IMPROVING SAWMILL RESIDUE CHIP QUALITY

by

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ABSTRACT

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The primary objective of this study was to improve residue chip quality at high production southern pine sawmills. A general economic analysis suggested that improving sawmill residue chip quality could be beneficial to both pulp and sawmills.

Studies were conducted at several sawmills to determine methods of improving residue chip quality. The first study examined the composition of material entering a residue chipper. Trim ends and oversize chips contributed the most pieces, but only 10% of the residue weight. Two-foot trim blocks accounted for the remaining material, 90% by weight. A number of these pieces resulted from slashing entire boards or cutting longer trim lengths into 2-foot pieces to clear them from the mill.

Two studies were conducted to examine the possibility of leaving trim in longer lengths to improve piece orientation and stability. Both studies found significant improvements in chip quality, the overthick chips decreased while the percentage of acceptable chips increased. Chip quality improved with each incremental increase in trim length, but increasing trim length to four feet alone accounted for 50% of the overall improvements. Four-foot trim lengths would generate an additional 4-5 tons of acceptable chips per day for the sawmill.

Feed conveyor loading was found to affect chip quality. Highest chip quality was achieved when the feed conveyor was half-full, two or three pieces entering simultaneously. An overloaded conveyor produced higher percentages of large chips, whereas chipping single pieces increased the percentage of smaller chips.

The effect of seasonal temperatures on pin chip and fine production at southern pine and hardwood chip mills was examined as a secondary objective. The pin chip and fine content at the hardwood mills increased as temperatures decreased, but variability in species and inventory obscured the relationship. Southern pine chip mills experienced 4-5% increases in the pin chip and fine content during winter months. Pin chips and fines increased 1% for every 10°F drop in temperature.

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CHAPTER 1

INTRODUCTION

Sawmills produce several by-products in the course of producing lumber, of which residue pulp chips usually have the greatest market value. Sawmills are in business to produce lumber and, until recently, have not given much consideration to residue chip quality. During good times, sawmill managers view residue chips as a way to dispose of sawmill waste, not a valuable product. During tight economic times however, residue chip sales often provide a sawmill's profit margin.

Sawmill residue chips are a major component of the pulp mill chip furnish. Approximately 35% of the weight of a pine log entering a sawmill leaves in the form of chips, accounting for over 73 million tons of residue chips yearly (Leary and Stuart, 1991). In 1988, sawmill residue from southern pine sawmills constituted 25% of the total raw material supply for southern pulp mills (Dubois et al., 1991).

A pulp and paper manufacturer benefits in several ways from sawmill residue chips. Wood chip production and purchase constitutes the single largest cost of pulp production (Hatton, 1987; Forbes, 1984). Residue chips can be purchased at a nominal cost since sawmills are looking for ways to dispose of their residues. Residue chips also provide a flow of raw material that is usually unaffected by short-term weather patterns. The majority of residue chips produced are "clean" chips, free of contaminants such as bark or sand that affect pulping.

Chip quality has a direct effect on both pulp yield and pulp quality (APA, 1992). Individual pulp mills, within the past decade, have refined their definition of optimum chip size and are continually re-evaluating chip quality as pulping processes and requirements evolve. They have documented the effects of unacceptable chip size fractions on the pulping process and pulp quality.

Overthick chips (generally greater than 8-mm thick) need more than one pass through the digester to dissolve all of the lignin. Extra passes reduce the mill's digester efficiency. Pin chips and fines (undersize chips) produce lower pulp yields and the resulting pulp has considerably less strength. Smaller chips also blind recovery screens and create handling problems.

BACKGROUND

This project originated, in part, from the findings of two previous studies investigating southern pine sawmill residue chip quality which explored the effects of chipper disk speed, knife angle, and anvil condition. Different forms of mill residue were used in each test including 6"x 6" cants (control), edgings, and trim blocks. Under all conditions tested, trim blocks consistently produced the worst quality chips. Trim blocks produced the highest percentage of overthick chips, along with large quantities of pin chips and fines.

Improving chip quality from trim blocks was determined to be equally beneficial to both pulp mills and sawmills. Sawmills could enhance their chip revenues and pulp mills could increase their pulp yield per ton of chips.

Trim blocks result from trimming a "finished" green board to length or removing excess wane to yield a higher grade board. Modern sawmills currently produce four types of trim (zero, top, grade, and slashing), each differentiated by length or the trimming objective. Trimmer optimizers utilized at these mills generally produce the trim in two lengths: less than six inches and two feet in length. The short trim (zero and some top) results from removing normal trim allowance from lumber that meets grade specifications. Some 2-foot pieces (grade and some top trim) are produced when trimming the lumber by multiples of two feet to remove wane. Two-foot pieces are also produced from slashing entire unacceptable boards to clear them from the mill.

Previous studies by Leary and Stuart (1991) and Edelman (1992) examined the effect of wood temperature on sawmill residue chip quality. Both studies found that wood chilled (36°F) and frozen (below 32°F) produced higher percentages of pin chips and fines than wood at ambient temperature. The difference in pin chip and fine production from wood chilled and frozen was not significant however. Increases in the percentage of pin chips and fines produced from both tree-length and residue material that freeze in northern climates is well known (Hatton, 1975). However, southern mills rarely experience severely cold temperatures for extended periods. Milder climates of the South have given little reason to suspect that chip quality was affected by seasonal temperatures. At the present time, the magnitude of this effect is not known, or only speculative at best.

Several days were spent at southern pine sawmills watching residue chippers and the material entering them to develop ideas for improving trim block chip quality without major capital investments. Several of these observations were especially important. First, there was no set orientation of a trim block relative to the chipper disk prior to chipping. Secondly, smaller material did not have the necessary weight to remain in the chipper throat during chipping. Much of this material consisted of trim ends (one or two inches in length) from the "zero" saw and rejected oversize chips. Blowing vanes attached to the disk of top discharge chippers create an air dam that does not allow the smaller pieces to enter the chipper under their own power. Smaller pieces build up until a larger piece would come along and push everything through the chipper. Occasionally, the chipper throat would become congested with smaller material and a trim block correctly oriented in the infeed conveyor would become misaligned after hitting and pushing the pile through the chipper.

OBJECTIVES

The primary objective of this study was to identify ways of improving residue chip quality. The study was divided into several parts to identify areas where improvements would be most beneficial and to evaluate possible solutions. The second objective of the study was to better define the relationship between pin chip and fine production and daily temperature in a "temperate" climate.

The specific research objectives were to:

1) Document and delineate the material entering a sawmill residue chipper at a modern sawmill and the chip furnish produced by this material.
2) Generate possible solutions for improving trim block chip quality.
3) Estimate how much could be invested by a sawmill to improve trim block chip quality.
4) Document the effect of seasonal temperatures on the production of pin chips and fines at a southern saw and chip mill.

CHAPTER 2

LITERATURE REVIEW

Nolan (1963) characterized chip quality in the past as something everyone talked about, but did nothing about. Opinions have changed as technology and pulping processes have changed. The quality of chips that a pulp mill uses affects operating efficiency, profits, and to some extent, effluent discharge. Overthick chips and fines are either unused or require additional expense to process (Robinson, 1987). Uniform, high quality acceptable chips can be pulped under precisely controlled conditions to produce maximum yields and quality.

Much of the research directed toward improved chip size uniformity has centered on roundwood and whole-tree chipping. Only a slight portion of the research has been associated with the sawmill residue furnish, the source most often criticized for its poor quality (Crammond, 1985). After improving roundwood chippers, emphasis shifted to improving chip screening systems. Improved screening will help improve chip uniformity, but reprocessing screen rejects increases costs and results in fiber loss.

CHIPPERS

Many sawmill residue chip quality problems can be traced back to the chipper. In fact, when talk centers around improving chip quality, the chipper is often the place where it can be improved the most (APA, 1992). Sawmill residue chippers are essentially a scaled-down version of those used to chip tree-length or roundwood material. The overall configuration is virtually the same except a residue chipper usually has fewer knives, a smaller disk, and requires less horsepower. Typically a 36- to 60-inch, 3-6 knife chipper is used for all residue. Unlike roundwood, each residue component is distinctively different in form, regularity of presentation to the chipper disc, and reaction during chipping. The ideal situation would have a separate chipper for each type of residue (slabs, edgings, and trim blocks), but this is not economically justifiable at most sawmills (Veuger, 1976).

Bergman (1985) reported that maintaining good control of chipping equipment and residue chips was the first step in achieving good chip quality. Furthermore, chip quality is a function of chipper operation and maintenance (Robinson, 1987). For example, sharp knives produce 3-5% more acceptable chips than worn knives regardless of the knife setting (Horng, 1986). Excessive wear to the infeed spout also produces more pin chips and fines (APA, 1992).

Maintenance not only leads to higher chip quality, but reduces power requirements and extends machine life.

The internal operation of a disk chipper does not vary. However, there are several ways to deliver material to the chipper and to discharge the chips from the chipper.

INFEED

There are two basic methods commonly employed for feeding material to residue disk chippers, gravity or drop feed and horizontal feed. The three typical spout locations (2 horizontal and 1 gravity) are shown in Figure 2.1. Spout locations A and C (gravity and horizontal, respectively) are the most typical of sawmill residue chippers, while a few use the above the shaft horizontal infeed (B). Some sawmills have modified these basic infeeds even further to assist in material control and feeding.

Horizontal Infeed

The horizontal infeed is most commonly used. It provides more initial control of the approach and feed rate of the material (Hartler, 1986). Vibrating conveyors have been found to provide the greatest control and are most commonly used. They shorten the dead spot between the conveyor and chipper disc preventing plug-ups (McLauchlan and Lapointe, 1979). Conveyors are sometimes altered to provide a greater degree of control (Robinson, 1987). Any feed conveyor used should deliver material to the chipper at

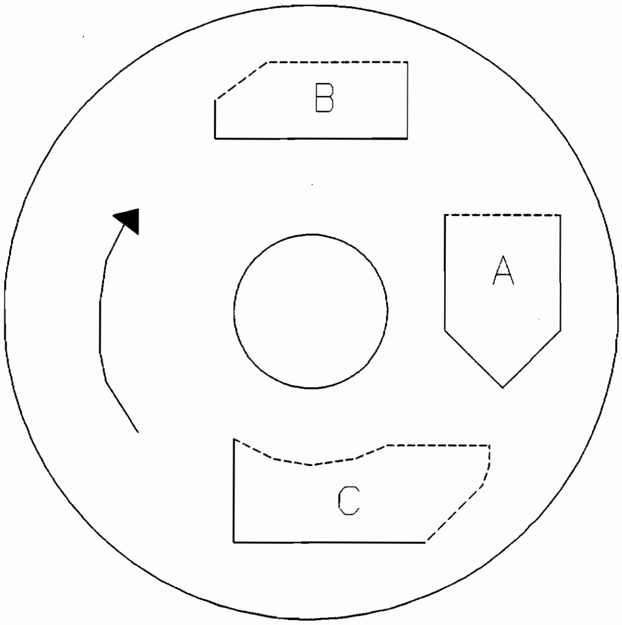


Figure 2.1. Spout locations in relation to a clockwise rotating disc (Hartler, 1986).

a rate 10-15% slower than the chipper feed rate to ensure the disc does not get overtaken by the material (McLauchlan and Lapointe, 1979).

Gravity Infeed

As the name implies, gravity assists feeding on a drop-fed chipper. Unlike a horizontal infeed, material entering the machine is raised above the chipper throat. Passing over a tip point, it then slides down a sloping steel chute into the disc. The sloped chute orients the material to chipper disk while keeping it parallel to the chute contour (Robinson, 1987).

The infeed chute is designed to smooth the transition from the conveyor to chipper, but its effectiveness is limited to material lengths of eight feet and less (McGovern, 1979). A gravity infeed chipper is best suited for short, heavy material (Veuger, 1976). Longer material generates more momentum when it falls because it must be raised higher to enter the chipper (Stuart, 1993).

FEEDING

Much of the research on material throughput for woodyard chippers can possibly be applied to residue chippers. There has been some debate on feeding material, in a bundle (full infeed) or 1 or 2 logs at a time. One advantage of bundle feeding material is that it increases machine utilization (Hartler, 1986). Hartler also reported that chip quality improved if the bundle were controlled as it was fed. Robinson (1987), however, found that chip quality normally suffers when the infeed is full. Likewise, Crowley and Wardwell (1961) found that a higher percentage of long chips are produced when more than 1 or 2 logs are fed at the same time.

Material alignment and feeding difficulties can arise when multiple pieces are fed. A constant, uniform feed angle undoubtedly improves chip quality (Robinson, 1987). He reports the optimum spout angle to be 34-45 degrees when chipping logs (Figures 2.2 and 2.3). In addition to uniform feeding, material stability during chipping influences chip quality. Material should be held and chipped against the vertical anvil (Veuger, 1976; Robinson, 1987). Movement during chipping creates different infeed angles and generates higher percentages of overs and fines (Robinson, 1987).

Well maintained chippers are self-feeding. Proper feeding is essential to sustain chip uniformity and formation (Hartler, 1986). If the material is not fed at the proper rate and angle, chances of splitting and increased compression damage to chips is possible. The feed rate is controlled by the "pull-in," or clearance angle, of the knives and is directly associated with chip length (Figure 2.3). The importance of the proper angle is

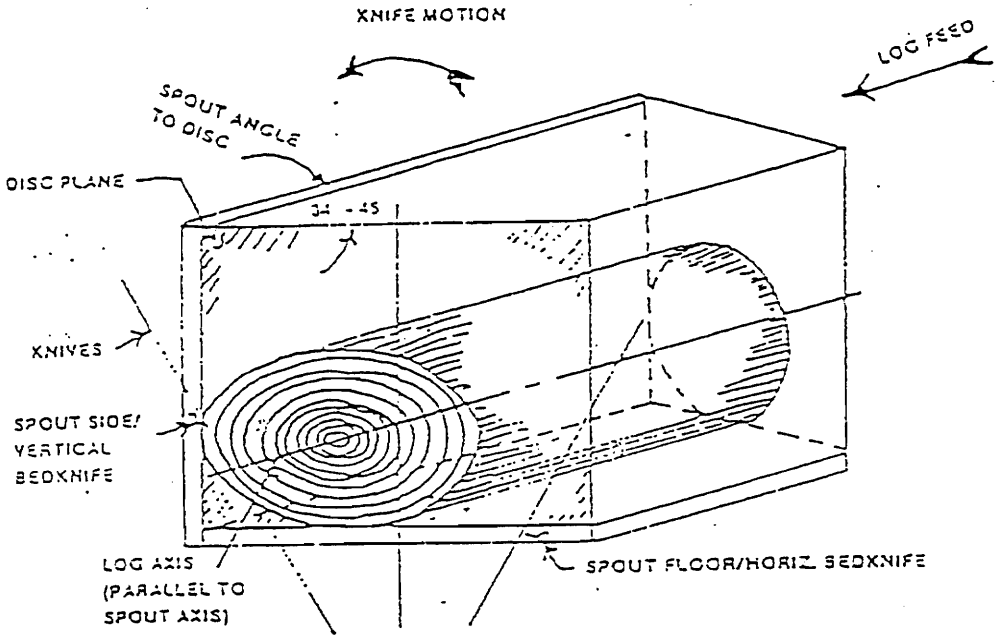
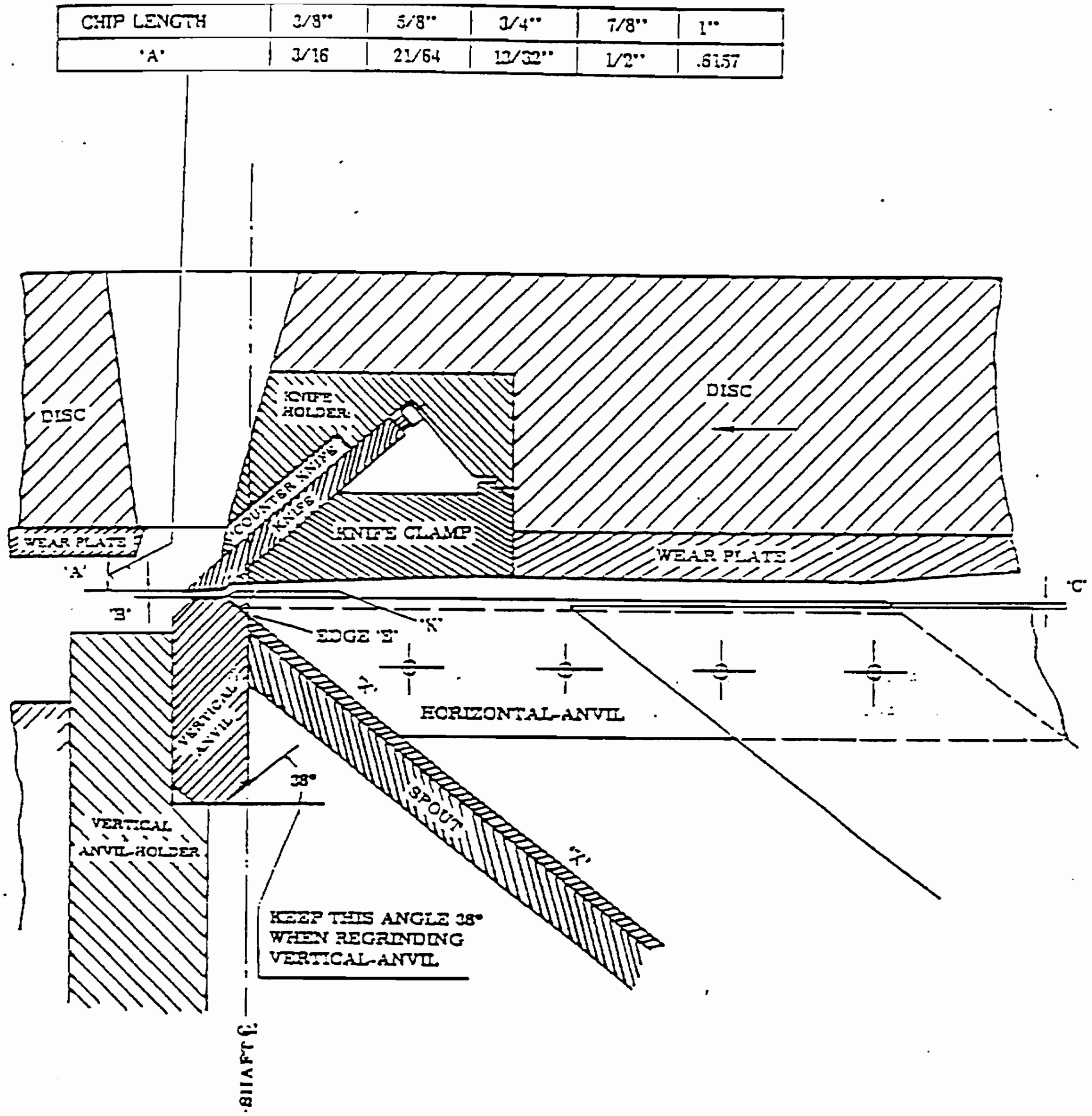


Figure 2.2. Above the shaft horizontal infeed spout with log entering at the correct angle (Robinson, 1987).



CHIP LENGTH	3/8"	5/8"	3/4"	7/8"	1"
'A'	3/16	21/64	13/32"	1/2"	.6157

Figure 2.3. Chipping components with correct infeed angle and clearance angle for desired chip lengths (Fulghum Industries, Inc., -).

reflected by Crowley and Wardwell (1961), stating that a "poor feed can spoil the operation of a good machine." A small clearance angle produces short chips, while an overly large angle causes excess wear on the disk. Large clearance angles also cause material to tip-up during chipping and produce short chips (Crowley and Wardwell, 1961).

CHIP FORMATION

Chips are formed when the knives of the chipper exert forces greater than the shear strength of the wood. Wood enters the chipper at an angle of approximately 34-45 degrees and butts up against wear plate on the chipper disc. The wood should be oriented with its grain parallel with the spout axis and against the vertical anvil. The chipper knife then applies a shearing force across the wood grain and shears a piece from the original material. The size of this piece depends on the clearance angle of the knife to the wear plate (Figure 2.3). The clearance angle controls chip length and indirectly controls chip thickness and the feed rate. At the same moment the piece is sheared from the material, splitting forces are applied along the grain of the cut piece to break it into smaller pieces or chips.

There is not a direct adjustment on a disc chipper to set chip thickness. Instead, chip thickness is largely a function of chip length and controlled by the clearance angle. Robinson (1987), chief engineer for Carthage Machine

Company, has found chip length to be approximately four times chip thickness. Therefore, chipping to a uniform length is the best way to chip to a uniform thickness on a disk chipper (Robinson, 1987). Horng (1986) found that significantly more overthick chips (greater than 8-mm) were produced at a knife setting of 7/8-inch than at 5/8-inch. He also reported that the percentage of 2-4 mm thick chips at the 5/8-inch knife setting almost doubled that of the 7/8-inch setting.

DISCHARGE

There are several methods for clearing chips from a chipper. Top, side, and bottom discharges are used, with top and bottom being the most common for sawmill residue chippers. Top discharge chippers are often referred to as blowing discharge chippers. Gravity assists chip expulsion on bottom discharge chippers.

Top discharge chippers are often used because of the simplicity of the pneumatic chip handling system. Blow pipes are easier and cheaper to install and route to handle the discharge (Veuger, 1976). Blowing vanes attached to the disc serve two purposes during chip discharge, they first sling the chips through the discharge and then act as a fan to help blow the chips to their destination (Figure 2.4).

Numerous studies have found that top discharge systems produce higher quantities of pin chips and fines than other

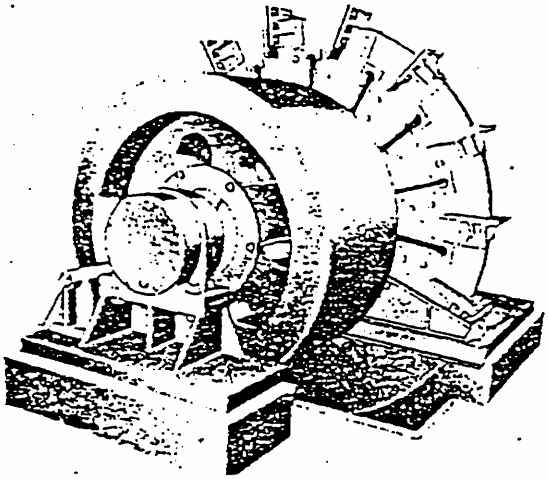


Figure 2.4. Top discharge chipper with blowing vanes attached to disc rim (Robinson, 1989).

discharge methods. There are several possible explanations for this increase. Robinson (1987) reported that some chips were mashed between the vanes and the chipper casing. Removing blowing vanes can reduce the amount of mashing that occurs, but blowing ability is reduced, increasing the risk of plug-ups in the blow pipes. A second reason is chipper disc speeds are higher for top discharge chippers (Robinson, 1987). Disc speeds are faster than comparable bottom discharge chippers to avoid plug-ups and maintain blowing velocities. Finally, since chips are discharged at high velocities and flow to the outside of blow pipes, obstacles or sharp turns in the blow pipes can easily fracture and break-up chips (Veuger, 1976).

By contrast, bottom discharge chippers are often equipped with card breakers on the back of the disc (Figure 2.5). Although chip damage is not as great with card breakers as with vanes, some chips do get broken into smaller size fractions. For this reason, the chipper should be equipped with the fewest number of card breakers necessary for balance (Robinson, 1987). Bottom discharge chippers allow slower disc speeds since gravity assists in the discharge, so there is more flexibility and control in disc speeds to control chip quality (Robinson, 1987).

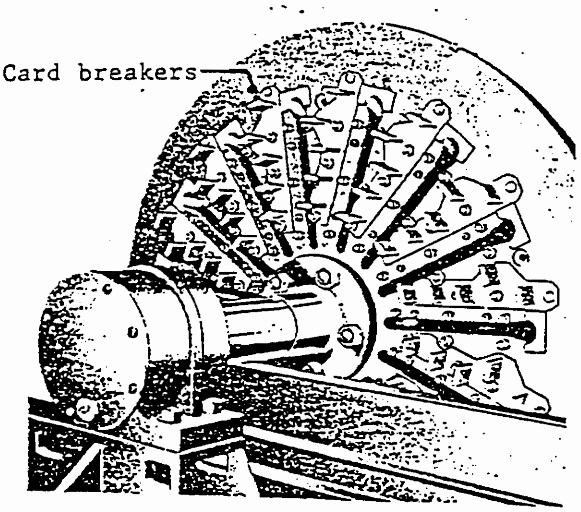


Figure 2.5. Bottom discharge chipper with card breakers on the back of the disc (Robinson, 1989).

IMPACT OF CHIP QUALITY ON PULPING

The factors most commonly associated with chip quality are length, thickness, and to some extent bark and dirt content. Critical factors are dependent on the pulp process and pulp mill (Table 2.1). Acceptable chips are generally defined to be 20- to 25-mm in length along the grain and 2- to 8-mm thick (Hartler, 1986). Chips differing from these thickness dimensions adversely affect pulp quality and operating efficiency. Thinner chips can be traced to mechanical instability during processing and tend to pulp too quickly (Hartler, 1986). On the other hand, thicker chips slow liquor penetration. These chips tend to be overcooked on the exterior and undercooked in the center of the chips (Grant and Schneider, 1987).

