1 History of Mechanical Pulping

It was the age of enlightenment, both the Gutenberg press and the Fourdrinier brothers papermachine had been invented and literacy was flourishing through Europe.

At this time all paper was made with cotton fibres (rags). However, the supply of cotton was not meeting the demand. Frederick Keller wrote in his diary: “It may be possible to make paper from wood”. He remembered from his childhood that he used to push cherry seeds into wood to grind them against a stone with water. One day he forgot to clean up and when he returned he noticed that the residue from the ground wood formed a white paper.

In 1843 he fashioned a simple stone grinder. This is the origin of mechanical pulp. At his own expense he made a grinder capable of making enough pulp to run on a papermachine, he added 20% rag (cotton) and made strong paper. This was the origin of reinforcing mechanical pulp with lignin free pulp. It was a great technical success, unfortunately the mill went bankrupt and Keller never made any money from this invention.

1848 Johan Mathaus Voith in Heidenheim Germany made one of the first commercial grinders. Later, in 1859 they also developed the Raffineur, another grinder used to grind course pulp into fibres (secondary grinding) to break up any course material not properly ground. The combination is what made grinding practical and successful.
1867 Full plant powered by steam. Paper made with 70% wood (Worlds fair paris)

1868 Tampella (Finnish company) started making grinders.

The rest is history. Voith is still a large manufacturer of modern pulp and paper equipment. Tampella became part of Valmet which is now known as Metso (still a Finnish company).

2 Debarking

Trees are usually cut into ‘bolts’ or short logs and then debarked using a ring de-barker or a drum de-barker:

*Drum De-barker*

The most common is drum debarking where the logs enter into a rotating drum. As the logs pass over each other they impact each other and against special shaped corrugations on the wall that cause the weaker layers between the bark and wood to separate.
Currugation in the wall of the drum debarker.

The bark falls down, through holes in the drum into chutes at the bottom.

There is an end gate that retains the logs in the drum if they require a longer residence time to be fully debarked.

**Ring Debarking:**

Used primarily to remove bark from saw logs and veneer bolts. An infeed conveyor advances the log longitudinally into the feed rollers, which automatically center the log in the rotating mechanical ring.

Typically, six air-loaded tool arms attached to a rotating ring provide a scraping action over the surface of the log, causing the bark to shear at the cambium layer. The relationship between the ring rotation speed, the number of tool tips, and the width of the tool tips is calculated to provide tool coverage with about five per cent overlap at operating feed speeds.

The ideal debarking machine is capable of providing high piece counts from a wide range of species and operating conditions, such as green, dry or frozen. The machine should also be able to handle a range of diameters and lengths.
Dual ring debarkers have shown to be effective in dealing with burnt wood, while some mills using a single ring debarker have added a second in-line. Many mills have designed a carousel system where logs that have not been satisfactorily debarked are kicked out and cycled back for a second pass. Where chip markets stipulate that no charred wood is permissible, “Rosserhead” debarkers have proven to be effective. Another option involves the use of flail ring debarkers for removal of the bark at the logging or sorting site. This option has not been popular in the west, but, if environmental concerns over handling and storage of burnt wood and the resultant leaching and run-off should intensify, debarking in the woods may become a more attractive option in this situation.

3 Stone Ground Wood (SGW)

Since Keller and Voith’s first grinders the principle of grinding technology has not changed too much. Essentially, wood is pushed up against a rotating stone to liberate the fibres. Stone Ground Wood (SGW) is still a very common way of making wood pulps.

![Figure: Typical grinder.](image_url)

The pulp wood is debarked and slit into 1 m lengths and fed through a chute into a chamber where a hydraulic piston pushes the logs against a rotating stone. Water is sprayed onto the stone to keep the wood cool during grinding. The resulting pulp is then falls into a pulp vat at the bottom.
Also note there is a stone sharpener that is used to cut very specific groove pattern into the stone periodically.

Figure: Temperature profile near wood surface.

