LOG ROTATION EFFECT ON CARRIAGE SAWING OF SWEPT LOGS

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ABSTRACT

A computer sawing system, which simulated a multiple saw edger, was used to investigate the effect of log rotation on the timber conversions of swept logs of three size-classes. A sample of 100 logs was stratified with respect to both log size and sweep, and four sawing methods (half-taper live sawing, half-taper cant sawing, offset live sawing, and offset cant sawing) were applied with the computer sawing simulation system AUTOSAW to each log at 37 positions representing rotation at 10° intervals from 0° (equivalent to the "sweep up" position) to 360° inclusive. All 14 800 simulations used the same carriage configuration, saw kerfs, and target dimensions, and the timber conversion percentage was determined for each.

The results suggest that, under the conditions selected for the simulations, any log rotation can be used with half-taper cant sawing without sacrifice of substantial volume, but rotation is more important with offset cant sawing. Increased conversions were obtained when the log rotation was approximately 145°, i.e., midway between the "sweep in" and "sweep down" positions. For every angle, half-taper sawing obtained conversions that were at least equal to, if not greater than, those obtained with offset sawing. Results were consistent with the general rule of thumb that each 0.1 increase in the sweep:diameter ratio (deviation : s.e.d.) leads to a 5% decrease in timber recovery.

Keywords: sweep; small-end diameter; sawing simulation; AUTOSAW.

INTRODUCTION

Although the problems associated with swept logs are well recognised by log buyers and sawyers alike, very little research effort has focused on this area. This may be due partially to the expense and time required for performing sawing studies, and to the difficulty of comparing results from sawing studies. The difficulty arises from the uniqueness of individual logs—no two logs are exactly alike. Thus a comparison of two similar log batches may yield a result that is biased due to a particular log sample.

Sawing studies examining sweep have been reported by Dobie (1964), Brown & Miller (1975), Dobie & Middleton (1980), and Cown *et al.* (1984), all of whom focused on quantifying losses in volume recovery due to swept logs. Cown *et al* (1984) also investigated grade recovery levels. These studies have provided some benchmarks and "rules of thumb", but their applicability is limited to specific sawing systems. In order to evaluate the effect of swept logs on recovery levels with different sawing systems (e.g., changes in kerf widths, log positioning, or sawing patterns) further sawing studies are required. Furthermore, as additional sawing studies would necessitate the sawing of a different group of logs, results might not be directly comparable. These difficulties can be overcome by applying computer analysis of the problem.

Unlike sawing studies, computer simulation systems allow repetitive sawing of the same log or group of logs. In early sawing simulation systems, logs were represented by truncated cones. Examples include the models of Hallock & Lewis (1971), Richards, (1973), Pnevmaticos *et al.* (1974), and Tejavibulya (1981). With this model of log representation, only three elements were required to describe log shape: small-end diameter (s.e.d.), log length, and taper. This simplified the mathematical analysis of different sawing methods, but by doing so, ignored the effects of sweep. When sweep is ignored, log rotation can have no effect on timber volume conversions. Therefore, in order to observe the effects of log rotation on swept logs, a more precise description of the log was required. Software that could support three-dimensional log descriptions included, amongst others, AUTOSAW (Todoroki 1990), SAWSIM (Leach & Co. Ltd 1990), and SAW3D (Funck 1993).

Using SAWSIM, Maness & Donald (1994) investigated the effect of log rotation strategies for small log "Chip and Saw" sawmills using the method known as split-taper log / full-taper cant. Based on a set of eight rotations at 45° increments from the "horns up" (sweep down) position they concluded that, on average, the "horns up" position provided significantly better results.

The effect of log rotation on a "mixed" sample of 20 logs (i.e., logs of various sizes) has also been examined using AUTOSAW (Todoroki 1995). A comparison of half-taper sawing with offset sawing applied to both a live sawing and a cant sawing pattern revealed that for all log rotations taken at 10° increments from 0° to 360°, half-taper sawing provided consistently better results, on average, than offset sawing.

