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Article

# The results of the research on theory of the scarification hard-seed by oblique impact

Amartuvshin Oidov[1], Dovchinvachig Maashaa[2*]

[1]Department of Electrical engineering and Electronic, School of Engineering and Technology, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia
[2]Department of Physics and Mathematics, Applied Sciences, Mongolian University of Life Sciences, Ulaanbaatar, Mongolia

*Corresponding author. Email:dovchinvanchig@muls.edu.mn

**Abstract.** If rate higher than 20% of seed of perennial plants for fodder have hard shell that restrict water, moisture and air, in order to ensure swelling of the seed, and regular sprouting as a result of air, water and moisture through hard shell, it is required to use one of four methods such as method of water and moisture-heating, chemical, electrical, physical and mechanical. The mechanic method is based on breaking hard shell by friction and stroke impact and creating fissure. The research is aimed to research on process of obtuse breaking. In doing so, as tangential of pre and post-friction speed is higher, the more works is made against friction force and breaking is occurred more. We determined a formula express this difference, analyzed the process and reflection angle of the best breaking. In obtuse impact, we determined a formula to determine ratio between normal and tangential factor of the impacting force using law of movement force and quantity, and determined the highest reflection angle of tangential force of friction in collusion impact. As a result of mechanic impact, seed may be crushed. Therefore, we identified crushing and damage of the seed, factors of efficient breaking of the seed shell.

**Keywords:** Flexible deformation, friction force, normal creator of the speed and tangential force

## 1 Introduction

Impacting the hard-shelled seeds of forage legumes is more significant. First: through such mechanical processing, moisture and air penetrate through the cracks and fissure in the seed shell and expel the seeds, resulting in uniform germination in a short period of time. Second, when a small impact is applied to the seed to be planted, it comes out of the "inactive" state during storage, and at this time, some part of the energy of the

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impact is absorbed by the seed and increases the growth intensity of the seed. Thirdly, during impact, the dust, dirt, and other impurities applied on the surface of the seed shell to be planted will fall apart, and thus, the conditions for good sterilization of the seeds will be created.

Therefore, we aimed to process a formula to identify the process of oblique opening of the hard shell and coat of the seed. In doing so, the seed to be planted was considered a material ore core.

The case where collision occurs on an abrasive flat surface is considered. Oblique impacts are considered in each of the deformation and recovery phases considered in some studies of impact theory, with normal and tangential components of impact velocities [1].

In the classical theory of impact and theoretical mechanics, it is assumed that during an oblique collision, there is no slip (transition) in the direction of the collision tangent, the tangential velocity before and after the collision does not change, or the tangential component of the collision momentum remains the same [2-4].

However, in this study, based on the assumption that even a small amount of slip will occur during the oblique impact, it is assumed that the seed shell will open during this slip, and a theoretical study of the process of opening due to impact was conducted. In other words, it is assumed that the tangential velocity components before and after the collision are different because the component of the velocity before the collision will decrease due to the friction force. Therefore, assuming that the greater the difference between the tangential speed before and after the collision, the better the discovery will be, we aimed to derive a formula for determining this difference in speed [5].

The researchers concluded that the device for opening the hard-shelled seeds with the action of impact has a major fault and disadvantage in which the seeds are cracked and crushed [6]. Based on the contact interaction theory of G. Hertz, it is possible to determine the maximum impact speed corresponding to the maximum permissible effect of the impact without damaging the seeds. The reason for choosing the angle of incidence of hitting the work surface for shelling seeds in the research on the basis and optimization of the parameters of the hard-shelled seed crushing device is not clear. Within the framework of the theoretical research conducted here, it was determined that the reflection angle would be effective [7].

Assuming that the greater the friction force in the oblique collision process, the better the opening will be occurred, we tried to process the formuJa for determining this friction force. In other words, it is assumed that the change in the tangential component of the momentum before and after the impact is caused by the action of the frictional force.

## 2 Purpose of the research

In this research work, based on the Hertzian contact interaction theory of impact and dry friction hypothesis of oblique impact, we aimed to find a formula to show the process of opening the hard shell of seed by impact, theoretically determine the main factors that affect the opening, and determine the basic level of the planned test depending on those factors.

