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ORIGINAL ARTICLE

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Calculation models of pressure and position of curved laminated veneer lumber in molds during pressing*

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Abstract Curved laminated veneer lumber (LVL) for use in furniture-making was produced from glue-coated pieces of rotary-cut veneers that were assembled and pressed between molds. Pressure was applied until glue-lines were set and finally held in an assembly of the desired curvature. Pressure was an important factor during pressing of curved LVL. In this study we deduced some equations for designing the shape of molds and calculating the total pressure from the mechanics. The results are summarized as follows: (1) The position angle of every section of curved LVL assembly in molds on the horizontal and the total pressure during pressing can be calculated in relation to the shapes and dimensions of the curved LVL. (2) The pressure distributions in the glue-line measured using pressure-sensitive film were in good agreement with the glue-line unit pressure provided for the experiment and calculation. Therefore, the equations deduced in this study were suitable for calculating the position angle and pressure of curved LVL in molds. (3) The total pressure on curved LVL was greater than the pressure on straight LVL. The total pressure consisted of the pressure on the glue-lines of straight LVL with the same length and width as curved LVL plus the supplementary pressure needed to bend the veneers. (4) The total pressures and position angles of curved LVL in molds were affected by the shape, bent angle, and length of each section of curved LVL.

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Key words Curved LVL · Mold · Position angle · Pressure

Introduction

When making and designing modern furniture, curved laminated veneer lumber (LVL) can provide a variety of functional and aesthetically pleasing wood members for furniture such as chairs, sofas, and tables.[1,2] The method used to produce curved LVL for use in furniture was to press the veneers in molds by bending and gluing and keep them at room temperature or at elevated temperatures.[1–3] The pressure was applied until glue-lines were set and finally held in an assembly of the desired curvature. Curved LVL members can be easily formed into many curved shapes (e.g., L, V, C, U, S, Z, O, h, X styles) with a small radius of curvature of the veneers during the bending and gluing operation. The position of curved LVL in molds, the shape of molds, and the pressure on glue-lines have important effects on the quality of curved LVL during pressing.[4–8]

To control these factors reliably, this study has dealt with the relation between the shape of molds and the pressure and deduced some equations for designing the shape of molds and calculating the total pressure of curved LVL in molds from the mechanical aspects.[9,10] The wooden molds were designed according to the results of our calculations using these equations and curved LVLs were produced using these molds. The pressure distributions in each section of curved LVLs were measured using pressure-sensitive film. When the total pressures (P) applied were the results of calculation using the pressure equations deduced, the glue-line unit pressure (p = 1MPa) provided for the experiment and calculation and the experimental results measured were compared. The influence of the main factors, such as the bent angle and each section length of curved LVL, on the pressure and position angle of curved LVL in molds was studied.

