Kraft Pulp Mill Wood Chips

Chuck Walls

Industrial Equipment Manufacturing Ltd.

March 2021

Wood Chips for Kraft Pulping

When I first joined the Pulp and Paper Industry 30 years ago, I was tasked to write a paper on what was "The Perfect Chip". At the time, I didn't think that was a particularly good use of my time (I was 22). Now I now understand that the exercise was to teach me that, while there is no "Perfect Chip", the selection and handling of the raw material, and equipment to handle chips for the Kraft Pulping process, is paramount for both final pulp quality and Pulp & Paper mill profitability.

Fundamentals

Variations in wood supply affect pulp quality. These variations can be due to the wood species, the geoclimatic zone from which the trees were harvested, where the chip comes from within a log, the age of the wood, bark content, moisture content or the average chip dimensions (thickness) and chip size distribution. Wood handling equipment can also have a significant effect on the wood fed into the process. Pulp mills are designed for the specific specie(s) harvested, however, neither fibre morphology nor the most appropriate end use of pulp made from a particular wood species is the focus of this discussion. We will focus on the chips themselves - not fibre characteristics.

Whole Log vs. Residual Chips

Kraft Pulp is made from either residual chips (wood chipped from sawmill residuals) or from whole logs. Most hardwood mills use whole log chips in their processes. The majority of softwood mills in North America however, have historically relied on the solid wood industry providing the chips from sawmill residuals with only a small amount of whole log chips in the mix.

Residual wood is typically sapwood since it comes from the outer parts of the tree. Sapwood is superior to heartwood for making pulp due to a lower extractives content. Lower extractives content make chips easier to pulp and producing higher yields.[i] Heartwood is denser and drier than sapwood. For these reasons, the ratio of whole log chips to residual chips has an effect on pulp quality. In the last decade or so, many softwood pulp & paper mills are seeing higher volumes of whole log chips due to reduced availability of saw log quality timber and this is, subsequently, affecting pulp quality characteristics.

Bark

Bark is a problem for quality pulp production. Bark contains high extractives, high dirt and low fibre making it all but useless for making pulp.[i] Good bark removal prior to chipping is, therefore, imperative.

Moisture Content

Although Kraft pulping is a chemical process, the cooking liquor (caustic soda and sodium sulfide) must physically penetrate into the chips in order to ensure an even application. Moisture content of the chips plays a role in the ability of cooking liquor to penetrate chips and has other effects on the pulping process, as well.

Drier chips tend to be more brittle resulting in higher fines and combustible dust generation during chip handling and screening. Next, drier chips are typically also older and thus more acidic, resulting in a higher white liquor application needed to achieve the target extent of lignin removal in the digester (Kappa number). Thirdly, intrinsic moisture in the chips is critical during chip pre-steaming as the moisture in the chips expands and drives out air which allows easier liquor diffusion into the chips.[iii] Kiln dry wood is very difficult to pulp, for this reason, as the kiln drives the intrinsic moisture out of the chips. Finally, in continuous hydraulic digesters, chip moisture content can affect the hydraulic balance of the digester requiring variable make-up liquor flows that can impede plug flow and/or liquor circulation.

An interesting observation during the pine beetle devastation in Western North America was that the mills saw an unusually high volume of very dry, longer-dead wood than was typically experienced. It was expected that this wood would not accept liquor well. This turned out NOT to be the case. The wood seemed to soak up the liquor like a sponge and pulping was relatively easy, as a result. So the wood being naturally dry is not necessarily a bad thing for the cooking process but is still a significant problem in the chip handling area (fines generation & fire hazard due to combustible dust).

Chip Thickness

Chip thickness is an important factor in Kraft pulping.[iv] As mentioned, liquor penetration into wood chips is critical. Over-thick chips can see under penetration and result in uncooked wood after the digester. Small pins and fines can be overcooked and result in lower average fibre length (lower pulp strength) and lower yield. Generally, chip thickness should range from 2mm to 8mm with the majority being around 4mm thick. However, there is no "ideal" chip size but, rather, an ideal chip size distribution and, therefore, a good chip thickness screening system is very important.

