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MATHEMATICAL MODEL FOR ESTABLISHING THE VIBRATING CONDITIONS SPECIFIC TO ELECTROMAGNETIC SIEVES

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Abstract: *The theoretic bases of some mathematical models for the sorting processes on vibrating sieves were established once the modern calculation equipment appeared. The present paper presents a simplified calculation model for vibrating conditions specific to the sieving of pulverized materials on electromagnetic sieves.*

Key words: *sorting process, electromagnetic sieves, false position method*

1. ESTABLISHING THE JUMP CONDITIONS

Let us consider an electromagnetic vibrator, with sieves tilted to angle α in reference to the horizontal line of the place, with the mobile coordinate system axes xO_1y, solitary with the sieve (axis *Ox* oriented along the sieve) and axes $\xi O\eta$ of the fixed coordinate system, as shown in figure 1.

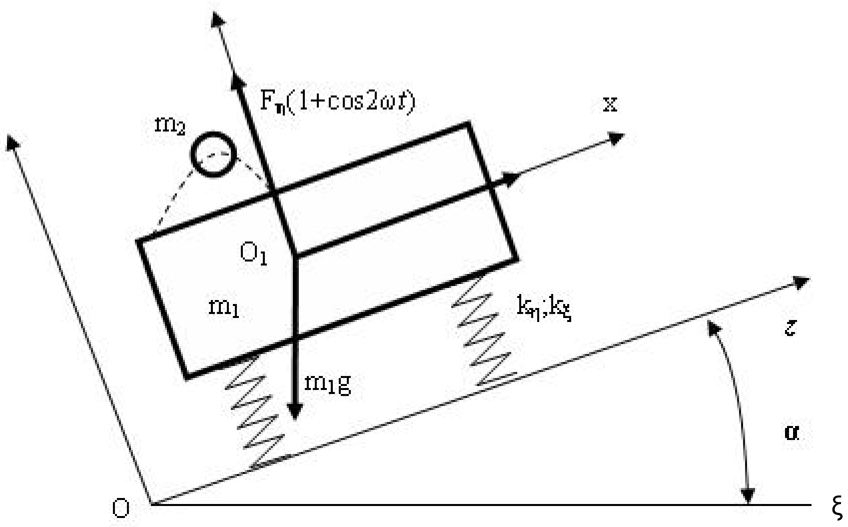

Figure 1. The fixed and mobile reference axes system

We shall approach the case of these conditions with a single jump of the grain of material at an oscillation period of the perturbing force. Let us further consider types of intervals symbolized with “**I**” for the moments when the material is on the sieve and move solitary with it, and symbolized with “**II**” those moments when the material is in mid-jump on the sieve. Thus, for the case in the above figure we shall have the differential equation of the movement in interval **I** as follows:

$$\ddot{\eta}+\frac{k_\eta}{m_1+m_2}\cdot\eta=\frac{F_\eta}{m_1+m_2}\cdot(1+\cos\omega t)-g\cdot\cos\alpha \qquad (1)$$

The following notations are made:

$$z=\frac{m_1\cdot\omega_1^2}{F_\eta}\cdot\eta\,;\quad z'=\frac{dz}{d\tau}\,;\quad \tau=\omega t\,;\quad \omega_1=\sqrt{\frac{k_\eta}{m_1}}\,;$$
$$k_1=\frac{\omega_1}{\omega}\,;\quad k_m=\frac{m_2}{m_1}\,;\quad n_1=\frac{m_1\cdot g\cdot\cos\alpha}{F_\eta} \qquad (2)$$

With these notations the above equations becomes:

$$z''+\frac{k_1^2}{1+k_m}\cdot z=\frac{k_1^2}{1+k_m}\cdot(1+\cos 2\tau)-k_1^2\cdot n_1 \qquad (3)$$

The solution of this equation is:

$$z_1=A_I\cdot\sin\left(\frac{k_1}{\sqrt{1+k_m}}\cdot\tau\right)+B_I\cdot\cos\left(\frac{k_1}{\sqrt{1+k_m}}\cdot\tau\right)-\frac{k_1^2}{4+4\cdot k_m-k_1^2}\cos 2\tau+1-n_1(1+k_m) \qquad (4)$$

The movement of the sieve after the material lifts at moment τ_0 is given by equation:

$$\ddot{\eta}+\frac{k_\eta}{m_1}\cdot\eta=\frac{F_\eta}{m_1}\cdot(1+\cos 2\omega t)-g\cdot\cos\alpha \qquad (5)$$