Short chips likewise affect pulping. Pin chips and fines (usually less than 1/4-inch) cook more rapidly because of their smaller size. They also constrict liquor circulation and clog recovery screens. Continuous digesters are especially subject to these problems. Increased resistance in the liquor flow often leads to plugging liquor extraction screens (Hartler and Stade, 1977). High percentages of pin chips and fines also lead to reduced diffusion washing efficiency in continuous digesters (Powell et al., 1975). Problems in continuous digesters do not arise until the upper limit of the pin chips and fines

Table 2.1. Effect of chip quality parameters in pulp processing (Hartler and Stade, 1979)

Chip Parameter	Pulping Process			
	Kraft	Sulfite	NSSC	Refiner-Mechanical
Length preferred range, mm	Not too critical 15-25	Critical 25-35	Not known	Not known
Width	Not critical	Not critical	Not critical	Not known
Thickness preferred range, mm	Very critical 1.5 - 4 (solid wood)	Not critical[1]	Not known	Not known
Chip Density	Constancy Critical			
Bark Content preferred range, %	Critical for production economy	Very critical < 1	Critical for production economy	Critical
Hard impurities (sand, metal)	Critical for high yield	Critical for dissolving pulp	Very critical for plate life	
Chip Damage	Not critical	Very critical	Not critical	Not known
Moisture Content	Not critical	Not critical	Not critical	Very critical

[1] - With increasing chip length in sulfite pulping chip thickness assumes increasing importance for ease of liquor penetration.

content has been exceeded (Hatton, 1975). Digesters using forced liquor circulation also have shown reduced liquor percolation rates through the chips, producing non-uniform cooking conditions and poor quality in the presence of pin chips and fines (Grant and Schneider, 1987). Most mills have only one continuous digester per pulping line so production can be shut down when problems arise.

Increased digester efficiency is not the lone beneficiary of good chip quality. The entire pulp mill operates more efficiently and economically. Along with higher pulp quality and yield, high chip uniformity means reduced cooking times, reduced sewage and landfill, and increased paper machine speeds and sheet quality (Robinson, 1987). Pulkki (1991) found increased chip quality contributed to less bleaching chemical consumption, which in turn lowered effluent treatment costs. Any deviation from a mill’s optimum set-up decreases chemical use efficiency, pulp quality and uniformity (Bergman, 1985). Chip quality is of even greater importance at pulp mills that have to place unusable chips in landfills (Pulkki, 1991). Although only a few mills are unable to use unwanted pulp chips, the economic impact of undersize chips to these mills is enormous.

Chip quality also influences possible cooking conditions at the mill. Cooks to lower Kappa numbers can be obtained with improved chip quality. Chip uniformity is essential for short cooks (Nolan, 1963). During shorter cooks, everything is intensified so each chip must be similar to receive comparable pulp yields and quality.

KRAFT PULPING

Kraft pulping is the most prevalent pulp producing process in the world. Approximately 60% of the pulp in North America was produced from the kraft process in 1990 (Smook, 1992). The overall objective in kraft pulping, as in any chemical pulping, is to cook chips to a desired degree of delignification. Delignification is achieved by chemical reactions from chemicals that penetrate the wood and dissolve the lignin fragments. Lignin content after cooking is normally 4-5% for softwoods and 3% for hardwoods (Smook, 1992). The degree of delignification is measured by either a Kappa number or the less commonly used permanganate number.

The ability of chemical penetration in kraft pulping, and for an economical operation, is highly dependent on chip quality (Smook, 1992; Hatton, 1987; Forbes, 1984; Hatton, 1976; Tikka et al., 1992; Hartler and Stade, 1977). Hatton (1986) conducted a survey in 1985 of Canadian Kraft pulp mills to determine the effects of chip quality on continuous digester operation. Questions on the effect of overthick, oversize, pin chips, and fines on operations and pulp yield and quality were posed to the mills. Results of the survey are shown in Table 2.2, with asterisks marking the most significant effects.

Chip thickness has been found to be the most critical chip parameter for the Kraft process in recent studies (Hatton, 1987; Forbes, 1984; Hatton, 1976; Tikka et al., 1992; Hartler and Stade, 1977; Worster et al., 1977). Earlier work by Hatton and Keays (1971) found the fines and oversize content in the chip supply to be the second most important quality parameter. Although length is not a critical chip quality parameter in the kraft process, chip thickness and size is greatly influenced by chip length.

Chemical penetration during cooking is depth dependent (Tikka et al., 1992; Forbes, 1984). Delignification beyond the depth where there is full penetration is incomplete. Overthick chips leave uncooked residues in the form of shives, knots, and knotter rejects in kraft pulp (Christie, 1986; Worster et al., 1977). Christie (1986) also compared the effects of overthick chips and thin chips in five kraft pulping experiments. Lignin content was 50% greater for the overthick chips in all cases after the first cook.

Hatton (1987) reported numerous studies concurred that maximum screened-pulp yields are achieved with a 3-mm thick chip. However, the 3-mm thickness is more representative of the "effective chip thickness" or actual chip thickness

Table 2.2. Qualitative effects of chip quality on kraft pulping (Hatton, 1986).

Factor	Overthick; Oversize	Pin Chips; Fines
Production Rate	Lower	Lower
Pulping Uniformity	Poor	Poor
Pulp Lignin Content	Higher	Lower
Liquor Circulation*	Satisfactory	Very Poor
Recovery Operations	Poor	Poor
Chemical Consumption	Higher	Higher
Pulp Yield	Lower	Lower
Pulp Quality	Lower	Lower
Pulp Bleachability	Hard	Soft
Bleached Pulp Quality*	Shives	Satisfactory
Process Control*	Poor	Poor
Costs	Higher	Higher

* - significant effect

(Hatton and Keays, 1973). Colombo et al. (1964) found that the nominal thickness of mill-cut or commercial chips is reduced by internal cracks or fissures whereas laboratory chips have no surface defects and internal cracks. As a result, mill chips could be slightly thicker and still produce comparable pulp yields because internal cracks compensate for the increased thickness (Figure 2.6). Several studies have reported that no more screen rejects were produced by larger mill cut chips than comparable laboratory chips (<u>Chip Quality Monograph</u>, 1979). Upon reviewing data and literature from several studies, Christie (1986) found all to be in agreement that the critical thickness of a commercial chip was 7-mm or slightly less. However, as chip thickness increases, screen rejects in kraft pulping also increase (Hatton, 1987; Worster et al., 1977; Horng, 1986; Forbes, 1984).

As the percentage of pins and fines increase, difficulties arise in processing and maintaining pulp quality. Pin chips and fines can be added in controlled amounts, but produce kraft pulps of lower strength and yield (Pulkki, 1991; Worster et al., 1977). Hatton (1975) attributes some of the yield loss to small bark particles that are present in pin chips and fines but not in acceptable chips. However, additional pin chips and fines increase the load on the recovery boiler. Forbes (1984)

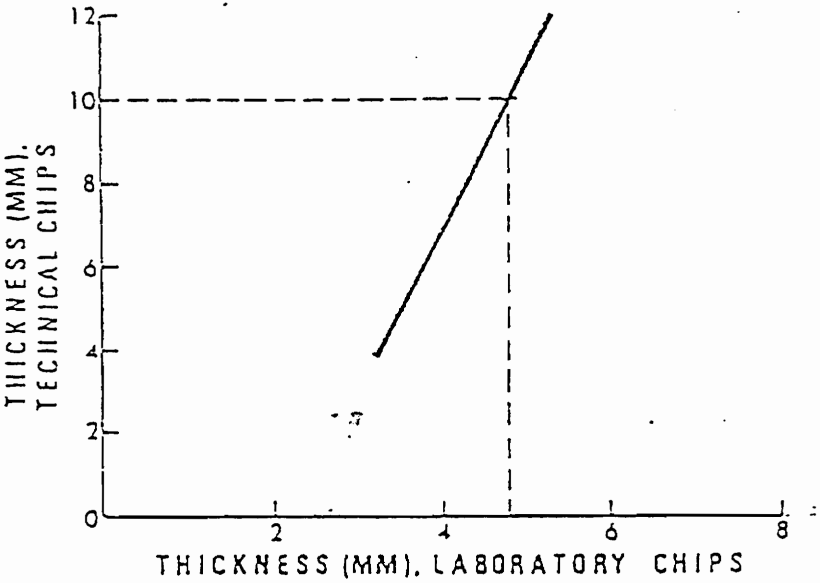


Figure 2.6. Thickness of commercial chips and laboratory chips required to produce equal pulp yields (Colombo et al., 1964).

suggests that the percentage of fines or dust remain below 1% and the total undersize chip content be limited to 10% by weight.

Reducing both overthick chips and fines entering batch digesters at Williamette Industries Albany, Oregon paper mill improved production as well as economic efficiency (Parker, 1985). Black liquor solids were decreased to the point that an inefficient recovery boiler could be shut down. Parker goes on to report better Kappa number control and reduced pulp rejects. More uniform chips also permitted higher yields at increased Kappa numbers.

SULFITE PULPING

The sulfite (acidic) process was the most widely used through the 1930's. Sulfite pulping involves combining sulfurous acid, and most commonly, a calcium-based bisulfite to delignify wood to a target number (Haygreen and Boyer, 1989). Delignification with the sulfite process is easier than the more popular Kraft process. The amount of hemicellulose remaining can also be controlled by the temperature and acidity of the cook. Cooks at higher temperatures and acidity will increase the pure cellulose content of the pulp (Smook, 1992). Unbleached sulfite pulp is also brighter than kraft pulp and can be bleached to full brightness and to higher yields than Kraft pulp (Smook, 1992).

The number of sulfite pulp mills is declining. One reason for this decline is the inability to accommodate variations in wood species. Species limitations crippled the growth of sulfite pulping as the wood supply shifted to the South. The sulfite process is sensitive to both resinous softwoods and tannin-containing hardwoods (Smook, 1992). Other reasons contributing to the decline include lower strength pulp and difficulties in chemical recovery.

The critical chip quality parameter in sulfite pulping is the length along the grain (Hatton, 1987; Hartler and Stade, 1977). Chips must be long enough to produce long fibers to offset the weaker sulfite pulp, but still allow for sufficient chemical penetration. Chemical reactions within the chips do not accelerate until the digester temperature has exceeded 110°C, but chemical impregnation must be complete before this temperature is reached. Chip thickness also remains as a crucial dimension in sulfite pulping as chip thickness is proportional to chip length (Hatton, 1987). Chemical penetration is again limited when chips become to thick.

TRIM BLOCKS

Trim blocks produce the lowest quality chips of all sawmill residue. Leary and Stuart (1991) found that under control, or normal operating conditions, trim blocks produced significantly more (26%) overthick chips (greater than 8-mm) than other residue types. Approximately 9% of the chip furnish was pin chips and fines. Likewise, in a companion study to Leary and Stuart (1991), Edelman (1992) reported that 25% and 13% of the trim block chip furnish was overthick and pin chips and fines, respectively.

Trim blocks rarely orient properly when entering the chipper and therefore are the most difficult to chip (Veuger, 1976). Consequently, chips are cut at random angles and many times do not have fissures that are characteristic of commercial chips increasing their nominal chip thickness (Christie, 1986). Additionally, trim blocks are proportionally small compared to the size of the residue chipper. Approximately one-half of the pieces of trim are only 1-2 inches in length (Jorgenson, 1985). As a result, Christie (1986) found that up to 20% of the chips from end-trim were non-uniform, overthick chunks compared with 3-4% when chipping whole logs.

TEMPERATURE

Cold wood, especially frozen or nearly frozen, produces greater amounts of pin chips and fines than wood at ambient temperature. Overall chip distributions shift toward the smaller chip fractions during winter months (Hatton, 1977). Hartler and Stade (1977) found that the amount of pins and undersize chips doubled and tripled, respectively, between 59°F and -22°F (15°C and -30°C). Nelson and Bafile (1989) reported a curvilinear relationship between 2-4 mm thick chips and temperature ranging from 27% at -22°C to 15% at 10°C. Leary and Stuart (1991) reported that pin chips and fines increase significantly as a result of reducing temperature of sawmill residues to near freezing and freezing. There was some evidence that the overthick percentage decreased for the frozen and chilled wood, but results were inconclusive.

Edelman (1992) performed a companion study to that of Leary and Stuart's summer trials in the winter of 1991. Again a significant increase in the production of pins and fines occurred with frozen and chilled wood. He also found that any decrease in overthick chips at lower temperatures was nullified by the significant increase of pin chips and fines resulting in a net loss of pulpable chips at frozen and chilled temperatures. The increase in pin chips and fines concurred with the results of Leary and Stuart (1991), thus allowing Edelman to suspect that temperature rather than physiological changes in the wood during different seasons was the cause of variation in chip quality (Edelman, 1992).

Slight modifications to the chipper have been found to offset the effects of cold temperatures. The "pull-in" angle, or feed rate of the chipper, should be increased during winter months to compensate for the brittle wood (Crowley and Wardwell, 1961). Decreasing chipper disc speed is an alternative to adjusting the feed rate. Overall chip distributions become skewed toward the larger chip sizes as disc speed is decreased (Leary and Stuart, 1991; Edelman, 1992; Robinson, 1989). Additionally, removing card breakers on bottom discharge chippers can also improve chip quality during the winter months (Robinson, 1989).

CHAPTER 3

METHODS AND PROCEDURES

IMPROVING RESIDUE CHIP QUALITY

Trim blocks consistently produce poor chips and create numerous quality problems at sawmills. A basic economic model was constructed to determine both the benefits of improved quality and the amount of money that could be made available to make improvements at the sawmills. The study was broken into several steps to document and understand trim block chip quality, as well as test possible solutions that would improve chip quality to an acceptable level.

RESIDUE COMPOSITION

The first step, or study, was conducted to determine the composition and volume of material entering trim block chippers and identify places where quality could be improved. Material entering a residue chipper at a high volume southern pine mill was collected during three 5-minute sampling periods throughout the day to classify the type, origin, and quantity of trim blocks. Each residue type was then chipped to document current chip quality. The quantity and chip quality from each form of trim blocks was then evaluated and several solutions developed.

The first study revealed that a substantial amount of

2-foot trim was produced from material that could have been left in 4-foot or longer pieces. It was hypothesized that lengthening trim blocks would ensure better orientation prior to chipping, improve stability, and reduce the number of ends chipped, all leading to an improved overall chip yield.

EFFECT OF PIECE LENGTH

The hypothesis was tested twice at two separate southern pine sawmills. The first study was conducted at a mill in Central Georgia that had a typical residue chipping set-up. The chipper size, infeed, and chip length were comparable to those found at most sawmills. Results from this study found strong evidence supporting the hypothesis that quality improved with trim block length. The relationship was tested again at a South Georgia sawmill with a more extreme set-up. A smaller chipper, set to produce a chip one-half the length of the first chipper, used the same size infeed conveyor to handle the residue, but modified it to fit the smaller chipper throat.

EFFECT OF CONVEYOR LOADING

The effects of chipper and/or conveyor loading on chip quality were also examined in South Georgia. The amount of residue entering a chipper can fluctuate quickly with changes in log quality, mill equipment capabilities, and head-rig settings. Sometimes the chipper and conveyor sit idle except for an occasional piece. There are other times when head-rig settings or log quality necessitates increased trimming and slashing that load the conveyor and chipper. Evening out the flow could be a second means of improving chip quality.

EFFECTS OF TEMPERATURE

The final component of the project examined the effect of seasonal temperatures on pin chip and fine production at Southern chip mills. The pin chip and fine content was widely believed to increase during the winter months, but the magnitude of the increase was not well known. Therefore, the project shifted from an experimental to empirical basis to measure this effect at both pine and hardwood chip mills.

Chip quality reports were obtained for a one-year period at seven chip mills, three pine and four hardwood. Daily temperatures were acquired from local weather stations for each mill. Daily temperatures were correlated with the chip sample data to establish the relationships.

CHAPTER 4

POTENTIAL CAPITAL FOR IMPROVEMENT

INTRODUCTION

Investments in equipment and procedures to improve chip quality must be made before any revenues are realized. Careful consideration must be made to ensure that the each participant's benefit matches its investment. The benefiting pulp mill can not expect a sawmill to cover improvement costs without any compensation. If benefits do outweigh the costs, the money to finance the changes has to come from the savings.

Pulp mills currently purchase chips at a flat rate regardless of the percentage of acceptable chips. Most mills will terminate a supplier who is unable or unwilling to meet their minimum chip quality specifications. Two incentive programs were explored to generate the money needed to implement changes in residue chip systems. Each program was developed on the basis that the pulp mill's actual cost per ton of chips decreases with each percent increase of acceptable chips. Sharing these savings with the supplying mills by paying a premium for improved chip quality becomes the simplest way to generate funds for process improvement. The potential capital for sawmills to invest in equipment or policing chip quality was determined for large and small sawmills using two different incentive programs. Three alternative solution scenarios, differing in the ratio of capital improvements to administrative and overhead costs, were explored.

ECONOMIC MODEL

A pulp mill's furnish from each supplier varies depending on raw material, use of screens, and quality control. Providing incentives is one way to improve chip quality and to encourage consistency. A simple economic model was developed to estimate the amount of money saved as a result of a higher quality furnish and, therefore, available to provide incentives. Although the model does not take all variables into account, it does provide some insight into the order of magnitude of funds available to bring about a change.

Both the pulp mill and chip supplier will require an economic reward for instituting a quality improvement program. Paying for quality requires more policing of chip quality by the pulp mills. Sawmills will have to increase their investment in equipment, or spend more on increased maintenance and operating costs. Gains from improved chip quality should be split between the two participants.

Several assumptions were made to generalize the model:

1) A 1,000 ton per day pulp mill purchases 140,000 tons of residue chips per year (400 tons per day x 350 days per year).

2) The pulp mill currently pays chip suppliers a flat rate of $20 per ton for pulp chips and $7 per ton for fuel chips.

3) The mill enforces a minimum standard of 70% accepts per ton of mill run chips delivered. Acceptable chips are less than 8-mm thick, pass through a 1 1/4-inch square hole, and are retained on a 3/8-inch round hole screen.

4) Incentives are derived from the savings associated with increasing the percentage of acceptable chips per delivered ton.

5) Savings to the pulp mill are split 50/50 with the sawmill to make improvements.

6) Three different approaches are available for implementing improvements at the sawmill.

   Low operating / high capital -
      25% of revenue for additional operating costs and 75% of revenue for capital investment. A technological solution.

   Balanced operating and capital -
      50% of revenue for additional operating costs and 50% of revenue for capital investment. A mixed solution.

   High operating costs / low capital -
      75% of revenue for additional operating costs and 25% of revenue for capital investment. A maintenance and administrative solution.

7) The recovery period for any capital investment is five years.

8) Money left after deducting operating and overhead costs each year is discounted at an interest rate of 8% to derive the amount of capital that can be invested for improvement.

CURRENT COSTS AND POTENTIAL SAVINGS FOR THE PULP MILL

The base cost per ton of acceptable chips for each actual level of accepts was determined using the following formula:

$$C = P / (a / 100) - F * (1 - a / 100),$$

where

C = cost per ton of acceptable chips
P = price per ton of mill run chips
a = percentage of acceptable chips
F = price per ton of fuel chips.

For example, a load containing 70% accepts costs the pulp mill $26.47 per ton of acceptable chips. A load with 100% accepts costs the mill $20.00 per ton, a savings of $6.47 per ton (Table 4.1). The expected gain, or pulp mill's savings, were then assumed to be the decrease in cost per ton of chips for each 1% improvement as shown in Table 4.1.

DISTRIBUTION OF THE PULP MILL'S SAVINGS

Fifty percent of the savings would be used to finance the incentive for the sawmills. The incentive available for each percent increase in accepts is reflected as the sawmill's potential marginal revenue per ton (Table 4.1). Twenty-five percent of the savings would be used to support chip quality monitoring and program administration while 10% would be used to purchase equipment needed to expand chip

Table 4.1. Price paid for a ton of acceptable chips ranging from 70 to 100 percent accepts.[1]

Percent Accepts	Percent Fuel	Price per ton of Accept Chips (\$/ton)[2]	Decrease in Cost/Ton of Acceptable Chips (\$/ton)	Marginal Revenue for Sawmill (\$/ton)
70	30	26.47	--	--
71	29	26.14	0.33	0.17
72	28	25.82	0.32	0.16
73	27	25.51	0.31	0.16
74	26	25.21	0.30	0.15
75	25	24.92	0.29	0.15
76	24	24.64	0.28	0.14
77	23	24.36	0.27	0.14
78	22	24.10	0.26	0.13
79	21	23.85	0.25	0.13
80	20	23.60	0.25	0.12
81	19	23.36	0.24	0.12
82	18	23.13	0.23	0.12
83	17	22.91	0.22	0.11
84	16	22.69	0.22	0.11
85	15	22.48	0.21	0.11
86	14	22.28	0.20	0.10
87	13	22.08	0.20	0.10
88	12	21.89	0.19	0.10
89	11	21.70	0.19	0.09
90	10	21.52	0.18	0.09
91	9	21.35	0.17	0.09
92	8	21.18	0.17	0.08
93	7	21.02	0.16	0.08
94	6	20.86	0.16	0.08
95	5	20.70	0.15	0.08
96	4	20.55	0.15	0.07
97	3	20.41	0.14	0.07
98	2	20.27	0.14	0.07
99	1	20.13	0.14	0.07
100	0	20.00	0.13	0.07
average marginal revenue				0.10

[1] - Assuming \$20/ton for pulp chips and \$7/ton for fuel chips.

[2] - $\$/\text{ton} = \$20 / (a / 100) - \$7 * (1 - a / 100)$
where a = percentage of acceptable chips delivered.

sampling and analyses. The remaining portion (15%) represents the pulp mill's net savings per year in chip purchases. Additional savings which would occur throughout the pulp mill were not included in this analysis.

FIRST INCENTIVE PLAN - PRICE FOR QUALITY

This incentive plan recognizes that suppliers with low-quality chips will need to invest more money to upgrade their quality. A 1% gain from a low-quality supplier also generates greater gains for the pulp mill.

This approach establishes a pay scale that rewards the supplier (sawmill) with the marginal revenue for each percent increase in acceptable chips (Table 4.2). Suppliers will receive more per ton for improving chip quality from the minimal level to a moderate level than for improving the level from a good to an exceptional level.

IMPROVING FROM 70 TO 80 PERCENT ACCEPTS

Improving from 70 to 80 percent accepts represents a situation where change is a necessity.

Pulp Mill's Savings

Increasing the acceptable residue furnish from 70 to 80 percent would save the pulp mill $2.87 per ton ($26.47 - $23.60, from Table 4.1) or roughly $400,000 per year in chip purchases. Half of the savings ($200,000) would be used for the supplier's incentives. Additional administration and

Table 4.2. Example of pay scale based on chip quality.

Percent Acceptable Chips	Pulp Chip Price ($/ton)
70	20.00
71	20.17
72	20.33
73	20.49
74	20.64
75	20.79
76	20.93
77	21.07
78	21.20
79	21.33
80	21.45
81	21.57
82	21.69
83	21.80
84	21.91
85	22.02
86	22.12
87	22.22
88	22.32
89	22.41
90	22.50
91	22.59
92	22.67
93	22.75
94	22.83
95	22.91
96	22.98
97	23.05
98	23.12
99	23.19
100	23.26

equipment costs at the pulp mill would consume another $140,000. The remaining 15% ($60,000) represents the annual savings in chip purchases.

Sawmill's Annual Revenue to Improve Chip Quality

A sawmill's annual revenue from improved chip quality depends on the amount of residue chips delivered to the pulp mill. It was assumed that sawmills operate 200 days per year, with a small mill producing 20 tons of chips per day (4,000 tons per year or 3% of the annual residue furnish received by the pulp mill) and a large mill producing 125 tons per day (25,000 tons per year or 18% of the annual residue furnish).

Improving from 70 to 80 percent would generate $1.45 additional revenue per ton ($21.45 - $20.00, from Table 4.2) for sawmills. A large mill receives $36,250 extra per year, whereas a small mill receives $5,800 per year (Table 4.3).

Distribution of Annual Revenue

Returns for improved quality will be spent for physical improvements, overhead and operating costs, and profit. Capital expenditures may be required to upgrade equipment, change handling systems, or install screens. Operating and overhead costs encompass expenses for repair and maintenance, labor, and any additional power needed by the improvement. There are trade-offs between the two costs, depending on the type of improvement a sawmill chooses.

Table 4.3. Annual revenue and capital money made available by improving from 70 to 80 percent acceptable chips using the price for quality incentive plan.

		Money Available for Capital Improvements by Improvement Strategy[1]		
Mill Size	Annual Revenue ($)	Low - 25% ($)	Medium - 50% ($)	High - 75% ($)
Large	36,250	36,183.93	72,367.87	108,551.80
Small	5,800	5,789.43	11,578.86	17,368.29

[1] - Present value of annual revenue allocated for capital improvements after five years.

Sawmills electing to invest heavily in capital improvements will have reduced operating and overhead costs. Money remaining after the improvement costs represents a sawmill's profit for improving chip quality.

The model was not expanded to detail all overhead and operating costs for each possible solution. Instead, overhead and operating costs were broken down into three categories (low operating/high capital, balanced operating and capital, and high operating/low capital) to estimate the capital available for investment.

The low operating cost, high capital option would involve a change in mill equipment. These changes could include modifying the trimmer optimizer outfeed table to accommodate 4- or 6-foot lengths and/or tilting the infeed conveyor to force pieces into alignment against the vertical anvil. Seventy-five percent of the increased cost are designated for capital improvements and 25% for overhead and operating expenses.

The balanced operating and capital cost option would involve a less expensive change in mill equipment. Fifty percent of the additional revenue would be for capital and 50% for operating and overhead costs. This solution includes changes such as installing a small, slow speed chipper to handle trim ends or changing from pneumatic systems to conveyors for transporting chips.

The high operating, low capital option is essentially a surveillance, maintenance, and repair solution. This entails rebuilding major equipment to bring it back to manufacturer's specifications, more frequent knife changes, and other similar procedures. Seventy-five percent of the costs are designated to operating and 25% for capital investment.

Sawmill's Capital for Improvement

A sawmill's potential investment over a five-year period was determined after subtracting overhead and operating costs each year, then discounting the remainder to present at 8%. Results for each size mill and improvement strategy are shown in Table 4.3.

IMPROVING FROM 85 TO 95 PERCENT ACCEPTS

Improving from 85 to 95 percent accepts represents a situation where the upgrade is a refinement of an already acceptable system. Potential gains are less so there is less money available for improvement.

Pulp Mill's Savings

The pulp mill would save $1.78 per ton or approximately $250,000 annually in chip purchases. The pulp mill would use $125,000 to finance the incentive and $87,150 to cover additional expenses, resulting in a net savings of $37,350 each year.

Sawmill's Annual Revenue and Capital for Improvement

This incentive plan would return $0.88 per ton to the sawmill for increasing the acceptable chip furnish from 85 to 95 percent. A large mill receives $22,000 per year in additional revenue while a small mill receives $3,520 per year (Table 4.4).

