LEVER-GEARS FOR TRACTOR-PLOUGHS II.

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(Received June 4, 1964)

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With the axle of the stubble-wheel turning, the adjustment of the furrow-wheel is also accomplished. For this purpose the mechanism can be constructed in the following way. The axle of the furrow-wheel is fixed to a bearing on the axle of the stubble-wheel. In this bearing the stubble-wheel can turn aside. But at the end of the axle of the stubble-wheel there is also a cogged-clutch which revolves along with the axle. The clutch contacts with the bearing of the furrow-wheel-axle and the turning of the stubble-wheel-axle takes the furrow-wheel-axle along with it.

When ploughing the first furrow the felloes of the stubble- and furrow-wheels are at the same height, accordingly, on lifting out, the cogged-clutch must instantly contact the gear of the furrow-wheel-axle.

Further ploughing the succeeding furrows the felloe of the furrow-wheel will not rise to the height of the stubble-wheel-felloe, but only to the height of the ploughshare-edge. So in the lifted position, the turning of the stubble-wheel-axle takes the clutch along with it, too, and makes the furrow-wheel-axle turn aside under the weight of the plough. When the furrow-wheel-axle comes to the height of the ploughshare-edge, though the further turn of the clutch could facilitate a further turn of the furrow-wheel-axle too, this will not come about as a projecting arm of the furrow-wheel-bearing lying upon the arm adjusting depth. In this way the stubble-wheel-axle turning further becomes disconnected from the furrow-wheel-axle.

On the other hand on lifting the plough the backward turn of the stubble-wheel-axle will not take the furrow-wheel-axle along with it until the claw-clutch is caught in the bearing of the furrow-wheel-axle.

Since at any ploughing depth the felloe of the furrow-wheel must be at the height of the plough-iron-edge (except in the case when ploughing the furrow as mentioned above), the adjustment of different ploughing depths has nothing to do with the furrow-wheel. On this account the buffer preventing the furrow-wheel in turning further could be firmly fixed. But as, when ploughing of the first furrow, the furrow-wheel must also rise higher according to the various ploughing depths, the buffer must be adjustable, too.

The adjustment can be accomplished by an adjusting handle moving around a joint. The adjusting handle is moved along an arc and can be fixed in position at various places (Figure 8).

The furrow-wheel axle sits on buffer-plate *ü*. In Position 1 of the handle the furrow-wheel felloe is at the height of the ploughshare-edge, accordingly, it gives the continuous ploughing position at any ploughing depth. For the deepest ploughing of the first furrow the adjusting handle stands in Position 2. In this case buffer-plate *ü* must turn at such an angle that the turn of the furrow-wheel at the same angle should result in a rise of the felloe to 28 cm.

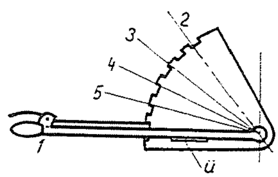

Fig. 8

Position 3, 4 (or may be the others) are needed for ploughing depths less than 28 cm when ploughing the first furrow. The dentations on the adjusting arc are arranged at a distribution that, e.g. at regular intervals of 4 cm, with the plough all ploughing depths could be adjusted down to the usual minimum ploughing depth, i.e. 24, 20 and 16 cm.

The geometrical relations are as follows:

The line of symmetry of the crank-axles of the stubble- and furrow-wheels passes through point S. In Fig. 9 the two wheels are drawn apart lest the simultaneous diagrams which concern both wheels should cover each other.

In the raised position axle k of stubble-wheel T forms an angle of α with the perpendicular. The ploughshare-edge is at height sz above the wheel-felloe. While at the same time axle k_k of the furrow-wheel B forms an angle

