EFFECTS OF SELECTED FACTORS ON
SAWMILL RESIDUE WOOD CHIP QUALITY

by

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(ABSTRACT)

This study examined the effects of disk speed, temperature and anvil condition on chip size from sawmill residues of Loblolly pine (Pinus taeda L.). Objectives were: 1) to document the effects of disk speed, temperature and anvil condition on the amount of overthick, oversize, accept, pin and fine chips produced from edgings, 6"x6" cants and trim blocks and 2) to recommend changes in processing sawmill residues to minimize the production of overthick, pin and fine chips. Ten trials were conducted at the Chesapeake Corporation's West Point, Virginia hardwood sawmill using a Fulghum Industries 60-in. (152-cm) diameter, six-knife, vertical disk chipper.

Tests were conducted at approximately 80, 70, 60, 50 and 40% of the full disk speed of 707 rpm for the three material types. It was found that decreasing disk speed decreases the amount of pin and fine chips and increases the amount of overthick chips for all material types. The
maximum amount of accept and oversize chips was obtained at 50% disk speed. If 50% efficient secondary processing of the overthick chips is achieved, the maximum amount of oversize and accept chips would be produced at 40% disk speed.

All frozen and chilled residue types tended to produce less oversize chips and significantly more pins and fines than wood at ambient temperature.

A worn anvil caused a significant increase in pins and fines while causing a significant decrease in oversize chips from the cants.

Design changes are suggested to reduce the amount of overthick chips produced by vertical disk chippers.
Acknowledgements

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I would like to extend my appreciation and thanks to family and friends for their prayer and support. Thanks Mom and Dad for always being there. Special thanks to my loving wife, Diane, who listened to the worst and most about my project. Your patience, inspiration and companionship were most needed. But this project would not have been a reality for me had it not been for the strength
of my Lord and His Son Jesus Christ.
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CHAPTER 1. INTRODUCTION

Approximately 35% of the weight of a pine log processed by a southern sawmill becomes wood chips for pulp production (Leary and Stuart, 1991). Often the receipts from lumber sales cover only the operating expenses of a sawmill. However, at 20 dollars per ton (22 dollars per metric ton) of pulpable chips, a sawmill can usually produce enough furnish from its residue wood to provide a margin of profit. Since marketing sawmill wood chips has been a source of income for sawmills, they are a major contributor to the total furnish of the southern United States pulp industry; over 73 tons (66 million metric tons) are consumed each year (Leary and Stuart, 1991).

Pulp and paper manufacturers will gain from any improvement in the quality of wood chips received from sawmills. Poor quality wood chips reduce the overall operating efficiency of the digester. For instance, at the Halsey, Oregon pulp mill, 20 tons (≈18 metric tons) of overthick chips were rejected each day. These chips required more than one cycle through the digester to completely dissolve the lignin in the chips. "This reprocessing of the rejects consumes additional steam and cooking chemicals while taking up space in the digester which could be occupied by fresh chips (Thireault, 1985)."
Consequently, an additional 20 tons (∼18 metric tons) of chips could have been processed if there were no overthick chips.

Wood chips that do not meet the specifications of the pulp manufacturers are used for fuel. Chips only suitable for fuel are sold for a mere seven to eight dollars per ton (∼eight to nine dollars per metric ton), a loss of 12 to 13 dollars per ton (∼13 to 14 dollars per metric ton). Clearly, any gain in the amount of quality wood chips produced is of a significance that both the sawmill and the pulpmill can appreciate.

This project is the second of a series of two studies conducted to explore the effects of chipper speed, wood temperature, summer and winter wood physiology, knife sharpness angle, and anvil condition on the quality of wood chips produced from southern pine sawmill residues. The first study examined the effects of disk speed, wood temperature, summer wood physiology, knife sharpness angle, and anvil condition on 6"x6" cants used as controls, slabs, edgings, and trim blocks. This second study examined the effects of disk speed, wood temperature and anvil condition on 6"x6" cants used as controls, edgings and trim blocks. The effect of winter wood physiology was not tested since the winter of 1990-1991 was too mild to have true dormancy of Loblolly pine (Pinus taede L.), the species of wood that
was tested.

Ten trials performed during the winter of 1990-1991 (dubbed the 'winter trials') were selected to succeed the 'summer trials' conducted by Pam Leary and William Stuart. Three areas of investigation were determined necessary. Two temperature trials paralleling those used by Leary and Stuart (1991) were chosen to ascertain if the cause of excess pins and fines during cold, winter conditions was temperature or physiologically dependent. However, the contention that excess pins and fines is influenced by the physiological state of a tree in dormancy could not be tested due to the mild conditions of the winter of 1990-1991. The results from the work of Leary and Stuart were not completely conclusive on the effects of a worn anvil on chip quality; therefore, that trial was repeated. More evidence was necessary to prove anvil wear does not effect chip quality. Three knife sharpness angles were tested by Leary and Stuart, but the differences from the recommended angle were not great enough to warrant further research in this study. This allowed further testing of the effect of disk speed on wood chip size. Their work indicated that decreasing disk speed decreases the amount of pins and fines produced for all material types, although only two speeds below full disk speed were tested. Five disk speeds were tested in these trials to better establish
this relationship. Slabs were not included in this study since it was determined from the summer trials that the size distribution of slabs was nearly the same as edgings. In addition, the amount of pins and fines produced from slabs at this mill is biased by the rosser head debarker.

OBJECTIVES

The objectives of this study were twofold:

1) To document the effect of material type, disk speed, wood temperature and anvil condition on the production of overthick, oversize, accept, pin and fine chips.

2) To recommend changes in operation, adjustment or design to minimize the production of overthick, pin and fine chips.
CHAPTER 2. LITERATURE REVIEW

Over the years, pulp mills have been able to better define the size of the chips that yield the most and best quality. They require a minimum of overthicks, pins and fines. This demand has been reflected in the research to improve whole-tree and round-wood chipping, but less work has been done on sawmill residue chips and chippers (Cramond, 1985). This lack of information is the motivation of this study. It is not clear if all of the principles that apply to round-wood and whole-tree chipping have a place with sawmill residue chipping.

PULPING REQUIREMENTS

Chip Size

All chips regardless of size are pulpable, but some sizes return a higher yield for the same chemical and energy input. The consuming mills have engaged in a constant pursuit of improved chip quality, tightening specifications to match improvements in technology, increased control of the pulping process and refined customer expectations (Figure 2.1 and Table 2.1).

Kraft and sulphite pulp mills are concerned with
Figure 2.1 - Typical chip shape for acceptable chip from a disc chipper. (Cramond, 1985)
Table 2.1 - Effect of chip specifications in pulp processing. (Logging and Sawmilling Journal, - )

<table>
<thead>
<tr>
<th>CHIP PARAMETER</th>
<th>PULPING PROCESS</th>
<th>Kraft</th>
<th>Sulphite</th>
<th>NSSC</th>
<th>Refiner-Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length preferred range, mm</td>
<td>Not too critical</td>
<td>Critical</td>
<td>Not Known</td>
<td>Not known</td>
<td>Not known</td>
</tr>
<tr>
<td>Width</td>
<td>Not critical</td>
<td>Not critical</td>
<td>Not critical</td>
<td>Not known</td>
<td>Not known</td>
</tr>
<tr>
<td>Thickness preferred range, mm</td>
<td>Very critical</td>
<td>Not critical*</td>
<td>Not known</td>
<td>Not known</td>
<td>Not known</td>
</tr>
<tr>
<td>Chip density</td>
<td>Constancy critical</td>
<td>Critical for production economy</td>
<td>Critical for plate life</td>
<td>Critical</td>
<td>Critical</td>
</tr>
<tr>
<td>Bark content preferred range, %</td>
<td>Critical for production economy</td>
<td>Very critical</td>
<td>Critical for production economy</td>
<td>Critical</td>
<td>Critical</td>
</tr>
<tr>
<td>Hard impurities (sand, metal)</td>
<td>Critical for high yield</td>
<td>Critical for dissolving pulp</td>
<td>Very critical for plate life</td>
<td>Critical</td>
<td>Critical</td>
</tr>
<tr>
<td>Chip damage</td>
<td>Not critical</td>
<td>Very critical</td>
<td>Not critical</td>
<td>Not known</td>
<td>Not known</td>
</tr>
<tr>
<td>Moisture content</td>
<td>Not critical</td>
<td>Not critical</td>
<td>Not critical</td>
<td>Not known</td>
<td>Very critical</td>
</tr>
</tbody>
</table>

*With increasing chip length in sulphite pulping, chip thickness assumes increasing importance for ease of liquor penetration.

Source: PAPRICAN
reducing the amount of overthicks, pins and fines in the chip furnish to their digesters. These chips reduce the overall operating efficiency of the pulping process and consequently reduce profit. All other chips in between these sizes are usable or more easily pulpable.

Overthick chips require additional pulping time. Undissolved fractions are screened out at the end of a batch and returned to the next batch, thus displacing chips that would have required only one pass through the digester (Thireault, 1985). Most mills in the southern United States define overthicks from Loblolly pine as anything that will not pass an 8-mm bar screen.

Pins and fines cause problems for both continuous and batch digesters. They are a parasitic drain on the entire pulping system with little or no pulp yield. By definition, they are chips that are not retained on a 3/8-in. (9.53-mm) screen. The problems of pulping them are well put by McMichael (1983) of Champion International Corp. at Missoula, Montana. "A high percentage of fines will hang the plug in our digester, stopping production, cause us to lose the extraction flow, cause poor cooking control, reduce the effectiveness of internal washing, and overload external washers. The pulp produced will cause us to lose speed and strength on our paper machines." Pin chips also inhibit the flow within a digester causing poor
heat transfer and cooking liquor circulation. Consequently, a heterogeneous cook will result consisting of "undelignified fiber bundles" (Hartler, et al., 1977). On an individual basis, the pulp quality of pin chips and fines is about 90 and 75%, respectively, of that from acceptable chips when examining the strength properties of the pulp, that is, the burst factor, tear factor, and breaking length at 300 ml CSF (Hatton, 1975).

