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Study of the motion of seeds around a spherical element fixed to the inner surface of a seed-coating drum

Urug‘larni qobiqlash barabanining ichki sirtiga mahkamlangan sferik element atrofidagi harakatini tadqiq etish

Исследование движения семян вокруг сферического элемента, закреплённого на внутренней поверхности дражирующего барабана

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Abstract. The article presents data on the theoretical study of the forces acting on seeds moving inside the working element of a shelling device with a spherical element attached to the inner surface of the drum, as well as their movement around the spherical element. The results of theoretical studies showed that the seed reaches its maximum flight distance when sin 2α=1, i.e., α=(π/4). Therefore, several seed layers struck by a spherical element are also forced to rotate at a certain angle after touching them. Since the spherical elements are arranged in a chess-like shape, after hitting the first spherical element, the seeds make a circular movement, hit the next one, spin again, and so on. This leads to efficient and complete sowing of seeds, as well as a reduction in the time required for the technological process.

Keywords: casing drum; spherical element; blur; motion; material point; differential equation; layer; effective; adjective

O‘ZBEKCHA

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Annotatsiya. Maqolada qobiqlash qurilmasining barabanini ichki sirtiga sferik element mahkamlanib, uning ichida harakatlanayotgan urug‘larga ta’sir etadigan kuchlar hamda ularni sferik element atrofidagi harakatini nazariy tadqiq etish natijalari to‘g‘risidagi ma’lumotlar keltirilgan. Nazariy tadqiqotlarning natijasi shuni ko‘rsatdiki, urug‘ uchish masofasining maksimal qiymatini sin 2α=1, ya’ni α=(π/4) ga teng bo‘lganda zabt etadi. Shuning uchun sferik elementga kelib urilgan bir nechta urug‘ qatlami ham ularga tekkandan keyin, ma’lum burchak ostida aylanma harakatlanishga majbur bo‘ladi. Sferik elementlar shaxmat shaklida joylashganligi sababli, urug‘lar birinchi sferik elementga urilgandan ktyin aylanma harakat qilib, keyingisiga uriladi va yana aylanadi va haqazo takrorlanadi. Bu holat urug‘larni samarali va to‘liq bulanishi hamda texnologik jarayonga ketadigan vaqtni qisqarishiga olib keladi.

Kalit so‘zlar: qobiqlash barabani; sferik element; bulanish; harakat; moddiy nuqta; diferensial

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tenglama; qatlam; samarali; sifatli

РУССКИЙ

ТУХТАҚУЗИЕВ Абдусалим[1,*], ХУДАЙБЕРДИЕВ Абдуазиз Абдувалиевич[2], РОСАБОЕВ Абдукадир Тухтақузиевич[1]

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Аннотация. В статье приведены сведения о результатах теоретического исследования сил, действующих на семена, движущиеся внутри сферического элемента, закрепленного на внутренней поверхности барабана дражирующего устройства, а также их движения вокруг сферического элемента. Результаты теоретических исследований показали, что максимальное значение дальности полета семян достигается при sin 2α=1, т.е. α= (π/4). Поэтому несколько слоев семян, ударившихся о сферический элемент, после соприкосновения с ними вынуждены совершать вращательное движение под определенным углом. Поскольку сферические элементы расположены в шахматной форме, семена после удара о первый сферический элемент совершают вращательное движение, ударяются о следующий, снова вращаются и так далее. Это приводит к эффективному и полному перемешиванию семян и сокращению времени, затрачиваемого на технологический процесс.

Ключевые слова: дражирующий барабан; сферический элемент; обволакивание; движение; материальная точка; дифференциальное уравнение; оболочка; эффективное; качество

1. INTRODUCTION

Introduction. It is known that drum devices of plate-shaped design have been developed for hulling agricultural crop seeds with various protective and nutritional compounds, the most common of which are drum hulling devices [1, 2]. In particular, drum casing devices were proposed by E.B. Beisenbayev [3], A.M. Zhukov, V.A. Panchenko, A.V. Shushlyakov [4], S.D. Sheruda, I.Ya. Ostashevsky, V.S. Budko [5], A. Sokhta [6], N. Rashidov, A. Khojiev, B. Eserkepov [7, 8], I.F. Borodin [9], A.T. Rosaboev, U.B. Imomkulov [10, 11, 12], A.T. Mamadaliev [13], and others.