The amount of money that each size mill sawmill can invest to improve chip quality under each improvement strategy is shown in Table 4.4.

SECOND INCENTIVE PLAN - BASE PLUS INCENTIVE

This plan puts all suppliers on an equal basis regardless of their present quality. Sawmills receive the same incentive whether improving from 70 to 80 percent or from 85 to 95 percent. Benefits to the pulp mill also balance out when offering this plan. Some of the benefits gained from improvements at mills producing the lowest quality chips are used to subsidize the bonus to further improve mills already producing at a high quality level.

IMPROVING THE ACCEPTABLE CHIP FURNISH 10 PERCENT

Pulp Mill's Savings

Improving chip quality 10% saves the pulp mill $2.00 per ton (average savings per ton for each percent increase in acceptable chips [$0.20] * 10%) in chip purchases. Net annual savings for the pulp mill equal $42,000 after

Table 4.4. Annual revenue and capital money made available by improving from 85 to 95 percent acceptable chips using the price for quality incentive plan.

		Money Available for Capital Improvements by Improvement Strategy[1]		
Mill Size	Annual Revenue ($)	Low - 25% ($)	Medium - 50% ($)	High - 75% ($)
Large	22,000	21,959.91	43,919.81	65,879.72
Small	3,520	3,513.59	7,027.17	10,540.75

[1] - Present value of annual revenue allocated for capital improvements after five years.

deducting $140,000 for sawmill incentives and $98,000 for program support from the gross annual savings of $280,000.

Sawmill's Annual Revenue and Capital for Improvement

This incentive plan establishes a base price and provides a fixed premium for each percent improvement over current quality. Base prices would remain the same (in our example, $20 per ton), but for each 1% increase in accepts, the sawmill would receive $0.10 per ton (average marginal revenue per percent increase over the 70 to 100 percent range) as a bonus.

Any sawmill improving chip quality 10% receives an additional $1.00 per ton ($0.10 * 10%). Large sawmills receive $25,000 extra per year while small mills receive an extra $4,000 per year (Table 4.5). The capital available to implement the improvement strategies at each size mill is shown in Table 4.5.

SUMMARY AND CONCLUSIONS

The amount of capital that can be invested by a sawmill to improve chip quality largely depends on the quantity of chips produced and how much they are willing to improve. A simple economic model was constructed to indicate the amount of money that could be generated to finance improvements by not buying fuel chips at pulp chip prices. The potential savings were split 50/50 between the pulp mill and sawmill.

Table 4.5. Annual revenue and capital money made available by increasing the acceptable chip furnish 10% using the base plus incentive plan.

		Money Available for Capital Improvements by Improvement Strategy[1]		
Mill Size	Annual Revenue ($)	Low - 25% ($)	Medium - 50% ($)	High - 75% ($)
Large	25,000	24,954.44	49,908.88	74,863.31
Small	4,000	3,992.71	7,985.42	11,978.13

[1] - Present value of annual revenue allocated for capital improvements after five years.

The pulp mill was assumed to use its savings to compensate for the added responsibilities of chip sampling and analyses, while the sawmill would use its additional revenue to invest in improvements. No attempt was made to estimate process savings within the mill that might be generalized from improved chip quality.

This general economic model suggests that a considerable amount of capital could be made available by initiating a chip quality bonus plan. A more extensive model could be developed to incorporate detailed costs associated with changing equipment and practices at the sawmills and increasing sampling and analyses at the pulp mills.

CHAPTER 5

COMPOSITION OF TRIM BLOCKS

INTRODUCTION

An exploratory study was conducted to determine the volume, type, and dimension of sawmill residue produced by a high volume southern pine sawmill. Material entering a sawmill residue chipper includes everything from oversize chips returned from the screen to lumber that has been slashed (cut into 2-foot sections) to clear it from the mill. The amount and percentage of each material type going to the chipper was identified to determine the impact of that component on chip quality.

METHODS AND PROCEDURES

A high production southern pine sawmill in South Carolina provided the use of their facility for this study. This mill had an optimum layout for capturing the material from the chip screen and trimmer optimizer. A vibrating conveyor served both pieces of equipment and fed into the chipper infeed conveyor at a point where the flow could be diverted onto a concrete slab for sampling, categorizing, and re-entry for chipping.

COLLECTING SAWMILL RESIDUE

A wooden chute was constructed to divert and capture all material from the conveyor serving the trimmer optimizer and chip screen. Three sampling periods, seven to nine minutes each, were spread over two shifts on February 6, 1992. Two boards were painted and placed in the production line going to the trimmer optimizer to coordinate the start and end of the sampling period with the production reports. The time of day and duration of each trial are shown in Table 5.1. A production report of pieces through the trimmer optimizer was taken directly before and after each trial. The volume slashed and trimmed, and the weight of residues generated, was calculated from these reports.

After each sampling period, trim blocks were classified by size, weighed, and stored for subsequent processing. Size categories included:

1) true end trim - all widths, but less than 6-inches in length
2) grade trim - 5/4x4, 5/4x6, 2x4, 2x6, 2x8, 2x10, and 2x12 in 2-foot lengths
3) oversize chips

End trim is that material trimmed to bring a board to its final green length. These pieces generally come from the butt end of the log and are usually less than six inches in length along the grain. Grade trim was classified as all 2-foot pieces cut to remove unacceptable wane from a board.

Table 5.1. Time and duration of each sampling period.

Sampling Period	Time of Day	Duration (min.)
1	9:30 am	9.10
2	11:08 am	7.18
3	2:00 pm	6.82

Boards that could not meet grade, and subsequently slashed, were also included in the grade trim category. Grade trim was further subdivided by dimension. Oversize chips include all chips that did not pass through the 2-inch square hole top screen and were channeled back to the conveyor for rechipping.

CHIPPER

A Precision 6-knife, 75-inch top discharge chipper, powered by a 250-horsepower electric motor, was used to process the test material. The chipper and motor were in good to excellent condition. Chipper knives were replaced prior to the chipping trials and had no operating hours on them.

CHIP SAMPLING

The chipping trials were conducted on a Saturday when the rest of the mill was shut down for maintenance. Categories chipped included:

- 5/4 x 4 x 2′
- 5/4 x 6 x 2′
- 2 x 4 x 2′
- 2 x 6 x 2′
- 2 x 8 x 2′
- 2 x 10 x 2′ and 2 x 12 x 2′
- end trim
- oversize chips

The chip transport system was allowed to purge before each trial and the first sample was taken after there was a substantial chip flow. Three chip samples, approximately 10 pounds each, were captured as each category was chipped. A large shovel was placed in the chip stream between the cyclone settler and the gyrating screen pack to capture samples. Each sample consisted of three shovel fulls.

CHIP CLASSIFICATION

Chip samples were classified immediately using the mill's Gilsom chip classifier. Five-pound samples were classified as oversize (greater than 1 1/4"), overthick (greater than 8-mm), accepts (1/4" - 1 1/4"), pins (1/8" - 1/4"), and fines (less than 1/8"). At the completion of each sample, the tray and chips were weighed together to the nearest one-thousandth of a pound. Once the weight stabilized, the scale was tared. The tray was cleaned and reweighed. The weight of the chips retained on the tray was then reflected as the reading on the scale and recorded. The percentage retained in each size class was then computed for each sample.

RESULTS AND DISCUSSION

CLASSIFICATION

A breakdown of the volume produced in each trial is shown in Table 5.2. The greatest volume of trim blocks was in the 2x4 and 2x6 inch dimensions. Interestingly, the 1-inch (5/4) lumber produced more trim block pieces than the other categories, even though relatively little of this dimension was produced. This anomaly was caused by the slashing of entire boards. These thinner boards are

Table 5.2. Breakdown of each dimension by trial.

Dimension	Trial	Pieces of Lumber Produced	Boardfeet Produced	Trim Blocks	
				Weight (pounds)	Number of Pieces[1]
1x4	1	17	75	219.69	251
	2	11	40	209.88	
	3	29	132	506.88	
1x6	1	10	58	158.00	107
	2	2	13	0.00	
	3	3	13	226.61	
2x4	1	15	145	88.75	223
	2	42	375	484.13	
	3	61	540	510.56	
2x6	1	21	286	86.38	174
	2	67	996	361.31	
	3	75	1014	802.13	
2x8	1	19	334	161.25	52
	2	32	610	147.31	
	3	32	633	199.88	
2x10	1	12	287	192.19	27
	2	22	536	259.25	
	3	11	264	131.50	
2x12	1	1	28	142.00	24
	2	4	108	72.19	
	3	9	252	197.25	

[1] - for all trials

produced from the outside portions of a log to eliminate log taper and are most subject to wane.

Not all 2-foot trim had wane, some were full dimension. Occasionally a board would have excessive wane on one or both edges that reached to the middle of the board. If the remaining board was too short after eliminating the wane, it was slashed to clear it from the mill.

The amount of wane on the trim blocks was noted during processing even though not considered as a key variable in the study. A majority of the 1-inch material was wane trim. The 2x4- and 6-inch categories contained mostly wane trim, but some full dimension trim was found. The 2x8-, 10-, and 12-inch trim blocks were predominately full dimension. This is likely a function of the board location in the log. One-inch boards, as discussed earlier, are cut along the exterior of the log to reduce some of the log taper. Consequently, these boards contain considerable wane. The 2x8-, 10-, and 12-inch lumber is cut from the center, where wane is minimal, thereby producing boards that have more knot defects.

Production through the trimmer optimizer and the weight of trim blocks produced for each trial is shown in Table 5.3. The mill had been down prior to the first trial and was not up to full production when the first sample was pulled. Production in trials 2 and 3 was fairly consistent,

Table 5.3. Weight of each trim block class per trial and the amount of boardfeet slashed per MBF.

Trial	Boardfeet Produced	Grade Trim (pounds)	End Trim (pounds)	Oversize Chips (pounds)	Boardfeet Slashed per MBF[1]
1	1213	1048	46	68	127
2	2678	1532	110	126	88
3	2848	2575	116	149	149

[1] - The weight of the slashed material is included in the grade trim category.

2678 and 2848 boardfeet respectively, but there is a 1000 pound increase in trim in trial 3. More pieces (nearly twice as much footage) did not meet the minimum dimension requirements in trial 3 and were slashed.

The amount of overs and end trim produced per thousand boardfeet (MBF) was fairly uniform across trials. There was roughly 900 pounds of trim per MBF of lumber produced (Table 5.4). The weight of the trim blocks per MBF was lower in trial 2 than in trials 1 and 3 because of the reduced amount of slashing in trial 2. Even though the production was not typical for trial 1, the quality of the logs, and hence, the amount of slashing required was equivalent to the other trials.

Because of the relatively small samples and the fragmentation of material into size categories, the data were summarized into broader categories. The three groups were:

1) 1-inch material

2) 2x4- and 6-inch material (small dimension)

3) 2x8-, 10-, and 12-inch material (large dimension)

Table 5.5 shows the amount of lumber and trim produced in each category by trial. Variability between trials is present even in these groups.

One-inch material produced considerably more trim blocks per MBF than the other groups. Grade trim from 1-

Table 5.4. Total weight of trim (end + 2-foot) and the weight per MBF for each trial.

Trial	Boardfeet Produced	Trim (pounds)	Pounds of Trim per MBF
1	1213	1094	901.90
2	2678	1642	613.14
3	2848	2691	944.87

Table 5.5. Weight of trim blocks, pounds per MBF, and percentage of production by the new categories.

Category	Trial	Board-feet	Trim (pounds)	Pounds of Trim per MBF	Percent of Lumber Produced	
					trial	normal[1]
1-inch	1	133	378	2842.11	10.96	5-6
	2	53	209	3943.40	1.98	
	3	145	733	5055.17	5.09	
2x4 & 6	1	431	175	406.03	35.53	58-59
	2	1371	845	616.34	51.19	
	3	1554	1313	844.92	54.56	
2x8, 10, and 12	1	649	495	762.71	53.50	36
	2	1254	478	381.18	46.83	
	3	1149	529	460.40	40.34	

[1] - from mill records

inch lumber was approximately six times that of small dimension and nearly 10 times that of large dimension, trial 1 of the large dimension being the lone exception. Small dimension produced roughly twice as many trim blocks per MBF as the large dimension.

The amount of lumber produced in each of the three categories during the trials was compared with the mill average. More 1-inch and large dimension (2x8, 2x10, and 2x12) lumber was produced than normal during trial 1. One-inch and small dimension (2x4 and 2x6) production was below normal during trial 2, while the percentage of large dimension remained above normal. The split in trial 3 was closest to normal production. Evidently, the mill was processing larger diameter logs than normal at the time of the study.

The linear feet of trim produced per board is another indication of log quality or the amount of slashing (Table 5.6). Almost 10 linear feet (2 ft. * 4.97 pieces) of trim was produced per board in the 1-inch category, indicating several boards were slashed. The 2x4 and 2x6 category generated 3 linear feet per piece, or three trim blocks for every two pieces of lumber. The amount of trim was further reduced in the 2x8-, 10-, and 12-inch category, to less than one trim block per piece.

Table 5.6. Total pieces of lumber produced, trim, and their ratio for each category.

Category	Pieces of Lumber Produced	Pieces of 2-foot Trim	Pieces of 2-foot Trim per Piece of Lumber
1-inch	72	358	4.97
2x4 & 6	281	397	1.41
2x8, 10, and 12	142	103	0.73

CHIP ANALYSIS

Two-inch material produced the best chips (Figure 5.1). The width of the board (ie. 4-, 6-, 8-, 10-, or 12-inches) did not provide a noticeable trend. Oversize chips and end trim produced the fewest acceptable chips, less than 50% on average. One-inch material provided a slightly lower yield of accepts than the 2-inch material.

Figure 5.2 shows the percentage of overs (greater than 8-mm thick and greater than 1 1/4-inches) by residue type. End trim and oversize chips generated the highest percentage of overs. Roughly 45% of the end trim chips were oversize, while about 35% of the oversize chips remained oversize after rechipping. Although end trim was classified as pieces less than 6-inches in length, many were only 1-inch or less in length and only slightly larger than the oversize chips. These small end trim pieces are able to pass through the chipper knife pocket intact to produce the high percentages of overs. One-inch material, on average, produced more oversize chips than 2-inch material.

Rechipping oversize chips produced the greatest amounts of undersize chips (pin chips and fines, less than 1/4 inch) at roughly 13% (Figure 5.3). No other obvious patterns were found. Variability within groups may have been masking trends.

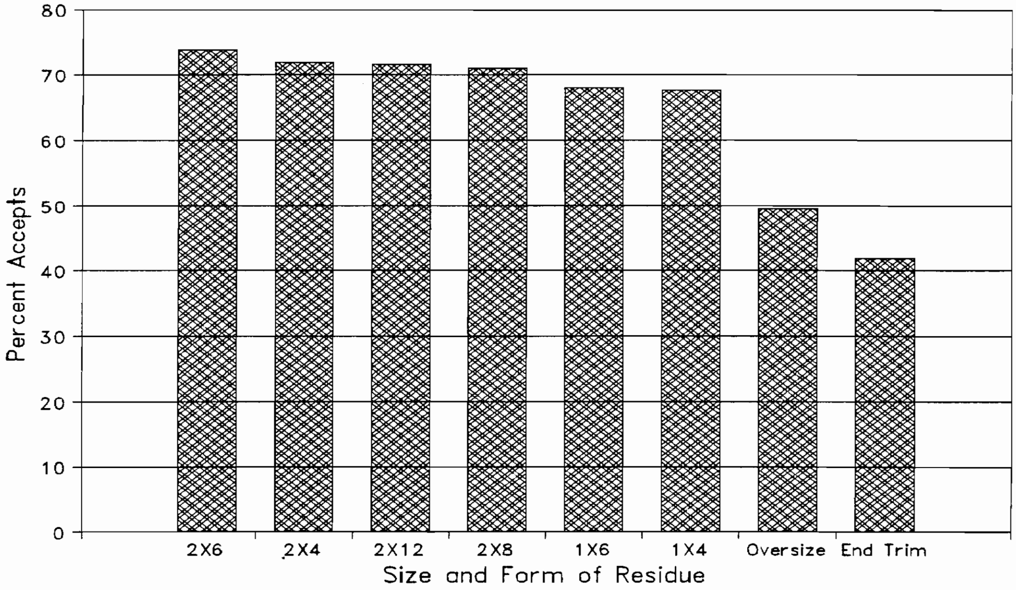


Figure 5.1. Rank order of the average acceptable chip furnish from each residue type.

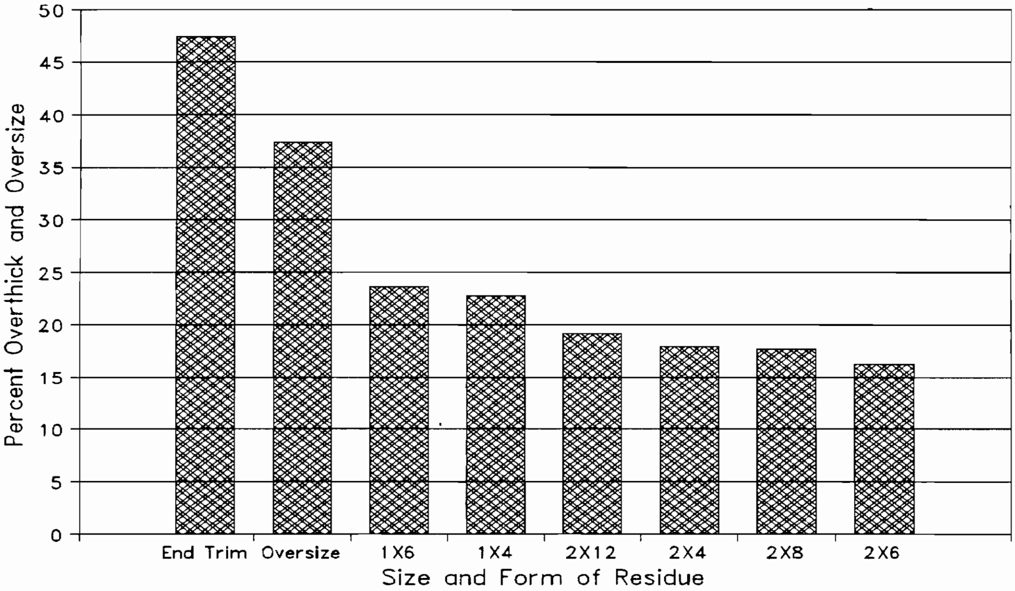


Figure 5.2. Average amount of overs (overthick and oversize chips) produced by each size residue.

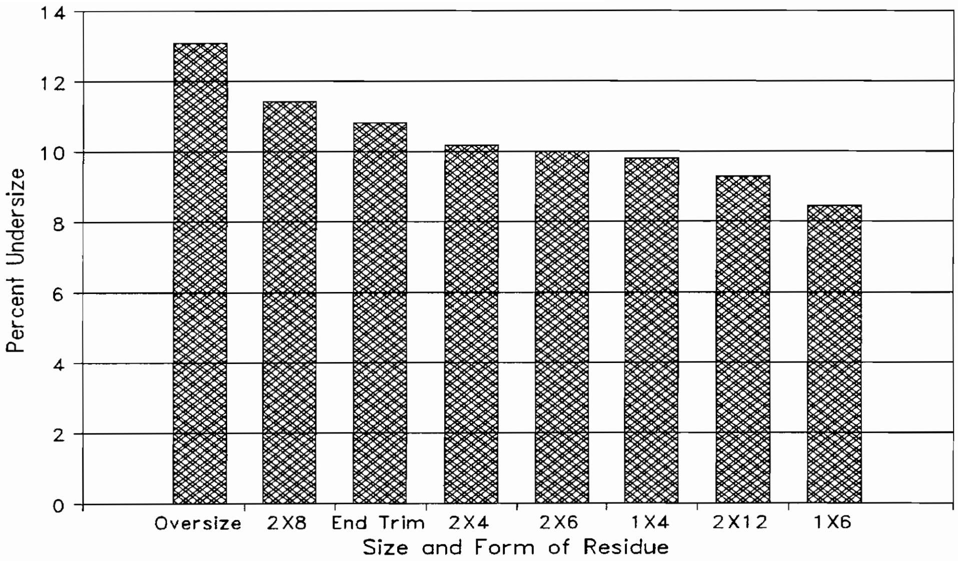


Figure 5.3. Average percentage of undersize chips (pin chips and fines) produced by each material form.

Several conclusions can be drawn from Figures 5.1, 5.2, and 5.3. Rechipping oversize chips simply recycles rejects through the system to furnish expensive fuel wood. Rechipping produces a low percentage of accepts and the greatest amount oversize and undersize chips. Rerouting oversize chips straight to the fuel pile may be the best alternative. Since oversize chips constitute a low percentage of the material going to the chipper (approximately 6% on a weight basis) and produce a low percentage of acceptable chips, there would be only a slight reduction in the acceptable chip volume. True end trim falls into the same category. End trim produces such poor quality chips that it might be best to chip them strictly for fuel. Additionally, many of the chips produced from end trim are small blocks or cubes that would not completely delignify in the digester (Jorgensen, 1985).

Chip quality improves as the material gets larger. Two-foot trim blocks produced markedly better chips than the trim ends and oversize chips. As trim block residue increased in size, the ability to orient and stabilize during chipping increased. Grade trim, or 2-foot pieces, accounted for the largest percentage of residue. Improvements from these pieces will have a substantial impact on the acceptable residue chip furnish.

POSSIBLE SOLUTIONS

Sawmill size has a direct influence on the means available to improve chip quality. The options available to a mill producing less than 20 MMBF per year are different from those for a large mill producing over 75 MMBF per year. Mills with yearly production falling between 20 MMBF and 75 MMBF can incorporate operating strategies of both mills. Characteristics that differentiate large sawmills from small sawmills include:

1) Large mills purchase tree-length material vs. cut-to-length purchases by small mills.
2) Large mills use chipper canters for primary breakdown vs. saw and carriage breakdown in the small mills.
3) Edging is performed by chipping in large mills vs. sawing in small mills.
4) Large mill residue chipper receives predominately trim blocks (true end trim and grade trim) vs. slabs, edgings, and trim blocks at small mills.
5) Large mills are equipped with chip screens.

LARGE SAWMILLS

Several possibilities exist for improving trim block chip quality in larger mills. Trimmer optimizer reports from this study found that approximately 130 boardfeet, or over 600 pounds of lumber, were slashed for every thousand boardfeet produced. Slashing may be operationally efficient, but this trim could be left in longer lengths.

Chip quality improved when increasing piece length in roundwood chipping and there is no reason to suspect different results for sawmill residues (Twaddle and Watson, 1991). Increasing trim block length would increase the acceptable chip volume through improved trim block orientation and stability. Longer lengths would require modifying the trimmer outfeed table. Sharp turns in the vibrating conveyor network that carry the trim blocks to the chipper would also have to be modified to handle the longer pieces.

Chip quality from 2-foot pieces would increase if the feed conveyor and chipper infeed were modified to insure that a trim block is properly oriented before chipping. The chipper infeed could be narrowed to force trim blocks to orient themselves before entering the chipper. Narrowing would start 4-6 feet from the chipper and gradually taper until 1-foot from the disk. To avoid clogging the infeed, one side of the conveyor should be in the shape of an involute curve to allow the trim blocks to ride up the side of the conveyor. Tipping the entire conveyor 10-15 degrees four feet from the disk would allow gravity to help orient the trim blocks and also provide a funneling action into the chipper. Veuger (1976) suggests that tipping the conveyor will reduce the percentage of overs and fines because material will consistently enter on the anvil side.

Another possible solution would be to lay a pattern of welding beads, or weld ribs in the bottom of the conveyor, on the side away from the anvil to move material to the anvil side. Time and distance would be needed for the beads to force the trim blocks over so they may have to start a minimum of 10 feet from the chipper. By increasing the bead or rib length across the conveyor width, trim blocks will gradually feed to the anvil side of the chipper. This solution may not be the most effective for systems where the feed conveyor is heavily loaded. Some of the material could ride or jump over the beads and not funnel to the anvil side (Veuger, 1976).

Regulating the flow of trim blocks to the chipper could be another way to improve chip quality for 2-foot material. Residue throughput varies depending on log quality and the amount of trimming necessary. Consolidating the residue or evening the flow of surges in the feed conveyor could influence chip quality. Finally, a set of hold-down "fingers" could be installed above the conveyor to rake trim blocks over to the preferred side and hold them in place during chipping (Egolf, 1991).

Installing a shorts trap to divert oversize chips and true trim ends (less than six inches along the grain) to a smaller chipper or hog producing fuel chips is another possibility. The study indicated that this material produced less than 50% accepts while generating high percentages of pin chips and fines. This material also contributed high percentages of overs which continuously recycle through the system until broken down, creating extra wear on the chipper. Furthermore, these pieces account for 10% of the throughput weight, so the overall chip volume would be reduced by only a small percentage if they were routed directly to fuel.

SUMMARY AND CONCLUSIONS

This study classified and quantified material entering a residue chipper at a high production southern pine sawmill. The study also evaluated chip quality from this material and identified areas where efforts should be concentrated to improve chip quality.

Trim block orientation and stability are crucial to produce high quality chips. Trim blocks did not enter or remain at the same angle to the disc during chipping making chip quality unpredictable. Smaller lengths, and even some of the 2-foot blocks, were unable to withstand knife impact and bounced around in the throat while being chipped. Two-foot trim blocks either entered or became turned sideways in the throat on many occasions. As a result, the material was chipped along the grain generating large slivers.

Several solutions were suggested to improve residue chip quality, ranging from eliminating small pieces to improving trim block orientation and stability by lengthening trim blocks. Two of these alternatives, increasing the maximum trim length and controlling the depth of material in the feed conveyor, were selected for further testing.

CHAPTER 6

EFFECT OF TRIM BLOCK LENGTH ON CHIP QUALITY

INTRODUCTION

The study described in Chapter 5 found that two types of trim blocks entered a residue chipper at large southern pine sawmills. End trim, or "zero" trim, ranging from one to four inches in length accounted for about 60% of the pieces, but only 6% of the weight. The remaining 94% of the weight was in the form of 2-foot trim blocks produced when wane was removed at the trimmer optimizer. This trim ranged from a single 2-foot section to slashing an entire 16- or 20-foot long board that would not "make grade" to clear it from the mill. Reducing everything to a maximum 2-foot length simplifies machine and conveyor design at the mill.