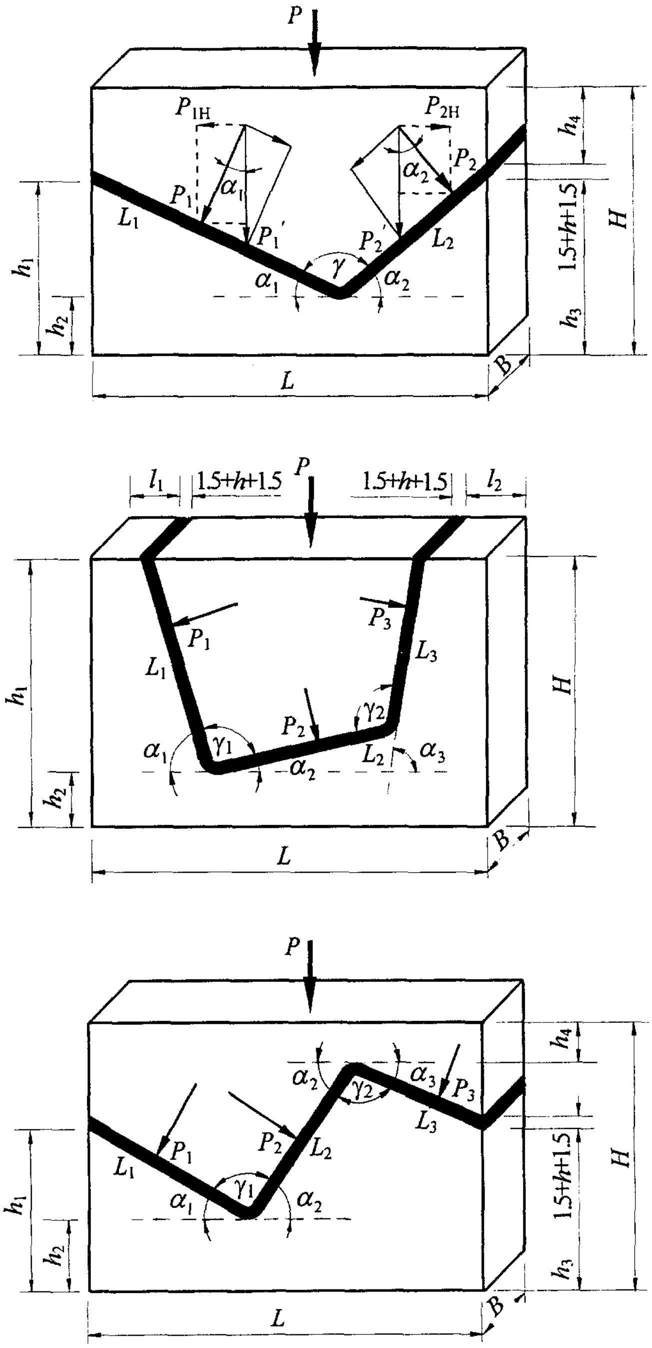

Fig. 1. Shape of molds and positions and pressures of curved LVLs. **a** L or V style. **b** U style. **c** Z style. P, total pressure; P_1, P_2, P_3, normal pressures on three sections of curved LVL; P_{1H}, P_{2H}, P_{3H}, horizontal pressures; P'_1, P'_2, P'_3, vertical pressures; B, width of curved LVL; L_1, L_2, L_3, three section lengths; γ, γ_1, γ_2, bent angles; α_1, α_2, α_3, position angles. The black line was curved LVL (thickness of h) and electrodes (thickness of 1.5mm) between the male mold and female mold

Theories and deductions

Position and pressure of L-style or V-style curved LVL in molds

The shape of the molds and the position of L- or V-style curved LVL in molds are shown in Fig. 1a.[4,5] When the radius of curvature was small, the curved part looked like the crossed part of two straight lines. To control the position of curved LVL in molds, the pressure of the glue-line, and the thickness of the curved LVL and to stabilize molds and not let them move horizontally during pressing, the sum of the horizontal pressures ($P_{1H} = BpL_1\sin\alpha_1$, $P_{2H} = BpL_2\sin\alpha_2$) on two sections should be zero. Therefore, the equation for the sum of the horizontal pressures can be written as follows:

$$L_1 \sin\alpha_1 - L_2 \sin\alpha_2 = 0 \qquad (1)$$

where α_1 and α_2 are the position angles of two sections of L- or V-style curved LVL in molds on the horizontal; L_1 and L_2 are the lengths of two sections; B is the width of curved LVL; and p is the unit pressure on the glue-line.

The relation between α_1, α_2, and the bent angle (γ) of curved LVL is given as

$$\alpha_2 = 180° - \gamma - \alpha_1 \qquad (2)$$

From Eqs. (1) and (2), the position angle α_1 of curved LVL in molds is represented as follows:

$$\alpha_1 = \tan^{-1}\left(\frac{L_2 \sin\gamma}{L_1 - L_2 \cos\gamma}\right) \qquad (3)$$

Pressures can be deduced from the mechanics as follows:

$$P = Bp\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2}\right) \qquad (4)$$

$$P_0 = Bp(L_1 + L_2) \qquad (5)$$

and

$$\Delta P = Bp\left\{\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2}\right) - (L_1 + L_2)\right\} \qquad (6)$$

where P is the total pressure of curved LVL in molds; P_0 is the pressure of straight LVL when the total length and width were the same as those of the curved LVL; and ΔP is the supplementary pressure or the difference in the pressures applied to curved LVL and straight LVL during pressing.

Position and pressure of U-style curved LVL in molds

The U-style curved LVL is made by whole male and female molds with all the pressure in one direction. The shape of these molds and the position of curved LVL in them are shown in Fig. 1b.[4] As stated above, to stabilize the molds and not allow them to move horizontally during pressing, the sum of the horizontal pressures on three sections should be zero. Therefore, the equation of the sum of the horizontal pressures is as follows:

$$L_1 \sin\alpha_1 - L_2 \sin\alpha_2 - L_3 \sin\alpha_3 = 0 \qquad (7)$$

where α_1, α_2, and α_3 are the position angles of three sections of U-style curved LVL in molds on the horizontal; and L_1, L_2, and L_3 are the lengths of three sections.

