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ORIGINAL ARTICLE

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Experimental verification of bandsaw roll-tensioning theory

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Abstract The validity of a bandsaw roll-tensioning theory developed by the author is verified based on a model experiment. It is shown that the actual roll-tensioning process can be clearly explained by this theory. Roll-stretching force transmission coefficients are introduced in this theory. These coefficients, which indicate the magnitude of the compression force parallel to the bandsaw surface at the roll-stretching position, are affected by the thickness of the bandsaw blade, the radius of the bandsaw blade vent at the measurement of tension, and the straightness of the bandsaw blade at the measurement of crown back, among others. For the practical use of this theory, therefore, it is necessary to determine the proper magnitude of these coefficients based on tensioning experiments.

Key words Bandsaw roll-tensioning · Roll-stretching force · Roll-stretching force transmission coefficient · Accumulated amount of tension · Accumulated amount of crown back

Introduction

In recent years the shortage of experienced saw filers has become an acute problem. Given this situation, it is necessary to develop computer-controlled automatic bandsaw-fitting machines.

To develop a computer-controlled automatic bandsaw stretcher, technical data on the bandsaw roll-tensioning technique is required. However there are few such quantitative data pertaining to this technique. The author therefore studied procedures on how to express the bandsaw roll-tensioning technique quantitatively.[1] In this study the author carried out a model experiment of roll-tensioning and clarified the validity of the roll-tensioning theory developed in the previous study.[2]

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Experimental

Stretcher and bandsaw blade

Table 1 shows the specifications of the stretcher and the bandsaw blade used. Except for the jointing part of the bandsaw blade, the straightening and leveling work before tensioning was not performed along the entire length of the blade.

Measurement of roll-stretching force

On the clamp side of the stretcher, as shown in Fig. 1, a thin steel plate with strain gauges and a coil spring are attached between the upper and lower jaws. The opening of the upper jaw on the clamp side is caused by the roll-stretching force during tensioning. The strain corresponding to this opening can be detected by the strain gauges.

To make a calibration curve, the lower stretching roll was detached from the frame, and a load cell was fixed at the same place of the frame. By pressing the upper stretching roll to the affixed load cell, the roll-stretching force can be transmitted to the load cell. Finally, the relation between the roll-stretching force and the strain recorded through the strain gauges can be determined. The calibration curve obtained is shown in the previous paper[1] and is given by:

$$F_R = 0.142h^2 + 8.807h - 1.391$$

where F_R is the roll-stretching force (kgf), and h is the displacement of the roll-stretching force curve on a recording paper (mm). The roll-stretching force is the force acting on the bandsaw blade between the upper and lower rolls during tensioning.

Table 1. Specifications of stretcher and bandsaw blade

Stretcher
- Radius of roll: 37.8 mm
- Radius of curvature of roll in cross section: 87 mm
- Peripheral speed of roll: 10.0 m/min

Bandsaw blade
- Steel material: SKS51
- Thickness t: 0.915 mm
- Young's modulus E: 21 000 kgf/mm^2
- Width between the gullet and the back L: 117 mm
- No. of teeth: 220
- Height of tooth: 10 mm
- Pitch of tooth: 32 mm