A continuous digester's production rate is set by the speed of a pocket feeder called the "Chip Meter" or by a screw feeder. The production rate is calculated assuming a constant bulk density of the chips. Changes in chip size distribution can result in either over-feeding or under-feeding the digester due to bulk density variation and can result in lignin content variability (high Kappa number variability), poor yields and/or high reject rates. It is important, therefore, that the bulk density is relatively constant and this can be somewhat controlled by controlling chip thickness with a chip thickness screening system.

Of course, chips are made with a wood chipper. The style of chipper and the regular maintenance on the chipper are major contributors to good quality chips and optimal size distribution. An ideal size distribution is one where the bulk density is constant and optimal for maximizing production while allowing free flow of liquor through the plug in the digester.

Chip Quality

Debarking

As mentioned, good bark removal is important to ensure quality pulp production from a Kraft pulp mill. There are number of different technologies used depending on raw material, capacity requirements, log dimensions, debarker geographical location, chip cleanliness, typical weather conditions and white wood loss requirements.

Ring Debarkers

A Ring Debarker is a machine with a large diameter circular assembly to which a number of curved tools are fitted with knives or blades. The assembly rotates as the log is inserted into the 'ring opening' at a steady rate of speed. The tools are pressed against the log and the rotating action scrapes and cuts the bark. They work well with large diameter logs that are straight. The logs are processed one at a time (singulated) so these machines are not capable of very high capacity but do a thorough job of bark removal providing the logs are straight. White wood losses and maintenance costs can be high but capital costs are relatively low.

Figure 1 - A Ring debarker in the closed position.[1]

[1] http://www.salemequip.com/ring-debarkers.html

Flail Debarkers

Usually there is one drum on the bottom and two drums on the top. The drums rotate such that the loose chain is extended by centrifugal force. Logs are fed through the drums and the chains literally beat the bark from the logs. This is not a common debarking technology for pulp and paper mills, sawmills, or any other site where wood costs and cleanliness are both important factors. Typically, this is reserved for fully portable applications and where white wood loss and log cleanliness are not both important. Similar to a ring debarker, these are relatively low-capacity machines.

Figure 2 - Flail Drum.[2]

Drum Debarkers

A Drum debarker is a large diameter cylinder with slots cut into the shell. Lifters are welded/fixed to the inside of the drum. As logs are tumbled around inside the drum, they impact each other, and bark is removed via the slots. Drum debarkers will often require a method to thaw the bark prior to entering the drum to accommodate frozen wood. They are high capacity and can handle multiple diameters and lengths. Capital cost to purchase and install are relatively high, but maintenance costs are reasonable. White wood loss is low compared to flail or ring debarkers.

[2] https://petersoncorp.com/wp-content/uploads/Chipper-Duo-Brochure-Screen.pdf

Figure 3 - Drum debarker.

Rotary Debarker

The rotary debarker uses rotors with discs welded to the circumference. Each disk is equipped with abrading tips to cut the bark and rotate logs within a chamber to further enhance bark removal and ensure equal contact with the abraders. A Rotary debarker can be an end discharge (continuous operation) or a side discharge (batch device). There are openings between the abrader disks and the bottom of the debarker to allow effective separation of refuse from the debarked logs. These debarkers have no diameter restrictions and length is only limited by the box dimensions. They handle frozen wood well with no pretreatment required. Capital costs are relatively high but maintenance and operating costs are low. The debarkers can be configured as fixed or mobile units.

Figure 4 - Inside a High Capacity, End Discharge Rotary Debarker.

For pulp and paper applications where capacity, yield and cleanliness are important, drum debarkers or rotary debarkers are typically used. Debarkers for solid wood operations providing residual chips to pulp mills may have different debarking set-ups.

Table 1 - Debarker Characteristics.

