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CONDITIONS FOR NO SOIL-PUSH BY OUTSIDE OF FRONT CUTTING SURFACE ON BENT BLADE

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ABSTRACT

One of the important restraint conditions for determination of rotary tiller parameters is whether the outside of front cutting surface on blade in rotary tiller pushes untilled soil in operation. By theoretical analysis and graphic verification on computer, no soil-push conditions is put forward and formula for calculating the position angle of its bent line derived, as is convenient for selection of rotary tiller parameters and design and drawing of its blade.

Key words: tiller blade, no soil-push conditions, position angle of bent line

CONDITIONS FOR NO SOIL-PUSH BY FRONT CUTTING SURFACE OUTSIDE

In China, domestic T.S. series blades (called standard bent blades for short below)are widely used for horizontal shaft rotary tillers.[1]The front cutting surface of standard bent blade is a inclined plane, as shown in Fig. 1.
where

R--radius of blade tip
γ--front cutting surface position angle at arbitrary point on front cutting edge (defined as the angle included between $\tilde{R}$ of arbitrary point on front cutting edge and front cutting surface)
α--position angle of bent line (defined as the angle included between bent line and R_1)
R_1--radius of end point of side cutting edge
γ_h--position angle of blade end
b--blade width

β--bent angle of front cutting surface

h--height of blade end

Whether outside of front cutting surface (called blade back for short below)pushes soil or not is an important factor affecting power consumption of rotary tiller which researchers of virious countries have paid much attention to and many treatises published.

Condition for no soil push by blade back put forward in Reference (2) is

$$v_m \leqslant (R - a)\omega \tag{1}$$

where v_m--forward speed of aggregate

a--tilth depth

ω--angular velocity of blade rotation

We hold that the expression isn't sufficient condition for no soil push by blade back, because h and γh fail to be considered. Proof is given below :

$$let \quad \lambda = \frac{R\omega}{v_m}$$

substitute into Eq. (1), after rearrangement,

$$\lambda \geqslant \frac{R}{R - a} \tag{2}$$

Now take standdard bent blade IT225 as an example. R equals 225 mm.When a = 180 mm is required, calculated with Eq. (2), no soil push by blade backcan be ensured if only $\lambda > 5$.

Graphs plotted by computer program RBWLD we compiled indicate that when $\lambda = 5$, if h = 40 mm , $\gamma_h = 68°$, blade back will not push soil (see Fig.2); but if h = 50 mm, $\gamma_h = 78°$, blade back will push soil (see Fig.3). From this we know that whether blade back pushes soil or not is related with h and γ_h. So,it is clear that Eq. (1) is not a sufficient condition for no-soil push by blade back.

The writer of Reference (3) paid attention to this and indicated that when cutting angle ε of front cutting surface of blade is too large (should be "too small" - the authors) blade back will push untilled soil at some points of cutting locus. Here, ε is defined as the included angle between tangent on absolute locus of arbitrary point on front cutting edge and outside of frontcutting surface (see Fig.4). From Fig.4 $\varepsilon = \varepsilon_0 - \Delta\varepsilon$,but $\varepsilon_0 = (\pi / 2) - \gamma$, so $\varepsilon = (\pi / 2) - \gamma - \Delta\varepsilon_0$. Here,$\gamma$ is the position angle at the same point of front cutting surface. So, we must select suitable γ when we reseach the effect of no soil push by blade back.

No matter where it is in cutting locus, if only the upper age B of front cutting surface always travels inside the cutting locus of front cutting edge,there will be no-soil push by blade back. Critical state is that B locates just on the cutting locus (as shown in Fig.5 a). For too big h (as shown in Fig.5 b)or too large γ(as shown in Fig.5 c),there will be soil push by blade back.

As shown in Fig.4,$\Delta\varepsilon$ is the included angle between tangent of absolute locus of blade cutting edge and tangent of its relative locus.

