FREE SHED OPENING AS BASIC FACTOR IN POWER LOOM KINEMATICS

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The number of revolutions per minute of the weaving loom, when operating in mill conditions, depend on kinematical and dynamical parameters.

Among the dynamical parameters it is first of all the effect of the shuttle movement which appears to restrain the increase of the number of revolutions per minute of the loom. In setting the loom, the movement of the shuttle has to be considered, as at higher shuttle velocities irregular stresses may arise. The velocity of the shuttle is determined by kinematical parameters ; it depends on the duration of the free shed opening, formation of which is governed by the laws, both of the slay motion and of the shedding. (With respect to the shuttle movement, the shed may be considered as free, when its dimension at the front of the shuttle — the shuttle being placed on the raceboard — attains, or is higher, than the depth of the front of the shuttle.)

The laws of slay motion and shedding have been, independently of each other, reviewed in detail, in technical literature [1, 2, 3]. The relations between the kinematical parameters and the effect produced by them on the free shed opening has not been discussed, even in the literature dealing with the setting of looms by gauges. For example, according to gauge loom setting instructions [6], the dimensions of the shed opening have to be adjusted so that at the back dead centre position of the slay, the top shed line should be 1 mm above the front of the shuttle. Malishev [2] suggests 4 mm for that distance.

Attention has been drawn by Hajós [4] to the importance of synchronizing the movements of the slay and shedding. He suggests coordinated slay and heald motions, and points out these two factors as deciding the moment when the shuttle enters and leaves the shed. He developed a method for building up the laws of movement for shed forming. With his method the law of movement satisfying all requirements may be defined for any given shuttle velocity and slay motion. However, for a direct analysis of the free shed opening the method does not appear to be appropriate.

1. Determination of the free shed opening by analytical method

The changes of the shed depth (y_v) measured at the front of the shuttle (Fig. 1.) depend on the displacement angle (β) of the slay and on the variations of the front shed angle (α). Considering the relative position of the slay and the shed opening, it can be stated that, in general, the axis (y) of the coordinate system taken, does not pass through end point B_0 of the shed. Using the symbols

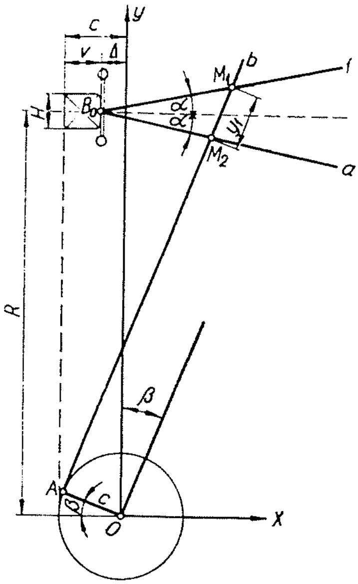


Fig. 1

of Fig. 1, in case of a horizontal base line, equations of the shed lines starting from point B_0 will be

$$y_f = x \operatorname{tg} \alpha + R + \Delta \operatorname{tg} \alpha \tag{1}$$

$$y_a = - x \operatorname{tg} \alpha + R - \Delta \operatorname{tg} \alpha . \tag{2}$$

The shed depth y_v measured at the front of the shuttle is indicated by the shed lines on the straight line b drawn at the distance of the shuttlewidth V parallel to the reed.

During the movement of the slay, the foot-end A of the straight line b moves around a circle with centre O and radius $C = V + \Delta$, the latter coincidings with the rocking shaft. Straight line b is parallel to the reed in every position.

Equation of straight line b is

$$y_b = x \operatorname{ctg} \beta + \frac{c}{\sin \beta} \tag{3}$$

using the symbols of Fig. 2.

$$\beta = \frac{180}{L\pi} s_\varphi . \tag{4}$$

In relation (4) the expression $s_\varphi = f(\varphi)$ representing the distance described by the sword pin, shows an appropriate approximation generally known. Using the symbols of Fig. 2

$$s_\varphi = k - l + \frac{d^2}{2l} - r \left| \cos\varphi - \frac{r}{2l} \sin^2\varphi - \frac{d}{l} \sin\varphi \right| .$$

