Database Construction Procedure for Bandsaw Roll–Tensioning Manual

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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 fillers. However the shortage of successors to experienced saw fillers 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).

For the range of \( 0 \leq x \leq x_R \),
\[
T = \frac{PL^3}{60DR} (-3+21 \alpha -30 \alpha^2 +10 \alpha^3) \beta_{-30 \alpha \beta^2 +10 \beta^3} \]

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)
- \( L \) = length of the bandsaw blade (mm)
- \( P \) = pressure per unit length of bandsaw blade (N/mm)
- \( R \) = radius of roll-stretching point (mm)
- \( D \) = diameter of bandsaw blade (mm)
- \( \alpha \) and \( \beta \) are coefficients depending on the gullet shape of the bandsaw blade.
The value of \( \alpha \) which maximizes or minimizes \( T \) in Equations (1) and (2) at an arbitrary value of \( \beta \) can be calculated (Fujiwara, 2002a). For the range of \( 0 \leq \beta \leq 0.500 \), the value of \( \alpha \) which maximizes \( T \) is given by:

\[
\alpha = -9.1355 \beta^4 + 31.515 \beta^3 - 41.409 \beta^2 + 24.712 \beta - 4.875
\]  
(6)

For the range of \( 0 \leq \beta \leq 0.556 \), the value of \( \alpha \) which minimizes \( T \) is given by:

\[
\alpha = 300.29 \beta^6 - 431.91 \beta^5 + 236.66 \beta^4 - 60.417 \beta^3 + 7.324 \beta^2 - 0.3389 \beta + 0.7659
\]  
(7)

2.1.1 Occurrence of Maximum or Minimum Value of Tension

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

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\]  
(7)

2.1.2 Calculation of Maximum or Minimum Value of Tension

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

\[
T_{\text{MAX}} = -1059 \beta^6 + 1432.6 \beta^5 - 729.54 \beta^4 + 177.55 \beta^3 - 18.905 \beta^2 + 0.7627 \beta - 0.0068
\]  
(9)

For the range of \( 0.500 < \beta \leq 1.000 \), \( T_{\text{MAX}} \) is given by:

\[
T_{\text{MAX}} = -1059 \beta^6 + 4921.7 \beta^5 - 9452.2 \beta^4 + 9595.6 \beta^3 - 5423.2 \beta^2 + 1613.9 \beta - 196.59
\]  
(10)

For the range of \( 0 \leq \beta \leq 0.556 \), \( T_{\text{MIN}} \) is given by:

\[
T_{\text{MIN}} = -1366.4 \beta^6 + 2020.4 \beta^5 - 1144.9 \beta^4 + 306.06 \beta^3 - 39.022 \beta^2 + 2.0353 \beta - 0.0265
\]  
(11)

For the range of \( 0 \leq \beta \leq 1.000 \), \( T_{\text{MIN}} \) is given by:

\[
T_{\text{MIN}} = -1358.8 \beta^6 + 6144.4 \beta^5 - 11478 \beta^4 + 11340 \beta^3 - 6251.9 \beta^2 + 1825.4 \beta - 220.89
\]  
(12)

2.1.3 Neutral Line of Tension

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

\[
\alpha = -0.7631 \beta^6 + 2.2278 \beta^5 - 2.2108 \beta^4 + 0.6617 \beta^3 + 0.1434 \beta^2 - 0.0148 \beta + 0.1924
\]  
(13)
The value of $\alpha$ in the range of $0.763 \leq \alpha \leq 0.808$ is calculated by:

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

### 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).

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

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

$x_{RC}$ can be expressed as follows:

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

From Equations (15) and (16),

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

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

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

$$P_B = k_B F_R \quad \text{(18)}$$

where:
- $k_B = \text{roll-stretching force transmission coefficient}$

$k_B$ 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:

$$C_S = \sum C_j \quad \text{(19)}$$

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

### 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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>$N$</th>
<th>$x_R$</th>
<th>$F_R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$L=117\text{mm}$</td>
<td>1</td>
<td>17.5</td>
<td>1500</td>
</tr>
<tr>
<td>$E=21000\text{kgf/mm}^2$</td>
<td>2</td>
<td>35.0</td>
<td>1500</td>
</tr>
<tr>
<td>$t=0.9\text{mm}$</td>
<td>3</td>
<td>55.0</td>
<td>1400</td>
</tr>
<tr>
<td>$\mu=0.3$</td>
<td>4</td>
<td>75.0</td>
<td>1400</td>
</tr>
<tr>
<td>$R=550\text{mm}$</td>
<td>5</td>
<td>95.0</td>
<td>1500</td>
</tr>
<tr>
<td>$b=750\text{mm}$</td>
<td>6</td>
<td>106.5</td>
<td>1500</td>
</tr>
<tr>
<td>$k_B=0.015$</td>
<td>7</td>
<td>24.5</td>
<td>1500</td>
</tr>
<tr>
<td>$k_B=0.050$</td>
<td>8</td>
<td>44.5</td>
<td>1400</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>65.5</td>
<td>1400</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>85.5</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>99.5</td>
<td>1500</td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>111.0</td>
<td>900</td>
</tr>
</tbody>
</table>

