INFLUENCE OF EQUAL-AREA PROJECTION OF THE CYLINDER DRUM'S CROSS-SECTION HEIGHT ON THE DESCRIPTION ACCURACY OF ITS OVERCOMING THE AIR RESISTANCE FORCE

ВПЛИВ ЕКВІВАЛЕНТНОЇ ПРОЕКЦІЇ ВИСОТИ ПЕРЕТИНУ БАРАБАНА НА ТОЧНІСТЬ ОПИСУ ПОДОЛАННЯ НИМ СИЛИ ОПОРУ ПОВІТРЯ

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ABSTRACT
The article presents a theoretical research on the influence of introducing height equal-area projection on the calculation accuracy of the air resistance power of the cylinder drum with blades. The effort was made to specify the resistance area depending on the angle setting and the number of blades of the crimper-roller. Research on the introduction of the equal-area projection of the height on the description accuracy of the crimper-roller air resistance power showed that the fractional error decreases by 1.5 times. This is explained by the absence of the uncertainty influence of the cylinder drum initial angle setting.

РЕЗЮМЕ
Стаття присвячена теоретичному дослідженню впливу внесення еквівалентної проекції висоти на точність визначення сили опору повітря барабану з ножом. Зроблено спробу уточнити площу опору в залежності від кутового положення та кількості ножів барабана котка-подрібнювача. Дослідження внесення еквівалентної проекції висоти на точність опису сили опору повітря барабану з ножами показали, що відносна похибка зменшується у 1,5 рази, що пояснюється виключенням впливу невизначеності початкового кутового положення барабану.

INTRODUCTION

In the last few years Ukraine was filled with non-traditional and in some cases unknown technologies of crop science *(Bohatyrov D.V., 2012; Vasylkovska K.V., 2016)*. The changes started by using imported harvesters which left practically all residues on the field. This practice allowed increasing the productivity of picking processes and shortening the terms of harvest period but there appeared the problem of plant residues further processing. The Ukrainian producers chose the simplest way to solve it and used disc equipment for soil cultivation. As a result, the structure of surface soil was damaged, valuable agro-technical aggregates were mashed, which led to their transformation into dusty unstructured condition. There was also over-tamping of subsoil, dysfunction of the aeration and infiltration processes, decrease of the storage of productive soil water in lower levels *(Salo V.M., 2014)*. Special machines (Fig. 1) are usually used in these cases abroad which are debris pulverisers *(Bohatyrov D.V., 2012; Salo V.M., 2016)*. In Ukraine, these machines are not well-known; they are expensive and perceived by agricultural producers as part of the technological process which needs extra costs, which are not obligatory *(Sysolin P.V., 2001)*. Besides, according to the special design of each of these machines, they do not provide necessary pulverization for Ukraine production technologies (*Salo V.M., 2014*).

In order to determine the accurate draught of the crimper-roller it is necessary to take into account the force to overcome air resistance. In the well-known works *(Ashford D.L., 2003; Korniecki T.S., 2006)* this issue was not studied in full details. For the first time, H. Tagaev suggested to take into account, the air resistance for the equipment that destroys weeds in the rice bays (*Tagaev Kh., 2015*).

The objective of the research is to determine theoretical projection of the height of cylinder drum's cross-section on the accuracy of description of its overcoming the air resistance force.

MATERIAL AND METHODS

The experimentally determined range of velocities from 15 to 24 km/h takes into account the peculiarities of the crimper-roller operation in field conditions, particularly the movement of the aggregate on ground slopes and humps in vertical as well as in horizontal planes *(Bohatyrov D.V., 2015)*. Having these values of movement velocity, it is worthwhile taking into account the force of air resistance *(Bohatyrov D.V., 2015)*. A drum with knives is similar to a lobed wheel. At working speeds, knives create resistance to its rotation both in soil and in the air. It is established that the traction resistance increases by 12% at speeds of 15-25 km/h (*Tagaev Kh., 2015*).

Fig. 1 - Crimper-roller KP-4.5

Let us consider height b_B of the half cylinder drum with blades cross-section with the angle values $-\frac{\beta}{2} \le \varphi \le \frac{\beta}{2}$ (Fig. 2).

