical means from pine and spruce wood was being commercially used for papermaking in Europe and the USA. In 1875 the first commercial use of chemically extracted wood fibre was in Sweden by the Sulphite pulping process, based on spruce wood. The "Kraft"(Sulphate) pulping process was first used commercially to chemically extract wood fibre from pine and spruce in the early 1900's, although it was not until the mid 1900's, that the latter became the dominant chemical pulping process, since it was found to be suitable for extracting fibre from any wood source.

Wood Structure and its Importance to Paper Quality

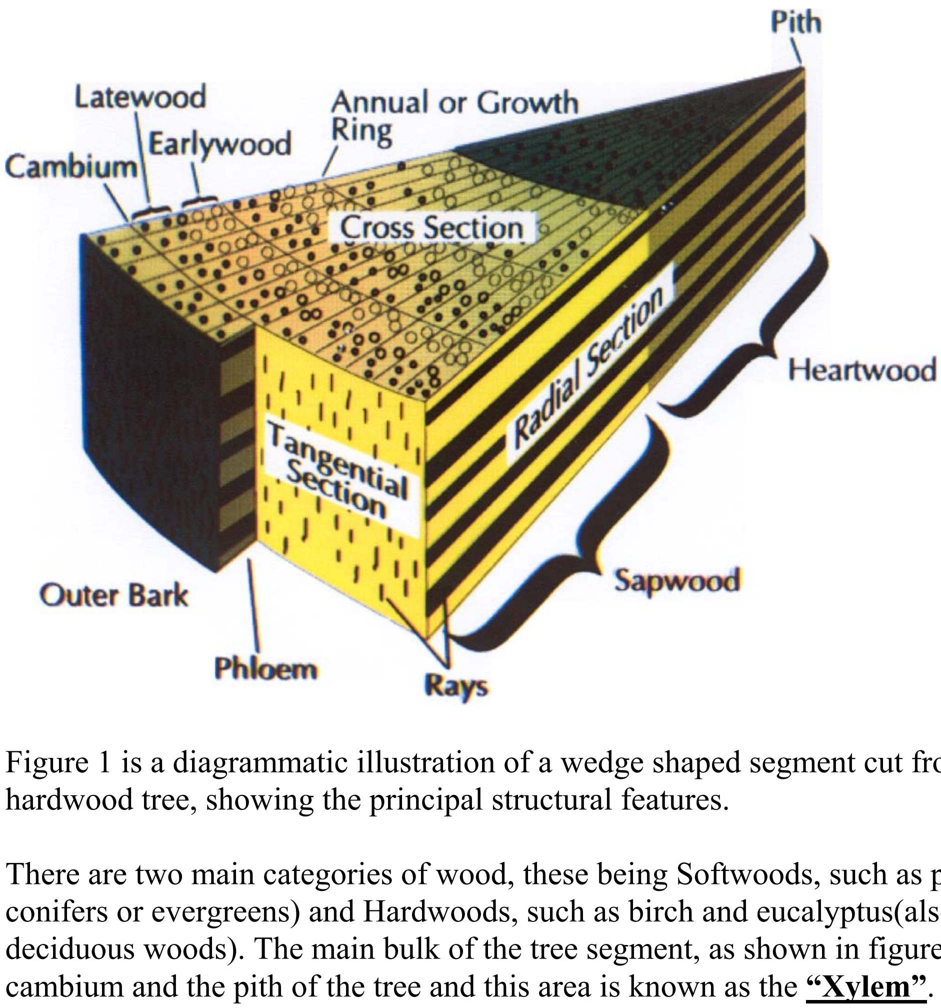

Figure 1 is a diagrammatic illustration of a wedge shaped segment cut from a five-year-old hardwood tree, showing the principal structural features.

There are two main categories of wood, these being Softwoods, such as pine and spruce(also called conifers or evergreens) and Hardwoods, such as birch and eucalyptus(also called broadleaf or deciduous woods). The main bulk of the tree segment, as shown in figure 1, occurs between the cambium and the pith of the tree and this area is known as the **"Xylem"**. It is in this area that there are significant differences in wood structure between softwoods and hardwoods that are important to the papermaker. These differences and other parts of the tree shown in the diagram are discussed below in relation to their importance to the papermaker.