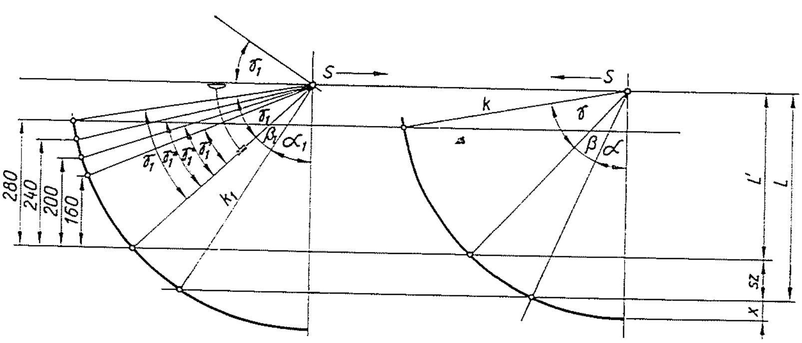

Fig. 9

of a_1 with the perpendicular. Both felloes are, of course, at the same height. It is possible only in case

$$\frac{l}{k_1} = \cos a_1 \text{ and } \frac{l}{k} \cos a$$

or hence:

$$k_1 \cdot \cos a_1 = k \cdot \cos a . \tag{39}$$

But angle β_1 at which the furrow-wheel must turn, so that the ploughshare should reach the height of the furrow-wheel felloe can be established as well. Here

$$\frac{l'}{k_1} = \cos (a_1 + \beta_1)$$

and

$$\frac{l'}{k} = \cos (a + \beta)$$

or hence:

$$k_1 \cdot \cos (a_1 + \beta_1) = k \cdot \cos (a + \beta). \tag{40}$$

In this connection it must be taken into account that the claw-clutch at the end of the stubble-wheel will contact the bearing of the furrow-wheel only when, on lifting, it has has turned at an angle of γ and that it takes the furrow-wheel-axle along with it only at an angle of β, so it can be seen that the turn of the furrow-wheel can be neither less nor greater than at an angle of β.

The equation given above changes accordingly:

$$k_1 \cdot \cos (a_1 + \beta) = k \cdot \cos (a + \beta). \tag{40a}$$

It is also obvious that in case the axle turns at an angle of β the felloe is raised to the height of transport, sz, and this can also be written as follows:

$$k \cdot \cos (a + \beta) + sz = k \cdot \cos a. \tag{41}$$

If the usual values $k = 480$ mm, $sz = 80$ mm are taken, a can be freely chosen considering that the weight of the ploughshare should exert its effect on an arm long enough to overcome frictions, and on pulling the handle the ploughshare should sink in with absolute certainty. For this reason a shall be chosen to be as large as possible, e.g. 30°.

Thus β can be computed, namely

$$\cos (a + \beta) = \frac{k}{k} \cdot \cos a - \frac{sz}{k} = \cos a - \frac{sz}{k}$$

Substituting the values chosen:

$$\cos(\alpha+\beta) = 0{,}86603 - \frac{80}{480} = 0{,}69936$$

$$\alpha+\beta \cong 45^\circ\, 20' \text{ and } \beta = 15^\circ\, 20'.$$

The value of k_1 is taken in the same way, e.g. 520 mm. According to that shown above:

$$\cos(\alpha_1+\beta) = \frac{k}{k_1}\cdot\cos\alpha - \frac{sz}{k_1} = \frac{480}{520}\cdot 0{,}86603 - \frac{80}{520}$$

$$\cos(\alpha_1+\beta) = \frac{12}{13}\cdot 0{,}86603 - \frac{2}{13} = \frac{10{,}3923-2}{13} = 0{,}64556$$

$$\alpha_1+\beta = 50^\circ\, 50'$$

$$\alpha_1 = 35^\circ\, 30'.$$

It would be interesting to investigate if there were a possibility, in case of different shaft-lengths, to find such angles of inclination of α and α_1 at which, after a further turn at an identical angle of β, both wheel-felloes would be at the same height. According to logical thinking there is no such possibility, but thus can be proved geometrically, too. The conditions to be fulfilled are:

