THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE XIV MECHANICHAL ENGINEERING, ISSN 1224-5615
2008

THE DYNAMIC OF MATERIAL PARTICLE MOVEMENT ON VIBRATING 2D AND 3D MODELED SIEVES IN CAD SYSTEMS

Lecturer Dr. Eng. HARAGA Georgeta[1]
Assoc. Prof. Dr. Eng. GHELASE Daniela[2]
Assoc. Prof. Dr. Eng. DASCHIEVICI Luiza[2]
[1]„Politehnica” University of Bucharest
[2]„Dunarea de Jos” University of Galati

ABSTRACT

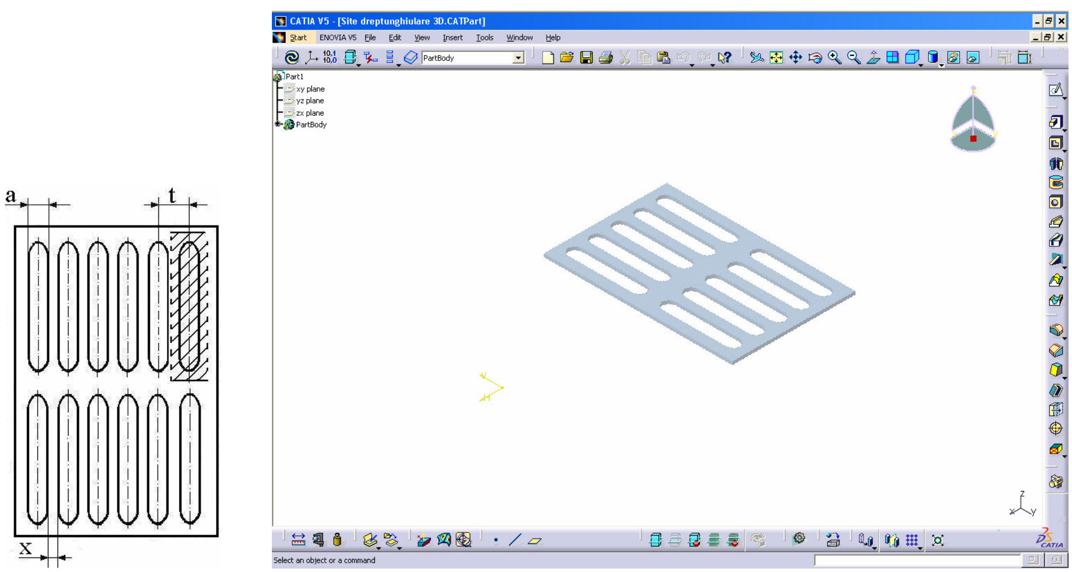
In this paper are presented aspects concerning the dynamic of material particle movement on sieves for cleaning and sorting. In the first part of the paper there is a short classification of the sieve types used for the cleaning machines, graphically 2D and 3D exemplified, by using CAD systems. In the second part of the paper are emphasized the three movement steps of the material particle on sieves, the second one being given by the elastic particle movement on the vibrating plane described by differential equations.

KEYWORDS: Vibrating sieves, Steps of the material particle movement, CATIA, AutoCAD.

1. The sieves types of the cleaning and sorting systems

In order to separate the material particles in the cleaning and sorting machines, we can use sieves classified according to several criteria [1]:

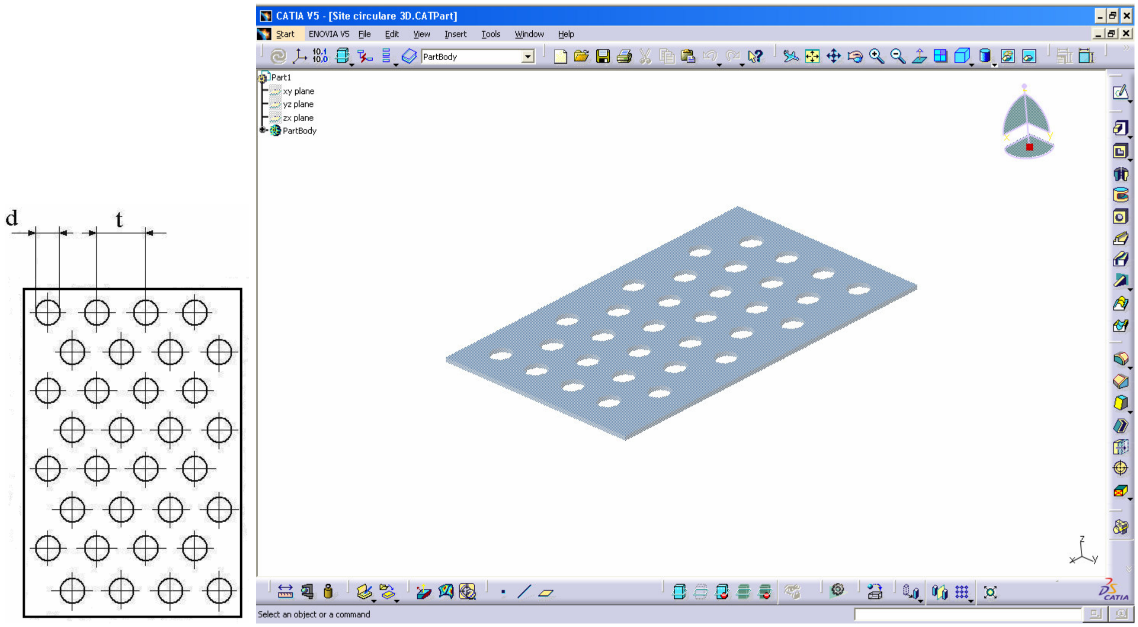
- ***by geometric shape:*** plane and cylindrical;
- ***by the orifices shape:*** with rectangular orifices (Fig. 1-a, b); with circular orifices (Fig. 2-a, b); with triangular orifices (Fig. 3-a, b);



a) b)

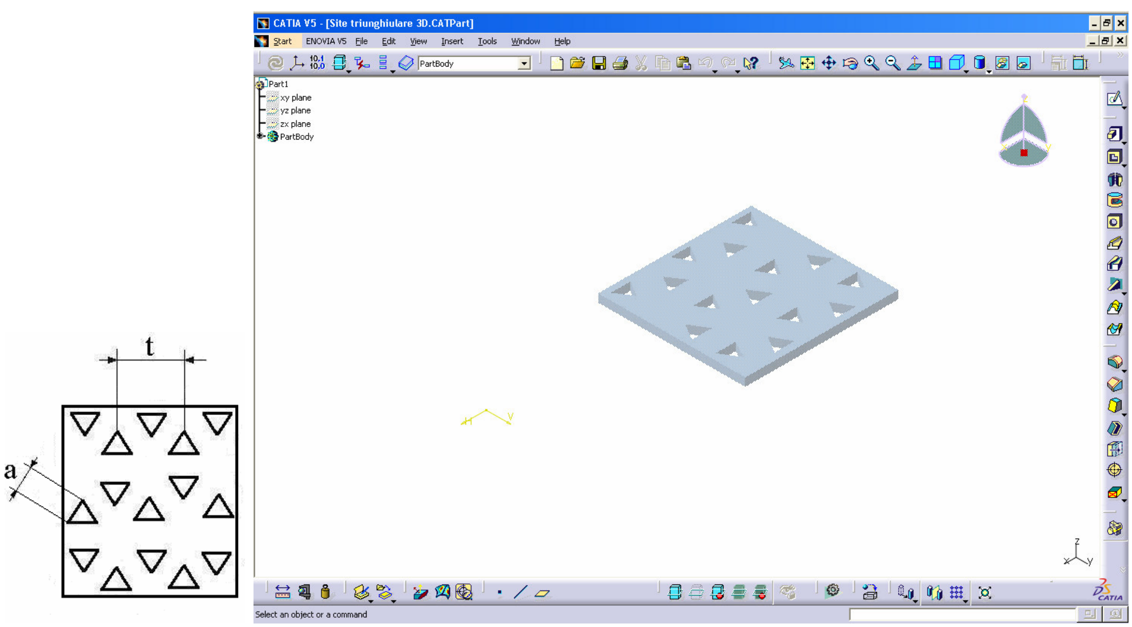
Fig.1 Sieves with rectangular orifices 2D modeling using AutoCAD (a) and 3D modeling using CATIA (b)

