An experimental Study on the Running Stability of Double-edge cutting Bandsaw Blade

Division of Wood Physics, Section III Hikoichi SUGIHARA

(*Received May 31, 1956*)

This paper is the 2nd report of "Studies on Sawing with Double-ege cutting Bandsaw", the co-operative investigation with Mr. Osamu DOI (Department of Engineering, Hokkaido University), Mr. Shigeru KIKUKAWA (KIKUKAWA Iron Works Co. Ltd.), Mr. Isamu SAITO. (FUJI Seisakusho Ltd.), and Mr. Shōzō TANIJIRI (AKITA Lumber Co. Ltd.). An abstract is to be published in the Journal of Japan Wood Research Society with the 1st report of this investigation in Japanese. This study was done mainly by H. Sugihara.

§ 1. Introductory Remarks

The problem of running stability of double-edge cutting bandsaw, as shown in the first theoretical report, is to be sufficiently treated through discussing x (the backward displacement of saw blade on the upper wheel from the situation hanging symmetrically) and s (the amount of retrocession on the lower wheel in comparison with the situation on the upper one).

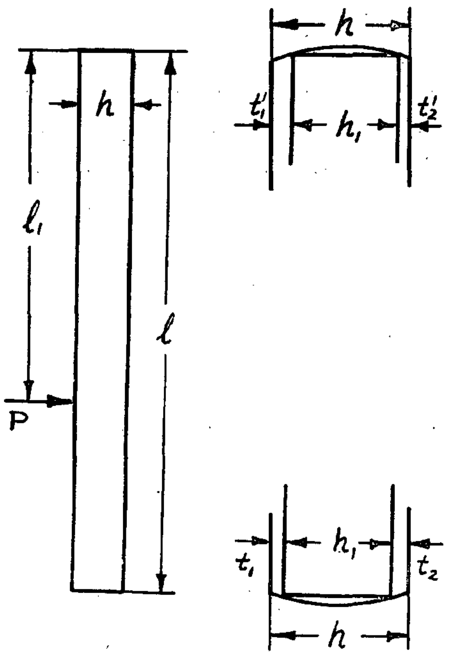


Fig. 1

In this study, measurement are made in the state of rest of t_1' and t_1, shown in Fig. 1, instead of x and s, after the machine has been run under every one condition. The relations between t_1', t_1 and x, s are as follows.

$$\left.\begin{aligned} t_1' &= \frac{h-h_1}{2} - x \\ t_1 &= \frac{h-h_1}{2} - (x+s) \end{aligned}\right\} \quad \cdots\cdots\cdots(1)$$

h : the width of saw blade
h_1 : the width of wheel

Accordingly, t_1' is the amount of hanging over forward on the upper wheel and t_1 the one on the lower wheel.

The problem about the difference between the amount in the state of running and and the one in rest will be discussed lately in § 3. But the t_1', t_1 in the state where feeding force P is acting, should be measured in running. But on account of difficulty of this measurement the displacement x_P was measured at the point acting of feeding force P. (l_1 : the distance from the centre line of upper wheel to this point) From this x_P is estimated the displacement x caused only by P. This x_P is described by x and y_{l1} (deflection of sawblade at l_1) as follows.

$$x_P=(x+y_{l1})_{P=P}-(x+y_{l1})_{P=0} \quad \cdots\cdots(2)$$

Hereupon, x, s and y_{l1} are expressed as follows as shown in the first report.

$$x=\frac{1}{U+Q}\left\{\frac{V}{2(U+V+Q)}\frac{l_1^2(l-l_1)}{l^2}P-\frac{4U+V+4Q}{U+V+Q}\cdot\frac{EI}{l}\alpha+\frac{EI}{R}\right.$$
$$\left.-\frac{EI\alpha_1}{h}T-\frac{V\cdot W}{2(U+V+Q)}(\omega'-\omega)+W\omega'\right\} \quad \cdots\cdots(3)$$

$$s=\frac{1}{U+V+Q}\left\{\frac{l_1^2(l-l_1)}{l^2}P+\frac{6EI}{l}\alpha-W(\omega'-\omega)\right\} \quad \cdots\cdots(4)$$

$$y_{l1}=\frac{l_1^3(l-l_1)^3}{3EI\,l^3}P+\frac{l_1^2(3l-2l_1)}{l^3}s+\frac{l_1(l-l_1)^2}{l^2}\alpha \quad \cdots\cdots(5)$$

So x_P is expressed as follows.

$$x_P=\left\{\frac{V}{2(U+V+Q)(U+Q)}\frac{l_1^2(l-l_1)}{l^2}\right.$$
$$\left.+\frac{1}{U+V+Q}\frac{l_1^4(l-l_1)(3l-2l_1)}{l^5}+\frac{l_1^3(l-l_1)^3}{3EI\,l^3}\right\}P \quad \cdots\cdots(6)$$

It is clear in double-edge cutting bandsaw that stretching for giving back radius (R), inclination of upper wheel (α), wheel's surface being tapered ($2\omega'$), such things are undesirable. Consequently, we should intend to make saw running stabilize presupposing $R=\infty$, $\alpha=0$, and $\omega=\omega'=0$. Being $R=\infty$, $\alpha=0$ and $\omega=\omega'=0$, the equations (3), (4) are reduced to the next.

$$x=\frac{1}{2(U+Q)\left(1+\frac{U+Q}{V}\right)}\frac{l_1^2(l-l_1)}{l^2}P \quad \cdots\cdots(3)_P$$

$$s=\frac{1}{V\left(1+\frac{U+Q}{V}\right)}\frac{l_1^2(l-l_1)}{l^2}P \quad \cdots\cdots(4)_P$$

Thus the factors effecting the running stability are to be such four ones as feeding force P, the value calculated by stiffness of saw blade V, $U=\frac{E}{\mu}\cdot\frac{b^{5/2}}{r}\cdot\frac{h_1}{\sqrt{a}}$ (E: Young modulus, $\mu=\sqrt[4]{1-\nu^2}$, ν: Poisson ratio, $\boldsymbol{b}$: thickness of saw blade, $\boldsymbol{r}$: radius of tensioning, $\boldsymbol{a}$: radius of wheel), and pulling force $\boldsymbol{Q}$. Being understood from eqs. $(3)_P$ and $(4)_P$, the larger $U+Q$ and V, the more stabilized the saw running should be. In other words this comes to such very conventional conclusion as the thicker and wider sawblade and the larger tensioning, the more stabilized.

But there may be other unknown factors than these adopted as the objects of theoretical investigation. Thus we, from the points of view described as above, have experimented the effects of P, Q, α, b and r on the running stability of saw blade and weighed the results with the theories in the first report.

§2 Methods of experiments

Bandsaw machine used: a table bandsaw machine with 42″ wheels [usual type for single-edge cutting],
width of wheel $h_1=121.4\ mm$,
normal running speed 860 *r. p. m.*,
distance between the two shaft of wheels $l=1885\ mm$,
inclination angle of lower wheel $\alpha'=0$,
magnifying power for pulling force 74.

Saw blades used: Six pieces of saw blades were used in this experiment with no back and not punched. In table 1 are shown width, thickness and hardness of Shore of each sawblade.

Table 1.

saw blade	h *mm* width of blade			b *mm* thickness of blade			H.S. hardness of Shore
	min.	mean	max.	min.	mean	max.	
A_1	155.73	155.758	155.83	0.89	0.912	0.94	63
K_1	153.06	153.139	153.24	1.24	1.253	1.27	59
K_2	152.69	152.963	153.03	1.06	1.097	1.14	60
K_3	151.43	151.587	151.69	0.83	0.862	0.90	61
K_4	152.42	152.891	152.98	0.79	0.822	0.85	61
K_5	152.60	152.645	152.72	0.69	0.707	0.74	62

A_1 blade is made in Sweden, ASSAB's make.
$K_1 \sim K_5$ blades are home made.