Experience with AUTOSAW showed that simulations incorporating the effect of sweep could be undertaken. Techniques used by Todoroki (1995) were therefore extended in order to study the effects of log rotation on the sawing of swept logs of different sizes.

METHOD

A sample of 100 logs was selected from the collection of nearly 1000 three-dimensional log descriptions held at NZ FRI. These log descriptions were obtained from sawing studies (Park & Leman 1983) and by cross-sectional analysis (Somerville 1985). Both methodologies capture the external and internal properties of logs. The log sample comprised 30 logs of each of minimal, moderate, and profound sweep, and 10 of extreme sweep. Sweep classification was based on the relationship between maximum deviation from the central log axis, and s.e.d. (Table 1).

For each of the minimal, moderate, and profound sweep samples, 10 "small" logs (s.e.d. 250–350 mm), 10 "medium" logs (s.e.d. 350–450 mm), and 10 "large" logs (s.e.d. 450–550 mm) were selected. The extreme sweep sample consisted of five "small" logs and five "medium" logs.

Detailed measurement information for each log was used to construct a three-dimensional representation of the log in the simulator. For each group of logs (Table 2) the average group

TABLE 1–Sweep class definition

Log sweep	Sweep range
Minimal	0 – D/8
Moderate	D/8 – D/6
Profound	D/6 – D/4
Extreme	>D/4

TABLE 2–Log groupings

Log group	Description
1	Minimally swept, small logs
2	Minimally swept, medium logs
3	Minimally swept, large logs
4	Moderately swept, small logs
5	Moderately swept, medium logs
6	Moderately swept, large logs
7	Profoundly swept, small logs
8	Profoundly swept, medium logs
9	Profoundly swept, large logs
10	Extremely swept, small logs
11	Extremely swept, medium logs

characteristics are summarised in Table 3. Sweep is shown in terms of both percentage sweep and absolute sweep. Average s.e.d., dbh (diameter at breast height), length, and taper, and round log volume are also given, together with the corresponding standard deviation.

Four sawing methods were applied. These were combinations of a live sawing pattern or a cant sawing pattern with half-taper sawing and offset sawing (Table 4). Flitches were restricted to one thickness only, and boards were cut so that volume was maximised. In all, 14 800 simulations were performed.

As the cant sawing pattern chosen for this exercise cut the log on three different sides (*see* Fig. 1) three log rotation angles were essentially combined. If $\alpha°$ is the angle of rotation of

TABLE 3–Log group characteristics

Log group	Sweep (%)	s.e.d. (mm)	dbh (mm)	Length (m)	Taper (mm/m)	Sweep (mm/m)	Volume (m^3)
1	8 ± 2	320 ± 20	420 ± 30	5.6 ± 0.3	9 ± 4	5 ± 2	0.55 ± 0.07
2	8 ± 2	400 ± 30	500 ± 50	5.6 ± 0.3	11 ± 4	6 ± 1	0.82 ± 0.16
3	7 ± 3	480 ± 20	610 ± 30	5.7 ± 0.4	12 ± 3	6 ± 2	1.22 ± 0.12
4	15 ± 1	310 ± 20	400 ± 30	5.8 ± 0.3	9 ± 3	8 ± 1	0.54 ± 0.09
5	14 ± 1	400 ± 30	510 ± 40	5.6 ± 0.3	12 ± 4	10 ± 2	0.85 ± 0.11
6	14 ± 1	470 ± 20	580 ± 50	5.7 ± 0.3	11 ± 7	12 ± 1	1.14 ± 0.17
7	20 ± 2	310 ± 30	400 ± 40	5.7 ± 0.3	9 ± 3	11 ± 1	0.51 ± 0.09
8	19 ± 2	390 ± 30	500 ± 50	5.8 ± 0.3	10 ± 3	13 ± 2	0.81 ± 0.13
9	19 ± 2	480 ± 20	590 ± 30	5.8 ± 0.4	10 ± 3	16 ± 2	1.16 ± 0.13
10	28 ± 3	310 ± 30	420 ± 50	6.1 ± 0.9	10 ± 4	15 ± 2	0.58 ± 0.19
11	26 ± 1	410 ± 30	510 ± 30	6.1 ± 0.5	8 ± 4	18 ± 2	0.88 ± 0.10