The situation is most dramatic for the 2x4's. The origin of this dimension (exterior portion of a log) generally results in a high occurrence of wane in the upper end of the piece. Fifty-three percent of the trim blocks were in the form of end trim. Table 6.1 demonstrates the effect of leaving trim in longer lengths on the number of 2x4's handled and processed. Increasing the maximum trim length from two to four feet reduces the number of 2-foot trim blocks 60% and the total number of pieces by almost a

Table 6.1. Effect of increasing maximum trim length on trim block piece count per day - 2x4's only.

Maximum Trim Length (ft.)	End Trim	Number of Trim Blocks by Length				
		2'	4'	6'	8'	Total
2	6877	5930	-	-	-	5930
4	6877	2434	1748	-	-	4182
6	6877	2200	872	662	-	3734
8	6877	2076	850	358	270	3554

third. Lengthening trim further, to six or eight feet, yields fewer total trim blocks, but the quantity of 2-foot trim blocks is not seriously affected.

EFFECT OF LENGTH ON CHIP QUALITY

The change in chip quality from leaving trim in longer lengths was not known. It was hypothesized that increasing trim block length would boost chip quality. Longer trim blocks would have more stability during chipping and the increased length would improve orientation of the trim block to the chipper disk.

The hypothesis was tested at two sawmills. The initial study was conducted at a large mill in Central Georgia that had a standard residue system - a 58-inch, 6-knife Kockums horizontal infeed, bottom discharge chipper powered by a 300 horsepower electric motor and set to produce a 5/8-inch chip.

The second study was performed at a mill in South Georgia to confirm the results of the first under different conditions. A 100 horsepower electric motor powered a 48-inch, 6-knife, horizontal infeed, bottom discharge Fulghum chipper set to cut a 5/16-inch chip. The chipper was also equipped with a number of card breakers.

The second study also explored the use of a tapered infeed to control trim block orientation and improve chip quality. Narrowing (or tapering) the vibrating conveyor to fit the chipper infeed was perceived as a low capital cost change that could be used in conjunction with longer trim blocks. The tapered infeed was expected to orient pieces before chipping, resulting in higher quality chips.

The vibrating conveyor feeding the chipper in South Georgia had been tapered from an 18.5-inch width to 9.5 inches to match the chipper throat. The tapering occurred in the final two feet nearest the chipper and involved modifying both sides of the trough (Figure 6.1).

METHODS AND PROCEDURES

FIRST STUDY - CENTRAL GEORGIA

Three replications of 17 separate tests, differentiated by overall trim block dimensions, were performed (Table 6.2). Tests were randomized within replications to avoid bias. The exact order of the tests is shown in Table 6.3.

Trim Blocks

Each trial consisted of 300 pounds of trim blocks. The number of pieces needed to achieve the desired test weight in each category was determined assuming green pine weighs 60 pounds per cubic foot (Appendix A). All 2-foot trim blocks were pulled from the vibrating conveyor between the trimmer optimizer and the chipper one day prior to running the tests. Remaining trim blocks were manufactured from rough green lumber.

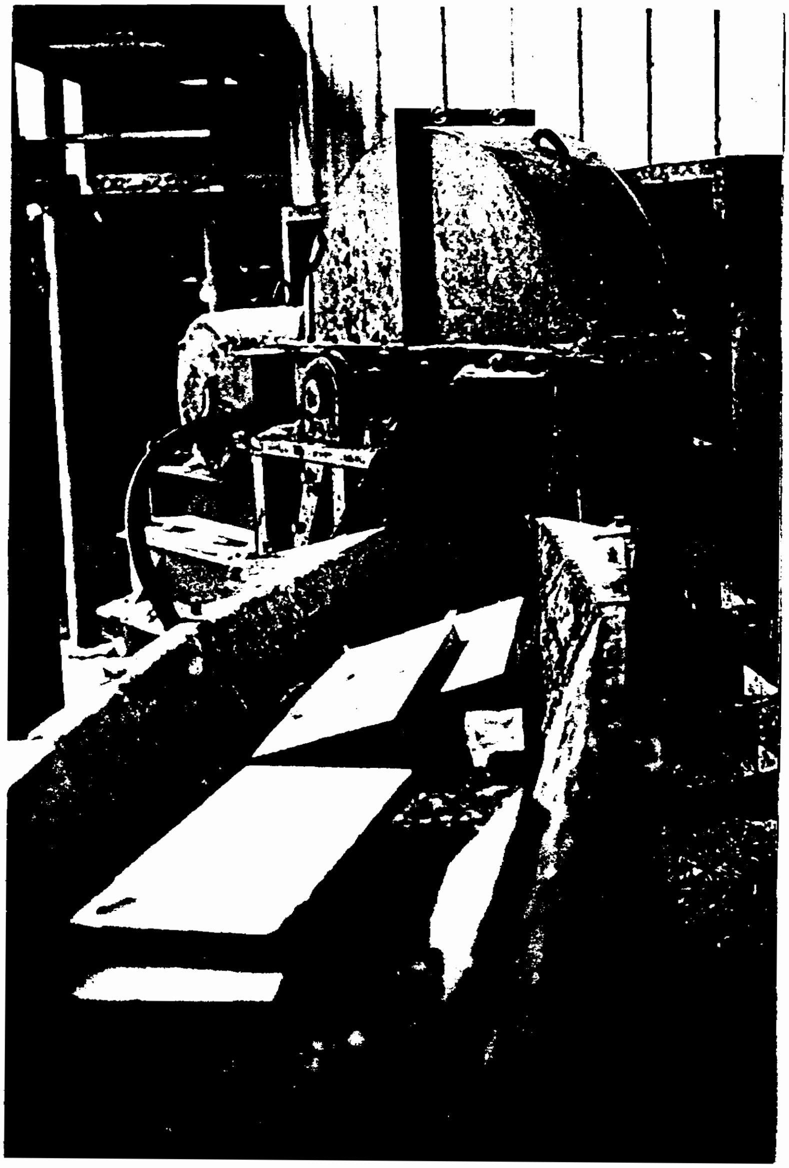


Figure 6.1. View of the chipper and tapered infeed conveyor used for the study in South Georgia.

Table 6.2. The 17 tests conducted in Central Georgia.

Length (ft.)	Dimension				
	5/4x4	2x4	2x6	2x8	2x10
2	x	x	x	x	x
4	-	x	x	x	x
6	-	x	x	x	x
8	-	x	x	x	x

x - tests that were conducted

Table 6.3. Testing order in Central Georgia.

Replication #1	Replication #2	Replication #3
2x6x8'	2x10x2'	2x10x8'
2x10x2'	2x10x4'	2x10x6'
2x10x8'	2x8x2'	2x8x4'
2x8x2'	2x6x6'	2x10x4'
2x8x8'	2x6x8'	2x10x2'
2x8x6'	2x8x4'	2x8x6'
2x10x4'	2x8x8'	2x6x8'
2x6x2'	2x10x6'	2x8x2'
2x4x8'	2x10x8'	2x8x8'
2x10x6'	5/4x4x2'	2x4x4'
2x4x4'	2x8x6'	2x6x2'
2x4x2'	2x4x2'	2x4x8'
2x8x4'	2x4x8'	2x6x4'
2x6x6'	2x6x4'	2x4x6'
2x4x6'	2x4x4'	5/4x4x2'
2x6x4'	2x6x2'	2x4x2'
5/4x4x2'	2x4x6'	2x6x6'

Chip Sampling

Fresh knives were installed and the chipper adjusted prior to the trials. The entire chip system was allowed to purge for several minutes before each test to ensure that chips did not get intermixed. Three 15-pound samples were pulled for each trial. The drag chain carrying chips from the chipper was stopped after each trial and all the chips were pulled from four links at three locations along the chain.

Chip Classification

Chips were taken back to Virginia Tech for classification by a Williams Classifier. Each sample was divided into a 10-pound sample for classification with the remainder stored in case anomalies arose in classification or interpretation of the results. Classification consisted of a two pass process with each pass lasting three minutes (Edelman, 1992). The first pass screened for overthick and oversize material, while the second pass screened the acceptable and undersize chips (Appendix B).

The first pass consisted of passing the entire 10-pound sample through five screens in the following order: 8-mm bar screen and 2-, 1 1/2-, 1 1/8- and 1/8-inch round-hole screens. Chips retained on the first four screens were weighed to the nearest one-hundredth of a pound on a Toledo scale, model 2081. Chips retained on the 1/8-inch screen were used for the second pass.

The 7/8-, 5/8-, 3/8-, and 1/8-inch round-hole screens were used for the second pass. After weighing the contents retained on these screens, chip fractions in the bottom pan (fines) were collected and weighed to the nearest one-hundredth of a pound on a Sartorius digital scale. The weights were entered into a spreadsheet and converted into percentages that were used for the analyses.

Observations during the initial classification revealed that many of the oversize chips were "cards" that would most likely have been broken up during chip handling. The acceptable and oversize chips were combined to form the pulpable chip classification.

Statistical Analysis

Chip distributions in the Central Georgia study were fairly symmetric, with the means and medians similar, so parametric procedures were used for both the statistical analyses and comparisons. The maximum, minimum, mean, and median percentages for each dimension tested are shown in Appendix C.

The effects of length, width, the length-width interaction, and replication were first examined in a 4x4x3 factorial analysis of variance (ANOVA) to test for differences in each chip class at an alpha level of 0.05. The null hypothesis tested in all instances was that the "means are equal." When significant differences occurred among lengths, widths, or replications, Fisher's LSD (Least Significant Difference) test was used to determine which means were different. The length/width ratio and piece weight of a trim block were used to further examine the length-width interaction. The length/width ratio and piece weight more accurately reflected and explained the interaction between length and width.

The effect of lumber thickness, 5/4 versus 2-inch, was compared only for the 2-foot length. The null hypothesis for each test was that the thinner material (5/4) produced higher quality chips.

SECOND STUDY - SOUTH GEORGIA

A total of 12 trials were conducted with three replications per trial in South Georgia (Table 6.4). Trim block lengths were reduced to 2, 4, and 6 feet because the first study found little change beyond the 6-foot trim lengths. No 5/4-inch material was included for this study. All tests were randomized within each replication with the testing order shown in Table 6.5.

Each test consisted of approximately 300 pounds of trim blocks which were manufactured from rough green lumber (Appendix A).

Table 6.4. The 12 tests conducted in South Georgia.

Length (ft.)	Dimension			
	2x4	2x6	2x8	2x10
2	x	x	x	x
4	x	x	x	x
6	x	x	x	x

x - cells where tests were conducted.

Table 6.5. Testing order in South Georgia.

Replication #1	Replication #2	Replication #3
2x6x6′	2x4x6′	2x6x6′
2x4x6′	2x8x6′	2x8x2′
2x6x4′	2x8x4′	2x8x6′
2x10x4′	2x10x6′	2x10x2′
2x6x2′	2x10x2′	2x8x4′
2x10x2′	2x10x4′	2x4x2′
2x8x6′	2x8x2′	2x4x4′
2x8x4′	2x6x2′	2x4x6′
2x8x2′	2x4x4′	2x10x6′
2x10x6′	2x4x2′	2x6x4′
2x4x2′	2x6x4′	2x6x2′
2x4x4′	2x6x6′	2x10x4′

Chip Sampling and Classification

The chip system was purged before each test to ensure that chips did not intermix between tests. Three 10-pound chip samples were collected during each test from the drag chain carrying the chips from the chipper.

Chip samples were returned to Virginia Tech for classification in a Williams Classifier using the two-pass operation. The percentage of the total furnish retained on each screen was then computed and used for analyses.

The range of size classes shifted from the first study because of the smaller target chip length (Appendix B). Overthick chips remained as those chips retained on the 8-mm bar top screen. Oversize chips consisted of those retained on 2-, 1 1/2-, 1 1/8-, and 7/8-inch round-hole screens. Acceptable chips were considered to be those retained on the 5/8-, 3/8-, and 1/8-inch screens. Chips passing through the 1/8-inch round-hole were classified as fines. The small chip size eliminated the pin chip category.

Statistical Analyses

Nonparametric statistical procedures were determined to be the most appropriate for this study. Although the distributions were similar to those from Central Georgia, they were not as symmetric (Appendix C). The Wilcoxon Rank Sum test, the nonparametric equivalent to the t-test, was used to test the null hypothesis in all instances.

Statistical analyses paralleled those of the first study. The null hypothesis for all tests was that smaller dimensions (lengths, length/width ratios, and piece weights) produced higher quality chips.

RESULTS AND DISCUSSION

The difference in target chip size prevented direct comparisons between the two studies. The 5/16-inch target chip shifted the chip distribution drastically and virtually eliminated the overthick and oversize content (Appendix C). Roughly 1% of the chips were overthick (> 8-mm) while less than 1% of the furnish was retained on the 2- and 1 1/2-inch screens. The percentage of chips retained on the 3/8- and 1/8-inch screens doubled and quadrupled, respectively, with the shift.

One-eighth inch chips were considered to be pin chips in Central Georgia but were acceptable chips in South Georgia. Only fines were considered as unacceptable undersize chips in South Georgia.

Six-foot material proved difficult to feed through the modified conveyor section in South Georgia, adversely affecting chip quality. The extra length prohibited the material from rolling up or moving to the vertical anvil and often ended up wedging in the conveyor. The taper also added resistance and would not allow the board to feed naturally or uniformly. Potential gains from longer lengths were lost because of the poor feeding and hang-ups in the conveyor.

REPLICATION EFFECT

Differences between replications were insignificant except for one test in one chip fraction, indicating that machine and material conditions remained constant over replications in both studies.

LENGTH EFFECT

The percentage of acceptable chips increased with longer trim blocks (Figure 6.2). Gains in acceptable chips resulted from decreases in overthick chips; oversize chips and pins and fines were relatively unchanged. As trim block length increased to four feet, 10% of the sample shifted from overthick to acceptable chips. This increment alone accounted for approximately 50% of the total gain in acceptable chips between 2- and 8-foot trim blocks.

Figure 6.3 shows the average amount of overthick chips produced from each length at Central Georgia. Two-foot material produced significantly more overthick chips than the 4-, 6-, and 8-foot lengths (Table 6.6). Increasing from four to six feet did not result in a significant decrease, but 8-foot lengths produced significantly less overthick chips than the other lengths.

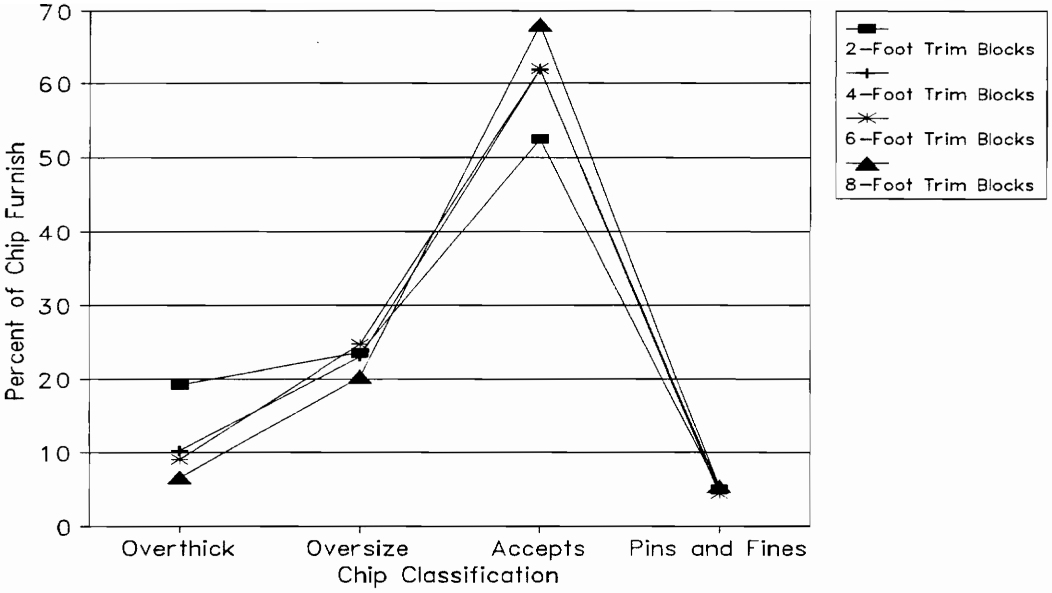


Figure 6.2. The effect of trim block length on the overall chip distribution in Central Georgia.

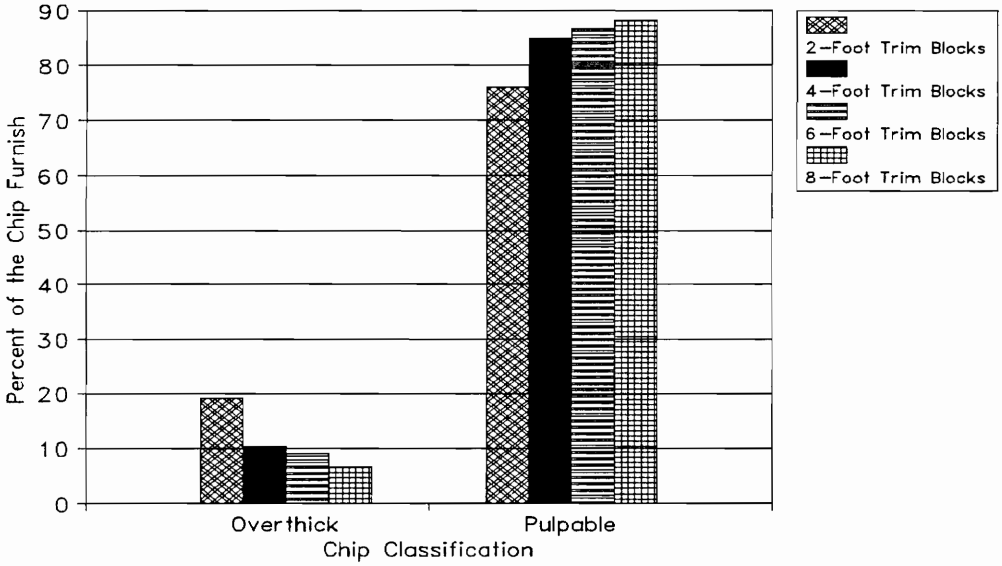


Figure 6.3. Percentage of overthick and pulpable chips produced by the tested trim lengths in the Central Georgia study.

Table 6.6. Fisher's LSD test results between trim block lengths in the overthick chip class in Central Georgia.

Piece Length (ft.)	Mean Overthick Percentage	Comparison Length (ft.)			
		2	4	6	8
2	19.15	-	x	x	x
4	10.22	x	-		x
6	9.07	x		-	x
8	6.53	x	x	x	-

x - significant difference at alpha level = 0.05.

The increase in the pulpable chip fraction was due to the conversion of overthick chips to acceptable chips as piece length increased (Figure 6.3). Two-foot trim blocks produced significantly fewer pulpable chips than the other lengths (Table 6.7). Pulpable chips continued to increase with length, but differences between 4-, 6-, and 8-foot material were insignificant.

Chip quality also improved with increased piece length at the South Georgia mill. Lengthening material decreased the amount of overs (overthick and oversize) while increasing the amount of accepts (Figures 6.4 and 6.5). The percentage of fines was unaffected. Increasing length from two to four feet again constituted the greatest gains in chip quality. Although chip quality improvements were not as striking when going from 4- to 6-foot material, the 6-foot length was significantly better than the 2-foot pieces.

The greatest improvement in chip quality occurred in the overthick and oversize chip classes (Figure 6.4). Although the small target chip size makes the decreases appear numerically insignificant, both the 4- and 6-foot lengths reduced the amount of overthick chips by half, a significant decrease over 2-foot material in both instances (Table 6.8). Oversize chip production decreased by almost a third when trim block length was increased beyond two feet.

Table 6.7. Fisher's LSD test results between trim block lengths in the pulpable chip class in Central Georgia.

Piece Length (ft.)	Mean Pulpable Percentage	Comparison Length (ft.)			
		2	4	6	8
2	75.97	-	x	x	x
4	84.86	x	-		x
6	86.64	x		-	
8	88.21	x	x		-

x - significant difference at alpha level = 0.05.

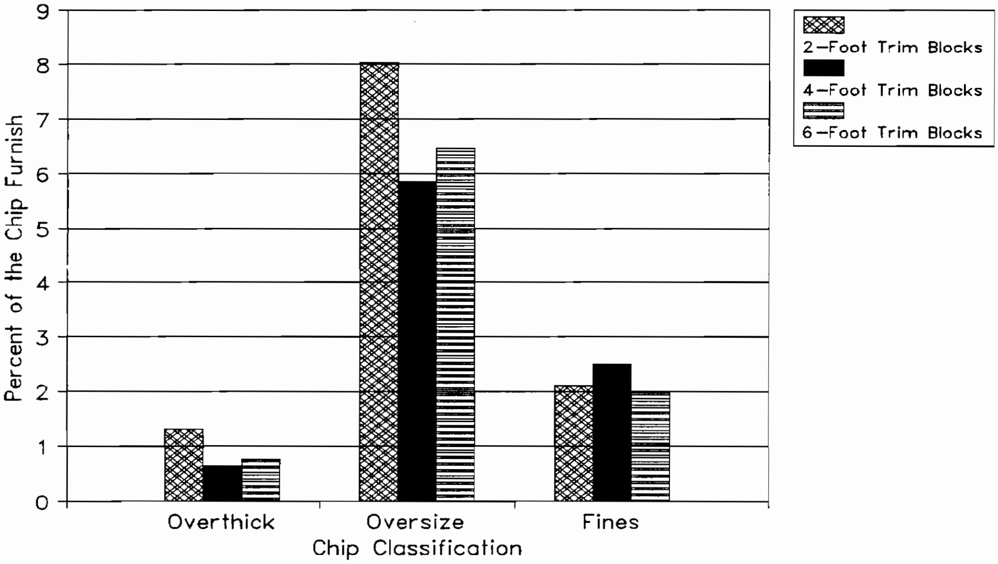


Figure 6.4. Percentage of overthick, oversize, and fines produced by each tested length in South Georgia.

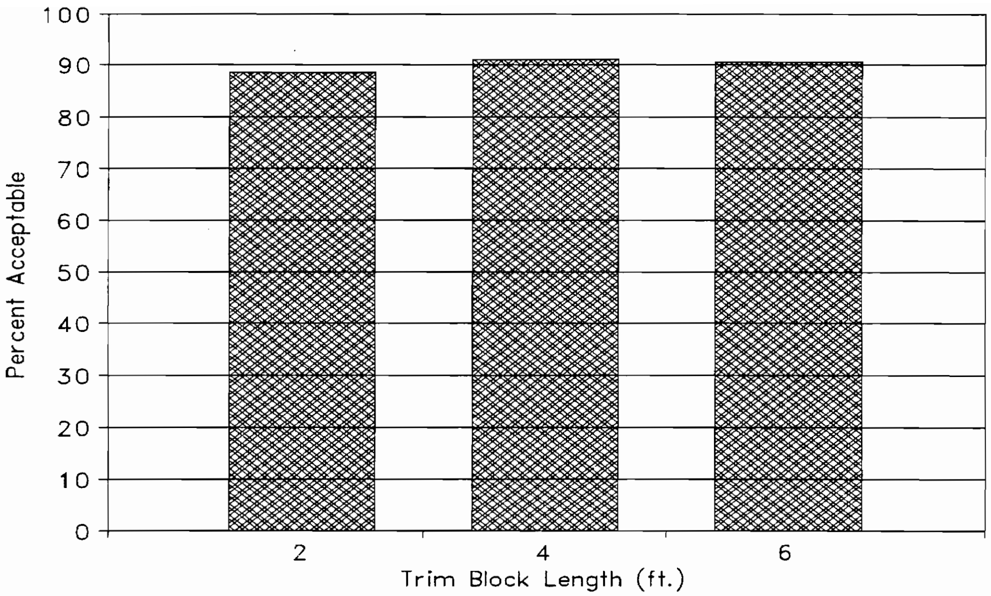


Figure 6.5. Percentage of acceptable chips produced at each tested length in South Georgia.

Table 6.8. Significant p-values from Wilcoxon Rank Sum tests between trim block lengths in the overthick chip class in South Georgia.

Piece Length (ft).	Median Overthick Percentage	Comparison Length		
		2	4	6
2	1.16	-	0.000	0.000
4	0.42	0.000	-	
6	0.54	0.000		-

Estimated Effect on Residue Chip Output

Trimmer optimizer reports from the Central Georgia mill were used to estimate the total potential increase in pulpable chips from increasing trim block length. Yearly production at the mill was between 90 and 100 MMBF per year (450 to 500 MBF per day) during the reporting time. The mill produced approximately 34,000 pieces of lumber per day, or 17,000 boards per shift. The number of boards trimmed, by dimension and trim length, each day is shown in Table 6.9. Entire boards not meeting grade and slashed are not included. For example, 2,020 boards processed through the trimmer optimizer and not slashed, were 2x4's that required only two feet of trim.

Table 6.10 displays the amount (in tons) of trim blocks generated each day at each trim length if the maximum trim length was 2, 4, 6, or 8 feet. Boards were assumed to be trimmed to leave all trim in the longest possible length. Table 6.10 also shows the volume of chips produced if the maximum possible trim length was 2, 4, 6, or 8 feet. Increasing trim length to four feet would produce almost three additional tons, or 6% more, pulpable chips a day. Increasing the maximum trim length to six or eight feet would increase the pulpable chip furnish 6.51 and 6.91 percent, respectively, above the current level.

Table 6.9. Number of 2x4, 2x6, 2x8, and 2x10 boards trimmed 2, 4, 6, 8, 10, or 12 feet each day at a 90 to 100 MMBF per year sawmill.

	Number of Boards Requiring Trimming					
	2′	4′	6′	8′	10′	12′
2x4	2020	816	358	180	56	34
2x6	2370	920	226	106	20	14
2x8	1160	246	24	12	4	2
2x10	932	292	42	6	0	0

Table 6.10. Tons of trim blocks and pulpable chips produced at trim lengths of 2, 4, 6, and 8 feet.

