Factors affecting sawmill residue chip quality

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A study was conducted to determine the effects of residue type, chipper speed, knife angle, and wood temperature on sawmill residue chip quality. Reducing chipper speed resulted in a major reduction in pin chips and fines.

Approximately 45% of the weight of a log entering a southern pine sawmill leaves as lumber, 35% leaves as chips, 15% leaves as bark, and 5% leaves as sawdust. Sawmill residue chips account for an increasingly large share of the furnish to the southern U.S. pulp industry; over 73 million tons are consumed each year.

Most of the research done on chipper design characteristics and their effects on chip quality has been done on pulpmill woodroom or whole-tree chippers, which deal with a much different furnish than the residue chipper in a sawmill. There is little published research on sawmill residue chippers. Concern over chip quality, especially thickness and pins and fines content, has stimulated an interest in research dealing solely with residue chips. The purpose of our research is to determine if the principles governing roundwood chipping apply to sawmill residue chipping as well.

Residue chippers in sawmills are typically medium-size (101–152 cm) disc chippers with 3–6 knives. The speed at which a disc rotates can have a pronounced effect on the particle size distribution of the chips it produces. Hartler (*1*) and Robinson (*2*) found that the percentage of undersized fractions (pins and fines) increases with increasing disc speed. Hartler (*1*) also found that if the speed is set too low, the wood only cracks and does not fully split up into distinct pieces.

Just as disc speed plays an important role in chip quality, so do knife angles. Crowley and Wardwell (*3*) of Carthage Machine explored the effects of knife angle on chipping. An angle which is too large creates too much pull-in force on the wood. Consequently, the wood is forced against the face of the chipper, which creates extra wear on the disc wear plates, produces longer chips, bruises and compresses the fibers, and tips the log up, causing the knives to cut progressively shorter chips as they proceed into the log. An angle which is too small does not create enough pull-in, thus producing shorter chips. Also, short pieces (trim blocks) may fly back up the chute. In 1963, Buchanan and Duchnicki (*4*) did some work with an experimental laboratory-scale chipper using angles of 20°, 30°, 40°, and 50° (a wider range than that used in most chippers). They found that chip thickness increased with increasing knife angle and moisture content of the wood.

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Robinson (*5*) looked at the importance of anvil and spout wear. Usually, the log projects in front of the anvil a distance of 0.5–1.00 mm. As the spout and anvil wear, the log tips up when the knife contacts it, thus producing a longer chip. The log may tip back and forth, creating variable-length chips.

In cold weather, chips break up more finely. In a study reported by Robinson (*2*), the percentage of fines produced as a result of temperature ranged in a curvilinear relationship from 27% at -22°C to 15% at 10°C. However, this study did not address the effects on the other size classes of chips.

Methods and procedures

A series of test trials is being conducted by the Industrial Forestry Operations Cooperative at Virginia Tech to explore alternative strategies for reducing the percentage of chips over 8 mm thick and the percentage of pin chips and fines in sawmill residue furnish. Four variables of interest were included in the first trials: anvil condition, knife angle, chipper disc speed, and wood temperature.

The trials were conducted at Chesapeake Corp.'s West Point, VA, sawmill in mid-July 1990. The mill is equipped with a 152-cm, six-knife Fulghum chipper turning at 707 rpm. The chipper was restored to factory-fresh condition by the manufacturer immediately before the trials.

Four material types were included: cants (15-cm x 15-cm timbers), slabs, edgings, and trim blocks. The slabs, edgings, and trim blocks were produced from a 20-metric-ton load of freshly cut loblolly pine saw logs delivered to the mill the week preceding the trials. The timbers were purchased locally.

In all, 10 trials were run:

- Beginning control
- Ending control
- 30° knife angle
- 32° knife angle
- 33° knife angle
- Chilled material (+2°C)
- Frozen material (–4°C)
- 80% disc speed (566 rpm)
- 60% disc speed (424 rpm)
- Worn anvil.

The control trials were run with wood at ambient temperature, 31° knife angles, and a disc speed of 707 rpm or 3385 m/min. Each trial consisted of three replications each of the four

I. Percentage of overthick chips produced

Treatment	Material type, % of total sample weight Cants	Slabs	Edgings	Blocks
Control	1.31	6.31	5.20	26.39
Worn anvil	4.61*	10.63*	5.25	35.50*
Temperature				
Frozen	2.82*	5.57	4.47	27.78
Chilled	4.24*	6.68	8.13*	25.24
Speed				
565 rpm	3.64*	9.43*	5.76	45.00*
424 rpm	3.63*	6.95	8.16*	43.95*
Knife angle				
30°	4.96	5.39*	5.86	29.90
32°	8.41	4.65*	5.99	24.72
33°	4.86*	5.88	4.99	30.91*

