https://doi.org/10.26160/2474-5901-2021-26-82-91

RATIONAL PROFILE OF A ROTARY TILLER KNIFE

Belov M.I., Storchevoy V.F., Kabdin N.E., Anashin D.V.

Keywords: L- type knife, rotary tiller.

Abstract. The object of the study was the L-type knife of a rotary tiller with a horizontal axis of rotation. The aim of the study was to define the rational profile of a rotary tiller knife that provides the minimal resistance force, when the knife enters the ground. Based on the results of experiments in which the specific work of pressure forces was determined, the mathematical model, the algorithm and the program application were developed for calculating the specific power per unit of knife blade width. It was found, that a profile of the L type knife affects the specific power of pressure and impact forces. The rational profile can be designed by specifying the radius of a rotor, the distance from a rotor axis to the ground, the pitch on a knife and the number of knives on one side of a flange. Results of calculations showed, that the rational profile of a knife provides specific power reduction in comparison with the straight line profile. The formula for rational profile calculation and the algorithm for specific power calculation were presented.

РАЦИОНАЛЬНЫЙ ПРОФИЛЬ НОЖА ПОЧВЕННОЙ РОТОРНОЙ ФРЕЗЫ

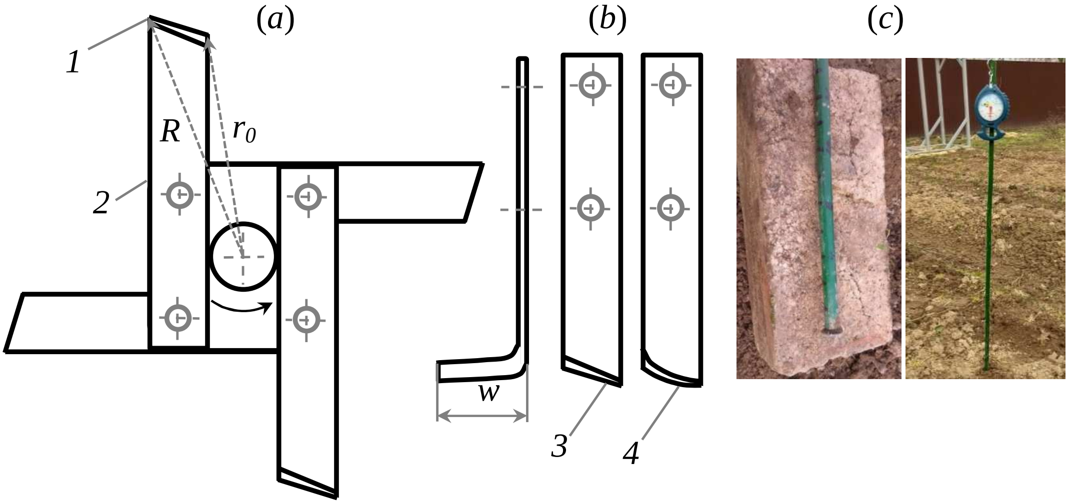
Белов М.И., Сторчевой В.Ф., Кабдин Н.Е., Анашин Д.В.

Ключевые слова: Г-образный нож, почвенная роторная фреза.

Аннотация. Объектом исследования служил Г-образный нож почвенной роторной фрезы с горизонтальной осью вращения. Цель исследования состояла в обосновании рационального профиля ножа, обеспечивающего минимальное сопротивление при входе ножа в почву. Разработаны математическая модель, алгоритм и приложение для оценки удельной мощности на единицу ширины захвата фрезы, оснащенной ножами с рациональным профилем и прямолинейным профилем в плоскости вращения. Результаты теоретических исследований показали, что рациональный профиль ножа позволяет уменьшить удельную мощность в сравнении с прямолинейным профилем ножа.