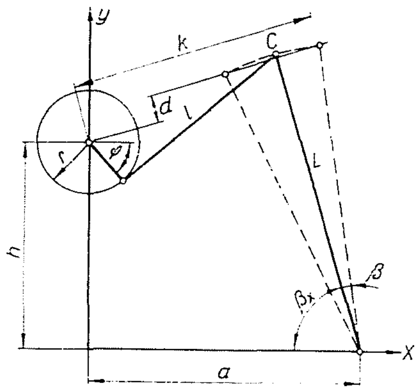


Fig. 2

According to Schneider's [3] formula the exact value of the displacement angle of the slay (β)

$$\beta = \beta_{\max} - \beta_x = \beta_{\max} - \arcsin \frac{AB + E\sqrt{B^2 + E^2 - A^2}}{B^2 + E^2}$$

where, using the symbols of Fig. 2

$$A = \frac{r^2 + L^2 + a^2 + h^2 - l^2}{2rL} - \frac{a}{L}\cos\varphi - \frac{h}{L}\sin\varphi$$

$$B = \frac{h}{r} - \sin\varphi$$

$$E = \frac{a}{r} - \cos\varphi$$

The common solution of equations 1, 2, 3, gives the ordinates of intersection points M_1 (ξ_1, η_1) and M_2 (ξ_2, η_2) according to which

$$y_v = \frac{2\,\mathrm{tg}\,\alpha}{\sin^2\beta} \quad \frac{c - R\sin\beta - \Delta\cos\beta}{\mathrm{tg}^2\alpha - \mathrm{ctg}^2\beta} . \tag{5}$$

For a warp base line deviating from the horizontal plane, relation (5) is valid with the following new variables: β', R', Δ'

Should the warp base line and the horizontal line form the angle δ_1 (Fig. 3), so the new variables obtained by shifting the coordinate system by the angle δ will be

$$R' = \overline{O\ B} = (R - \Delta \operatorname{tg} \delta_1) \cos \delta_1 \tag{6}$$

$$\Delta' = \Delta_1 + \Delta_2 = \frac{\Delta}{\cos \delta_1} + R' \operatorname{tg} \delta_1 \tag{7}$$

$$\beta' = \beta - \delta_1 \tag{8}$$

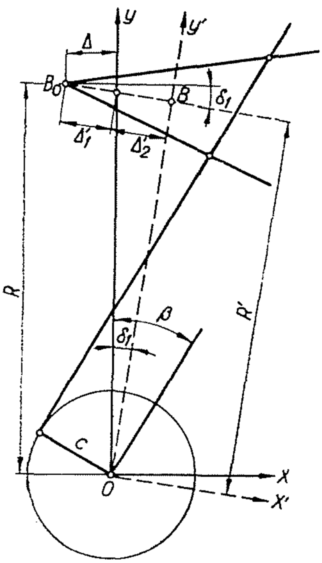


Fig. 3

Relation (5) may be considerably simplified. In practice, such values for cottonlooms vary between $\alpha = 0$—$12°$ and $\beta = 0$—$10°$. As $\operatorname{tg}^2 12° = 0{,}045199 \cong$ $\cong 0$; $\cos 10° = 0{,}9849 \cong 1$ and $V = C - \Delta$ after rearranging relation (5), it may be simplified to the form:

$$y_v = \frac{2 \operatorname{tg} \alpha \,(V - R \sin \beta)}{-\cos^2 \beta}$$

Introducing the approximation $\cos^2 10° \cong 1$ as above:

$$y_v = 2 \ \operatorname{tg} \alpha \,(R \ \sin \beta - V) \tag{9}$$

The deviation from the exact value, as an effect of the approximation, reaches its highest value in the back dead centre position of the slay. For example, on the Hungarian loom type R 105 ($\alpha_{max} \cong 12°$, $\beta \cong 10°$) the exact value of the shed depth measured at the front of the shuttle will be, according to relation (5)

$$y_v = 39{,}67 \text{ mm}$$

and using the approximation formula (9)

$$y_v = 38{,}44 \text{ mm}.$$

In the considered case, with the slay being in back dead centre position, the value obtained by the approximation formula is but 3,1 percent lower than the exact value, which provides reasonable safety in the determination of shuttle velocity.