The relations between α_1, α_2, α_3 and the bent angles (γ_1, γ_2) of curved LVL can be given as

$$\alpha_2 = 180° - \gamma_1 - \alpha_1 \tag{8}$$

and

$$\alpha_3 = 360° - \gamma_1 - \gamma_2 - \alpha_1 \tag{9}$$

From Eqs. (7), (8), and (9), the position angle α_1 of curved LVL in molds is represented as follows:

$$\alpha_1 = \tan^{-1}\left\{\frac{L_2 \sin\gamma_1 - L_3 \sin(\gamma_1 + \gamma_2)}{L_1 - L_2 \cos\gamma_1 + L_3 \cos(\gamma_1 + \gamma_2)}\right\} \tag{10}$$

Pressure equations also can be represented as:

$$P = Bp\left\{\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2} + \frac{L_3}{\cos\alpha_3}\right)\right\} \tag{11}$$

$$P_0 = Bp(L_1 + L_2 + L_3) \tag{12}$$

and

$$\Delta P = Bp\left\{\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2} + \frac{L_3}{\cos\alpha_3}\right) - (L_1 + L_2 + L_3)\right\} \tag{13}$$

Position and pressure of Z-style curved LVL in molds

The Z-style curved LVL is made by whole male and female molds with the total pressure in one direction. The shapes of these molds and the position of the curved LVL in the molds are shown in Fig. 1c.[4] As stated above, to stabilize the molds and not allow them to move horizontally during pressing, the equation of the sum of the horizontal pressures on three sections and the relations between α_1, α_2, α_3 and bent angles (γ_1, γ_2) of Z-style curved LVL can be written as follows:

$$L_1 \sin\alpha_1 - L_2 \sin\alpha_2 + L_3 \sin\alpha_3 = 0 \tag{14}$$

$$\alpha_2 = 180° - \gamma_1 - \alpha_1 \tag{15}$$

and

$$\alpha_3 = \gamma_1 - \gamma_2 + \alpha_1 \tag{16}$$

The position angle α_1 of curved LVL in molds and the pressures can be deduced from Eqs. (14), (15), and (16).

$$\alpha_1 = \tan^{-1}\left\{\frac{L_2 \sin\gamma_1 - L_3 \sin(\gamma_1 - \gamma_2)}{L_1 - L_2 \cos\gamma_1 + L_3 \cos(\gamma_1 - \gamma_2)}\right\} \tag{17}$$

$$P = Bp\left\{\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2} + \frac{L_3}{\cos\alpha_3}\right)\right\} \tag{18}$$

$$P_0 = Bp(L_1 + L_2 + L_3) \tag{19}$$

and

$$\Delta P = Bp\left\{\left(\frac{L_1}{\cos\alpha_1} + \frac{L_2}{\cos\alpha_2} + \frac{L_3}{\cos\alpha_3}\right) - (L_1 + L_2 + L_3)\right\} \tag{20}$$

Table 1. Shape and dimensions of curved LVLs

LVL no.	LVL style	Dimensions (mm)				Bent angle (°)	
		B	L_1	L_2	L_3	γ_1	γ_2
1	L	400	280	320	–	95	–
2	L	150	500	700	–	95	–
3	V	400	420	420	–	45	–
4	V	300	600	600	–	60	–
5	L	300	720	720	–	90	–
6	L	300	650	650	–	150	–
7	U	300	600	450	600	115	115
8	U	300	700	400	600	108	120
9	Z	300	700	400	220	94	105
10	Z	300	500	420	450	95	95

B, L_1, L_2, L_3, γ_1, γ_2: see Fig. 1
The thickness (h) and curvature radius of curved LVL were 22mm and 42mm, respectively

Experiments

Shape and dimensions of curved LVL

The shapes of the curved LVLs produced here were L, V, U, and Z styles, as shown as in Fig. 1. The thickness and moisture content of rotary-cut veneers produced from massion pine (*Pinus massoniana* Lamb.) were 1.2 mm and 8%–12%, respectively. The type of glue used in this study was urea formaldehyde (UF) resin with a solid content of 61%–62%. The amount of the adhesives applied by a hand roller to the veneers was 200 g/m^2 (single spread).[1,3] There were 22 veneers, so the curved LVL was maintained at 22mm thickness. The inside curvature radius of curved LVL in the curved part was 42mm. The shapes, bent angles, and dimensions of curved LVLs are shown in Table 1.