1. $k\cdot\cos\alpha = k_1\cdot\cos\alpha_1$
2. $k\cdot\cos(\alpha+\beta) = k_1\cdot\cos(\alpha_1+\beta)$
3. $k\cdot\cos\alpha - k\cdot\cos(\alpha+\beta) = sz$

where the values of k_1, α and sz can be freely chosen. According to the former conditions they should be:

$$\alpha = 30^\circ,\ k_1 = 480 \text{ mm and } n = 80 \text{ mm}.$$

Then from 1.:

$$k_1 = k\cdot\frac{\cos\alpha}{\cos\alpha_1}$$

From 3.:

$$\cos - \frac{sz}{k} = \cos(\alpha+\beta)$$

$$\cos 30^\circ - \frac{80}{480} = \cos(\alpha+\beta)$$

$$0{,}86603 - 0{,}16667 = \cos(\alpha+\beta)$$

$$\cos(\alpha+\beta) = 0{,}69936$$

$$\alpha+\beta = 45^\circ\, 33'$$

$$\beta = 15^\circ\, 33'.$$

Substituting the value of k_1 in 2.:

$$\cos 45^\circ\, 33' = \frac{\cos 30^\circ}{\cos \alpha_1} \cdot \cos(\alpha_1 + 15^\circ\, 33')$$

$$\frac{\cos 45^\circ\, 33'}{\cos 30^\circ} \cdot \cos \alpha_1 = \cos(\alpha_1 + 15^\circ\, 33')$$

$$\frac{0{,}69936}{0{,}86603} \cdot \cos \alpha_1 = \cos 15^\circ\, 33' - \cos \alpha_1 - \sin 15^\circ\, 33' \cdot \sin \alpha_1$$

$$\sin 15^\circ\, 33' \cdot \sin \alpha_1 = \cos 15^\circ\, 33' - \frac{0{,}69936}{0{,}86603} \cdot \cos \alpha_1$$

$$\sin 15^\circ\, 33' \cdot \sqrt{1 - \cos^2 \alpha_1} = (0{,}96340 - 0{,}8075) \cdot \cos \alpha_1$$

$$\sqrt{1 - \cos^2 \alpha_1} = \frac{0{,}1559}{0{,}2681} \cdot \cos \alpha_1$$

$$\sqrt{1 - \cos^2 \alpha_1} = 0{,}5815 \cdot \cos^2 \alpha_1$$

$$1 - \cos^2 \alpha_1 = 0{,}5815^2 \cdot \cos^2 \alpha_1$$

$$1 - \cos^2 \alpha_1 = 0{,}3381 \cdot \cos^2 \alpha_1$$

$$1 = 1{,}3381 \cdot \cos^2 \alpha_1$$

$$\cos^2 \alpha_1 = \frac{1}{1{,}3381} = 0{,}7474$$

$$\cos \alpha_1 = \sqrt{0{,}7474} = 0{,}865$$

$$\cos \alpha_1 = 0{,}865$$

$$\alpha_1 \cong 30^\circ$$

and then from equation 1. $k_1 = k = 480$ mm.

From this it clearly follows that it is only at identical angles of inclination and length of arm which makes it possible for both felloes to remain at the same height after turning at an identical angle of β.

Since with the solutions adopted in practice $\alpha \neq \alpha_1$ and $k \neq k_1$ in principle the conditions can not be fulfilled either. In this case for the correct working the only reservation should be that after turning aside at an angle — *i.e.* in lowered (ploughing) position — the felloe of the furrow-wheel must be at the height of the ploughshare-edge, while in the raised position neither of the felloes shall be at a shorter distance from the ploughshare-edge than the value of *sz*. This means that in transport position the ploughframe will not be wholly parallel to the soil, but the following computation shows the deviation between both sides to be only a few millimeters.

The distance between the furrow-wheel felloe and the bearing of the axle is:

$$520 \cdot \cos 35°30' = 520 \cdot 0{,}81412 = \mathit{424\ mm}.$$

While the distance of the stubble-wheel felloe is:

$$480 \cdot \cos 30° = 480 \cdot 0{,}86603 = \mathit{416\ mm}.$$

The distance is then 8 mm. As the distance of the wheels from each other is 1210 mm the slant sidewards is only 6.6 per cent, i.e. slightly higher than 1/2 per cent. To this 1/2 per cent no objection can be raised even from an aesthetical point of view. For ploughing the first furrow the felloes of both wheels must be rised by a value which is in accordance with the maximum ploughing depth compared with the ploughshare-edge.