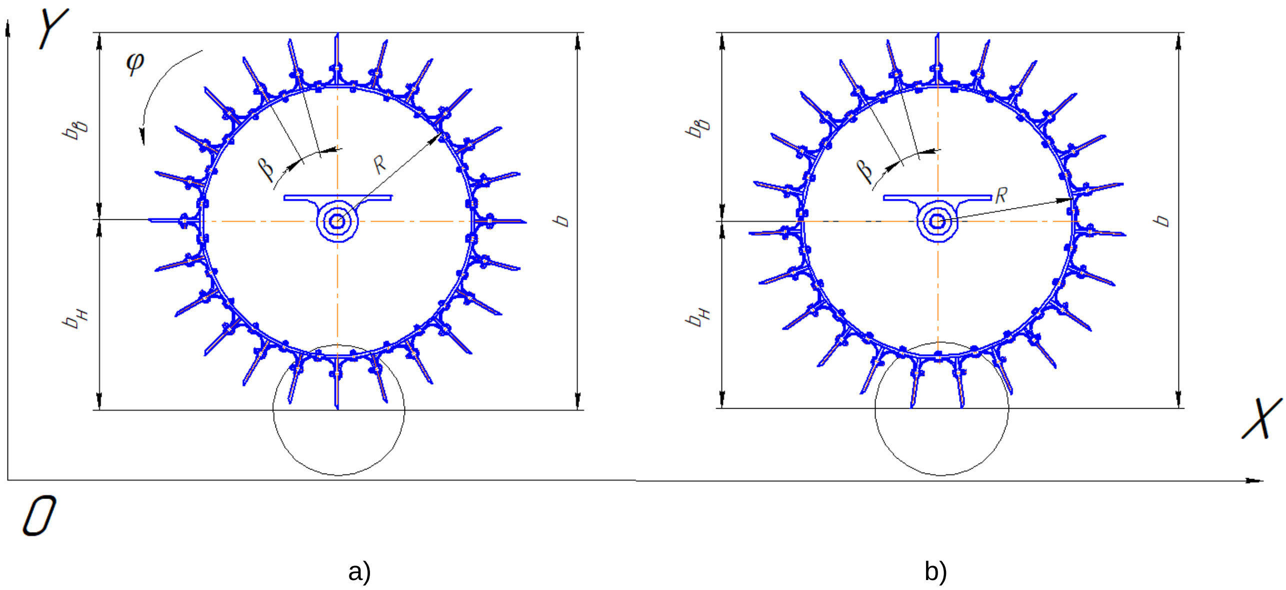


Fig. 2 - Cases with blade placement:

a) even number of blades (z=24 pieces); b) odd number of blades (z=23 pieces);

β – angle between the blades, $\beta = \frac{2 \cdot \pi}{z}$; b - cross-section of the height of half cylinder drum with blade on the axis OY.

We determine the height projection $b_в$ in relation to the angle φ if $b_в \geq R$,

$$b_B = (h+R)\cdot\cos\varphi \text{ [m]} \quad (1)$$

where: R – radius of the cylinder drum, m;

h – height of the blade, m.

When the crimper-roller operates with a certain number of blades *z* it may happen that the surface of the cylinder drum is seen between the blades $b_B < R$ (Fig. 2, b), then $b_B = R$.

Let us consider the cases with even and odd numbers of blades *z*. With even number of blades the value of the height projection b_B on the axis OY is $b_н = b_B$. Let us consider the case with odd number of blades on the cylinder drum of the crimper-roller.

With odd number of blades:

$b_н = (h+R)\cdot\cos\left(\frac{\beta}{2}-\varphi\right)$, where $0 \leq \varphi \leq \frac{\beta}{2}$; $b_н = (h+R)\cdot\cos\left(\frac{\beta}{2}+\varphi\right)$, where $-\frac{\beta}{2} \leq \varphi \leq 0$.

So, we have general expression to determine the height projection of the half cylinder drum's cross-section with a blade, where $-\frac{\beta}{2} \leq \varphi \leq \frac{\beta}{2}$:

$$b_н = (h+R)\cdot\cos\left(\frac{\beta}{2}-|\varphi|\right). \text{ [m]} \quad (2)$$

Much the same, when the crimper-roller is operating with a certain number of blades *z* it may happen that the surface of the cylinder drum is seen between the blades $b_н < R$, then $b_н = R$.

Mechanically, the blades are fixed on the cylinder drum of the crimper-roller in such a way that the case when $b_в < R$ and $b_н < R$ cannot be possible.

In general situation, the height projection of the cylinder drum's cross-section with even and odd numbers of blades z will be determined in the following way:

$$b(\varphi) = (h+R)\cdot\left(\frac{3-(-1)^{z+1}}{2}\cdot\cos(\varphi)+\frac{1-(-1)^{z}}{2}\cdot\cos\left(\frac{\pi}{z}-|\varphi|\right)\right), \text{ [m]} \quad (3)$$

where the angle value will be in the limits of $-\frac{\pi}{z} \leq \varphi \leq \frac{\pi}{z}$.