Relation (9) in the ranges $\beta_0 < \beta < \beta_{max}$ has real values. The approximating value of β_0 from relation (3) is $\cos \beta \cong 1$, $y = R$ and substituting $x = -\Delta$

$$\beta_0 = \arcsin \frac{C - \Delta}{R}$$

2. Graphic method for the determination of the free shed opening

The shed depth measured at the front of the shuttle can be obtained in the function of the crank position directly by the graphic method. The principle of that method is outlined by HANTON [5]. A detailed description of the procedure is as follows (Fig. 4):

1. From the circle representing the path of the crank and divided into an appropriate number of even parts, cut the length of the connecting arm on the path of movement described by the sword pin C.

2. Project cloth fell B_0 through the centre of the rocking rail to shaft y, this latter moving parallel with the reed (point 0); cut the distance CO consecutively on the path of movement of point 0. Connect points 1, 2, 3. with the centre of the rocking rail (y_1, y_2, y_3 . . .).

3. For designing the vertical projections of the shed opening, draw the warp base line B_0B starting from the clothfell B_0 and through the point B the plane of movement of the heald nearest to the clothfell ($n - n$). (For the purpose of lucidity the warp base line and the further stages of the construction are separately given.)

In the different positions of the crank, the shed depths measured at the front of the shuttle are indicated by the intersection points of the shed lines and the straight line running parallel to the straight line y_i at a distance $C =$

$= V + \Delta$ towards the end-point of the front shed. Should the projection of the shed opening, together with the plane of movement of the heald be parallely displaced to itself to the right of point B_0 with the distance C towards the healds, then — according to the principle of Hantons' method — the shed lines indicate

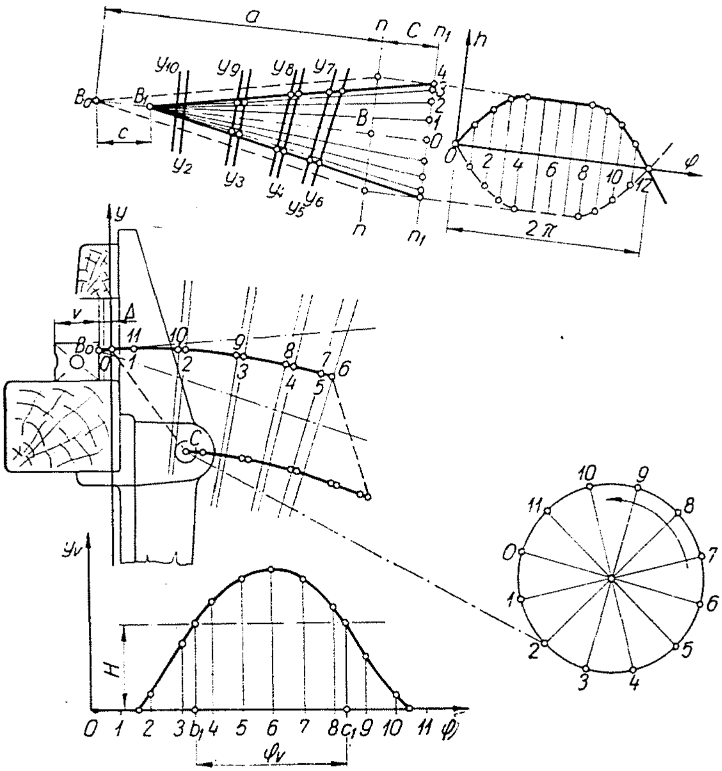


Fig. 4

the shed depth measured at the front of the shuttle on straight line y_1 directly, with an appropriate exactness for practical requirements.

In the projections of the shed opening, clothfell B_0 is at point B_1 and the plane of movement of the heald, displaced also by the distance C comes into the plane $n_1 — n_1$.

4. After drawing the basic dimensions of the shed opening and extending the straight line $B_0 — B_1$, plot the diagram of the heald motion $h = f(\varphi)$ symmetrically to the base line. This means a simplification of the design, as — assuming a clear shed — projections of the shed opening can be constructed by using the plane of movement of the heald, and its displacement.

5. The diagrams of the heald motion having been designed, project the ordinates belonging to the identical abscissae of the curves drawn with full and dotted lines to the plane of movement $n_1 - n_1$.

6. Connecting the point B_1 with the points related to each other, projections of the shed opening indicating the shed depths measured at the front of the shuttle on the straight line b_1, can be obtained.