**Research object.** The main process of sowing seeds of alfalfa in the impact-based opening device.

The research object. Establishing the relationship between the essential factors affecting the opening of the hard shell and coat of alfalfa seeds and the degree of opening, and theoretically determining the specific values of those factors.

1. Find the equation for the difference between the tangential components of the velocity before and after the collision.
2. Find the ratio of the normal and tangential components of the force during an oblique collision.

## 3 The research results

**Objectives 1.** The speed of oblique collision is divided into normal and tangential components, and Hertz's theory of contact interaction is used for the normal component. For the tangential constructor, based on the assumption of collision in dry friction, the equations of motion were written and the following formulas were derived. If the differential equation of motion of the seed during oblique collision is written as a normal constructor:

$$m\ddot{x}_n = -f(x_n)$$

According to Hertz's theory of contact interaction, the relationship between the shear deformation caused by collision and the shear force generated at this time is determined by the following Hertz Eq. 1.

$$f(x_n) = c{x_n}^{\frac{3}{2}} \tag{1}$$

$$\frac{1}{c} = \frac{3}{4}\left(\frac{1-\mu_1^2}{E_1} + \frac{1-\mu_2^2}{E_2}\right)\sqrt{\frac{1}{R_1} + \frac{1}{R_2}} \tag{2}$$

Where: $x$ is amount of deformation, $\mu_1$ is Poisson's ratio of the hard-seed, $\mu_2$ is Poisson's ratio of the working surface, $R_1$ is radius of curvature of the hard-seed, $R_2$ is radius of curvature of the working surface, $E_1$ is Young's modulus of the hard-seed, $E_2$ is Young's modulus of the working surface.

Collision consists of two phases: the deformation phase and the recovery phase. If we write the equation of motion for the collision normal in the deformation phase:

$$m\dot{v}_n \cdot \frac{dx_n}{dx_n} = -f(x_n)$$

$$m \cdot v_n dv_n = -f(x_n) \cdot dx_n$$

At the beginning of the deformation phase, the value of the vertical component of the collision velocity will be $v_{1n} = v_1 \cdot \cos\alpha$ and the elastic deformation will begin ($x_n = 0$). However, at the end of the deformation phase, the vertical component of the collision velocity will be $v_{1n} = 0$ and the elastic deformation will reach its maximum value, so consider the integral below.

$$m\int_{v_{1n}}^{0} v_{1n} dv_{1n} = -\int_{0}^{x_{nmax}} f(x_n)\cdot dx_n$$

$$-\frac{m}{2}\cdot v_{1n}^2 = -\int_{0}^{x_{nm}} c{x_n}^{\frac{3}{2}}\cdot dx_n = -\frac{2}{5}cx_{nmax}^{\frac{5}{2}}$$

$$v_{1n}^2 = \frac{4}{5m}\cdot c\cdot x_{nmax}^{\frac{5}{2}} \tag{3}$$

Eq. 3. above determines the maximum speed of the normal component of the velocity before the collision.

At the beginning of the recovery phase, the normal component of the reflection velocity is $v_{2n} = 0$ and the maximum value of the elastic deformation ($x_n = x_{nmax}$) is obtained. At the end of the recovery phase, the normal component of the reflection $v_{2n} = v_2\cdot\cos\beta$ pand the elastic deformation disappears ($x_n = 0$).

$$m\int_{0}^{v_{2n}} v_{2n} dv_{2n} = -\int_{x_{nmax}}^{0} f(x_n)\cdot dx_n$$

$$\frac{m}{2}\cdot v_{2n}^2 = -\int_{x_{nmax}}^{0} c^{x_n^{\frac{3}{2}}}\cdot dx_n = \frac{2}{5}cx_{nmax}^{\frac{5}{2}}$$

Assuming that the coefficient of restitution of a steep collision is valid for the vertical constructor of an oblique couision, the normal constructor of the reflection velocity is written:

$$v_{2n}^2 = k^2\cdot v_{1n}^2 = k^2\cdot\frac{4}{5m}\cdot c\cdot x_{nmax}^{\frac{5}{2}}$$