Feed force: Feed force P is given by pressing the ball bearing $\boldsymbol{A}$ against saw blade as shown in fig. 2. In fig. 2, $\boldsymbol{A}$ is a ball bearing, its diameter 120 *mm* and $\boldsymbol{B}$ is a rod holding the bearing $\boldsymbol{A}$ at one end and the other end connected with frame $\boldsymbol{D}$ by spring $\boldsymbol{C}$. The magnitude of P is measured by

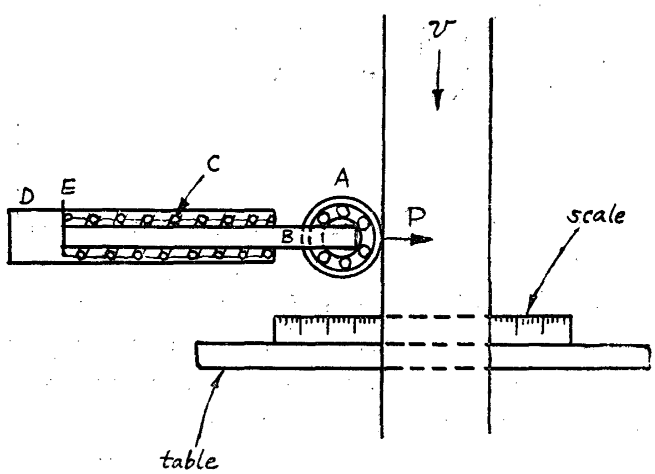


Fig. 2

indicating the elongation of spring ***C*** with an indicator ***E***. This elongation has been calibrated in kilogram.

P was given at four steps — 3.5, 5.5, 8.0 and 10.5 *kg* — every times at the front backward (α, $\omega'>0$) and also at the rear forward (α, $\omega'<0$). Loaded point with P is $l_1=1165\ mm$.

Pulling force: Pulling force Q is calculated by the equation (7).

$$Q=\frac{W_0\cdot n-G}{2} \qquad \cdots\cdots(7)$$

Here W_0 : weight hung on lever

n : magnifying power 74

G : effective weight of pulling lever mechanism (including upper wheel) -40 *kg*.

Pulling forces given are indicated in table 2.

Table 2

saw blade	A1			K1	K2	K3	K4	K5
Q *kg*	1260	950	560	1260	1100	870	870	720
σ_t kg/mm^2	8.9	6.7	3.9	6.6	6.6	6.7	6.9	6.7

Three kinds of pulling force were given to the sawblade A_1 and for the sawblade $K_1 \sim K_5$ the lever were weighed so as to give the same pulling stress $\sigma_t=6.6\ kg/mm^2$.

Tensioning: Tension radius r of each sawblade is calculated from the equation (8) by measuring ΔH in fig. 3 with micro-depthgauge, supposing that the section of sawblade is circular arc on account of tensioning.

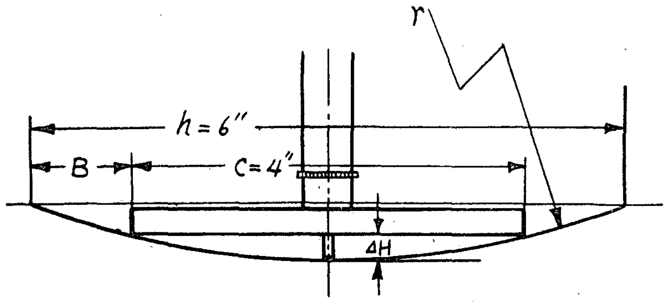


Fig. 3

$$r=\frac{c^2}{8\ \Delta H} \qquad \cdots\cdots(8)$$

At every one section were measured three points varying ***B*** in fig. 3 as 2″, 3″, and 4″. Ten sections for each one sawblade are unselectively taken and the mean value of these is indicated in fig. 4, taking as the axis of abscissa ρ the other radius of principal curvatures — the radius of curvature along the direction of saw length.

In this experiment the diameter of wheel is 42″, and so the tension radius r to be used in theoretical calculations should be the one at $\rho=53\ cm$.

When the sawblade is bent, the deformation in sectional direction is made only in both edges in the case of no tension, while the width of blade is sufficiently so wide

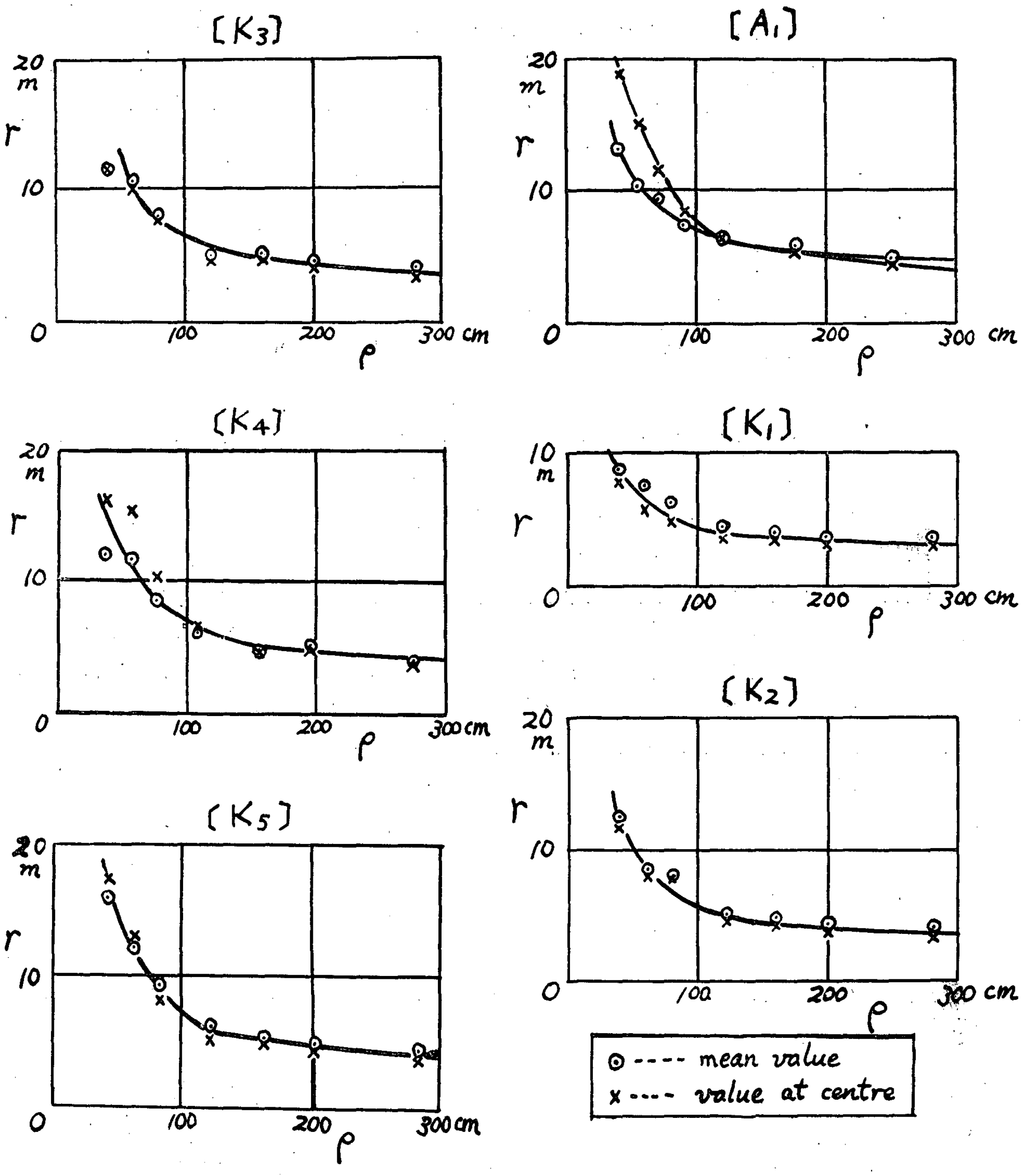


Fig. 4

comparing with the thickness. Thus in this case we may regard the radius as ∞.