It is proposed to install various devices and elements inside the drum hulling units to ensure the efficient process of sowing seeds. To ensure the efficient turning process in the drum casing device we propose, a thin metal sheet with spherical elements is attached to the inner surface of the cylindrical drum. Since the geometric dimensions of the seeds are much smaller than the diameter of the drum, they move uniformly in a straight line when striking a spherical element. In this case, when seeds moving in a circle hit a spherical element, the direction of movement changes; that is, they first begin to ascend along the slope and, while sliding along a spherical surface with or without reaching the top point, perform a rotational motion to the right or left and overturn. At the same time, the lower part of the seeds, which is rubbed against the surface of the drum, i.e., which is difficult to separate with compounds, also has the opportunity to be contaminated. As a result, the quality of sowing seeds with various protective and nutritional compounds improves, the time spent on it is reduced, and electricity consumption is saved [14, 15, 16].

The aim of the research. Theoretical study of the movement of seeds around a spherical element attached to the inner surface of the seed hulling drum and substantiation of its positive impact on the technological process of hulling.

2. RESEARCH METHODS AND MATERIALS

Research methods and materials. The theoretical study of the movement of the seed peeling device around a spherical element fixed to the inner surface of the drum was conducted based on mathematical analysis using the laws and rules of theoretical mechanics and higher mathematics. Based on the results of the theoretical research, conclusions were formulated and a proposal was made to use a welding element attached to the inner surface of the casing device drum.

3. RESULTS AND DISCUSSION

Discussion of the research results. When the drum of the peeling device rotates, the following movements of the seeds can be observed:

- rotation along the internal surface;

- after hitting a spherical element, it also performs rotational motion around its axis for a short time.

In other words, the seeds undergo a complex movement inside the hulling drum.

Figure 1 shows a diagram of the drum's movement at an inclined angle and the forces acting on the seeds.

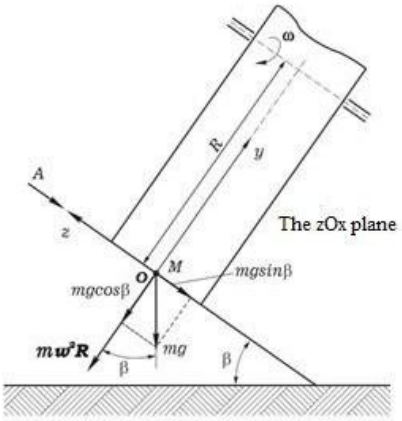

Fig. 1. Barabanning og'ma burchak ostidagi harakati va ta'sir etuvchi kuchlar sxemasi / **Fig. 1.** Movement of the drum at an inclined angle and scheme of acting forces

Since the size of the seeds is very small compared to the drum radius, we consider the small length around point O to be a flat surface and consider their motion to be rectilinear for that point [17].

Figure 2 shows a material point, i.e., the trajectory of the seed's movement.

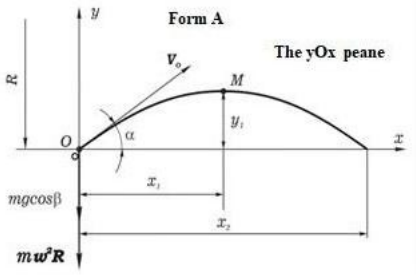

Fig. 2. Moddiy nuqta, ya'ni urug' harakatining trayektoriyasi / **Fig. 2.** Material point, i.e. the trajectory of the seed's movement

Considering the family as a material point M, let us assume that it is thrown from some point O at an angle α to the horizon with an initial velocity Vo.