Maximum Trim Length (ft.)	Tons of Chips Produced by Trim Length				Pulpable Chips (tons)[1]	Percent Increase over 2 feet
	2′	4′	6′	8′		
2	73.16	-	-	-	55.58	--
4	37.24	35.92	-	-	58.78	5.75
6	35.36	23.42	14.38	-	59.20	6.51
8	34.40	23.16	8.52	7.08	59.42	6.91

[1] - Assuming percentage of pulpable chips at each length is:
2′ - 75.97
4′ - 84.86
6′ - 86.64
8′ - 88.22

WIDTH EFFECT

The effect of trim block width in all chip classes was found to be significant in most cases. However, the results from the South Georgia study contradicted those found in Central Georgia. For example, 2x10 material produced the largest percentage of overthick chips in Central Georgia and the smallest percentage in South Georgia (Figure 6.6). Similar results also occurred in the oversize and acceptable chip classes. Ten-inch wide material produced better chips on average in South Georgia, but yielded the poorest quality chips in Central Georgia (Figures 6.7 and 6.8). Small average differences between widths in each class also made trends inconsistent.

LENGTH/WIDTH RATIO EFFECT

The length-width interaction at the Central Georgia mill was significant at the 95% level in all instances except for the overthick chip class, where it was significant at the 94.4% level. Combining length and width, into a length/width ratio, further defined the relationship between piece dimensions and chip quality. The overthick furnish declined exponentially as the length/width ratio increased (Figure 6.9). A simple curvilinear regression fitted to the data points resulted in an R^2 of nearly 0.50. The complementary function for pulpable chips, shown Figure 6.10, resulted in an R^2 of 0.43.

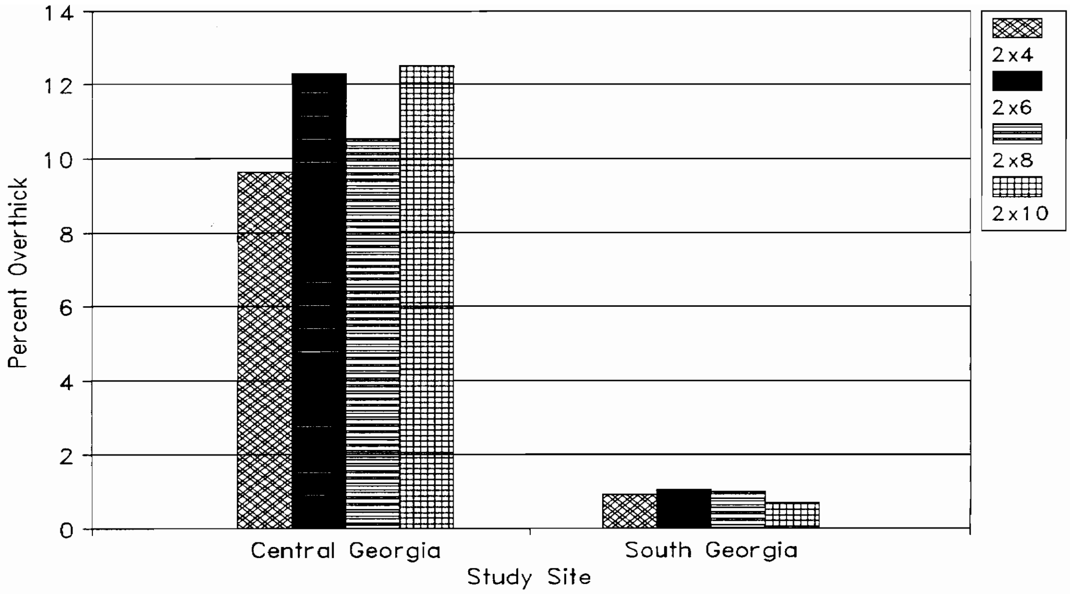


Figure 6.6. The effect of trim block width on overthick chips at the Central and South Georgia studies.

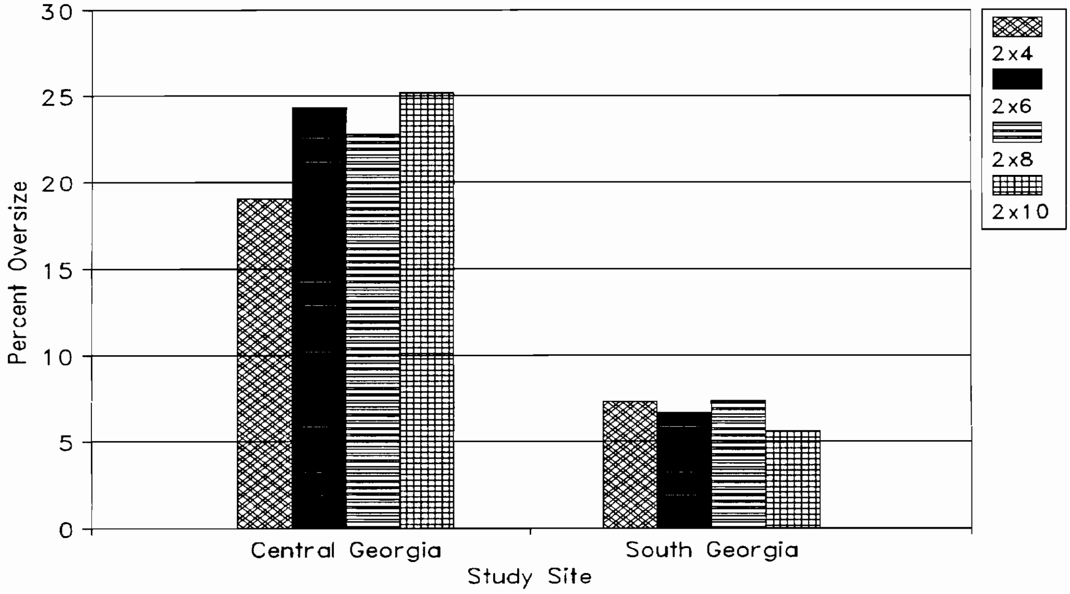


Figure 6.7. The effect of trim block width on oversize chips at the Central and South Georgia studies.

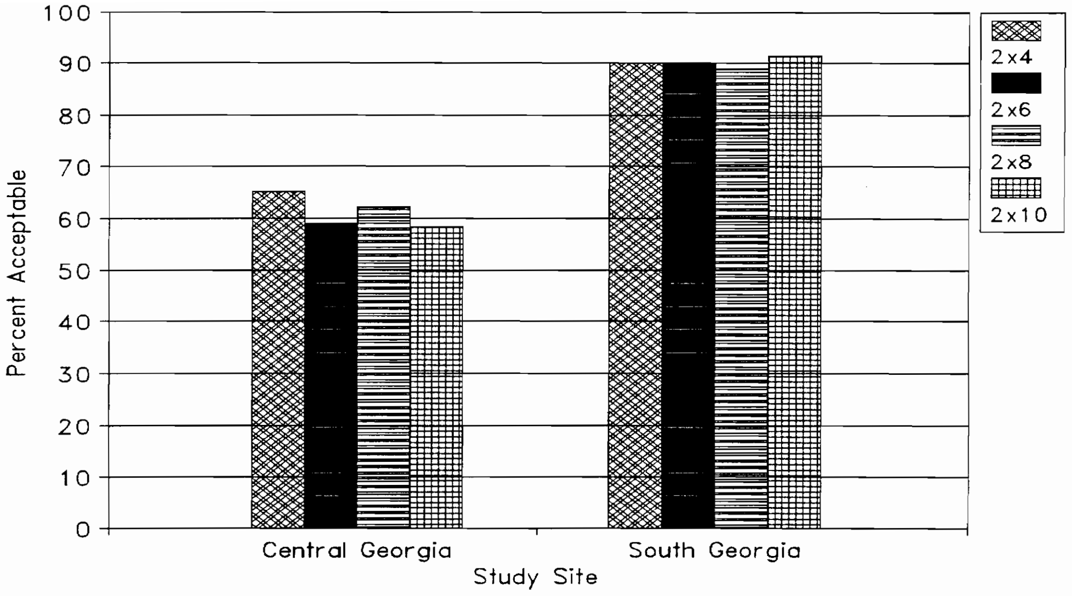


Figure 6.8. The effect of trim block width on acceptable chips at the Central and South Georgia studies.

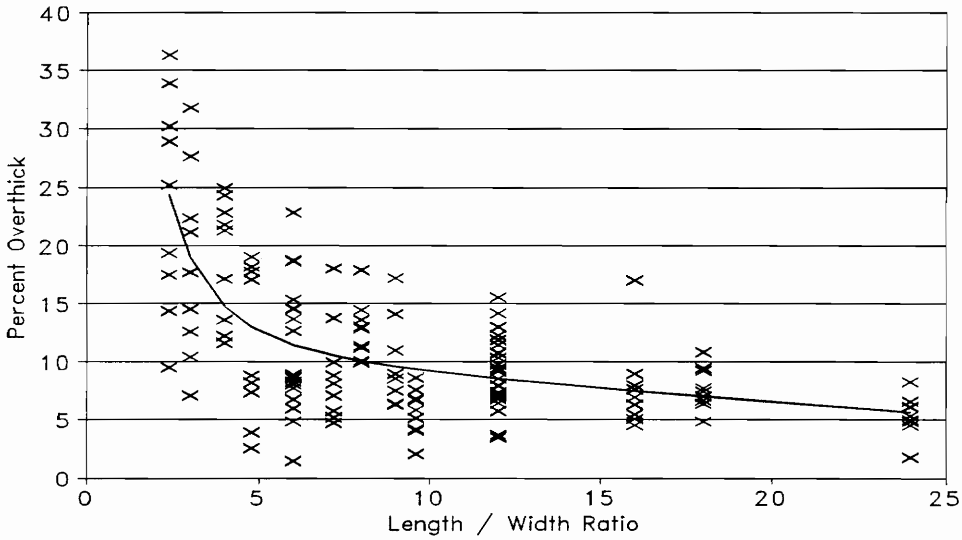


Figure 6.9. Relationship between trim block length/width ratios and the percentage of overthick chips in Central Georgia.

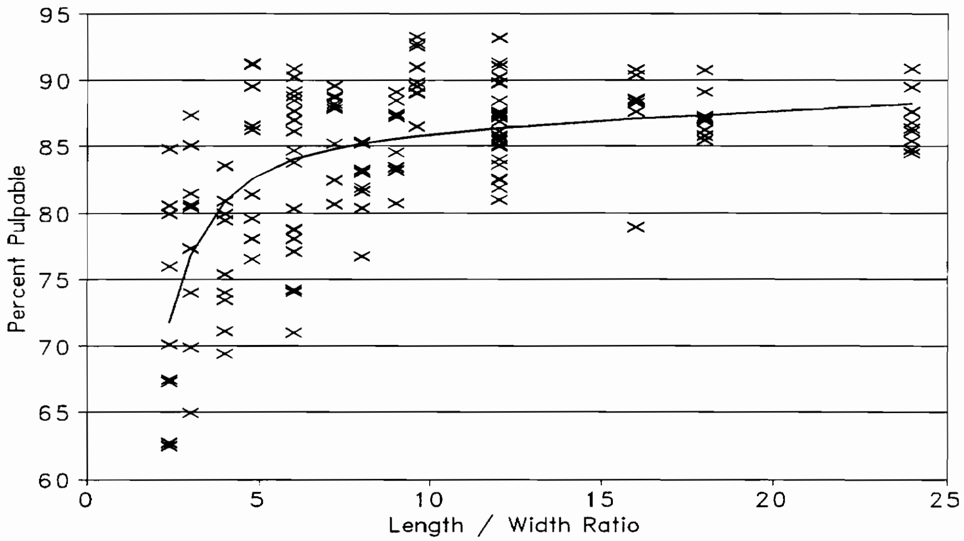


Figure 6.10. Relationship between the percentage of pulpable chips and trim block length/width ratios in Central Georgia.

The effect of the length/width ratio at each trim length can be seen in Figure 6.11. The percentage of overthick chips increases as width increases. Four-inch material had the greatest length/width ratio (Table 6.11) and produced the fewest overthick chips in all but one instance. Less variation existed among the different widths as material length increased.

Two-sample T-tests were performed to test differences between length/width ratios. The null hypothesis for all tests was that "smaller length/width ratios produce more overthick and fewer pulpable chips than the larger ratios." The results of the T-tests are shown in Appendix D. Smaller ratios produced significantly more overthick chips nearly 75% of the time, and produced less pulpable chips in 65% of the tests.

Chip quality improves dramatically until the length/width ratio reaches 10:1 (Figures 6.9 and 6.10). Overthick chips decrease and the percentage of pulpable chips increase. Most trim blocks with length/width ratios less than 10:1 also weighed less than 20 pounds (Table 6.11). Increasing trim lengths not only improved orientation to the chipper disk, but also helped stabilize these light trim blocks during chipping.

Although there is an increase in chip quality beyond a 10:1 ratio, increases are more modest because improvements

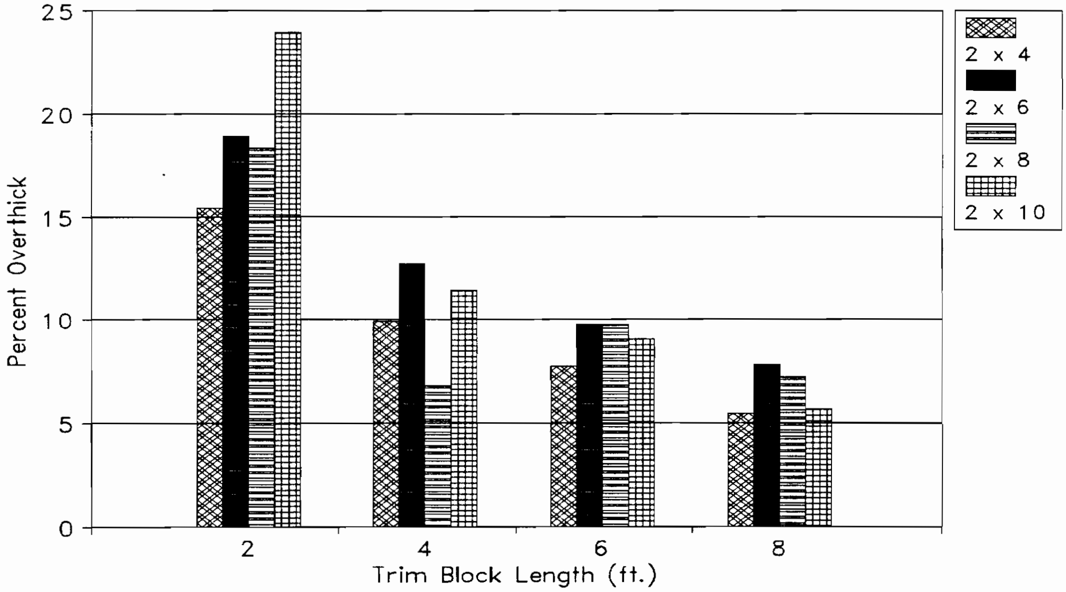


Figure 6.11. Percentage of overthick chips produced by each trim block dimension in Central Georgia.

Table 6.11. Length/width ratios and piece weight for the trim blocks tested.

Trim Block	Length/Width Ratio	Computed Piece Weight[1] (lbs.)
2x4x2'	6	6.7
2x6x2'	4	10
2x8x2'	3	13.3
2x10x2'	2.4	16.7
2x4x4'	12	13.3
2x6x4'	8	20
2x8x4'	6	26.7
2x10x4'	4.8	33.3
2x4x6'	18	20
2x6x6'	12	30
2x8x6'	9	40
2x10x6'	7.2	50
2x4x8'	24	26.7
2x6x8'	16	40
2x8x8'	12	53.3
2x10x8'	9.6	66.7

[1] Assuming 60 pounds per cubic foot.

in orientation and stability are less profound. Further evidence of this can be seen in Figures 6.9 and 6.10. As the length/width ratio increases, the chip furnish becomes more consistent with less variation between samples.

Length/width ratios had moderate effects on chip quality at the South Georgia mill. Six-foot material was eliminated from the analysis because problems associated with the tapered conveyor overshadowed the true effects of the length/width ratio. Increasing length/width ratios had the primary effect of reducing the overthick percentage to yield parallel gains in the pulpable chip class. However, overthick chips were so rare in South Georgia that increasing length/width ratios had little effect (Figure 6.12).

PIECE WEIGHT EFFECT

The piece weights computed from trim block volumes proved to be a good indicator of chip quality. Overthick and pulpable chip production improved linearly with piece weight at Central Georgia. The T-tests performed between piece weights in the overthick and pulpable chip classes showed significant differences between those trim blocks under 20 pounds and those greater than 20 pounds (Appendix E).

Figure 6.13 shows that variations in the overthick chip furnish diminishes as piece weight increases past 20 pounds.

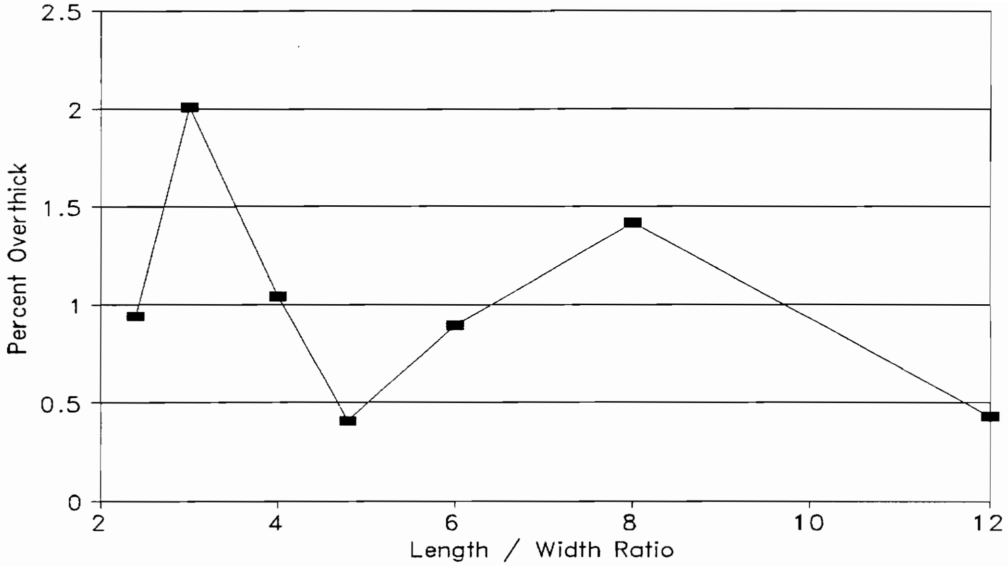


Figure 6.12. The effect of length/width ratio on the overthick chip furnish in South Georgia.

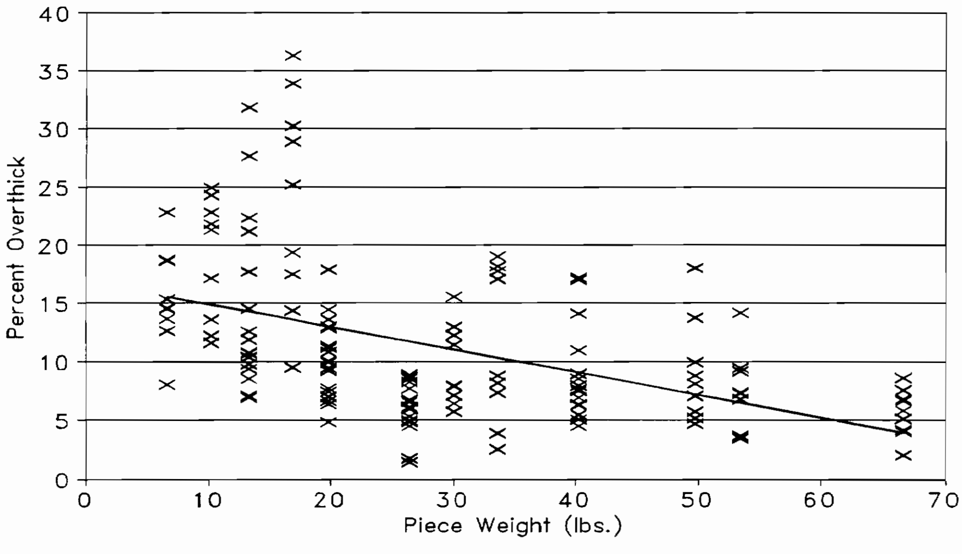


Figure 6.13. Relationship between the percentage of overthick chips produced and trim block piece weight in Central Georgia.

The trend then tends to flatten as piece weight exceeds 30 pounds. Chip quality probably became more uniform as piece weight increased because heavier pieces better resisted shifting in the chipper throat by knife impact.

Overthick chip production at South Georgia also decreased with increases in piece weight. Six-foot material again was not included in the analysis because of the feeding problems. Heavier pieces produced higher quality chips in over two-thirds of the cases (Table 6.12). Again, most significant differences occurred between trim blocks weighing less than 20 pounds and those greater than 20 pounds.

Similar, but lesser, improvements were also seen in the oversize and acceptable chip categories in South Georgia (Figures 6.14 and 6.15). Significant differences were found in approximately 55% of the tests in both chip classes.

THICKNESS EFFECT

The effect of trim block thickness was only examined in Central Georgia. Piece thickness had limited effects on the resulting chip furnish. Five-quarter material produced roughly 3% more overthick and oversize chips than 2-inch material (Figure 6.16). Significant differences were found in the oversize and acceptable chip fractions, but not in the overthick, pulpable, and pin chips and fines.

Table 6.12. Wilcoxon Rank Sum test results for differences in the overthick chip furnish among trim block piece weights in South Georgia.

	6.7	10	13.3	16.7	20	26.7	33.3
6.7	-	x	xx	x	xx	xxxx	xxx
10		-				xxx	xxx
13.3			-			xx	xx
16.7				-		xx	xx
20					-	xxxx	xxx
26.7						-	
33.3							-

p-values:
x <= 0.1
xx <= 0.05
xxx <= 0.01
xxxx <= 0.001

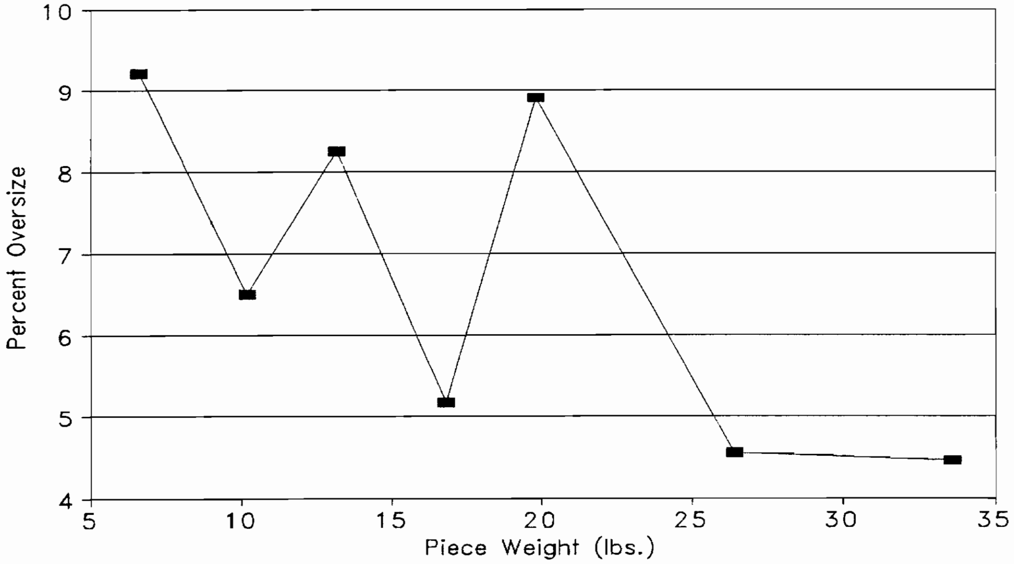


Figure 6.14. Percentage of oversize chips produced by each trim block piece weight in South Georgia.

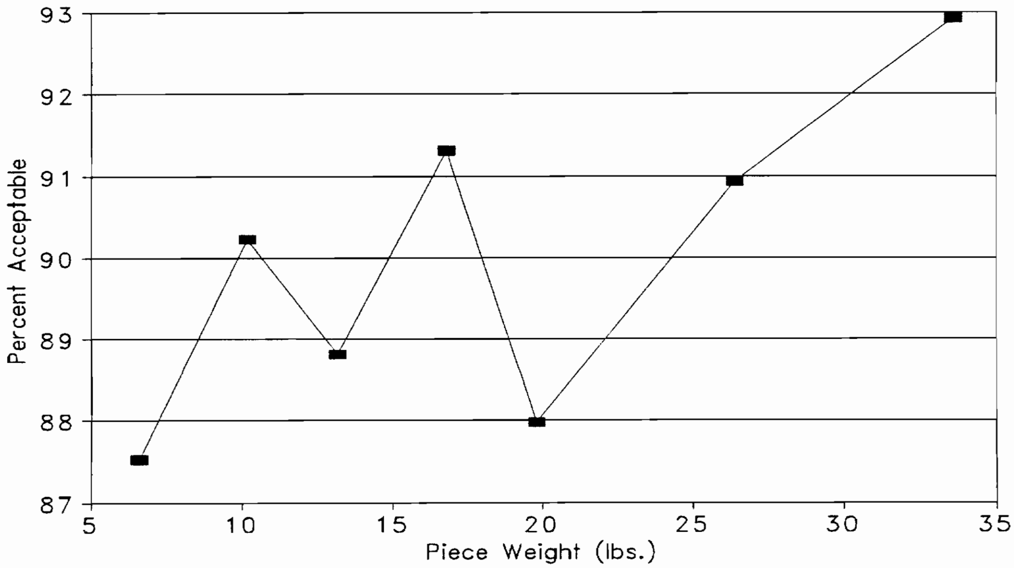


Figure 6.15. Percentage of acceptable chips produced by trim block piece weights in South Georgia.