In working process of blade, $\Delta\varepsilon$ varies.At the point where tangent of absolute locus at right angle with X axis (see Fig.6), $\Delta\varepsilon$ has maxium value.

$$\Delta\varepsilon_{max} = arctg\frac{1}{\sqrt{\lambda^2 - 1}}^{[3]} \tag{3}$$

Let $\varepsilon = \Delta\gamma$,*we have*

$$\gamma = \pi / 2 - \Delta\varepsilon_{max} - \Delta\gamma \tag{4}$$

Moreover,$\Delta\gamma$ is related with λ ,h, and R as follows

$$\frac{\lambda h}{R} sin\Delta\gamma + arc(\frac{1}{\lambda} - \frac{h}{R} cos\Delta\gamma) + \sqrt{\lambda^2 - (1 - \frac{\lambda h}{R} cos\Delta\gamma)^2} = \sqrt{\lambda^2 - 1} + arcsin\frac{1}{\lambda} \tag{5}$$

Eq.(5) can be deduced as follows (see Fig.6).

(1) Let coordinates of points A be (X_A, Y_A),B(X_B, Y_B), from geometric relation,

$$sin\Delta\gamma = \frac{X_A - X_B}{h} \tag{6}$$

$$cos\Delta\gamma = \frac{Y_A - Y_B}{h} \tag{7}$$

(2) Equations of absolute locus are

$$\begin{cases} X = v_m t + Rcos\omega t \\ Y = Rsin\omega t \end{cases} \tag{8}$$

Here, t ----- time

v_m, ω, R defined as above

(3) Solve for X_A

From Eq. (8),

$$X_A = v_m t_A + Rcos\omega t_A \tag{9}$$

as $\quad \omega t_A = \psi, \quad t_A = \frac{\psi}{\omega}$ (10)

and $\quad \psi = arcsin\frac{1}{\lambda}^{[3]}$ (11)

We have $\quad cos\psi = \sqrt{1 - (\frac{1}{\lambda})^2}$ (12)

Combining Eqs. (9),(10),(11), and (12), and rearranging

$$X_A = \frac{R}{\lambda}(\sqrt{\lambda^2 - 1} + arcsin\frac{1}{\lambda}) \tag{13}$$

(4) *Solve for* X_B

From Eq.(8) $\quad Y_A = Rsin\omega t_A = Rsin\psi,$

Substitute into Eq.(7), we get

$Y_B = R\lambda - hcos\Delta\gamma$

Eq.(8) can be written as

$Y_B = Rsin\omega t_B$

$$so \qquad \frac{R}{\lambda} - hcos\Delta\gamma = Rsin\omega t_B$$

$$or \qquad t_B = \frac{1}{\omega}arcsin(\frac{1}{\lambda} - \frac{h}{R}cos\Delta\gamma) \tag{14}$$

$$cos\omega t_B = \sqrt{1 - (\frac{1}{\lambda} - \frac{h}{R}cos\Delta\gamma)^2} = \frac{1}{\lambda}\sqrt{\lambda^2 - (1 - \frac{h\lambda}{R}cos\Delta\gamma)^2} \tag{15}$$

From Eq.(8), we have

$$X_B = v_m t_B = Rcos\omega t_B \tag{16}$$

conbining Eqs.(13) and (17) into (16), we get

$$X_B = \frac{R}{\lambda}arcsin(\frac{1}{\lambda} - \frac{h}{R}cos\Delta\gamma) + \frac{R}{\lambda}\sqrt{\lambda^2 - (1 - \frac{h\lambda}{R}cos\Delta\gamma)^2} \tag{17}$$

(5) Subtitute Eqs.(13) and (17) into (6), we get Eq.(5)

$$\frac{\lambda h}{R}sin\Delta\gamma + arcsin(\frac{1}{\lambda} - \frac{h}{R}cos\Delta\gamma) + \sqrt{\lambda^2 - (1 - \frac{\lambda h}{R}cos\Delta\gamma)^2} = \sqrt{\lambda^2 - 1} + arcsin\frac{1}{\lambda}$$

We can say, if no soil is pushed by blade back at $\Delta\varepsilon = \Delta\varepsilon_{max}$then the same will be at any point on whole cutting locus. Thus, the sufficient condition for no soil push by blade back is

$$\gamma \leqslant \frac{\pi}{2} - \Delta\varepsilon_{max} - \Delta\gamma \tag{18}$$

Now take standard bent blade IT225 as an example for demonstration :

Here, R = 225 mm, h = 50 mm, calculate with Eqs.(5),(3) and (18),for $\lambda = 5, \Delta\gamma =$ 6.36 ° , critical position angle for no soil push $\gamma_h = 72.1$ ° , for $\lambda = 9$, and $\Delta\lambda = 6.32$ ° , $\gamma_h = 73.3$ ° . By Program RBWLD, we can get its working process chart (see Fig.7), which indicates that if only the condition for Eq.(18) is satisfied, there will be soil push by blade back. Thisproves that Eq.(18) is a sufficent condition for no soil push by blade back.