Influence on Pulp and Paper Quality

Tree Feature

Bark

Usually removed before pulping (mechanical or chemical pulping). Use of unbarked wood can give rise to a higher dirt and fines level.

Phloem

Usually removed with the bark, but this band of cells in some softwoods can contain a high level of thick (dense) walled cells called Scleroids or “Stone Cells” which can give rise to transparent spots or “Fisheyes” as the dense cells crush under the calender stack

Cambium

No direct interest to the papermaker.

Xylem

The area of the tree where most of the fibre occurs.
The structure of the cells (fibres) is different between the softwoods and hardwoods.

Xylem -Softwoods

Wood substance composed mainly of Tracheids cells (Fibres), which provide mechanical strength and water transport for the tree. These cells vary between 2-6mm in length and 30-45μm in width depending on species and growing conditions.

Xylem - Hardwoods

Hardwood trees are composed of mainly cells, which support the tree ie the fibres, and vessel cells, responsible for water transport. The fibre cells are 0.5-2.0mm in length and 10-30 μm in diameter. Vessel cells have a characteristic shape depending on species (used to identify a particular species). Depending on the vessel shape and abundance, vessels in pulp can cause the papermaker picking problems at the wet presses or on printing machines or can give “shiny spots” or a mottled effect in the paper. Pulps containing eucalyptus or oak (mixed hardwoods) fibres are the most susceptible to this problem.

Rays

No direct interest to the papermaker.

Springwood and Summerwood (also known as Earlywood and Latewood)

In northern climates (EG Scandinavia) there is a more definite growing season and a growth ring is produced by changes cell walls of the fibre as the seasons change. In the spring the fibres will have thin walls and wide lumens while in the summer the opposite effect tends to occur. No tree will have 100% Springwood or Summerwood, and the ratio of the amount of each type of wood, in each tree, is dependent on climatic growth conditions. The behaviour of springwood and summerwood fibres in the paper mill is quite different. Springwood fibres refine quickly producing a strong, dense sheet, whereas summerwood fibres refine more slowly and have the opposite effect on papermaking.

Sapwood and Heartwood

The effects of Sapwood and Heartwood in papermaking is usually masked by the effects of the Springwood/Summerwood fibres as described above.
There are however two important effects. The centre of the tree (Heartwood) will, in time, die and become resinous, which can cause pitch problems in papermaking. The Sapwood tends to contain longer, thicker walled fibres, than the Heartwood and if the pulp source is predominately from waste saw mill chips, such pulps tend to have higher tear strength.

Chemistry of Wood Constituents and Effects on Pulp/Paper Quality

Wood is composed of three major constituents, **Cellulose, Hemicellulose** and **Lignin.** Their effects on pulp and paper quality are discussed below.

Cellulose

Cellulose is a major wood component comprising about 40-50% of the dry wood weight. Cellulose molecules form thread like microfibrils, which in turn form fibrils that are the basic structure of fibres. Hydrogen bonding between the cellulose molecules results in the high strength of the cellulose fibres.

Hemicellulose

Wood contains up to 25-30% hemicellulose, depending on wood species. In chemical pulping most of the hemicelluloses are dissolved or degraded, but usually between 3 and 15% remain in the pulp. The presence of hemicellulose in the finished pulp increases the pulp yield and also the strength of paper made from that pulp in terms of tensile, burst and fold. Chemically pulped birch wood has been claimed to have a relatively high hemicellulose content.

Lignin

Wood contains around 25-50% Lignin. In the tree it provides stiffness to the wood fibres and binds them together. In mechanical pulping, the lignin is not removed and therefore the yield of mechanical pulp from the tree is high. However lignin is light sensitive and hinders good interfibre bonding. Shorter life papers such as Newsprint and Magazines made from mechanical pulp will become yellow and brittle due to the presence of the lignin. Chemical pulping aims to remove the lignin which means the yield from the tree is less, but ensures that the pulp will produce white, light stable and strongly bonded papers.