Wood chip bulk density strongly influences the amount of wood that can be processed by the digester. Bulk density is controlled by two parameters: the ratio of the diagonal dimension to the thickness dimension of the wood chip, and the consistency of the chip size. The ideal ratio for industrial chips is 10 or higher for fairly homogeneous chips, resulting in an unique bulk density (Figure 2.2) (Gislerud, 1976). Addition of overthicks to this uniform sample raises the bulk density by displacing particles and the void space between them. Addition of pins and fines will cause an increases in the bulk density double that of the overthicks because it fills the voids between chips without displacing other chips. Addition of either of these to homogeneous chips results in uneven filtration resistance throughout the mass of chips in the digester. In turn, the heat transfer and circulation of the cooking liquors is inhibited and finally results in a
Figure 2.2 - Bulk density according to a standard laboratory procedure in relation to the ratio between average diagonal (D) and thickness (T) for some different industrial chip samples. (Gislerud, 1976)
non-uniform cook (Gislerud, 1976).

Kraft pulping

Chip thickness is the critical chip dimension, in kraft cooking (Figure 2.3). Diffusion of the cooking liquor occurs in the three main directions of the wood at nearly the same rate. Controlling the thickness of the chips affects the overall uniformity of penetration of the liquor into and ultimately the delignification of the chips. A more uniform cook means more fiber extracted per batch (Gislerud, 1976). Those chips which are too thick to be fully processed are removed from the pulp fiber as rejects and are returned to the digesters to recook. "This reprocessing of the rejects consumes additional steam and cooking chemicals while taking up space in the digester which could be occupied by fresh chips," according to Thireault (1985). At his mill, 20 tons (18 metric tons) per day of rejected overthick chips translates to 20 (18 metric tons) tons per day of lost pulp production.

Laboratory prepared chips are 0.48 to 0.67 times as thick as commercial chips (Hatton, 1989 and Gislerud, 1976). They are solid and without surface defect or cracking. Commercial chips have fissures, cracks and corrugations along the grain. The nominal thickness of a
Figure 2.3 - Weight distribution of chip thickness for an industrial chip sample. (Gislerud, 1976)
commercial chip is larger than its true thickness. The fissures and lamellations of the industrial chips provide quicker penetration of the liquors than for solid chips. Hatton (1975) suggests using 13/32-in. (10-mm) as the upper thickness limit for softwood chips. Thireault (1985) reports that the James River Corp. mill in Halsey, Oregon uses a 1/4-in. (6-mm) thickness screening system to limit the amount of overthick chips to its continuous digester.

A lower limit of chip thickness can also be established; chips too thin lack mechanical stability and may present a problem in processing. In a few instances they will lower the quality of the final product. The severity of handling these chips can result in reduction to smaller size fractions (Gislerud, 1976).

Length of the chip is not as critical a dimension in kraft pulping since thickness determines the cooking time. However, in commercial chippers, length is related to thickness at approximately a 5 - 7 to one ratio. Typical chip length should be 19/32 to 1-3/16 in. (15 to 30 mm) for kraft cooking. This ratio is important for two processes: screening for acceptable chips with round-hole screens, and setting the proper chip length on a chipper since thickness cannot be directly set (Nelson, et al., 1989 and Gislerud, 1976).
Sulfite pulping

Sulfite pulping is an acid process using sulfur dioxide and lime typically for cooking coniferous pulp. Advances in this process have produced pulps of superior quality (Britt, 1970). In sulfite pulping, length along the grain is the more critical dimension of the wood chip, because the cooking liquors primarily penetrate the chip along this dimension. Thus, the upper limit of chip length is set by the penetration time necessary to delignify the fiber. Long cooking times would result in degrading and possibly dissolving the outside fibers. A typical upper length limit would be 1-3/8 to 1-9/16 in. (35 to 40 mm). Chips cannot be too thick since length is related to thickness as previously described. Short chips cause similar problems, loss of the outside fibers occurs as previously stated. In sulfite pulping, strength of the pulp is strongly related to fiber length; therefore, maximum fiber length is necessary. "There is a recognized relationship between chip length and resulting mean fibre length of the pulp: the shorter the chip in the grain direction, the higher the frequency of fibres cut during chipping and thus the shorter the mean fibre length," as shown in Figure 2.4 (Gislerud, 1976). Consequently, the shorter the mean fibre length, the weaker the pulp.
Figure 2.4 - Calculated relationship between average fibre length and chip length, assuming the average fibre length in the uncut wood to be 3.0 mm. (Gislerud, 1976)
FACTORS THAT AFFECT CHIP SIZE

Chip Formation

Chips are created by the severing action of the knives of a disk chipper on a piece of wood. This type of orthogonal cutting can be described by a two-number notation developed by Mckenzie (1960) as 90-90 (Figure 2.5). The first number is the angle of the cutting edge of the knife relative to the grain of the wood. The second number is the angle between the direction of travel of the knife edge and the grain.

A description of the process of forming chips on a vertical disk chipper as seen in Figures 2.6 and 2.7 follows. The wood enters the infeed spout of the chipper at an acute angle to the disk. Proper orientation of the wood is with the grain parallel to the spout and resting against the vertical anvil. The knife of the chipper forces the wood against the anvil and applies a shearing force across the grain resulting in severing a section off of the original piece. Simultaneously, a shearing force is applied along the grain of the piece being severed by the wedging action of the knife. This produces two simultaneous results. First, the severed section is sheared into several smaller pieces, called chips, by
Figure 2.5 – Designation of the major machining directions. The first number is the angle the cutting edge makes with the grain; the second is the angle between cutter movement and grain. (Koch, 1985)
Figure 2.6 - Fulghum chipper casing and disc assembly. (Fulghum Ind., Inc. - )
<table>
<thead>
<tr>
<th>CHIP LENGTH</th>
<th>3/32&quot;</th>
<th>5/32&quot;</th>
<th>3/32&quot;</th>
<th>7/32&quot;</th>
<th>1&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td>'A'</td>
<td>3/16</td>
<td>21/64</td>
<td>13/32</td>
<td>1/2&quot;</td>
<td>.6157</td>
</tr>
</tbody>
</table>

Figure 2.7 - Chipping components and knife setup length. (Fulghum Ind., Inc., - )
exceeding the shear strength along the grain of the wood. Second, the reaction to this shear force causes the wood to be pulled into the disk for the succeeding knife to cut the wood. The clearance angle of the knife (Figure 2.8) controls the amount of pull in, which consequently affects the chip length, chip shape, the amount of bruising, compression damage and disk wear. Regulation of the chip length is shared with the set up length or the distance that the knife projects in front of the disk wear plate (Figure 2.7). Chip thickness is determined by a combination of the physical properties of the wood and the shear force from the wedging action of the knife (APA, - ).

Knife Angles

Improvement in chip size quality by varying knife angles has been successful in round-wood chipping. The four angles that influence overall results are the sharpness, clearance and cutting angles and the complementary angle to the sum of these three angles (Figure 2.8). The cutting or spout angle is fixed. The sharpness angle is the actual angle of the knife. A change in it corresponds to a direct change in the clearance, rake or "pull-in" angle for knives mounted so that they extend through the disk. Typically, the clearance angle is
\[ \lambda = 90 - (\alpha + \beta + \varepsilon) \]

Figure 2.8 - Vertical cross section with the angles \( \alpha \) (= clearance angle), \( \beta \) (= sharpness angle) and \( \varepsilon \) (= cutting angle) and the angle \( \lambda \) defined through the above angles. (Hartler, 1977)
maintained at 6°. Changing the sharpness angle on knives that are face mounted corresponds only to a direct change in the complementary angle. According to Hartler, et al. (1977), this complementary angle influences undersize chips (those that pass through a 3/16-in. (5-mm) circular opening) and the chip thickness without increasing chip length. The quantities of both fractions can be reduced by increasing this angle. Leary and Stuart (1991) found that sharpness angle had less influence on chip quality on sawmill residues than as predicted by Crowell, et al. (1961) and Hartler, et al. (1977) in round-wood chipping. The sharpness angles Leary and Stuart (1991) studied were 30, 31, 32 and 33°. Only the clearance angle was changed by the change in sharpness angle because the knives were mounted through the disk.

Anvil Condition

Anvil wear causes excessive amounts of overthicks, slivers and fines (Logging and Sawmilling Journal, - and APA, - ). An anvil in fresh condition will properly position the wood relative to the chipper disk and knives resulting in proper chip length and thickness. As the anvil wears, the angle between the anvil and the disk decreases allowing the wood to tip to an acute angle as it
is being chipped. Excessive wear of the anvil will leave the wood supported in a non-uniform manner (Figure 2.9). This will allow slabs and shingles to pass the anvil by the forcing action of the knives. The unsupported portion of the wood will shatter, forming excessive pins, fines and slivers. Cramond (1985) verified that the knife-to-anvil clearance is critical to reducing excessive amounts of chips over 1-1/8 in. (28.58 mm) and under 3/8 in. (9.53 mm) on wastewood chippers. Increasing this dimension steadily increases the production of these fractions (Figure 2.10). However, a properly set knife-to-anvil clearance is nullified by a worn anvil (Cramond, 1985).

