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An Investigation into Chipped Surface Quality Problems at Canter Lines

by

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Project Leader

Reviewed by

Department Manager

Notice

Abstract

The purpose of this study is to investigate and record the principal problems associated with chipped surface quality at canter lines and evaluate degrade and value losses due to these problems.

Mill measurements were conducted in five member sawmills in British Columbia to evaluate the value losses and lumber degrades due to chipped surface defects. The test lumber was sampled from the planing mills to identify the chipping losses and main problems. The five types of chipped surface defects influencing lumber grade are: knot tear-out; failure to remove chipped spline channel; torn grain without knots; scalloping; and chipped thin end.

Average value losses for all mills were $11.4/MBF and $12.6/MBF in freezing and non-freezing conditions respectively. Removing the non-freezing data from one mill changed this to $11.4/MBF and $9.0/MBF respectively. Knot tear out caused 60% of lumber to be degraded. On average, over 55% of knots had tear-out. 42.3% of trim length was caused by failure to remove chipped spline channel.

Acknowledgements

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1 Objectives

The objectives of this study are:

- To study and record the principal problems associated with chipped surface quality at canter lines
- To identify degrade and value losses due to chipping problems

2 Introduction

Canter lines are used extensively to produce lumber and wood chips in North American sawmills (Figure 1). Presently, a significant amount of lumber degrade occurs because of the poor chipped surface quality produced by canter lines. Several western member mills have mentioned that the fibre tear-out produced by their 4 side canters with drum chipping heads has caused lumber degrade for their export markets. Figure 2 shows knot tear-out on the planed surface. Some member mills have said that severe scallops caused by drum chipping heads can not be planed off on thinner lumber so that a portion of the chipped lumber degrades. It was also observed that chipped spline channel often appeared on the board surface and chipped lumber was sometimes thinner at the ends.

The higher value of solid wood products compared to chips has increased awareness of the need to produce high-grade lumber. Sawmills are concerned about enhancing chipping quality and recovery in canter lines by improving chipped surface quality. However, the scale of the problems and the effect on planed products is unclear. The problems associated with chipped surface quality need to be clearly defined so that proposals can be put forward to improve the chipped lumber quality. The sawmill measurements described in this report were carried out to study and record the principal chipping problems at canter lines and quantify degrade and volume losses due to these problems.

Related wood processing literature was reviewed. Earlier studies [1, 2] mention that at rake angles of 30 and 40 degrees, the main surface defect was torn grain for green and dry stock. A rake angle of 40 degrees combined with clearance angles of 20 and 30 degrees caused a considerable amount of chip marking. Koch [3] presents wood machining fundamentals that include chip formation and cut surface profiles as well as the theoretical scallop depth. Chipping headrigs are described in several studies [4, 5, 6]. Three cutting models of chipping headrigs were constructed to study chip types and cut surfaces for some commercial machines. This literature indicates that in some designs of machines, severe tear-out around knots caused poor surface quality which normal planing could not remedy. Also, end-milling and planing cutterheads with large bite per tooth tended to tear out grain around knots and splinter board edges. Article [7] shows that better surface quality could be produced with optimum angle combinations between the grain and tool movement, regardless of whether the machining was with or against the grain. A study conducted in Finland shows that average knot tear-out depth varied from 2.0 to 2.7 mm [8]. Results [9] show that cutting knives which have small microbevel width combined with large microbevel angle reduce torn grain depth. An increase in the rake angle from 50 degrees to 60 degrees reduced torn grain depth independently of microbevel. A practical investigation was conducted on canter line bottom boards [10]. A significant percentage of knots had tear-out. The knife marks were from the spline remover. The author also stated that cutting thinner chips would cause less tear-out. Reducing tear-out by reducing the rake angle would increase the cutting force which would result in surges or loss of control of the logs.

In this study, five sawmills in the interior of British Columbia were selected to conduct the tests in freezing and non-freezing conditions because, based on the preliminary mill visits, typical chipping problems existed in those mills. Two or three samples (40-90 boards) were randomly selected from the rough dry lumber packs to evaluate the severity of the chipping degrade and trim losses.

Lumber degrade and value losses due to chipped surface defects were found to be significant for the majority of the test mills. Knot tear-out and chipped spline channel were found to be the most severe defects which caused lumber degrade and trim losses.

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4 Materials and Methods

4.1 Canter Lines

Two to three canters were used in each of the five sawmills. A four-side canter with drum chipping heads plus a spline remover was installed in the majority of those mills (Figure 1). The bottom head of the machine cuts the bottom side of a log and leaves splines to guide the log movement. Top and side chipping heads cut the other three sides according to the required product breakdown pattern, followed by the spline remover that removes the splines on the bottom side. Finally, the close-coupled circular saws, which are mounted on two vertical arbors, cut the cant into boards. These circular saws closely follow the spline remover at one type of canter line and are at longer distance (over the length of one cant) from the canter at the other type of canter line. Table 1 in Appendix B lists some facts about one four-side canter for each of the five test sawmills.

There is another type of canter line with two sets of two sided drum chipping heads. At the first set, logs are chipped by two side heads, which are closely followed by two close-coupled circular saws to remove side boards. At the second set, the side chipping heads cuts the other two sides. Then, a group of circular saws, which are mounted on two horizontal arbors, cut the cant into boards.

Two of the test sawmills used canters with conical chipping heads to cut four sides of logs. Then, the close-coupled circular saws mounted on two horizontal arbors cut the cant into boards.