Introduction. A rotary tiller is designed for soil treatment (Figure 1 *a*). The soil is cultivated by rotor knives with a horizontal axis if rotation. The blades of the knives cut the soil into pieces, the front surface of the knife squeezes and breaks the soil with pressure. Power consumption increases when the heavy soil is handled, for example, the wet loam is cultivated. In this case, it is advisable to provide such a knife shape for which soil resistance to the knife movement is minimal. Currently, there are many works that study the effect of geometric parameters of a knife on the performance and the energy intensity of the soil treatment by a rotary tiller (Beeny and Khoo, 1970; Ahmad, 1986; Hirasawa et al., 2013; Khodabakhshi and Kalantari, 2013; Hirasawa, 2016; Ramazanova et al, 2016; Manda et al., 2016; Dhruwe et al., 2018). Effect of rotary tiller kinematic parameters on the quality of soil treatment is also studied full enough (Hendrick and Gill, 1978; Celik and Altikat, 2008; Belov, 2018). The new task was put forward in the given study. It consisted in defining the rational profile of the L-type knife that provides the minimal soil resistance force, when the knife enters the ground. Among the knives of different types L-type knives are more common in rotary tillers because of its effectiveness (Selvi, 2017).

The profile of the L-type knife in the rotation plane represents a section of the line close to the straight line or some curved line (Figure 1 *b*).



1 − knife blade; 2 − vertical blade; 3 − straight line profile; 4 − curved line profile

Fig. 1. Rotary tiller flange with two knives on one side (*a*), different knife profiles (*b*) and tube with spherical tip at lower end and dynamometer on top end (*c*)

The object of the study was the L-type knife of a rotary tiller with a horizontal axis of rotation. The aim of the study was to define the knife rational profile, which ensures the least soil resistance while entering the soil

Materials and methods. Experiments were carried out to evaluate the specific work of pressure forces. A metal 10 mm diameter straight tube with the 18 mm spherical tip was pressed into loamy soil at different angles to the vertical (Figure 1 *c*).A pressure force was measured by the spring dynamometer attached to the upper end of the tube. Displacement of the tip in the soil was measured with accuracy 5 mm due to the marked lines on the tube. The force measurement accuracy did not exceed 5 N. By definition, the specific work ε of pressure force can be defined as derivative of function *A* with respect *V*

$$\varepsilon = \frac{dA}{dV},$$

where *A* is the work of a pressure force, [J]; *V* − volume, [m^3].

By definition, $dV = \pi D^2 dL/4$, $dA = P\, dL$, where *D* is the diameter of the spherical tip, [m]; *P* – pressure force, [N]; *L* – the displacement of the tip, [m].

Therefore (Table 1),

$$\varepsilon = 4P/(\pi D^2).$$

A linear regression equation was chosen to estimate dependence of the specific work (ε) from the tip penetration depth (*h*) and the angle of inclination of the tube relative to the vertical (θ)

$$\varepsilon = k_0 + k_1 h + k_2 \theta + k_3 h \theta,$$

where k_1, k_1, k_2, k_3 –regression coefficients; $h = L \cos \theta$.

Tab. 1. Experiment number (Num), tip displacement (*L)*, angle of tube inclination relative to vertical (θ), pressure force (*P*), calculated value of specific work (ε)

Num	1	2	3	4	5	6	7	8	9	10	11
L (cm)	10	20	20	30	30	30	40	50	60	60	60
θ (□)	45	45	45	45	45	45	45	45	45	45	45
P (N)	9,81	21,6	15,7	37,3	42,2	34,3	46,1	56,9	58,9	66,7	60,8
ε (kJ m^{-3})	38,6	84,8	61,7	146,5	165,8	134,9	181,2	223,6	231,3	262,1	239
Num	12	13	14	15	16	17	18	19	20	21	22
L(cm)	70	70	80	80	10	20	20	20	30	30	40
θ (□)	45	45	45	45	30	30	30	30	30	30	30
P (N)	69,7	72,6	81,4	87,3	0	24,5	17,7	14,7	33,4	27,5	29,4
ε (kJ m^{-3})	273,7	285,3	320	343,1	0	96,4	69,4	57,8	131,1	108	115,7
Num	23	24	25	26	27	28	29	30	31	32	33
L (cm)	40	40	50	50	60	60	60	70	80	10	20
θ (□)	30	30	30	30	30	30	30	30	30	0	0
P (N)	39,2	34,3	63,8	45,1	43,1	39,2	58,9	61,8	71,6	0	7,8
ε (kJ m^{-3})	154,2	134,9	250,6	177,3	169,6	154,2	231,3	242,9	281,4	0	30,8
Num	34	35	36	37	38	39	40	41	42	43	44
L (cm)	20	20	30	40	40	40	40	45	45	45	50
θ (□)	0	0	0	0	0	0	0	0	0	0	0
P (N)	25,5	19,6	41,2	24,5	29,4	27,5	27,5	40,2	39,2	45,1	50
ε (kJ m^{-3})	100,2	77,1	161,9	96,4	115,7	107,9	107,9	158,1	154,2	177,3	196,6
Num	45	46	47	48	49	50	52	52			
L (cm)	50	50	60	60	65	65	80	80			
θ (□)	0	0	0	0	0	0	0	0			
P (N)	58,7	55,9	61,8	49,1	68,7	56,9	76,5	73,6			
ε (kJ m^{-3})	231,3	219,7	242,9	192,8	269,9	223,6	300,7	289,1			

