MOTION SIMULATION PARTICLES ON A ROUGH HORIZONTAL PLANE WHICH ARE RECTILINEAR OSCILLATING MOVEMENT

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***Summary.* Trajectory-kinematic properties of a particle motion on a rough horizontal area making rectilinear oscillatory movement are given.**

***Keywords:* motion of a particle, rough area, oscillatory displacement, differential equations, trajectory, speed.**

Formulation of the problem. Heap grain separation into individual fractions is carried out with various technological principles [2], in particular, due to certain movements of particles on a rough oscillatory area. Development of simulation models for oscillatory motion of a particle planes necessitates appropriate processing software of computer mathematics systems, which is a problem of the research.

Analysis of recent research. Analytical support for use moving trihedral trajectory of particle to describe its movement on the rough horizontal area performing parallel movement in space is processed in the work [3]. The development of simulation models of a particle is advisable to perform in an environment of symbolic mathematics Maple [1].

Formulation of Article purposes. To develop for Maple environment [1] a simulation model of a particle movement on rough horizontal area, which provides rectilinear oscillating motion and with its help explore trajectory-kinematic properties according to the following initial conditions:1) kinematic parameters of rectilinear oscillation area; 2) initial rate of throwing *Vo* particles; 3) throwing particle corner α_o in the direction of the plane; 4) external friction coefficient f.

Main part. In case of a area parallel displacement (its general line is parallel to itself) the moving particle in this area is not subjected to Coriolis force, which greatly simplifies the formation of a system of differential equations of 2nd order law of its motion. In the projections on the axis *Ou* and *Ov* local coordinate system *Ouv* law of motion of a particle is written the following way:

$$\begin{cases} Ou := m\,W\,cos\left(\widehat{\boldsymbol{R}_u,\boldsymbol{w}}\right) = F_g\ cos\left(\widehat{\boldsymbol{R}_u,\boldsymbol{G}}\right) - f\ F_N\,cos\left(\widehat{\boldsymbol{R}_u,\boldsymbol{\tau}_{\boldsymbol{\rho}}}\right) \\ Ov := m\,W\,cos\left(\widehat{\boldsymbol{R}_v,\boldsymbol{w}}\right) = F_g\ cos\left(\widehat{\boldsymbol{R}_v,\boldsymbol{G}}\right) - f\ F_N\,cos\left(\widehat{\boldsymbol{R}_v,\boldsymbol{\tau}_{\boldsymbol{\rho}}}\right) \end{cases} \quad (1)$$

where: $\boldsymbol{G} = [0,0,-1]$ – direction of gravity $F_g = mg$ in system *Oxyz*;

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W = | $\boldsymbol{w}$ | - value acceleration;

$F_N = F_g\, cos(\widehat{\boldsymbol{N},\boldsymbol{G}}) \pm F_C\, cos(\widehat{\boldsymbol{N},\boldsymbol{n}})$- the normal reaction force;

$F_g = mg$ and $F_C = m\, V^2 k$ - gravity and centrifugal force;

N = [0,0,1] – normal to the area $\boldsymbol{R}$ *(u, v)* the points of the trajectory **r**;

n - the principle normal of particles trajectory **r**;

$\boldsymbol{\tau_\rho}$ –the tangent relative trajectory vector **ρ**.

Plane equation written in parametric form:

$$\boldsymbol{R}(u, v) = \boldsymbol{R}[u,\ v,\ 0], \tag{2}$$

Where $u \in [u_1..u_2]$, $v \in [v_1..v_2]$ – coordinates internal surface $\boldsymbol{R}(u, v)$.

There is an unlimited number of parallel movements of a area (2) in the space *Oxyz*, which laws can be viewed by function of vector M [x (t), y (t), z (t)]. The simplest of these are:

1. rectilinear along the axis Ox - $\boldsymbol{M}[\upsilon t,\ 0,\ 0]$;
2. accelerated along the axis Ox -$\boldsymbol{M}\left[\upsilon t + \frac{wt^2}{2}, 0, 0\right]$,
3. vibrational along the axis $\boldsymbol{M}\left[l\, cos(\upsilon t) + \sqrt{L^2 - sin^2(\upsilon t)}, 0, 0\right]$;
4. vibrational circular in the area $\boldsymbol{M}[l\, cos(\upsilon t),\ l\, sin(\upsilon t), 0]$, etc.