Disk Speed

The effect of disk speed on chipping round-wood has been well documented over the years; the slower the disk speed the larger the chip size. The implementation of higher chipper speeds has been endorsed by chipper manufacturers to claim the ability of their chippers to chip at high production rates (Hartler, et al., 1977). In combination with more knives, this has usually worked for round-wood chipping, although at the sacrifice of producing extra pins and fines. But the principles of round-wood chipping may not so easily apply to sawmill residue.
Figure 2.9 - New and worn anvil from left to right.
Figure 2.10 - Screened fractions < 3/8" and > 1-1/8" versus anvil to knife clearance. (Cramond, 1985)
chipping. Some of the problems associated with round-wood chipping were inherited by using the horizontal disk chipper, a unit originally designed for chipping round-wood. Simple modifications were made to it to improve its performance with sawmill residues, but it cannot always do as good a job as it does with round-wood. The few studies on chipping sawmill residue that exist do verify the principle that increasing disk speed shifts the chip size distribution to the smaller fractions. A study performed by CAE Machinery chipped 8 ft. (2.44 m) long, green hemlock 2"x4" boards at disk speeds from 150 to 600 rpm on a 65-in. (165-cm) vertical disk, horizontal feed 8-knife chipper. They found that as disk speed increases, the amount of chips retained on a 1-1/8-in. (25.58-mm) hole screen decreases significantly when increasing disk speed from 150 to 350 rpm and nearly goes to zero at 600 rpm (Figure 2.11). The amount of chips passing through a 3/8-in. (9.53-mm) hole screen decreased as disk speed increased from 150 to 400 rpm. However, above 400 rpm the pins and fines increased significantly. The combined effect of the two categories is a parabolic curve with the minimum at 425 rpm and increasing on either side with increasing and decreasing speeds (Figure 2.11) (Cramond, 1985). Hartler, et al. (1977) tested cutting speeds from 65.62 to 82.02 ft/s (20 to 35 m/s) resulting in nearly doubling the amount
Figure 2.11 - Screened fractions < 3/8" and > 1-1/8" versus disc speed for 2" x 4' x 8' green hemlock boards. (Cramond, 1985)
of pin chips and undersize fractions (through 3/16 in. (5 mm) in thickness) from 3.94 - 7.87 in. (10 to 20 cm) and 19.69 in. (50 cm) sawmill trim blocks. He found that "any increase in cutting speed from approximately 25 m/s results in increased quantities of pins as well as undersized chips. It is therefore advisable not to exceed 20 - 25 m/s in cutting speed,...." However, overhead discharge disk chippers must be operated above a certain disk speed to insure proper conveyance of the chips through the transport system.

Temperature

The effect of temperature on chipping is known for producing high amounts of overthick chips at warm temperatures and high quantities of undersize and pin chips at cold temperatures. Hartler, et al. (1977), found a doubling and tripling in the amount of pins and undersize chips, respectively, across a temperature range of 59° F to -22° F (+15 to -30° C). The quantities of pin and undersize chips changed linearly with temperature. A parallel trend was found by pulp mills in Sweden. A non-linear relationship was anticipated considering changes in physical properties with temperature. A mill in Georgia also found the production of pins and fines inversely
proportional to the temperature throughout the seasons. At the extreme temperatures, this variable had a lesser effect. The work of Hartler, et al. (1977), also shows that increasing the disk speed from 98.42 to 131.23 ft/s (30 to 40 m/s) doubles the amount of pins and undersize chips (through 5 mm) across nearly the entire temperature range of 59°F to -22°F (+15 to -30°C). This suggests that lower disk speeds would be appropriate during the colder months. The Quinnesec, Michigan woodyard of Champion International Corp. has successfully attempted to reduce the quantity of overthicks at warm temperatures and the amount of 0- to 5/32-in.- (0- to 4-mm-) thick chips at cold temperatures by adjusting the setup length of the knives (Nelson, et al., 1989).

Dormancy

Literature that discusses chipping in winter and summer conditions contributes the differences between them to the change in temperature. Dormancy in the winter is not considered a factor. Hartler, et al. (1977), showed strong evidence of a linear relationship between temperature and chip size. Although, he did not anticipate a linear relationship since other interacting physical properties of the wood would vary with temperature as well.
This finding does not support the effect of dormancy on chip size. Other researches also do not address the issue of dormancy when referring to effects on chipping during summer versus winter. However, experiments performed several decades ago have already established that "the time of felling may, and often does, affect the properties of wood ... due to the weather conditions rather than to the condition of the wood (Record, 1914)," that is, the physiological state of the tree. Record goes on to add that the only portion of the tree that experiences seasonal change to an extent is the sapwood since heartwood is dead wood. The density of the sapwood essentially does not change throughout the year with exception to the layer of cells forming beneath the bark. Record (1914) concludes that "the time of cutting can have no material effect on the inherent strength and other mechanical properties of wood except in the outermost annual ring of growth." Most sawmill residues are the outer portion of the tree, of which only a fraction contains the outermost annual ring of growth.

Moisture Content

Moisture content of wood typically reduces the mechanical properties of wood. However, the energy
required to reduce wood into particles is not clearly related to moisture content. Grinding dry wood residues requires less power than does green (Koch, 1985). This effect on the comminution of wood tends to vary the output of chips as well, although it is not completely understood. Low moisture content may lower the amount of acceptable chips. The "consistency of chip quality" could be controlled by "specifying the moisture content..." according to Cramond (1985). McKenzie (1962, 1960) states that moisture content influences how chip formation occurs resulting in different size chips. He found saturated wood to form more chips of acceptable size that probably would not require carding. At 5 percent moisture content McKenzie found fracturing of chips below the plane of the knife which would result in poorly formed chips. An excess of oversize, overthick, pin and fine chips would most likely be produced.

Material Types

Typical waste wood materials in a sawmill that are being chipped for pulp are slabs, edgings and trim blocks. Fewer slabs and edgings are chipped because more sawmills are gearing their production toward direct conversion of wastewood into chips via chip-n-saw or similar arrangement.
This is in part due to the intended purpose of the sawmill; that is, produce lumber first and chips as a byproduct. The mills that focus on lumber production are more likely to have all three material types (Stuart, 1992). Trim blocks produce the least acceptable chips of the three sawmill residues. Ray Jorgensen (1985) of Nicholson Manufacturing Co. reports that about half the number of trims are in the range of one to two in. in length, sometimes called "nubbins." The remainder of the trims are between one and two ft. in length. It is the shorter pieces that cause the majority of the poorer quality chips because of the difficulty in presenting them to the chipper and maintaining that proper orientation. Jorgensen (1985) goes on to say that these "nubbins" are only reduced to small blocks or cubes by the chipper but are screened as accepts. Unfortunately, they do not completely delignify in the digesters resulting as rejects on the deknotter screens and contributing nothing to the final yield.

In a study conducted at the Westvaco Lumber Co., Summerville, NC sawmill by Wallace and Stuart (1992), 5% (by weight) of the total trim blocks were end trims and the remaining 95% were grade and wane trim in 2 ft. (61.0 cm) lengths. No more than 45% of these end trims were converted into acceptable chips when chipped. The remaining trim blocks they measured produced acceptable
chips ranging from 60 to 75%. (The oversize chips they measured are not included in these percentages.)

OTHER METHODS TO REDUCE OVERTHICK CHIPS

These methods are secondary processing of overthick chips screened out from the chip stream of a round-wood chipper. The simplest, least expensive and most often used method is to reintroduce the overthicks back to the chipper. This method will result in a pulpable chips level of 40 to 50%. Rechipping is used by some pulp and paper mills where they dedicate a chipper to chipping overthicks. The Newsprint South mill has a Murray 60-in. (152-cm), 15-knife, blowing rechipper set up for a 0.75-in. (19.05-mm) nominal chip length. Similar units can convert as much as 50% of the overthicks to nominally acceptable chips, as low as 8% to pin chips and thins, and 2% to fines. Chip slicers offer up to 90% conversion of overthick chips to accepts. However, the balance of the overthicks is 2% fines and 18% pins and thins. In comparison to rechippers, they are more expensive to set up, purchase and run and require more expensive protection from contaminants (Stoves, 1991). They also are limited in their ability to handle slabs and shingles (Stuart, 1992).

A drop-feed, drum chipper with a specially serrated
anvil offers an alternative (Figure 2.12). The knives are mounted on the drum so that they mesh with the notched anvil. The knives extend 3/16 in. (4.76 mm) from the drum surface to mate with the notched portion of the anvil and the knives that extend 1/16 in. (1.59 mm) from the drum match with the raised portion of the anvil. Chips formed by this chipper can either enter the drum through the chip slot that precedes the knife or pass the anvil. The chips inside the drum exit one end of the drum. The chips that pass the anvil either fall through the screen below or are recut before going through the screen. This chipper is designed to minimize the amount of oversize and sliver chips produced from overthick chips, but it has also been found effective in chipping end trims (Jorgensen, 1985).
Figure 2.12 - Small knife drum chipper with serrated anvil to chip oversize and overthick chips. (Jorgensen, 1985)
CHAPTER 3. METHODS AND PROCEDURES

A series of ten trials were conducted to study the effect of temperature, anvil condition and disk speed on the size distribution of wood chips from sawmill residue. The test setup and the sampling procedure used were refinements of the system previously used in the summer trials (Leary and Stuart, 1991). As previously discussed, selection of the ten trials was based on the results of the summer trials and the mild winter conditions. The ten trials conducted included the following:

- beginning control
- 50 percent disk speed (354 rpm)
- 60 percent disk speed (424 rpm)
- 70 percent disk speed (495 rpm)
- 80 percent disk speed (566 rpm)
- 90 percent disk speed (636 rpm)
- chilled materials (36° F (2° C))
- frozen materials (25° F (−4° C))
- worn anvil
- ending control

Within each trial, tests were conducted with three material
types: cants, edgings and trim blocks. Each trial was replicated three times, resulting in a total of 90 tests.

EXPERIMENTAL SETUP

Chipper

The winter trials were conducted at the Chesapeake Corporation’s West Point, Virginia hardwood sawmill in mid-March 1991. A Fulghum Industries 60-in. (152-cm) diameter, six-knife, vertical disk chipper used for the trials has a horizontal, vibrating conveyor for an infeed and a top discharge (Figure 3.1 and 3.2). It is powered by a 200+ hp. (150+ kW) electric motor. Before the trials, the manufacturer restored the chipper to factory-fresh condition. The specified operating speed of the chipper is 707 rpm.

