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研究資料 (Research Material)

Database Construction Procedure for Bandsaw Roll-Tensioning Manual

FUJIWARA Katsutoshi[1)]

Abstract

The database construction procedure for a bandsaw roll-tensioning manual is shown in this article. The procedure consists of calculating the amount of tension and crown back, setting the calculation algorithm for the modification of tension and/or crown back, and collecting the quantitative data of bandsaw roll-tensioning of skilled saw fillers.

Key words : basic theory of bandsaw roll-tensioning, calculation of the amount of tension and crown back, modification of tension and/or crown back, database construction

1. Introduction

The manufacturing and maintenance of bandsaw blades depend on the skills of saw filers. However the shortage of successors to experienced saw filers has become an acute problem in recent years.

The most promising measure to solve this problem is to develop a computer controlled automatic bandsaw stretching machine. To develop this machine, the author has studied the roll-tensioning theory (Fujiwara, 2002a) and the procedures for expressing bandsaw roll-tensioning technique quantitatively (Fujiwara, 2002b). However, it is also necessary to collect technical data on bandsaw roll-tensioning.

In this article, the database construction procedure for bandsaw roll-tensioning manual is shown based on the roll-tensioning theory developed by the author and a series of bandsaw roll-tensioning operations.

2. Basic Theory of Bandsaw Roll-Tensioning

2.1 Basic Equation of Tension

The amount of tension (the deflection to the transverse deflected bandsaw surface) T (mm) in the transverse direction of a bandsaw blade after a roll-stretching pass is shown in Fig. 1 and is given by following equations (Aoyama, 1970b).

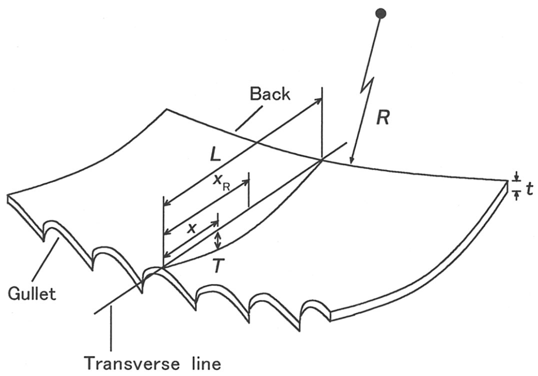

Fig.1. Transverse deflection of tensioned bandsaw blade bent over radius R

For the range of $0 \leqq x \leqq x_R$,

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

For the range of $x_R < x \leqq L$,

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

where:

x = distance from the gullet in the transverse direction of the bandsaw blade (mm)

x_R = distance from the gullet in the transverse direction of the bandsaw blade to the roll-stretching point (mm)

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1) Department of Wood Processing, Forestry and Forest Products Research Institute (FFPRI), 1 Matsunosato, Tsukuba , Ibaraki 305-8687, Japan; e-mail : sdust@ffpri.affrc.go.jp

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

P_A increases with increasing roll-stretching force F_R (kgf). Then,

$$P_A = k_A F_R \tag{3}$$

where:
k_A = roll-stretching force transmission coefficient

k_A indicates the magnitude of compression force parallel to the bandsaw surface at the roll-stretching position. It has been shown that k_A is affected by the thickness of the bandsaw blade, and the radius of curvature of the bandsaw blade at the measurement of tension, among other factors (Aoyama, 1971). Therefore, it is practical to determine k_A based on the experiments of tensioning.

In the 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:

$$T_S = \Sigma T_j \tag{4}$$

where:
$j = 1,2,3 \cdots N$
N = number of roll-stretching passes

2.1.1 Occurrence of Maximum or Minimum Value of Tension

The value of α which maximizes or minimizes T in Equations (1) and (2) at an arbitrary value of β can be calculated (Fujiwara, 2002a). For the range of $0 \leqq \beta \leqq 0.500$, the value of α which maximizes T is given by:

$$\alpha = 9.1354\beta^4 - 5.0272\beta^3 + 1.6781\beta^2 - 0.1048\beta + 0.1934 \tag{5}$$

For the range of $0.500 < \beta \leqq 1.000$, the value of α which maximizes T is given by:

$$\alpha = -9.1355\beta^4 + 31.515\beta^3 - 41.409\beta^2 + 24.712\beta - 4.875 \tag{6}$$