TABLE 4–Sawing methods

Saw pattern\ Sawing method	Live sawing	Cant sawing
Half-taper	A	B
Offset	C	D

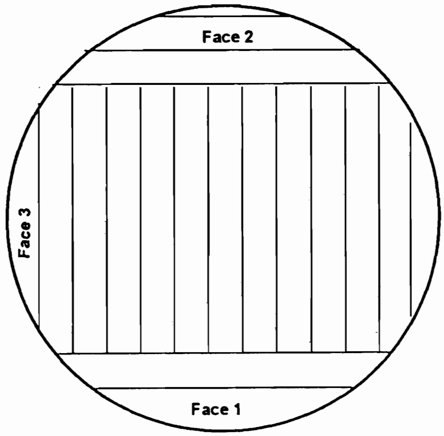

FIG. 1–Stylised example of cant sawing pattern

the log on the carriage relative to the plane of maximum sweep, then α°, α+180°, and α+270° all contribute to the final conversion. Thus, results from the live sawn logs reflect the full effect of log rotation at a given angle whilst those from the cant sawn logs reflect a combination of the three orthogonal angles.

For each of these four sawing methods, the sawmill variables such as position of the carriage knees, headrig, and edger sawkerfs, were held constant for all simulations. At the headrig, flitches of 27.0 mm thickness (including a 2.0-mm level of overcut) were cut. Edging was simulated using a three-saw edger. The edging practice adopted was one in which total board volume was to be maximised. The minimum allowable length for boards was 1.8 m with widths being selected from the following: 50, 75, 100, 125, 150, 200, 225, 250, 300, 350 mm. For the cant sawing methods, a cant of 250 mm was centred in the log.

Initially, all logs were positioned with their plane of maximum sweep up. This was taken to be the reference position, and was assigned the angle 0°. For successive simulations, the orientation of the log on the carriage was altered by 10° intervals until an orientation of 360° was obtained. Simulations at 360° were performed in order to check numerical accuracy between the 0° and 360° result. The 37 batch simulations (0°–360° in increments of 10°) were performed for each of the four sawing methods.

The output from each simulation was processed to obtain individual log (percentage) conversions at each rotation angle. Conversion differences relative to that at 0° position, average conversion differences for each log group, and average conversion differences taken over all angles (excluding 360°) were calculated.

RESULTS

The first observation was that the conversions obtained for all logs and all sawing methods were identical at 0° and 360°; hence, group averages were calculated over the angles 0°, 10°, ..., 350°.

As was to be expected, logs with minimal sweep showed the least variation due to rotation, and logs with extreme sweep showed the greatest variation. In addition, the following trends were observed:

(1) Half-taper live sawing (Fig. 2)

With the exception of the extremely swept small logs, a two-peak trend, with peaks approximately 180° apart, was apparent in each of the log classes. This indicated that there were two angles to which logs could be rotated in order to obtain an increase in average conversions. These angles differed for each log class, but were approximately equal to the "sweep in" and "sweep out" positions (90° ±20° and 270° ±20°).