The angle of deviation, γ_1, by which the furrow-wheel turns can be computed in the following way:

$$k_1 \cdot \cos(a_1 + \beta + \gamma_1) + 280 = k_1 \cdot \cos(a_1 + \beta) \qquad (42)$$

$$\cos(a_1 + \beta + \gamma_1) = \cos(a_1 + \beta) - \frac{280}{520} = 0{,}64556 - 0{,}53846$$

$$\cos(a_1 + \beta + \gamma_1) = 0{,}10716$$

$$a_1 + \beta + \gamma_1 = 83°\ 50'$$

$$\gamma_1 = 38°.$$

The angle of deviation, γ, by which the stubble-wheel turns:

$$k \cdot \cos(a + \beta + \gamma) + 280 = k \cdot \cos(a + \beta) \qquad (43)$$

$$\cos(a + \beta + \gamma) = \cos(a + \beta) - \frac{280}{480} = 0{,}69936 - 0{,}58333$$

$$\cos(a + \beta + \gamma) = 0{,}11603$$

$$a + \beta + \gamma \cong 83°\ 20'$$

$$\gamma \cong 38°.$$

That is the axle of the stubble-wheel must turn at a greater angle than that of the furrow-wheel. Thus, when the furrow-wheel has reached its highest position limited by the adjusting handle, the axle of the stubble-wheel will turn further. Inversly too: on lifting out after a turn at an angle of $\gamma - \gamma_1$ the claw-clutch at the end of the stubble-wheel-axle contacts the bearing of the furrow-wheel and then they jointly rise to the full height.

In case of continuous ploughing after the turn of the furrow-wheel at an angle the stubble-wheel turns further at an angle of γ. Therefore, the claw-clutch must be able to turn freely at an angle of $\gamma = 38°$.

The turn of the stubble-wheel-axle at an angle of $\beta + \gamma$ is caused by the weight of the plough. The turn at an angle of γ is needed only if the plough is required to be adjusted to the position of deepest ploughing. In case of a lesser ploughing depth a turn only at an angle of $\gamma' < \gamma$ can be permitted. But the weight of the plough exerts its effect even after the turn at an angle of $\gamma + \beta$, for this reason the axle must be impeded in turning further. Accordingly, in case of lesser turns, e.g. at an angle of γ', γ'' ... etc., needed for adjusting more shallow ploughing depths, a way must be found to prevent the plough from sinking deeper. This can be achieved by fixing an arm to the axle by which one can limit the turn of the axle and so position it according to the different ploughing depths. Its practical solution is as follows:

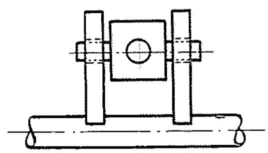

Fig. 10

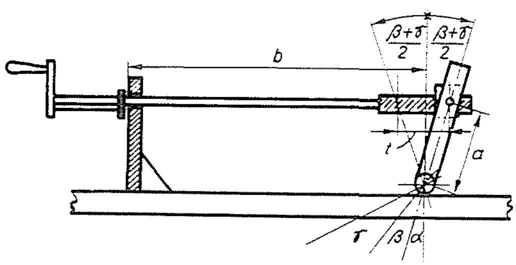

Fig. 11

To the axle of the stubble-wheel lying across the frame, two parallel arms are to be fixed provided with pin-holes (Figure 10). Between both arms a screw-nut provided with pins on its opposite sides is placed. The pins fit into the pin-holes and can freely turn about in them.

Through the nut a screw-bolt passes. At the end of the bolt there is a buffer which, on the turning of the axle, lies down on the holding arm rigidly fixed to the ploughframe. On lifting the parallel arms turn together with the axle and push the screw-bolt forward into the screw-nut through the opening of the holding arm. On lowering, the axle can turn as far back as is permitted by the buffer fixed to the screw-bolt. Since the screw-bolt can be turned by a handle, the turn of the stubble-wheel, i.e. the ploughing depth, can be adjusted in this way.

The fundamental setting can be seen in Figure 11.