Debarker Style	Min Diameter	Max Diameter	Max Length	Frozen Wood	Multiple Stems	Capacity	Crooked Stems	Log Cleanliness	Stringy Bark?	White Wood Loss	Capital Cost	Maintenance Cost	Operating Cost
Ring	Y	Y	N	✓✓	N	✓✓	N	✓✓	x	xx	$$	$$	$$
Chain Flail	Y	Y	N	✓	N	✓	Y	✓✓	✓	xxx	$	$$	$$
Drum	N	N	Y	✓	Y	✓✓✓	Y	✓	x	x	$$$	$	$
Rotary	N	N	Y	✓✓✓	Y	✓✓✓	Y	✓	✓✓	x	$$	$	$

Chippers

The importance of chip thickness and chip size distribution has already been discussed. Therefore, it is important that equipment selected to produce chips is chosen accordingly. There are basically 2 types of chippers: drum chippers and disc chippers. Both types introduce logs to blades (knives) mounted on either a disc or a drum spinning at high speed and force.

In a disc chipper, the knives are mounted in slots in a disc. The wood is cut against an anvil and once cut, pass through the disc, where casting plates will throw the chips out of the chute. The casting wings also generate a generous air stream, helping to blow the chips out of the spout.

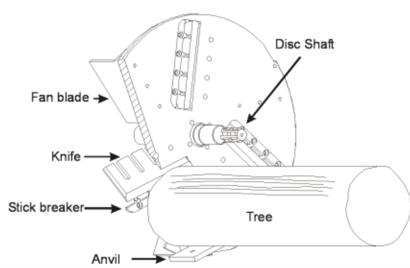

Figure 5 - Disc Chipper Disc Illustration. (http://woodenergy.ie/woodharvestingequipment/)

Disc chippers produce a high quality chip providing the knives are sharp and the logs are long and fed perpendicular to the disc. Shorter logs can turn in the feed chute and tend to produce “cards” that must be separated in screening after chipper operation.

In a drum chipper the knives are mounted on the periphery of a large steel drum. In front of the knife, there is typically a pocket, where the chips that have been cut are stored until they can be released behind or below the drum.

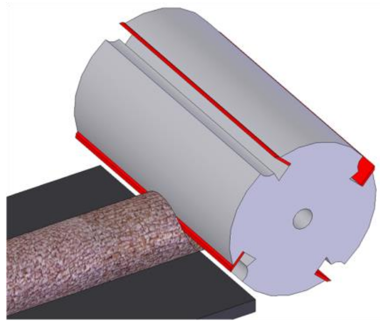

Figure 6 - Drum Chipper Drum Illustration. (http://woodenergy.ie/woodharvestingequipment/)

A drum chipper does not have fan blades on the drum and, therefore, an extra fan has to be added to blow the chips out of the spout or the chips can be dropped onto a conveyor belt.

Drum chipper chip quality is not typically as uniform as that achieved with a disc chipper. (http://woodenergy.ie/woodharvestingequipment/)

Air Density Separation

Most screening operations will feed oversize chips from the screening system to an air density separation (ADS) system to facilitate contaminant removal. The systems incorporate a fan and pocket feeder that allow heavier material (rock, metal, knots) to fall out and blows the lighter wood chips to the next process step. It is also typical for the ADS to be on the overs (rejects) from the primary chip screens. This means that any smaller rocks or metal that pass through the screens can still be introduced to downstream processes.

Figure 7- Air Density Separation System (https://acrowood.com/specialty/air-density-separator/).

Chip Screening

As described previously, chip size and size distribution are very important in Kraft pulping. There are a number of different technologies for screening – each with advantages and disadvantages. The basic principles of chip screening at a Kraft pulp mill is to ensure as uniform and consistent chip thickness and chip size distribution, as possible.

All screening systems should remove fines (<2mm in thickness), oversize material (>10mm thickness) and remove high density material such as rocks and knots. This is typically done is 2-3 stages of screening. As well, for yield and cost efficiency, oversize wood should be treated to either “reslice” the chips to thinner material or otherwise treat the chips to enhance liquor penetration. There are a number of screening technologies on the market designed to provide the three operational parameters needed to classify chips effectively: screening, agitation and residence time.