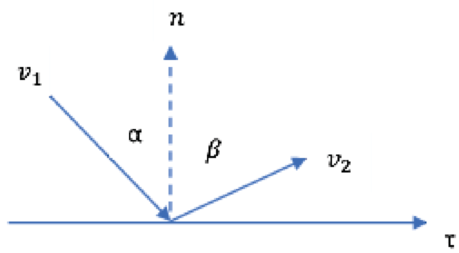


**Figure 1.** Velocity diagram during oblique impact collision.

The equation of motion is written in the deformation phase for the tangential component of the velocity of the oblique collision. The reason for the change in the tangential component of the speed was assumed to be the frictional force.

$$m\dot{v}_\tau = -\mu\cdot f(x_n)$$

where: $f(x_n) = c{x_n}^{\frac{3}{2}}$

$$m\cdot v_\tau dv_\tau = -\mu\cdot f(x_n)dx_\tau$$

$$dx_\tau = dx_n\cdot tg\alpha$$

At the beginning of the deformation phase, the tangential component of the velocity is $v_{1\tau} = v_1 \cdot \sin\alpha,$ and the elastic deformation begins ($x_n = 0$). However, at the end of the deformation phase,the tangential component of the impact velocity takes some value $v_\tau'$. In other words, it is $v_{1\tau} = v_\tau'$ and at this moment the elastic deformation has reached its maximum value. Considering this, we have of the following integral.

$$m\int_{v_{1\tau}}^{v_\tau'} v_\tau dv_\tau = -\mu \cdot tg\alpha \int_0^{x_{max}} f(x_n)dx_n$$

$$(v_\tau')^2 = (v_{1\tau})^2 - \mu \cdot tg\alpha \cdot \frac{4}{5m} \cdot c \cdot x_{nmax}^{\frac{5}{2}} \quad (4)$$

In the recovery phase, let's write the equation of motion for the tangential velocity component of the oblique collision. The tangential component of the instantaneous velocity at the start of the recovery phase is $v_\tau = v_\tau'$ and the deformation is $x_n = x_{max}$. At the end of the recovery phase, the tangential component of speed becomes $v_\tau = v_{2\tau}$ and the defonnation disappears. In otherwords, $x_n = 0$.

$$m\int_{v_{1\tau}'}^{v_{2\tau}} v_\tau dv_\tau = -\mu \cdot tg\beta \int_{x_{max}}^{0} f(x_n)dx_n$$

$$dx_\tau = dx_n \cdot tg\beta$$

$$(v_{2\tau})^2 - (v_\tau')^2 = \mu \cdot tg\beta \cdot k^2 \cdot \frac{4}{5m} \cdot c \cdot x_{nmax}^{\frac{5}{2}} \quad (5)$$

Since the tangential velocity at the end of the deformation phase and the beginning of the recovery phase is the same velocity, calculate the tangential component of the oblique impact velocity by calculating the Eq. 6 in Eq. 5.

$$(v_{2\tau})^2 - (v_{1\tau})^2 = \mu \cdot \frac{4}{5m} \cdot c \cdot x_{nmax}^{\frac{5}{2}}(tg\beta \cdot k^2 - tg\alpha) \quad (6)$$

In estimating the Eq.3. in the above Eq. 6.

$$(v_{2\tau})^2 - (v_{1\tau})^2 = \mu \cdot v_{1n}^2 \cdot (tg\beta \cdot k^2 - tg\alpha) \quad (7)$$

In the Eq. 7. $v_{1n} = v_1 \cdot \cos\alpha$:

$$(v_{2\tau})^2 - (v_{1\tau})^2 = \mu \cdot v_1^2 \cdot cos^2\alpha \cdot (tg\beta \cdot k^2 - tg\alpha) \quad (8)$$

Using the relationship between the angle of reflection and the angle of reflection, express Eq. 6. in terms of the angle of reflection.

$$tg\beta = \frac{v_{2\tau}}{v_{2n}} \; ; \; tg\alpha = \frac{v_{1\tau}}{v_{1n}}; \quad \frac{v_{2n}}{v_{1n}} = k$$

Since we are considering the difference in the square of the velocity before and after the collision, the coefficient of restitution is taken as the modulus.