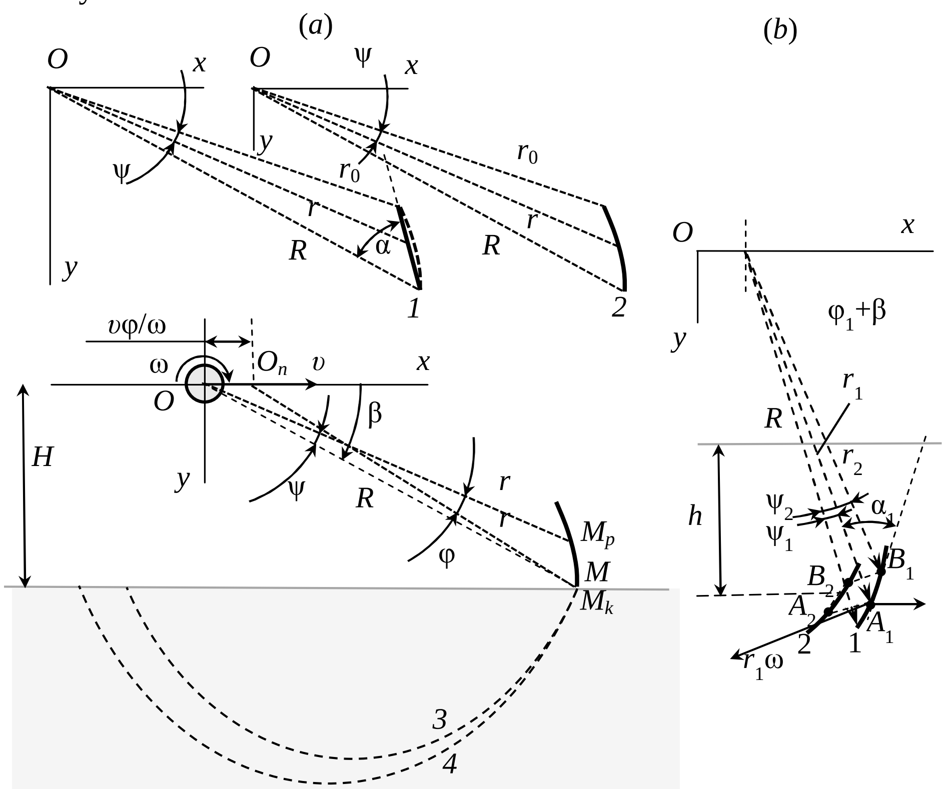
The software package “Statistica 10” was used to perform statistical analysis (StatSoft Inc., 2011). One coefficient (k_1) was significant with a confidence level of 95%. Confidence levels of significance for other coefficients did not exceed 90%. The regression equation was written as follows:

$$\varepsilon = 4043\ 10^3\ h. \quad (1)$$

The multiple coefficient of correlation was equaled to 0.92 and it was significant with a confidence level of 99%. Mathematical model, algorithm and program application were developed for calculating the specific power required. Program environment “Lazarus” was used to develop the application (Lazarus, 2017).

Results. Designations (Figures 1*a*, 1*b*, 2). *Oxyz* − stationary orthogonal Cartesian coordinate system with horizontal axis *Ox*, vertical axis *Oy* and axis *Oz*; *k* – number of knives on one side of a flange; *h* – depth, [m]; *H* – distance from the rotor axis to the ground, [m]; *R*, r_0 – distance from the rotor axis to the blade and to the back of a knife respectively, [m]; *r* – polar radius of point in the plane of rotor rotation ($r_0 \le r \le R$), [m]; *w* – knife blade width, [m]; *s* – tilling pitch for one knife (length of one tilling cut), [m]; β – the angle of rotor rotation measured from the axis *Ox* at the moment the first knife begins to penetrate into the soil, [rad]; φ – the angle of rotor rotation after the moment when the first knife begins to penetrate into the soil, [rad]; ψ – polar angle of the point of the knife profile, [rad]; ω – angular speed of the rotor, [rad s^{-1}]; *v* – the speed of the rotor axis point along the axis *Ox*, [m s^{-1}]; ρ – soil density, [kg m^{-3}]; E_p, E_k – work of the pressure and impact forces for one knife pass respectively, [J]; *W* – specific power of pressure forces and impact forces per unit of knife width, [W m^{-1}]; *n* – number of intervals for φ; *m* – number of intervals for *r*.