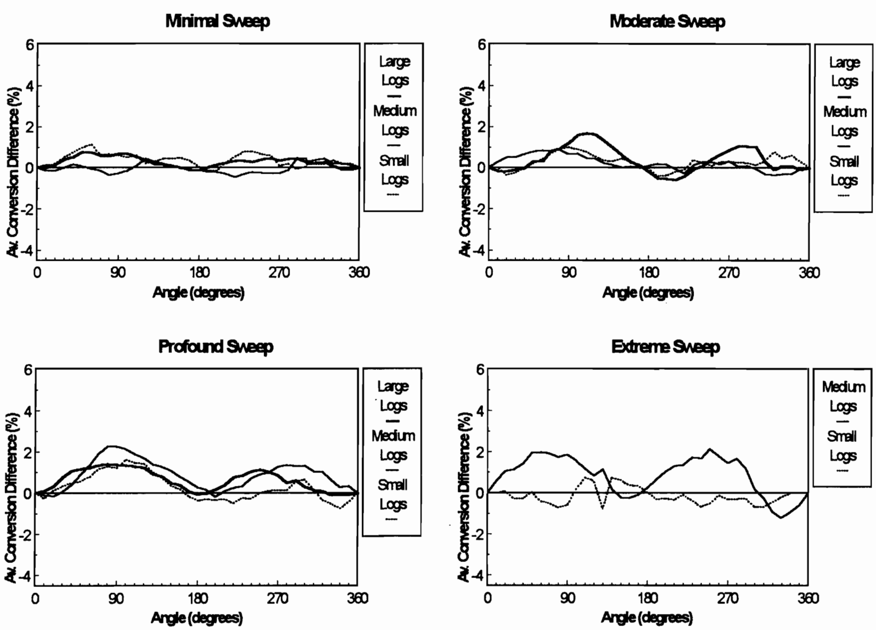

FIG. 2–Half-taper live sawing

(2) Half-taper cant sawing (Fig. 3)

Very little variation due to log rotation (<1.5%) was observed among the 11 log classes.

(3) Offset live sawing (Fig. 4)

Unlike half-taper live sawing, this method demonstrated a one-peak trend, and a notable trough. The position of the peak approximated to the first peak of the half-taper method.

