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To Study Motion of the Grain Mixture on Sieve Surface

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ABSTRACT: Sowing areas of oilseeds (sunflower, safflower, soybean, etc.) are expanding in Uzbekistan. Crops of these cultures harvested by existing grain harvesters. The grain material collected in bunker of the combine is a grains mixture of the main culture, foreign plants and impurities of heterogeneous litter of mineral and organic origin. At the Research Institute of Agricultural Mechanization, a small-sized machine has been developed for cleaning oilseeds from weed impurities. Differential equations are obtained that describe the oscillatory motion of the sieve of its speed and acceleration. Based on the results of decision obtained equations, influence graphs number of vibrations, angle of inclination and amplitude of sieve vibrations on the length movement of the seed material on its surface over the period of time crank rotates are constructed. The rational parameters of sieve are substantiated: an angle of inclination of 10^0, the number of oscillations 300 min^{-1}, the amplitude of oscillations of 7.5 mm.

KEY WORDS: sieve, grain mixture, differential equation, rational frequency, amplitude, angle of inclination.

I. INTRODUCTION

Currently, harvesting of such oil crops as sunflower, safflower, soybeans grown in agricultural clusters and farms is carried out by combine harvesters “Case-2166”, “Dominator-130”, “New Holland TS-5060”, “Vector”. In the bunker of the combinealong with clean seeds falls impurities consisting of small brushwood, dry leaves and small particles of soil. In the composition of such a mixture, the proportion of impurities is more than 2 percent, seed moisture is more than 13 percent, and i.e. they exceed permissible norms. Because in rainfed areas, except oil crops, weed plants such as small-fruited cousin, saltbush, camel thorn and others grow and ripen. The part of such plants is 8–13%, of which 2–3% are light impurities [Astanakulov, 2018; Zaika, 1977; Alferov, 1973]. When processing weed mixtures in creameries, the percentage of oil yield from seeds decreases, its taste deteriorates, and other quality indicators deteriorate.

Therefore, it is required cleaning and drying seed mixture before processing. Unfortunately, due to the lack of seed cleaning machines at farms and household plots, such work is done manually.

In order to eliminate these shortcomings, the Scientific-Research Institute of Agricultural Mechanization has created a small-sized mobile machine for cleaning oilseeds from impurities in conditions of farms [Astanakulov et al., 2017]. The flat sieves of this machine oscillating movement under the action of a crank mechanism. Theoretical and innovative research is underway to optimize parameters and increase the efficiency of this machine.

II. MATERIALS AND METHODS

The primary materials are oilseeds and impurities, consisting of small particles of weeds and soil. The development was carried out on the basis of methods of higher mathematics and theoretical mechanics.

III. RESULTS AND DISCUSSION

We accept the following assumptions:

1) the movement of grain layer element is considered as the motion of material particle;
2) the resistance force to the displacement of layer element along sieve surface is taken equal to the friction force;
3) the resistance of air to the layer movement is neglected;
4) It is believed that the sieve, and with it the material point, perform harmonic vibrations. The equation of oscillatory motion of any point of sieve, installed at an angle α to the horizon (Fig. 1):

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$$X = A - A\cos(\frac{2\pi}{T}t + \varphi) \quad (1)$$

where A–is the oscillation amplitude of sieve, m; T – oscillation period, s; T=60/w; w–is the number of oscillations, m^{-1}; φ–is the phase of oscillations (It varies between 0-2π).

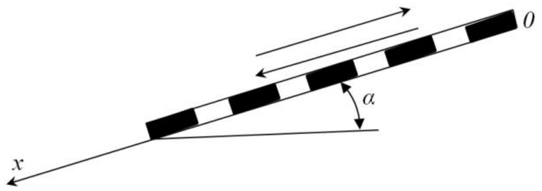

Fig. 1. Scheme of oscillatory motion of sieve

The values of sieve point displacements according to (1):

$$\text{at } \frac{2\pi}{T}t + \varphi = 0^0 \quad X = A - A\cos 0^0 = 0;$$

$$\text{at } \frac{2\pi}{T}t + \varphi = \frac{\pi}{2} \quad X = A - A\cos\frac{\pi}{2} = A;$$

$$\text{at } \frac{2\pi}{T}t + \varphi = \pi \quad X = A - A\cos\pi = 2A;$$

$$\text{at } \frac{2\pi}{T}t + \varphi = \frac{3\pi}{2} \quad X = A - A\cos\frac{3\pi}{2} = A;$$

$$\text{at } \frac{2\pi}{T}t + \varphi = 2\pi \quad X = A - A\cos 2\pi = 0;$$

$$\text{at } \frac{2\pi}{T}t + \varphi = \frac{5\pi}{2} \quad X = A - A\cos\frac{5\pi}{2} = A.$$

The movement diagram corresponding to these values is shown in Fig. 2.