During normal operation of the chipping system, the wood chips are blown through the overhead discharge to a cyclone settler. The chips then drop onto a gyrating two-screen pack. The top screen retains the overthick chips and diverts them back to the infeed conveyor for rechipping. The bottom screen removes the pins and fines and diverts them to the sawdust conveyor for fuel. The pulpable chips pass through the bottom screen to a rotary
Figure 3.1 - Chipper experimental setup: sampling area, chute and buckets.

Figure 3.2 - Chipper experimental setup with vibrating conveyor in foreground and chip vans in background.
valve that meters the chips into the discharge of a blower carrying them into a chip van (Figure 3.1).

During the trials, the top screen of the gyratory screen pack was blinded with tight fitting sheets of wood-tempered hardboard. This arrangement diverted the entire flow of chips down the chute normally used to route overthick chips back into the chipper. This chute was extended to carry chips over the chipper infeed conveyor and onto the concrete pad adjacent to the chipper infeed for taking the samples (Figure 3.2).

Trials

The West Point mill, laid out for producing hardwood lumber, was used for these trials because of location, ease of access to the chipper and ready accessibility of pine material in the immediate area. The equipment used in the trials: a chipper, conveyors and screens, are common to both hardwood and softwood mills. The species of wood used for these trials was Loblolly pine (Pinus taeda L.).

A 25 ton (23 metric ton) load of wood was harvested locally and converted to lumber during the week prior to the trials. The lumber used in the trials was prepared into three material types during off-production hours: 6-in. by 6-in. (15.2 cm by 15.2 cm) cants (henceforth
called 6x6 cants), edgings and trim blocks. Additional cants were purchased locally since not enough could be made from the original load of logs. The cants weighing approximately 200 lbs. (90 kg) each, were intended to serve as a standard of comparison for the other material types. The edgings consisted of 1- and 2-in. (25.4- and 50.8-mm) square pieces of wood about 8 ft. (2.4 m) in length. The trim blocks included 3-, 6- and 12-in. (7.62-, 15.2- and 30.5-cm) long 1- and 2-in. (2.54- and 5.08-cm) thick pieces of wood of various widths.

Four types of trials were determined necessary: two control trials, five speed trials, two temperature trials and one worn anvil trial. The control trials were conducted with the wood at an average ambient temperature of 50° F (10° C), a chipper disk speed of 707 rpm, and a new anvil. The beginning and ending control trials served as a means of monitoring any significant changes in the physical characteristics of the chipper, knives, anvil or power supply that may have occurred during the test period. One control would serve as the 100% disk speed for the speed trials, the ambient temperature trial for the temperature trials and the new anvil trial for the anvil condition trials.

The five speeds for the speed trials were obtained by the drift down method. The material to be chipped was
moved to the chipper infeed spout and the vibrating conveyor stopped. The power to the chipper motor was shut off to allow the chipper disk to slow down. Disk speed was monitored with a Monarch digital optical tachometer, model TACH-IVR. The vibrating conveyor was started when the disk speed was 35.5 rpm above the desired test speed. The expectation was that the chipper would pass through the desired test speed at the midpoint of the chipping process and finish chipping the batch at 35.5 rpm below the test speed. The speed trials were conducted with a new anvil and with the wood at ambient temperature.

To conduct the worn anvil trial, the good anvil was replaced by an anvil that had experienced extensive use. The worn anvil trial was performed at full disk speed of 707 rpm and at ambient temperature.

The wood for the temperature trials was placed in a freezer van set at 25° F (-4° C). The frozen wood bundles were stored in the freezer for several days. The appearance of ice on them would suggest that freezing conditions were obtained. The chilled wood was in the freezer van long enough to assure that external temperatures of the wood were near 32° F (0° C). This was established by noting the appearance of frost on the exterior of the wood and by obtaining a between piece temperature near 35° F (2° C). The temperature trials were
conducted at full disk speed of 707 rpm and with a new anvil.

The speed replications were randomized to avoid any bias associated with machine condition or operating environment in the data. In total, fifteen replications were randomized. The order of material type tests was not randomized. The worn anvil replications had to be performed as a set to minimize the amount of time and money spent to make the necessary changes to the chipper before and after the trial (Table 3.1).

DATA COLLECTION

Sampling Method

Two-hundred pound (90 kg) batches of each material type were chipped for each of the three replications. The chip stream was temporarily bypassed from the top of the screen pack into the overthicks chute and then diverted from reaching the vibrating conveyor so that the entire chip stream could be sampled (Figure 3.1 and 3.2). Five 20-lb. (9.07 kg) samples were taken from the chip stream for each material within each repetition of each trial. In total, approximately half of the original 200 lb. (90 kg) batch was retained by the five samples.
Table 3.1 - Order in which trials were replicated.

<table>
<thead>
<tr>
<th>Trial</th>
<th>Replication #</th>
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<tbody>
<tr>
<td>Beginning Control</td>
<td>1</td>
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<tr>
<td>Beginning Control</td>
<td>2</td>
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<tr>
<td>Beginning Control</td>
<td>3</td>
</tr>
<tr>
<td>50 % Disk Speed</td>
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</tr>
<tr>
<td>60 % Disk Speed</td>
<td>1</td>
</tr>
<tr>
<td>70 % Disk Speed</td>
<td>1</td>
</tr>
<tr>
<td>80 % Disk Speed</td>
<td>1</td>
</tr>
<tr>
<td>90 % Disk Speed</td>
<td>1</td>
</tr>
<tr>
<td>70 % Disk Speed</td>
<td>2</td>
</tr>
<tr>
<td>90 % Disk Speed</td>
<td>2</td>
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<tr>
<td>60 % Disk Speed</td>
<td>2</td>
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<tr>
<td>50 % Disk Speed</td>
<td>2</td>
</tr>
<tr>
<td>80 % Disk Speed</td>
<td>2</td>
</tr>
<tr>
<td>Worn Anvil</td>
<td>1</td>
</tr>
<tr>
<td>Worn Anvil</td>
<td>2</td>
</tr>
<tr>
<td>Worn Anvil</td>
<td>3</td>
</tr>
<tr>
<td>Chilled</td>
<td>1</td>
</tr>
<tr>
<td>Chilled</td>
<td>2</td>
</tr>
<tr>
<td>Chilled</td>
<td>3</td>
</tr>
<tr>
<td>Frozen</td>
<td>1</td>
</tr>
<tr>
<td>Frozen</td>
<td>2</td>
</tr>
<tr>
<td>Frozen</td>
<td>3</td>
</tr>
<tr>
<td>90 % Disk Speed</td>
<td>3</td>
</tr>
<tr>
<td>80 % Disk Speed</td>
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<tr>
<td>70 % Disk Speed</td>
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<tr>
<td>60 % Disk Speed</td>
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<td>50 % Disk Speed</td>
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</tr>
<tr>
<td>Ending Control</td>
<td>1</td>
</tr>
<tr>
<td>Ending Control</td>
<td>2</td>
</tr>
<tr>
<td>Ending Control</td>
<td>3</td>
</tr>
</tbody>
</table>
Five-gallon (19 L) buckets were placed under the temporary chute to capture the samples from the chip stream. The five samples consisted of the entire contents of the first five even numbered buckets. The samples were obtained in this alternating fashion so that the duration of the chip stream of each batch was sampled. The chips from the first bucket were not used to avoid end chips and to avoid stratification of the chip stream on the gyratory screen. After each batch was chipped, the system was allowed to purge itself of any remaining chips to prevent contamination of the next batch. Immediately after the samples were taken, they were emptied, labelled in plastic bags and sealed.

Three one-lb. (450-gm) samples were obtained for moisture content analysis, while the samples for size classification were being taken for each replication. These samples were also taken for each material type within each replication of each trial. They were obtained from the odd numbered buckets starting with the third bucket in a manner similar to that described above. The chips were immediately sealed in labelled plastic bags. All of the samples were taken to the Industrial Forestry Operations Laboratory for gravimetric measurements.
Moisture Content

The first analytical activity was the initial weighing of the moisture content samples. The initial measurement included the weight of the chips, the bag and the identification tag. After all samples were weighed, they were opened and stored in a low temperature dryer to remove the moisture from the chips. The dryer consisted of several expanded-metal shelves with high power heater bulbs beneath them to raise the temperature within the dryer to approximately 150° F (65° C). A small fan exhausted the humid air from the dryer. Higher temperature was not used since temperature above 150° F (65° C) could drive off volatile extractives in the wood and result in an inaccurate reading of the moisture content. Drying time is typically two to three weeks, but varies by species and moisture content.

After the weight of the chip samples had stabilized, the chips were removed from the dryer and weighed in the bag with the identification tag. An average bag and tag weight was also determined to tare from the dry, final chip weight. A technique developed by Gene Wengert (1985) utilizing a microwave oven was used on several of the samples to verify the chips were completely dry. The samples were uniformly placed on a paper towel on the
perimeter of the microwave carrousel. Then they were exposed for ten minutes at a medium-low power setting before weighing. Then the samples were dried for an additional minute and weighed again. If the sample weights were the same, then they were considered oven-dry. Measurements accurate to one-thousandth of a pound (0.45 gm) were taken.