For the range of $0 \leqq \beta \leqq 0.556$, the value of α which minimizes T is given by:

$$\alpha = 300.29\beta^6 - 431.91\beta^5 + 236.66\beta^4 - 60.417\beta^3 + 7.324\beta^2 - 0.3389\beta + 0.7659 \tag{7}$$

For the range of $0.444 \leqq \beta \leqq 1.000$, the value of α which minimizes T is given by:

$$\alpha = -300.29\beta^6 + 1369.8\beta^5 - 2581.5\beta^4 + 2573\beta^3 - 1431.3\beta^2 + 421.9\beta - 51.376 \tag{8}$$

2.1.2 Calculation of Maximum or Minimum Value of Tension

Under the assumption that $P_A L^3/(60DR)$ is equal to 1, the maximum value of tension T_{MAX} or the minimum one T_{MIN} for a pair of α and β can be calculated by Equations (1) and (2) (Fujiwara, 2002a). For the range of $0 \leqq \beta \leqq 0.500$, T_{MAX} is given by:

$$T_{MAX} = -1059\beta^6 + 1432.6\beta^5 - 729.54\beta^4 + 177.55\beta^3 - 18.905\beta^2 + 0.7627\beta - 0.0068 \tag{9}$$

For the range of $0.500 < \beta \leqq 1.000$, T_{MAX} is given by:

$$T_{MAX} = -1059\beta^6 + 4921.7\beta^5 - 9452.2\beta^4 + 9595.6\beta^3 - 5423.2\beta^2 + 1613.9\beta - 196.59 \tag{10}$$

For the range of $0 \leqq \beta \leqq 0.556$, T_{MIN} is given by:

$$T_{MIN} = -1366.4\beta^6 + 2020.4\beta^5 - 1144.9\beta^4 + 306.06\beta^3 - 39.022\beta^2 + 2.0353\beta - 0.0265 \tag{11}$$

For the range of $0.444 \leqq \beta \leqq 1.000$, T_{MIN} is given by:

$$T_{MIN} = -1358.8\beta^6 + 6144.4\beta^5 - 11478\beta^4 + 11340\beta^3 - 6251.9\beta^2 + 1825.4\beta - 220.89 \tag{12}$$

2.1.3 Neutral Line of Tension

Positive and negative values of tension coexist in the ranges of $0.192 \leqq \alpha \leqq 0.237$ and $0.763 \leqq \alpha \leqq 0.808$ (Fujiwara, 2002a). Therefore, the value of α at which T in Equations (1) and (2) becomes zero at an arbitrary value of β can be calculated. The value of α in the range of $0.192 \leqq \alpha \leqq 0.237$ is calculated by:

$$\alpha = -0.7631\beta^6 + 2.2278\beta^5 - 2.2108\beta^4 + 0.6617\beta^3 + 0.1434\beta^2 - 0.0148\beta + 0.1924 \tag{13}$$

The value of α in the range of $0.763 \leqq \alpha \leqq 0.808$ is calculated by:

$$\alpha = 0.7631\beta^6 - 2.3505\beta^5 + 2.5176\beta^4 - 1.1646\beta^3 + 0.3043\beta^2 - 0.0256\beta + 0.7635 \quad (14)$$

2.2 Basic Equation of Crown Back

The amount of crown back C (mm) of the bandsaw blade after a roll-stretching pass is given by following equation (Aoyama, 1970a).

$$C = \frac{3b^2 P_B}{2L^3 tE} x_{RC} \quad (15)$$

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

$$x_{RC} = x_R - 0.5L \quad (16)$$

From Equations (15) and (16),

$$C = \frac{1.5b^2 P_B}{L^2 tE}(\alpha - 0.5) \quad (17)$$

In Equation (17), C is a negative value in the range of $\alpha \leqq 0.500$ and positive in $0.500 < \alpha$.

P_B increases with increasing roll-stretching force F_R (kgf). Thus,

$$P_B = k_B F_R \quad (18)$$

where:
k_B = roll-stretching force transmission coefficient

k_B indicates the magnitude of compression force parallel to the bandsaw surface at the roll-stretching position. It has been shown that k_B is affected by the thickness of the bandsaw blade, and the radius of curvature of the bandsaw blade at the measurement of tension, among other factors (Aoyama, 1971). Therefore, it is practical to determine k_B based on the experiments of tensioning.