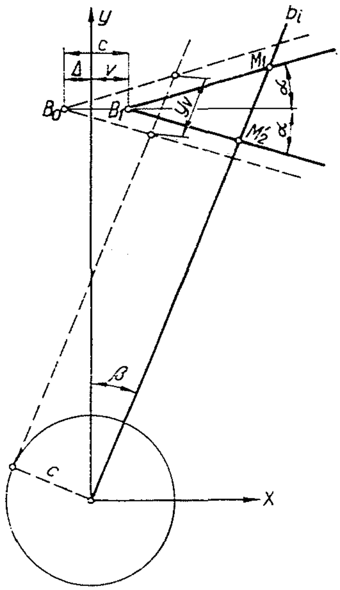


Fig. 5

In Fig. 4. the diagram $y_v = f(\varphi)$ has been also plotted. The duration of the free shed opening is given in the displacement angle (φ_v) of the crank.

Following the above method, the errors introduced by using the graphic method can be determined on the basis of Fig. 5. With the ordinates of the intersection points M_1' and M_2'

$$y_v' = \overline{M_1' M_2'} = \frac{2 \operatorname{tg} \alpha}{\sin^2 \beta} \frac{V \cos \beta - R \sin \beta}{\operatorname{tg}^2 \alpha - \operatorname{ctg}^2 \beta} .$$

On the loom type R 105, at the extreme values of $\alpha = 12°$, $\beta = 10°$

$$y_v' = 39{,}96 \text{ mm},$$

while the exact value from relation (5)

$$y_v = 39{,}67 \text{ mm}.$$

Thus, in the above case the graphic method gives fairly accurate results, and the value y_v' obtained at the back dead centre position of the slay is but 0,8 per cent higher than the exact value defined by the analytical method.

3. Variation of the free shed opening depending on some of the parameters

Among the kinematical parameters of the free shed opening it is the law of the slay movement which influences the variations of the total energy of the loom, while shedding, i. e. the dimensions of the shed affects the occurring warp tensions. The necessary velocity of the shuttle and the energy required for picking, may be also decisively influenced by the characteristic parameters of the two afore-said mechanisms.

a) *Effect of the parameters of the slay mechanism*

As to kinematical sensitivity, the axial displacement (*d*) and the crank—connecting arm ratio (*r*/*l*) are decisive parameters of the slay mechanism.

These two parameters have been analyzed, taking into consideration the laws of the heald motion characterized by a sinusoid acceleration of

$$h = 2\,h_0 \left[\frac{\varphi}{\varphi_0} - \frac{1}{2\,\pi}\sin\frac{2\,\pi}{\varphi_0}\,\varphi\right] \tag{10}$$

(where $\varphi_0 = 240°$), and by the pause of the heald measured in a $\varphi_p = 120°$ displacement of the crank (Fig. 9. I.), under the following conditions:

Loom type: *R* 105,
bottom width of the shuttle $V = 43$ mm,
depth of the shuttle $H_1 = 33$ mm,
rate of early shed $\varphi_e = o°$
depth of the shed $h_0 = 45$ mm,
length of the front shed $a = 200$ mm

In our tests the angle of the base line, amounting to $\delta_1 = 3°$ suggested by gauge loom setting instructions, had also been considered.

Variations of the shed depth (y_v) measured at the front of the shuttle depending on the crank position (φ) are shown in Fig. 6 by the axial displacement (*d*) and in Fig. 7 by the relation *r*/*l* ($d = 34$ mm axial displacement).

HAJÓS in his work mentioned above gives the value of $y_v = 0{,}9$ H for the moment when the shuttle enters the shed, which can be explained by the torpedolike shape of the shuttle and by the close setting and higher strength of the selvedge threads. Thus, in the following, the duration of the free shed opening will be marked on the diagrams by a horizontal line drawn at the height of $y_v = 0{,}9\ H$.