Rational profile equation. The profile of a knife was considered as the line of the front (working) surface of the knife in the plane of rotor rotation. The rational profile of a knife was considered as a profile each point of which enters the ground at one point. Figure 2 *a* shows the position of a rational profile at the moment of entry into ground through the point *M*, when the point M_k of the blade is situated at the position *M*. Some point M_p of this rational profile with some polar radius *r* takes place at the point *M*, when the rotor axis displaces from the position *O* to some position O_n and the rotor rotates at some angle φ. Coordinates x_p, y_p of the point M_p in the position *M* are to be equaled to coordinates x_M, y_M of the point *M* respectively.



1 − straight line profile; 2 − rational profile; 3 − trajectory of point M_p; 4 − trajectory of point M_k

Fig. 2. Profiles of knife and trajectories of profile points M_p, M_k in soil when moving through point *M* (*a*) and points *A*, *B* of knife profile in positions A_1, B_1 and positions A_2, B_2 (*b*)

So

$$\begin{cases} r\cos(\beta-\psi+\varphi)+\upsilon\varphi/\omega=R\cos\beta, \\ r\sin(\beta-\psi+\varphi)=R\sin\beta, \end{cases} \quad (2)$$

where $\beta = \arcsin (H/R)$. (3)

After excluding the variable φ from equations (2) the equation of the rational profile in the polar coordinates r, ψ can be written as follows:

$$\psi=\beta+\frac{2\pi R}{sk}\left(\cos\beta-\sqrt{(r/R)^2-\sin^2\beta}\right)-\arcsin\left(\frac{R\sin\beta}{r}\right), \quad (4)$$

where $s = 2\,\upsilon\,\pi/(k\,\omega)$. (5)

The function ψ increases, when variable r decreases. The function ψ reaches a maximum ψ_0 at $r = r_0$:

$$\psi_0=\beta+\frac{2\pi R}{sk}\left(\cos\beta-\sqrt{(r_0/R)^2-\sin^2\beta}\right)-\arcsin\left(\frac{R\sin\beta}{r_0}\right). \quad (6)$$

Straight line profile equation. A straight line profile was formed by a straight section connecting two end points of the rational profile. The polar coordinates of these points can be write as follows:

$r = R$, $\psi = 0$ and $r = r_0$, $\psi = \psi_0$.

The equation of the straight line profile in polar coordinates r, ψ can be written in the next form:

$r = R \sin \alpha /\sin (\alpha + \psi)$, (7)

where $0 < \psi \le \psi_0$;

$\alpha = \arctan[r_0 \sin \psi_0 /(R - r_0 \cos \psi_0)]$. (8)

Knife point trajectory equations. Equations of the trajectory of the profile point M_p with polar coordinates r, ψ can be written in parametric form:

$$\begin{cases} x=sk\varphi/(2\pi)+r\cos(\beta-\psi+\varphi), \\ y=r\sin(\beta-\psi+\varphi), \end{cases} \quad (9)$$

where φ – a parameter (an angle of rotor rotation, $0 \le \varphi$); r, ψ − constants ($0 \le \psi \le \psi_0$; $r_0 \le r \le R$).