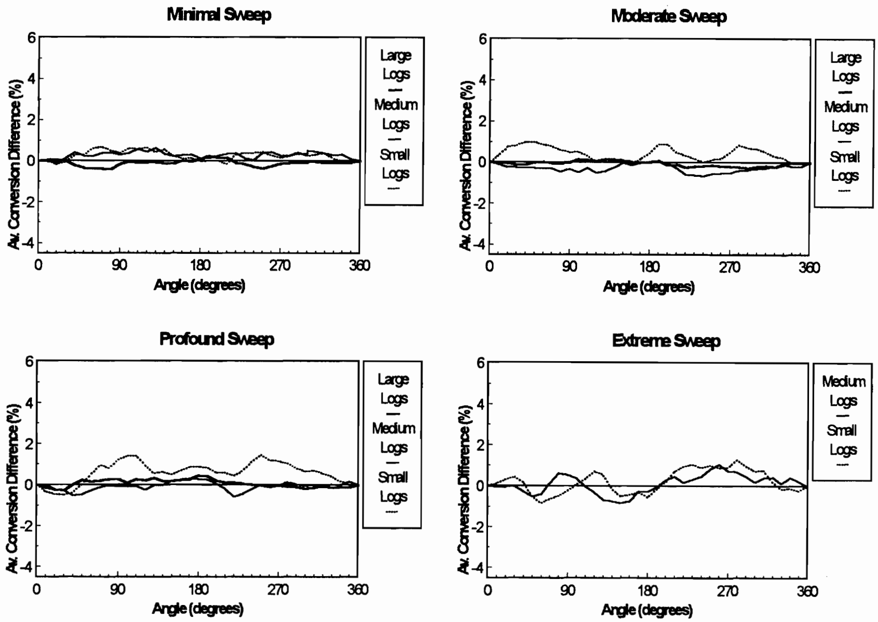

FIG. 3–Half-taper cant sawing

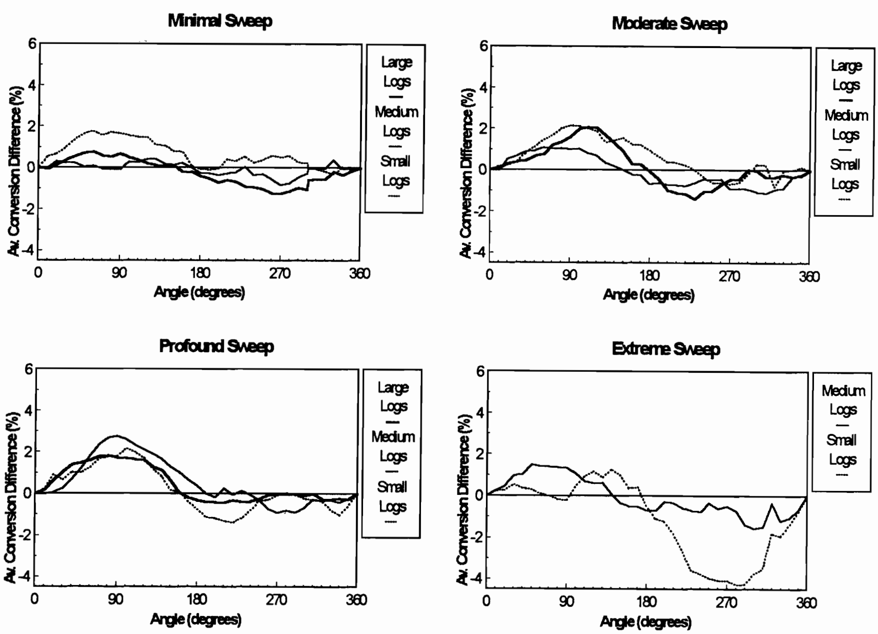

FIG. 4–Offset live sawing

(4) Offset cant sawing (Fig. 5)

Here, a one-peak trend prevailed for all log classes. For the moderately swept logs greatest conversions were obtained at 140° for both large and small log classes, and

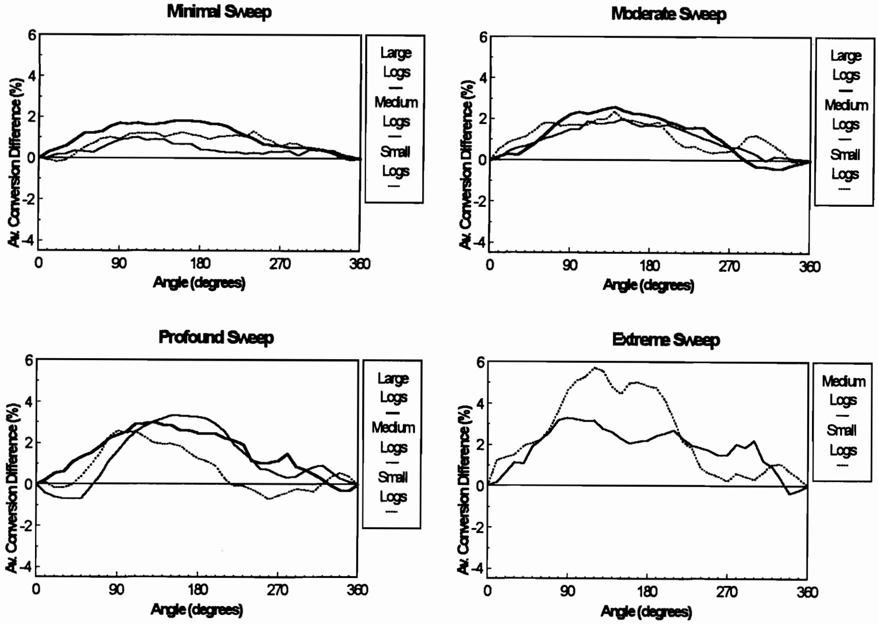

FIG. 5—Offset cant sawing

at 150° for the medium log class. Furthermore, increased conversions were obtained for all log classes when the angle of rotation was between 70° and 210°.