If the distance of the pin of the nut from the centre of rotation is a, the parallel arms must be fixed to the stubble-wheel-axle so that the angle formed by the deepest sinking, i.e. the deepest ploughing position, and the position of the extreme lifting out, i.e. $\beta + \gamma$, should be in a lifted position by half compared with the horizontal. In this case the maximum longitudinal motion of the nut:

$$t = 2a \cdot \sin \frac{a + \gamma}{2}. \tag{44}$$

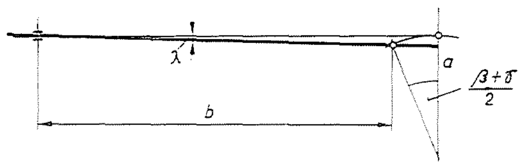

Fig. 12

Simultaneously the screw-bar also turns aside. The angle of the turn can be computed as follows (Figure 12):

$$\operatorname{tg} \lambda = \frac{a - a \cdot \cos \dfrac{\beta + \gamma}{2}}{b + a \cdot \sin \dfrac{\beta + \gamma}{2}}. \tag{45}$$

As a consequence of that stated above, $\beta + \gamma = 48°20'$, while the half $24°10'$; $a = 200$ mm, $b = 750$ mm. So

$$\operatorname{tg} \lambda = \frac{200 \cdot 1 - 0{,}91236}{750 + 200 \cdot 0{,}40939} = \frac{17{,}528}{831{,}878} \cong 0{,}02$$

which roughly corresponds to 1°.

In an extreme position the end of the screw-bar rises at approx. 18 mm from the initial position. The greatest length of thread needed can obviously be computed from $t = 2\,a \cdot \sin \dfrac{\beta + \gamma}{2}$.

Finally the angles to the positions 2, 3, 4 and 5 on the arc of the depth-adjusting handle shown in Fig. 4 must be determined according to 28, 24, 20, 16 cm ploughing depths. Obviously, to plough the first furrow of the deepest ploughing the adjusting handle must stand at such an angle to permit the furrow-wheel to turn at an angle of γ_1. So, Position 2 forms an angle of γ_1.

With the angles of the further Positions 3, 4 and 5 — marked respectively $\gamma_1', \gamma_1'', \gamma_1'''$ — the following relationships can be found:

$$k_1 \cdot \cos\,(a_1 + \beta + \gamma_1') + 240 = k_1 \cdot \cos\,(a_1 + \beta)$$

$$k_1 \cdot \cos\,(a_1 + \beta + \gamma_1'') + 200 = k_1 \cdot \cos\,(a_1 + \beta)$$

$$k_1 \cdot \cos\,(a_1 + \beta + \gamma_1''') + 160 = k_1 \cdot \cos\,(a_1 + \beta).$$

Making use of the earlier data:

$$\cos(a_1 + \beta + \gamma_1') = \cos(a_1 + \beta) - \frac{240}{k_1} - 0{,}64556 - 0{,}46154 = 0{,}18402$$

$$a_1 + \beta + \gamma_1' = 79^\circ\, 36'$$

$$a_1 + \beta = 50^\circ\, 50'$$

$$\gamma_1' = 28^\circ\, 46'$$

$$\cos(a_1 + \beta + \gamma_1'') = 0{,}64556 - \frac{200}{520} = 0{,}64556 - 0{,}30769 = 0{,}26095$$

$$a_1 + \beta + \gamma_1'' = 74^\circ\, 38'$$

$$a_1 + \beta = 50^\circ\, 50'$$

$$\gamma_1'' = 23^\circ\, 48'$$

$$\cos(a_1 + \beta + \gamma_1''') = 0{,}64556 - \frac{160}{520} = 0{,}64556 - 0{,}30769 = 0{,}33787$$

$$a_1 + \beta + \gamma_1''' = 70^\circ\, 15'$$

$$a_1 + \beta = 50^\circ\, 50'$$

$$\gamma_1'''\ 19^\circ\, 25'.$$

The third point of support of the plough-frame is the rear-wheel. Its adjustment is also controlled by the furrow-wheel.

The construction of the rear-wheel is shown in Fig. 13.