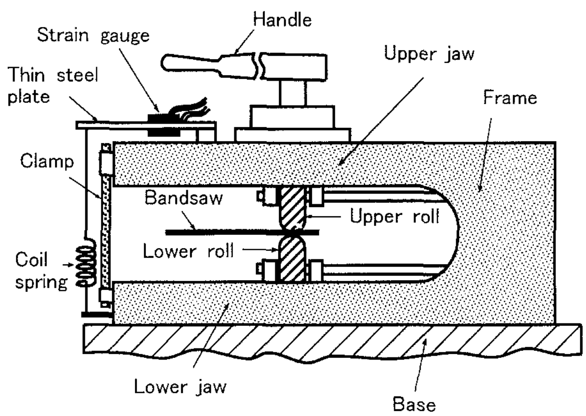

Fig. 1. Measurement of roll-stretching force

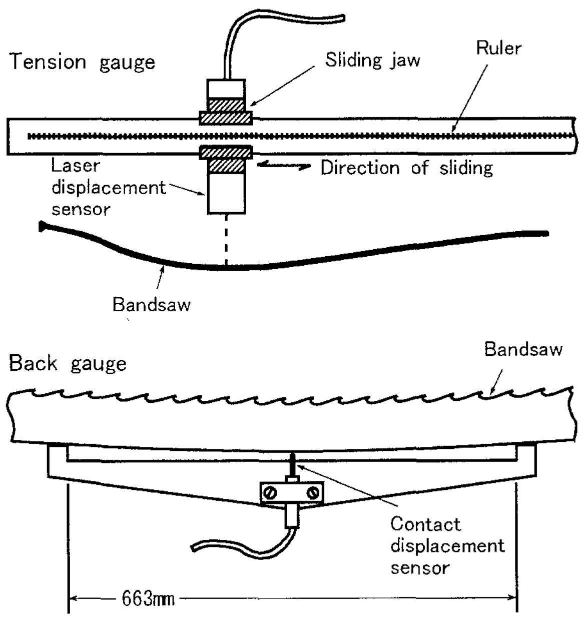

Fig. 2. Tension gauge and back gauge used in the experiment

Measurement of tension and crown back

As shown in Fig. 2, a prototype tension gauge with a laser displacement sensor attached to the sliding jaw of a vernier caliper was used to measure the amount of tension; and a prototype back gauge of 663 mm span with a contact displacement sensor was used to measure the amount of crown back. The former had an effective range of −5 to +5 mm and a resolving power of 1 μm; the latter had an effective range of −2 to +2 mm and a resolving power of 1 μm.

Table 2. Sample data for tensioning

N	x_R (mm)	H_A (°)	F_R (kgf) Calculated	F_R (kgf) Actual
1	17.5	40	1334	1369
2	33.0	43	1523	1612
3	55.0	43	1523	1549
4	75.0	43	1523	1581
5	95.0	43	1523	1549
6	106.5	43	1523	1612
7	23.5	41	1396	1428
8	44.5	43	1523	1549
9	65.5	41	1396	1473
10	85.5	43	1523	1596
11	99.5	43	1523	1580
12	111.0	33	934	987

N, x_R, F_R, see Appendix; and H_A is the turning angle of the stretcher handle

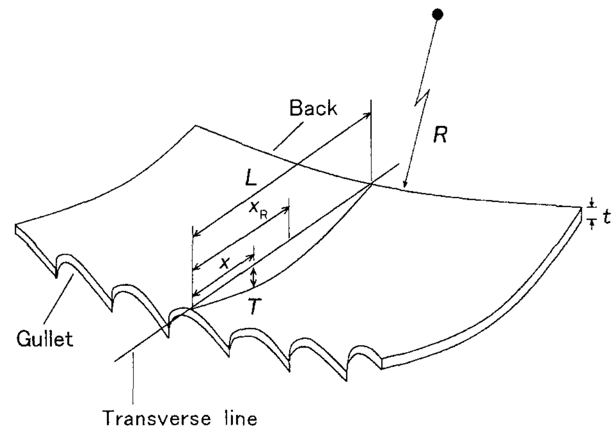

Fig. 3. Transverse deflection of tensioned bandsaw blade bent over radius R. L, x_R, x, T, t, R, see Appendix

Tensioning model

Table 2 shows the sample data used for the roll-tensioning experiment. The magnitude of the roll-stretching force F_R can be controlled by changing the turning angle H_A of the stretcher handle. To set the intended value of H_A, an angle indicator was attached to the spindle of the stretcher handle. The actual roll-stretching force was somewhat different from the calculated one because it was difficult to set an intended turning angle manually. From the predetermined calibration curve, for example, F_R was 1334 kgf at 40 degrees of H_A, but the actual roll-stretching force was 1369 kgf.

At 11 positions along the length of the bandsaw blade (except the jointing part and neighboring area) the amount of tension was measured at 14 points on the transverse lines through the gullet bottom, shown in Fig. 3. The radius of curvature of the bandsaw blade R was 550 mm during the