Power requirement. There were considered only pressure and impact forces acting on the soil from the knife surface. Two adjacent positions 1, 2 of knife with two adjacent profile points A, B were investigated at first (Figure 2 *b*). Some designations were added: φ_1, φ_2 – the rotor rotation angle in correspondent profile position 1, 2 (A_1B_1, A_2B_2); r_1, r_2 – polar radius of correspondent point A_1, B_1; ψ_1, ψ_2 – polar angular of correspondent point A_1, B_1; α_1 – front angle formed by the polar radius of the profile at point A_1 and the tangent to the profile at point A_1; F – area of the figure $A_1A_2B_2B_1$. It was assumed that at a small value ($\varphi_2 - \varphi_1$) and a short arc length A_1B_1 the figure $A_1A_2B_2B_1$ is small, and value F equals to the area of the quadrangle $A_1A_2B_2B_1$ with sufficient precision:

$F = |(x_{B1} - x_{A2})(y_{A1} - y_{B2}) + x_{A1} (y_{A2} - y_{B1}) + x_{B2} (y_{A2} + y_{B1})|/2$, (10)

where x_{A1}, y_{A1} – coordinates of point A_1, x_{A2}, y_{A2} – coordinates of point A_2, x_{B1}, y_{B1} and x_{B2}, y_{B2} – coordinates of points B_1 and B_2 respectively.

Pressure forces perform the work e_p to push (squeeze out) soil in the area $A_1A_2B_2B_1$. By definition,

$$e_p = \varepsilon\, Fw.$$

If h – average depth at points A_1, A_2, B_1, B_2, then the latest formula with equality (1) can be written as follows

$$e_p = 4043\ 10^3\ [y_{A1} + y_{A2} + y_{B1} + y_{B2})/4 - H]\ F\ w. \quad (11)$$

Impact forces perform the work e_k to move soil particles in the area $A_1A_2B_2B_1$. By definition,

$$e_k = \rho\ F\ w\ \upsilon_n^2/2, \quad (12)$$

where υ_n – velocity of the center of mass for the area $A_1A_2B_2B_1$.

The value v_n was considered as projection of the point A_1 velocity on the outer normal to the profile in the plane of rotor rotation:

$$\upsilon_n = r_1\ \omega \cos\alpha_1 - \upsilon \sin(\varphi_1 + \beta + \alpha_1 - \psi_1).$$

After replace value ω by its expression from equality (5) the latest formula can be written as follows:

$$\upsilon_n = r_1\ 2\ \pi\ \upsilon \cos\alpha_1/(k\ s) - \upsilon \sin(\varphi_1 + \beta + \alpha_1 - \psi_1), \quad (13)$$

where $\alpha_1 = \arctan[r_2 \sin(\psi_2 - \psi_1)/(r_1 - r_2 \cos(\psi_2 - \psi_1))]$.

It was assumed, that $e_k \neq 0$, if the next conditions were true:

$$\upsilon_n > 0; \quad \varphi_1 + \beta - \psi_1 < \pi/2. \quad (14)$$

Conditions (14) are fulfilled, if the area $A_1A_2B_2B_1$ is located in front of the knife and the point A_1 deepens. The values E_p, E_k was calculated as sums of correspondent values e_p, e_k for each area $A_1A_2B_2B_1$, cultivated with one knife for one pass. By definition,

$$W = (E_p + E_k)\ \upsilon/(s\ w). \quad (15)$$

So, in this case the specific power per unit of knife blade width did not depend on value w.

Knife back pushing against ground. The value υ_x was considered as projection of velocity of the point of the rational profile on the axis Ox at the moment of the point entry into the ground. The following condition must be fulfilled to prevent the back of the knife from pushing against the ground:

$$\upsilon_x < 0 \text{ or } \upsilon - H\ \omega < 0.$$

After replace value ω by its expression from equality (5) this condition can be written as follows