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

$$C_S = \Sigma C_j \quad (19)$$

where:
$j = 1,2,3 \cdots N$
N = number of roll-stretching passes

3. Calculation of the Amount of Tension and Crown Back

The sample data used for the calculations of tension and crown back are shown in Table 1. The accumulated amount of tension by Equation (4) is shown in Fig. 2 (Fujiwara, 2002a). The accumulation curve of tension C_{12}

Table 1. Sample data used for the calculation of tension and crown back

Parameters	N	x_R	F_R
L=117mm	1	17.5	1500
E=21000kgf/mm^2	2	35.0	1500
t=0.9mm	3	55.0	1400
μ=0.3	4	75.0	1400
R=550mm	5	95.0	1500
b=750mm	6	106.5	1500
k_A=0.015	7	24.5	1500
k_B=0.050	8	44.5	1400
	9	65.5	1400
	10	85.5	1500
	11	99.5	1500
	12	111.0	900

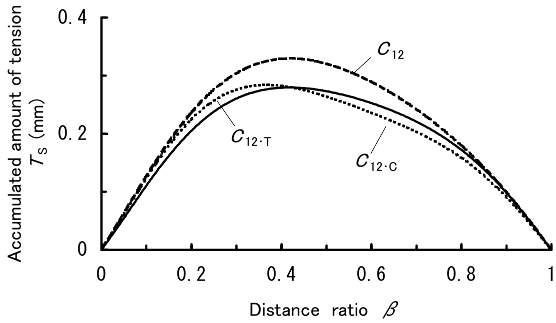

Fig.2. Accumulation curve of tension
C_{12} : after 12 roll-stretching passes,
$C_{12\cdot T}$: after the adjustment of tension,
$C_{12\cdot C}$: after the adjustment of crown back.

after 12 roll-stretching passes is expressed by:

$$T_S = 5.1075\beta^6 - 18.273\beta^5 + 24.592\beta^4 - 14.682\beta^3 + 2.072\beta^2 + 1.1821\beta + 0.0008 \quad (20)$$

From Equation (20) the maximum accumulated amount of tension $T_{S.M}$ is 0.330mm at β=0.427. And from Equation (19) the accumulated amount of crown back C_S is 0.190mm.

4. Modification of the Amount of Tension and Crown Back

In actual tensioning, there is a continual need to adjust the amount of tension and/or crown back. The modification procedure according to modification pattern 7 in Table 2 is shown using an example data (Fujiwara, 2002a). The calculation algorithm for the modification of tension and/or crown back is shown in Appendix.

OBJECTIVE:

Decrease the value of $T_{S.M}$ from 0.330mm to 0.280 mm without changing the value of C_S of 0.190mm.

RESULTS OF CALCULATION:

After the adjustment of tension:

The accumulation curve of tension after the adjustment of tension is shown in Fig. 2 as curve $C_{12\cdot T}$ and is expressed by:

$$T_S = 7.603\beta^6 - 25.429\beta^5 + 31.522\beta^4 - 17.257\beta^3 + 2.577\beta^2 + 0.9808\beta + 0.0012 \quad (21)$$

From Equation (21), the maximum accumulated amount of tension $T_{S.M}$ is 0.280mm at β=0.427. In addition, the accumulated amount of crown back C_S increases to 0.236mm.

Table 2. Modification patterns of tension and/or crown back

Pattern	Tension	Crown back
1	Unchanged	Unchanged
2	Unchanged	Increase
3	Unchanged	Decrease
4	Increase	Unchanged
5	Increase	Increase
6	Increase	Decrease
7	Decrease	Unchanged
8	Decrease	Increase
9	Decrease	Decrease

After the adjustment of crown back:

The accumulation curve of tension after the adjustment of crown back is also shown in Fig. 2 as curve $C_{12\cdot C}$ and is expressed by:

$$T_S = 10.665\beta^6 - 35.456\beta^5 + 43.455\beta^4 - 23.075\beta^3 + 3.3285\beta^2 + 1.0808\beta + 0.0013 \quad (22)$$

From Equation (22), T_S is 0.279mm at β=0.427, and the maximum accumulated amount of tension $T_{S.M}$ is 0.284mm at β=0.385. The accumulated amount of crown back C_S is 0.190mm.