Bar Screens or Blade Screens

A Bar Screen or Blade Screen provides thickness screening based on the size of the opening between the bars (Inter-Facial Opening or IFO), agitation by the oscillation of the bars and residence time for screening by the length and angle of the screen. Bar screens are quite mechanically complex and efficiency can be affected by wear.

Figure 8 - Bar Screen.

Oscillating/Shaker/Gyratory Screens

There are many variations and manufacturers of this type of screen. Typically, they achieve screening by the use of a sieve (plates with holes and/or mesh screens) that are gyrated or vibrated mechanically. As with the bar screen, the dimensions and angle of the screen determine capacity and residence time. These screens are mechanically complex, as well, but are relatively inexpensive to purchase and can combine screening stages in one unit resulting in a smaller footprint. However, they are not normally “thickness” screens but separate based on the dimensions of the screen opening. These screens are also susceptible to blinding over if the screen opening approaches average chip dimensions. Changing screens is relatively easy if they become blinded or damaged, however. They are used more often in sawmills and chipping plants as a pre-screen prior to pulp mill delivery.

Figure 9 - Gyratory Screen

Disc Screens

Disc screens provide screening by allowing chips to fall between the interfacial opening (IFO) between discs as they are conveyed from feed to discharge by the serrated discs. Mechanically, disc screens are simple and maintenance is minimal. They lack the agitation to the degree provided by gyrator or bar screens, however, which may require additional footprint to achieve similar results. Residence time can be affected by angling the screen but this is not typically done. Disc screens are true thickness screens, however.

Figure 10 - Disc Screen.

Roll Screens

Roll screens are a variation on the disc screen that utilizes rolls of various designs to agitate and convey the chips along the screen. Similar to disc screens, the inter roll opening (IRO) determines the screening size. There are roll screens available now that provide the opportunity to adjust the IRO (while in operation) to fine tune the screens for incoming conditions or downstream requirements. If chip feed changes, as rolls wear or as downstream process conditions dictate, the operator can adjust the IRO of the screens accordingly. Roll screens are similar to disc screens in terms of maintenance costs, and they are also true thickness screens.

Figure 11 - Roll Screens.

Mat Screens

Mat screens use a series of offset rotors to undulate a flexible mat over which the chips pass. These screens provide excellent agitation to improve separation efficiency and do not suffer from blinding over to the extent of that seen with gyratory screens. The mats are made of a flexible plastic that are susceptible to failure with wear and use. The fact they are plastic is a concern for many pulp mills as plastic is difficult (if not impossible) to remove in downstream processing. However, many mills use these screens with great success. They openings on the mats are typically round or square holes and, therefore, are not true thickness screens.

Air Impulse Chip Screen

Another screen type uses air jets to separate chips by thickness is also available. This screen has the advantage of fewer moving parts than other screening methods. This screen has the ability to adjust accept and rejects fractions by manipulating the air flow/pressure. Maintenance would be low due to the lack of rotating equipment and dust control would be excellent due to the enclosed nature of the equipment. This type of screen has not been widely adopted (in North America, at least) as experience suggests additional, conventional screening is still often required.

Figure 12 - Andritz JetScreen©

Some types of screens are more suitable to primary screens designed for overs removal and some more suitable to fines screening. Many mills have chosen different screen types for the different stages to maximize efficiency. Capital, maintenance, and operating costs must be taken into consideration (as well as separation efficiency) when choosing the most appropriate screen and screening system.

Overs Treatment

Oversize chips reaching the cooking stage result in inefficient chemical use, yield loss and high rejects rates in subsequent processing steps. Typically, overs removed after primary screening are about 10% of the total chip feed. Because the value of acceptable wood chips is 2-3 times higher than that of hog fuel, they should be separated and treated prior to reintroduction into the digester feed. There two methods for doing this.