The circumferential speed of the stone is approximately 30 m/s. The grinding pressure is approximately 250 kPa

The stone is made of small grains or grits. The grits deform the fibre-lignin matrix. The repeated visco-elastic deformation creates heat that softens the lignin in the middle lamella. This helps release the fibres from the wood matrix.
Fibres are ‘peeled’ out of the wood matrix from repeated action of the grits. Repeated passing of grits over the partially removed fibres helps to remove some of the lignin rich outer covering. It also helps increase the surface area of the fibres and the flexibility of the fibre. The higher surface areas gives more area for bonding together and the more flexible fibres allows for fibres to conform better to each other making smoother and more bonded paper.

Operating parameters

Grinders do not offer a lot of operating variables to modify the properties of the pulp produced.

You can vary

- Species: Almost always long fibres softwood, typically spruce because good strength can only be obtained with softwood.
- Amount of spray/dilution water
- Temperature of spray water (If the pulp is too hot it will darken the wood).
- Rate of wood feed
  - Pressure applied
  - Speed of grinder
  - Structure of stone
The resulting pulp contains a combination of long, intact fibres, broken fibres and fines. The fines can be broken down into three types, dust, fibrils, and flour. Long and short fibres provide strength to the paper.

The fines (small fibre cell wall pieces, defined as fraction that passes thorough a 200 mesh screen). Fines influence the smoothness and formation by filing the inter-fibre spaces during forming, also provide high scattering of light (scattering coefficient). High scattering means the fibres has a high opacity reducing read through on low basis weight (thin) papers. This is why they are almost always used in low weight printing grades, such as directory and newsprint papers.

**Pulp Properties**

As an increase amount of energy per tonne of pulp (*specific energy*) is applied during grinding, the fibres are being increasingly worked. That is, there is more energy going into producing more fibre surface area which results in increased paper strength. A standard measure of pulp / paper strength is the tensile strength and the tear strength. Tensile strength is a measure of the in-plane resistance to fracture of the paper while tear strength is an out-of plane measure of the fracture resistance of paper. The strength of the paper increases as specific energy increases.
Figure: Effect of increased specific energy on tear and tensile strength during grinding.

The ability for water to drain through the pulp, which can limit the speed of a papermachines operation also decreases with increased specific energy.

If too much energy is applied the pulp will start to darken. Typical brightness of unbleached SGW is about 65 ISO.

The scattering of the paper is very high which gives it a high opacity which prevents 'read through' which is where you can see the printing through the paper. (not good for newspapers).

*Stone Sharpening*
Although most stones are now made of ceramic, the stones wear out due to constant high speed abrasion and need to be sharpened about every 6-14 days. The sharpness of the stone affects both the specific energy applied to the logs and the throughput of the grinders.

The sharpening tool is used to periodically sharpen the stones by carving the shape of the grits back in.

**Improvements in grinding:**

Continuous grinders:

Instead of a hydraulic ram, the logs are pressed against the stone using a conveyor system. This allows the stones to be continuously loaded.
Pressure Ground wood (PGW):

The chamber that holds the logs is sealed such that the temperature during grinding can be increased and the water will not turn to steam. This softens the lignin even more which allows more long fibres to be liberated intact. The result is a stronger pulp.

Example,
The quality of the pulp produced during grinding is dependent on the temperature in the grinding zone. Fibre can be liberated largely intact if the lignin has been softened by temperature, however, if the temperature is too low the fibres will be largely broken or if the temperature is too high the wood will start to darken.
Since virtually all of the grinding power is dissipated as heat in the grinding zone, it follows that temperature in that zone is controlled by the addition of shower water.

For a given grinding operation, wood, F, and dilution, D, (kg/s) enter the grinder at $T_{in}$ degrees C. The suspension leaving the grinder at $T_{out}$ and at a consistency, C. Assume that the steam is not formed. Determine the electrical energy applied, $E$ (J/kg), to maintain these outlet conditions.