Its structural parts form a four-jointed mechanism. This is shown in Fig. 14. The motion of point k is given here by the motion of shaft BC because shafts t_1 and t_2 together with section b form a rigid triangle.

With this arrangement the question is: at what angle whould shaft AB turn about point A, so that wheel k, *i.e.* the rearwheel-felloe should simultaneously rise or sink in the measure just needed then. How does the motion of point k take place to come into the position k_1 is in, for the time being is a matter of no import; what matters is that the level difference between positions k_1 and k should be 80 mm corresponding to the transport height. Namely, the rear-wheel-felloe is moving along the bottom also when ploughing the first furrow, *i.e.* at a level with the ploughshare, and on lifting out it must be raised 80 mm above it.

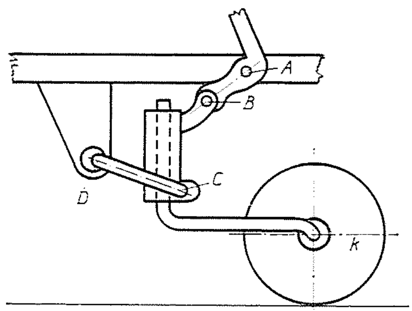

Fig. 13

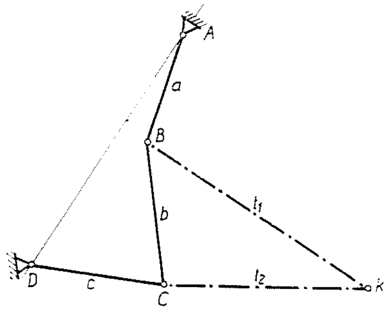

Fig. 14

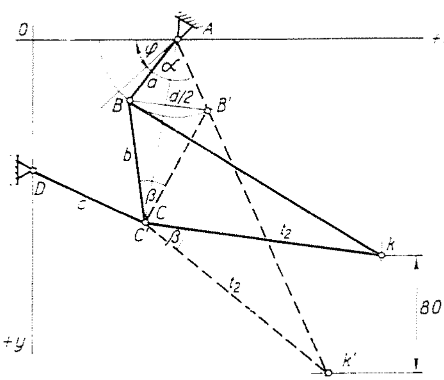

Fig. 15

To make the computations needed let us take a system of co-ordinates where x-axis passes through point A, while y-axis through point D; the axis of positive abscisses is directed to the right, that of positive ordinates downwards (Fig. 15).

The known data of the mechanism (else we could not draw them) drawn in the system of co-ordinates are a, b, c, t_1 and t_2 sides, moreover, angle φ formed by section AB and the horizontal.

The co-ordinates of point A are obviously x_A, 0; those of point D: 0, y_D.

The co-ordinates of point B can be obtained if a circle is drawn around centre A with a radius a and is intersected by the tangent of direction φ passing through point A.

The equation of the circle is:

$$a^2 = (x - x_A)^2 + y^2. \tag{46}$$

The equation of the straight line is:

$$y = -\text{tg}\,\varphi\,(x - x_A). \tag{47}$$

The system of equations has two solutions where the values belonging to positive ordinate are chosen, *i.e.* x_B and y_B.

The coordinates of point C can be obtained by the intersection of two circles, where the centre of the first circle is B and its radius b, while the centre of the second circle is D and its radius c. Their equations are:

$$b^2 = (x - x_B)^2 + (y - y_B)^2 \tag{48}$$

$$c^2 = x^2 + (y - y_D)^2. \tag{49}$$

On their solutions two pairs of values are obtained, of them those belonging to the greater x are chosen, *i.e.* x_C and y_C. The co-ordinates of point k can similarly be computed. In this case the equations of the two circles are)

$$t_1^2 = (x - x_B)^2 + (y - y_B)^2 \qquad (50:$$

$$t_2^2 = (x - x_C)^2 + (y - y_C)^2. \tag{51}$$

Of the two solutions obtained the pair of values belonging to the greater x is to be chosen; these will be x_k and y_k. To determine the co-ordinates of k_1 let us take that $y_{k_1} = y_k + 80$, but later on these have be neglectful to some degree.