One mill used canters with drum heads to cut the top and bottom surfaces and conical side heads to cut the two side surfaces. A group of close-coupled circular saws mounted on two vertical arbors cut the cant into boards.

4.2 Work Methodology

From visits to 14 mills in the interior of British Columbia, five mills (Mills A-E) were selected to do mill measurements. These measurements were taken in non-freezing (November 2000) and freezing (February 2001) conditions in order to identify the severity of chipping losses and principal problems associated with chipped surface quality. Due to problems with the first unfrozen test results, the losses for Mill C were evaluated in June 2001 with a sample of finished lumber. An additional mill, Mill F was used to conduct a preliminary simplified study in order to verify work methodology, to estimate how much the mill measurement work would be for one test mill, and to get familiar with mill measurements. The planned test procedures were as follows.

Before Planing
After drying (Mill D produced green products and did not dry lumber), 15 to 30 boards for each sample were randomly selected from a bundle of lumber (with dimensions 2"x4", 2"x6" and 2"x8"). Two to three samples were collected for each test mill (this depended on the availability in dimensions). The purpose for this was to prepare the representative test lumber for each mill. In order to track the test boards after planing, marks were put on the end surfaces of each board.

In order to evaluate how frequently knot tear-out was produced, the numbers of knots over 4mm in diameter, and those with tear-out, were counted on each chipped surface of the sampled boards. Surfaces with two knots or less were not used in the count. In order to evaluate the severity of knot tear-out, the depth, length and width of one to five of the deepest tear-outs (over 2.0mm) as well as the knot diameter, were measured. Later in the project, a scanner was made to scan surface defects in freezing conditions in order to obtain more accurate defect images. A computer program was developed to analyze these defect images. Figures 5 and 6 show the scanner and interface of the program respectively. The accurate measurement results of knot tear-out were correlated to manually measured volume in order to estimate more accurate tear-out volume.

Scallop geometry was measured with a "BoardRunner" (Figure 4) or the above scanner (Figure 5), in order to identify the severity of the scallop marks.

After Planing
For those sampled boards with chipped surfaces, graders evaluated the finished board grades and trim allowance, with and without taking into account chipped surface defects. There were five types of chipping defects: torn grain without knots; knot tear-out; scallops; failure to remove chipped spline channel; and chipped thin end. These measurement results would be used to estimate degrade and trim value losses due to chipped surface defects.

4.3 Data Processing

Degrade and trim value losses due to chipped surface defects were calculated based on the formulae shown in Appendix A.

Value per MBF of different products was obtained from Madison's [11], Export [12], Yearbook 2000 [13] as well as the lumber prices provided by the test mills. In order to calculate chip recovery, trim lumber was converted to chips by using the method in the literature [14] (calculations are shown in Appendix A).

The average degrade and trim value losses of the sampled lumber were calculated for each test mill using the measurement results after planing

Degrade percentage was calculated by dividing the number of degraded boards by that of the sampled boards to evaluate how frequently the lumber degraded. The average degrade percentage was calculated for each test mill and total test mills.

In order to ascertain the main trend in chipped surface defects, the percentage of degraded boards was calculated for each of five types of recorded chipping defects for the total test mills. The number of degraded boards and the length of trimmed lumber were counted first. A record had been kept of the reason for the degrade of each board. Each percentage was obtained by dividing the number of the degraded boards for each type of defect by the total number of the degraded boards. The percentages of trim were also calculated for these chipping defects for the total test mills. Each percentage was calculated by dividing the length of the trimmed ends for each type of defect by the total length of the trimmed ends.

The average percentages of knot tear-out were calculated for each test mill by dividing the number of knots with tear-out by the total number of knots.

Figure 10 was used to correlate the manually measured volume of tear-out (depth x length x width) with the actual scanned volume of tear-out (all the data in the test mills was used in the graph). The slope of the trend line was used to convert all the manually measured volume to actual volume in order to evaluate the severity of knot tear-out. The converted scanned knot tear-out volume was divided by knot diameter to normalize the effect of knot diameter on knot tear-out. The larger the quotient, the more severe the knot tear-out is.

Means and standard deviations of scallop depths and widths were calculated for each chipped surface, for each test mill, in order to identify typical scalloping dimensions.

5 Results and Discussions

The mill measurements were completed to:

1) Evaluate degrade and trim value losses due to chipped surface defects for each test mill
2) Identify the principal chipping problems which include
    a. knot tear-out
    b. chipped spline channel
    c. torn grain without knots
    d. scalloping
    e. chipped thin end

5.1 Lumber Degrade and Estimated Value Losses due to Chipped Surface

The sampled boards for the five test mills were graded after planing in order to evaluate general degrade and trim value losses, as well as degrade percentage of the sampled boards. The average results of each mill are presented in Figures 7 and 8. The combined results of all the mills are presented in Table 2.

The value losses presented below are a ‘snap-shot’ of five sawmill operations and are intended to be used as a guide to determine the magnitude of individual chipping problems.

Sampled Boards Measured in Planing Mills

As one would expect the value losses and degrade percentages tend to be higher in freezing conditions and this was the case for mills B, D and E. Conversely, Mill C had the highest value losses and degrade percentages of any mill, and these were in non-freezing conditions (Figures 7 and 8). This is most likely due to the sampled lumber coming from logs that had been decked for some months before processing (see comments under Section 4.2 - Work Methodology). Mill A also had a higher value loss in non-freezing conditions, possibly due to:

1. No value losses were taken into account for a 2”x 4” board degraded from the first grade to the second grade. This is because the mill could make a little more profit by selling the second grade lumber to market A than selling the first grade lumber to market B.