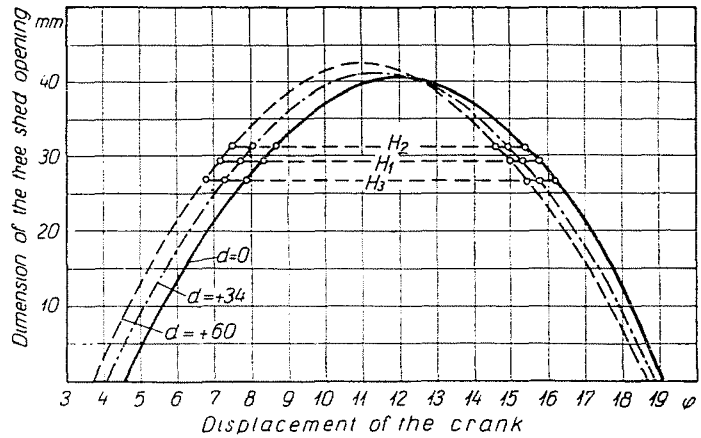


Fig. 6

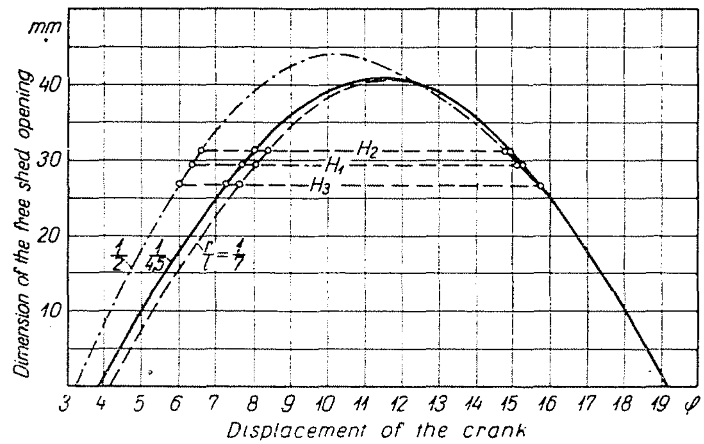


Fig. 7

Taking the distance made by the shuttle $s_v = 1{,}2$ m, the slowing down of the shuttle during traversing $p = 10\%$ and the number of revolutions per minute of the loom $n = 200/\text{min}$, the effect of the parameters of the slay mechanism produced on the duration of the free shed opening (φ_v), on the initial driving velocity determined by the formula

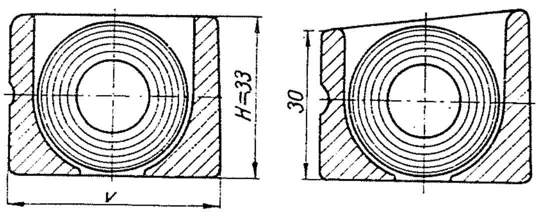
$$v_i = \frac{100}{100 - p\%} \cdot \frac{6\, s_v\, n}{\varphi_v} \text{ m/sec} \tag{11}$$

and on the initial driving energy of a shuttle with a weight of $G = 400\ g$ is shown in Table I.

Table I

d	r/l	$H_1 = 33$ mm		E_i^{mkg}	$H_2 = 33$ mm		E_i^{mkg}
		φ_v	v_i m/sec		φ_v	$v_i^{m/sec}$	
	1/2	132°	12,0	2,94	146°	10,85	2,38
+34	1/4,5	113,5	14,1	4,05	127,5	12,42	3,13
	1/7	106,5	14.9	4,52	121,5	13,02	3,45
0		110°	14,4	4,22	124,5°	12,72	3,28
+34	1/4,5	112,5	14,1	4,05	127,5	12,42	3,13
+60		117	13,52	3,72	130,5	12,14	2,98

The data of Table I clearly demonstrate the beneficiary influence of a short crank on the free shed opening and on the initial driving velocity of the



a b

Fig. 8

shuttle under given condition (in between the limitvalues of r/l and the axial displacement generally applied).

While, for example, with a shuttle depth of $H_1 = 33$ mm, the axial displacement increases from 0 to +60 mm, the increase of the free shed opening merely amounts to $\Delta\varphi_v = 7°$ (6,37 per cent) ; the decrease in r/l from 1/4,5 to ½ prolongs the duration of the free shed opening by $\Delta\varphi_v = 18{,}5°$ (17,15 per cent), reducing the initial energy necessary to drive the shuttle by $E_i = 1{,}11$ mkg (27,4 per cent) ; the effect of the change in the axial displacement mentioned, resulting but a $E_i = 0{,}5$ mkg decrease in the necessary energy. (It should be considered that on Picanol looms with a reedspace of 120 cm running with $n = 180$ revolutions per min and with an axial displacement of $d = 20$ mm, the crank-connecting arm ratio applied, is 1 : 2,9, the advantage of which is quite obvious according to the afore-said.