There is no sense to use formula (3) for further calculations because it is impossible to set the initial angle of the cylinder drum with blades. There is a need to have additional calculations which will take into account the calculation's errors. That will enable introducing equal-area projection of the height of cylinder drum's cross-section.

Let us determine the equal-area height $b_{ек}$ for

$$b_{ек} = \frac{z}{2\cdot\pi}\cdot\int_{\frac{\pi}{z}}^{\frac{\pi}{z}} b(\varphi)\,d\varphi \text{ ,[m]} \quad (4)$$

For an even number of blades

$$b_{ек} = \frac{z}{2\cdot\pi}\cdot\int_{\frac{\pi}{z}}^{\frac{\pi}{z}} b(\varphi)\,d\varphi = \frac{2\cdot z\cdot(R+h)}{\pi}\cdot\sin\left(\frac{\pi}{z}\right), \text{ [m]} \quad .(5)$$

Let us find the ratio error δ, which is formed as a result of taking into account equal-area projection of the height of the bladed cylinder drum's cross-section during one complete revolution.

The function $\cos\left(\varphi-\frac{\pi}{2\cdot z}\right)$ where $-\frac{\pi}{z} \leq \varphi \leq 0$ increases to its highest level value, if $\varphi = 0$.

Let us consider the cylinder drum revolution on one blade $-\frac{\pi}{z} \leq \varphi \leq \frac{\pi}{z}$ for the even number of blades

$$\frac{b(\varphi)}{b_{ек}} = \frac{2\cdot(R+h)\cdot(\cos\varphi)}{\frac{2}{\pi}\cdot(R+h)\cdot z\cdot\sin\left(\frac{\pi}{z}\right)} = \frac{\pi\cdot\cos(\varphi)}{z\cdot\sin\left(\frac{\pi}{z}\right)},$$

where $-\frac{\pi}{z} \le \varphi \le \frac{\pi}{z}$.

The highest value of the error δ is when the cylinder drum is rotating with the values of the angle $\varphi = -\frac{\pi}{z}$ та $\varphi = \frac{\pi}{z}$, will be

$$\delta = \left| 1 - \frac{\pi \cdot \cos\frac{\pi}{z}}{z \cdot \sin\frac{\pi}{z}} \right| \cdot 100\% = \left| 1 - \frac{\pi}{z} \cdot ctg\frac{\pi}{z} \right| \cdot 100\% . \ [\%] \quad (6)$$

Let us assess the error of the accuracy of the force determination as a result of introduction of $b_{ек}$ for the odd number of blades when $-\frac{\pi}{z} \le \varphi \le 0$

$$\frac{b(\varphi)}{b_{ек}} = \frac{\pi \cdot \cos\left(-\frac{\pi}{2 \cdot z}\right) \cdot \cos\left(\varphi + \frac{\pi}{2 \cdot z}\right)}{z \cdot \sin\frac{\pi}{z}}.$$

where $0 \le \varphi \le \frac{\pi}{z}$

$$\frac{b(\varphi)}{b_{ек}} = \frac{\pi \cdot \cos\left(\frac{\pi}{2 \cdot z}\right) \cdot \cos\left(\varphi - \frac{\pi}{2 \cdot z}\right)}{z \cdot \sin\frac{\pi}{z}}.$$

the highest value of the error δ is when the cylinder drum is rotating with the values of the angle $\varphi = -\frac{\pi}{z}$, $\varphi = 0$ and $\varphi = \frac{\pi}{z}$:

$$\delta = \left| 1 - \frac{\pi}{2 \cdot z} \cdot ctg\frac{\pi}{2 \cdot z} \right| \cdot 100\%. \ [\%] \quad (7)$$

Let us determine the error δ_t, which is introduced by the indeterminateness of the initial angle set of the cylinder drum with blades while applying the exact determination of the height projection of the cylinder drum's cross-section b. For the even number of blades

$$\delta_t = \left| 1 - \frac{2 \cdot (h+R) \cdot \cos 0^o}{2 \cdot (h+R) \cdot \cos\frac{\pi}{z}} \right| \cdot 100\% = \left| 1 - \frac{1}{\cos\frac{\pi}{z}} \right| \cdot 100\%. \ [\%] \quad (8)$$