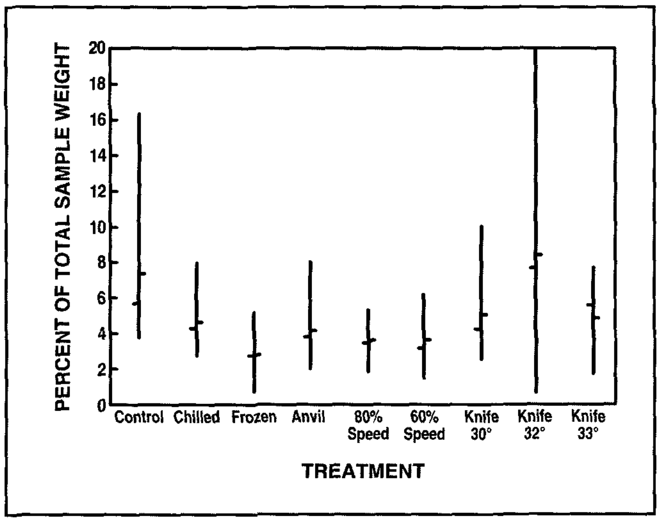
*Significantly different from the control at $\alpha = 0.05$

II. Percentage of pins and fines produced

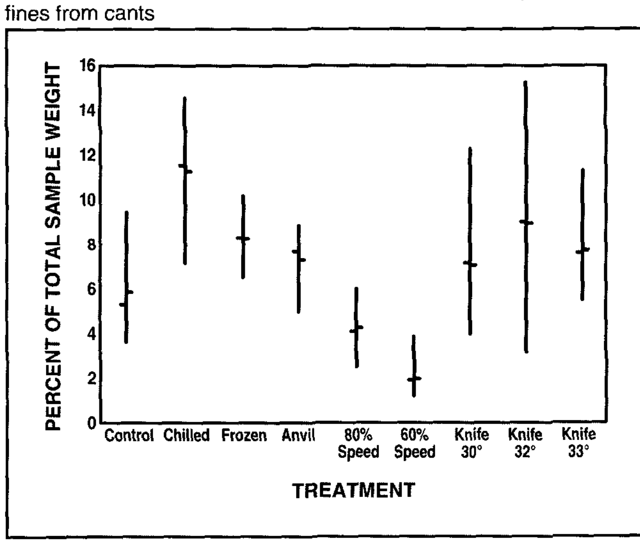
Treatment	Material type, % of total sample weight Cants	Slabs	Edgings	Blocks
Control	5.85	7.93	8.06	9.43
Worn anvil	7.24*	5.95*	9.01*	7.86*
Temperature				
Frozen	8.21*	10.74*	12.63*	13.00*
Chilled	11.26*	9.54*	10.25*	12.37*
Speed				
565 rpm	4.27*	5.54*	5.12*	4.21*
424 rpm	1.99*	2.50*	2.73*	3.17*
Knife angle				
30°	7.01	8.31	7.77	7.52*
32°	8.96*	8.72*	8.18	10.30*
33°	7.71*	8.36	10.65*	10.68*

*Significantly different from the control at $\alpha = 0.05$

1. Minimum, mean, median, and maximum values for overthick chips from cants



2. Minimum, mean, median, and maximum values for pin chips and fines from cants



material types and of a mix of slabs, edgings, and trim blocks to approximate the normal material flow to a sawmill chipper. The disc speed, temperature, and control replications were randomized together. The replications of the worn anvil and knife angle trials had to be run as a series because of the time and expense associated with changing the chipper setup. Bundles weighing 100 kg of each material type were fed to the chipper. Five bucket samples, each weighing approximately 10 kg, were captured from the chip stream by alternating bucket sequence (the first bucket filled was rejected, the second kept as a sample, the third rejected, etc.). In all, roughly half the weight of the input material was retained as samples.

The samples were returned to the laboratory and evaluated using a Williams classifier. A bar screen was used to separate out the over-8-mm material, followed by 5.08-mm, 3.81-mm, 2.86-mm, 2.22-mm, 1.59-mm, 0.95-mm, and 0.32-mm round-hole screens.

For the purposes of this analysis, the fraction retained on the 8-mm screen are designated as overthick. Those retained on the 2.86-mm round-hole screen and larger but less than 8 mm thick, are designated as oversize. Those retained on the 0.95-mm, 1.59-mm, and 2.22-mm screens are designated as acceptable chips. Those passing and retained on the 0.32-mm screen are considered pin chips and fines. The oversize and acceptable chips are pulped at most mills.