DETERMINATION FOR POSITION ANGLE OF BENT LINE

In designing bent blade, we have often to determine position angle of bent line first, and then make a plot of working drawing of blade acorring to parameters.From configuration, position angles of bent line and of arbitrary section on front cutting edge have relation as follows (see Fig.1):

$$sin\alpha = \frac{1}{R_1}(Rsin\gamma - rtg\frac{\beta}{2} - b_n tg\delta) \quad (19)$$

Deduction of which is the following : from Fig.1,

$$sin\alpha = OA' / R_1 \quad (20)$$

$$OA' = OM' - A'M' \quad (21)$$

$$OM' = Rsin\gamma \quad (22)$$

$$AM = AB + BM = rtg(\beta / 2) + b_n tg\delta \quad (23)$$

Substitute Eqs.(22) and (23) into (21), we have

$$OA' = Rsin\gamma - rtg(\beta / 2) - b_n tg\delta \quad (24)$$

Substitute Eq.(24) into (20), we get (19).

Thus ,in designing bent blades, we would better consider comprehensively all factors such as working quality ,perfromance of soil–throwing, power consumption as well as meet the requirements of Eq.(18), to select suitable value of γ, and then calculate value α with Eq.(19).

It is necessary to notice that different point on front cutting edge have different h and different γ_h. At the end point of blade, γ_h has its maximum value.While at point C(see Fig.1),htakes the maximum value. Check with computer on different situations indicates that at $b_n = b$ (end point of blade) there will most probably be soil push by blade back.So angle α has to be determined according to $\gamma_h$and b.

For the convenience of designers, Fig.8 is plotted with computer from Eqs.(3),(4) and (19).Selecting h and λ from Fig.8, suitable value α can be decided to ensure no soil push by blade back.

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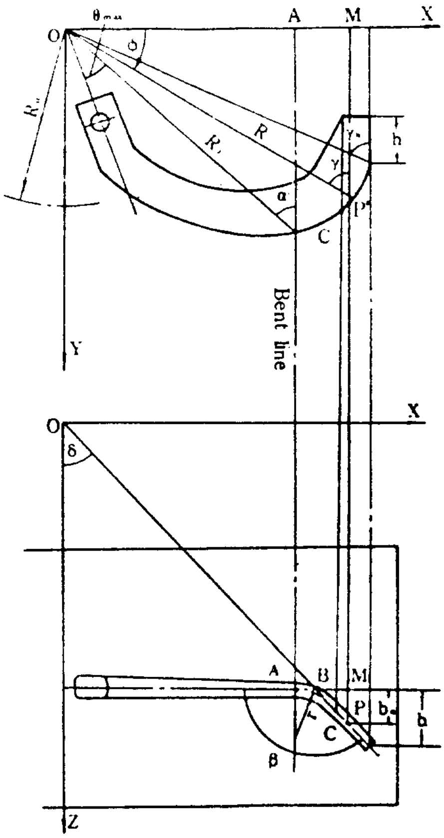