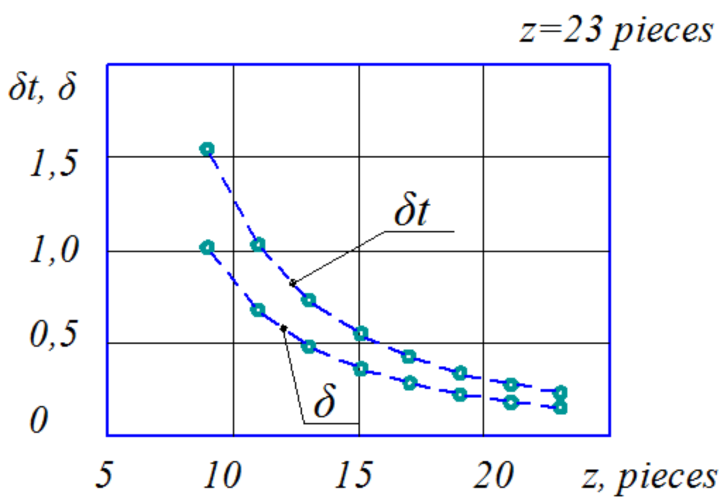
For the odd number of blades

$$\delta_t = \left| 1 - \frac{(h+R) \cdot \left(\cos\varphi_{max} + \cos\left(\frac{\pi}{z} - |\varphi_{max}| \right) \right)}{(h+R) \cdot \left(\cos\varphi_{min} + \cos\left(\frac{\pi}{z} - |\varphi_{min}| \right) \right)} \right| \cdot 100\% = \left| 1 - \frac{1}{\cos\frac{\pi}{2 \cdot z}} \right| \cdot 100\%, \ [\%] \quad (9)$$

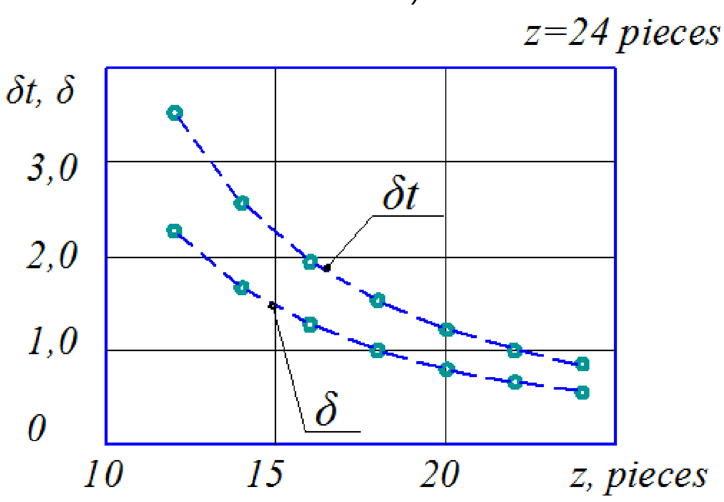
where: $\varphi_{min} = 0 = -\frac{\pi}{z}$, $\varphi_{max} = -\frac{\pi}{2 \cdot z}$.

RESULTS

Graphic interpretations (Fig. 3) of the research findings of the influence of the equal-area projection of the height $b_{ек}$ on the accuracy of the description of the air resistance force showed that the ratio error decreases by 1.5 times. That is explained by the indeterminateness of the initial angle set of the cylinder drum with blades and equals: for the odd number of blades δ=1%, δ_t=1.6%; for the even number of blades is (z=24 pieces) (z=23 pieces) δ=2.2%, δ_t=3.5%.



a)



b)

Fig. 3 - Dependence of the ratio errors δ and δ_T on the number of blades z:

a) odd number of blades (z=11…23 pieces); b) even number of blades (z=10…24 pieces).

δ – the error which is formed as a result of introduction of $b_{ек}$ equal-area projection of the height of the cylinder drum with blades;

δ_T – the error which is formed as a result of the indeterminateness of the initial angle set of the cylinder drum with blades;

Taking into consideration formulae (5, 6) the force to overcome the air resistance can be determined in the following way:

$$P_c = k \cdot k_0 \cdot L_н \cdot b_{ек} \cdot \left(\vartheta_0 - \vartheta_{агр}\right)^2, \text{ [N]} \tag{11}$$

where: k is the number of cylinder drums with blades on the crimper-roller, pieces;

k_0 is a coefficient which takes into account the type of environment;

$L_н$ is the length of the blade, m;

ϑ_0 is the wind speed, m/s;

$\vartheta_{агр}$ is the speed of the aggregate, m/s.

CONCLUSIONS

Theoretical determination of the equal-area height projection depending on the angle setting and the number of blades will enable determining the value of the effort to overcome the air resistance force by the crimper-roller. Theoretical dependencies were obtained for the first time. They allow taking into account the required amount of energy and fuel used to overcome the resistance to air at speeds of 15-25 km/h. Given the research, further theoretical grounding of the rational design and technological parameters of the crimper-roller is necessary.

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