Further improvements can be attained in the conditions of shuttle traversing, by reducing the dimensions of the front of the shuttle. Szőke [7] in his work, dealing with shuttle measurements for normal shed dimensions on cotton looms, and for a maximal weft-pirn diameter of 32 mm, determines the cross-section of the shuttle in V × H = 43 × 33 mm (Fig. 8a). Developing the cross-section of the shuttle according to Fig. 8b and taking identical weft-pirn dimensions and bottom-width, the front depth of the shuttle can be reduced without causing any detrimental effect.

According to the last column of Table I, on a loom running 200 r. p. m. the reduction of the front depth of the shuttle by 3 mm would involve a 1,9 m/sec (10—13 per cent) decrease in the shuttle velocity, which represents a saving of 0,56—1,07 mkg (19—23,8 per cent) in the initial energy necessary to start the shuttle.

b) *Effect of shedding parameters*

The parameters of shedding producing an effect on the duration of the free shed opening are the following:

dimensions of the shed,
laws of the heald motions,
dwelling of the healds and
rate of the early shed.

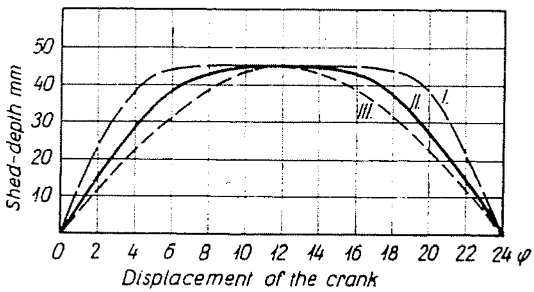


Fig. 9

The effect of the laws of heald motion has been investigated on the basis of the laws of movement given below, on loom type R 105, assuming constant shed dimensions ($a = 200$ mm, $h_0 = 45$ mm) and an early shed of $\varphi_e = 0°$

$$h = 2\,h_0 \left| \frac{\varphi}{\varphi_0} - \frac{1}{2\pi} \sin \frac{2\pi}{\varphi_0} \varphi \right| , \tag{12}$$

where $\varphi_0 = 240°$ and the pause of the healds is $\varphi_p = 120°$ (Fig. 9 I)

$$h = 2\,h_0 \left| \frac{\varphi}{\varphi_0} - \frac{1}{2\pi} \sin \frac{2\pi}{\varphi_0} \varphi \right| , \tag{13}$$

where $\varphi_0 = 360°$ and the pause of the healds is $\varphi_p = o°$ (Fig. 9 II)

$$h = 2\,h_0 \sin \frac{2\,\pi}{\varphi_0}\,\varphi,$$

where $\varphi_0 = 360°$, (Fig. 9 III)

Fig. 10 shows the effect of the laws of movement produced on the free shed opening. With a shuttle depth of $H_1 = 33$ mm, for the free shed opening (φ_v) marked by the horizontal line $y_v = 0{,}9\ H_1$ the following characteristics are to be found (Table II):

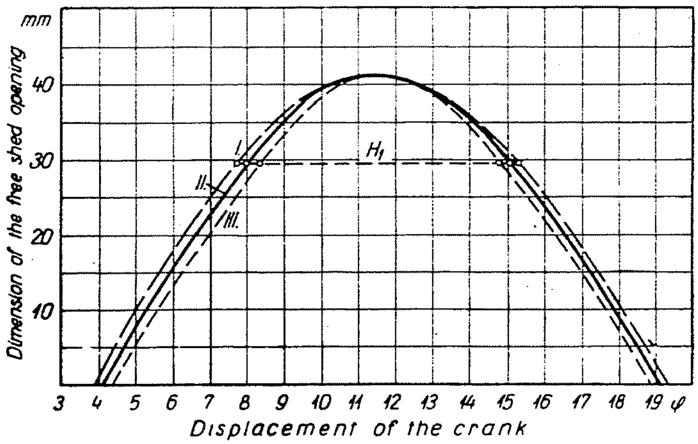


Fig. 10

Table II

Law of movement Fig. 9.	φ_v	$v_i^{m/sec}$	E_i^{mkg}
I.	112,5°	14,10	4,05
II.	106,0°	14,95	4,55
III.	97,5°	15,25	5,35