- ***by the movement type:*** with oscillating movement, with vibrating movement, with rotation movement, and fixed;
- ***by destination:*** for big impurities separating; for separating cleaned particles of the principal culture in fractions;
- ***by the surface state:*** with smooth surface; with wavy surface, the orifices for plate, particles separation being made on the undulations bottom;
- ***from construction point of view:*** made of perforated (stamped) *iron plate;* made of wire knitting.



a) b)

Fig.2 Sieves with circular orifices 2D modeling using AutoCAD (a) and 3D modeling using CATIA (b)



a) b)

Fig.3 Sieves with triangular orifices 2D modeling using AutoCAD (a) and 3D modeling using CATIA (b)

The sieves working process implies the material particle mass moving, distributed in a uniform layer on the sieves surface and material particle separation through the sieves orifices with smaller dimension than the sieves orifices dimension.

Following the sieves action, the material particle mass is divided in two fractions:

- the fractions which flow from the sieves are made up of material particle with bigger dimensions than the sieves orifices dimensions;
- the part which passes through the sieves made up of material particles with smaller dimensions than the sieves orifices ones.

The main forms orifices used at the sieves for cleaning and sorting material particles are rectangular and circular.

In figure 1-a is represented surface of sieve made of perorated iron plate with smooth surface with rectangular orifices set in straight rows. The rectangular orifices are determinated by two dimensions: the width and length. The working orifices dimension is its width **a**, (Fig. 1-a) and these are set on the sieves surface with their length parallel with the moving direction of the material on the sieve.

CATIA is a modeling and drafting package, the projecting in this soft guiding to a 3D prototype realization of the product and to caption of new information which lead to an exact projecting process without errors. Especially made for technical drawing generation, CATIA assures an excellent representation, detailed describing, annotations and quotations which automatically correspond to the used quotation standard. CATIA Part Design is used to construct individual part models. Part models are constructed by adding and removing material from a base feature. The field of solid modeling has developed a variety of techniques for unambiguous representations of three-dimensional objects. If we work with a solid component, with a model of the assemble or with a blank sheet of drawing, the CATIA Drafting and its detailing instruments help us to make the drawings faster and more easily than any other CAD system.

The CATIA soft is divided in more modules the Sketcher, Part Design and Drafting ones being emphasized in a special way. CATIA gives us a variety of tools that allow us to easily document designs during any stage of drawing production. We can create associative drawing views of 3-D parts and assemblies that we can quickly update when the part or assembly changes. We can also create drawing views that consist of 2-D elements drawn from scratch that we can quickly modify without making changes to a part document [3].

Starting from 2D models realized in AutoCAD (Fig. 1-a, Fig. 2-a, Fig. 3-a) we will achieve, by using CATIA Part Design, 3D modeling of the sieves with rectangular orifices set in straight rows (Fig. 1-b), with circular orifices (Fig. 2-b) and with triangular orifices (Fig. 3-b). For their modeling the following commands have been used: Sketch, Pad and Pocket [2, 4].

In figure 2-a is represented the surface of sieve made of perorated iron plate with smooth surface with circular orifices. The circular orifices are characterized by a single dimension and they can better stop the passing of the seeds than the circular orifices diameter. The working dimension of the circular orifice is its diameter **d** (Fig. 2-a).

In conclusion, the sieves with rectangular orifices separate the material – in accordance with the material particle thickness, and the sieves with circular orifices – in accordance with width.

In figure 3-a is represented surface of sieve made of perorated iron plate with smooth surface with triangular orifices. The triangular orifices (Fig. 3-a) are used to separate material particles with edges (buckwheat, sorrel, etc.). Their working dimension is the triangle edge **a**. In order to separate the corn particles we use undulation sieves with rectangular and circular orifices being set on the undulation bottom – that favours the particle separation by guiding the flat particles from the sieve surface, to the orifices.

In the case of the cereals stalk harvesting, machines the cleaning systems of the sieves are of more types as for example:

- sieves from perforated plate with rectangular or circular orifices;
- sieves of Graepel type;
- sieves with adjustable blinds, etc.