Pulping Methods - Effect on Pulp/ Papermaking Quality

Mechanical Pulping

Mechanical pulping is the oldest system for converting wood into pulp suitable for papermaking and was started commercially around 1850-1860. There are broadly four processes for producing mechanical pulp.

Stone Groundwood

The oldest process, referred to as **Stone Groundwood**, was to grind wood, under pressure, against a revolving grindstone. The grindstone breaks the wood into some fibres, fibre fragments, fibre bundles and "secondary fines", which are very short created fibres (ie not naturally present short fibres) less than 2mm in length.

Refiner Groundwood

Following the development of refiners in the mid 1900's, three further processes for producing mechanical pulp emerged. The first was **Refiner Groundwood.** In this process wood in chip form, is fed into a disc refiner in two stages, initially at high consistency (20-30%) and then at medium consistency(10-20%).

Thermo Mechanical Pulp(TMP)

An adaptation of Refiner Groundwood was the **Thermo Mechanical Pulp(TMP)** process, which is similar, except that in the first refining stage the refiners are steam pressurised to soften the chips. The basic difference between Stone Groundwood and Refiner Groundwood/TMP processes is that the latter, particularly TMP, produces a product where the wood fragments are much more fibrous and stronger than from Stone Groundwood.

In all three of the above processes screening may produce different mechanical pulp grades and all may be bleached using hydrogen peroxide.

It is Softwoods that are mainly suitable for pulping by the mechanical processes, but an adaptation of the TMP processs allowed mechanical pulp to be produced from Hardwoods. In this process the

Chemi-Themo-Mechanical-Pulp(CTMP)

Hardwoods are given a mild chemical treatment prior to the TMP system This process, which is known as **Chemi-Themo-Mechanical-Pulp(CTMP)** produces a product which is easier to bleach and produces fibres which are closer to chemical pulp than previous mechanical types. Aspen hardwood is a species in frequent use in the CTMP process.

For the papermaker all mechanical pulps have the following general characteristics:

A high pulp yield from the wood means that the pulp cost is lower than for chemically prepared pulp.

Bleached mechanical pulps have a lower brightness than chemical pulps. The maximum mechanical pulp brightness using softwoods is about 80% and 85% with hardwoods. Chemical pulps have brightness levels of 90-92%.

As no lignin, or very little, is removed in mechanical pulping, the pulp fibres are sensitive to light and papers made from such pulps will become yellow. There is less tendency for yellowing in hardwoods pulped by the CTMP process as hardwoods have a lower lignin content than softwoods.

All mechanical pulps will contain a higher level of fines than chemically produced pulps. The level of fines is dependent on the degree of screening of the pulp. Because of a higher fines content, mechanical pulp stocks tend to be slower draining on the paper machine. The high level of secondary fines however means that papers produced from mechanical pulps will have high opacities and bulk.

Because of the presence of high lignin content in mechanical pulps, the fibres tend to be stiff and less flexible compared to chemical fibres. This leads to less interfibre bonding and lower strength properties.

The use of mechanical pulps in papermaking is generally confined to papers with a short life use such as newsprint, magazine, catalogue papers, envelopes and some packaging grades. These papers may be uncoated or coated. However pulps produced by the CTMP process, particularly hardwoods, are finding uses in some printing and writing grades.

Chemical Pulping

Chemical pulping of wood started commercially in the late 1800's and currently two methods of extraction of wood fibre are in use. These methods are the **Sulphite** process and the **Sulphate(Kraft)** process. Essentially both methods consist of cooking debarked wood chips with specific chemicals to release the fibres, removing the chemicals by washing, bleaching the pulp and either using this pulp at an integrated pulp and paper mill, or drying the pulp for market use. In both processes the aim is to remove the lignin component of the wood without fibre deterioration. In modern systems the chemicals used are recovered and recycled. For both cooking processes, the sequences used to bleach the fibres and in some cases the method of drying, have an effect on the pulp quality and hence on paper quality.

Sulphite Process

The Sulphite process is an acid based process and was the first chemical method (circa 1875) to be used for extracting fibre from wood. Originally it used a mixture of sulphurous acid and a calcium salt to extract fibre from Spruce softwood. This particular acid process has now died out because the chemicals could not be recovered and presented an environmental hazard. The modern Sulphite process combines sulphurous acid with cations such as Magnesium, Sodium or Ammonium salts to form a neutral acid sulphite where chemical recovery, although more complex, is possible. The Sulphite process is mainly used with softwoods, although some hardwoods may also be pulped by this process.