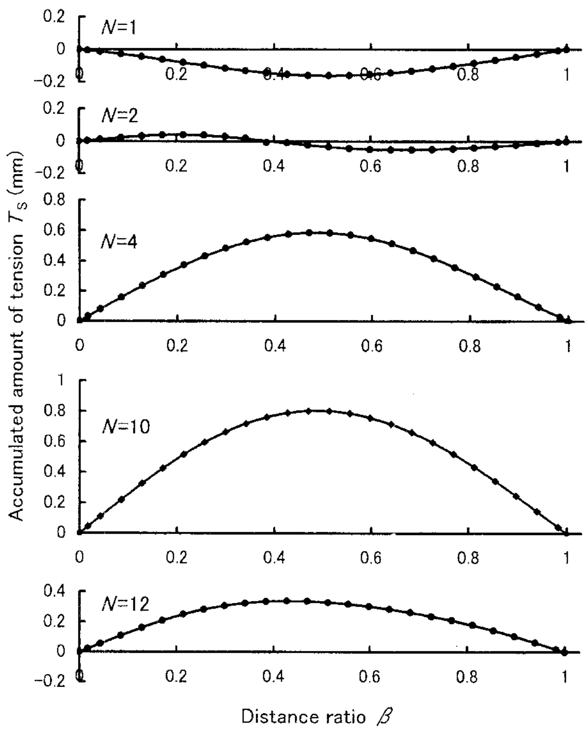

Fig. 4. Theoretical accumulation curve of tension. N, see Appendix

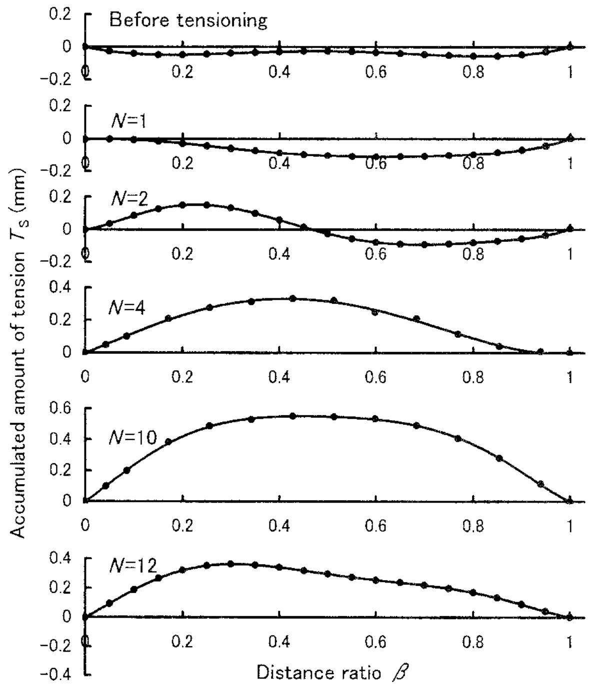

Fig. 5. Experimental accumulation curve of tension

tension measurement. On the stretching bench, the amount of crown back was measured at 11 points on the back of the bandsaw blade along the transverse line, used as a reference for tension measurement.

Results and discussion

Accumulation curve of tension

All the theoretical values reported in this paper were calculated using the theoretical equations developed in the previous study.[2] Figure 4 shows the theoretical accumulation curves of tension, and Fig. 5 shows the experimental ones. The shapes of the experimental curves are similar to the theoretical curves. At $N = 4$ and 10 roll-stretching passes, however, the experimental accumulated degrees of tension are considerably different from the theoretical ones. The author is now examining the cause of these differences.

Maximum accumulated degree of tension and its point of occurrence

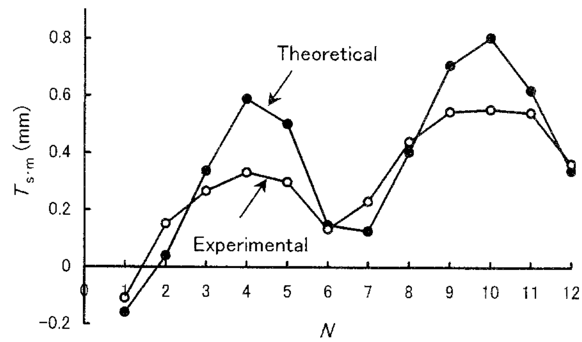

Fig. 6. Change in maximum accumulated amount of tension $T_{s.m}$

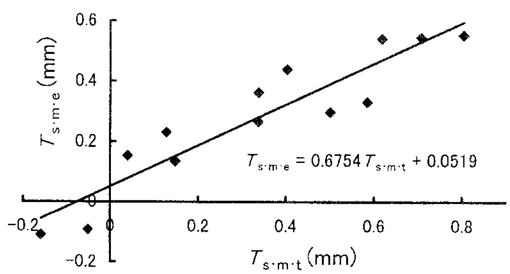

Fig. 7. Comparison of theoretical maximum accumulated amount of tension $T_{s.m.t}$ and experimental $T_{s.m.e}$