Inclination angle of upper wheel : Inclination angle α is calculated by measuring ΔB and L shown in fig. 5, using the bob $\boldsymbol{B}$. One revolution of handle shaft operating the inclination is equivalent to $\alpha=1.2\times10^{-3}$ *radian*.

Measurment of t_1' and t_1 : After the machine has been run under every one condition, the values of t_1' and t_1 at three points — immediatly after running in, uppermost, and just before running out — were measured in the state of rest and the average of them were taken.

Measurement of x_P : A scale is put on the table inside the sawblade, as shown

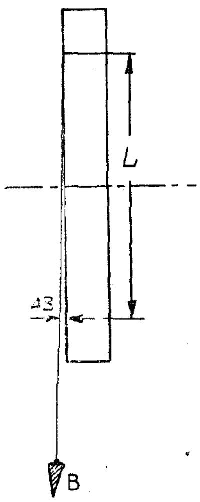


Fig. 5

in fig. 2, and the displacement of back line of sawblade was observed from the side.

Tapered angle of wheel surface: It is to desired that ω' and ω are equal to O, but on account of working error the value of both ω' and ω were 1.7×10^{-3} *radian.*

§ 3 The results of experiment and the discussion on them

Before the results of experiment are discussed, some problems about this experiment should be described.

Taper angle of wheel surface: This is an undesirable working error and it has been acertained that this angle, even though small, effects very sensitively on the position of stable running. Such a small error as 1.7×10^{-3} *radian* in this experiment displaces the position about 8∼10 *mm* as shown in table 3.

This fact shows that the bandsaw machine should be worked very precisely.

The values of x calculated from the theoretical equation in the first report, that is, putting $P=0$, $\alpha=0$, $R=\infty$, $T=0$ and $\omega=\omega'$ in the equation (3), and the ones of x obtained in this experiment are recorded comparatively in table 3. Both theoretical and experimental are sufficiently close.

Table 3

x	experimental	9.0	9.0	11.5	7.4	—	7.5	—	9.5	—	10.7	16.8	10.0	17.1
mm	theoretical	8.2	9.9	13.2	7.5	19.6	7.9	15.9	8.5	16.2	9.2	14.7	9.0	14.5
		$Q=$ 1260 (kg)	$Q=$ 950	$Q=$ 560	$r=7.3$ (m)	$r=\infty$	$r=9.3$	$r=\infty$	$r=$ 10.6	$r=\infty$	$r=$ 14.8	$r=\infty$	$r=$ 13.6	$r=\infty$
saw blade		A_1 ($r=15.1m$)			K_1		K_2		K_3		K_4		K_5	

State of contact of sawblade and wheel surface: In the first theoretical study we have assumed the two states of contact, the line contact (U) and the areal contact (U'). But the fact is considered to be that the larger Q, the larger r and the smaller b, the nearer the state is to the latter and in the contrary case nearer to the former.

In this paper in comparing the experimental and theoretical the line contact, U, is taken in calculation, if without notice.

Among the magnitudes of U, V, Q and U' in this experiment only V is widely larger than the others. So employment of either U or U' in the theoretical calculation does not effect so much on s, but does considerably on x, when Q is small.

Effects of centrifugal force: The values of t_1' and t_1 or x and s are measured not in the running state but in the rest. The different effects on the stable position of running from the rest may be considered, excepting the infinitesimal vibration, to be only the fact that the centrifugal force increases the pulling force Q.

The centrifugal forces of saw blade in this experiment at the running speed of 860 *r. p. m.* are shown in table 4.

Table 4

saw blade	A_1	K_1	K_2	K_3	K_4	K_5
centrifugal force ΔQ (*kg*)	260	350	310	240	230	200

This effects may be small on s, but large on x.

Checking the effects on x, the results are shown in table 5. It cannot be measured correctly in the running state, but both do not indicate the wide difference.

Table 5

A_1 $\binom{\alpha=8.4\times10^{-3}}{P=0}$		$Q=1260$		$Q=560$	
		in rest	in running	in rest	in running
t_1'	experimental	23.8	23～24	24.8	23.5～24.5
mm	theoretical	17.9	18.0	17.5	17.7

The others : In actual sawing it may be produced the temperature gradient in the direction of saw section. This has a great effect on the running stability as shown in the first theoretical study and also on the problem of buckling. So we should investigate this problem, but the methods of experiment and measurement are so much difficult that it was not able to be taken in this study.

Thus in this study it may be considered to be $T=0$ and also $R=\infty$.

The wheel is newly made and not used so much that the front or back edge of wheel surface is scarcely abraded.

The results of this experiment are shown in table 6～11.

In table 6 are described the values of t_1', s, and x_P of the saw blade A_1. In the table of x_P (a) shows the values that feed force P is given backward at the front edge of saw blade, that is, ω' and α are positive and the values of α correspond to the left-most column, (b) shows the values that feed force P is given forward at the back edge, that is, ω' and α are negative and the absolute values of this case correspond to the left-most column. In the tables of x_P the four values indicated in the same column correspond to the four values of P — 3.5 *kg*, 5.5 *kg*, 8.0 *kg* and 10.5 *kg*.

And the situations in table 7～11 are as same as this.

1) On the effects of inclination angle of the upper wheel α

As before described, it is supposed that $\alpha=0$ is desirable in double-edge cutting. But even though $\alpha=0$, saw blade does not come to $x=0$, on account of such factors that ω' or ω is not zero as in this experiment, saw blade is not perfectly finished, and the others un-

Table 6 〔A_1〕

〔r=15.1 m〕

α \ Q	t_1' mm 1260 kg	950	560	s mm 1260	950	560
radian 0	8.8	8.4	6.2	0.0	0.0	0.0
1.2×10⁻³	11.7	11.8	10.5	1.0	1.1	0.7
2.4×10⁻³	14.8	14.8	14.5	1.9	2.2	2.0
3.6×10⁻³	17.8	17.6	17.9	2.9	3.2	3.1
4.8×10⁻³	20.7	20.7	21.0	4.0	4.1	3.9
6.0×10⁻³	23.8	24.0	24.8	4.9	5.1	5.2
7.2×10⁻³	28.2	28.5	29.4	6.6	6.3	6.6

x_P mm

α \ Q	(a) 1260	950	560	(b) 1260	950	560
radian 0	—	—	2.1 3.8 3.0 5.3	—	1.2 2.3 1.8 2.7	2.0 3.2 2.8 3.6
1.2×10⁻³	1.3 2.1 1.7 2.7	1.2 2.5 2.0 3.0	1.5 2.7 2.2 3.3	1.0 2.0 1.6 2.3	1.0 2.3 1.7 2.7	1.2 2.5 1.9 3.0
2.4×10⁻³	1.0 1.9 1.4 2.3	1.1 2.0 1.5 2.5	1.3 2.2 1.8 2.7	1.1 2.0 1.5 2.4	1.1 2.0 1.5 2.5	1.3 2.3 1.9 2.8
3.6×10⁻³	1.0 2.0 1.4 2.4	1.0 1.9 1.5 2.3	1.3 2.2 1.8 2.7	0.6 1.4 1.0 1.9	1.2 2.1 1.7 2.5	1.2 2.2 1.7 2.6
4.8×10⁻³	0.9 1.7 1.4 2.1	1.0 2.0 1.4 2.3	1.3 2.2 1.8 2.6	0.8 1.7 1.3 2.1	0.9 1.8 1.4 2.4	1.3 2.3 1.8 2.9
6.0×10⁻³	1.0 2.0 1.5 2.5	1.0 1.9 1.4 2.3	1.2 2.2 1.7 2.8	1.0 2.0 1.5 2.5	1.0 2.3 2.0 2.7	1.1 3.1 2.3 3.6
7.2×10⁻³	1.0 2.2 1.6 2.5	1.3 2.2 1.8 2.7	1.7 3.0 2.5 3.5	1.2 2.5 2.0 3.1	1.0 3.2 2.7 4.5	2.5 7.5 3.7 13.5