Molds and pressure

According to the calculated results of the position angles of curved LVL in molds on the horizontal, the wooden molds were made of pairs of male and female forms, with the sheets of thick plywood routed or spindled to shape and then bolted or doweled together. The working faces of the molds were covered with aluminum electrodes that could carry radiofrequency (RF) currents.[7] The clearance between the male mold and the female mold was 25mm (each of the two electrodes was 1.5mm). The curvature radius of the convex part of the molds was 40.5mm. The total pressure (P) of calculation using the pressure equations deduced above (the unit pressure provided for the experiment and calculation was 1 MPa) were applied to the glue-line by a hydraulic press under a one-step hot-pressing curve with RF heating.[1–3]

Table 2. Dimensions of molds and positions of curved LVLs in molds

LVL no.	LVL style	Dimensions (mm)									Position angle (°)		
		B	H	h_1	h_2	h_3	h_4	L	l_1	l_2	α_1	α_2	α_3
1	L	400	565	380	180	380	160	445	–	–	46.0	39.0	–
2	L	150	755	570	180	570	160	895	–	–	51.2	33.8	–
3	V	400	835	610	220	610	200	325	–	–	67.5	67.5	–
4	V	300	965	740	220	740	200	600	–	–	60.0	60.0	–
5	L	300	915	710	200	710	180	1020	–	–	45.0	45.0	–
6	L	300	505	335	165	335	145	1260	–	–	15.0	15.0	–
7	U	300	770	770	200	–	–	1345	180	180	65.0	0	65.0
8	U	300	850	850	200	–	–	1315	180	180	63.0	9.0	69.0
9	Z	300	755	496	200	496	180	1045	–	–	25.0	61.0	14.0
10	Z	300	776	395	200	395	180	1072	–	–	23.0	62.0	23.0

B, H, h_1, h_2, h_3, h_4, L, l_1, l_2, α_1, α_2, α_3: see Fig. 1

The thickness (h) and curvature radius of the curved LVL were the same as those in Table 1. The angles of molds (γ_1, γ_2) were the same as those of the curved LVLs in Table 1

Effect of factors on the position and pressure of curved LVL in molds

The pressure distributions in the glue-line of each section of the curved LVLs were measured using pressure-sensitive film.[11,12] The glue-line unit pressure (p = 1 MPa) provided for the experiment and calculation was compared with the experimental results. From the calculated results using the equations deduced under the various curved LVL shapes, the effects of the main factors, such as the bent angle (γ_n) and the length (L_n) of each section of curved LVL, on the position angle and pressure of curved LVL in molds were studied.

Results and discussion

Shape of mold and position of curved LVL in molds

The position of the curved LVL in molds could be expressed by the position angles (α_ns) of each section of curved LVL on the horizontal. First, these angles were calculated using Eqs. (2), (3), (8)–(10), and (15)–(17) deduced from the mechanical theory. Then the wooden molds were designed according to the bent angles (γ_ns), lengths (L_ns), and position angles (α_ns) of each section of curved LVL. The parameters of the shapes of molds and the positions of curved LVL in molds for the various curved LVL shapes (L, V, U, and Z) are shown in Table 2.

According to the data in Table 2, the end positions of the two sections of L-, V-, and Z-style curved LVLs in molds on the horizontal were the same ($h_1 = h_3$). In L- or V-style curved LVL, according to Tables 1 and 2, the position angles (α_1, α_2) of two sections of curved LVL in molds were similar to each other when the lengths (L_1, L_2) of the two sections were the same. When the length (L_2 in Table 1) of one section of L-style curved LVL was greater than that of another section, the position angle (α_2 in Table 2) of this section was smaller than that of the other section. The position angles (α_1 and α_2 in Table 2) of L- or V-style curved LVL in molds decreased with an increase in the bent angle (γ_1 in Table 1) of the curved LVL.

In U-style curved LVL, when the bent angles (γ_1, γ_2) and lengths (L_1, L_3) of two side sections were the same, the position angles (α_1, α_3) of the two side sections of curved LVL in molds were the same. The position angle (α_2) of the center section of curved LVL in molds was zero.

In Z-style curved LVL, the position angles (α_1, α_3) of two side sections of curved LVL in molds were the same when the bent angles (γ_1, γ_2) of curved LVL were the same. The position angle (α_2) of the center section of curved LVL in molds, however, was not zero.

Pressures of curved LVL in molds

The pressures (P, P_0) and supplementary pressure (ΔP) were calculated using Eqs. (4)–(6), (11)–(13), and (18)–(20) deduced from the mechanical theory. The practical pressure distributions (p_1, p_2, p_3) in the glue-line of each section of curved LVL were measured using pressure-sensitive film.[11,12] The glue-line unit pressure (p = 1 MPa) provided for the experiment and calculation and the experimental results were compared. The percents ($\Delta P/P$, $\Delta P/P_0$) of supplementary pressure added to the total pressure are shown in Table 3.