After the adjustment the point β, at which the maximum value of tension appears, is slightly shifted from 0.427 to 0.385. However, as shown here, the amount of tension and/or crown back was sufficiently adjusted.

5. Database construction for a bandsaw roll-tensioning manual

The quantitative data of bandsaw roll-tensioning technique of skilled saw filers can be collected by the following procedure.

Step 1: After final adjustment of joining part, straightening and levelling work should be conducted along the entire length of the bandsaw blade.

Step 2: Set several cross lines through the bottom of the gullet (for example, at intervals of 20 teeth) along the entire length of the blade.

Step 3: At these points on all the cross lines (as shown in Table 3), check the amount of tension and crown back before tensioning by a tension gauge and a back gauge (Fujiwara, 2002b). Finally, calculate the mean value of tension at each point and the mean value of crown back,and set these values as the standard values before tensioning.

Step 4: Roll-stretching pass should be done along the entire length of the bandsaw blade. In this case, check the value of roll-stretching force by a strain gauge method (Fujiwara, 2002b) and the distance from the gullet in the transverse direction of the bandsaw blade to the roll-stretching point.

Step 5: Measure the amount of tension at all the points set on all the cross lines and the amount of crown back after tensioning. Finally, calculate the mean value of tension at each point and the mean value of crown back, and set standard values

Table 3. Measurement of tension and crown back (sample of a data sheet) No.

Order, position and length of roll-stretching			F_R[3] (kgf)	Remarks: Thickness of blade; 0.915mm, Width of blade; 127mm, Width of the blade between the bottom of gullet and the back; 117mm, Number of teeth; 220.
Order	x_R[1] (mm)	Length[2]		
		～		

Number of gullet	Amount of tension (mm)								Amount of crown back (mm)
	0*	5*	10*	20*	・・・	90*	110*	117*	
1									
2									
3									
・ ・ ・									
11									
Mean									

[1]: Distance from the gullet in the transverse direction of the blade to the roll-stretching point.
[2]: Applicable number of teeth.
[3]: Roll-stretching force.
*: Distance from the gullet in the transverse direction of the blade.

Table 4. Standard value of tension and crown back (sample of a data sheet) No.

Order, position and length of roll-stretching			F_R[3] (kgf)	Remarks: Thickness of blade; 0.915mm, Width of blade; 127mm, Width of the blade between the bottom of gullet and the back; 117mm, Number of teeth; 220.
Order	x_R[1] (mm)	Length[2]		
1		～		
2		～		
3		～		
・ ・ ・				
12		～		

Order	Standard value of tension (mm)								Standard value of crown back (mm)
	0*	5*	10*	20*	・・・	90*	110*	117*	
1									
2									
3									
・ ・ ・									
12									

[1]: Distance from the gullet in the transverse direction of the blade to the roll-stretching point.
[2]: Applicable number of teeth.
[3]: Roll-stretching force.
*: Distance from the gullet in the transverse direction of the blade.

from these mean values taking account of the standard values before tensioning.

Step 6: As long as the roll-stretching pass is repeated, repeat the processes of Steps 4 and 5.

Step 7: After a series of bandsaw roll-tensioning operations, complete Table 4.

The data in Table 4 is very useful for the operation of a computer controlled automatic bandsaw stretching machine as well as for the training of saw filers.

Appendix : Setting the calculation algorithm for the modification of the amount of tension and crown back

OBJECTIVES: 1. Decide the value of β and the increment T_Δ (＋) or the decrement T_Δ (－) of tension.

2. Decide the increment C_Δ (＋) or the decrement C_Δ (－) of crown back.

RESTRICTION: Roll-stretching pass in the ranges of $\alpha \leqq 0.100$ and $\alpha \geqq 0.950$ is prohibited.