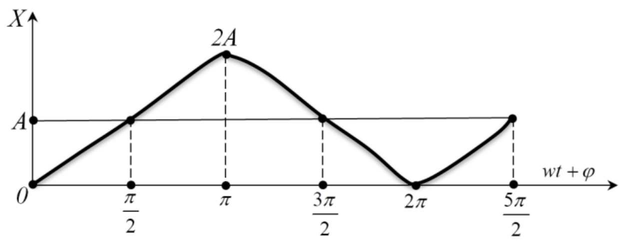

Fig. 2. Oscillatory motion schedule of sieve

Differentiating (1), we obtain the expression for sieve velocity:

$$\dot{X} = -A[-\sin(\frac{2\pi}{T}t + \varphi)]\frac{2\pi}{T} = \frac{2\pi A}{T}\sin(\frac{2\pi}{T}t + \varphi)$$

Differentiating this expression, we determine the sieve acceleration:

$$\ddot{X} = \frac{2\pi A}{T}\cos(\frac{2\pi}{T}t + \varphi)\frac{2\pi}{T} = \frac{4\pi^2 A}{T^2}\cos(\frac{2\pi}{T}t + \varphi)$$

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The following forces act on a material particle lying on surface of a sieve, performing harmonic vibrations: mg – grain weight; F_i– portable inertia force; N – normal reaction of sieve; F –the friction force (Fig. 3).

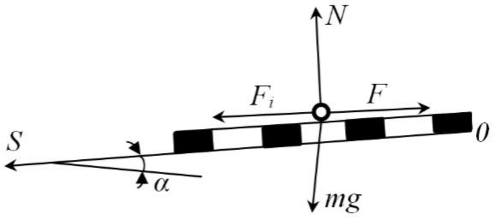

Fig. 3. Scheme of forces acting on a material point in the process of sieve oscillatory motion

Formulas for determining the inertia forces and resistance:

$$F_i = -m\ddot{X} = -m\frac{4\pi^2 A}{T^2}\cos(\frac{2\pi}{T}t+\varphi);$$

$$F = \pm fN = \pm fmg\cos\alpha,$$

where m– the particle mass, kg;f–particle friction coefficient over the surface of sieve;g– acceleration of gravity, m/s^2.
The differential equation of a particle relative motion on surface of sieve with acceleration $\ddot{S}$:

$$m\ddot{s} = F_i + mg\sin\alpha - F = -m\frac{4\pi^2 A}{T^2}\cos(\frac{2\pi}{T}t+\varphi) + mg\sin\alpha \pm fmg\cos\alpha$$

or $$\ddot{S} = -\frac{4\pi^2 A}{T^2}\cos(\frac{2\pi}{T}t+\varphi) + g\sin\alpha \pm f\cos\alpha. \quad (2)$$

Integrating expression (2), one can determine the particle displacement over distance S and corresponding velocity $\dot{S}$. At $\dot{S}< 0$ in expression (2) take the sign "+", and at $\dot{S}> 0$ the sign "-" [Barefoot et al., 1977].
The initial conditions of differential equation (2):$S(0)=S_o$,$\dot{S}(0)=\dot{S}_o$,Where S_o- the initial coordinate of the particle on sieve surface, m; $\dot{S}_o$- initial particle velocity, m/s.
The solution of equation (2) was sought using the numerical Runge-Kutta method [Myshkis, 1969]. Calculated values of displacements S particles in the time range were determined $t=\varphi/w=0-2$ sec of the sieve crank turn in various input parameters $w, A, \varphi, \alpha, S_o, \dot{S}_o$(Fig. 4, 5, 6).
From the graphs shown in Fig. 4, 5, 6 it can be seen that with increasing movement time t, the number of oscillations w, the angle of inclination α, and the amplitude of oscillations A, the displacements S of the grain mixture along sieve surface will increase.