From Table II it can be concluded that a heald motion following the laws of movement (12) appears to be extremely advantageous. The reduced sensibility of the free shed opening with respect to the shorter dwelling of the healds can be considered as one of the beneficient influences. Should the dwelling of the healds decrease from $\varphi_0 = 120°$ to $0°$, than the reduction in the free shed opening will only be $\Delta\varphi_v = 6{,}5°$ (5,7 per cent) and the shuttle velocity required, computed from relation (11) will be but $\Delta v_i = 0{,}85$ m/sec higher, which means an increase of 12,35 per cent in the energy necessary for picking.

The sinusoid movement (14) with respect to the law of movement (12) represents a reduction of $\Delta\varphi_v = 15°$ (13,4 per cent) in the free shed opening increasing by $\Delta v_i = 2{,}15$ m/sec the shuttle velocity and reducing by 1,3 mkg. (32,15 per cent) the initial energy required.

The problem of early shedding does not appear to be sufficiently explained in technical literature from point of view of shuttle-traversing.Generally it is suggested, that increased early shedding involves, to set the beat-up earlier.

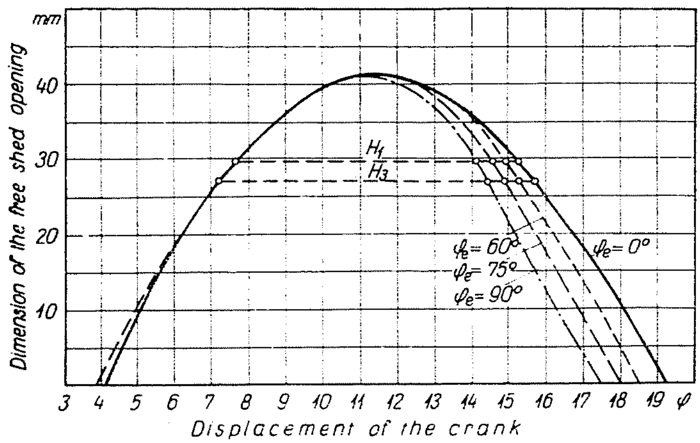


Fig. 11

Fig. 11 shows the effect of early shedding using the law of movement given in Fig. 9. I. The characteristic data for free shed opening marked at the height of $H_1 = 33$ mm is summerized in Table III.

Table III

Early shed		φ_v	$v_i^{\mathrm{m/sec}}$	E_i^{mkg}
φ_e	mm*			
0°	0	112,5°	14,10	4,05
60°	46,6	108,0°	14,65	4,36
75°	65,0	102,0°	15,52	4,90
90°	83,0	97,5°	16,25	5,37

* Distance between the reed and the clothfell at the moment of closing the shed.

From Fig. 11 and Table III it is to be seen that the increased early shed is accompanied by a free shed opening of reduced duration, therefore, the satisfactory traversing of the shuttle cannot be ensured merely by an earlier timing of the beating up.

According to the results obtained, when increasing the early shed to $\varphi_e = 75°$, the duration of the free open shed — compared to an early shed of 0° — will be decreased by $\Delta\varphi_v = 10{,}5°$ (9,4 per cent), while the necessary shuttle velocity will be raised by $\Delta v_i = 1{,}42$ m/sec and the initial energy required increases by 0,85 mkg (17,5 per cent). Hence, by increasing the early shed, the velocity of the shuttle has also to be increased.

For given shed length and slay movement, taking a shuttle velocity predicted by family curve $y_v = f(\varphi)$ derived by the parameter $\alpha =$ const, shed depth

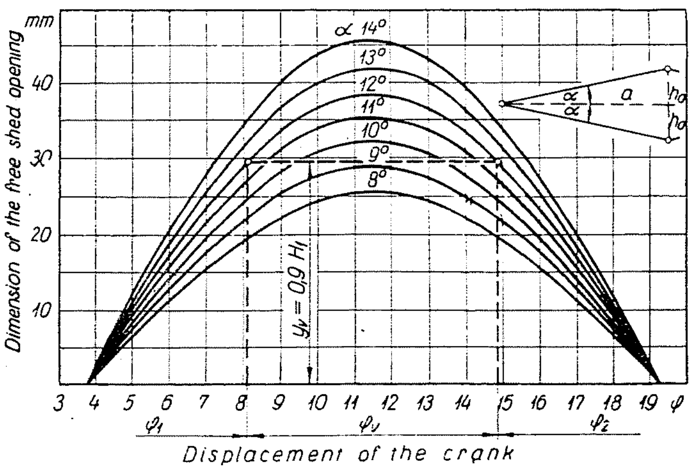


Fig. 12

h_0 offering favourable conditions with reference to the traversing of the shuttle and of the stresses acting on the yarn, can be determined.