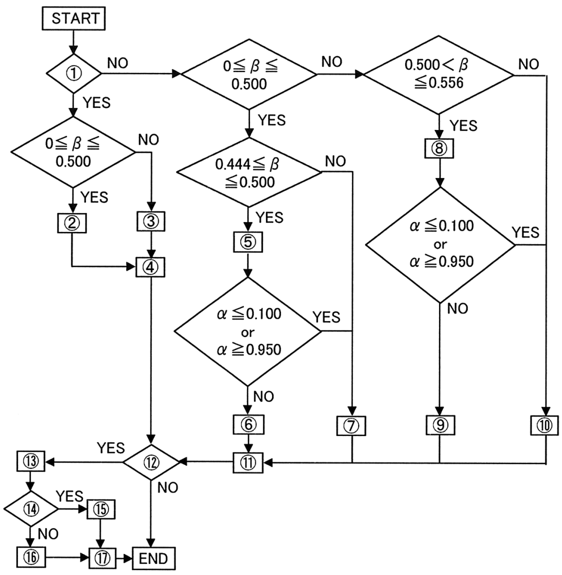

Fig.3. Calculation algorithm for the modification of the amount of tension and/or crown back

CALCULATION: Calculation can be done based on the calculation algorithm in Fig. 3.

Treatment in Fig. 3:

① Do you want to increase the degree of tension?

② Using Equation (5), calculate α at which the maximum amount of tension appears at the point β. Using Equation (9), calculate the maximum value of tension T_{MAX} at β.

③ Using Equation (6), calculate α at which the maximum amount of tension appears at the point β. Using Equation (10), calculate the maximum value of tension T_{MAX} at β.

④ T_{MAX} is the value under the assumption that $P_A L^3/(60DR)$ is equal to 1. Since the increment of tension is T_Δ, calculate the effective roll-stretching force $F_{R\cdot E}$ by $F_{R\cdot E} = (P_A/k_A)(T_\Delta/T_{MAX})$.

⑤ Using Equation (8), calculate α at which the minimum amount of tension appears at the point β.

⑥ Using Equation (12), calculate the minimum value of tension T_{MIN} at β.

⑦ Using Equation (7), calculate α at which the minimum amount of tension appears at the point β. Using Equation (11), calculate the minimum value of tension T_{MIN} at β.

⑧ Using Equation (7), calculate α at which the minimum amount of tension appears at the point β.

⑨ Using Equation (11), calculate the minimum value of tension T_{MIN} at β.

⑩ Using Equation (8), calculate α at which the minimum amount of tension appears at the point β. Using Equation (12), calculate the minimum value of tension T_{MIN} at β.

⑪ T_{MIN} is the value under the assumption that $P_A L^3/(60DR)$ is equal to 1. Since the decrement of tension is T_Δ, calculate the effective roll-stretching force $F_{R\cdot E}$ by $F_{R\cdot E} = (P_A/k_A)(T_\Delta/T_{MIN})$.

⑫ Do you want to change the degree of crown back without changing the value of tension at β?

⑬ Under the roll-stretching force $F_{R\cdot E}$ at α, calculate the increment or decrement of crown back C_j by $C_j = 1.5b^2 k_B F_{R\cdot E}(\alpha - 0.5)/(L^2 tE)$.

⑭ Do you want to increase the degree of crown back?

⑮ Calculate α to increase the degree of crown back without changing the value of tension at β by Equation (14).

⑯ Calculate α to decrease the degree of crown back without changing the value of tension at β by Equation (13).

⑰ Calculate the increment or decrement of crown back C_c by $C_c = C_\Delta - C_j$. In order to produce C_c at α, calculate the roll-stretching force F_R by $F_R = C_c L^2 tE/(1.5b^2 k_B(\alpha - 0.5))$.

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帯鋸ロール腰入れマニュアルのためのデータベースの構築方法

藤原　勝敏 [1)]

要　旨

帯鋸ロール腰入れにおける腰入れ量と背盛り量の計算方法およびその変更計算アルゴリズムについて示した。また、一連の帯鋸ロール腰入れ作業に基づく腰入れマニュアル作成のためのデータベース構築の方法を示した。

キーワード：帯鋸ロール腰入れの基礎理論、腰入れ量と背盛りの計算およびその変更計算アルゴリズム、データベース構築

1) 森林総合研究所加工技術研究領域　〒305-8687　つくば市松の里 1　e-mail : sdust@ffpri.affrc.go.jp