Results and discussion

The effects of changes in material type and experimental treatments were analyzed for each chip classification from dust to overthick. Only the changes in overthick and pins and fines will be discussed in this paper.

Significant differences were found between the chips produced from cants, slabs, and edgings and those from trim blocks. Chipping cants, slabs, and edgings resulted in overthick chip percentages ranging from 3% to 10% across all treatments. The blocks produced a chip stream which ranged between 25% and 45% overthick chips (**Table I**). The trim blocks were significantly different from the other material types at the 1% level.

The percent pins and fines tended to be more uniform across all four material types (**Table II**), with the values from trim blocks only slightly larger than those for the cants, slabs, and edgings.

The response of material types to treatments varied widely. Reinstalling the worn anvil in the chipper, for example, resulted in a decrease in overthick chips from cants, an increase in overthick chips from slabs, no change in those from edgings, and an increase in overthick chips from blocks (Table I). This pattern of random effects was common for the overthick chips, providing few insights for improving chip quality.

The response of pins and fines to the treatments was more patterned. Chilling and freezing the wood resulted in an increase in the pins and fines component for all material types that was significant at the 5% level or higher. Slowing the chipper disc speed to 80% and then 60% of the manufacturer's recommendation decreased pins and fines production for all material types. The response to the knife and anvil changes was variable both in direction and by material type.

Variation between samples

A surprising variation between samples was found for all material types and treatments. The range of the percentage of chips over 8 mm thick from cants for the nine treatments is shown in **Fig. 1**, and the range for pin chips and fines is shown in **Fig. 2**. These ranges are based on 13 samples. Five samples were collected for each of three replications of the experiment; the highest and the lowest sample were discarded before proceeding with the analysis. The tick mark to the right of the line indicates the sample mean, and the one to the left the sample median. The ranges for slabs and edgings were similar for both overthick (from 0% to 20%) and for pins and fines (from 0% to 16%). The range for overthick chips from blocks was three times that for the other material types (from 14% to 56%) and roughly the same for pins and fines. This amount of variability calls into question the validity of one or two grab samples as a means of documenting changes in chip quality.

Effects of temperature

Reducing wood temperature resulted in a significant increase in pins and fines (Table II). There was some evidence that the overthick percentage may decrease as well, but the results from this study were inconclusive.

Physiological changes in the wood during the dormant season was one hypothesis put forward to explain the increase in pins and fines during the winter months. All of the material used in this study was from trees harvested in June and July, during the active growth stage. The significant increase in pins and fines shown here tends to indicate that other factors are at work.

A second hypothesis was that the increase in the smaller chip fractions was due to the presence of frozen water crystals in the wood. This study indicates that freezing is not a necessary condition. The increase from ambient to chilled in **Fig. 3** accounts for roughly half of the total increase in pins and fines as the wood is cooled from ambient to frozen condition. The break in pattern for the cants is probably related to the characteristics of one of the three cants used in the chilled trials. The general trend for the cants, from ambient to frozen, parallels that of the other material types.

Effects of chipper disc speed

A 40% reduction in speed, from 707 rpm to 424 rpm, reduced the pins and fines by two-thirds for all material types. The decrease was linear for three of the four material types across the range of speeds tested (**Fig. 4**).

This reduction was achieved with a mixed response in overthick chips. The variability in both the direction and magnitude of the changes indicates that additional research is warranted. The large increase in overthick chips from blocks is possibly due to the ability of the block to turn into the knife pocket as the disc revolves more slowly (**Fig. 5**).

Effects of knife angle

No strong, consistent relationships could be found between knife angle and the production of overthick chips (Fig. 5). There appears to be a trend of increasing pins and fines production with increasing knife angle (Fig. 5), but the test results were inconclusive and sometimes contradictory.

The range of angles tested (from 30° to 33°) was quite narrow. The variability inherent to the residue material may have overwhelmed subtle differences and trends. A great range of angles and larger experimental units will be required to support or refute the presence of trends.