Should the depth of the shuttle be $H_1 = 33$ mm, the speed of the loom $n = 180$ r.p.m., the distance made by the shuttle $s_v = 1{,}2$ m., the average retardation of the shuttle during traversing $p = 9$ per cent, and the velocity of the shuttle $v_i = 13$ m/sec.

From relation (11)

$$\varphi_v = \frac{100}{100 - p\,\%} \cdot \frac{6\, s_v\, n}{v_i} \cong 100°$$

According to our previous considerations, the straight line drawn in Fig. 12 at the height of $y_v = 0{,}9\ H$, cut the $\varphi_v = 100°$ free shed opening required on the curve $\alpha = 12° =$ const.

With $\alpha = 12°$ and with a front shed length of 200 mm, for the heald nearest to the reed

$$h_0 = a \ \mathrm{tg}\ \alpha \cong 45 \ \text{mm}.$$

For the purpose of building up the law of movement, it would be practical to take $\varphi_0 = \varphi_\nu$ for the dwelling position of the heald. Thus, the moment, the free shed opening takes place, the heald completes its motion, and since no superfluous movement occurs, the stresses acting on the warp yarns do not exceed the necessary magnitude.

From Fig. 12 it can be seen that with an axially displaced driving of the slay, the shed opening given, can take place only if $\varphi_1 — \varphi_2$, a condition which can be fulfilled by operating the healds, independently from each other.

The effect of early shedding may be well-fitted into the above considerations, and it can be compensated appropriately.

Conclusion

The free shed opening depending on the kinematical conditions of the loom and decisively influencing the velocity of the shuttle, i. e. the energy demand of picking, has been analyzed. The free shed opening can be determined by the developed analytical method or by the graphic method described, the latter being based on HANTON's basic principle. Using the approximation formula deduced from the analytical method, an exactitude satisfying loom construction requirements, and suitable for the analysis of the kinetical parameters of the free shed opening is obtained.

The analysis of the free shed opening shows that by reducing the $\frac{r}{l} = \frac{1}{4,5}$ crankshaft — connecting arm ratio to 1/2, on loom type R 105, running at a speed of 200 r. m. p. the duration of the shed opening increases by 17,15 per cent, which — assuming a shuttle weight of 400 g — represents a 27,4 per cent reduction in the initial energy required.

It has been shown that when using weft pirns of normal dimensions, by the possible reduction of the front depth of the shuttle the necessary shuttle velocity will be reduced by 10—13 percent and the energy demand by 19—23,8 per cent.

The effect of the law of movement of the heald appears to be characteristic. A heald motion of 120° dwelling with a sinusoid acceleration compared to a heald motion without any dwelling, gives a difference of 6,5 per cent in the free shed opening, while in the energy necessary for picking, it results in a difference of 12,35 per cent. An increased difference is shown between a heald motion of 120° dwelling with sinusoid acceleration and a sinusoid heald motion. The difference amounts to 13,4 per cent in the free shed opening, and to 32,15 per cent in the energy required.

The effect of early shedding has also been analyzed. For example, increasing the early shed from 0° to 7,5°, the free shed opening will be decreased by 9,4 per cent and the energy required will be raised by 17,5 per cent.

According to the results obtained, with increased early shed, picking need not be earlier timed, as higher shuttle velocity ensures the undisturbed passing of the shuttle.

By the analytical method described, for a slay motion given, the dwelling of the heald and the required maximal dimensions of the shed may be determined.

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Summary

The free shed openin_ as a basic kinematical parameter of loom construction has been defined. A method of definition based on calculations and on designing has been given. Effects of other parameters influencing the free shed opening, the energy of picking and the necessary initial driving velocity of the shuttle have been analyzed. It has been shown that the free shed opening seems to determine other kinematical parameters of the loom.

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