According to the data in Table 3, the unit pressure distributions (p_1, p_2, p_3) in the glue-line measured using pressure-sensitive film were in good agreement with the glue-line unit pressure (1 MPa) provided for the experiment and calculation when the total pressures (P) of the calculation using Eqs. (4), (11), and (18) were applied. Thus, the equations deduced in this study were suitable for calculating the position angle and pressure of curved LVL in molds. The equation representing the total pressure (P) can be written as:

$$P = Bp\sum\left(L_n/\cos\alpha_n\right) \qquad (21)$$

where p is the unit pressure of the glue-line, B is the width of the curved LVL, n is the number of curve sec-

Table 3. Pressures of curved LVL in molds

LVL no.	LVL style	Glue-line pressure (MPa)				Calculated pressure (kN)						$\Delta P/P$ (%)	$\Delta P/P_0$ (%)
		p_1	p_2	p_3	p	P_1	P_2	P_3	P_0	P	ΔP		
1	L	1.01 (0.04)	1.02 (0.03)	–	1.00	112	128	–	240	326	86	26.4	36.7
2	L	0.99 (0.05)	1.01 (0.06)	–	1.00	75	105	–	180	246	66	26.8	35.8
3	V	1.11 (0.03)	1.12 (0.05)	–	1.00	168	168	–	336	878	542	61.7	116.3
4	V	1.10 (0.07)	1.09 (0.04)	–	1.00	180	180	–	360	720	360	50	100
5	L	1.05 (0.05)	1.04 (0.03)	–	1.00	216	216	–	432	611	179	29.3	41.4
6	L	0.99 (0.06)	0.98 (0.08)	–	1.00	195	195	–	390	404	14	3.4	3.6
7	U	1.06 (0.07)	1.02 (0.05)	1.05 (0.08)	1.00	180	135	180	495	987	492	49.8	99.4
8	U	1.08 (0.06)	1.01 (0.04)	1.09 (0.05)	1.00	210	120	180	510	1087	577	53.1	113.1
9	Z	0.98 (0.04)	1.02 (0.03)	0.99 (0.06)	1.00	210	120	66	396	547	151	27.6	38.1
10	Z	0.97 (0.06)	1.01 (0.02)	0.99 (0.03)	1.00	150	126	135	411	654	243	28.9	40.7

p_1, p_2, p_3, experimental measurement values of the glue-line unit pressure for each section of curved LVL; p, provided glue-line unit pressure for experiment and calculation; P_1, P_2, P_3, calculated pressures in each section of curved LVL ($P_1 = BpL_1$; $P_2 = BpL_2$; $P_3 = BpL_3$; B, L_1, L_2, L_3, see Fig. 1); $P, P_0, \Delta P$, calculated pressures with Eqs. (3)–(5), (9)–(11), (15)–(17)
Each measurement value is the average of five tests. Values in parentheses represent standard deviations

tions of the curved LVL, and α_n and L_n are the position angle and length of each section.

As shown in Table 3, the total pressure (P) on curved LVL was greater than the pressure (P_0) on straight LVL that the total length and width were the same as those of the curved LVL. The total pressure (P) consisted of the glue-line pressure (P_0) of straight LVL with the same length and width as curved LVL and the supplementary pressure (ΔP) needed to bend the veneers.[2,4]

For L- or Z-style curved LVL the percents of the supplementary pressure added to the pressure on curved LVL in molds, $\Delta P/P$ and $\Delta P/P_0$, were approximately 30% and 40%, respectively (Table 3), when the bent angles (γ_1 and γ_2 in Table 1) of curved LVL were 90°–105°. For L- or V-style curved LVL, the pressure decreased ($\Delta P/P$ from 61.7% to 3.4%; $\Delta P/P_0$ from 116.3% to 3.6%) with an increase in the bent angle (γ_1 in Table 1) of curved LVL from 45° to 150°.

For U-style curved LVL, when the curve angles (γ_1 and γ_2 were approximately 110°) and the lengths (L_1, L_3) of two side sections of curved LVL were the same, $\Delta P/P$ and $\Delta P/P_0$ were almost 50% and 100%, respectively. The supplementary pressure (ΔP) needed to bend the veneers could be said to be approximately equal to the glue-line pressure (P_0) of straight LVL with the same length and width as curved LVL.[13,14]

In addition, for Z-style curved LVL, when the two bent angles (γ_1, γ_2) of curved LVL were the same, the position angles and pressures of curved LVL in molds could be calculated using equations deduced for L- or V-style curved LVL. [The sum of the lengths of two side sections ($L_1 + L_3$) was considered to be the length (L_1) of L- or V-style curved LVL[4] because two side sections (L_1, L_3) of the curved LVL were parallel.]

Effect of position and pressure of curved LVL in molds

From the equations deduced above, it was apparent that the position angle (α_n) of curved LVL in molds was affected mainly by the shape and dimensions of the curved LVL, such as the length (L_n) of each section and the bent angle (γ_n) of the curved LVL. The total pressure (P) of curved LVL in molds was affected by these factors (L_n, γ_n), the width (B) of the curved LVL, and the unit pressure (p) on the glue-line. The supplementary pressure (ΔP) needed to bend the veneers, or the difference in the pressure between curved LVL and straight LVL during pressing, also was affected mainly by the length (L_n) of each section and the bent angle (γ_n) of the curved LVL.