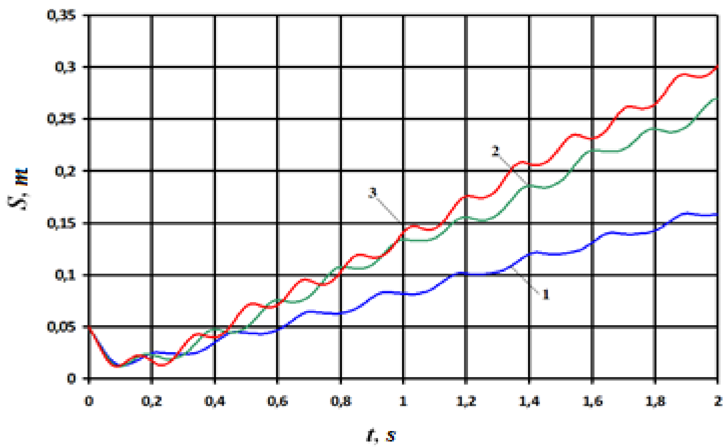

Fig. 4. Graphs influence number of oscillations (w) of the sieve (1, 2, 3) on length (S) of the seeds movement on surface of sieve in time t:1 - w = 250 rpm, 2 - w = 300 rpm, 3 - w = 350 rpm

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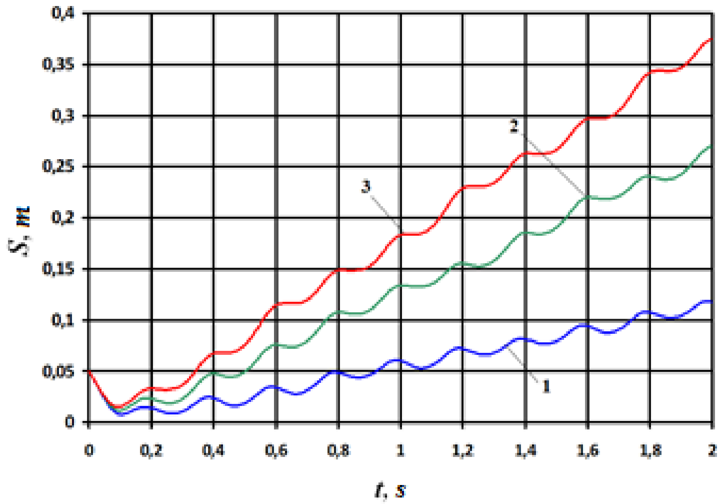

Fig. 5. Graphs influence of inclination angle (α) of the sieve (1, 2, 3) on length (S) of seeds movement on surface of sieve for time t:1 - α = 50, 2 - α = 100, 3 - α = 150

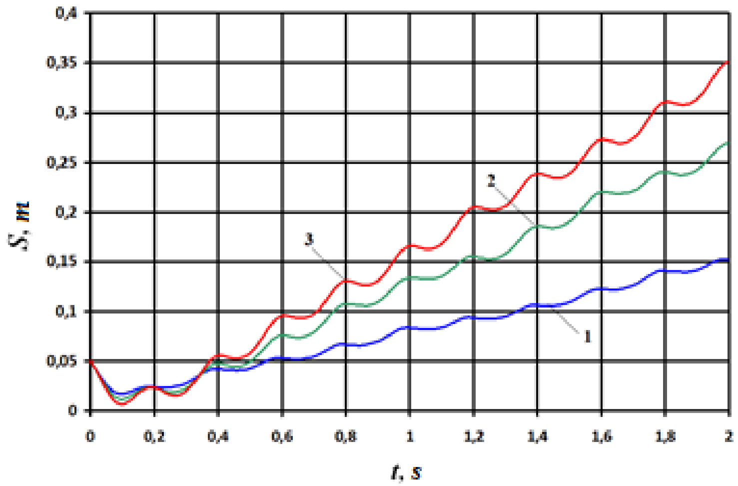

Fig. 6. Graphs influence of oscillations amplitude (A) of sieve (1, 2, 3) on length (S) of the seeds movement along the sieve surface during time t:1 - A = 5 mm, 2 - A = 7.5 mm, 3 - A = 10 mm

The calculations showed an increase in the degree of grain purification from impurities with number of sieve vibrations w=300 min^{-1}, oscillations amplitude A=7.5 mm, sieve angle α=10°, at the starting point S_o=0.05 m and speed $\dot{S}$=0.5 m/s hit of the mixture on sieve surface. At w=250 min^{-1},α=5° and A=5 mm the quality of seed cleaning decreases, and at values w=350 min^{-1},α=15° and A=10 mm the probability of some particles escaping from sieve surface increases.

IV. CONCLUSIONS

Rational parameters that ensure high-quality cleaning of seeds from weedy impurities moving along the surface of an oscillating sieve: an inclination angle of 10°, the number of oscillations of 300 min^{-1} and oscillations amplitude of 7.5 mm.

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