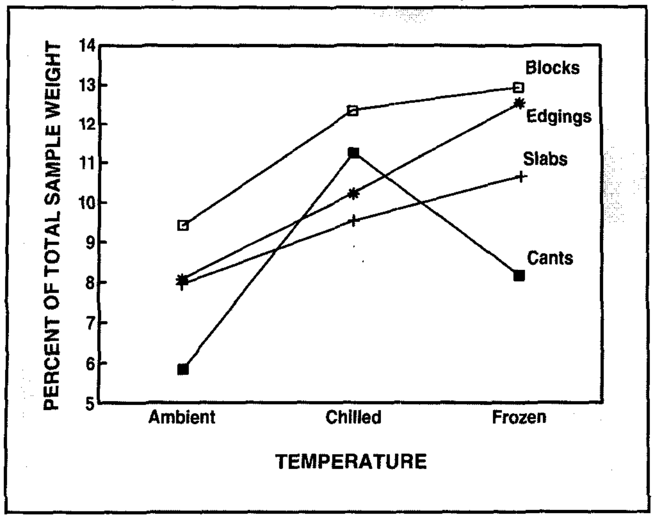
Summary

Overthick chips

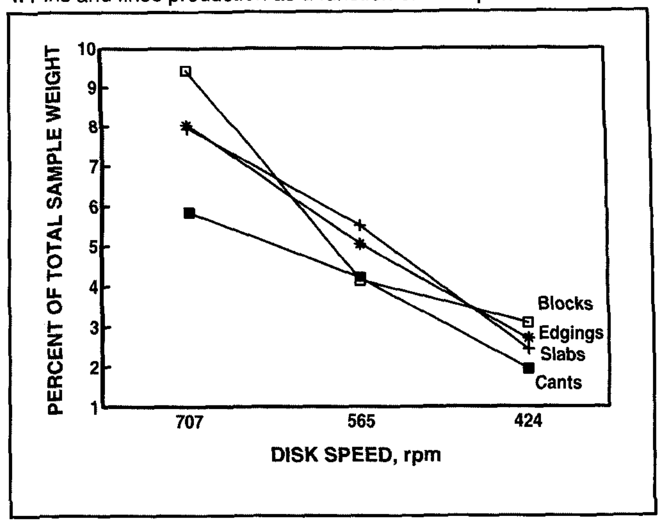
A major share of overthick chips originated from the trim block material. Short pieces get turned sideways in the chipper spout, and the knife splits pieces off along the grain, producing a shingle or "shake" that has poor pulping characteristics and is difficult to upgrade into a quality chip.

Installing a "shorts" trap in the chipper infeed to separate material less than one foot long for processing either in a specialized chipper or routing directly to fuel would seem a reasonable solution. Alternatively, there are several changes in the designs of the chipper infeed and throat which could keep these short pieces aligned and positioned such that a larger percentage of quality chips can be recovered (*6*).

3. Pins and fines production as a function of temperature



4. Pins and fines production as a function of disc speed



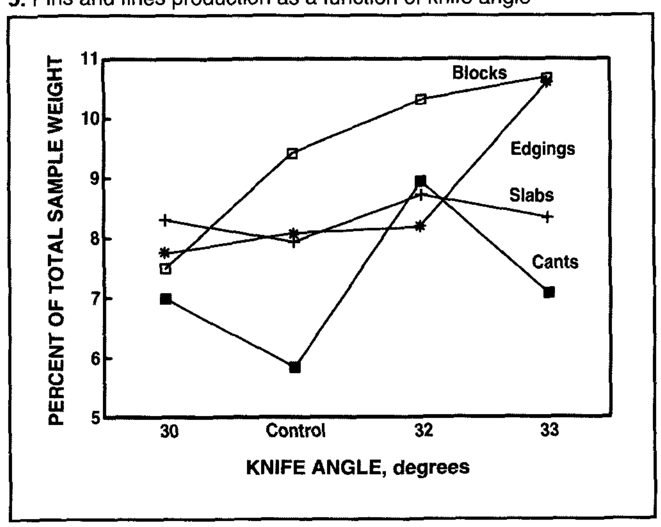
Wood temperature

The percentage of pins and fines increases dramatically as the wood is chilled and frozen, a change which is apparently linked more closely with temperature than with changes in wood physiology. Each mill will have to evaluate whether or not the change is great enough to justify the installation of a means of warming the wood on its way to the chipper.

Chipper speed

Reducing the disc speed of the chipper significantly decreased the percentage of pins and fines produced. No attempt was made to determine the effect that the decrease in speed would have on chipper throughput or on power requirements. One of the participants in this study has slowed their chipper with no adverse effects on production or power costs.

5. Pins and fines production as a function of knife angle



Conclusion

Slabs, edgings, and trim blocks are very different from the roundwood stick most chippers were designed to handle. The mix and dimension of material types arriving at a residue chipper are likely different for each mill and vary over the course of the year within mills. Traditional chipper maintenance solutions for improving chip quality are limited in the gains possible. Additional experimentation measuring the response of chip quality to fundamental changes in both material type and machine operating parameters is needed to move beyond the current limits.

A second set of trials replicating the chilled and frozen tests, the worn anvil trial, and speed ranges of 100%, 90%, 80%, 70%, 60%, and 50% of the manufacturer's recommendations was conducted during the spring of 1991 on three material types—cants, edgings, and trim blocks. The results of these tests will be available this year. □

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