2. The steps of the material particle movement on sieve

The installations with vibrating sieves have been used more and more often recently, these having a more rational form of action of the working machine and a series of constructive advantages compared to the installations with oscillatory sieves. Taking this into consideration there are three steps of material particle movement on sieves [5, 7].

2.1 The first movement step

In this case, the particles of the first layer that are on the vibrating sieve, under the normal impulse action, defeat the joint resistance and so they move towards the second layer.

In the collision moment particles of the first layer, will send the rest of its energy to the particles of the second layer, and these, in their turn, will consume the received energy to defeat the resistance and to send the rest of energy towards the third layer and so on. During this particle movement the spaces among the cereal mass particles grow and so are created conditions of the penetration for the particles with small dimensions and bigger specific weight on the surface of the vibrating sieves.

The particle penetration on the sieves surface is also favoured by the cavities which are made as a consequence of the particle separation through the orifices.

If the cereal layer is in the form of layers of balls, then we can obtain the following condition of the cereal mass breaking up:

$$\omega A \geq \frac{\sqrt{2gD}}{\pi n k^{n-1}} \frac{1-k^n}{1-k} \quad (1)$$

where:

g - gravitational acceleration;

D - material particles diameter;

k - restoring coefficient ;

n – the material particle number on vertical which depends on the vibrating sieve loading (the layer height).

2.2 The second movement step

This step is given by the elastic particle movement on the vibrating plane and can be described by the following differential equations:

$$\begin{cases} \ddot{x}g \sin\alpha - \omega^2 A_1 \cos(\omega t - \varphi_0) - \dfrac{2(1-f)}{1+f}\delta(t)\dot{x} \\ \ddot{y}g \cos\alpha + \omega^2 A_1 \sin(\omega t + \varphi_0) - \dfrac{2(1+k)}{1-k}\delta(t)\dot{y} \end{cases} \quad (2)$$

where:

α - the inclination angle of the vibrating plane faced with the horizontal plane;

ω - the vibration pulsation;

A_1, A_2 - the horizontal and vertical components of the vibration amplitude, in this case, $A_2 = A_1 tg\beta$;

φ_0 - the initial phase; (β - the direction angle of the vibrations);

t - the time;

f - the coefficient of instantaneous friction;

k - the restoring coefficient;

$\delta(t)$ - the impulse function; at $t \neq 0 \Longrightarrow \delta(t) = 0$, and at $t = 0 \Longrightarrow \int_{-\infty}^{+\infty} \delta(t)dt = 1$.

The equations are written in accordance with fig. 4, where are pointed the forces that act upon the material particle when colliding the vibrating surface: the weight force of the P particle; the instantaneous reaction components of the plane, conditioned through the action of the impulses of normal pressure and friction P_H and T; the forces of inertia in relative movement and of transport F_r and F_t [6].

By solving the differential equations (2) and taking into account the initial conditions, that is the conditions of the movement periodicity, we can find all the necessary elements for the material particle movement:

a) the phase of collision with vibrating plane:

$$\varphi = ar\cos\left[\frac{\pi\nu(1-k)\cos\alpha}{1+k} \times \frac{g}{\omega^2 A^2}\right] \quad (3)$$

where:

ν - the frequency of the material particle collision with the sieve surface.

b) the phase of periodical movement restoring:

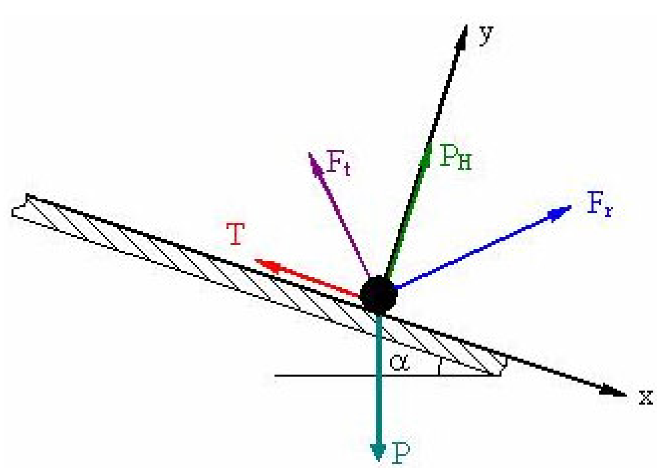


Fig. 4 The forces that act upon the material particle when colliding the vibrating surface