2. The value losses for 2”x 6” boards in non-freezing conditions were 101% higher than those in freezing conditions.

As previously mentioned in Section 4, the losses in non-freezing conditions for Mill C were conducted with very dry logs some months later than the other mills. If these somewhat excessive losses are excluded from the overall results, the average value losses and degrade percentages would change from 10% lower and 14% higher in freezing conditions to 27% higher and 90% higher in freezing conditions. The values, excluding the non-frozen results from Mill C, are shown in brackets in Table 2.

For a sawmill with 100 MMBF/year, a value loss of $ 5.0/MBF would cause $ 500,000/year loss. The majority of the results (Figure 7) had values over $ 5.0/MBF. Value losses tended to be higher in freezing conditions but are skewed by the results from Mill C where excessive value losses occurred in cutting dry logs. The majority of the test mills had significant degrade and trim value losses.

5.2 Principal Problems Associated with Chipped Surface

This section discusses the five types of chipping problems determined by the study. Table 3 lists the main defects that caused lumber degrade and trim. Knot tear-out caused the highest percentage of degraded lumber and the second highest percentage for trim. 57% of the boards degraded due to knot tear-out were degraded from J Grade lumber to a lower grade. Knot tear-out also caused the lumber of other markets (such as US markets) to degrade. Failure to remove chipped spline channel is the most severe problem in trim losses.

5.2.1 Knot Tear-out

Knot tear-out on chipped surfaces of the test boards was measured to evaluate how frequently it occurred and its severity. The results are presented in Figures 9 and 11.

Knot Tear-out Percentage

In all the test mills, over 55% of knots had tear-out on the chipped surfaces (Figures 9). The maximum percentage of tear-out was 73% for Mills C and E in non-freezing conditions. Mill C used a different knife type than the other mills. Mill E installed a new knife type on some machines prior to the data collected in freezing conditions. This was possibly the reason that the percentage of knot tear-out for this mill decreased from 73% in non-freezing conditions to 57% in freezing conditions.

The knot tear-out percentages tend to be higher in non-freezing condition. The possible explanations for this are that more care was taken to maintain knives in winter, the knife type was changed for some machines in Mill E and the winter was uncharacteristically mild in February 2001.

Knot Size and Knot Tear-out Size

In order to obtain an indication of the severity of knot tear-out, the volume of tear-out and the knot diameters were measured for Mills D and E in non-freezing conditions and all Mills in freezing conditions. Figure 12 shows the relationship between knot tear-out volume and knot diameter for one of the test canters (121 data points). The relationship is not strong (R^2 = 0.36) and it is possible that the various knot directions and grain complexities around knots greatly affect tear out volume. In general, the regression line represents the main trend. The larger the knot diameter, the greater the tear-out volume.

5.2.2 Failure to Remove Chipped Spline Channel

Failure to remove chipped spline channel caused the highest percentage for trimming. The defect often occurring at the front end of bottom boards. This caused significant trim losses, which were intensified in freezing conditions. One explanation is that the hold down roll above the spline remover allowed the cant to move. This problem tended to occur in freezing conditions, in two mills at the beginning of the workday. Remains of the chipped spline channel were also found at the back end of bottom boards in some mills.

5.2.3 Torn Grain without Knots

Conical chipping heads with facing knives often caused this problem. It was observed that torn grain tended to occur below the centre line of lumber. This is because the cutting direction below the centre line goes against the grain. Torn grain is not as severe as knot tear-out in affecting lumber grade.

Drum chipping heads caused less torn grain without knots. Although not severe, uneven scallop also tends to cause this problem. When one knife cuts a shallow scallop and the next knife cuts a deeper scallop, the second knife can easily tear grain.

5.2.4 Scalloping

Scallops were measured for the chipped surfaces to identify effect of scalloping on surface quality and to obtain some basic data on scallop dimensions. The results are presented in Table 4.

Mill A had the largest scallop depth of 0.035". The total average scallop depths were 0.018" and 0.022" in non-freezing and freezing conditions respectively. For Mills A, C and E, the scallop depth of bottom surfaces showed an increase of 45% or more in freezing conditions. For Mill B, the scallop depth of bottom surfaces had a decrease of 57% in freezing conditions. Mill D had no change for bottom scallop depth in freezing conditions. These indicate that the spline remover speeds were different in these test mills. Mills A, C and E used lower speeds for the bottom heads in freezing conditions. In most of the results, scallop depth and its standard deviation for the side surface tended to be larger than those of the top or bottom surface. Lower rotation speeds for side heads are the possible reason for causing larger scallop depth. Movement of logs and uneven knife extensions above anvil are possible reasons for higher standard deviations of the scallop depth on the side surfaces.

In general, scalloping was acceptable based on the planing allowances of the mills (which were from 0.040" to 0.050"). The main reason for scalloping causing degraded lumber was that part of the chipped boards was too thin to plane away the scallops.

5.2.5 Chipping Machinery

All above-mentioned problems are closely related to machines. Machine misalignment and log movement can cause severe chipped surface problems, such as failure to remove the chipped spline channel. It was found that the lead for conical chipping heads was 0.10" to 0.20" in one mill. This needs to be examined to see if larger lead causes logs to be unstable in cutting. As a general observation, it was noted that wear on counter-knives and gullets was severe in two mills. Knife extensions above anvil and wear on counter-knives and gullets need to be precisely measured to determine if these have a relationship with the five types of chipped surface defects.