Table 7 〔K_1〕

t_1' mm

α \ r (m)	∞	7.3
radian 0	—	—
1.2×10^{-3}	—	8.7
2.4×10^{-3}	2.6	12.6
3.6×10^{-3}	10.3	15.9
4.8×10^{-3}	20.4	19.8
6.0×10^{-3}	34.9	23.3
7.2×10^{-3}	—	27.4
8.4×10^{-3}	—	32.2
9.6×10^{-3}	—	36.5

s mm

∞	7.3
—	—
—	1.1
2.0	2.1
2.8	3.1
4.6	4.4
6.0	5.5
—	6.7
—	8.2
—	8.8

x_P mm

(a)

α \ r	∞		7.3	
radian 0	—		—	
1.2×10^{-3}	—		1.5 2.2	3.0 3.5
2.4×10^{-3}	2.5 —	— —	1.5 1.7	2.2 2.5
3.6×10^{-3}	2.0 2.5	3.5 4.3	1.0 1.3	1.6 1.8
4.8×10^{-3}	2.2 3.5	4.5 5.2	0.8 1.3	1.8 2.1
6.0×10^{-3}	6.0 8.0	11.0 —	0.8 1.2	1.7 2.2
7.2×10^{-3}	—		0.9 1.5	1.8 2.3
8.4×10^{-3}	—		1.3 1.8	2.3 2.7
9.6×10^{-3}	—		1.5 2.2	2.7 3.2

(b)

∞		7.3	
—		—	
—		1.3 1.8	2.3 2.8
2.0 3.0	4.0 5.0	1.0 1.5	1.8 2.1
2.5 3.5	4.0 5.0	1.0 1.2	1.5 1.8
4.2 7.5	12.0 —	0.8 1.3	1.7 2.2
—		1.0 1.5	1.8 2.2
—		1.2 1.7	2.2 2.7
—		1.5 2.0	2.7 3.2
—		2.0 3.0	4.0 5.0

Table 8 $[K_2]$

α \ r	t_1' mm ∞	t_1' mm 9.3	s mm ∞	s mm 9.3
radian 0	—	—	—	—
1.2×10^{-3}	—	8.7	—	1.2
2.4×10^{-3}	6.5	11.8	2.0	2.2
3.6×10^{-3}	14.0	14.9	3.4	3.5
4.8×10^{-3}	22.6	17.9	4.5	3.8
6.0×10^{-3}	33.8	21.3	5.7	5.4
7.2×10^{-3}	—	26.5	—	7.2
8.4×10^{-3}	—	33.8	—	8.1

x_P mm

α \ r	(a) ∞		(a) 9.3		(b) ∞		(b) 9.3	
radian 0	—		—		—		—	
1.2×10^{-3}	—		1.0 1.5	2.0 2.5	—		1.0 1.5	2.0 2.5
2.4×10^{-3}	2.5 4.0	5.0 —	0.9 1.2	1.7 2.0	2.7 4.0	5.0 6.0	1.0 1.3	1.5 1.8
3.6×10^{-3}	2.7 3.5	4.5 5.0	0.7 1.2	1.5 1.8	2.5 4.0	5.2 6.5	0.5 0.9	1.0 1.4
4.8×10^{-3}	3.0 3.5	4.8 5.8	1.0 1.5	1.8 2.2	4.5 6.0	8.3 10.8	1.0 1.5	1.8 2.0
6.0×10^{-3}	4.0 5.5	7.0 8.3	1.0 1.5	1.8 2.3	8.0 10.5	12.5 —	1.0 1.5	2.0 2.5
7.2×10^{-3}	—		1.2 1.7	2.2 2.7	—		1.7 2.9	4.2 5.7
8.4×10^{-3}	—		2.5 4.0	5.2 6.2	—		8.0 12.0	13.5 16.5

Table 9 〔K_3〕

t_1' mm

α \ r	m ∞	10.6
radian 0	—	2.4
1.2×10^{-3}	2.9	6.6
2.4×10^{-3}	9.3	10.7
3.6×10^{-3}	14.7	14.0
4.8×10^{-3}	20.4	17.7
6.0×10^{-3}	28.1	21.1
7.2×10^{-3}	—	25.5
8.4×10^{-3}	—	30.6
9.6×10^{-3}	—	37.4

(a)

s mm

∞	10.6
—	0.3
1.0	0.9
2.1	1.8
3.3	3.4
4.5	4.3
5.4	5.5
—	6.8
—	8.2
—	8.8

(b)

x_p mm

α \ r	∞		10.6		∞		10.6	
radian 0	—		—		—		—	
1.2×10^{-3}	—		2.0 2.5	3.3 4.5	2.5 4.0	5.0 5.7	1.0 1.8	2.5 3.0
2.4×10^{-3}	2.5 3.7	4.5 5.5	1.2 2.0	2.5 3.0	2.5 3.3	4.0 4.5	1.5 2.0	2.5 2.8
3.6×10^{-3}	2.5 3.3	4.0 5.0	1.3 2.0	2.5 3.0	2.5 3.0	4.0 4.7	1.0 1.5	2.2 2.7
4.8×10^{-3}	2.5 3.0	3.7 4.8	1.3 1.7	2.2 2.7	3.0 4.0	5.0 6.0	1.3 1.8	2.5 3.1
6.0×10^{-3}	3.0 4.5	5.5 6.5	1.5 2.3	2.7 3.2	5.0 7.0	8.5 10.0	1.5 2.0	2.7 3.5
7.2×10^{-3}	—		1.5 2.2	3.0 3.7	—		2.0 3.0	3.5 4.0
8.4×10^{-3}	—		2.5 3.2	4.0 4.7	—		3.0 4.5	6.0 8.0
9.6×10^{-3}	—		2.5 3.7	4.5 6.0	—		5.0 7.0	9.0 11.5

Table 10 〔K_4〕

t_1' *mm*

α \ r (m)	∞	14.8
radian 0	-1.0	5.2
1.2×10⁻³	5.7	9.2
2.4×10⁻³	10.9	13.0
3.6×10⁻³	15.9	15.9
4.8×10⁻³	20.6	19.0
6.0×10⁻³	26.9	22.3
7.2×10⁻³	—	27.2
8.4×10⁻³	—	36.4

s mm

α \ r	∞	14.8
radian 0	0.1	-0.1
1.2×10⁻³	1.5	1.0
2.4×10⁻³	2.1	2.1
3.6×10⁻³	3.6	3.4
4.8×10⁻³	4.6	4.5
6.0×10⁻³	5.5	5.3
7.2×10⁻³	—	6.8
8.4×10⁻³	—	7.9

x_p *mm*

(a)

α \ r	∞	14.8
radian 0	—	2.3 4.2 3.0 4.8
1.2×10⁻³	2.2 4.5 3.7 —	1.7 2.8 2.2 3.3
2.4×10⁻³	2.3 3.7 3.0 4.5	1.5 2.5 2.0 3.0
3.6×10⁻³	2.0 3.5 2.8 4.0	1.5 2.3 2.0 2.7
4.8×10⁻³	1.8 3.3 2.6 4.1	1.2 2.2 1.7 2.7
6.0×10⁻³	2.5 4.5 3.5 5.3	1.3 2.5 2.0 3.0
7.2×10⁻³	—	1.7 3.0 2.5 3.5
8.4×10⁻³	—	3.3 5.5 4.7 6.2

(b)

α \ r	∞	14.8
radian 0	—	1.5 2.8 2.2 3.7
1.2×10⁻³	2.3 5.0 3.8 6.0	1.5 2.7 2.3 3.2
2.4×10⁻³	1.8 3.5 2.7 4.5	1.0 2.0 1.7 2.5
3.6×10⁻³	2.3 4.0 3.3 4.8	1.3 2.3 1.8 3.0
4.8×10⁻³	2.5 5.0 3.5 6.2	1.5 2.3 1.8 3.0
6.0×10⁻³	6.5 — 10.5 —	1.2 3.0 2.0 4.0
7.2×10⁻³	—	2.8 7.5 4.3 17.0
8.4×10⁻³	—	—