$$\varphi_y \geq \pi - \sqrt{\left(\frac{\pi}{\cos\varphi}\cdot\frac{1-k}{1+k}\right)^2 - 1} - \\ - \arcsin\left(\frac{\cos\varphi}{\pi}\cdot\frac{1+k}{1-K}\right) \tag{4}$$

c) the angle of falling j_u and of reflection i_u:

$$j_u = arctg\left(\frac{1+k}{1-\varphi}\cdot tg\alpha\right); \\ i_u = arctg\left(\frac{1+k}{1-k}\cdot\frac{f}{k}\cdot tg\alpha\right). \tag{5}$$

d) the falling velocity $v_{căd}$, the reflection velocity v_{ref} and the travelling average speed v_m:

$$v_{cad} = \frac{2\pi\nu^2 g}{\omega}\sqrt{\frac{\sin^2\alpha}{(1-f)^2}\cdot\frac{\cos^2\alpha}{(1+k)^2}} \tag{6}$$

$$v_{ref} = \frac{2\pi\nu^2 g}{\omega}\sqrt{\frac{f^2\sin^2\alpha}{(1-f)^2}\cdot\frac{k^2\cos^2\alpha}{(1+k)^2}} \tag{7}$$

$$v_m = \omega A_2\sqrt{1-\frac{4\pi\nu^2\cos^2\alpha}{\tau_1^2}\cdot\frac{g^2}{A^2\omega^4}\cdot ctg\beta +} \\ + \frac{2\pi\nu\sin\alpha}{\tau_2}\cdot\frac{g}{A^2\omega^2} \tag{8}$$

where:

$$\tau_1 = 2\frac{1+k}{1-k};$$

$$\tau_2 = 2\frac{1-f}{1+f}.$$

In the periodical conditions of movement:

$$v_{cad} = \frac{2\omega A_2\cos\varphi_y}{1-k}\sqrt{\left(\frac{1+k}{1-f}tg\,\alpha\right)^2 + 1} \tag{9}$$

$$v_{ref} = \frac{2\omega A_2\cos\varphi_y}{1-k}\sqrt{\left(f\cdot\frac{1+k}{1-f}tg\alpha\right)^2 + k^2} \tag{10}$$

$$v_m = \omega A_2$$

$$v_m = \omega A_2\left(\sin\varphi_y\cdot ctg\beta + \frac{\tau_1}{\beta}\cos\varphi_y tg\alpha\right) \tag{11}$$

e) the jumping distance:

$$L = 2\pi\nu A_2 ctg\beta\cdot \\ \cdot\left(\sqrt{1-\frac{4\pi^2\nu^2\cos^2\alpha}{\tau_1^2}\cdot\frac{g^2}{A_2^2\omega^4}} + \frac{2\pi\nu\sin\alpha}{\tau_2}\cdot\frac{g}{A_2\omega^2}\right) \tag{12}$$

In the periodical conditions:

$$L = \omega^2 A_2^2\tau_1\cdot \\ \cdot\sec\alpha\left(0{,}5\sin 2\varphi_y ctg\beta + \frac{\tau_1}{\tau_2}\cos^2\varphi_y\cdot tg\alpha\right) \tag{13}$$

The step of the particle movement on the vibrating sieve ends when the material particles penetrate into orifice [1, 8].

2.3 The third movement step

Knowing the orifices disposing law and dimensions, the movement parameters of the material particles and of the vibrating sieve it is necessary to establish what number of orifices must meet the particles to penetrate into the orifice, what way the particles must following and how much time it takes the particles to do this.