Fig.2. Accumulation curve of tension

$C_{12} : \text{after 12 roll-stretching passes}$,
$C_{12-T} : \text{after the adjustment of tension}$,
$C_{12-C} : \text{after the adjustment of crown back}$.
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 \( \beta = 0.427 \). 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 0.280mm 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 \( C_{12-T} \) 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 \( \beta = 0.427 \). In addition, the accumulated amount of crown back \( C_s \) increases to 0.236mm.

**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 \( C_{12-C} \) 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 \( \beta = 0.427 \), and the maximum accumulated amount of tension \( T_{S,M} \) is 0.284mm at \( \beta = 0.385 \). The accumulated amount of crown back \( C_s \) is 0.190mm.

After the adjustment the point \( \beta \), 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)  

<table>
<thead>
<tr>
<th>Order</th>
<th>$x_k$ (mm)</th>
<th>Length $(l)$</th>
<th>$F_n$ (kgf)</th>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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)  

<table>
<thead>
<tr>
<th>Order</th>
<th>$x_k$ (mm)</th>
<th>Length $(l)$</th>
<th>$F_n$ (kgf)</th>
<th>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.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>5</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 $\beta$ and the increment $T_\Delta (\pm)$ or the decrement $T_\Delta (\mp)$ of tension.
2. Decide the increment $C_\Delta (\pm)$ or the decrement $C_\Delta (\mp)$ of crown back.

**RESTRICTION:** Roll-stretching pass in the ranges of $\alpha \leq 0.100$ and $\alpha \geq 0.950$ 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 $\alpha$ at which the maximum amount of tension appears at the point $\beta$. Using Equation (9), calculate the maximum value of tension $T_{\text{MAX}}$ at $\beta$.
③ Using Equation (6), calculate $\alpha$ at which the maximum amount of tension appears at the point $\beta$. Using Equation (10), calculate the maximum value of tension $T_{\text{MAX}}$ at $\beta$.
④ $T_{\text{MAX}}$ is the value under the assumption that $P_{A}L^{3}/(60DR)$ is equal to 1. Since the increment of tension is $T_{\Delta}$, calculate the effective roll-stretching force $F_{R \times E} = (P_{A}/k_{B})(T_{\Delta}/T_{\text{MAX}})$.
⑤ Using Equation (8), calculate $\alpha$ at which the minimum amount of tension appears at the point $\beta$.
⑥ Using Equation (12), calculate the minimum value of tension $T_{\text{MIN}}$ at $\beta$.
⑦ Using Equation (7), calculate $\alpha$ at which the minimum amount of tension appears at the point $\beta$. Using Equation (11), calculate the minimum value of tension $T_{\text{MIN}}$ at $\beta$.
⑧ Using Equation (7), calculate $\alpha$ at which the minimum amount of tension appears at the point $\beta$.
⑨ Using Equation (11), calculate the minimum value of tension $T_{\text{MIN}}$ at $\beta$.
⑩ Using Equation (8), calculate $\alpha$ at which the minimum amount of tension appears at the point $\beta$. Using Equation (12), calculate the minimum value of tension $T_{\text{MIN}}$ at $\beta$.
⑪ $T_{\text{MIN}}$ is the value under the assumption that $P_{A}L^{3}/(60DR)$ is equal to 1. Since the decrement of tension is $T_{\Delta}$, calculate the effective roll-stretching force $F_{R \times E} = (P_{A}/k_{B})(T_{\Delta}/T_{\text{MIN}})$.
⑫ Do you want to change the degree of crown back without changing the value of tension at $\beta$?
⑬ Under the roll-stretching force $F_{R \times E}$ at $\alpha$, calculate the increment or decrement of crown back $C_{\beta}$ by $C_{\beta} = 1.5b^{2}k_{B}F_{R \times E}(\alpha - 0.5)/L^2iE$.
⑭ Do you want to increase the degree of crown back?
⑮ Calculate $\alpha$ to increase the degree of crown back without changing the value of tension at $\beta$ by Equation (14).
⑯ Calculate $\alpha$ to decrease the degree of crown back without changing the value of tension at $\beta$ by Equation (13).
⑰ Calculate the increment or decrement of crown back $C_{\beta}$ by $C_{\beta} = C_{\Delta} - C_{\beta}$. In order to produce $C_{\beta}$ at $\alpha$, calculate the roll-stretching force $F_{R}$ by $F_{R} = C_{\beta}L^2iE/(1.5b^{2}k_{B}(\alpha - 0.5))$.

References
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

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

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