Let's focus on oscillatory movement of the area along the axis Ox, which is implemented with a crank mechanism:

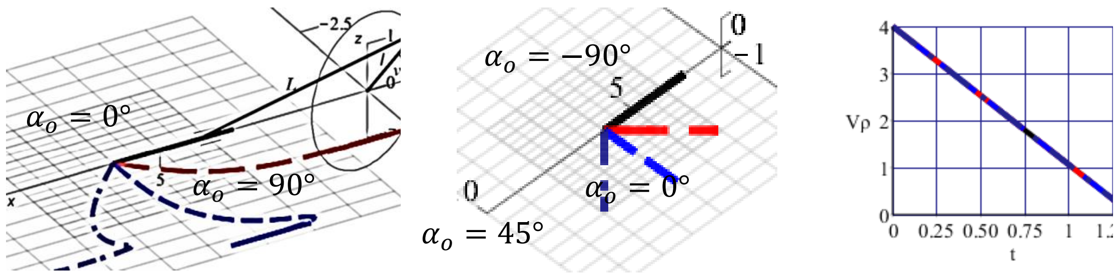
$$\mathbf{M} = \mathbf{M}\left[\mathrm{l}\cos(\upsilon t) + \sqrt{\mathrm{L}^2 - \sin^2(\upsilon t)}, 0, 0\right], \tag{3}$$

where: $\upsilon, \mathrm{c}^{-1}$- the angular velocity of the crank;

$l,\ L,$ м- according to the crank and connecting rod length (Figure 1, A).

The developed hardware for symbolic mathematics Maple environment [1] enables to make automatically all analytical transformation to formulate the law (1) of a particle and to implementits approximate solution. These calculations are fairly cumbersome, so here they will be not given, and only the results of computational experiments of a particle at different initial conditions will be given.

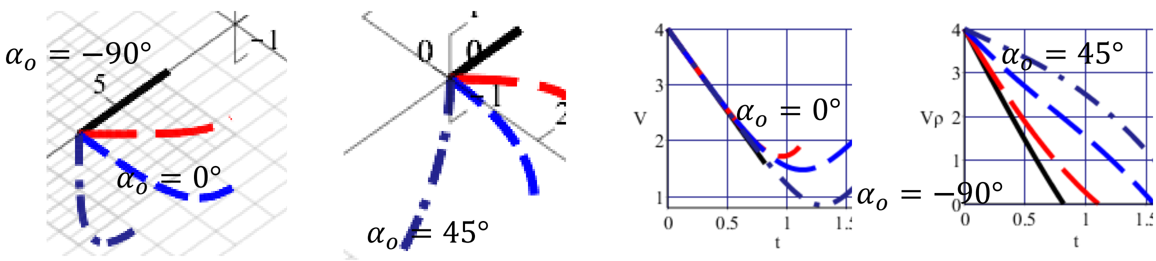
If the crank length *l* = 2, connecting rod length *L*= 4, initial speed *Vo* = 4 m /c discharge particles, its starting position $u_o = v_o = 0$ and friction coefficient f = 0.3. First of all , lets conduct a test experiment - take the crank angular velocity υ equal υ = 0 (immovable area). Then the absolute trajectory $\boldsymbol{r}(t)$ and the relative trajectory $\boldsymbol{\rho}(t)$ converge along the straight lines (Fig. 1, B) and the angle of throwing the particle $\alpha_o = -90°, -45°, 0°, 45°$ isn`t important. Similarly, absolute ***V(t)*** and relative $\boldsymbol{V_\rho(t)}$ graphics of speed particles behave , demonstrating evenly decreasing to a complete stop in a immovable area.



a) b) c)

Fig.1. Motion of the area and the particle moving in a motion area, depending on the angle of throwing α_o

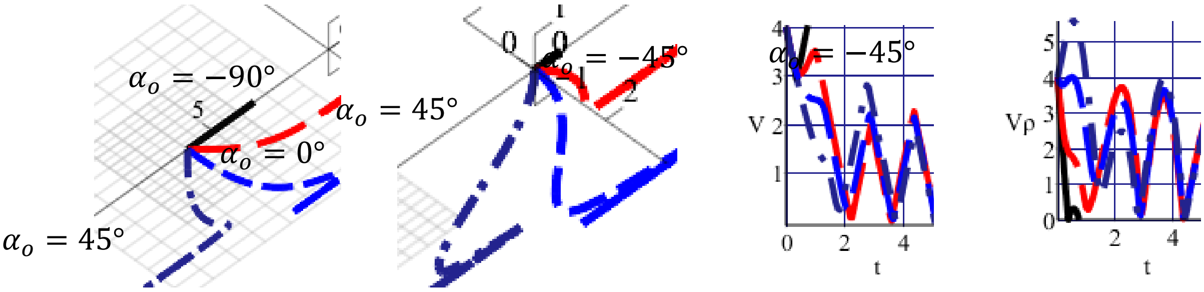
Let`s increase crank angular velocity υ to υ = 1 s^{-1}. According to the graphs relative particles velocities *Vρ (t)* (Fig. 2, d), it can be argued that they will stop during the period t≈0.8-2s. Note that the first will stop the particle, which is thrown angle wise α_o= -90 ° - moving towards a oscillatory area with t = 0. The same particle will have the smallest relative trajectory length ***ρ****(t)* (Figure 2, B). Absolute particles trajectories ***r*** *(t)* (Figure 2, a) and absolute velocities graphs *V (t)* (Fig. 2, c) are built over the time until they will be stopped completely.



a) b) c) d)

Fig.2. Absolute and relative particle trajectories and their velocity graphs for the angular crank speed υ = 1 s^{-1}.