Table 11 〔K_5〕

t_1' *mm*

α \ r m	∞	13.6
radian 0	—	6.0
1.2×10^{-3}	6.1	9.7
2.4×10^{-3}	11.3	12.9
3.6×10^{-3}	15.6	15.6
4.8×10^{-3}	20.2	18.6
6.0×10^{-3}	26.7	22.1
7.2×10^{-3}	35.8	27.3
8.4×10^{-3}	—	33.6

s mm

α \ r	∞	13.6
radian 0	—	0.0
1.2×10^{-3}	1.1	1.1
2.4×10^{-3}	2.0	2.3
3.6×10^{-3}	3.0	3.0
4.8×10^{-3}	4.2	4.2
6.0×10^{-3}	5.7	5.4
7.2×10^{-3}	6.6	6.9
8.4×10^{-3}	—	7.8

x_P *mm*

α \ r	(a) ∞	(a) 13.6	(b) ∞	(b) 13.6
radian 0	—	2.5 3.3 2.8 4.0	—	1.5 3.7 3.0 4.2
1.2×10^{-3}	3.0 6.0 4.5 —	1.7 3.5 2.5 4.0	2.5 5.5 4.0 6.7	1.5 3.0 2.5 3.7
2.4×10^{-3}	1.9 4.2 3.2 5.4	1.5 3.0 2.3 3.5	2.5 4.3 3.5 5.5	1.2 2.2 1.7 2.7
3.6×10^{-3}	2.0 3.7 3.0 4.2	1.3 2.5 1.8 2.8	2.5 4.7 3.7 5.7	1.2 2.2 1.7 2.7
4.8×10^{-3}	1.8 3.5 2.7 4.5	1.2 2.3 1.8 2.8	3.0 6.0 4.5 9.5	1.5 2.5 2.0 3.3
6.0×10^{-3}	2.7 5.2 4.0 6.2	1.3 2.3 1.8 2.8	8.0 18.0 14.0 21.5	2.0 3.7 2.8 5.0
7.2×10^{-3}	4.0 8.0 6.0 9.5	2.0 3.5 2.8 4.0	4.5 — — —	3.5 13.0 6.2 —
8.4×10^{-3}	—	2.5 4.7 3.5 5.7	—	12.0 — — —

known. Thus adjusting α slightly, it is used to make saw blade run in the state of $x=0$.

As it is easy to adjust α in present type bandsaw machine, in this experiment the inclination angle α is so much increased or decreased to investigate the effect of α on s, x and x_P, until t_1' or t_2' becomes negative, or either of sawblade edges comes on wheel surface.

On the relation of $x-\alpha$: The relation $x-\alpha$ or $t_1'-\alpha$ is theoretically represented by the equation $(3)_\alpha$, putting $P=0$, $R=\infty$ and $\omega=\omega'$ in the eq. (3).

$$x=\frac{1}{U+Q}\left\{-\frac{4U+V+4Q}{U+V+Q}\frac{EI}{l}\alpha+W\omega'\right\}\cdots\cdots\cdots\cdots(3)_\alpha$$

The eq. $(3)_\alpha$ shows that the relation of $x-\alpha$ is to be linear.

The experimental results of saw blades A_1, K_1 and K_5 are shown in fig. 6-t_1', comparing with the theoretical calculation by the eq. $(3)_\alpha$. In A_1 and K_5, that is, thin saw blade both the experimental and the theoretical nearly coincide with each other in all cases of pulling force Q and tension radius r, excepting the scope of large α. But in K_1, that is, thick saw blade both do not coincide and the experimental is widely larger than the theoretical.

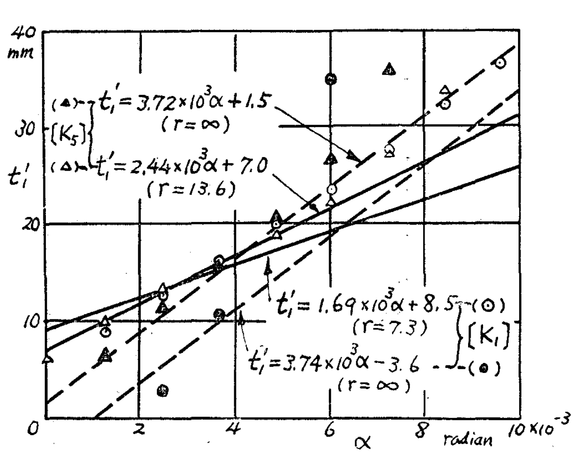


Fig. 6—t_1' [A_1]

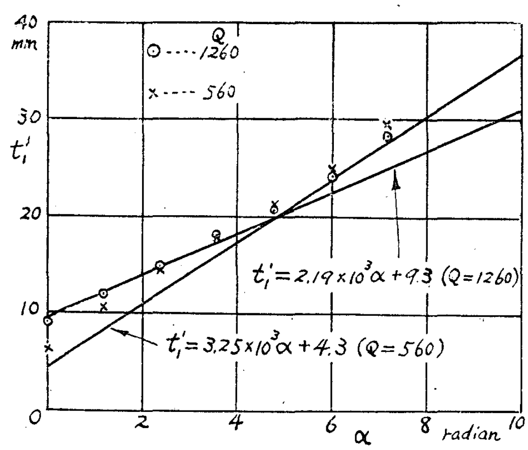


Fig. 6—t_1' [K_1, K_5]

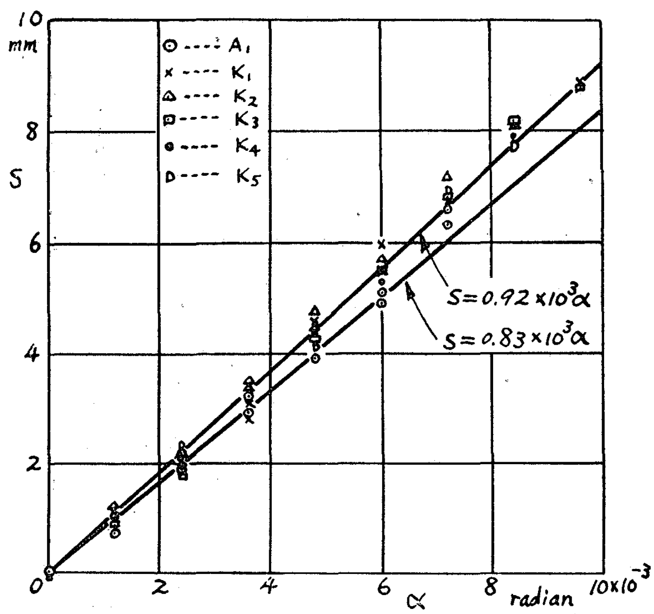


Fig. 6—s

On the relation of $s-\alpha$: The values of s-α in all cases are plotted in fig. 6-s. In all cases of sawblade thickness b, tension radius r and pulling force Q the relation of $s-\alpha$ does not change widely. This is reasonably understood as follows:

Putting $P=0$, $\omega=\omega'$ in the eq. (4), we obtain

$$S=\frac{1}{U+V+Q}\cdot\frac{6EI}{l}\alpha \cdots\cdots (4)_\alpha$$

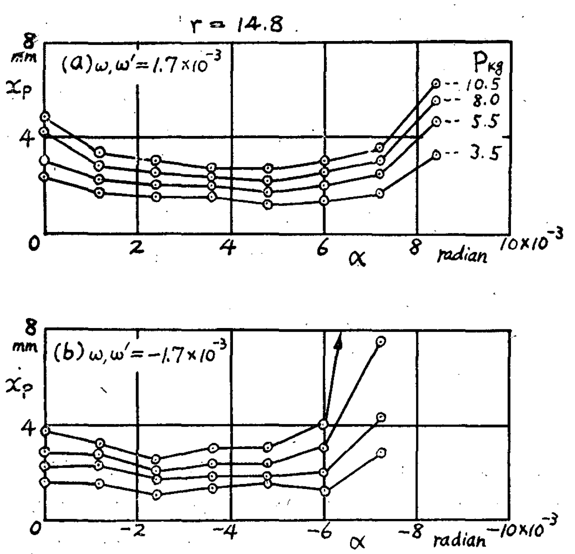
Transforming the eq. $(4)_\alpha$ with $V \doteqdot 12EI/l^2$

$$S=\frac{1}{1+\frac{U+Q}{V}}\cdot\frac{l}{2}\alpha$$

and in this experiment being $V \gg U,Q,U'$ in all cases, so it will be assumed,

$$S \doteqdot \frac{l}{2}\alpha \cdots\cdots (4)_\alpha'$$

Thus s is almost determined by l and α, and the other conditions do not act effectively. The lines in the figure are the ones with maximum and minimum direction coefficient among the theoretical equations.