Figure 6 shows the changes in the maximum (or minimum) accumulated amount of tension during the sequence of the roll-stretching pass. The shape of the experimental curve is similar to that of the theoretical one. After 12 roll-stretching passes, the experimental value is 0.362mm and the theoretical one is 0.338mm. At $N = 4$, 5, 9, and 10, however, the experimental values are considerably lower than the theoretical ones. Figure 7 shows the relation between the experimental maximum accumulated amount of tension and the theoretical amount. On average, the former is 0.675 times the latter, as shown in the experimental equation. The theoretical values were calculated under the assumption that $k_A = 0.015$ in Eq. (3) in the Appendix.[2] Changing this value to 0.010 (0.015 × 0.675), the difference

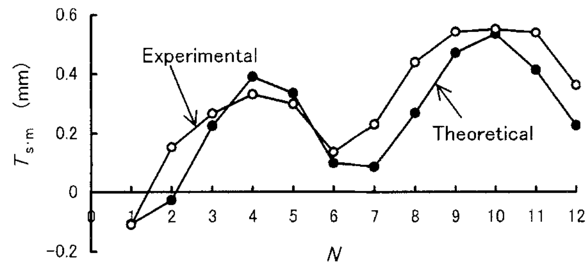

Fig. 8. Change in maximum accumulated amount of tension $T_{s.m}$ at $k_A = 0.010$

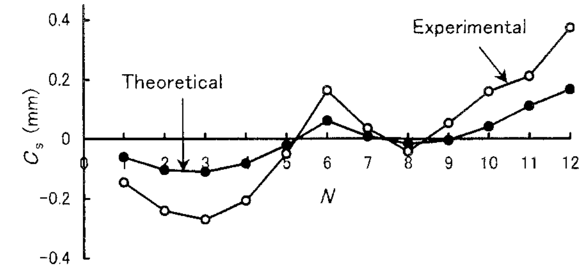

Fig. 11. Change in accumulated amount of crown back C_s

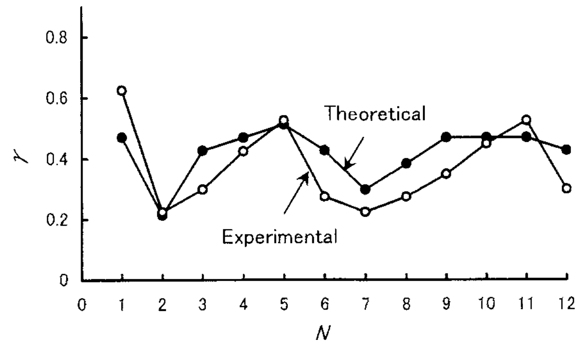

Fig. 9. Occurrence position ratio γ (X_P/L) of maximum accumulated amount of tension. X_P is the distance from the gullet at which maximum accumulated amount of tension appears. L, see Appendix

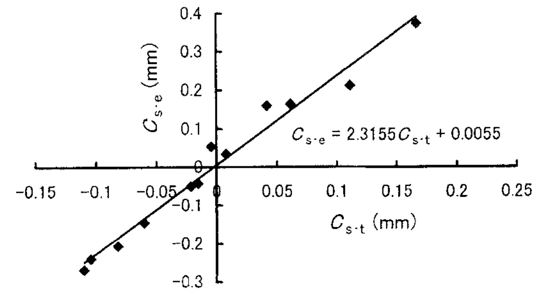

Fig. 12. Comparison of theoretical accumulated amount of crown back $C_{s,t}$ and experimental $C_{s,e}$

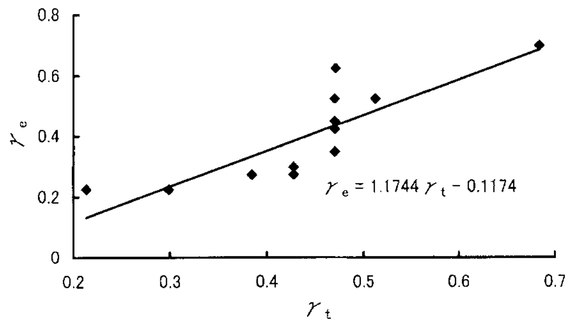

Fig. 10. Comparison of theoretical occurrence position ratio of maximum accumulated amount of tension γ_t and experimental γ_e