The effects of the main factors such as the length (L_1, L_2) of each section and bent angle (γ) of L- or V-style curved LVL on the position angle and pressure of curved LVL in molds are shown in Figs. 2 and 3. According to these figures, the position angles (α_1, α_2) were the same when the lengths of two sections of curved LVL were the same ($L_1/L_2 = 1$). The position angle (α_1) increased with a decrease in the ratio of the two section lengths (L_1/L_2) of L- or V-style curved LVL. In contrast, the position angle (α_2) decreased with a decrease in the ratio of the two section lengths (L_1/L_2). In Fig. 2, the position angles (α_1, α_2) of each section of L- or V-style curved LVL in molds decreased with an increase in the bent angle (γ) of curved LVL. When the bent angle (γ) of curved LVL decreased from 80° to 45°, the total pressure (P) and supplementary pressure (ΔP) of curved LVL in molds, and the percent ($\Delta P/P_0$) of the supplementary pressure to the pressure needed for straight LVL increased rapidly and significantly. In Fig. 3, the pressures (P, P_0) and supplementary pressure (ΔP) needed for curved LVL in molds increased significantly when the ratio of the two section lengths (L_1/L_2) of curved LVL decreased from 0.75.

The relations between the position angles (α_1, α_2, α_3) or pressures of U- and Z-style curved LVL in molds and the bent angle (γ_1 or γ_2) are shown in Figs. 4 and 5. The results showed that three position angles (α_1, α_2, α_3) of U-style curved LVL in molds and two position angles (α_1, α_2) of Z-style curved LVL in molds decreased with an increase in the bent angle (γ_1 or γ_2). However, the position angle (α_3) of Z-style curved LVL in molds increased with an increase in the bent angle (γ_1 or γ_2). In U-style curved LVL, the total pressure (P) and supplementary pressure (ΔP) of curved LVL in molds and the percent ($\Delta P/P_0$) of the supplementary pressure to the pressure needed for straight LVL increased