6 Conclusions

1. The principal problems associated with chipped surfaces are knot tear-out, failure to remove chipped spline channel, torn grain without knots, chipped thin ends and scallops.

2. Chipped surface defects cause significant value losses due to degrade and trimming. Including all the mills in the study, the average value losses were $11.4/MBF and $12.6/MBF in freezing and non-freezing conditions respectively. If the very large losses from one mill (in non-freezing conditions) are excluded, the average losses become $11.4/MBF and $9.0/MBF in freezing and non-freezing conditions respectively.

3. Chipping defects in dry logs causes excessive value loss. In one mill processing dry logs, the percentage of degraded lumber was 27.15% leading to value losses of $27.67/MBF.

4. Chipped surface defects degrade a significant percentage of lumber. The average percentages of degraded lumber were 11.6% and 10.2% in freezing and non-freezing conditions respectively.

5. Knot tear-out was the most severe problem causing degraded lumber, with 55% to 73% of knots having tear out.

6. A weak relationship exists between knot diameter and tear-out volume.
7. Chipped spline channel caused the most severe trim losses. This caused up to 42.3% of total trim losses.

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Appendix I

Calculation of Degrade and Trim Value Losses

Calculations of Degrade and Trim Value Losses

$$SWE = \frac{A_1}{A_2} \times A_3$$

$$C = (1 - A_4) \times (\frac{A_5 \times V}{SWE}) \times (\frac{A_1}{A_6}) \times A_7$$

$$\text{Value Losses} = \frac{D + T + L - C}{M}$$

Where

A_1 = Bone Dry lbs per Bone Dry Unit (2400.00)

A_2 = basic density (lb/ft^3)

A_3 = factor for converting $1 ft^3$ to m^3

SWE = solid wood equivalent per Bone Dry Unit (m^3 / BDU)

Species	SWE
Douglas Fir	2.55
Lodgepole Pine	2.66
SPF	2.69
Cedar	3.32

A_4 = percentage of chipping losses for converting lumber to chips (0.05)

A_5 = factor for converting 1MBF to the volume in m^3 (2.36)

V = trim solid wood volume (MBF)

A_6 = Bone Dry lbs per Bone Dry Metric Tonne (2204.6)

A_7 = price per Bone Dry Metric Tonne ($)

C = value for chip recovery from trim wood volume ($)

D = value without chipping degrade - value with chipping degrade ($)

T = value of trimmed wood based on the grades of the boards ($)

L = value before trimming - value after trimming ($)

M = volume of sampled lumber (MBF)

Value Losses = degrade and trim value losses ($/MBF)

Appendix II

Tables

Table 1 Facts on one four-side canter in each of the test mills

Sawmills	A	B	C	D	E
Head Type	Drum	Drum	Drum	Drum	Drum
Knife Type	Key Knife	Key Knife	Profile Knife	• Key Knife for bottom head and spline remover • Turn knife for side and top heads	Key Knife
Number of knives per segment	3	3	3	• 3 for side and top heads • 3 for 2 segments & 4 for 3 segments for the other heads	2
Width of Knives	• 2" for bottom head & spline remover • 2.625" for side heads, • 2.125" for top head	• 2" for bottom head & spline remover, • 2.625" for side heads • 2.125" for top head	2"	2"	2"
Infeed speed	450 fpm	415 fpm	400 fpm	210-390 fpm	200-268 fpm
Rotation speed	• 1535 rpm for bottom and top heads • 1200 rpm for side heads • 1350 rpm for spline remover	• 1600 rpm, 1260 rpm and 1200 rpm for bottom, side and top heads • 2200 rpm for spline remover	• 1477 rpm for bottom head • 1395 rpm for the other heads	• 1487 rpm for top head, • 1584 rpm for side heads • 1775 rpm for bottom head, • 1512 rpm for spline remover	1015 rpm for all the heads
Clean-up sawing for top boards	Yes	Yes	No	Yes	No
Species	SPF and Fir/L	SPF and Fir/L	Lodgepole Pine	Douglas Fir	SPF
Average log top diameter	5.6"	5.3"	5.6"	7"	8"
Average log length	15.3 ft	15.9 ft	15.1 ft	15 ft	13.75 ft
Piece count/shift	6250	6000	6644	4500	3000
Knife change-over rate	8 hrs	8 hrs	4-8 hrs	4 hrs turn over for Turn Knife 4 hrs for Key Knife	9 hrs

Table 2 Value Losses and Degrade Percentages for Total Sampled Lumber

	Value losses before freezing, $/MBF	Value losses after freezing, $/MBF	Degrade percentage before freezing, %	Degrade percentage after freezing, %
Average	12.6 (9.0)	11.4	10.2 (6.1)	11.6
Maximum	27.2	17.9	26.7	16.7
Minimum	5.2	6.2	1.9	8.8

Note: The values in brackets are the average losses when the results from Mill C in non-frozen conditions (see Figures 7 and 8) are excluded.