Here's a reflection angle:

$$tg\beta = \frac{v_{2\tau}}{k \cdot v_{1n}} = \frac{v_{2\tau} \cdot tg\alpha}{k \cdot v_{1\tau}} = tg\alpha \cdot \frac{v_{2\tau}}{k \cdot v_{1\tau}}$$

Assuming this in Eq. 8:

$$(v_{2\tau})^2 - (v_{1\tau})^2 = \mu \cdot v_1^2 \cdot cos\alpha \cdot sin\alpha \left(\frac{v_{2\tau}}{v_{1\tau}} \cdot k - 1\right) \quad (9)$$

It is considered that the greater the difference between the tangential speed before and after the collision, the better the opening will be. It can be seen from the Eq. 9. above that the friction coefficient, impact speed, and recovery coefficient of the seeds that open this difference are directly dependent on the angle of incidence. From Eq. 9. , it can be seen that the angle of impact for the most effective crushing of grain by oblique impact is $\alpha \approx 45^0$.

**Objective 2.** Using the law of conservation of momentum, determine the ratio between the elastic force acting in the normal direction and the frictional force acting in the tangential direction during an oblique collision.

For the normal direction of the pulse:

$$mv_{1n} - mv_{2n} = F_n \cdot \Delta t \quad \rightarrow \; F_n = \frac{mv_{1n} - mv_{2n}}{\Delta t}$$

For the tangential direction of the pulse:

$$mv_{1n} - mv_{2n} = F_\tau \cdot \Delta t \quad \rightarrow \; F_\tau = \frac{mv_{1n} - mv_{2n}}{\Delta t}$$

We found time $\Delta t$ of the collision from the equation of equation of the impulse tangential direction and inserted it in equation of normal creator of the impulse.

$$F_n = \frac{mv_{1n} - mv_{2n}}{mv_{1\tau} - mv_{2\tau}} F_\tau \tag{10}$$

In the respect of the Eq. 10, $tg\beta = \frac{v_{2\tau}}{v_{2и}}, tg\alpha = \frac{v_{1\tau}}{v_{1n}}, \frac{v_{2n}}{v_{1n}} = -k$

Since the law of conservation of momentum is used, the direction of the velocity is taken into account in the coefficient of restitution.

$$F_n = \frac{(1+k)}{tg\alpha + ktg\beta} F_\tau$$

$$F_\tau = F_n \cdot \frac{(tg\alpha + ktg\beta)}{(1+k)} \tag{11}$$

$$tg\beta = \frac{v_{2\tau}}{v_{2n}} = \frac{v_{2\tau}}{kv_{1n}} \tag{12}$$

$$v_{2\tau} = v_{1\tau} - \mu \cdot v_{1n}(1+k) \tag{13}$$

In the Eq.12. and Eq. 13. was converted further.

$$tg\beta = \frac{v_{2\tau}}{v_{2n}} = \frac{v_{1\tau} - \mu \cdot v_{1n}(1+k)}{kv_{1n}} = \frac{tg\alpha - \mu \cdot (1+k)}{k}$$

$$tg\beta = \frac{tg\alpha - \mu \cdot (1+k)}{k} \tag{14}$$

In Eq. 11 and Eq. 14, further conversions were made.

$$F_\tau = F_n \cdot \frac{2tg\alpha}{(1+k)} - F_n \cdot \mu \tag{15}$$

Since $F_\tau$ is the last member on the right-hand side of the above equation, equation 20 entered in the following form and expresses the ratio of normal and tangential forces of oblique impact.

$$F_\tau = \frac{F_n}{2} \cdot \frac{2 \cdot tg\alpha}{(1+k)} \tag{16}$$

From Eq.16. , it can be concluded that the friction force 1s the maximum when the reflection angle $a = 45°$. In other word:

$$F_{\tau} = \frac{F_n}{(1 + k)}$$

Therefore, the theoretically calculated formulas with the above results are the theoretical basis for carrying out a planned test of hard-shelled seeds depending on 4 factors: impact speed, angle of impact, coefficient of friction of the oblique impact surface, and seed moisture.

## 4 Conclusions

1. It can be seen from the Eq. 9. that the difference between the tangential speed before and after the impact, the friction coefficient of the seed, the impact speed, and the recovery coefficient are directly dependent on the angle of incidence and the larger this difference, the more effective the angle of impact is $\alpha \approx 45^0$.
2. From Eq. 16., which expresses the ratio of normal and tangential forces of oblique collisions derived based on the law of conservation of momentum, the friction force is maximum when the reflection angle $\alpha = 45^0$.

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