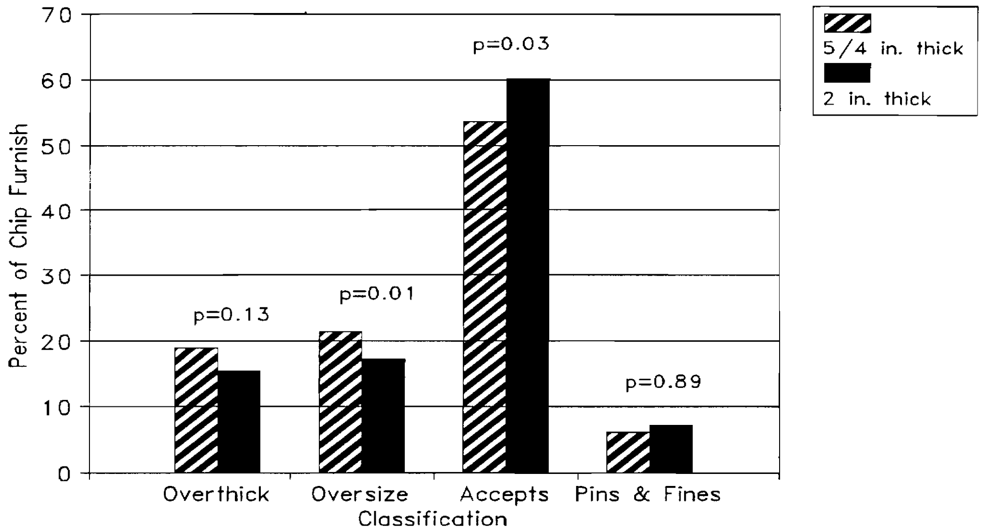


Figure 6.16. The effect of trim block thickness on chip quality and t-test p-values at each chip classification in Central Georgia.

SUMMARY AND CONCLUSIONS

The Central Georgia study indicated that increasing trim length could result in a 5-7% increase in pulpable chips. Increasing length resulted in a decrease in the overthick chip fraction and a proportional increase in the pulpable chip fraction. No significant changes in the percentage of pin chips and fines were found as length increased.

An interesting relationship existed between piece weight and length/width ratio. The pulpable chip percentage increased as the length/width ratio increased for blocks weighing less than 20 pounds. Once the 20 pound threshold was crossed, increasing weight was more important than increasing length/width ratios.

Approximately 50% of the increase observed in chip quality occurred when increasing trim block length from two to four feet. Even though ratios are still below 10:1 for the wider trim blocks (2x8, 2x10, and 2x12), the increase to four feet doubles their weight.

The second study in South Georgia corroborated the results of the first study. The target chip length (5/16-inch) was half that of the first study (5/8-inch) which weakened some comparisons. Chip quality improved significantly with longer lengths. Overs (overthick and oversize) were shifted to the acceptable chip class.

Lengthening trim blocks to four feet accounted for 50% of the gains.

This study also found a relationship between trim block length and width. Increased length/width ratios and piece weights generally produced chip yields of higher quality.

Increasing trim length by modifying the trimmer outfeed table at large mills could prove to be well worth the investment. The second study shed little light on the effectiveness of tapering the infeed to improve trim block orientation. The conveyor was not tapered to improve chip quality, but to fit the narrow throat of the chipper.

CHAPTER 7

EFFECT OF CHIPPER SPOUT LOADING

INTRODUCTION

The depth of material in the conveyor feeding the chipper was thought to be a variable controlling chip quality. Residue chippers rarely operate at constant levels of throughput for extended periods of time. Chippers become overloaded when the mill is processing poor quality logs requiring extensive trim or when plugs break loose and move as a unit. Low throughput occurs when processes are interrupted or log quality is high. The objective of this study was to determine if chip quality could be influenced by controlling the depth of trim blocks in the feed conveyor.

METHODS AND PROCEDURES

Tests were conducted under three simulated loading conditions at the mill in South Georgia. The three loading conditions (single piece feed, conveyor half-full and full) were replicated three times using 200 pounds of 2x6x2′ trim blocks. Each replication consisted of loading the required amount of material in the vibrating conveyor feeding the chipper at a point approximately 40 feet from the chipper throat. Single piece feeding involved sending trim blocks down the conveyor one after the other. The half-full condition was simulated by placing trim blocks in the conveyor in piles two high and two wide. The full condition was simulated by piling the trim blocks three high to completely fill the conveyor trough.

Trim blocks were loaded and allowed to vibrate up to a point approximately 15 feet from the chipper throat. At this point, stray trim blocks were collected before vibrating the rest of the way into the chipper. The orderly arrangement of the half and full conditions was lost as the material vibrated down the conveyor and into the chipper.

The chipper used in the study is the same as described in the second study of Chapter 6. Chipper knives were not replaced for the study, but were in satisfactory condition following the completion of the length study.

CHIP SAMPLING AND CLASSIFICATION

The chip system was allowed to purge before each test to ensure that chips did not intermix. Three 10-pound chip samples were collected from the drag chain carrying the chips away from the chipper.

Chip samples were returned to Virginia Tech for classification in a Williams Classifier. Chips were screened into nine chip-size fractions using a two-pass operation (Appendix B). The first pass screened out the overthick (8-mm) and 2+ inch, 1 1/2+ inch, and 1 1/8+ inch chips. The second pass separated the 7/8+ inch, 5/8+ inch, 3/8+ inch, 1/8+ inch chips and fines. The percentage of the total furnish retained on each screen was then computed and used for analyses.

STATISTICAL ANALYSIS

The effects of material feeding were examined for significant differences in chip quality. A one-way ANOVA was used to test for differences at an alpha level of 0.05 in each chip-size class. The null hypothesis tested in each instance was that the "mean percentage of chips in each class from the three conveyor loadings are equal."

RESULTS AND DISCUSSION

Chip size shifted toward the larger fractions as the conveyor became filled (Figure 7.1). Single piece feeding resulted in 20% of the chips being 5/8-inch or larger in size and 0.5% overthick. Thirty-six percent of this furnish was 1/8-inch or less. The full conveyor condition resulted in over 40% of the chips being 5/8-inch or larger and roughly 23% of the overall furnish 1/8-inch or smaller in size. Roughly 2.5% of these chips were over 8-mm thick. The half-full condition fell midway between the single piece feeding and full conveyor condition in all classes confirming the trend. Differences between the two extreme

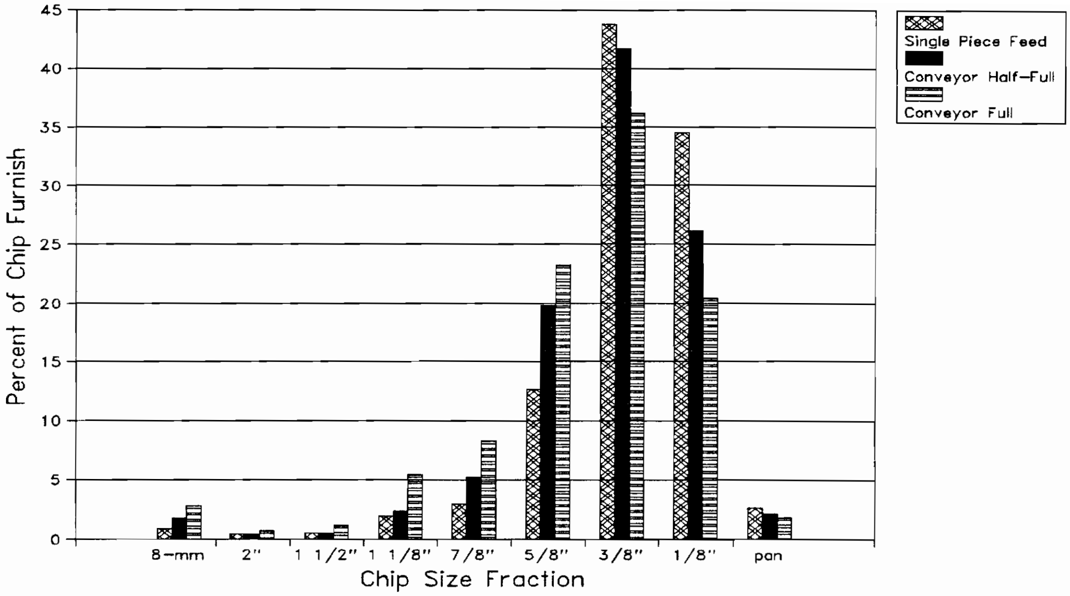


Figure 7.1. The effect of chipper spout loading on the distribution of chips in each size class.

conditions (single piece and full) were significant at the 95% level for all chip classes except for the 2- and 1 1/2-inch classes (Table 7.1). These two fractions accounted for less than 2% of the total yield.

There are two possible explanations for the shift toward the larger chip fractions with increased spout loadings. When the throat is fully loaded, the ability for the material to shift around during chipping declines. Consequently, trim blocks adjacent to the knife are pushed through the knife pocket by material behind before they are completely chipped (Stuart, 1993). When pieces are fed singularly, they have the opportunity to bounce back and get re-fed, thus producing higher percentages of small chip sizes. The second explanation for the shift is a decrease in disc speed during chipping. A fuller spout has more pieces being chipped simultaneously and places more of a load on the chipper at one time. The initial impact of the material may slow disc speed and result in larger chips being produced from the remaining pieces. However, this explanation can not be confirmed because the chipper disc was not equipped with a tachometer during the trials.

Table 7.1. Results of the one-way ANOVA in each chip-size fraction for chipper spout loading.

Chip-Size Fraction	Load Condition	Average	P-value
8-mm	Single	0.82	0.0042
	Half	1.70	
	Full	2.81	
2-inch	Single	0.38	0.5222
	Half	0.41	
	Full	0.71	
1 1/2-inch	Single	0.55	0.1645
	Half	0.45	
	Full	1.15	
1 1/8-inch	Single	1.95	0.0001
	Half	2.34	
	Full	5.43	
7/8-inch	Single	2.90	0.0000
	Half	5.23	
	Full	8.28	
5/8-inch	Single	12.63	0.0000
	Half	19.85	
	Full	23.19	
3/8-inch	Single	43.76	0.0002
	Half	41.71	
	Full	36.24	
1/8-inch	Single	34.47	0.0000
	Half	26.16	
	Full	20.44	
Fines	Single	2.55	0.0075
	Half	2.16	
	Full	1.75	

SUMMARY AND CONCLUSIONS

This pilot study clearly indicates that chipper spout loading has an effect on the chip distribution. Mills concerned about pin chips and fines may be benefit from chipping with a full throat. Conversely, the percentage of overthick chips can be reduced by regulating the flow of material through the chipper to a half-full conveyor or less.

Future studies should examine the effects of loading on a chipper with a larger target chip-size. Trends from different loading conditions should be obtained with a larger chip size. However, the small chip size (5/16-inch) used in this study may be obscuring shifts in the overthick, pin chips, and fines classes as feed rates change. The effect of fully loading the chipper on disc speed, power requirements, and chipper maintenance should also be examined.

CHAPTER 8

EFFECTS OF TEMPERATURE ON PIN CHIP AND FINE PRODUCTION AT SOUTHERN PINE CHIP MILLS

INTRODUCTION

The effect of wood temperature on chip quality has been the subject of studies that have largely concentrated on a specific temperature range in an experimental or laboratory environment (Hatton, 1977; Hartler and Stade, 1977; Leary and Stuart, 1991; Edelman, 1992). This study looked at the effects of temperature as they occurred in a natural environment over a period of time.

A preliminary analysis conducted using chip quality reports and local weather records from one mill found a linear relationship between pin chip and fine production and daily temperature. Daily chip analyses and weather records from two other chip mills were obtained for one year to test this relationship.

METHODS AND PROCEDURES

Two of the three mills were located in the piedmont and one in the coastal plain. One of the piedmont mills was located in Georgia, the others in South Carolina. Mill operations were similar at all three mills. All processed tree-length material, preferably direct from deliveries, and had similar inventory practices and equipment. All equipment was well maintained, but normal variation from knife dulling, anvil wear, wear plate erosion, wood, and other sources was present.

Chip samples were taken by mill employees using each mills respective sampling procedure and time schedule. Weather data for each mill was obtained from the nearest weather station. Daily high and low temperatures were used to compute the average daily temperature for those days when a sample was drawn.

The data, as received, were summarized by percentages into four size classes: oversize, accept, and pin chips, and sawdust. When the data were entered in a spreadsheet, the pin chip and sawdust classes were combined for the analysis.

STATISTICAL ANALYSIS

All analyses concentrated on the undersize chip fractions. Past studies have proven that these size classes are more readily affected by freezing and near freezing temperatures. Efforts were spent on defining the extent of this relationship over the 30°F to 80°F temperature range.

A seven-day rolling average was used to smooth the temperature data and to reflect the lagging temperature changes in wood.

Of the three mills, only the Georgia piedmont mill took and recorded daily chip sample summaries. The two South Carolina chip mills had variable sampling schedules. The consistency of the Georgia data allowed use of a seven-day rolling average to smooth the chip and temperature data. Rolling averages could not be accurately calculated for the chip data at the two South Carolina chip mills because of missing days. For those days where a chip sample was taken, the single sample value was correlated with the rolling average temperature for that day. A simple linear regression, $y = mx + b$, was used to determine the strength of the relationship between pins and fines and temperature at each mill.

RESULTS AND DISCUSSION

A strong relationship between undersize chip production and daily temperature was found for all three chip mills (Figures 8.1, 8.2, and 8.3). As temperatures fluctuated through the range of 30°F to 80°F, pin chip and fine content varied three to five percent. During the spring months when temperatures start to rise, pin chip and fine production starts declining. As colder temperatures arrive during the fall, the pin chip and fine content starts to increase.

Figure 8.1, using the more complete Georgia data set, best depicts the wood temperature relationship.

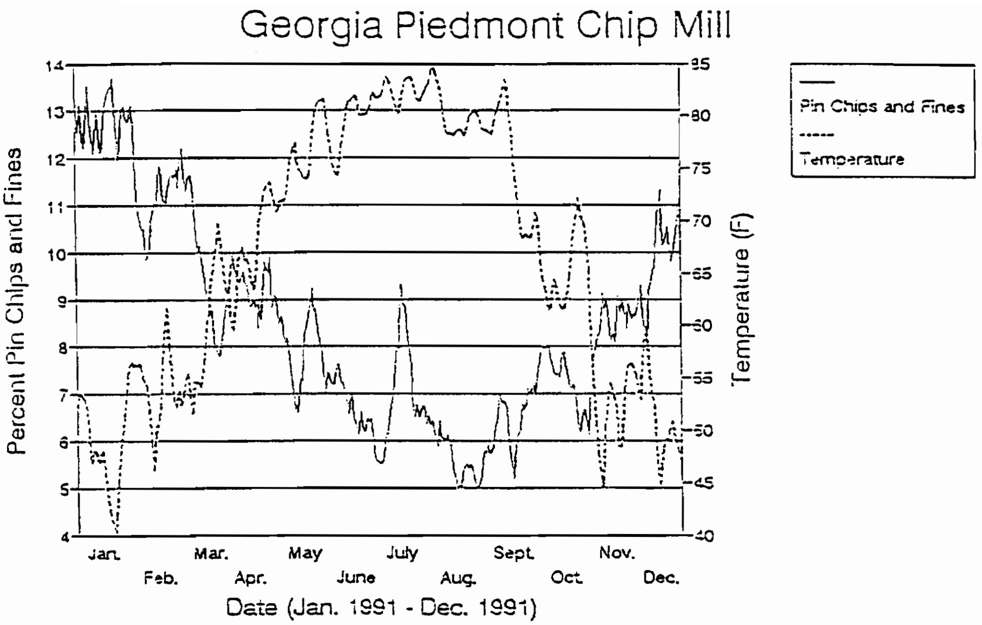


Figure 8.1. Seven-day rolling average of pin chip and fine production over a one-year period at a Georgia piedmont chip mill.

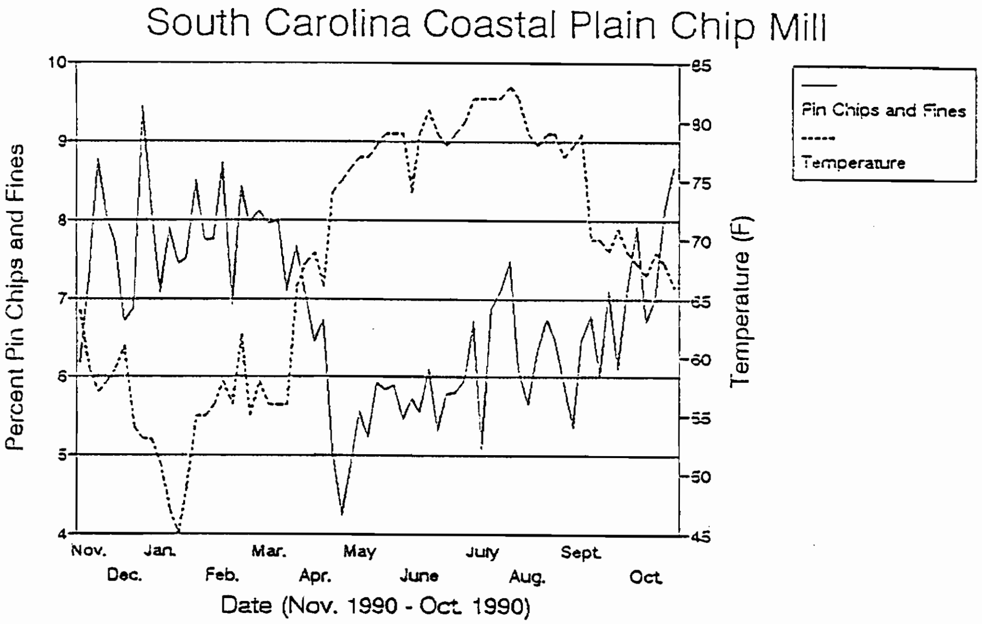


Figure 8.2. Pin chip and fine production at a South Carolina coastal plain chip mill over a one-year period.

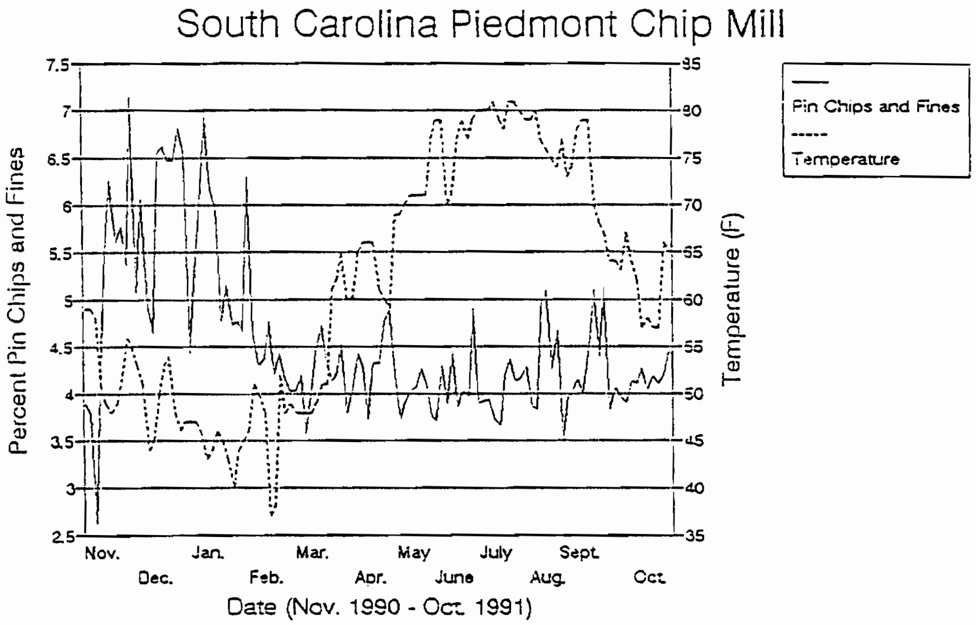


Figure 8.3. The percentage of pin chips and fines produced during the course of a year at a South Carolina piedmont chip mill.

Unseasonably high or low short term temperatures had minimal effect on pin and fine production because of the natural insulating quality of wood. However, if the temperatures persisted for several days, changes in chip quality could be found.

The simple linear regression was found to be significant ($p < 0.001$) for all three mills. As seen in Table 8.1, R^2 values for the Georgia piedmont and South Carolina coastal plain mill, 0.65 and 0.50 respectively, provide evidence that much of the variability was due to temperature. Temperature explained less of the variation at the South Carolina piedmont mill ($R^2 = 0.25$). This mill likely had a greater variability in species (Longleaf, Shortleaf, Virginia, and Loblolly) and perhaps greater variation in the length of time the wood had been stored in inventory.

Figures 8.4, 8.5, and 8.6 show the regression line and data points for each mill (correspond with Table 8.1). The regression equation for the Georgia piedmont and South Carolina coastal plain mill is strongest (Figures 8.4 and 8.5). The pattern of the data between 30° and 45°F may indicate that the relationship is in fact curvilinear with pin chip and fine production increasing with decreasing temperature. The data sets available were too small to justify a more elaborate analysis.

Table 8.1. Summary of the regression analysis for the three southern pine chip mills.

Chip Mill	Slope	Intercept	R^2	F-Ratio	p-value
Georgia Piedmont	-0.141	17.86	0.65	588.72	0.000
South Carolina Coastal Plain	-0.073	11.76	0.50	63.84	0.000
South Carolina Piedmont	-0.033	6.61	0.25	35.97	0.000

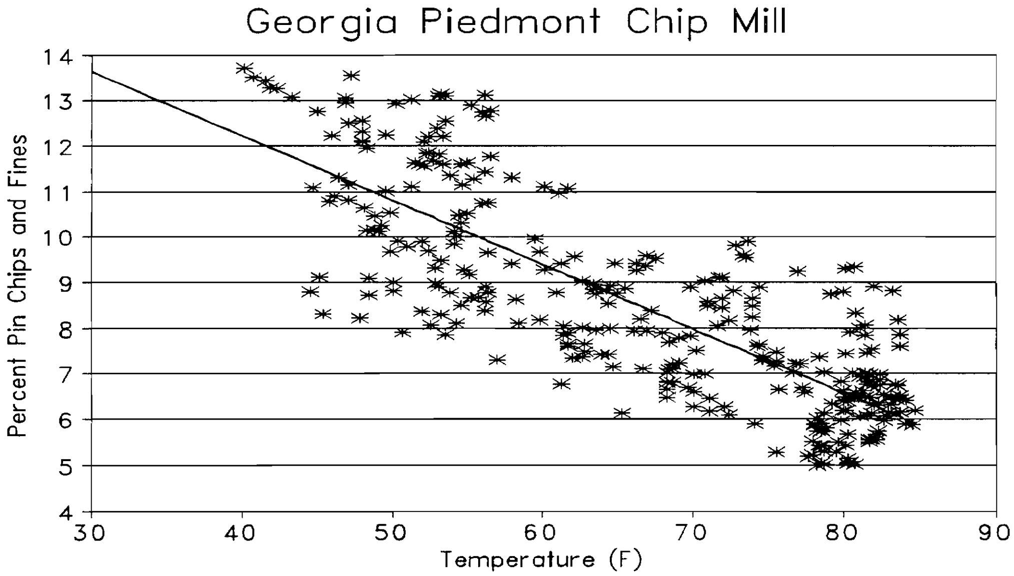


Figure 8.4. Linear regression line and data points for the Georgia piedmont mill.

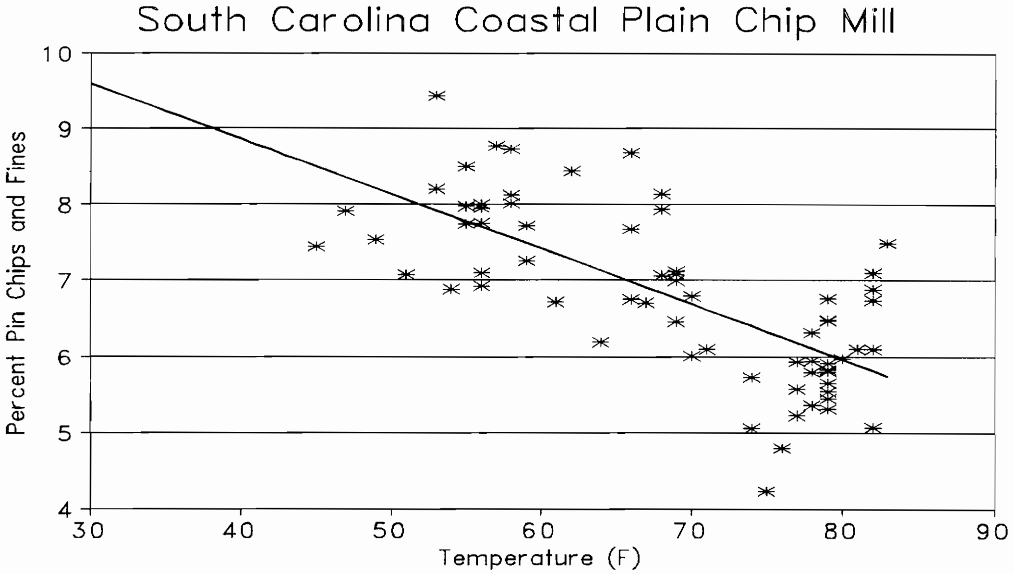


Figure 8.5. Linear regression line and data points for a South Carolina coastal plain chip mill.