Re-chippers

One option is to "re-chip" the overs and create chips of acceptable thickness. The chips can then be added directly to the digester feed or be recycled to the primary screen feed. Typically, to avoid increasing chip screening system capacity, the re-chipped overs are added to the digester feed. This means that the re-chipping must be efficient enough to eliminate over-thick chips but create a minimum volume of fines. A re-chipper (or reslicer) is a variation of a wood chipper; designed with over thick chips in mind instead of logs. Unfortunately, experience with these devices is that of high maintenance (at a frequency and cost at parallel with a log chipper) and excessive fines generation. The high percentage of fines results in reduced digester yields and/or lower strength pulp. Reslicers are relatively low capital cost items, however, as they have a small footprint. Chip Sizers are a variation on the theme of reducing over-thick chips to acceptable thickness but are more closely related to hammer mill or wood hog. They tend operate slower than a hog unit and, reportedly, create only 5-15% reject material compared to up to 50% with a reslicer. They are also relatively inexpensive from a capital perspective, but maintenance costs are lower than a reslicer.

Chip Conditioners/Chip Crackers

An alternative to re-chipping overs is to increase the surface area available for liquor penetration by fracturing and dimpling the chips using a chip conditioner or chip cracker. These devices use two large drums with textured surfaces rotating towards each other. Chips pass through the nip created by the rolls and are "dimpled" by the roll texture and fractured (or cracked) by the force of the rolls coming together. This effectively creates a chip that liquor can penetrate as easily as a chip with optimal thickness. These are capitally expensive machines, however, and require a large footprint. Typically, due to their size in comparison to a reslicer or chip sizer, additional conveying equipment must also be purchased to accommodate feeding these machines. They are far superior, however, for fines generation in comparison to a reslicer or chip sizer and this fact (along with maintenance costs) has been used as justification to replace many chip slicers in mills. Studies done on over-thick chips fed through one of these devices, however, have indicated that intrinsic damage to fibres results in lower fibre lengths and handsheet strength.[v] This should be considered in equipment selection and balanced against yield losses from fines generation and capital, maintenance and operating costs.

Figure 13 - Acrowood Chip Cracker.

Figure 14 - Jeffrey Rader Chip Sizer.

Storage

Often a chip pile is just that – a pile of chips. Chips are introduced to the pile by conveyor using a “flinger” or some type of rotating conveyor arm to distribute the chips or are dumped on the ground and pushed onto the pile by bulldozer. A bulldozer will also be used to push the chips into a reclaim conveyor where the chips will be introduced to the process via a belt conveyor or chip blowing system. This type of system is closer to a first in – last out (FILO) system. Blower systems are rare now due to high energy requirements and because of significant chip breakage.

A better system is a first in – first out (FIFO) system but these are very expensive. A true FIFO system will result in higher pulp/wood yield and more consistent final pulp properties due to consistent aging and minimal handling. They can also reduce manpower to operate mobile equipment. Typically, FIFO systems are found in jurisdictions where chip costs are higher and even small increases in yield can result in significant payback. You can also see FIFO systems where multiple species are stored and metered into the process when certain pulp recipes are required or variations in chip feed ratios will upset the process. Chip silos can also achieve this purpose but storage capacities tend to be more limited. Winter conditions can be problematic for chip silos, as well, but a good screw and slew chip removal system can alleviate those challenges. FIFO systems come in different stacker reclaimer arrangements but are typically either in a circle or in an 'A' frame configuration.

Figure 15 - Bulldozer pushing chips on a FILO chip storage pile.

Figure 16 - Circular Blending Bed Stacker Reclaimer (Bruks Siwertell).

Figure 17 - 'A' Frame type FIFO Stacker Reclaimer (Valmet)

Figure 18 - Wood Chip Silos.

Wood chips can represent 25-50% of the manufacturing costs of a Kraft pulp mill yet wood handling is often the most neglected area of the mill. Equipment selection, operation and maintenance in wood handling can have a significant effect on the bottom line of any Kraft Pulpmill but, as wood costs continue to escalate and competitiveness in the market place tightens, the importance of these factors is increasing. With the age of the average Kraft pulp mill in North America well over 30 years, modernizing wood handling operations has the potential to yield high returns.

---

[i] Harder, M. et. al., (1978), "Bark Fibrous Yield for 42 Pulpwood Species", *Tappi Journal*, Vol 61, No. 11, http://www.kraftpulpingcourse.knowledgefirstwebsites.com/f/Harder1978.pdf