Chip Size

The chips were classified by a Williams Classifier using a two pass process. The first pass removed the overthick and oversize material. The second pass classified the acceptable and undersized chips (Figure 3.3). At the beginning of the classification process, the entire bag of chips, the bag and the identification tag were weighed together on a Toledo scale, model 2081. This served as a check for the sum of the individual size classification weights and the final weighing of the chips, bag and identification tag together. Then the entire sample of the wood chips was carefully loaded into the Williams Classifier (Figure 3.4 and 3.5). The chips were first sorted through a five screen stack consisting of a 5/16 in. (8-mm) bar screen and 2-, 1-1/2-, 1-1/8- and 1/8-in. (50.8-, 38.1, -28.6- and 3.18-mm-) round-hole screens. The
## WILLIAMS CLASSIFIER SET-UP

<table>
<thead>
<tr>
<th>Screen Size</th>
<th>First Pass</th>
<th>Second Pass</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 MM BAR SCREEN</td>
<td>OVERTHICKS</td>
<td>FIRST PASS</td>
</tr>
<tr>
<td>2&quot; ROUND HOLE</td>
<td>OVERSIZE</td>
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</tr>
<tr>
<td>1-1/2&quot; ROUND HOLE</td>
<td></td>
<td>ACCEPPTS</td>
</tr>
<tr>
<td>1-1/8&quot; ROUND HOLE</td>
<td></td>
<td>PIN CHIPS</td>
</tr>
<tr>
<td>7/8&quot; ROUND HOLE</td>
<td></td>
<td>FINES</td>
</tr>
<tr>
<td>5/8&quot; ROUND HOLE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3/8&quot; ROUND HOLE</td>
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<tr>
<td>PAN</td>
<td></td>
<td>BOTH PASSES</td>
</tr>
</tbody>
</table>

**Figure 3.3** - Williams Classifier two-pass setup.
Figure 3.4 - Chip size classification analysis setup.

Figure 3.5 - Williams Classifier set up for first pass of sample, second-pass screens in background.
1/8-in. (3.18-mm) screen both captured all of the material from the 1-1/8-in. (28.6-mm) screen and removed a portion of the fines, thus reducing the load on the same screen during the second pass. After operating the classifier for two minutes, the screens were removed, the retained chips weighed, and the classifier reassembled with the second stack of screens. These screens consisted of a 7/8-, 5/8-, 3/8- and 1/8-in. (22.2-, 15.8-, 9.53- and 3.18-mm-) diameter holes. (From henceforth, the chips retained on the above listed screens will be named by the English size designation with exception of 8 mm for the chips retained on the bar screen.) The chips that went through the 1/8-in. (3.18-mm) screen were collected by the bottom pan in both passes. The second pass lasted three minutes and was followed by removal of the screens and weighing of the retained fractions. The chips were weighed to an accuracy of one-thousandth of a pound (0.45 gm) on a Sartorius PT1200-OUR. The bag, tag and tie were also weighed to the same level of accuracy and deducted from the total weight to check the sum of the weights of the size fractions. A weighing of the wood chips, bag and tag together was done as a final check on the Toledo scale.

After all the samples from a trial were classified, the weights were entered into a spreadsheet to verify the measurement process. A five percent error was used to
determine if resorting and reweighing of a sample was necessary. This maximum error threshold was based on anticipated loss in weight due to change in moisture content during the measuring process and a possible loss of wood chip particles in handling, sorting and weighing. The error was determined from the summed weights of the nine size fractions, the bag, the tag and the tie, and comparing them to the average of the initial and the final weights of the bag, tag, tie and wood chips.

DATA ANALYSIS

Statistical Analysis

The paired t-test was used to compare the results of the experimental trials with the control trials and between material types (the 6x6 cants and the edgings and trim blocks). The null hypothesis used was that no difference existed between means. A two-tailed rejection region was used for all t-tests. The data were coded into percent weight to perform comparisons on an equal basis. The descriptive statistics of Number Cruncher Statistical System were used to determine the mean, median and confidence intervals. Normality of the data was anticipated since that was the findings of the work by
Leary and Stuart (1991), but tests of normality were used as a first step in the analysis to determine if the data was skewed. It was found in this preliminary analysis that the means best conveyed the sense of the data and the data was mostly normal; therefore, parametric statistics were used.
CHAPTER 4. RESULTS AND DISCUSSION

These trials, intended as 'winter trials,' were to be conducted when the ambient temperature was near the freezing point and when the trees were in a winter physiological state. Unfortunately, the winter of 1990-1991 was exceptionally mild in the Virginia Tidewater region. Weather patterns were watched carefully during the months of December, January and February for an extended cold period. By March, it was obvious that the desired conditions were not going to occur, and the emphasis shifted to completing the study before the spring growth flush began. Therefore, this study focused on the effects of chipper disk speed, wood temperature and anvil condition on the size distribution of wood chips from sawmill residues.

CONTROL TRIALS

Two control trials were conducted for the purpose of documenting the beginning and ending conditions of the chipper and to serve as a standard of comparison for the tests. One control trial also served as the 100% disk speed condition for the speed trials, the ambient temperature trial for the temperature effect studies and
the new anvil trial for the effect of anvil condition. Statistical comparison of the two controls using a two-tailed, paired t-test revealed that about one third of the tests failed to reject the null hypothesis (Table 4.1). The null hypothesis is "the means are equal," and the alternate hypothesis is "the means are not equal." The dissimilarity between the two controls is more likely due to the chipper undergoing an initial 'breaking-in' of the factory-fresh conditions, that is the 'breaking-in' of the wire edge of the newly sharpened knives and the sharp edges of the new anvil and bed plate. Differences in the properties of the wood could also have contributed to the shift in the data. For all three materials, the variation in moisture content of samples drawn during the first control was larger than the second.

The second control was selected as the standard of comparison for the other trials, because its results were in agreement with the controls of the summer trials. The data from the two controls could not be pooled because their variances were unequal. Comparisons were made between the medians of the 8 mm, 2 in., 1-1/2 in., 1-1/8 in., accepts and pins and fines fractions. Also, the second control had a smaller and more consistent range of moisture contents for all three material types as compared to the first control.
Table 4.1 - P-level for pairwise comparison of the first and the second control.

<table>
<thead>
<tr>
<th>TRIAL MATERIAL</th>
<th>0 MM</th>
<th>2&quot;</th>
<th>1-1/2&quot;</th>
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<th>5/8&quot;</th>
<th>3/8&quot;</th>
<th>1/8&quot;</th>
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<tr>
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EFFECT OF SPEED ON CHIP SIZE DISTRIBUTION

The five speeds for the speed trials were obtained by the drift down method as previously described. The desired and actual speeds at which chipping began and ended are shown in Table 4.2. A batch of wood was sent through the chipper when the disk speed was 35.5 rpm higher than the desired test speed, but it always finished slower than the intended 35.5 rpm below the test speed. The intent of this method was that the chipper would pass through the desired test speed at the midpoint of the chipping process. However, control could not be exercised over precisely when the material hit the disk, or whether it tended to bunch or separate on the vibrating conveyor. Sometimes the chipper would start chipping the wood at a speed lower than intended because the wood did not move readily on the conveyor. At other times, a large 'bunch' entered the chipper at the start of the test, slowing the disk speed more quickly than expected. Had the chipper been powered at the desired disk speeds, the variation between samples related to the inconsistency in chipping would have been decreased. The midpoints of the chipping ranges were approximately 10% slower than the intended speeds. Possibly the energy required to chip each batch of wood was more than anticipated. Henceforth, the discussion and
Table 4.2 - Desired test speed, target start and finish speeds, actual finishing speeds, and actual average test speed.

<table>
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<tr>
<th>DESIRED TEST SPEED</th>
<th>REP #</th>
<th>TARGET SPEED START</th>
<th>TARGET SPEED FINISH</th>
<th>ACTUAL FINISH SPEED 6X6</th>
<th>ACTUAL FINISH SPEED EDGING BLOCK</th>
<th>ACTUAL AVERAGE TEST SPEED</th>
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<td>50 %, 354 rpm</td>
<td>1</td>
<td>389</td>
<td>318</td>
<td>202</td>
<td>201</td>
<td>206</td>
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<tr>
<td>50 %, 354 rpm</td>
<td>2</td>
<td>389</td>
<td>318</td>
<td>168</td>
<td>210</td>
<td>219</td>
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<tr>
<td>50 %, 354 rpm</td>
<td>3</td>
<td>389</td>
<td>318</td>
<td>209</td>
<td>211</td>
<td>234</td>
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<tr>
<td>60 %, 424 rpm</td>
<td>1</td>
<td>460</td>
<td>389</td>
<td>265</td>
<td>245</td>
<td>272</td>
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<tr>
<td>60 %, 424 rpm</td>
<td>2</td>
<td>460</td>
<td>389</td>
<td>308</td>
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<td>275</td>
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<tr>
<td>60 %, 424 rpm</td>
<td>3</td>
<td>460</td>
<td>389</td>
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<tr>
<td>70 %, 495 rpm</td>
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<td>530</td>
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<td>332</td>
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<td>346</td>
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<tr>
<td>70 %, 495 rpm</td>
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<td>530</td>
<td>460</td>
<td>322</td>
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<td>339</td>
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<td>70 %, 495 rpm</td>
<td>3</td>
<td>530</td>
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<td>80 %, 566 rpm</td>
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<td>601</td>
<td>530</td>
<td>448</td>
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<td>431</td>
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<tr>
<td>80 %, 566 rpm</td>
<td>2</td>
<td>601</td>
<td>530</td>
<td>474</td>
<td>391</td>
<td>407</td>
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<tr>
<td>80 %, 566 rpm</td>
<td>3</td>
<td>601</td>
<td>530</td>
<td>475</td>
<td>413</td>
<td>464</td>
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<tr>
<td>90 %, 636 rpm</td>
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<td>671</td>
<td>601</td>
<td>553</td>
<td>473</td>
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graphs will reflect the five test speeds as 80, 70, 60, 50 and 40% (nominal) disk speeds.