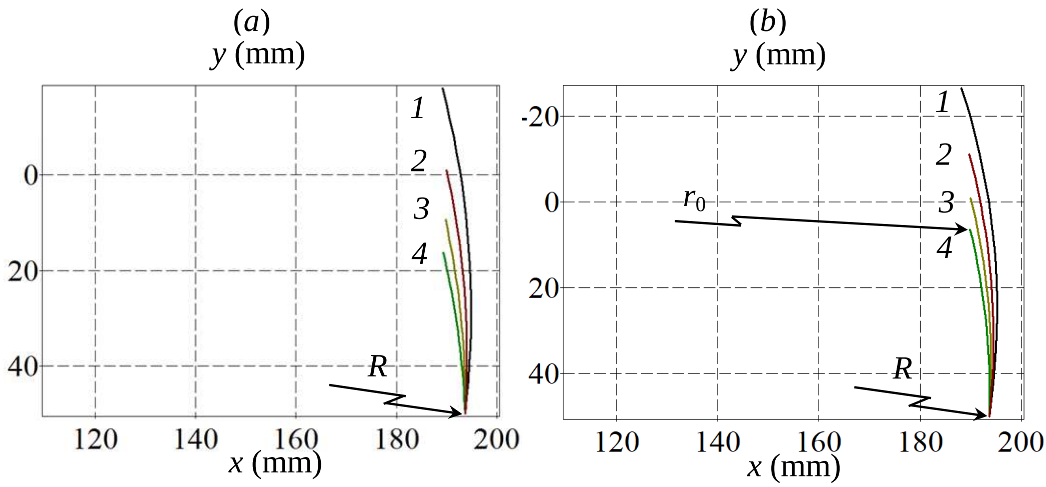
$$s < 2\ \pi\ H/k. \quad (16)$$

The power calculation algorithm. **1**. Initialization of input variables k, H, R, r_0, w, s, υ, ρ, n, m (Table 2). Check of the condition (16). **2**. Calculation of the value β by the formula (3), the value ψ_0 by the formula (6), the value α by the formula (8). **3**. Calculation of steps Δ_ψ, Δ_φ as $\Delta_\psi = \psi_0/m$; $\Delta_\varphi = (\pi - 2\ \beta)/n$. **4**. Initialization of the number i and the values E_p, E_k : $i = 0$; $E_p = 0$; $E_k = 0$. **5**. Calculation of the values φ_1, φ_2 as $\varphi_1 = \beta + i\ \Delta_\varphi$; $\varphi_2 = \varphi_1 + \Delta_\varphi$. **6**. Initialization of the number j: $j = 0$. **7**. Calculation of the values ψ_1, ψ_2 as $\psi_1 = j\ \Delta_\psi$; $\psi_2 = \psi_1 + \Delta_\psi$. **8**. Calculation of the value r from the equation (4) at $\psi = \psi_1$ for determination of the value r_1 ($r_1 = r$) and the value r from the equation (4) at $\psi = \psi_2$ for determination the value of r_2 ($r_2 = r$). **9**. Calculation of the values x, y by the formulas (9) at $r = r_1$, $\varphi = \varphi_1$, $\psi = \psi_1$ for determination of the values x_{A1}, y_{A1} ($x_{A1}= x$, $y_{A1}= y$); calculation of the values x, y by the formulas (9) at $r = r_2$, $\varphi = \varphi_1$, $\psi = \psi_2$ for determination of the values x_{B1}, y_{B1} ($x_{B1}= x$, $y_{B1}= y$); calculation of the values x, y by the formulas (9) at $r = r_1$, $\varphi = \varphi_2$, $\psi = \psi_1$ for determination of the values x_{A2}, y_{A2} ($x_{A2}= x$, $y_{A2}= y$); calculation of the values x, y by the formulas (9) at $r = r_2$, $\varphi = \varphi_2$, $\psi = \psi_2$ for determination of the values x_{B2}, y_{B2} ($x_{B2}= x$, $y_{B2}= y$). **10**. Calculation of the value F by the formula (10) and the value v_n by the formula (13). **11**. Calculation of the value e_p by the formula (11) and increase in the value E_p by e_p, if $H \le y_{A1}, y_{A2}, y_{B1}, y_{B2}$ and conditions (14) are true. **12**. Calculation of the value e_k by the formula (12) and increase in the value E_k by e_k, if $H \le y_{A1}$; $H \le y_{B1}$; $H \le y_{A2}$; $H \le y_{B2}$. **13**. Calculation of the value r from the equation (7) at $\psi = \psi_1$ for determination of r_1 ($r_1 = r$) and r from the equation (7) at $\psi = \psi_2$ for determination r_2 ($r_2 = r$); execution of the points **10**, **11**, **12** for the straight line profile. **14**. Increase in the value j by 1 and repetition of the points from 7 to 14, if $j < m$. **15**. Increase in the value i by 1 and repetition of the points from **5** to **15**, if $i < n$. **16**. Calculation of the value W by the formula (15).

Tab. 2. Initial data

k	H, mm	R, mm	r_0, mm	w, mm	s, mm	υ, m/s	ρ, kg m^{-3}	n	m
2, 3	50	200	190	60	60−120	1.5	1400	200	100

The results of calculations. Analysis of the function (4) and the formula (3) shows that values H, R, s, k effect on rational profile of the knife (Figure 3). It should be noted, that the rational profile as a line keeps its shape at different distances from a rotor axis to the back of a knife (r_0), if values H, R, s, k are not changed. As the distance r_0 decreases, the rational profile lengthens due to addition of new section of line. So, the part of a rational profile with the point on the knife blade is a rational profile for bigger distance from a rotor axis to the back of a knife.