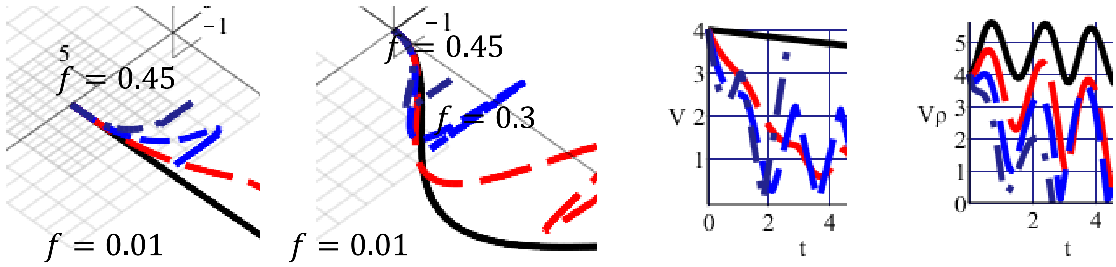
Let`s increase the crank angular velocity υ = 2 s^{-1}. Graphics of relative *Vρ (t)* velocity particles (Fig. 3 d) show that only particles thrown at an angle $\alpha_o = -90°$ stop after period of time t ≈ 1s, and all others will perform relative movement in the area. After a period of time t ≈ 3s particles motion stabilized - they all carry the same rectilinear oscillatory movements, but in different parts of the area.



a) b) c) d)

Fig. 3. Absolute and relative trajectory particles and their velocity graphs for the crank angular speed $\upsilon = 2\ s^{-1}$.

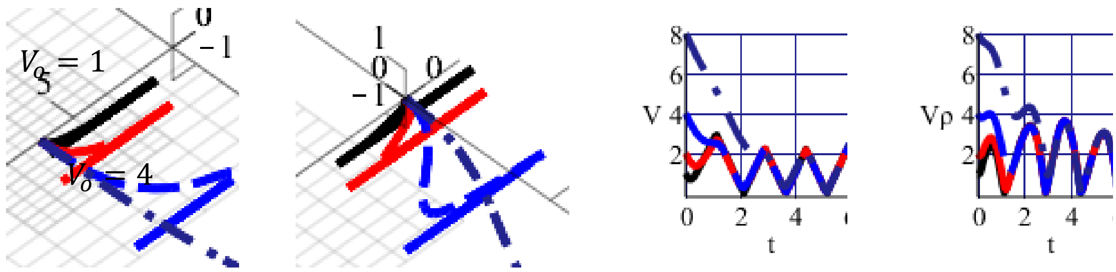
Now let particles have different friction coefficients f = 0.01, 0.15, 0.3, 0.45. If they will be thrown to the perpendicular direction in the oscillatory area ($\alpha_o = 0°$), their trajectory-kinematic properties are significantly different (Figure 4). So the particle with friction f = 0.45 after interval t ≈ 2.7 generally stop in the oscillatory area. Moreover, if the friction coefficient f is the greater, the particle stabilizes faster its absolute and relative trajectory. Particles with a lower friction coefficient f have less absolute trajectory amplitude.



a) b) c) d)

Fig. 4. Absolute and relative particle trajectories and their velocity graphs depending on the friction coefficient *f*.

The value of the initial speed *Vo* of throwing particle affects only during stabilization period of movement (Fig. 5).



a) b) c) d)

Fig. 5. Absolute and relative particle trajectories and their velocities depend on the initial velocity *Vo*.

The transition of the particle with initial velocity *Vo* = 1 m /s to straight oscillating trajectory will be after an interval *t≈0.6c,* and for particles with speed *Vo* = 8 m / s after *t≈3s*.

Conclusions. Heap grain separation into individual fractions can be carried out only with varying friction particle coefficients or their throwing to different directions in the oscillatory area. Initial velocity of particle throwing affects only at the stabilization time of the motion. In case of certain relations of crank angular velocity and the friction particle coefficient, it is possible to stop oscillatory area, but it is unacceptable for the process of separation.

Literature

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