Namely, if the turn of shaft AB at an angle of a comes out in such a way that the straight line connecting points A and C would lie just at an angle of $\frac{a}{2}$ point C, on turning at an angle of a, would stay in its original place. But, on the other hand, given straight CC_1 is rather a small value and by neglecting it no mistake can be made.

By neglecting it, the angle of turn of side b, β, can be computed in the following way:

$$\frac{\frac{d}{2}}{a} = \sin\frac{\alpha}{2} \text{ and } \frac{\frac{d}{2}}{b} = \sin\frac{\beta}{2} \qquad \begin{matrix}(52)\\(53)\end{matrix}$$

and hence

$$\sin\frac{\beta}{2} = \frac{a}{b}\cdot\sin\frac{a}{2}$$

But a is not known yet. It can be computed as follows:

If shaft CB turns around C at an angle of β, shaft C_k fixed to it will turn at an angle of β as well. In this case the distance kk_1 will be the base of an isosceles triangle, its length will be:

$$\frac{\frac{kk'}{2}}{t_2} = \sin\frac{\beta}{2} = \frac{a}{b}\cdot\sin\frac{a}{2}\cdot \quad (54)$$

The circle drawn around centre C with radius t_2 intersects the straight passing through point k_1 parallel with x-axis. Of the co-ordinates of k_1 only y_k

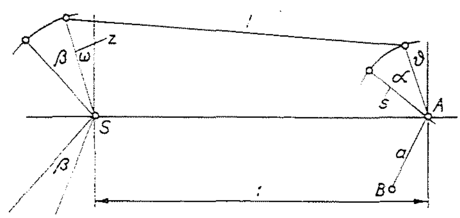

Fig. 16

is known, but it is sufficient to determine the straight. Thus the two equations are:

$$y = y_k + 80 \quad (55)$$

$$t_2^2 = (x - x_C)^2 + (y - y_C)^2 \,. \quad (56)$$

The solution yields two pairs of values, of these that belonging to the greater values of x is chosen and x_{k1} is obtained. But the co-ordinates of k and k_1 yield the distance kk_1:

$$kk_1^2 = (x - x_C)^2 + (y - y_C)^2 \quad (57)$$

This being substituted:

$$\sin\frac{a}{2} = \frac{kk_1}{2at_2}\cdot b\,.$$

The value of a is needed because the axle of the stubble-wheel has to make the shaft of the rear-wheel, a, turn at such an angle.

The geometrical relationships are to be established as follows (Fig. 16):

On lifting the rear-wheel the lifting-arm has to turn at an angle of a. The axle of the stubble-wheel turns at an angle of β at the same time. Let us take the lever of the rear-wheel to be s and its angle of inclination to the horizontal, the length of arm Z fixed to the axle of the stubble-wheel is to be sought foe. The inclination of the arm Z to the vertical is at an angle of ω. The distance of the stubble-wheel-axle and the lever-arm-pin of the rear-wheel has yet to be known.

If it is taken on t, the following equations are valid:

$$l^2 = [t - s \cdot \cos(90^\circ - \vartheta) + Z \cdot \cos(90^\circ - \omega)]^2 + \\ + [Z \cdot \sin(90^\circ - \vartheta) - s \cdot \sin(90^\circ - \vartheta)]^2 \tag{58}$$

$$l^2 = [t - s \cdot \cos(90^\circ - \vartheta - \alpha) + Z \cdot \cos(90^\circ - \omega - \beta)]^2 + \\ + [Z \cdot \sin(90^\circ - \omega - \beta) - s \cdot \sin(90^\circ - \alpha - \vartheta)]^2 . \tag{59}$$

Making both equations equal, l falls away and only Z remains unknown which can be determined unambigously.

Summary

The computations of strength for the structural parts of plough-levers can be made if their measurements of length are known. The measurements of length must, however, be determined in such a way that their freedom of motion should allow the fulfillment of the given conditions. The task is: starting from the strictly fixed conditions, to establish the proper working of each structural part, their geometrical relationships and last to compute all measurements of length by way of geometrical analysis.

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