Let us consider the motion of point M, assuming that a centrifugal force mω2R acts on it in addition to the gravitational force G, which constitutes mgcosβ. Taking point O as the origin, we direct the X-axis to the right in the horizontal plane and the Y-axis upward in the vertical plane. Let us write the differential equation of the motion of a point.

$$m\frac{d^2x}{dt^2}=0; \tag{1}$$

$$m\frac{d^2y}{dt^2}=-mg\cos\beta-m\omega^2R. \tag{2}$$

We reduce expressions (1) and (2) to m

$$\frac{d^2x}{dt^2}=0; \tag{3}$$

$$\frac{d^2y}{dt^2}=-g\cos\beta-\omega^2R. \tag{4}$$

Integrating expression (3), we obtain

$$dx/dt=C_1. \tag{5}$$

Based on the equation of the velocity projection onto the coordinate axes,

$$V_x=dx/dt=C_1. \tag{6}$$

The projection of the velocity of point M onto the X-axis always has the

same magnitude, i.e.,

$$C_1=V_x=V_0\cos\alpha. \tag{7}$$

From expressions (6) and (7), we get:

$$dx/dt=V_0\cdot\cos\alpha. \tag{8}$$

Integrating this equation, we get:

$$x=V_0t\cdot\cos\alpha+C_2. \tag{9}$$

If t = 0, x = 0, then the constant C2 = 0.

The final result will be as follows:

$$x=V_0t\cdot\cos\alpha. \tag{10}$$

By integrating equation (4), we get:

$$V_y=dy/dt=-gt\cos\beta-\omega^2Rt+C_3. \tag{11}$$

Substituting t = 0 into this equation, we find the constant of integration C3.

$$C_3=V_y=V_0\cdot\sin\alpha. \tag{12}$$

So,

$$dy/dt=V_0\sin\alpha-gt\cos\beta-\omega^2Rt. \tag{13}$$

By integrating expression (13) once more, we obtain:

$$y=V_0t\sin\alpha-\frac{gt^2}{2}\cos\beta-\frac{\omega^2R}{2}t^2+C_4. \tag{14}$$

If t = 0, y = 0, then an arbitrary constant C4 = 0.

As a result

$$y=V_0t\sin\alpha-\frac{gt^2}{2}\cos\beta-\frac{\omega^2Rt^2}{2}. \tag{15}$$

Thus, the equation of motion for point M, directed at an angle α relative to the horizontal plane and possessing an initial velocity V0, is expressed as follows.

$$x=V_0t\cdot\cos\alpha; \tag{16}$$

$$y=V_0t\sin\alpha-\frac{gt^2}{2}\cos\beta-\frac{\omega^2Rt^2}{2}. \tag{17}$$

To determine the trajectory of point M, we substitute the values of t into expressions (16) and (17).

From equation (16), we find t.

$$t=\frac{x}{(V_0\cdot\cos\alpha)}. \tag{18}$$

By substituting this value of t into (17), we obtain the trajectory equation

$$\begin{aligned}y&=x\cdot tg\alpha-\frac{gx^2\cdot\cos\beta}{(2v_0^2\cos^2\alpha)}-\frac{\omega^2Rx^2}{2v_0^2\cos^2\alpha}=\\&x\cdot tg\alpha-\frac{gx^2\cdot\cos\beta-\omega^2Rx^2}{2v_0^2\cos^2\alpha}=\\&x\cdot tg\alpha-\frac{x^2\cdot(g\cos\beta-\omega^2R)}{2v_0^2\cos^2\alpha}.\end{aligned} \tag{19}$$

The trajectory of point M is a parabola with a vertical axis of symmetry. To find the flight time of point M, we substitute the value y = 0 into equation (15). Then the equation takes the following form:

$$V_0t\sin\alpha-\frac{gt^2}{2}\cdot\cos\beta-\frac{\omega^2Rt^2}{2}=0; \tag{20}$$

$$V_0t\sin\alpha-\frac{(-g\cdot\cos\beta-\omega^2R)t^2}{2}=0. \tag{21}$$

From this, we find two values of time when the ordinate is zero.

$$t_0=0,\quad t_2=-\frac{2V_0\sin\alpha}{(-g\cdot\cos\beta-\omega^2R)}. \tag{22}$$

The first time value corresponds to the start of the flight, and the second to the end.