Fig.1 Parameters of bent blade

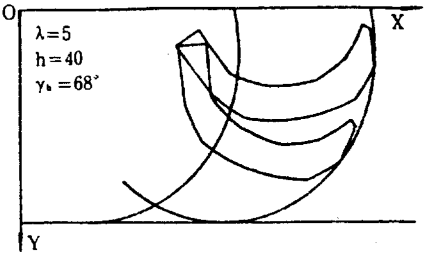


Fig.2 No soil push by outside of front cutting surface on bent blade

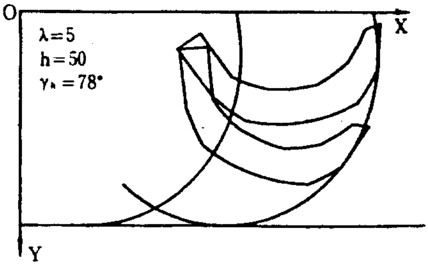


Fig.3 Soil push by outside of front cutting surface on bent blade

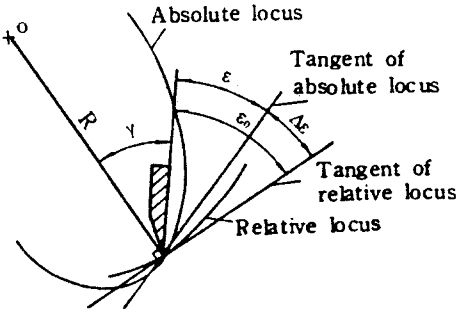
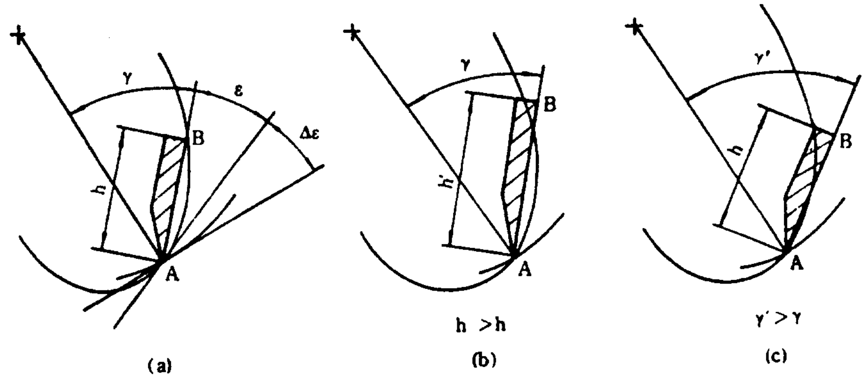


Fig.4 Parameters of front cutting surface in operation



(a)

h' > h
(b)

γ' > γ
(c)

Fig.5 Effect of *h*, *γ*

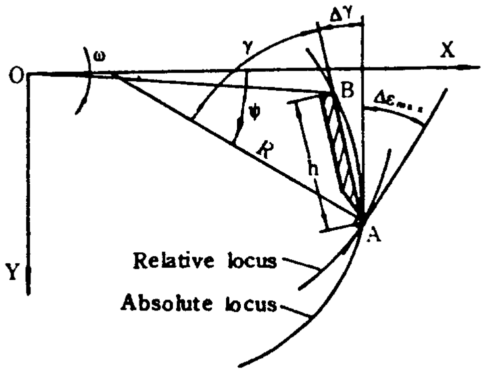


Fig.6 *γ* and Δ*γ*

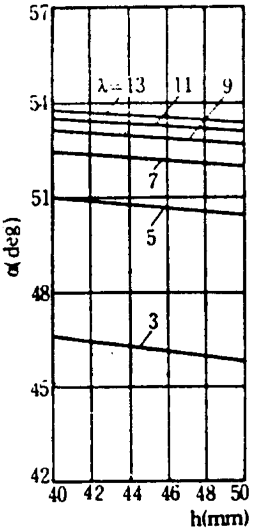


Fig.8 Relations among *h*, *λ*, *α*

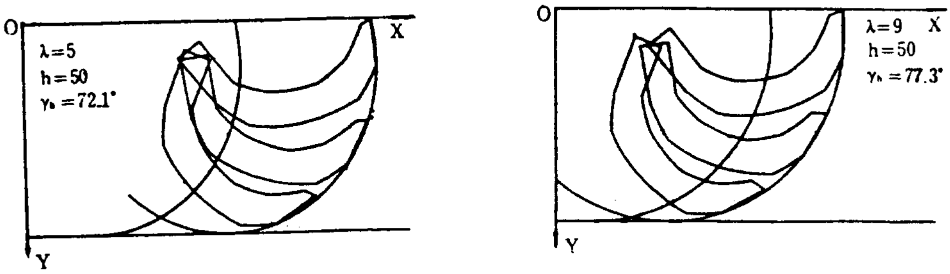


Fig.7 Chart of working process