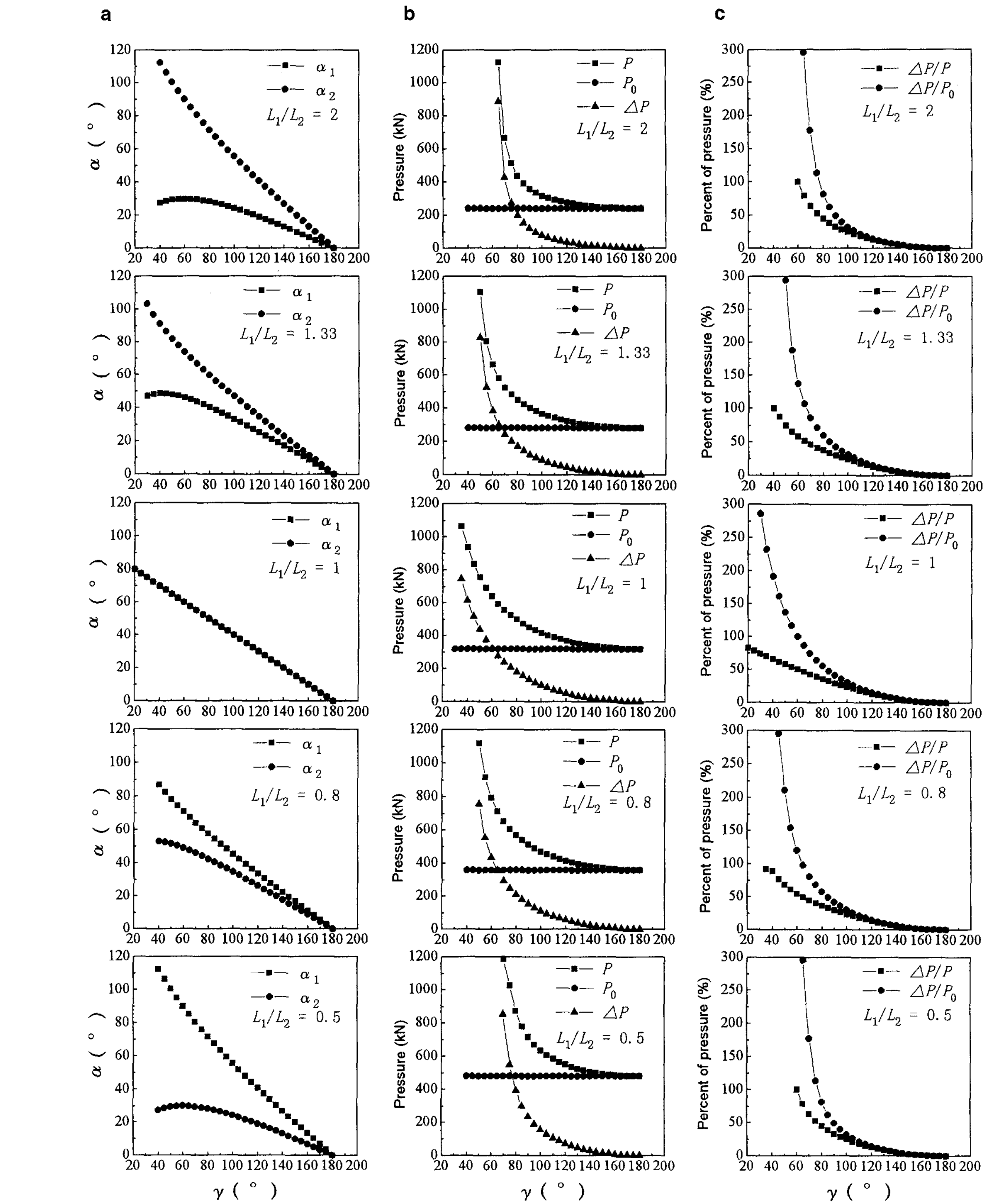

Fig. 2. Effects of bent angles (γ) and length ratios (L_1/L_2) on the position angle (**a**), pressure (**b**), and percent of pressure (**c**) of L- and V-style curved LVLs in molds. α_1, α_2, position angles; L_1, L_2, two section lengths of curved LVL; P, total pressure of curved LVL; P_0, pressure of straight LVL with the total length and width the same as those of the curved LVL; ΔP, supplementary pressure. $B = 400\,\text{mm}$; $L_1 = 400\,\text{mm}$

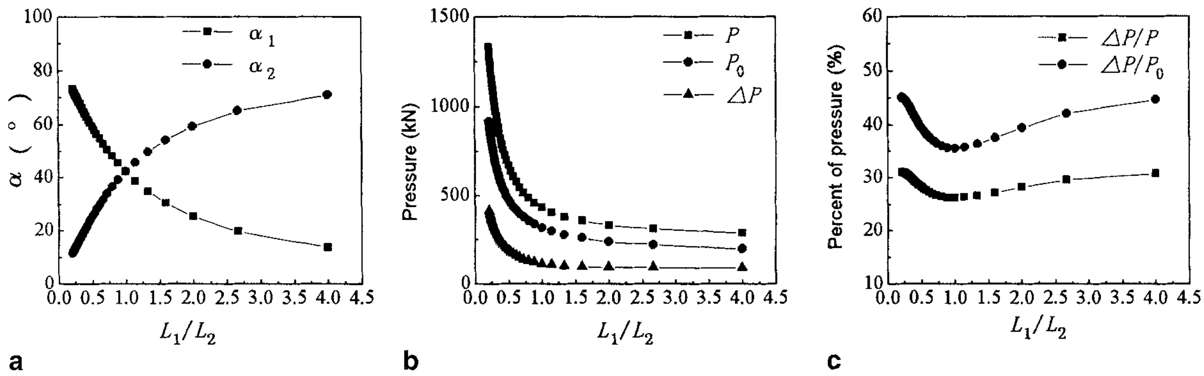

Fig. 3. Effects of the length ratios (L_1/L_2) on the position angle (**a**), pressure (**b**), and percent of pressure (**c**) of L- and V-style curved LVLs in molds. B = 400 mm; L_1 = 400 mm; γ = 95°