According to the theory of probabilities we can find the number of orifices that assure the material particle penetration into the sieve orifices:

$$n_{orif} \approx \frac{2{,}86}{1-\frac{0{,}85D}{d_H\sin j}} \tag{14}$$

The trajectory of the material particles of the sieve surface:

$$L_p = \frac{3{,}72 d_H}{1-\frac{0{,}85D}{d_H\sin j}} \tag{15}$$

The duration of the material particle movement on the sieve surface (the duration of the second step):

$$t = \frac{3{,}72 d_H}{\omega A_2 \left(1 - \frac{0{,}85 D}{d_H \sin j}\right)^2 \left(\sin \varphi_y \cdot ctg\beta + \frac{\tau_1}{\tau_2} \cos \varphi_y tg\alpha\right)} \tag{16}$$

In the general case of vibration according to elliptical law, the condition that assures the material particle penetration through orifice has the following value:

$$\omega \le \frac{\left(\arcsin \frac{x'_c}{A_1} - \arcsin \frac{x'_a}{A_1}\right) g \cos \alpha}{-v_n \sin j + \sqrt{v_n^2 \sin^2 j + (D + 2A_2) g \cos \alpha}} \tag{17}$$

where:

$$x'_a = \frac{\frac{\Delta r tg^2 j}{A_2^2}}{\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}} + \frac{\sqrt{\left(\frac{\Delta r tg^2 j}{A_2^2}\right)^2 - \left(\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}\right) \cdot \left[\frac{(\Delta r)^2 tg^2 j}{A_2^2} - 1\right]}}{\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}} \tag{18}$$

$$x'_c = \frac{-\frac{\Delta r tg^2 j}{A_2^2}}{\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}} - \frac{\sqrt{\left(\frac{\Delta r tg^2 j}{A_2^2}\right)^2 - \left(\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}\right) \cdot \left[\frac{(\Delta r)^2 tg^2 j}{A_2^2} - 1\right]}}{\frac{1}{A_1^2} + \frac{tg^2 j}{A_2^2}} \tag{19}$$

$$\Delta r = 0{,}5(\alpha - D \cos ecj) \tag{20}$$

3. Conclusions

The inequality analysis (17) shows that the most rational vibration is the rectilinear one, perpendicular on the sieve plane. Besides this, we study the influence of various factors upon the sieves obstruction. The optimal conditions necessary for an efficient separation do not coincide with the optimal conditions necessary for avoiding the sieves obstruction.

The unique and productive tools of the CATIA are very accessible and easy to use, assuring the advantages of a performance three-dimensional mechanical projection.

Starting with the basic shapes created from plane sketches drawn after one direction or axis, the users can easily add usual mechanic elements as sections, fillets and elements with thin walls, as well as more complex elements.

References

[1] **Gherghe (Haraga), G.** *Contribuții la studiul dinamicii particulelor materiale în mişcările lor pe sisteme vibratorii de scuturare, separare şi transport,* teză de doctorat, 2004.

[2] **Goanță A. M.,** *3D graphical processing (with autocad 2000) in the field of ironfoundry technology for the crankshaft of dacia 1310 engine.* MicroCAD' 2000 -International Computers Science Conference University of Miskolc, Section B: Materials Tehnology, ISBN 963-661- 415 - 6.

[3] **Haraga G.** *Modeling in Draft and Part modules with the Solid Edge soft,* The 2nd International Conference on Engineering Graphics and Design, "Dunarea de Jos" University, Galati, Graphics, Mechanisms and Tolerances Department, ICEGD, ISBN 978-973-667-252-1 Ed. CERMI, , Roumania, 2007.

[4] **Ion E.E., Haraga G., Ioniță E.,** *Elemente de grafică computerizată*, Ed. MATRIX ROM, ISBN 973-685-645-3, Bucureşti, 2003.

[5] **Letoşnev, M.N.** *"Maşini agricole"*, (traducere din lb.rusă), Ed. Agro - Silvică de Stat, Bucureşti, 1959.

[6] **Manole C., Paraschiv G.** *Model matematic al traiectoriei unei particule aruncate cu viteză inițială într-un curent de aer înclinat, cu aplicație la separarea fracțiilor uşoare, din masa de vraf la combinele de cereale*, Construcția de Maşini, Nr.12, Bucureşti, 1999.

[7] **Neculăiasa, V., Dănilă, I.,** *Procese de lucru şi maşini agricole de recoltat,* Ed. A 92, Iaşi, 1995.

[8] **Thomson, W.T.** *Teoria vibrațiilor şi aplicații*, Englewood Cliffs, N.T.. Pretice Hall, 1988.