Figure 4.1 illustrates the typical chip size distribution based on the chip length and width at 100% disk speed (707 rpm). The overthick chips are shown on a separate graph, because they are measured on the basis of thickness. The total percentage of the sample fractions represented by the distributions of each material type is shown in the figures. For the control trial, the 5/8-in. category is the peak for both the 6x6 cants and the edgings. The maximum of the trim blocks is at the 3/8-in. size category.

As disk speed decreases, the distribution shifts to the larger size categories. This trend can be seen by examining the 60% and 40% disk speeds (Figure 4.2 and 4.3). At 60% disk speed, the center of the distribution of the 6x6 cants is at the 7/8-in. category. The maximum for the edgings remains at the 5/8-in. category, but the distribution has flattened. The maximum for the trim blocks is shared between the 5/8-in. and 3/8-in. classes. Only five out of the 24 paired t-tests performed on the eight size fractions for the three material types of the 60% disk speed trial did not reject the null hypothesis at the 95% significance level. The effect of lowering disk speed on shifting the chip size distribution to the larger
Figure 4.1 - Chip size distribution for the three materials at 100% disk speed.

Figure 4.2 - Chip size distribution for the three materials at 60% disk speed.
Figure 4.3 - Chip size distribution for the three materials at 40 % disk speed.
chip fractions is most evident in the 40% disk speed trial as shown in Figure 4.3. The peak of the distributions for both the cants and the edgings is at the 1-1/8-in. category, with a large percentage in the 7/8-in. category for the cants. The maximum of the trim block distribution is shared by the 1-1/8 in. through the 3/8 in. categories, due to the severe flattening of the distribution. All but two of the 24 paired t-tests performed on the eight size fractions for the three material types of the 40% disk speed trial rejected the null hypothesis at the 99% significance level; that is, chip size production is significantly different at nearly all levels of comparison of the 40% to the 100% disk speeds.

Overthicks

The production of overthick chips from edgings and trim blocks is inversely proportional to speed (Figure 4.4). There was no difference in the percentage of overthick chips from cants at the five test speeds and the 100% control at the 95% significance level. However, at the 90% level, a significant decrease in overthicks occurred at 50 and 60% disk speeds, while the maximum amount of overthick chips produced was at 40% speed. Although not well understood, this may be due to variation
Figure 4.4 - Overthick fraction as a function of disk speed for the three materials.

Figure 4.5 - Pins and fines fraction as a function of disk speed for the three materials.
in moisture content and differences in the variance between tests possibly caused by the cants originating from two sources. A significant increase in the amount of overthick chips from edgings occurred at 40 and 50% disk speeds. A 6% increase was observed in the case of the edgings as the disk speed decreased to 40%. When the disk speed decreased to 40%, the amount of overthick chips produced by trim blocks increased by nearly 18%. The amount of overthick chips from trim blocks at the five test speeds was more than that at the 100% control at the 95% significance level or higher.

Pins and Fines

The amount of pins and fines produced as a function of disk speed was found to be positively related to disk speed for all three material types (Figure 4.5). The trend was especially strong for the edgings and trim blocks for both pins and fines. Only two out of the 15 t-tests did not show a significant difference between the means of the fines from the three material types at the 90% significance level. The inconsistency in the trends of the 6x6 cants seen in Figure 4.5 may be due to the broad range of moisture contents of the wood and the fact that not all of the cants came from the same source. The amount of pins
and fines produced from the cants decreased by four percent as disk speed decreased from 100 to 40%. A 6.5% decrease in the amount of pins and fines produced from edgings occurred when disk speed was decreased to 40%. A 8.5% decrease in pins and fines was appreciated for the trim blocks as disk speed was decreased to 40% disk speed.

Pulpable Chips

All wood chips are pulpable regardless of size, but some chip sizes pulp more easily and produce better quality pulp than others. For the purpose of this report, the desirable chips will be called 'pulpable' chips, defined as the oversize and accept chips (as previously described), that is, < 8 mm thick and > 3/8 in. in length and width. 'Unacceptable' chips will be defined as overthick, pin and fine chips (as previously described); that is, > 8 mm thick and < 3/8 in. in length and width. This distinction is made since the effort of this study is to reduce the amount of unacceptable chips and will make presentation of the results easier. (The definitions of overthicks, oversize, accepts, pins and fines remain as previously described.)

The countervailing effects of the decrease in pins and fines and the increase in overthicks combine to affect the production of desirable chips (< 8 mm thick and > 3/8
in.) when decreasing disk speed. A five percent increase in pulpable chips was obtained from the cants when the disk speed was decreased from 100 to 50% disk speed (Figure 4.6). A sudden increase in the amount of overthick chips at 40% speed reduced the amount of pulpable chips from that at 50% speed (Figure 4.7). The amount of pulpable chips from edgings increased and then decreased as disk speed decreased. The amount of pulpable chips at 40% speed was nearly the same as that at 100% speed (Figure 4.8). The amount of overthick chips overtook the decreasing amount of pins and fines as disk speed decreased (Figure 4.9). The amount of pulpable chips from the trim blocks remained mostly unchanged through 70% disk speed, but below that speed, the amount of pulpable chips decreased more than seven percent as compared to 100% disk speed (Figure 4.10). This is in large due to the very significant increase in the amount of overthicks produced as disk speed decreases, even though the amount of pins and fines decreased significantly (Figure 4.11). If an equal amount of cants, edgings and trim blocks were chipped, they would produce the most pulpable chips, nearly 80%, at 70% disk speed (Figure 4.12). At 40% speed, 75.5% pulpable chips would be produced but less than four percent of the total furnish would be pins and fines as compared to nearly 6.5% pins and fines at 70% speed (Figure 4.13).
Figure 4.6 - Pulpable and accept chips vs. disk speed from cants.

Figure 4.7 - Overthick, oversized, pins and fines, and unaccept chips vs. disk speed from cants.
Figure 4.8 - Pulpable and accept chips vs. disk speed from edgings.

Figure 4.9 - Overthick, oversize, pins and fines, and unaccept chips vs. disk speed from edgings.
Figure 4.10 - Pulpable and accept chips vs. disk speed from trim blocks.

Figure 4.11 - Overthick, oversize, pins and fines, and unaccept chips vs. disk speed from trim blocks.
Figure 4.12 - Pulpable and accept chips vs. disk speed from cants, edgings and trim blocks combined.

Figure 4.13 - Overthick, oversize, pins and fines, and unaccept chips vs. disk speed from cants, edgings and trim blocks combined.
Table 4.3 lists the statistical significance between the five test speeds and the 100% control.

EFFECT OF TEMPERATURE ON CHIP SIZE DISTRIBUTION

The wood for the chilled and frozen trials were refrigerated in a freezer van set at 25°F (-4°C). The frozen wood bundles were stored in the freezer for several days. A between piece temperature of 34°F (1°C) was measured in the bags of frozen trim blocks before chipping. Ice was present on the wood. The chilled wood was in the freezer van long enough to insure that external temperature of the wood was near freezing. The between piece temperature in the bags of trim blocks was 40°F (5°C).

The control trial served as the ambient temperature trial. The size distributions had a maximum of 5/8-in. chips for the cants and the edgings (Figure 4.14). The peak for the trim block distribution was at the 3/8-in. size category.

At chilled conditions, the size distributions of the three material types experienced a shift to the smaller size fractions (Figure 4.15). The shift of the maximum of the 6x6 cants to the 3/8-in. category was the most evident. The peak of the chip distribution from trim blocks did not change from that obtained at ambient temperature. The peak
Table 4.3 - P-level for pairwise comparison of the five test speeds and the control (full speed).

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<th>1/8&quot;</th>
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**SYMBOL** | **P-VALUE** | **S. L.**
---|---|---
* | (10% 0.100) | 90%
** | (5% 0.050) | 95%
*** | (1% 0.010) | 99%
**** | (0.1% 0.001) | 99.9%
Figure 4.14 - Chip size distribution for the three materials at ambient temperature.
Figure 4.15 - Chip size distribution for the three materials at chilled temperature.

Figure 4.16 - Chip size distribution for the three materials at frozen temperature.
of the chip distribution from edgings was shared by the 5/8-in. and the 3/8-in. fractions. Only two out of the 24 two-tailed, paired t-tests performed on the eight size fractions of the three material types did not reject the null hypothesis that the means of the ambient and chilled material were equal at the 95% significance level.

Under frozen conditions, all three of the material size-distributions shifted to the smaller size fractions but not to the same extent as that in the chilled trial (Figure 4.16). The chip distribution obtained from the cants experienced the most change; the peak of its distribution moved to the 3/8-in. fraction.

Overthicks

The amount of overthick chips decreased as the temperature decreased for all three material types (Figure 4.17). However, this relationship was not linear for the trim blocks. The amount of overthicks from the trim blocks increased by 3% when comparing frozen to chilled conditions. A similar, but weaker trend existed for the edgings. This decreasing and increasing phenomenon as temperature decreases is contrary to the changes in the overthick chips but parallel to the changes in the oversize chips from the temperature tests of the summer trials
Figure 4.17 - Overthick fraction as a function of temperature for the three materials.

Figure 4.18 - Pins and fines fraction as a function of temperature for the three materials.
(Leary and Stuart, 1991). The null hypothesis that means are equal, was rejected at the 99% level for both temperatures and all three material types.

Pins and Fines

The amount of pins and fines produced as a function of temperature was found to increase with decreasing temperature for all three material types (Figure 4.18). All 12 of the paired t-tests rejected the null hypothesis that the percentage of pins and fines of the three material types produced at the two temperatures below ambient were equal at the 99.9% significance level. Only the edgings showed a consistent trend of increasing pins and fines as temperature decreased. Similar trends of pins and fines increase with temperature decrease were also observed by Leary and Stuart (1991).

Pulpable Chips

The amount of pulpable chips decreased with temperature for the 6x6 cants and edgings as seen in Figures 4.19 and 4.21. The significant increase in pins and fines nullified any gains from the significant decrease in overthick chips resulting in a decrease in pulpable
Figure 4.19 - Pulpable and accept chips from cants at the three temperatures.