Table 3 Percentages of Degraded Boards and Trim due to Various Chipping Defects

	Percentage of degraded boards, %	Percentage of trim, %
Torn grain without knots	16.4	7.8
Knot tear-out	63.3	29.1
Scallops	10.2	9.7
Failure to remove chipped spline channel	7.0	37.4
Chipped thin end	3.1	16.1

Table 4 Summary of average scallop depth and length for each mill

		Before freezing				After freezing			
		Average Depth, in.	Standard deviation of depth, in.	Average length, in.	Standard deviation of length, in.	Average Depth, in.	Standard deviation of depth, in.	Average length, in.	Standard deviation of length, in.
Total average		0.018	0.006	1.084	0.204	0.022	0.007	1.067	0.350
Mills	Surface								
A	Side surface	0.035	0.010	1.474	0.189	0.035	0.008	1.406	0.131
A	Bottom surface	0.020	0.005	0.979	0.086	0.029	0.008	1.127	0.167
B	Side surface	0.025	0.006	1.298	0.177	0.026	0.006	1.381	0.344
B	Bottom surface	0.026	0.005	1.365	0.202	0.011	0.007	0.791	0.302
B	Top surface	0.007	0.001	0.665	0.070	N/A	N/A	N/A	N/A
C	Side surface	0.016	0.007	1.019	0.245	0.030	0.011	1.115	0.179
C	Bottom surface	0.019	0.007	0.980	0.153	0.029	0.007	0.953	0.112
C	Top surface	0.016	0.005	0.988	0.138	0.023	0.006	0.965	0.136
D	Side surface	0.015	0.008	1.064	0.388	0.021	0.009	1.093	0.353
D	Bottom surface	0.010	0.005	0.877	0.171	0.010	0.004	0.734	0.202
D	Top surface	0.016	0.007	1.345	0.277	0.006	0.003	1.158	1.733
E	Side surface	0.013	0.004	1.015	0.224	N/A	N/A	N/A	N/A
E	Bottom surface	0.016	0.010	1.022	0.334	0.025	0.007	1.013	0.194