For medium-sized cant-sawn logs (Fig. 6), at all rotation angles half-taper sawing resulted in consistently better conversions than offset sawing. This was also true for all other log classes and sawing methods. Results for average conversion percentages, taken over all angles 0°, 10°, ..., 350°, are given in Table 5 and graphically in Fig. 7 and 8. Results of a two-tailed paired T-test showed that, for cant sawing, conversion differences were significant at

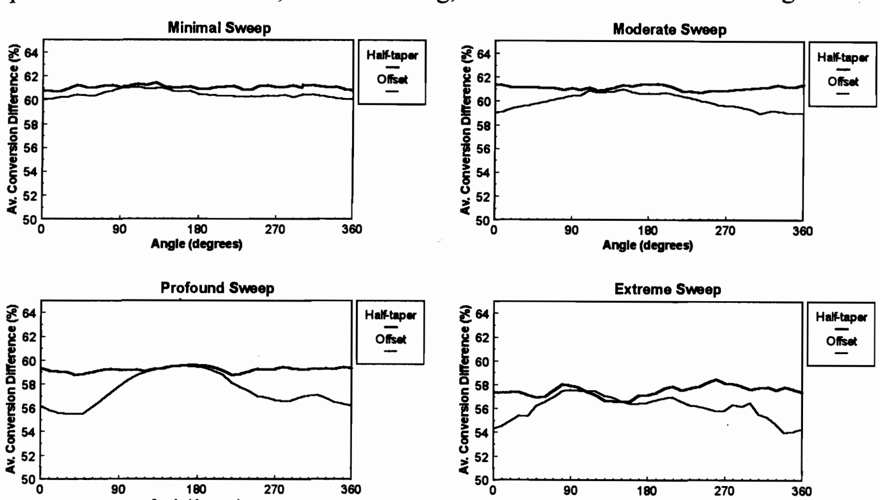

FIG. 6—Half-taper *v.* offset sawing (cant sawn, medium logs)

TABLE 5–Average percentage conversions

Sawing method / Log group		A (H/taper live)	B (H/taper cant)	C (Offset live)	D (Offset cant)
1	(min, sml)	61.2	60.1	60.3	59.2
2	(min, med)	62.2	61.1	61.5	60.5
3	(min, lge)	64.5	64.4	63.5	63.2
4	(mod, sml)	59.7	58.8	58.9	57.5
5	(mod, med)	62.0	61.1	61.2	60.0
6	(mod, lge)	62.3	62.7	61.6	61.6
7	(prfd, sml)	56.7	56.6	56.0	55.0
8	(prfd, med)	59.1	59.2	58.3	57.5
9	(prfd, lge)	60.1	60.7	59.5	59.5
10	(ext, sml)	56.4	55.4	54.8	52.6
11	(ext, med)	56.5	57.5	55.8	56.2