Figure 4.20 - Overthick, oversize, pins and fines, and unaccept chips from cants at the three temperatures.
Figure 4.21 - Pulpable and accept chips from edgings at the three temperatures.

Figure 4.22 - Overthick, oversize, pins and fines, and unaccept chips from edgings at the three temperatures.
chips (Figure 4.20 and 4.22). A slight decrease occurred in the amount of pulpable chips between ambient and chilled edgings, while there was a 2.5% decrease in the amount of pulpable chips from the frozen edgings (Figure 4.21). Figure 4.23 illustrates the effect of decreasing temperature on chip fractions from the trim blocks. Again, the significant increase in pins and fines nullified any significant gains appreciated by the decrease in overthicks for both test temperatures (Figure 4.24). Chipping equal amounts of cants, edgings and trim blocks produces a one and two percent decrease in the amount of pulpable chips under chilled and frozen conditions, respectively (Figures 4.25 and 4.26).

Table 4.4 lists the statistical significance between the two test temperatures and the ambient control.

**EFFECT OF ANVIL CONDITION ON CHIP SIZE DISTRIBUTION**

The new anvil was replaced by one that was badly worn to test the effect of anvil condition on the chip size distribution. The knife to anvil clearance was not reset when the anvil was changed. A worn anvil does not provide a flat surface of uniform support against which the knives of the chipper force the wood. Consequently, more shattering of the wood may be experienced.
Figure 4.23 - Pulpable and accept chips from trim blocks at the three temperatures.

Figure 4.24 - Overthick, oversize, pins and fines, and unaccept chips from trim blocks at the three temperatures.
Figure 4.25 - Pulpable and accept chips from cants, edgings and trim blocks combined at the three temperatures.

Figure 4.26 - Overthick, oversize, pins and fines, and unaccept chips from cants, edgings and trim blocks combined at the three temperatures.
Table 4.4 - P-level for pairwise comparison of the two test temperatures and the ambient.

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<td>***</td>
<td>(1% 0.010)</td>
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<tr>
<td>****</td>
<td>(.1% 0.001)</td>
<td>99.9%</td>
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The control served as the new anvil trial. Figure 4.27 illustrates the chip size distributions for the three material types.

The general result of the worn anvil was a shift of the distributions to the 3/8- and 1/8-in. classes. The tails remained relatively unaffected for the edgings and trim blocks. The 6x6 cants were the most sensitive with a shift of the chip size distribution to smaller size chips (Figure 4.28). The peak of the cant distribution shifted to the 3/8-in. size category, whereas the peaks of the other distributions remained unchanged. Only 13 of the 24 paired two-tailed t-tests comparing means of the eight size fractions of the three material types were rejected at the 90% significance level or higher, of which eight were the cants.

Overthicks

The production of overthick chips decreased slightly due to anvil wear for the trim blocks and 6x6 cants (Figure 4.29). Only the change for the 6x6 cants was significant. The amount of overthicks produced from the edgings did not change.
Figure 4.27 - Chip size distribution for the three materials with new anvil.

Figure 4.28 - Chip size distribution for the three materials with worn anvil.
Figure 4.29 - Overthick fraction at the two anvil conditions for the three materials.

Figure 4.30 - Pins and fines fraction at the two anvil conditions for the three materials.
Pins and Fines

A significant amount of pins and fines were produced from the 6x6 cants as a result of the worn anvil condition (Figure 4.30). No significant change occurred for the trim blocks and the edgings.

Pulpable Chips

The amount of pulpable chips decreased for the 6x6 cants and increased for the edgings and trim blocks when the worn anvil was installed. A 1% significant decrease in pulpable chips occurred when using a worn anvil on 6x6 cants (Figure 4.31). The increase in the amount of pins and fines slightly offset the decrease in the amount of overthicks (Figure 4.32). A slight but not significant increase in pulpable chips from the edgings was measured when using a worn anvil (Figure 4.33 and 4.34). The increase in pulpable chips from the trim blocks was not statistically significant (Figure 4.35 and 4.36). Chipping equal amounts of cants, edgings and trim blocks with a worn anvil would produce a slight increase in the amount of pulpable chips while increasing the amount of pins and fines when chipping with a worn anvil (Figures 4.37 and 4.38). These results reflect the general conclusion from
Figure 4.31 - Pulpable and accept chips from cants at the two anvil conditions.

Figure 4.32 - Overthick, oversize, pins and fines, and unaccept chips from cants at the two anvil conditions.
Figure 4.33 - Pulpable and accept chips from edgings at the two anvil conditions.

Figure 4.34 - Overthick, oversize, pins and fines, and unaccept chips from edgings at the two anvil conditions.
Figure 4.35 - Pulpable and accept chips from trim blocks at the two anvil conditions.

Figure 4.36 - Overthick, oversize, pins and fines, and unaccept chips from trim blocks at the two anvil conditions.
Figure 4.37 - Pulpable and accept chips from cants, edgings and trim blocks combined at the two anvil conditions.

Figure 4.38 - Overthick, oversize, pins and fines, and unaccept chips from cants, edgings and trim blocks combined at the two anvil conditions.
the summer trials that anvil condition does not affect chip size from sawmill residues as much as literature on chipping roundwood indicates (Leary and Stuart, 1991). The response of the cants to the worn anvil is as expected since they resemble roundwood.

Table 4.5 lists the statistical significance between the worn anvil and the new anvil control.

EFFECT OF MATERIAL TYPE ON CHIP SIZE DISTRIBUTION

Significant differences existed across all material types for all ten trials (Table 4.6). The 6x6 cants served as the standard of comparison for the edgings and trim blocks. Paired t-tests with two-tail rejection regions were used on the nine chip size fractions, totaling 180 tests. Out of those, 147 rejected the null hypothesis that the means of the materials were equal at the 90% significance level or higher. All but one of 60 comparisons across the ten trials supported the trend that edgings and trim blocks produce more 8 mm, 2 in. and 1-1/2 in. chips than 6x6 cants. Only seven out of those 60 t-tests did not show a significant increase at the 95% level or higher. The trim blocks tended to produce lesser amounts of the 1-1/8-in., 7/8-in., 5/8-in. and 3/8-in. chips as compared to the cants for all ten trials. No
Table 4.5 - P-level for pairwise comparison of the worn anvil and the new anvil.

| TRIAL MATERIAL | 8 || 2" | 1-1/2" | 1-1/8" | 7/8" | 5/8" | 3/8" | 1/8" | PAN |
|----------------|-----|------|--------|--------|------|------|------|------|-----|
| WORN CANTS     | *** | ***  | ****   | ****   | ***  | **   | **** | **** |     |
| WORN EDGINGS   | *   |      |        | **     | *    |      |      |      |     |
| WORN BLOCKS    |     |      |        |        |      |      |      |      | *   |

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Table 4.6 – P-level for pairwise comparison of the edgings and trim blocks to the cants.

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clear trend existed for the 1-1/8-in. to the 3/8-in. sizes for the edgings in all ten trials. There tended to be more pins and fines from the trim blocks than from the cants; 13 out of the 20 t-tests of all the trials experienced a significant increase. Five of the seven comparisons that were not significant were different by less than 0.1% in their means.

More 8-mm, 2-in. and 1-1/2-in. chips were produced from the edgings and trim blocks than the 6x6 cants in the five speed and the two control trials. Only four out of the 42 paired t-tests did not reject the null hypothesis at the 95% significance level. No clear trend existed for the pins and the fines from edgings in the speed and control trials. More pins and fines were produced from trim blocks than cants at the 90% level for ten out of 14 t-tests in the speed and control trials. Less 3/8-in., pins and fines were produced from edgings than from cants at the 90% significance level in the frozen, chilled and worn anvil trials.

EFFECT OF MOISTURE CONTENT ON CHIP SIZE DISTRIBUTION

6x6 Cants

Moisture content was measured on a dry weight basis.
The 6x6 cants had the greatest variation across the three replications as well as between the replications (Figures 4.39 - 4.44). The maximum difference across all replications was 70%, ranging from 50 to 120% moisture content in the speed trials. This large variation in moisture content is one of the suspected causes of the inconsistencies in the chip size data for the cants and probably can be attributed to the two different sources of cants. The maximum difference in moisture content across replications in a trial was 50% in the 80% disk speed trial. The maximum difference between two replications within a trial was 35% in the 40% disk speed trial. The minimum difference between replications within a trial was 2.5%.

The relationship between moisture content and the amount of overthick chips and the amount of pins and fines produced was explored (Figure 4.39 - 4.44). The variability in moisture content and overthick chips and pins and fines production between replications within the trials was sufficient to thwart any definitive statement. There appears to be a tendency toward decreasing overthick chips and increasing pins and fines with increasing moisture content for the speed, temperature and anvil trials.
Figure 4.39 - Overthicks vs. moisture content from cants in speed trials.

Figure 4.40 - Pins and fines vs. moisture content from cants in speed trials.
Figure 4.41 - Overthicks vs. moisture content from cants in temperature trials.

Figure 4.42 - Pins and fines vs. moisture content from cants in temperature trials.
Figure 4.43 - Overthicks vs. moisture content from cants in anvil trials.

Figure 4.44 - Pins and fines vs. moisture content from cants in anvil trials.
Edgings

The edgings had the most consistent moisture content with a maximum difference across all replications of 25%, ranging from 55 to 80% moisture content (Figures 4.45 - 4.50). The maximum difference across replications within a trial was 20%, common to several of the speed trials. The maximum difference between two replications within a trial was 20%, again common to several of the speed trials, while the minimum was less than 2.5%. The amount of overthicks and pins and fines produced was very consistent regardless of moisture content.