In general sulphite pulps are characterised by easy bleaching and refining producing soft, rather weak but flexible fibres which produce and rather dense papers. The ease of bleaching of Sulphite pulps make them suitable candidates for "chlorine free" products in the disposable sector and also in printing and writing grades where a higher whiteness is required. The ease of refining of Sulphite pulps means these pulps also find uses in dense paper products such as tracing paper, glassine, and also coating papers where a high coating holdout is required such as silicone release paper.

Sulphate(Kraft) Process

The Sulphate process is an alkaline process and was developed in the late 1800's by the German chemist Carl Dahl who called it the **"Kraft"** process because of the Strong fibres that were produced. Originally the cooking liquor was a mixture of caustic soda, sodium sulphide and sulphate. Nowadays the process is usually referred solely as the **Kraft** process, as the source of the sulphide comes from adding sulphur. The major advantages of the Kraft process over the Sulphite process are that the recovery of the chemicals is easier, the process is energy efficient and it can be adapted to pulp any kind of wood(Softwood or Hardwood) or non wood fibre. For the above reasons the Kraft process has become the dominant method for producing chemical wood pulp.

The Kraft process produces pulped fibres which are generally more difficult to bleach at the pulp mill and refine in the paper mill compared to fibres from the Sulphite process. Nevertheless the Kraft fibres can be refined to give higher strength properties and the properties of pulp produced by the Kraft process are largely dependent on the properties of the wood species.

Softwood kraft pulps are available as unbleached, semi-bleached and fully bleached pulps. The high strength potential of these fibres make them suitable as reinforcement materials for a wide range of graphic and industrial grade papers. Hardwood kraft pulps are generally available as fully bleached pulps. They find complementary uses to the softwood krafts in printing and writing papers in improving the opacity and surface properties of such papers.

Effects of Bleaching and Drying on Pulp/Paper Properties

All mechanical pulp grades, if bleached, are treated with hydrogen peroxide only and these pulps are dried by the Flash Drying process. There are no known specific characteristics or problems associated with the bleaching and drying of mechanical pulps.

The purpose of bleaching of chemical pulps is to remove the small amount of lignin left over from the cooking operation so as to produce a white pulp which is stable to light (ie will not discolour when exposed to light). The principal chemicals used in bleaching are either Chlorine or Oxygen or compounds of these elements.

Elemental chlorine is very selective to lignin, but its use has been greatly diminished in recent times, because bleach plant effluent residues were found to contain small amounts of toxic compounds. Oxygen is also selective to lignin but less so than chlorine.

In the most common bleaching sequence for kraft pulps, chlorine dioxide has replaced elemental chlorine; supplemented with oxygen and oxygen compounds(eg hydrogen peroxide). In this way the toxicity of the bleach plant effluent is greatly reduced.

Some markets require the paper to be produced from pulps where no chlorine compounds are used for bleaching. For this purpose Sulphite and Kraft pulps are available which have been bleached with Ozone(O_3) and hydrogen peroxide. Ozone is an extremely aggressive bleaching agent and will attack both lignin and cellulose and great care is needed in its use in the pulp mill to avoid cellulose degradation. Compared to pulps bleached with oxygen and chlorine dioxide, ozone tends to reduce the pulp viscosity and increase the pulp's response to refining in the paper mill(refining is faster with ozone bleached pulps). Ozone bleached softwood pulps may also have a slightly lower brightness level.

Most market chemical pulps are dried in sheet form, which present no difficulties to the papermaker. A few softwood kraft pulps are dried using the Flash Drying process(fibres pass through hot air cyclones). Occasionally over drying in this way, leads to unslushable hard fibre lumps which consequentially are crushed on the paper machine calenders giving rise to transparent spots or "fisheyes". Flash dried softwood kraft pulps will also provide a more porous, absorbent sheet in the early stages of refining. This property is made use of in some filter paper grades.