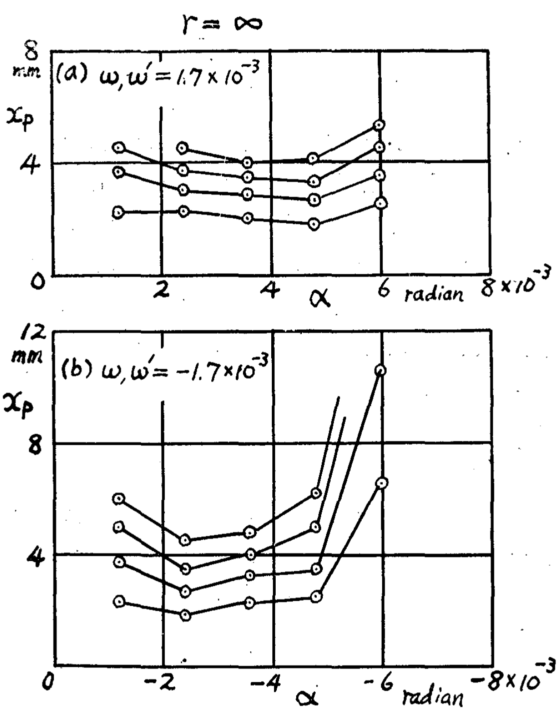


Fig. 6—x_P [K_4]

On the relation of $x_P-\alpha$: x_P has theoretically no relation with α, as shown in the eq. (6). Also in the experimental, as shown in fig. 6-x_P, within the limits of 2.4×10^{-3} and 4.8×10^{-3} of α, that is, saw blade hanging not so much one-sided on the wheel x_P is nearly constant without relation with α, but if α is beyond this limits, that is, saw blade hangs so much one-sided, x_P increases in either cases. We suppose this to be caused on that the theory is constructed assuming that t_1' is sufficiently so large that the deformations of saw blade w_1 and w_2 are independent on t_1' or α, consequently $e^{-\beta t_1'}\approx 0$. (Conserning w_1, w_2, see the 1st report.)

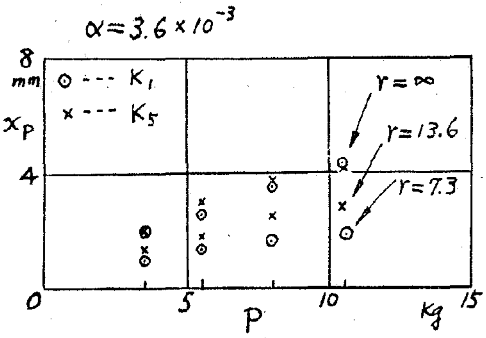


Fig 7

And the experimental is widely larger than the theoretical. The reason of this difference is not certain, and we shall investigate it furthermore.

The experimental results of saw blade K_4 are shown in fig. 6-x_P in the four cases of $r=\infty$, $r=14.8\ m$ and pressing the blade backward at the front edge (ω, ω', $\alpha>0$), forward at the back edge (ω, ω', $\alpha<0$) respectively.

2) On the effects of feed force P

As before described, not the relations of $P-x$ and $P-s$ but the ones of $P-x_P$ have been experimented.

Some examples of the results obtained in the saw blade K_1 and K_5 are shown in fig. 7. In this case ($\alpha=3.6\times10^{-3}$) the theoretical relations are as follows:

$$[K_1]\begin{cases} x_P=4.7\times10^{-2}P & (r=7.3) \\ x_P=16.2\times10^{-2}P & (r=\infty) \end{cases} \qquad [K_5]\begin{cases} x_P=12.7\times10^{-2}P & (r=13.6) \\ x_P=24.9\times10^{-2}P & (r=\infty) \end{cases}$$

As described in **1**), the experimental displacement of saw blade x_P caused on feed force P is widely larger than the theoretical. But the linear relation of x_P-P is in existence theoretically and experimentally.

From this results is proved that in the state of saw blade hanging nearly symmetrically on the wheel the displacement is only a few centimeters at the most, even though feed force P becomes so much as 10 *kg*, with no tensioning and small pulling force.

3) On the effects of pulling force Q

It is naturally expected that the larger Q, the more stable running and the stronger for buckling by feed force. But we must pay attention to the excessively large Q from the standpoint of strength of sawblade.

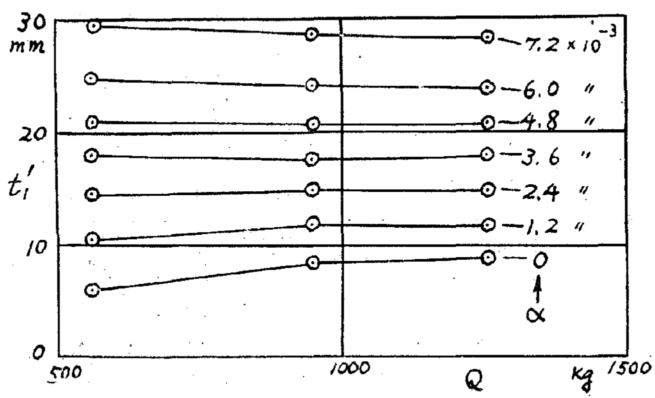


Fig. 8—t_1' [A_1]

On the relation of $x-Q$: The relation of $x-Q$, or $t_1'-Q$ is shown in fig. 8-t_1'. On the other hand the results calculated theoretically are shown in table 12. The experimental results, as shown in the figure, show that in the region of small α ($\alpha<3.6\times10^{-3}$) as Q increases, so increases t_1', or sawblade advances forward, but in the region of large α ($\alpha > 3.6 \times 10^{-3}$) as Q increases, so decreases t_1', or sawblade goes backward. Numerically the theoretical do not coincide with the experimental, but the tendency is the same in the theoretical.

Thus it has been proved that as pulling force Q increases, so goes sawblade to hang more symmetrically or to be $x=0$.