Appendix III

Figures

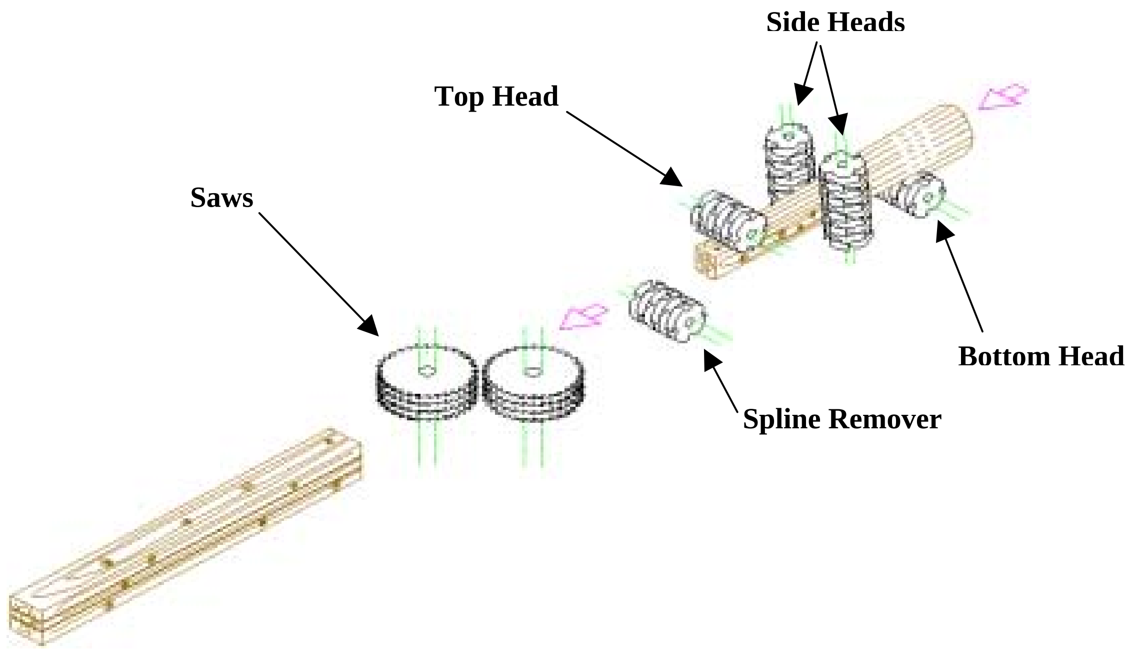

Figure 1   Schematic of Chipping Canter Line

Figure 2   Knot tear out

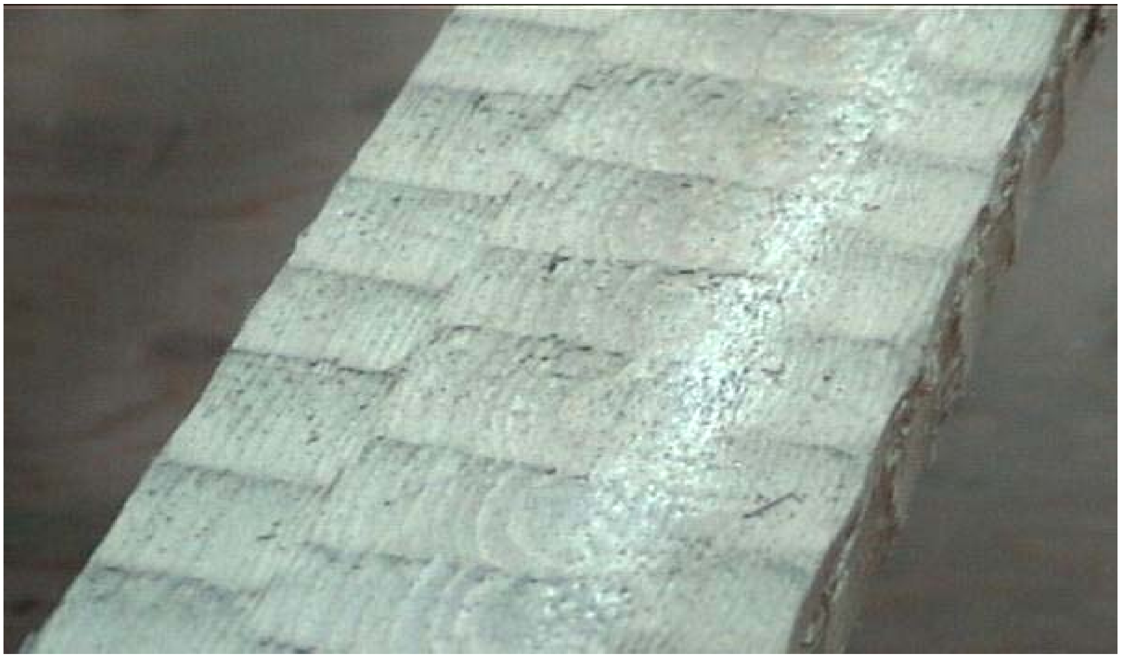

Figure 3 Typical chipped surface

Figure 4 Board measurement device - BoardRunner

Figure 5 Scanner for measuring knot tear-out volume

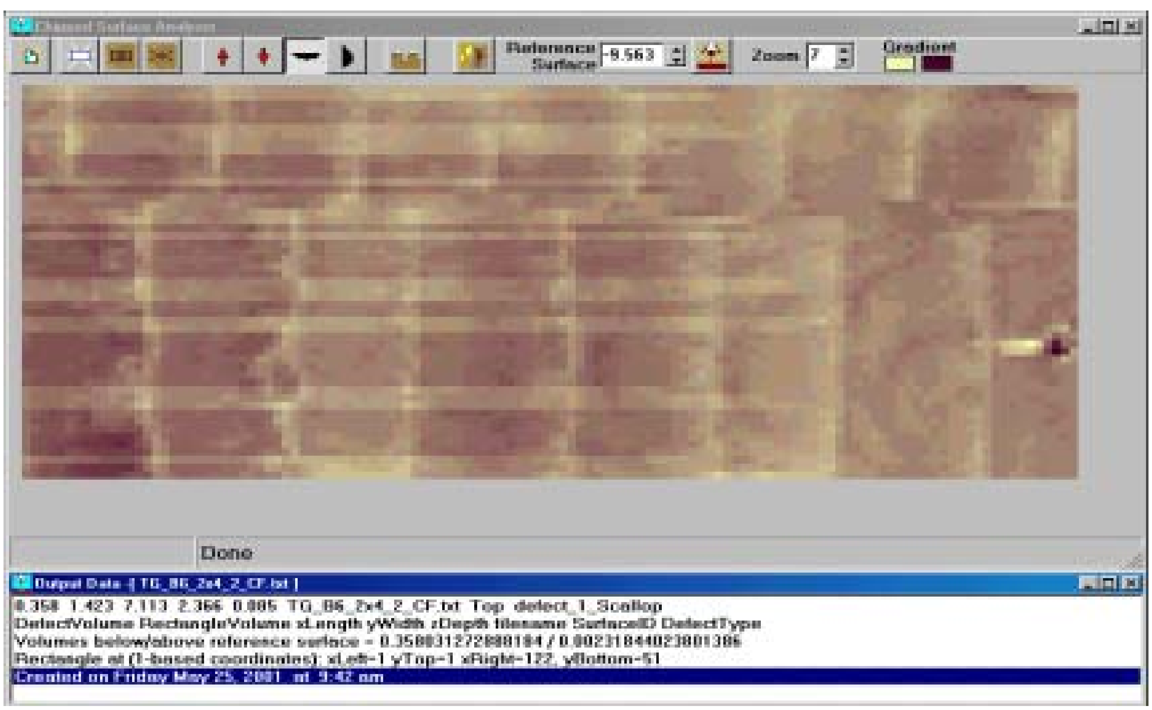