Duration of flight

$$t_2-t_0=t_2=-\frac{2v_0\sin\alpha}{-g\cdot\cos\beta-\omega^2R} \tag{23}$$

To find the flight distance of the seeds, we substitute the value of t2 into the equation of motion (14).

$$x_2=V_0t_2\cos\alpha=\frac{(V_0\cos\alpha\cdot2V_0\sin\alpha)}{(-g\cos\beta-\omega^2R)}$$

or

$$x_2=\frac{V_0^2\sin2\alpha}{(-g\cos\beta-\omega^2R)}. \tag{24}$$

It is evident from this equation that the maximum value of the flight distance Xmax is reached when sin2α = 1, i.e., α = π/4.

$$x_{max}=\frac{V_0^2}{(-g\cos\beta-\omega^2R)}. \tag{25}$$

Let us determine the maximum height of point M, in which case the projection of its velocity relative to the ordinate axis will be zero.

$$\frac{dy}{dt}=V_y=V_0\sin\alpha-(-g\cos\beta-\omega^2R)t=0. \quad (26)$$

From the last equation, we find t1.

$$t_1=\frac{V_0\sin\alpha}{(-g\cos\beta-\omega^2R)}=\frac{t_2}{2}. \quad (27)$$

It is evident from expression (27) that it reaches its maximum height in half the time, i.e.

$$x_1=x_2/2. \quad (28)$$

Substituting the value of t1 in expression (27) into equation (19)

$$y_1=\frac{V_0\sin\alpha\cdot V_0\sin\alpha)}{(-g\cos\beta-\omega^2R)}-\frac{(-g\cos\beta-\omega^2R)V_0^2\sin^2\alpha}{2(-g\cos\beta-\omega^2R)^2}. \quad (29)$$

In here

$$y_1=\frac{V_0^2\sin^2\alpha}{2(-g\cos\beta-\omega^2R)}. \quad (30)$$

As can be seen from the last expression, the point has the maximum height

sin α = 1 or α=π/2, i.e. when the point is pointed vertically upward, it is equal to

$$y_{max}=\frac{-V_0^2}{2(-g\cos\beta-\omega^2R)}. \quad (31)$$

The parameters of the spherical element have a strong influence on the quality of the seed moistening process with adhesive liquid in the proposed shelling device. The height of the element can be determined by expression (17) and the distance by expression (16). The value of the slope angle ensures that spherical elements do not adversely affect seed movement, i.e., successive seeds approach the slope, encounter excessive resistance, and do not create congestion. This is because its high values lead to excessive resistance from successive seeds. This causes excessive friction forces, i.e., an increase in the friction force of the seeds against each other, and a decrease in their moisture quality.

Inside the existing hulling drum, the seeds move in several layers. Several layers struck by a spherical element are also forced to perform rotational motion at some angle after hitting it. Since the spherical elements are arranged in a chess-like shape, the seeds take a circular motion after the first spherical element, move to the next, and rotate again, and so on. This condition leads to efficient and complete contamination of the seeds.

4. CONCLUSION

Conclusion. Among the devices for hulling agricultural crop seeds with various protective and nutritional compounds, the most common type is the drum type, which is equipped with various devices and elements to improve the quality of hulling. Therefore, it is recommended to equip the inner surface of the drum with spherical elements in order to increase the effectiveness of the degree of shelling of difficult-to-spread seeds of agricultural crops with various protective-nutrient compounds and to reduce their damage. As a result, the seeds undergo complex movement, and their surface is effectively and completely covered with protective-nutrient compounds.

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Author contributions CRediT

Conceptualization; Methodology; Investigation; Data curation; Writing – original draft; Writing – review & editing. All authors have read and agreed to the published version of the manuscript.

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Ethics approval

Not applicable. This study did not involve humans, animals or other regulated materials.

Informed consent

All authors have read and approved the final version of the manuscript and have given their consent to its submission and publication. The study involved no human participants and no personal data.

Data availability statement

All data supporting the findings of this study are presented in the article and are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest.

Generative AI disclosure

Generative AI was used only partially. The authors used Claude (Anthropic, Opus 5) for language editing, formatting of the reference list and preparation of the English and Russian metadata. No text, data, figures or conclusions were generated by AI. The authors reviewed and verified all output and take full responsibility for the content of the publication.

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