Table 12

α \ Q	1260kg	950	560
0	mm 4.8	2.5	-2.0
3.6×10^{-3}	12.7	11.7	9.7
4.8×10^{-3}	15.3	14.7	13.6
6.0×10^{-3}	17.9	17.7	17.5
7.2×10^{-3}	20.5	20.8	21.4

Table 13

P \ Q	1260kg	950	560
3.5 kg	mm 0.3	0.3	0.4
5.5	0.4	0.5	0.7
8.0	0.6	0.8	1.0
10.5	0.9	1.0	1.3

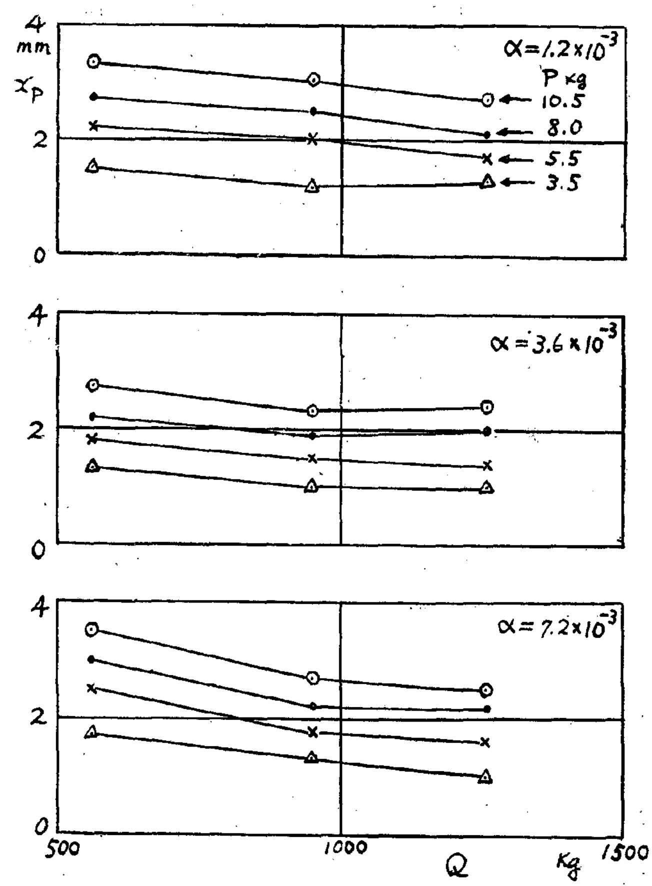


Fig. 8—x_P [A_1]

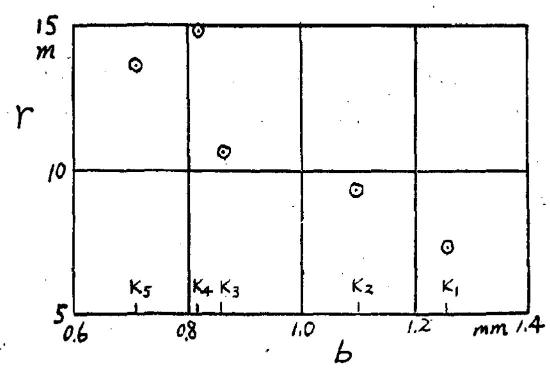


Fig. 9

On the relation of $s-Q$: As described in 1), Q scarecely effects on s.

On the relation of x_P-Q: The experimental results are shown in fig. 8-x_P. Properly expected, as increases Q, so decreases x_P. The results of theoretical calculation are shown in table 13. These are independent on α and their tendency is similar with the experimental, but numerically so much different.

4) On the effects of sawblade thickness b

It was worked so that $K_1 \sim K_5$ all sawblades might be tensioned to the same extent, but actual measurement indicated

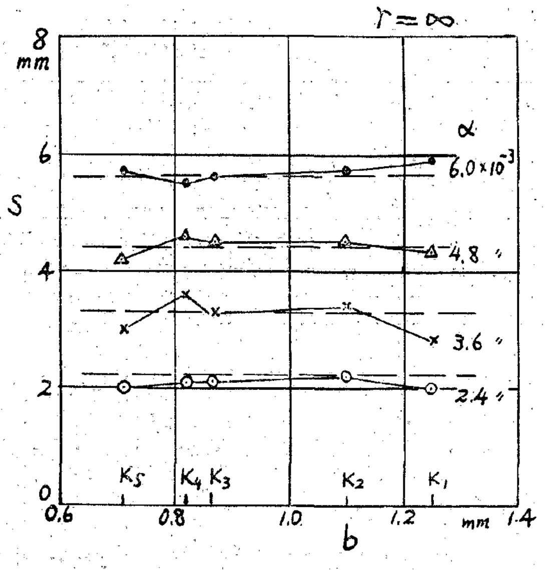


Fig. 10—s

that it is not the case. This relation of thickness b and tension radius r is shown in fig. 9. Thus in this experiment it reached to the result that the thicker blade had the smaller tension. Therefore it can not be discussed the effects of b in the state of tensioned, so the case of no tension $r=\infty$ will be done.

On the relation of x-b: The experimental results are shown in fig. 10-t_1' and for reference the tensioned case is also shown.

In table 14 are shown the results comparing the theoretical and the experimental. The values in ( ) are the experimental.

Table 14

α \ saw	K_1	K_2	K_3	K_4	K_5
radian 0	−3.6 (—)	0.1 (—)	−0.2 (—)	1.3 (−1.0)	1.5 (—)
2.4×10^{-3}	5.4 (2.6)	9.1 (6.5)	8.6 (9.3)	9.9 (10.9)	10.4 (11.3)
3.6×10^{-3}	9.9 (10.3)	13.6 (14.0)	13.0 (14.7)	14.2 (15.9)	14.7 (15.6)
4.8×10^{-3}	14.3 (20.4)	18.1 (22.6)	16.6 (20.4)	18.5 (20.6)	19.4 (20.2)
6.0×10^{-3}	18.8 (34.9)	22.6 (33.8)	22.4 (28.1)	22.9 (26.9)	23.8 (26.7)

With the same pulling force and the same tension radius, the thicker sawblade displaces the more sensitively.

In the thin sawblade the experimental and the theoretical nearly coincide with each other, but in the thick sawblade, specially in the case of one-sided hanging, both are widely different and in contrary tendency.

On the relation of s-b: The theoretical equation is

$$s=\frac{1}{V+Q}\frac{6EI}{l}\alpha=\frac{Eh^2l}{2(Eh^2+\sigma_t l^2)}\alpha \quad \cdots\cdots(4)_b$$

and as the pulling stresses σ_t are nearly equal as shown in table 2, s is to be independent on b in this case.