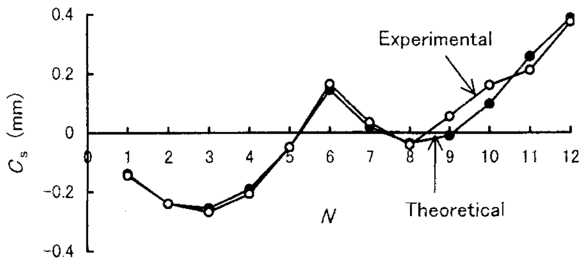

Fig. 13. Change in accumulated amount of crown back C_s at $k_B = 0.116$

between the experimental and theoretical values decreases, as shown in Fig. 8. The k_A is affected by the thickness of the bandsaw blade, the radius of the curvature of the bandsaw blade at the time of measuring the tension, and so forth.[3] Therefore, it is important and practical to determine the adequate value of k_A based on the tensioning experiments.

Figure 9 shows the occurrence position ratio of the maximum accumulated tension during the sequence of the roll-stretching pass. The shape of the experimental curve is similar to that of the theoretical curve, but the experimental values are somewhat different. After 12 roll-stretching passes, for example, the experimental value is 0.300 and the theoretical one is 0.427.

Figure 10 shows the relation of the maximum accumulated tension between the experimental occurrence position and the theoretical one. On average, the former is 1.174 times the latter.

Accumulated amount of crown back

Figure 11 shows the accumulated amount of crown back during the sequence of the roll-stretching pass. The shape of the experimental curve is similar to that of the theoretical curve, although there are considerable differences between the experimental and theoretical values. After 12 roll-stretching passes, for example, the experimental value is 0.374 mm and the theoretical one is 0.167 mm. Based on the experimental equation in Fig. 12, the experimental value is 2.316 times the theoretical one. The theoretical values shown here were calculated under the assumption that $k_B = 0.050$ in Eq. (8) in the Appendix.[2] If this value is changed to 0.116 (0.050 × 2.316), the difference between the experimental and theoretical values decreases significantly, as shown in Fig. 13. The k_B is affected by the thickness of the bandsaw blade, the straightness of the bandsaw blade when measuring crown back, and so forth.[3] Therefore, it is important and practical to determine the value of k_B based on tensioning experiments.

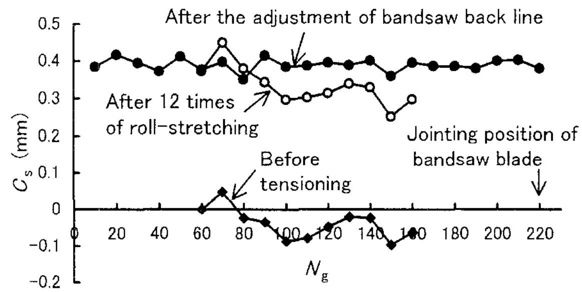

Fig. 14. Change in the amount of crown back C_s. N_g is the gullet number related to the measuring position of crown back in the longitudinal direction of the bandsaw blade

Importance of straightening and leveling before tensioning

It is obvious from Fig. 14 that the shape of the bandsaw back line after 12 roll-stretching passes coincided with that before the tensioning process and was not uniform. As previously mentioned, the straightening and leveling work before the tensioning was not performed along the entire length of the bandsaw blade. During the running test of the bandsaw at 550 rpm using a 1100-mm bandsaw machine, the movement of the bandsaw on the bandsaw wheels during running was unstable, and the maximum back-and-forth movement of the bandsaw was 0.83 mm.

After adjusting the bandsaw back line by straightening and leveling it, the shape of the bandsaw back line became uniform, and running the bandsaw at 550 rpm proved to be stable with a maximum back-and-forth movement of 0.22 mm.

As is often the case, the amount of tension is sensitive to adjustment of the bandsaw blade. Accordingly, the desired amount of tension obtained after intended roll-stretching passes is more or less changed.

These results show that the straightening and leveling work along the entire length of the bandsaw blade before the tensioning process is important for attaining uniform crown back.