Figure 6 Scanner image showing scalloped surface

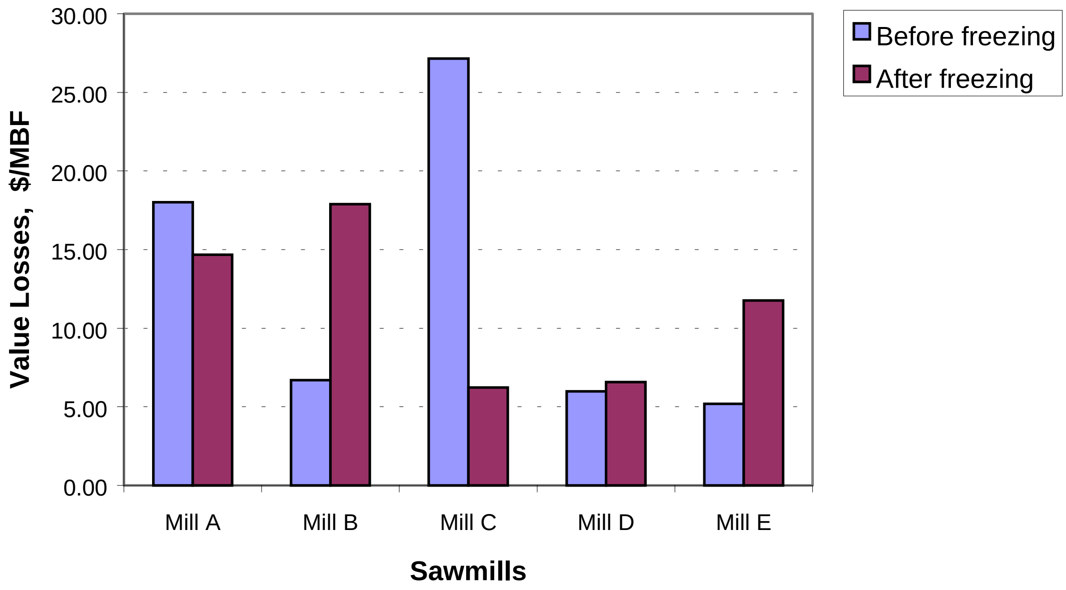

Figure 7 Average estimated value losses due to chipped surface defect

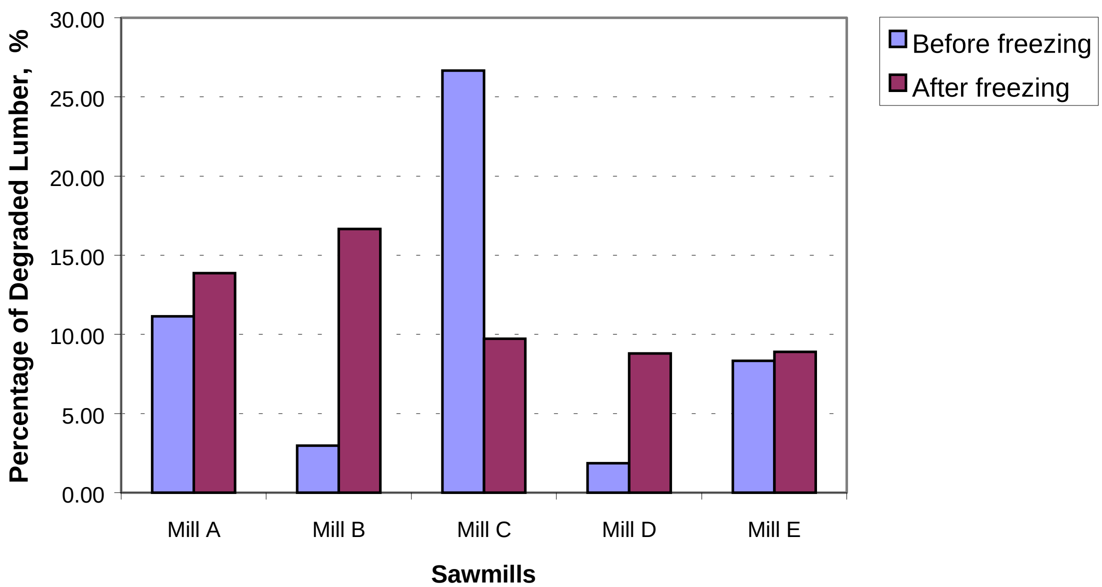

Figure 8 Percentages of degraded lumber due to chipped surface defects

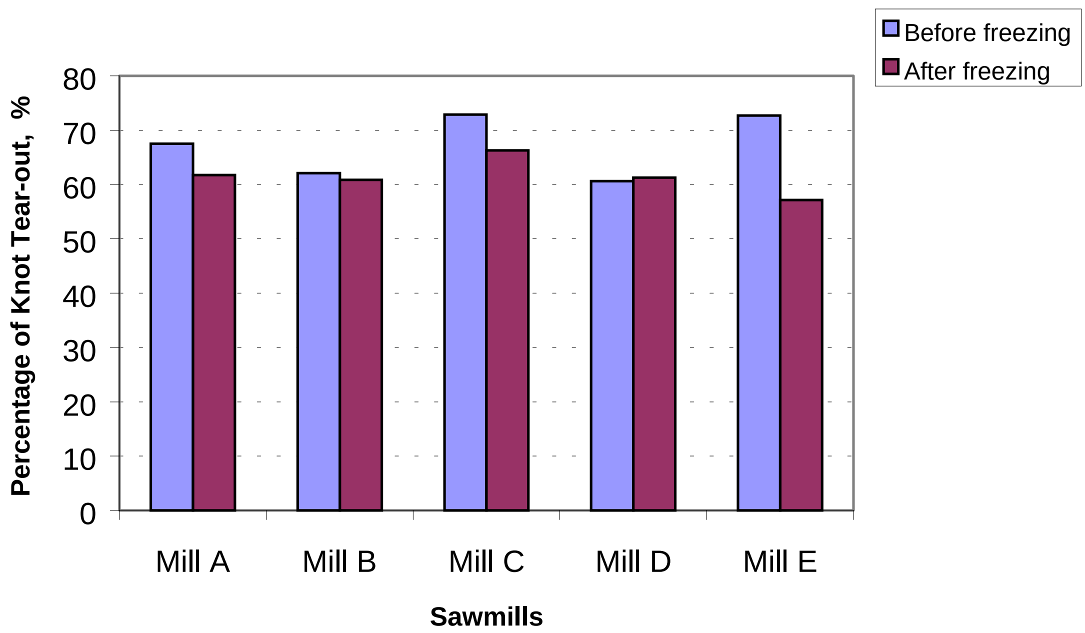