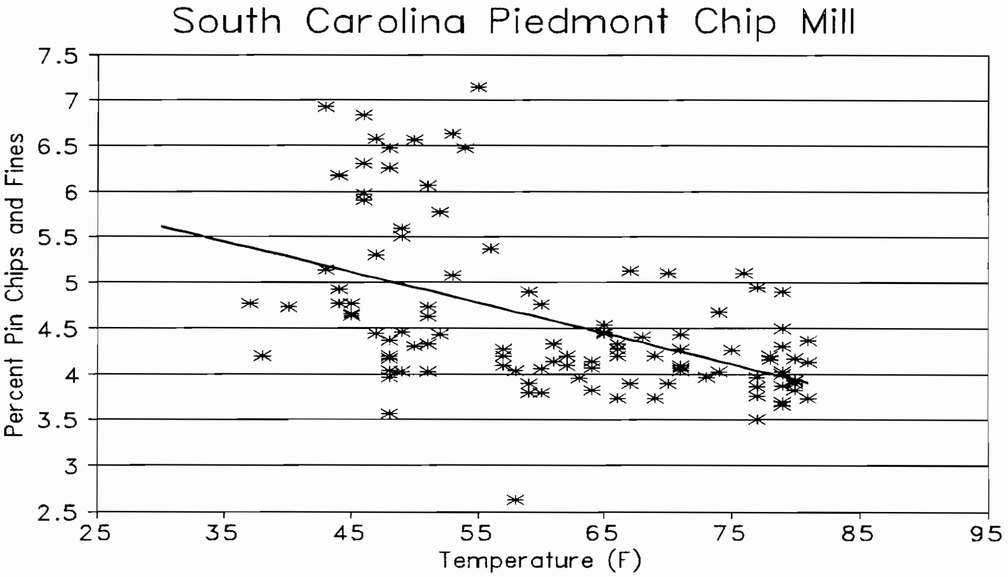


Figure 8.6. Linear regression line and data points for a South Carolina piedmont chip mill.

This simple regression analysis indicates that as a "rule of thumb," pin chip and fine production increases by approximately one-tenth to one-twentieth of one percent for each 1°F drop in daily temperature. A more comprehensive study spanning two or more years supported by information on wood species, time in inventory, and equipment condition would be required to develop predictive equations.

SUMMARY AND CONCLUSIONS

Pin chip and fine production was inversely related to seasonal temperatures at all three chip mills. The percentage of pins and fines produced increased as daily temperatures became colder and wood temperatures decreased. Winter temperatures rarely reached freezing, but caused the pin chip and fine content to increase by up to 5% over summer months.

The effect may not be great enough to justify major capital investments, such as a steam table, but some low costs solutions may be appropriate. For example, waste hot water can be used in wood flumes or effects of shade and wind exposure might be considered when selecting wood inventory locations. Slowing chipper disc speed during the winter months has also been found to reduce the number of pins and fines.

CHAPTER 9

EFFECTS OF TEMPERATURE ON PIN CHIP AND FINE PRODUCTION AT SOUTHERN HARDWOOD CHIP MILLS

INTRODUCTION

The previous analysis found a strong relationship between undersize chip production and temperature at Southern pine chip mills. Pin chip and fine production increased with colder temperatures and decreased as daily temperatures rose. Temperature effects in hardwoods are less well known. The strong correlation found in pine gave reason to believe that the percentage of pins and fines in hardwood chipping might be similarly affected.

Hardwoods are generally more brittle than pine and tend to break into finer pieces more easily. Freezing temperatures, especially in northern climates, magnify this characteristic. Mills there are especially aware of increases when temperatures dip well below freezing for extended periods (Nelson and Bafile, 1989; Hatton, 1975). Temperatures in the South are much milder throughout the year and wood rarely reaches a frozen state.

Species differences further complicate generalizations between northern and southern mills. Hardwood species chipped in the North include aspen, birch, maple, and beech.

Southern mills chip gum, oak, hickory, and tupelo.

METHODS AND PROCEDURES

Chip sample reports from four hardwood chip mills, covering an 18-month period, were obtained from a Southern pulp mill. All four mills are located in North Carolina, three in the piedmont region and one in the coastal plain. Chip samples were taken and analyzed at the pulp mill. Weather data for each chip mill was obtained from the weather station nearest to each mill.

Mill operations are similar for all four chip mills. All process tree-length material, preferably direct from deliveries, and have similar equipment. All the equipment was well maintained, but normal variation that occurs due to normal dulling, wear, wood, and other sources is present. Additionally, all four mills screen for fines (dust) which obscured the true relationship. The fines that were included in the analysis included only those that were produced during chip handling or were unscreened because of low screening efficiency. One mill screened for overs.

When received, the data for each sample were summarized by percentages into five size classes: overthick, oversize, accepts, pin chips, and sawdust. The pin chip and sawdust classes were combined to form the pin and fines category. Each sample also noted the type of transportation, rail car or truck, and the date the chips were unloaded by the mill. It was assumed that truck deliveries were chipped within 24 hours and the unloading date could serve as the chipping date. Seven days were subtracted from the unloading date on rail car deliveries to reflect the chipping date.

Preliminary plots of pin and fine production showed a great amount of variation within each day, week, and month. Several obvious outliers were also present in the data. The middle 50%, or interquartile range, of the chip samples were used to reduce the "noise" in the data set while retaining trend information.

STATISTICAL ANALYSIS

All analyses concentrated on the undersize chip fractions (pin chips and fines). A seven-day rolling average was used to smooth daily temperatures. A rolling average was more characteristic of lagging temperature changes in wood and therefore wood temperature at the time of chipping. A simple linear regression, $y = mx + b$, was used to determine the strength of the relationship at each chip mill.

RESULTS AND DISCUSSION

The quantity of pin chips and fines produced at a hardwood mill was influenced by seasonal temperatures. The percentages generally declined with increasing seasonal temperatures and increased during the colder winter months (Figures 9.1, 9.2, 9.3, and 9.4). Although the production of undersize chips did follow a seasonal trend, there was variability within seasons that contradicted the relationship. These inconsistencies prompted further investigations into inventory practices, chipping operations, species, and wood quality.

Hardwood chip quality naturally fluctuates more than pine because of the diversity of species. A hardwood mill, depending on location, may process up to a dozen different species while a pine chip mill may only handle two, three, or at most four on a regular basis. Differences in wood properties between species of southern pine are also less dramatic than the differences between soft and hard hardwood pulping species.

Although the four mills are similar in physiographic region, species composition is slightly different. Mills 1 and 2 are in the upper piedmont while Mill 3 lies on the fall line of the piedmont and coastal plain. The upper piedmont mills usually process hard hardwoods (oaks and hickory) with an occasional mixture of soft hardwoods (gum, tupelo, and poplar). Both the lower piedmont and coastal plain mills process equal proportions of hard and soft hardwoods. During winter months or extremely wet periods in the coastal plain, logging crews are forced to the ridges to

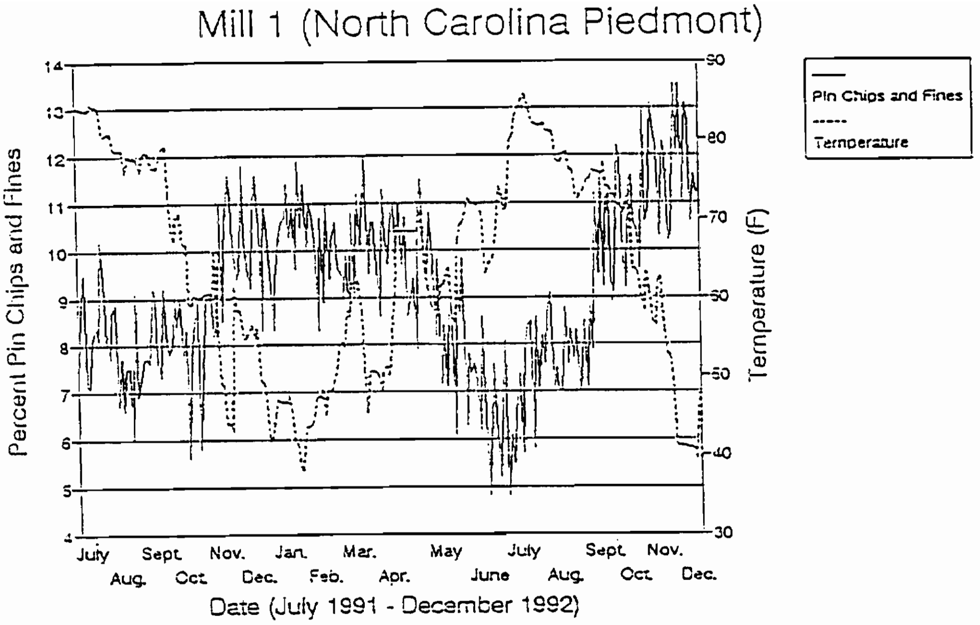


Figure 9.1. Percentage of pin chips and fines produced with relation to daily temperatures at a North Carolina piedmont chip mill.

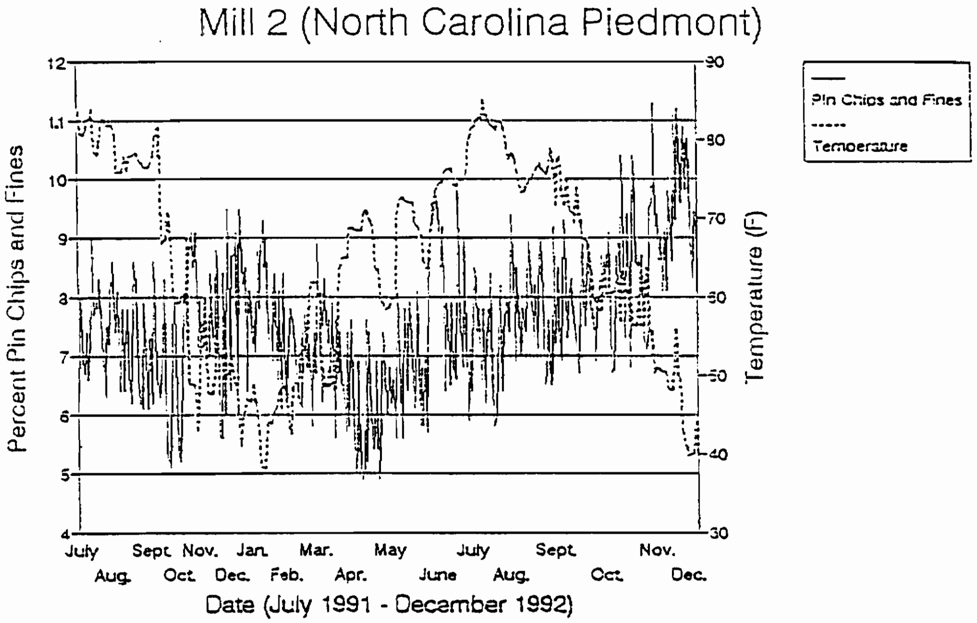


Figure 9.2. The pin chip and fine content and daily temperature at a North Carolina piedmont chip mill.

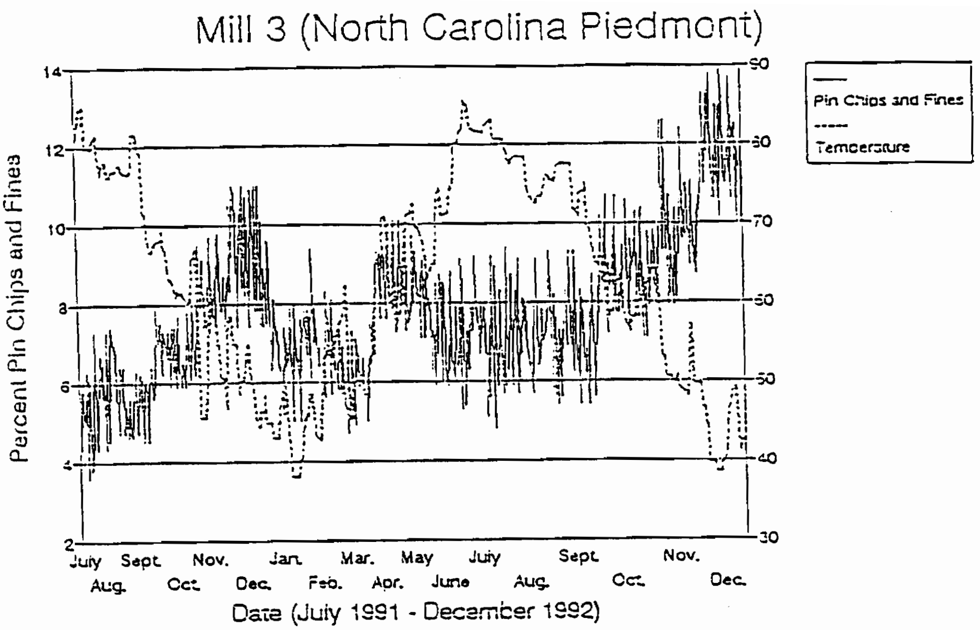


Figure 9.3. The percentage of pin chips and fines produced at a North Carolina piedmont chip mill.

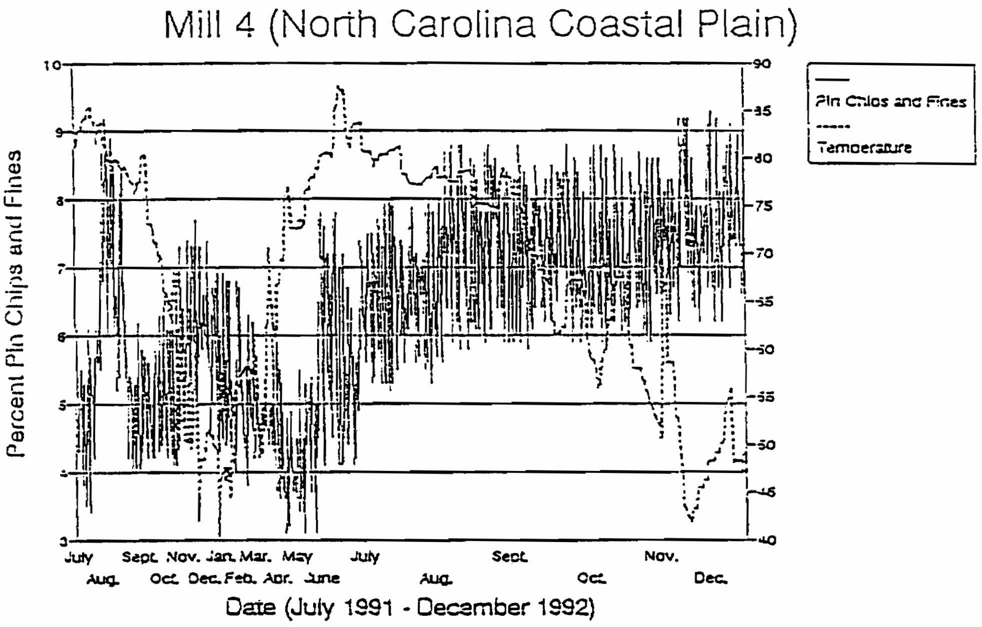


Figure 9.4. The percentage of pin chips and fines produced by a North Carolina coastal plain chip mill.

cut hard hardwoods while harvesting soft hardwoods from the swamps and bottom lands in the drier, warmer months. Conversely, in the upper piedmont cover type is more homogenous and crews harvest mostly hard hardwoods year-round.

Inventory practices and levels may have contributed to the variability. Hardwood mills, especially in the coastal plain, have a tendency to inventory more wood than pine mills. Hardwood stands that have escaped conversion to pine tend to be in the wetter sites that are less accessible in winter. Hardwood mills are forced to maintain higher inventory levels to compensate for winter related wood flow problems.

Screening efficiency and chip handling may have also contributed to the overall relationship. During cold winter months, chips break up easier during handling or stick to the screens, decreasing their efficiency. However, the fine, or dust, content was less than 0.2% on average and had no seasonal affect on the undersize chip content. The relationship may have been stronger if the fine content was unscreened.

The strongest relationship was found at Mill 1, resulting in an R^2 of 0.34 (Table 9.1). The pin chip and fine content varied approximately 4-5% between the winter and summer seasons (Figure 9.1). Pins and fines averaged

Table 9.1. Summary of the regression analysis for the four hardwood chip mills.

Mill	Location	Slope	Intercept	R^2	F-Ratio	p-value
1	North Carolina Piedmont	0.079	14.24	0.34	110.97	0.000
2	North Carolina Piedmont	0.023	9.14	0.06	20.74	0.000
3	North Carolina Piedmont	0.065	11.87	0.21	149.45	0.000
4	North Carolina Coastal Plain	0.019	7.71	0.03	24.12	0.000

about 7-8% during the summer and increased to 12 or 13% during the cooler winter months.

A prime example of unrelated variables producing counter-effects on chip quality is seen at Mill 2 (Figure 9.2) which shows a trend toward increasing amounts of pins and fines during the winter months even though the correlation was weak ($R^2 = 0.06$). Rainfall during the fall and winter of 1991 was well below normal (almost 6 inches) allowing the mill to continue chipping fresh wood during a period when it would normally be processing inventory wood. Then as late spring approached and rainfall increased, the mill was forced to turn to inventory when, in a "normal" year, it would have been chipping fresh wood.

Comparing pin chip and fine production in the winter of 1991 with that of 1992 also indicates changes in inventory and species. During the winter of 1991, the pin chip and fine content did not increase as dramatically as in the winter of 1992, increasing approximately 1% and 3% respectively. However, pin chip and fine production during the summer months of 1992 remained below winter 1991 levels. The dry fall and winter of 1991 may have also provided conditions for delivery and inventory of a higher percentage of soft hardwoods. Mill 2 was also just coming on-line during the spring of 1991 and was going through operational shakedown in the first year.

Mill 3 followed the expected trend, except for a portion of the time between December 1991 to February 1992 (Figure 9.3). During this three month period, the percentage of pin chips dropped by about 2%, but then rose back to previous levels. Otherwise, the percentage of pins and fines varied with each season and held the hypothesized pattern. Approximately 5% more pin chips and fines were produced during the winter months.

There are several possible causes of the shift during the winter of 1991 and the increased pin chip and fine content during the summer and winter of 1992. Mill 3 is also a pallet mill and emphasis is placed on this product. Past experience has shown that chip quality suffers slightly when pallet production increases because more hard hardwoods are used.

Some of the shift may also be explained by the mill's location and weather. Mill 3 lies on the fall line of the piedmont and coastal plain and uses a greater diversity of species than the other piedmont mills. The fall and winter of 1991 were very dry and allowed for the processing of more soft hardwoods during periods of low demands for pallets.

The weakest correlation between temperature and undersize chip production was found at Mill 4, the only coastal plain mill (Table 9.1). The expected trend is present during the latter part of 1991. Other variables appear to be countering temperature effects in the remaining months (Figure 9.4). The sharp increase during August 1991 was most likely caused by chipping inventory. Over 14 inches of rain fell during the last week of July and August, forcing the mill to rely more heavily on inventory. It is unlikely that there was a species change during this period because rainfall made harvesting difficult on all areas. After the rains ended, pin chip and fine content shifted back to normal in September. The winter months were mild, averaging 48°F, and the mill produced slightly more undersize chips.

In late winter, early spring Mill 4 encountered some operating problems. The chipper started producing unacceptable quantities of overs. The pulp mill objected strenuously. The chip mill then began experimenting with different knife, anvil, and counter-knife angles to remedy the problem. The problem was eventually corrected, but at the expense of more pins and fines.

The spring of 1992 was the fourth wettest spring on record for this area. The wood supply probably shifted toward hard hardwoods as logging crews moved to higher ground.

SUMMARY AND CONCLUSIONS

All four chip mills showed increases in the percentage of pins and fines as the temperatures dropped. The change in undersize chip production varied between mills, but generally increased 4-5% during the winter months. Other factors contribute to hardwood chip quality and weakened the strength of the relationship. Further studies, more closely monitoring species and inventory practices, are needed to understand the relationship fully.

CHAPTER 10

SUMMARY AND CONCLUSIONS

IMPROVING TRIM BLOCK CHIP QUALITY

The primary objective of this research was explore ways to improve chip quality from residue trim blocks at high production southern pine sawmills. Improved trim block chip quality would benefit both sawmills and pulp mills by increasing chip revenues for sawmills while helping maintain quality and productivity at pulp mills.

The first step was to determine the material forms entering the residue chipper at a typical sawmill. Three forms of material were processed, end trim, grade trim, and oversize chips. End trim, or "zero" trim less than six inches in length, was the result of trimming an acceptable board to length. Grade trim consisted of 2-foot trim blocks that resulted when excessive wane was removed from the end of a board or an entire board that would not meet minimum grade requirements was slashed. Oversize chips included all chips that did not pass through the top screen of the screen pack and were recycled through the chipper.

The next step was to identify the source of the greatest volume of unacceptable residue chips. An overwhelming majority (85-90% by weight) of material entering the residue chipper was grade trim. End trim and oversize chips yielded lower percentages of accepts (less than 50%) but did not contribute substantially to the chip furnish (10-15% by weight).

Efforts shifted to improving chip quality from grade trim by identifying methods of improving piece orientation when entering the chipper and piece stability while being chipped. Increasing trim block length was an obvious way to accomplish both objectives.

Increasing trim block length significantly improved chip quality. The percentage of overthick chips declined and the acceptable percentage increased proportionately. As trim length increased, the orientation and stability of the piece improved. Trim block orientation influenced chip quality for those pieces weighing less than 20 pounds. Improvements for those pieces weighing more than 20 pounds were attributed to piece weight. When trim lengths were increased to four feet, a trim block's length/width ratio (a measure of the ability for a piece to become oriented) and piece weight doubled resulting in a 10% increase in accepts. Chip quality continued to improve with longer trim lengths, but increases were less dramatic.

Over half of the trim blocks would remain as 2-foot pieces and increasing material length was not an alternative at all mills. Tapering the chipper infeed conveyor would force the orientation of these smaller pieces prior to chipping.

The effect of conveyor loading on chip quality was examined as another way to improve chip quality from the 2-foot trim blocks. Material throughput for a residue chipper can be inconsistent. Single pieces are often chipped when log quality is good and trimming minimal. There are other times when, because of log quality or other reasons, the feed conveyor is overloaded.

Chip quality was highest when residue throughput was between the extreme conveyor loading conditions (half-full conveyor). Overloaded and underloaded conveyors were found to shift the chip distribution. Chipping single pieces resulted in the fewest amount of overs, but a 10% increase in the percentage of undersize chips. When chipper throughput was maximized, the percentage of overs increased 5%, while the pin and fine content decreased 10%.

EFFECTS OF TEMPERATURE ON CHIP QUALITY

The secondary objective of the study was to examine the effects of temperature on both pine and hardwood pins and fines production. Frozen or chilled wood was known to produce significantly more pins and fines than wood at ambient temperatures but little was known about temperature changes through the temperate range. Chip quality reports were obtained from three pine and four hardwood chip mills in the South to document the effects of temperature over the 30°F to 80°F range.

The undersize chip content increased 4-5% from summer to winter conditions at the southern pine chip mills. Wood did not have to approach chilling or freezing conditions before the pin chip and fine content was affected.

Similar, but less defined, trends existed at the hardwood chip mills. In general, pin chip and fine production decreased as temperatures increased. The hardwood mills were more variable in production scheduling, species mix, inventory policy, and sampling intensity which obscured the more subtle temperature effects.

RECOMMENDATIONS

Trim lengths should be left in the longest form possible.

Increasing trim block length significantly improved chip quality suggesting that it may be well worth the effort and investment to modify the trimmer optimizer outfeed table. Overs, mainly overthick, decreased and were converted to acceptable chips. There was no affect on the undersize chip furnish. Chip quality improved with each 2-foot incremental increase, but doubling the trim length to four feet resulted in 50% of the total gains. Increasing trim lengths to four feet would yield 3 additional tons of acceptable chips per day for a high production sawmill.

Residue chippers should not be overloaded or underloaded.

It was found that keeping the chipper throat half-full produced the highest quality chips. Overfilling the conveyor shifted the distribution toward the larger chip sizes. Trim blocks fed as a unit when the conveyor was full and forced material through the knife pockets. Underfeeding increased the pins and fines content. Observations, rather than experimental findings, indicate that single trim blocks did not have any support and bounced off the chipper disc.

Wood inventories should be stored in locations that will keep them warm.

Temperature changes, even in the mild range, were found to influence pin chip and fine production at both southern pine and hardwood chip mills. The pin chip and fine content was affected across the entire range of normal daily temperatures, indicating that temperatures do not have to fall below or near freezing before chip quality is affected. On average, increasing wood temperatures 10°F reduced the percentage of pin chips and fines by about 1%. Additionally, wood transfers heat slowly, so inventorying wood in a warm place will help maintain wood temperatures for longer periods.

FOCUSES FOR FURTHER RESEARCH

Among the alternatives proposed, but not evaluated because of time and budget constraints were:

1) **Modifying the infeed conveyor.** The South Georgia study was an attempt at evaluating this alternative but both sides of the conveyor were tapered to fit a narrow chipper throat. Increased tapering should only be done on one side and should not affect the transportation of residue to the chipper or chipping. Gradual tapering and shaping of the altered side in an involute curve would allow larger residue pieces to pass through unimpeded.

2) **Tipping the infeed conveyor.** Tipping the residue chipper infeed conveyor 10 to 15 degrees toward the anvil side of the chipper would help align the pieces against the anvil and produce more uniform chipping.

3) **Packaging or bundling trim blocks.** Although there is some discrepancy in the literature, chipping material in a bundle under control has been found to improve chip quality. Developing a way to accumulate trim blocks and then organize them in a bundle before

chipping would fix trim block orientation and provide needed stability during chipping.

Further work is also needed to fully document the effects of temperature on hardwood chip quality since both species and inventory levels vary with seasons and weather. The effects of temperature could be established more accurately by monitoring the species and inventory levels throughout the year.

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APPENDIX A

Table A.1. Number of trim blocks needed to reach 300 pounds per trial for each dimension tested.

Length (ft.)	Dimension				
	5/4x4	2x4	2x6	2x8	2x10
2	50	45	30	23	18
4	-	23	15	12	10
6	-	15	10	8	6
8	-	12	8	6	5

APPENDIX B

Table B.1. Williams Classifier two-pass set-up and size fractions used to form the chip classes in the first study (Central Georgia).

8-MM BAR SCREEN	OVERTHICKS	FIRST PASS
2" ROUND-HOLE	OVERSIZE	
1-1/2" ROUND-HOLE		
1-1/8" ROUND-HOLE		
7/8" ROUND-HOLE	ACCEPTS	SECOND PASS
5/8" ROUND-HOLE		
3/8" ROUND-HOLE		
1/8" ROUND-HOLE	PIN CHIPS	BOTH PASSES
PAN	FINES	

Table B.2. Williams Classifier two-pass set-up and size fractions representing each chip class in the second study (South Georgia).