Conclusions

It was shown that the actual roll-tensioning process can be clearly explained by the roll-tensioning theory developed by the author. The shapes of the experimental tension or crown back curves were similar to the theoretical curves, although the experimental values were somewhat or considerably different from the theoretical ones. The difference depended significantly on the magnitude of the roll-stretching force transmission coefficients. It is extremely important and practical to determine the adequate values for these coefficients based on tensioning experiments.

Straightening and leveling work along the entire length of the bandsaw blade before the tensioning process is important for attaining uniform crown back and, in turn, stable running of the bandsaw blade.

Acknowledgment The author thanks Mr. Shigetoshi Suzuki, a saw filer at the Department of Wood Processing, Forestry and Forest Products Research Institute, for his continuing assistance.

Appendix

Basic tension equation

The amount of tension (the deflection to the transverse deflected bandsaw surface) T (mm) in the transverse direction of the bandsaw blade after a roll-stretching pass is given by Eqs. (1) and (2).[4] For the range of $0 \le x \le x_R$

$$T = \frac{P_A L^3}{60DR}\left[\left(-3 + 21\alpha - 30\alpha^2 + 10\alpha^3\right)\beta - \left(10 - 15\alpha\right)\beta^4 + \left(3 - 6\alpha\right)\beta^5\right] \quad (1)$$

For the range of $x_R \le x \le L$

$$T = \frac{P_A L^3}{60DR}\left[-10\alpha^3 - \left(3 - 21\alpha - 10\alpha^3\right)\beta - 30\alpha\beta^2 + 10\beta^3 - \left(10 - 15\alpha\right)\beta^4 + \left(3 - 6\alpha\right)\beta^5\right] \quad (2)$$

where x is the distance from the gullet in the transverse direction of the bandsaw blade (mm); x_R is the distance from the gullet in the transverse direction of the bandsaw blade to the roll-stretching point (mm); P_A is the compression force parallel to the bandsaw surface at the roll-stretching position (kgf); L is the width of the bandsaw blade between the gullet and the back (mm); D is the flexural rigidity of the bandsaw blade (kgf·mm) $[Et^3/12(1 - \mu^2)]$; E is Young's modulus (kgf/mm^2); t is the thickness of the bandsaw blade (mm); μ is Poisson's ratio; R is the radius of curvature of the bandsaw blade (mm); α is the roll-stretching position ratio (x_R/L); and β is the distance ratio (x/L).

According to Aoyama,[3] P_A increases with increasing roll-stretching force F_R (kgf). Then

$$P_A = k_A F_R \quad (3)$$

where F_R is the roll-stretching force (kgf); k_A is the roll-stretching force transmission coefficient; and k_A indicates the magnitude of the compression force parallel to the bandsaw surface at the roll-stretching position.

During actual roll-tensioning, an appropriate tensioning performance for sawing operations is achieved after several roll-stretching passes. Therefore, the accumulated amount of tension T_S (mm) is given by:

$$T_S = \Sigma T_j \quad (4)$$

where j is 1, 2, 3 . . . N; and N is the number of roll-stretching passes.

Basic equation of crown back

The amount of crown back C (mm) of the bandsaw blade after a roll-stretching pass is given by Eq. (5).[5]

$$C = \frac{3b^2 P_B}{2L^3 tE} x_{RC} \tag{5}$$

where b is the length of the back gauge (mm); P_B is the compression force parallel to the bandsaw surface at the roll-stretching position (kgf); x_{RC} is the roll-stretching distance from the center of the bandsaw blade (mm); and x_{RC} can be expressed as follows.

$$x_{RC} = x_R - 0.5L \tag{6}$$

From Eqs. (5) and (6)

$$C = \frac{1.5b^2 P_B}{L^2 tE}(\alpha - 0.5) \tag{7}$$

In Eq. (7), C is a negative value when $\alpha \leq 0.5$ and positive when $0.5 \leq \alpha$.

According to Aoyama,[3] P_B increases with increasing roll-stretching force F_R (kgf). Thus

$$P_B = k_B F_R \tag{8}$$

where k_B is the roll-stretching force transmission coefficient; and k_B indicates the magnitude of the compression force parallel to the bandsaw surface at the roll-stretching position.

During actual roll-tensioning, an appropriate tensioning performance for sawing operations is achieved after several roll-stretching passes. Therefore, the accumulated amount of crown back C_S (mm) is given by:

$$C_S = \Sigma C_j \tag{9}$$

where j is 1, 2, 3, . . . N; and N is the number of roll-stretching passes.

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