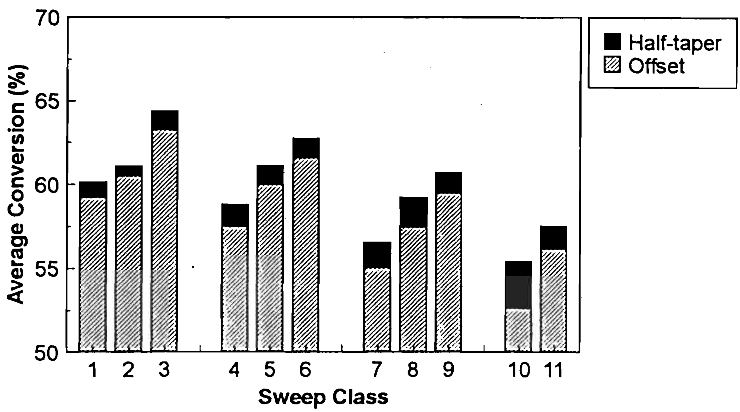

FIG. 7–Cant sawing

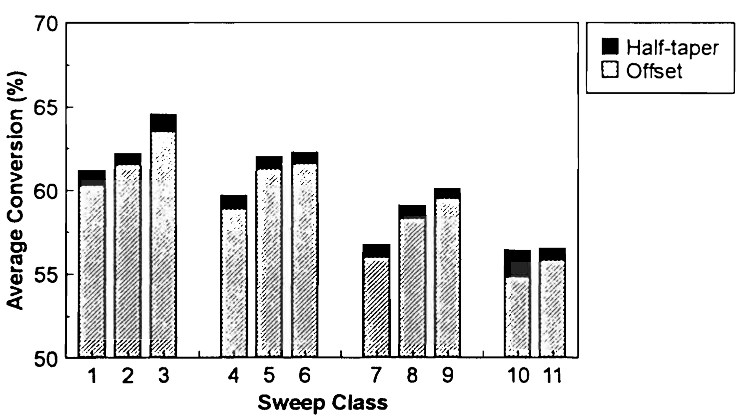

FIG. 8–Live sawing

the 1% level for 93% of the log sample, with a further 2% significant at the 5% level. For live sawing 74% were significant at the 1% level, and a further 11% significant at the 5% level.

Average percentage conversion losses for the moderately, profoundly, and extremely swept logs, calculated with respect to the minimally swept logs of each log size-class are shown in Table 6. Conversion losses were greatest for the extremely swept small and medium-sized logs, and the profoundly swept small logs. Compared to the logs of minimal sweep, the overall average decrease in conversion percentage for the moderately swept logs was 2 ±1%. For the profoundly swept logs the decrease was of the order of 6 ±1%, and for the extremely swept logs 8 ±2%.

TABLE 6–Average percentage conversion losses

Sawing method / Log group		A (H/taper live)	B (H/taper cant)	C (Offset live)	D (Offset cant)
4	(mod, sml)	2.5	2.2	2.3	2.9
5	(mod, med)	0.3	0.0	0.5	0.8
6	(mod, lge)	3.4	2.6	3.0	2.5
7	(prfd, sml)	7.4	5.8	7.1	7.1
8	(prfd, med)	5.0	3.1	5.2	5.0
9	(prfd, lge)	6.8	5.7	6.3	5.9
10	(ext, sml)	7.8	7.8	9.1	11.1
11	(ext, med)	9.2	5.9	9.6	7.1

DISCUSSION AND CONCLUSIONS

The results of this study suggest that, under the conditions selected for the cant sawing simulations, log rotation had little effect on timber conversions when half-taper sawing was simulated but, when offset sawing was simulated, increased conversions were obtained when the log rotation was approximately 145°, i.e., midway between the "sweep in" and "sweep down" positions.

For every angle, half-taper sawing gave conversions that were at least equal to, if not greater than, those obtained with offset sawing. This was also observed by Todoroki (1995) with reference to a different sawing pattern. The trends observed for half-taper and offset sawing indicate that, other than log rotation, log placement has a significant effect on conversions. This may account for the different conclusion of Maness & Donald (1994) who found that the "horns up" position was significantly better when using the method of split-taper log - full-taper cant.

Overall conversion losses associated with sweep were consistent with the general "rule of thumb" (Cown *et al.* 1984) that for each 0.1 increase in the sweep : diameter ratio (deviation : s.e.d.) there is a 5% decrease in timber recovery.

Because the cant sawing pattern chosen for this exercise cut the log on three sides, three orthogonal log rotation angles were essentially combined. It had been hoped that the conversions obtained for the live sawn logs could be used to predict cant sawing conversions at any given log rotation. In the event this was not possible.

These results suggest that the best way of positioning swept logs is dependent on both the sawing method applied and log sample used. In this study the sample was stratified with respect to log size and sweep, but not to taper, eccentricity, and butt flare, which will also influence conversions.

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