Figure 9 Percentage of knots with tear-out

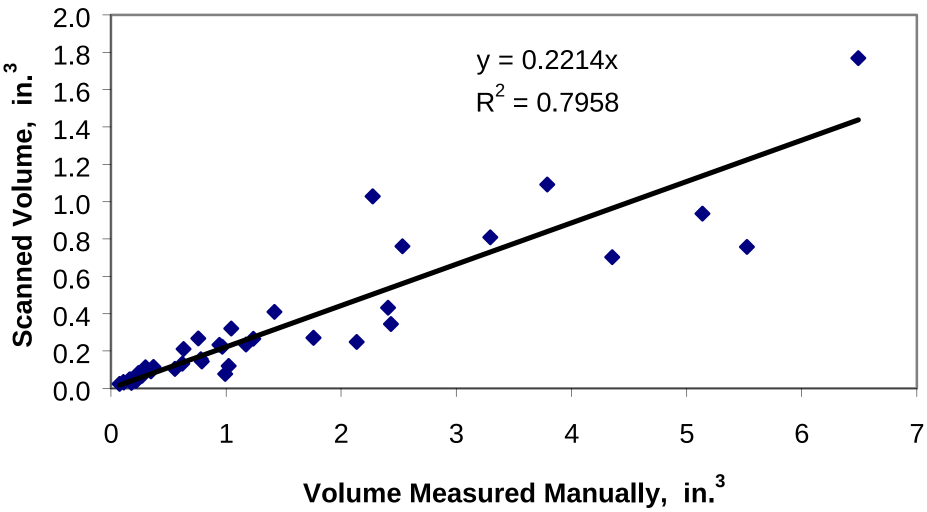

Figure 10 knot tear-out volume, scanned vs. measured values

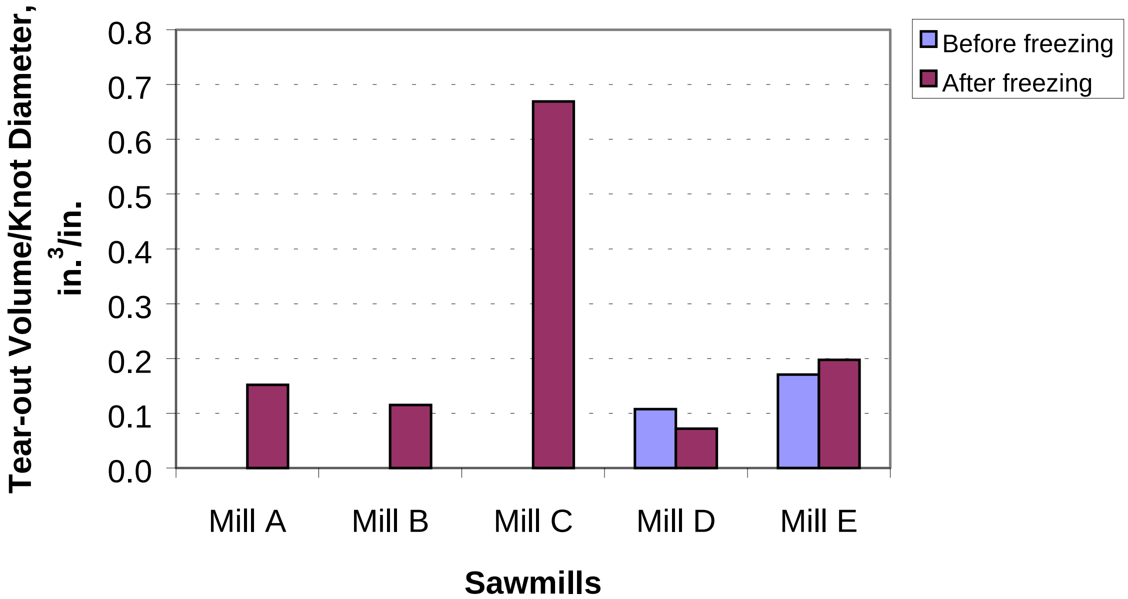

Figure 11 Knot tear-out volume divided by knot diameter

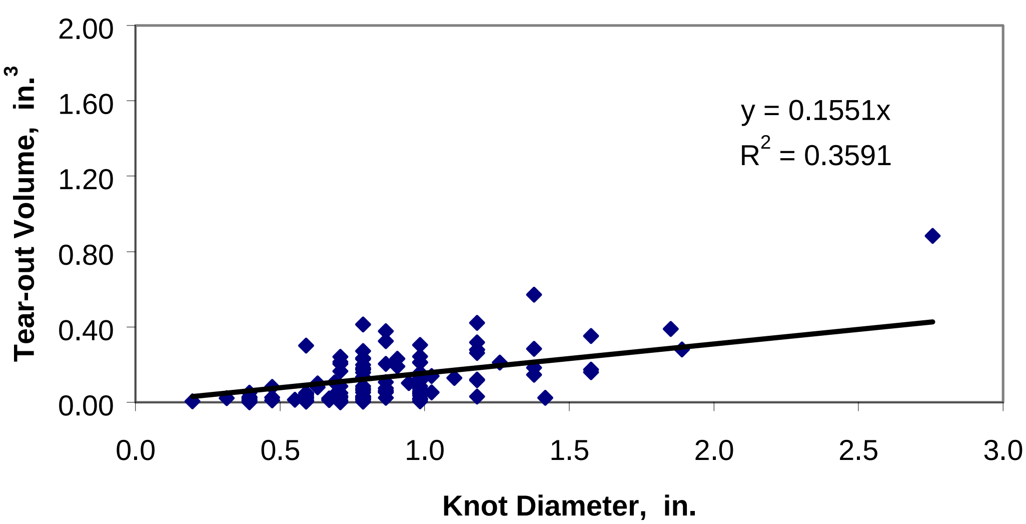

Figure 12 Knot tear-out volume vs. knot diameter