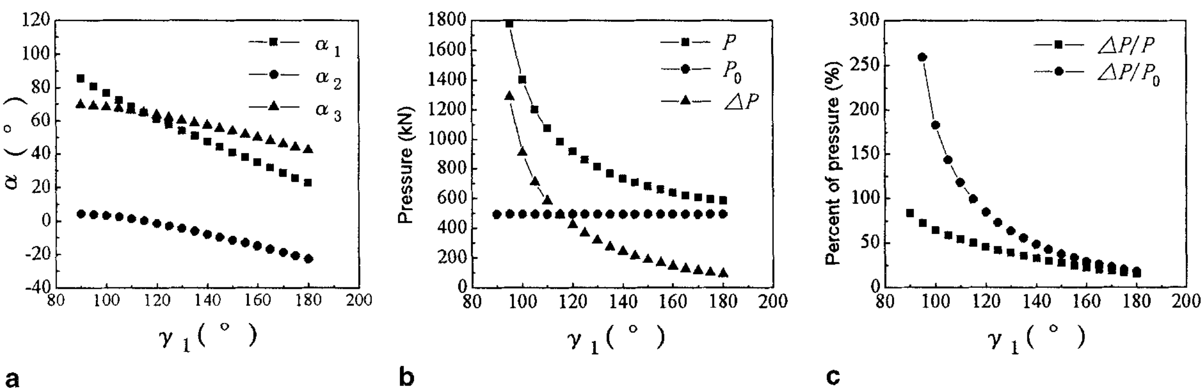

Fig. 4. Effects of the bent angle (γ_1) on the position angle (**a**), pressure (**b**), and percent of pressure (**c**) of U-style curved LVL in molds. α_1, α_2, α_3, position angles; B = 300 mm; L_1 = 600 mm; L_2 = 450 mm; L_3 = 600 mm; γ_2 = 115°

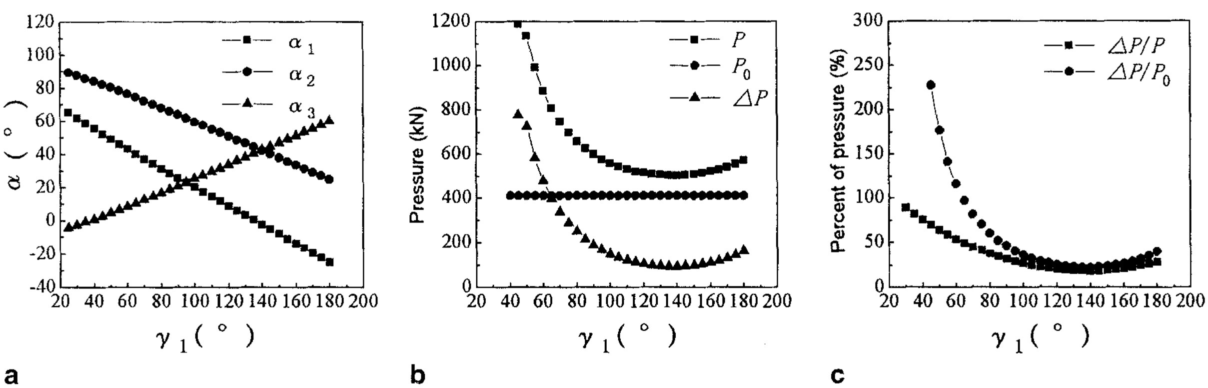

Fig. 5. Effects of the bent angle (γ_1) on the position angle (**a**), pressure (**b**), and percent of pressure (**c**) of Z-style curved LVL in molds. B = 300 mm; L_1 = 500 mm; L_2 = 420 mm; L_3 = 450 mm; γ_2 = 95°

rapidly and significantly when the bent angle (γ_1 or γ_2) was less than approximately 110°. Therefore, suitable bent angles (γ_1, γ_2) of U-style curved LVL in molds are larger than approximately 110° when the U-style curved LVL is made in the whole male and female molds with the pressure in a single direction. Otherwise, the U-style curved LVL should be made by a whole male mold and the multi-section female molds with the pressure in multiple directions. In contrast, the L-, V-, and Z-style curved LVLs generally are made in the whole male and female molds with the pressure in one direction, though the length (L_n) of each section and the bent angle (γ_n) of curved LVL have a greater effect on the position angle and pressure of curved LVL in molds during pressing.

Conclusions

The results obtained from this study are as follows.

1. The position of curved LVL in molds can be expressed by the position angle (α_n) of each section of curved LVL on the horizontal plane. These position angles can be calculated in relation to the length (L_n) of each section and the bent angle (γ_n) of the curved LVL.

2. The total pressure (P) of curved LVL in molds during pressing can be calculated by the following equation: $P = Bp\Sigma(L_n/\cos\alpha_n)$, where p is the unit pressure on the glue-line, B is the width of the curved LVL, n is the number of curve sections of curved LVL, and L_n is the length of each section.

3. When the total pressures (P) applied were the results of calculation using the pressure equations deduced, the pressure distribution in the glue-line measured using pressure-sensitive film was in good agreement with the glue-line unit pressure provided for the experiment and calculation. Therefore, the equations deduced in this study were suitable for calculating the position angle and pressure of curved LVL in molds.

4. The total pressure (P) on curved LVL was greater than the pressure (P_0) on straight LVL of the same length and width. The total pressure (P) consisted of the pressure (P_0) on straight LVL and the supplementary pressure (ΔP) needed to bend the veneers.

5. The total pressure and position angle of curved LVL in molds were affected by shape and dimension, such as the length (L_n) of each section and the bent angle (γ_n) of the curved LVL.

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