Trim Blocks

The trim blocks had the narrowest range of moisture contents with a maximum difference across all replications of 20% in the temperature trials (Figures 4.51 - 4.56). The moisture contents ranged from 65 to 85%. The maximum difference across replications within a trial was 15%. The maximum difference between two replications within a trial was 15%, occurring in the chilled trial, while the minimum was less than 2.5%. No trend was evident between moisture content and the amount of pins and fines or overthick chips retained.
Figure 4.45 - Overthicks vs. moisture content from edgings in speed trials.

Figure 4.46 - Pins and fines vs. moisture content from edgings in speed trials.
Figure 4.47 - Overthicks vs. moisture content from edgings in temperature trials.

Figure 4.48 - Pins and fines vs. moisture content from edgings in temperature trials.
Figure 4.49 - Overthicks vs. moisture content from edgings in anvil trials.

Figure 4.50 - Pins and fines vs. moisture content from edgings in anvil trials.
Figure 4.51 - Overthicks vs. moisture content from trim blocks in speed trials.

Figure 4.52 - Pins and fines vs. moisture content from trim blocks in speed trials.
Figure 4.53 - Overthicks vs. moisture content from trim blocks in temperature trials.

Figure 4.54 - Pins and fines vs. moisture content from trim blocks in temperature trials.
Figure 4.55 - Overthicks vs. moisture content from trim blocks in anvil trials.

Figure 4.56 - Pins and fines vs. moisture content from trim blocks in anvil trials.
CHAPTER 5. SUMMARY AND CONCLUSIONS

Chips from sawmill residue constitute a significant portion of the chips used by pulp mills. Eliminating overthick, pin and fine chips will increase the wood chip quality and benefit both sawmills and pulp mills. Higher quality chips from sawmills will not only yield greater revenues but also increase the quality of pulp and the productivity of pulp mills.

Information dealing with the effects of disk speed, temperature and anvil condition on sawmill residue chip quality is minimal. Therefore, the purpose of this study is to examine the effects these variables have on the production of overthick, oversize, accept, pin and fine chips and to make recommendations to improve chip quality.

Ten trials were conducted in mid-March 1991 at the Chesapeake Corporation's West Point, VA hardwood sawmill. A Fulghum Industries 60-in. (152-cm) diameter, six-knife, vertical disk chipper was used. Tests were conducted with Loblolly pine (Pinus taeda L.) samples. Each trial was replicated three times and included cants, edgings and trim blocks as the test materials. Before the tests began, the chipper was restored to factory-fresh conditions. The speed trials were conducted by slowing the chipper by the drift down method. The wood for the below ambient...
temperature trials were chilled in a refrigerated van. A severely worn anvil was used in one series of tests to determine the effect of a worn anvil on chip quality. Beginning and ending control trials served to document the initial and final operating conditions of the chipper and as a standard of comparison for the speed, temperature and anvil trials. Samples taken were sorted by size on a Williams Classifier.

DISK SPEED

Decreasing disk speed decreases the amount of pins and fines and tends to increase the amount of overthick chips for all material types. The overthick component from cants tended to decrease through the 50% speed range and then increased at the 40% disk speed. The overthicks from edgings did not increase until 50% disk speed. The trim block overthicks steadily increased as disk speed decreased.

The countervailing effects of increasing overthicks and decreasing pins and fines caused the amount of pulpable chips to increase and then decrease as disk speed decreased. The maximum amount of pulpable chips was obtained at 50, 60, 70 and 70% for the cants, edgings, trim blocks and the three materials combined, respectively. Note
that these percentages do not reflect rechipping of the overthick chips. If they were rechipped or sliced at a 50% recovery rate, then the recommended disk speed could be lowered to 40% for all three material types. If no facility to rechip the overthicks exists, then those previously quoted speeds for maximum pulpable chips would be the recommended operating speeds.

The effect of reducing chipper speed on the throughput rate is unknown. Literature only deals with round-wood and whole-tree chipping rates and power requirements. The residue chipper utilization at each sawmill will have to be evaluated before recommending changes in disk speed. Recalculation of the infeed rate at the desired lower disk speed is necessary to insure that physical limitations of the existing conveyor system and chipper infeed spout are not exceeded. Otherwise, residues will overflow the conveyor or back-up at the chipper spout.

Peak and continual power draw of the chipper need to be measured, and future throughput rates should be determined. The power to throughput relationships in TAPPI technical publication TIS 0406-02 can be used to determine the volume throughput rate based on measured power draw. Then, one should determine the feed rate of the chipper at the desired lower disk speed. Divide the anticipated peak volume throughput rate by the feed rate of the lower speed
to obtain the cross sectional area of the wood flow. If this area exceeds the minimum infeed spout area, or if this area is larger than the minimum useful cross sectional area of the vibrating conveyor, then the speed is too low. When lowering the disk speed, the vibrating conveyor feed rate should be slightly less than the chipper feed rate.

The current motor should be evaluated to prevent burnout from continuous chipping or load surges, because of the loss of stored energy associated with the decrease in disk speed. Lowering disk speed by half, reduces the stored energy by 75%. Addition of a flywheel is not recommended for continuous type chipping as anticipated here, because it will not provide any additional energy to the chipper. Instead, it will only contribute another load on the motor. A synchronous motor is recommended because it is designed to handle the continuous load anticipated from a steady stream of residue. The selection of chipper drive should be done according to TAPPI technical publication TIS 0406–02 (TAPPI, 1992).

TEMPERATURE

Chilling and freezing wood prior to chipping tended to decrease the percentage of oversize chips slightly and significantly increase the production of pins and fines.
This indicates that pins and fines production is strongly influenced by temperature. The effect of temperature apparently overwhelms any physiological effect, however, changes in wood characteristics during winter months cannot be completely ruled out since the winter of 1990 - 1991 was too mild to have fully set dormancy in the Loblolly pine.

The effect of ambient temperature on the production of pins and fines have been observed at a Georgia mill. Further research in this area is necessary to verify the full effects of dormancy on the production of pins and fines.

Chipping chilled and frozen cants, edgings and trim blocks in most cases produced significantly less overthick chips. Decreasing the temperature to reduce the amount of overthicks is not a viable option. However, a facility equipped to rechip overthick chips would operate with a higher pulpable chips percentage if the wood temperature was above chilled conditions. Facilities equipped with a flume can heat the logs by heating the flume water from the residual heat of a liquor boiler.

Two other successful approaches to reduce excessive undersize chips in the winter and excessive overthick and oversize chips in the summer are suggested. As previously discussed, Hartler (1977) showed that increasing the complementary angle to the sum of the cutting, clearance
and sharpness angle can reduce the amount of undersize chips, but "the relationship differs for different wood species and their origin." The mill in Quinnesec, Michigan (Nelson, 1985), which uses birch, maple and Northern hardwoods, found that chip thickness increases associated with warm temperatures can be decreased by shortening the knife setup length, and the amount of undersize chips experienced during winter conditions can be limited by lengthening the knife setup length. These two methods can be applied in combination with the suggested lower disk speeds to optimize chip quality, but warrant further research.

WORN ANVIL

The worn anvil resulted in a decrease in pulpable chips only for the 6x6 cants, which showed a significant decrease in the amount of overthicks and a significant increase in the amount of pins and fines. There tended to be more fines but less pins from edgings due to the worn anvil. There tended to be less overthicks from trim blocks with the worn anvil. In general, these results parallel the work of Leary and Stuart (1991); the effect of anvil wear on residue chip quality is not as pronounced as for whole-tree chipping and round-wood chipping. Anvil
condition should not be neglected to minimize the amount of pins and fines produced from larger residues.

MATERIAL TYPES

All three material types can produce pulpable chips if the proper equipment is used. Without rechipping or slicing, trim blocks produce significant amounts of overthick chips to warrant possible discontinuation of chipping them when lowering the disk speed. At 50 and 40% disk speeds, the amount of overthicks from trim blocks was over 40% as compared with 22% at 100% speed.

Trim blocks tend to spin and chipping occurs at random orientations of the grain. This is the greatest cause of the high percentage of overthick chips from trim blocks. Suggestions for improvement are; forcing the trim blocks into a v-shaped infeed spout before the chipper knives make contact with the wood to minimize spinning by restraining them with a hold-down device consisting of weighted, spring-loaded, or hydraulically operated fingers, rollers or belt (Egolf, 1990); or removing the smallest size residues from the flow to the chipper by means of trap in the vibrating conveyor. A piece too small will tip into the opening of the trap in the conveyor bottom while larger pieces will span the opening. The trapped pieces can
either be hogged for fuel or sent to a special drum chipper
(Jorgensen, 1985). A study is under way by the Industrial
Forestry Operations Department of Virginia Tech to improve
the amount of pulpable chips from trim blocks.

HARDWOOD CHIPPING

The implications of this study on hardwood chipping
can only be speculative and would require further research.
However, general trends in chipping hardwood should
parallel that of Loblolly pine thus allowing
generalizations to be drawn from these data. Direct
application of the numbers obtained from this study would
be improper, because differences in strength properties and
moisture content lie between the two wood types.
Literature Cited


Fulghum Industries, Inc. Date Unknown. Management’s Guidelines for Proper Operation of the Fulghum Chipper. Wadley, GA.


VITA

The author, son of Dana F. and Dorothy Carol Edelman, was born July 27, 1967 in Plainfield, New Jersey. He grew up in Roselle, New Jersey where he graduated salutatorian from Abraham Clark High School in 1985.

He entered the engineering program at Virginia Tech in the fall of 1985 and completed his Bachelor of Science degree in Mechanical Engineering in May 1990. While pursuing his undergraduate degree, he worked for Whitman, Requardt, and Associates, an engineering consultant firm, in Baltimore, MD for a year and a half through the Cooperative Education program.

John began his master’s degree in Agricultural Engineering with an emphasis on forestry engineering at Virginia Tech in the fall of 1990. He completed his degree in May, 1992.

John S. Edelman