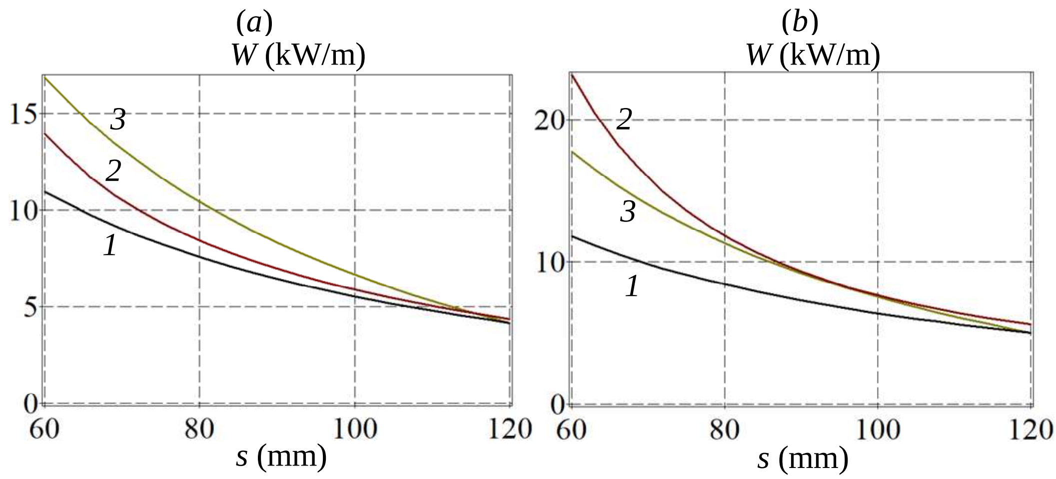


1 – s = 60 mm; 2 − s = 80 mm; 3 − s = 100 mm; 4 − s = 120 mm

Fig. 3. Rational profiles of knife for k = 3 (*a*) and k = 2 (*b*)

It follows from the above, that a rational profile for some tilling pitch is not a rational profile for another tilling pitch. Thus, to ensure the quality of soil cultivation it is advisable to change or adjust the shape of the knife for another tilling pitch. The minimum distance from the rotor axis to the knife back cannot exceed the distance from the rotor axis to the ground. Hence, the distance from the rotor axis to the back point of a rational profile cannot be less than the distance from the axis to the ground. It should be noted the importance of fulfilling condition (16), violation of which does not allow to find a rational profile. A connection of two end points of a rational profile with a straight line segment makes it possible to obtain a straight line profile. The profile obtained in this way ensures the movement of the knife without pressure of knife back on the ground.

The specific power of pressure forces and impact forces depend on the knife profile and tilling pitch (Figure 4). Rational profile knives provide less specific power than straight line profile knives. Three knives on one side of a flange provide less specific power and less difference between rational profile and straight line profile compared to two knives. The power increased slightly if the number of rational profile knives on one side of a flange decreased from 3 to 2. The power increased by 20 to 100%, if the number of straight line profile knives on one side of a flange decreased from 3 to 2.Thus, it is advisable to install three knives on one side of a flange instead of two knives when using knives with a straight line profile. The rational profile knife for 120 mm tilling pitch can be used for cultivating soil with less tilling pitch. However at this case this profile is not rational.



1 – rational profiles; 2 − straight line profiles; 3 − rational profile for $s = 120$ mm

Fig. 4. Effect of *s* on *W* for $k = 3$ (*a*) and $k = 2$ (*b*)

A comparison of lines 1, 3 on the Figure 4 makes it possible to accept that use of knives with an irrational profile leads to an increase in power. It can be seen on the Figure 4 that a number of knives on one side of a flange has little effect on power if a knife profile is rational. Thus, three or two knives can be installed on one side of a flange to provide the specified tilling pitch at the same power.