8-MM BAR SCREEN	OVERTHICKS	FIRST PASS
2" ROUND-HOLE	OVERSIZE	
1-1/2" ROUND-HOLE		
1-1/8" ROUND-HOLE		
7/8" ROUND-HOLE		SECOND PASS
5/8" ROUND-HOLE	ACCEPTS	
3/8" ROUND-HOLE		
1/8" ROUND-HOLE		BOTH PASSES
PAN	FINES	

APPENDIX C

CHIP DISTRIBUTIONS FROM THE TRIM LENGTH STUDIES

Table C.1. Average percentage of the chip furnish retained on each screen from the two studies.

Central Georgia

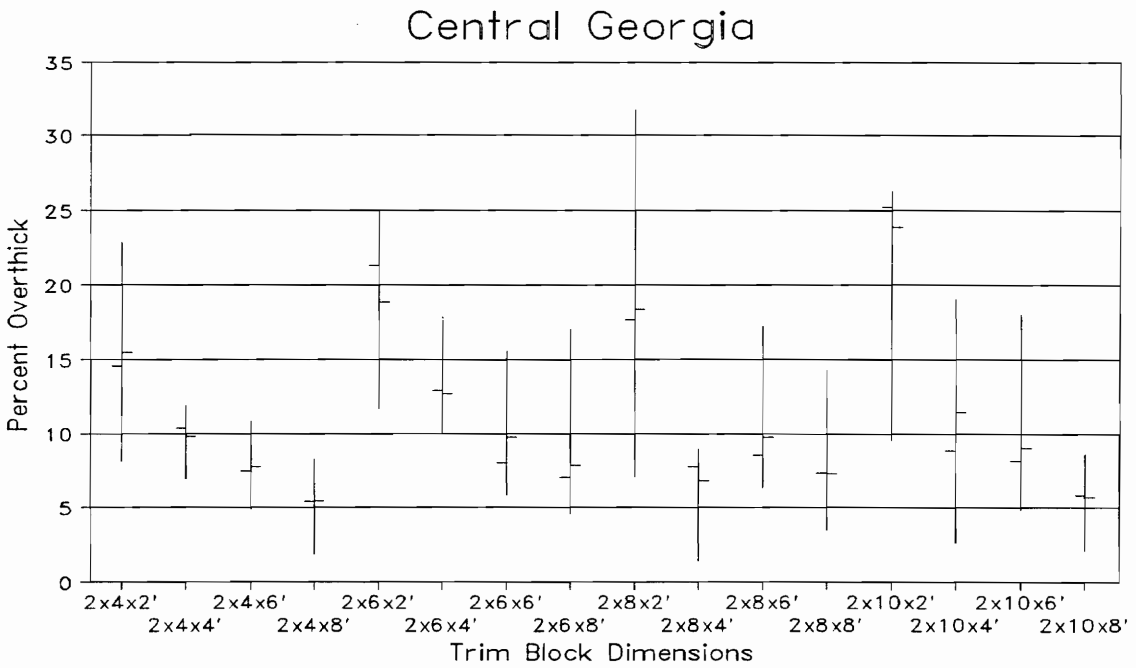
Trim Block	8-mm	2	1 1/2	1 1/8	7/8	5/8	3/8	1/8	pan
2x4x2′	15.46	2.85	3.09	11.32	16.47	23.55	20.03	6.56	0.67
2x4x4′	9.92	2.33	3.83	15.13	20.95	24.65	17.76	5.02	0.50
2x4x6′	7.74	1.59	4.01	16.36	20.63	25.87	18.85	4.54	0.42
2x4x8′	5.43	0.93	2.12	12.62	19.78	28.06	23.34	7.00	0.73
2x6x2′	18.88	3.83	6.15	16.43	16.73	19.99	13.20	4.33	0.46
2x6x4′	12.71	3.34	4.90	16.40	19.30	22.19	16.14	4.64	0.38
2x6x6′	9.75	1.16	4.20	22.85	22.01	22.72	13.89	3.18	0.26
2x6x8′	7.80	1.22	2.83	14.16	20.92	28.14	20.43	4.16	0.34
2x8x2′	18.36	3.97	5.10	15.98	17.27	20.90	14.67	3.49	0.25
2x8x4′	6.80	1.73	3.72	16.29	21.21	26.06	19.07	4.69	0.43
2x8x6′	9.74	2.02	4.22	17.55	20.17	23.99	17.93	4.00	0.38
2x8x8′	7.23	1.57	3.46	15.57	20.25	26.95	20.16	4.41	0.40
2x10x2′	23.90	4.18	5.12	15.99	15.91	18.34	12.81	3.39	0.35
2x10x4′	11.45	2.45	3.90	17.99	20.49	23.64	15.99	3.76	0.33
2x10x6′	9.06	1.81	4.47	18.36	20.06	24.28	17.60	3.97	0.38
2x10x8′	5.67	0.99	3.90	21.64	21.86	24.81	17.17	3.58	0.38

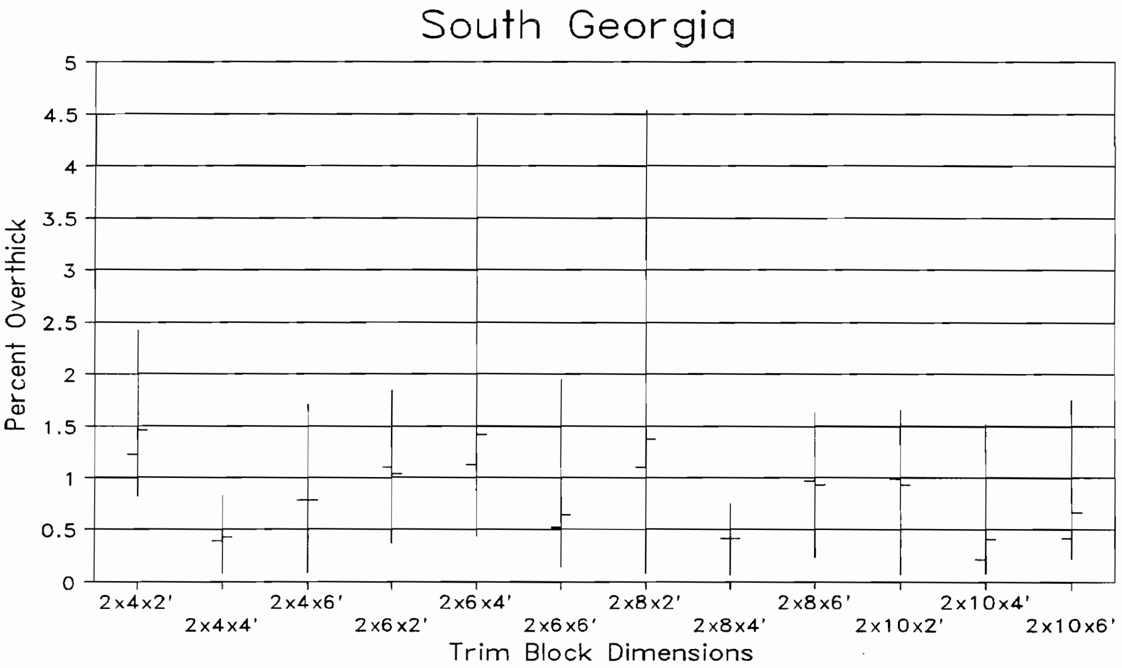
South Georgia

Trim Block	8-mm	2	1 1/2	1 1/8	7/8	5/8	3/8	1/8	pan
2x4x2′	1.46	0.20	0.42	2.78	5.80	21.95	42.90	22.67	1.81
2x4x4′	0.43	0.01	0.04	1.24	4.21	19.34	45.71	27.06	1.93
2x4x6′	0.78	0.09	0.10	1.86	5.25	25.13	43.74	16.31	1.34
2x6x2′	1.04	0.04	0.23	2.00	4.23	18.43	44.15	27.65	2.23
2x6x4′	1.42	0.02	0.46	2.68	5.74	21.56	43.72	22.70	1.70
2x6x6′	0.64	0.02	0.07	1.25	3.19	18.04	45.35	28.09	2.24
2x8x2′	2.01	0.71	0.91	3.79	6.93	23.76	38.99	21.11	1.78
2x8x4′	0.31	0.08	0.08	1.02	3.37	16.69	41.41	32.84	4.19
2x8x6′	0.94	0.14	0.14	1.91	4.74	21.06	42.87	26.13	2.07
2x10x2′	0.94	0.09	0.09	1.54	3.46	21.63	44.28	25.41	2.57
2x10x4′	0.41	0.14	0.37	0.89	3.07	21.44	44.95	26.54	2.20
2x10x6′	0.67	0.10	0.20	2.02	4.74	22.63	41.85	25.44	2.34

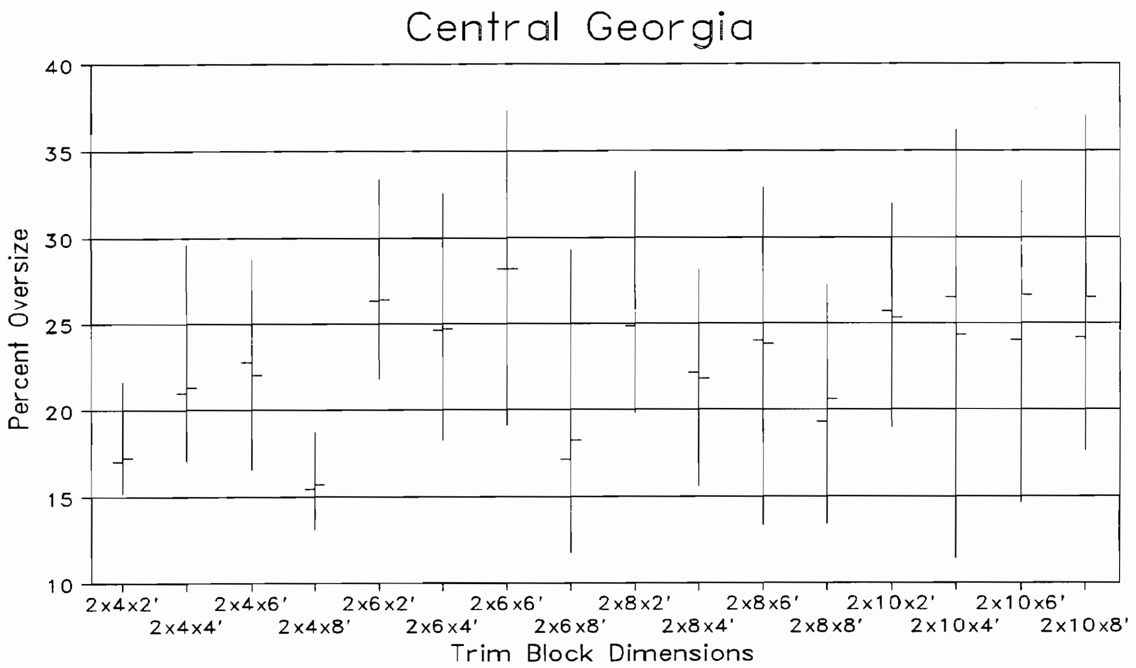
Figure C.2. Maximum, minimum, mean, and median percentages in each chip class from each dimension tested at Central and South Georgia. The left tick represents the median and the right tick the mean.

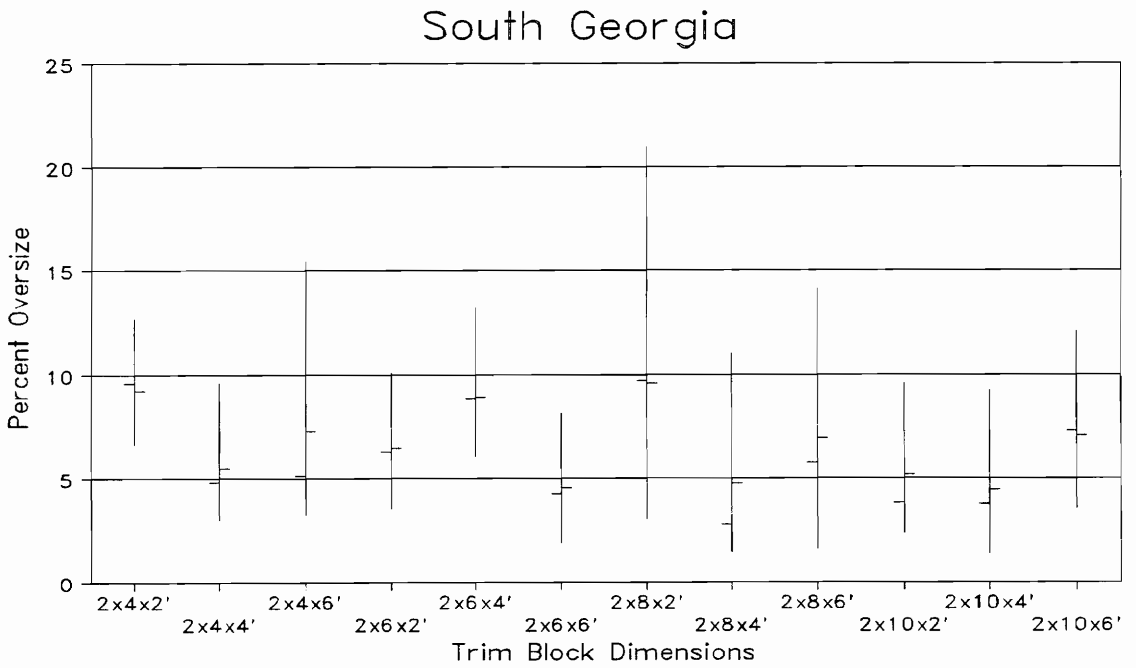
OVERTHICK CHIPS



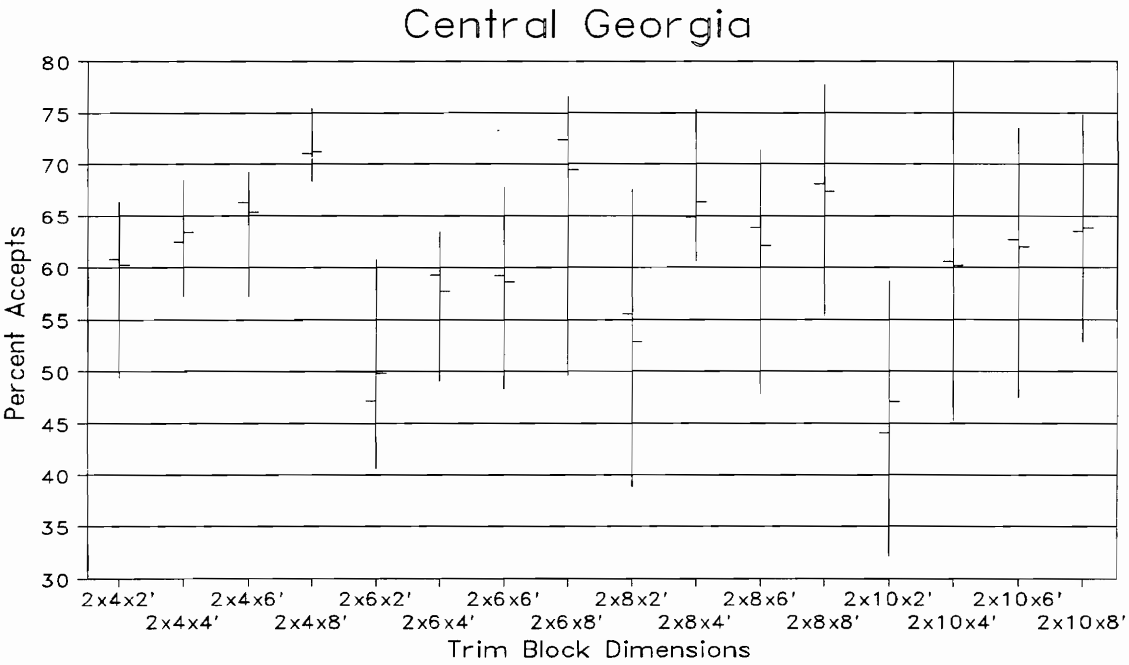


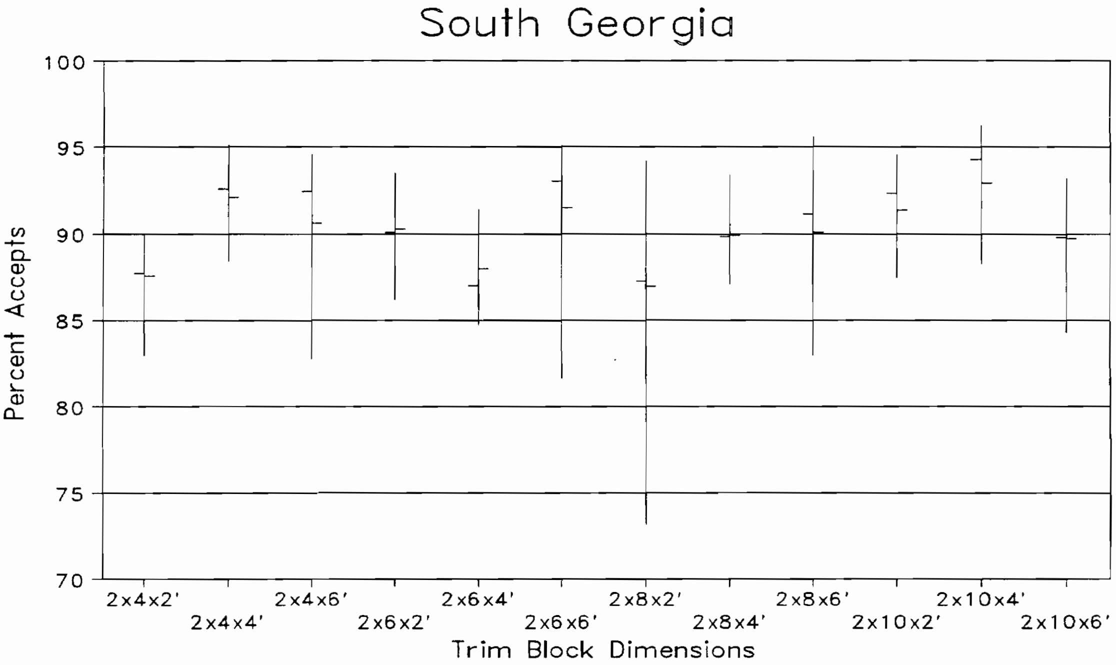
OVERSIZE CHIPS



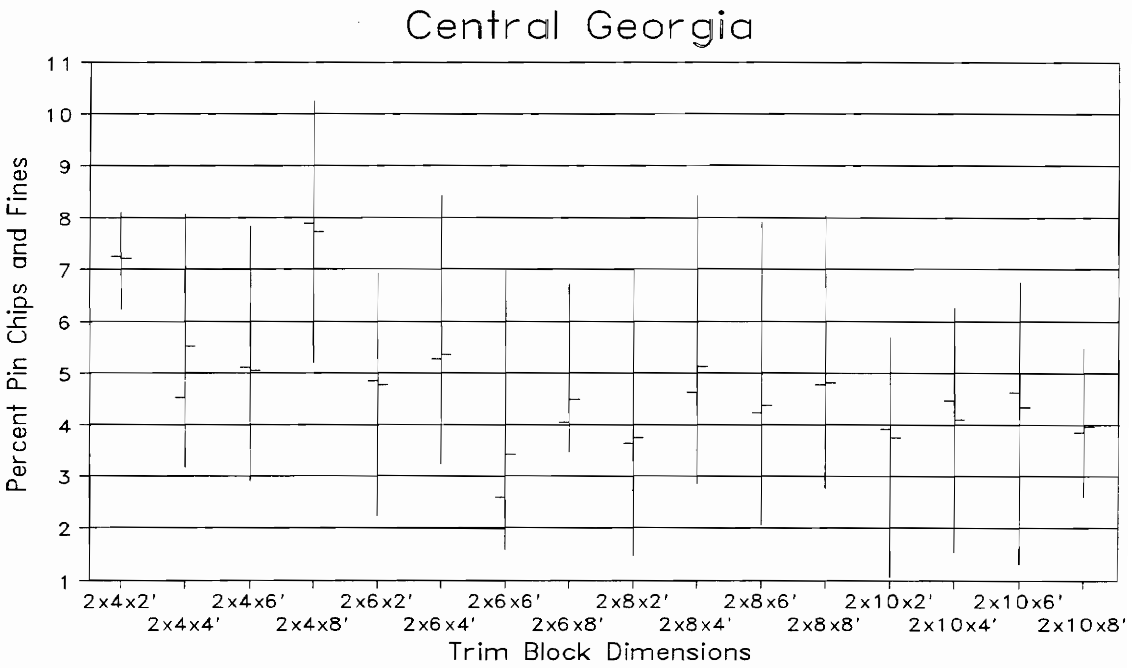


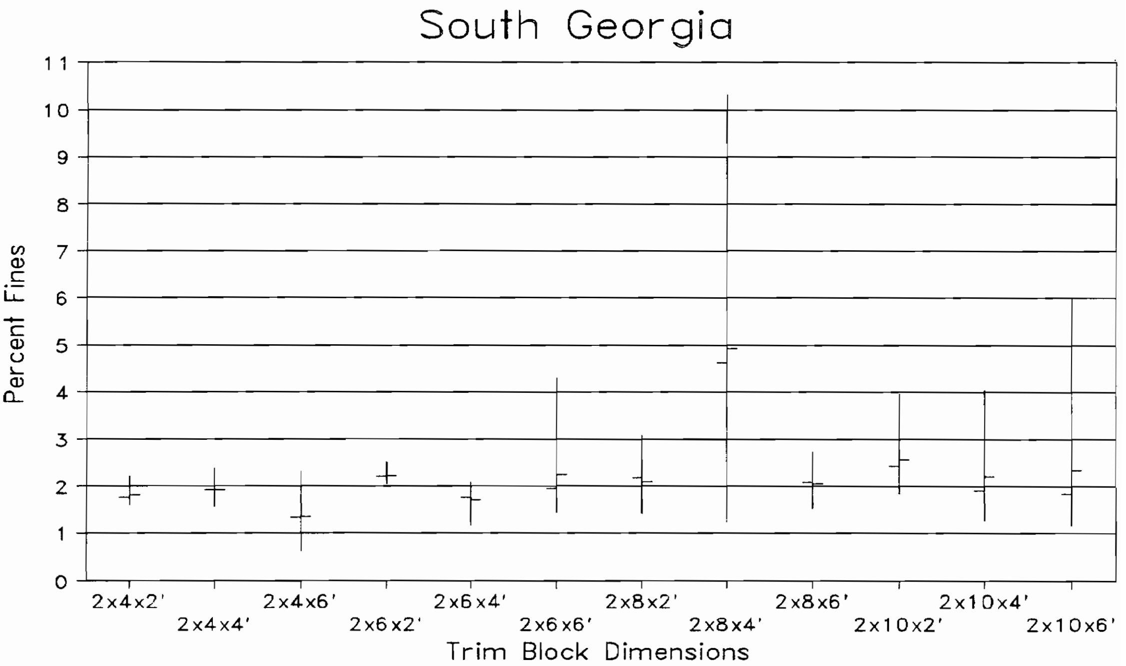
ACCEPTABLE CHIPS





UNDERSIZE CHIPS





APPENDIX D

Two-sample t-test results for differences in overthick and pulpable chip production between the trim block length/width ratios tested in Central Georgia.

Table D.1. Differences in overthick chip production between trim block length/width ratios.

	2.4	3	4	4.8	6	7.2	8	9	9.6	12	16	18	24
2.4	-	*	*	***	***	****	***	****	****	****	****	****	****
3		-		**	**	***	**	***	****	***	***	***	****
4			-	***	***	****	***	****	****	****	****	****	****
4.8				-					**		*	*	**
6					-				****	*	**	**	****
7.2						-			**				**
8							-	**	****	****	***	****	****
9								-	***			*	***
9.6									-				
12										-		*	****
16											-		*
18												-	***
24													-

p-values

*	<=	0.1
**	<=	0.05
***	<=	0.01
****	<=	0.001

Table D.2. Differences in pulpable chip production between trim block length/width ratios.

	2.4	3	4	4.8	6	7.2	8	9	9.6	12	16	18	24
2.4	-	*		***	***	****	***	****	****	****	****	****	****
3		-		**	*	***	*	***	****	***	***	***	***
4			-	***	***	****	***	****	****	****	****	****	****
4.8				-					***		*	*	
6					-	**		**	****	**	***	***	***
7.2						-			***				
8							-	***	****	****	****	****	****
9								-	***				
9.6									-				
12										-			
16											-		
18												-	
24													-

p-values

*	<=	0.1
**	<=	0.05
***	<=	0.01
****	<=	0.001

APPENDIX E

Two-sample t-test results for differences in overthick and pulpable chip production between the trim block piece weights tested in Central Georgia.

Table E.1. Differences in overthick chip production between trim block piece weights.

	6.7	10	13.3	16.7	20	26.7	30	33.3	40	50	53.3	66.7
6.7	-				***	****	***	*	****	***	****	****
10		-	**		****	****	****	***	****	****	****	****
13.3			-		**	****	**		***	**	***	****
16.7				-	****	****	****	***	****	****	****	****
20					-	****					**	****
26.7						-					*	***
30							-				*	***
33.3								-			*	**
40									-			***
50										-		**
53.3											-	
66.7												-

p-values

*	<=	0.1
**	<=	0.05
***	<=	0.01
****	<=	0.001

Table E.2. Differences in pulpable chip production between trim block piece weights.

	6.7	10	13.3	16.7	20	26.7	30	33.3	40	50	53.3	66.7
6.7	-		**		****	****	****	***	****	****	****	****
10		-	**		****	****	****	***	****	****	****	****
13.3			-		**	****	***	*	***	***	****	****
16.7				-	****	****	****	***	****	****	****	****
20					-	***	*		**	*	**	****
26.7						-						***
30							-					***
33.3								-			*	***
40									-			***
50										-		***
53.3											-	**
66.7												-

p-values

*	<=	0.1
**	<=	0.05
***	<=	0.01
****	<=	0.001

VITA

The author, son of Larry D. and Patricia Wallace, was born in 1969 in Richmond, Virginia. After graduating from Midlothian High School in 1987, he enrolled at Virginia Tech where he completed his B.S. degree in Forestry in 1991. He then continued his education at Virginia Tech, pursuing a Master of Science degree in Forestry, completing it in May, 1993.

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