The experimental results are shown in fig. 10-s. In the figure the theoretical

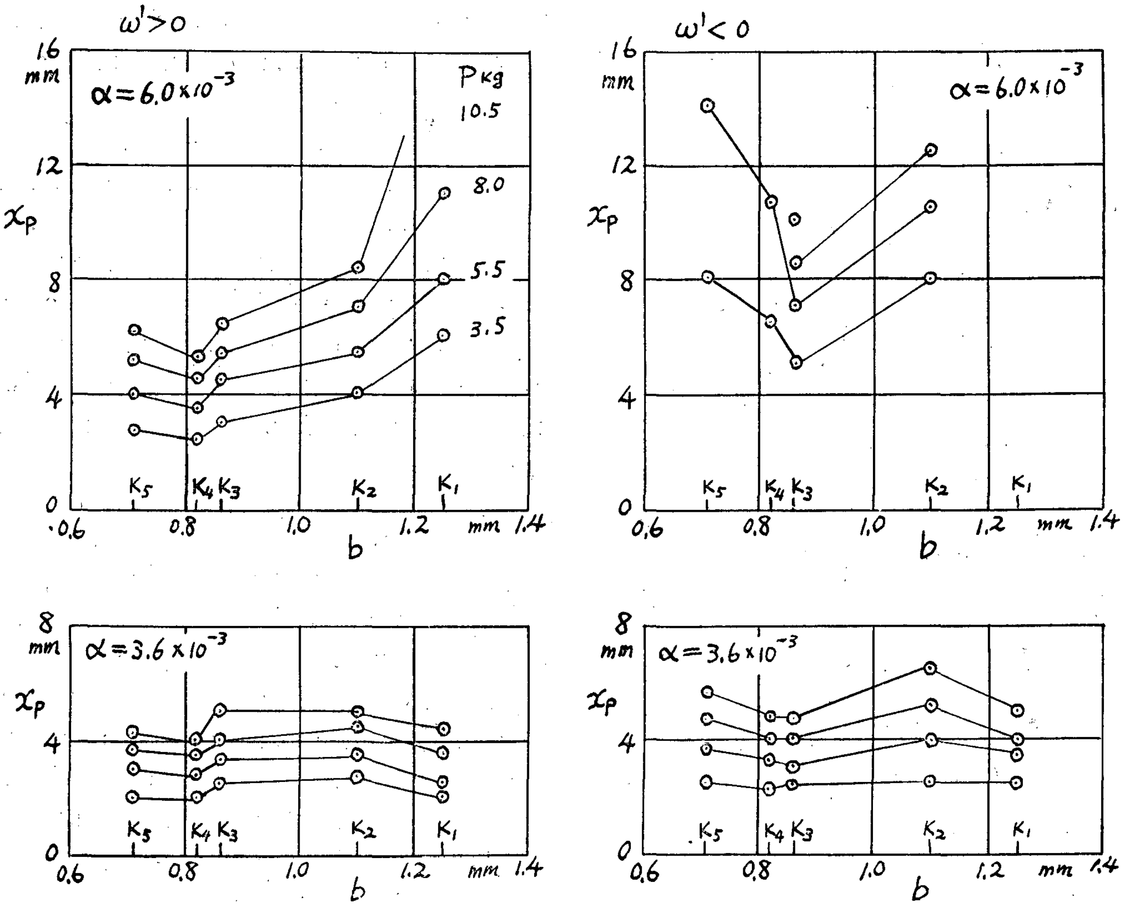


Fig. 10—x_P

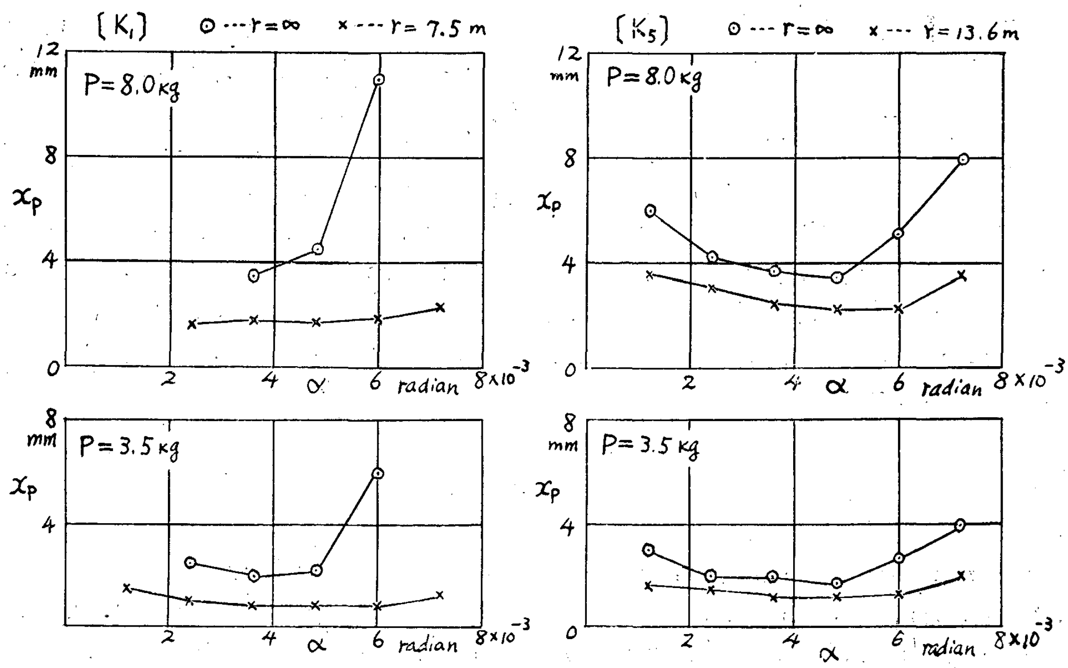


Fig. 11—x_P

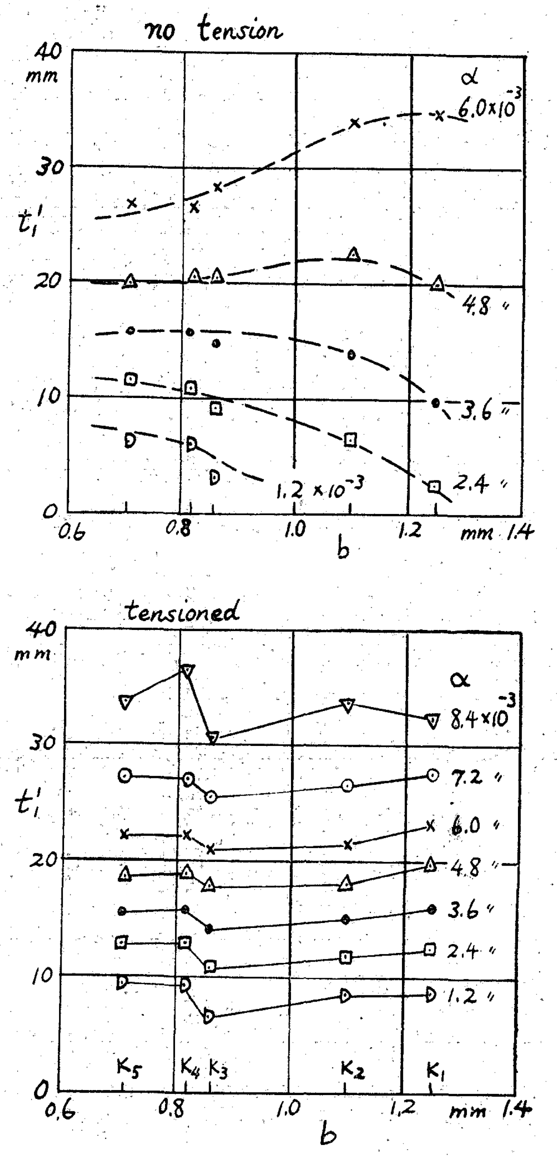


Fig. 10—t_1'

values from eq. $(4)_b$ are described by dotted lines and nearly coincide with the experimental.

On the relation of x_p-b: The experimental results of this relation are shown in fig. 10-x_p.

In the state of hanging symmetrically ($\alpha=3.6\times10^{-3}$), even in $\omega'<0$, x_p does not so much depend on the thickness of sawblade. But one-sided hanging, the thicker sawblade is the more unstable for feed force P.

5) On the effects of tesion radius r

It is supposed that the less tensioned or the larger tension radius, the more unstable sawblade.

In this experiment the only two cases of tension radius, that is, $r=\infty$ and the respective value, are compared, but it may be found the tendency of this effects.

On the relation of $x-r$: If not so much tensioned, the saw running is unstable and the running position displaces sensitively backward or forward, responding to a little change of α, as shown in fig. 6-t_1'. This is also expected theoretically from eq. (3).

On the relation of $s-r$: As described before, r scarecely effects on s.

On the relation of x_p-r: The respective two cases of the tension radius $r=\infty$ and the respective value are compared in fig. 11-x_P, with the same conditions except the tensioning. The running position changes sensitively by feed force P and in the larger or smaller region of α this tendency is remarkable.

§4 Conclusion

From these results mentioned above it is concluded as follows:

The necessary and sufficient condition for stable running is for saw to run on the wheel hanging symmetrically. In this case, even though α is not zero, pulling force Q small, thickness of blade b thin, the amount of tensioning little, the sawblade runs stably standing against considerable feeding force P.

To place the blade on the wheel to hang over to both sides in symmetry, it is enough to adjust the inclination angle α of upper wheel.

As increasing of pulling force Q, the saw tends to run more symmetrically.

When hung one-sided, the thicker sawblade gives the more unstable running.

The more amount of tensioning gives the stabler running.

The centrifugal force of blade has no great effects on the position of running.

If the wheel has tapered surface, even though so slightly as 10^{-3} *radian*, the position of saw running on the wheel is remarkably affected.

Addendum: This paper was read at the 2nd meeting of Japan Wood Research Society on April 9, 1956, at Tokyo University.

The writer desires to acknowledge the deep comprehension and the kind suggestions of Prof. R. KUNO, Hokkaido University, and the unmeasurable helps and supports of AKITA Lumber Co. Ltd., FUJI Seisakusho, Ltd., and KIKUKAWA Iron Works Co. Ltd.

And I must acknowledge the earnest assistance of Mr. K. SUMIYA and Mr. G. YOSHIDA, the members of this institute.