Conclusions. 1. A profile of L-type knife affects the specific power of pressure and impact forces. 2. The rational profile can be designed by specifying radius of the rotor, distance from a rotor axis to the ground, tilling pitch and number of knives on one side of a flange. 3. The rational profile of a knife provides specific power reduction in comparison with the straight line profile. 4. A knife with the rational profile, designed for some tilling pitch, can be used for smaller tilling pitch. Such a knife profile ensures the movement of the knife without pressure of its back on the ground. 5. Number of knives on one side of a flange has little effect on specific power if the knife profile is rational. 6. The rational profile knives make it possible to provide the given pitch on a knife without changing the power with both three knives on one side of a flange and two knives on one side of a flange.

References / Список литературы

1. Ahmad, D. (1986). A width of cut analysis on the performance of a rotary strip tiller. Pertanika, 9(1), 7 – 15.
2. Belov, M. (2018). Kinematics of twin rotary tiller. Agricultural Engineering International: CIGR Journal, 20(4), 91– 96.
3. Beeny, J. M.& Khoo, D. C. (1970). Preliminary investigations into the performance of different shaped blades for the rotary tillage of wet rice soil. Journal of Agricultural Engineering Research, 15(1), 27-33.
4. Celik, A. & Altikat, S. (2008). Geometrical analysis of the effects of rotary tiller blade path on the distribution of soil slice size. Applied Engineering in Agriculture, 24(4), 409 – 413.
5. Dhruwe, N., Sahu, S., Raghuwanshi, R. & Nishad P. (2018). Field performance evaluation of L-shaped blade rotary tiller cum inter row weeder. International Journal of Agricultural Engineeing, 11(1), 64–72.
6. Hendrick, J.G. & Gill, W.R. (1978). Rotary-tiller design parameters: Part V. Kinematics. Transections of the ASAE, 21(4), 658-664.
7. Hirasawa, K., Kataoka, T. & Kubo, T. (2013). Prediction and evaluation for leveling performance in rotary tiller. 4th IFAC Conference on modelling and control in agriculture, horticulture and post harvest industry, Espoo, Finland. IFAC Proceedings, 46, 315−320.
8. Hirasawa, K. (2016). Prediction and evaluation of leveling performance for rotary tillers. Yanmar technical review.
9. Khodabakhshi, A. & Kalantari, D. (2013). Effect of design parameters of rotary tillers on unevenness of the bottom of the furrows. Advances in Agriculture, Sciences and Engineering Research , 3(7), 950−955.
10. Mandal, S.K., Bhattacharyya, B., Mukherjee, S. & Prasad, A.,K. (2016). Design Optimization of Rotary Tiller Blade using Specific Energy Requirement. International Journal of Current Engineering and Technology, 6(4), 1257−1263.
11. Ramazanova, G., Belov, M., Khadzhiev P. 2016. Theoretical Justification of Work Surface Profile of Rotary Tiller Knife. Machinery and Equipment for Rural Area. 2, 32−37.

11. Рамазанова Г.Г., М.И. Белов, П.И. Гаджиев. Обоснование профиля рабочей поверхности ножа фрезы для обработки почвы // Техника и оборудование для села. 2016. №2. С. 32-37.
12. Selvi, K. (2017). A new blade design of rotary tiller and static analysis using computer-aided tool. INMATECH-Agricultural Engineering, 53(3), 29−34.

Белов Михаил Иванович – доктор технических наук, профессор, B-Mikhael@yandex.ru	**Belov Mikhail Ivanovich** – doctor of technical sciences, professor, B-Mikhael@yandex.ru
Сторчевой Владимир Федорович – доктор технических наук, профессор, заведующий кафедрой, v.storchevoy@rgau-msha.ru	**Storchevoy Vladimir Fedorovich** – doctor of technical sciences, professor, head of department, v.storchevoy@rgau-msha.ru
Кабдин Николай Егорович – кандидат технических наук, доцент, Kabdin-nek@mail.ru	**Kabdin Nikolai Egorovich** – candidate of technical sciences, associate professor, Kabdin-nek@mail.ru
Анашин Дмитрий Викторович – старший преподаватель, anashin@rgau-msha.ru	**Anashin Dmitriy Victorovich** – senior lecturer, anashin@rgau-msha.ru
Российский государственный аграрный университет − Московская сельскохозяйственная академия имени К.А. Тимирязева, Москва, Россия	Russian State Agrarian University − Moscow Agricultural Academy by K. A. Timiryazev, Moscow, Russia

Received 17.09.2021