We again adopt the notations in (1.2), and we obtain the following equation:

$$z''+k_1^2\cdot z=k_1^2\cdot(1+\cos 2\tau)-k_1^2\cdot n_1 \qquad (6)$$

The solution of the equation is:

$$z_{II}=A_{II}\cdot\sin(k_1\cdot\tau)+B_{II}\cdot\cos(k_1\cdot\tau)-\frac{k_1^2}{4-k_1^2}\cdot\cos 2\tau+1-n_1 \qquad (7)$$

2. ESTABLISHING THE MATHEMATICAL MODEL

In order to determine the oscillating movement equations in the specific field of pulverized materials sorting, we further determine the constants A_I, B_I, A_{II}, B_{II} which appear in relations (4) and (7). Determining the value of these constants was made using the nomograms in [2]. The values of the constants extracted from these nomograms are given in accordance with the throw coefficient „c” in the table bellow (Table 1).

Table 1: The values of coefficients A_I, B_I, A_{II}, B_{II}

C	A1	B1	A2	B2
2.5	0.042	-0.4	-0.05	-0.168
2.55	0.05	-0.425	-0.04	-0.173
2.6	0.06	-0.44	-0.035	-0.175
2.65	0.08	-0.45	-0.032	-0.185
2.7	0.09	-0.465	-0.025	-0.19
2.75	0.11	-0.475	0	-0.195
2.8	0.12	-0.49	0.03	-0.2
2.85	0.14	-0.5	0.04	-0.205
2.9	0.143	-0.515	0.042	-0.21
2.95	0.147	-0.525	0.048	-0.215
3	0.15	-0.545	0.05	-0.22
3.05	0.154	-0.555	0.053	-0.215
3.1	0.156	-0.558	0.055	-0.215
3.15	0.159	-0.575	0.058	-0.21
3.2	0.16	-0.585	0.059	-0.21
3.25	0.162	-0.61	0.06	-0.21
3.3	0.165	-0.620	0.068	-0.215

Using relation

$$A_I \cdot \sin\left(\frac{k_1}{\sqrt{1+k_m}} \cdot \tau_0\right) + B_I \cdot \cos\left(\frac{k_1}{\sqrt{1+k_m}} \cdot \tau_0\right) - \frac{k_1^2}{4+4k_m-k_1^2} \cdot \cos 2\tau_0 - n_1 \cdot (1+k_m) =$$
$$= A_{II} \cdot \sin(k_1 \cdot \tau_0) + B_{II} \cdot \cos(k_1 \cdot \tau_0) - \frac{k_1^2}{4-k_1^2} \cdot \cos 2\tau_0 + 1 - n_1 \qquad (8)$$

we will determine the moment when the throw of the grain off the sieve takes place. The left side member of the equation represents the movement of the mobile frame with the material-to-be-sieved on it, and the right side member represents the movement of the mobile frame without the material-to-be-sieved on it. Relation (8) represents the space continuity condition at the moment the grain is thrown, that is to say that the position of the mobile frame immediately before the grain lifts must coincide with its position immediately after the grain lifts.

Because equation (8) is a transcendental one, it can be solved through the so-called method of the “false position” with the help of a proper calculation algorithm. The algorithm is designed with the help of the programmer MatLab ([1], [3], [4]).

The false position method consists in using an equality between two derivative functions. In this case we use, as mentioned, relation (8). In this case the difference between the two functions results from equation (9), where the unknown is τ_0 - the moment of the grain's jump off the sieve:

$$g(\tau_0) = A_I \cdot \sin\left(\frac{k_1}{\sqrt{1+k_m}} \cdot \tau_0\right) + B_I \cdot \cos\left(\frac{k_1}{\sqrt{1+k_m}} \cdot \tau_0\right) - \frac{k_1^2}{1+k_m-k_1^2} \cdot \sin\tau_0 - n_1 \cdot (1+k_m) -$$
$$- A_{II} \cdot \sin(k_1 \cdot \tau_0) + B_{II} \cdot \cos(k_1 \cdot \tau_0) - \frac{k_1^2}{1-k_1^2} \cdot \sin\tau_0 - n_1 = 0 \qquad (9)$$

The solution can be determined by linear approximation between two given values of equation (9), as in figure 2:

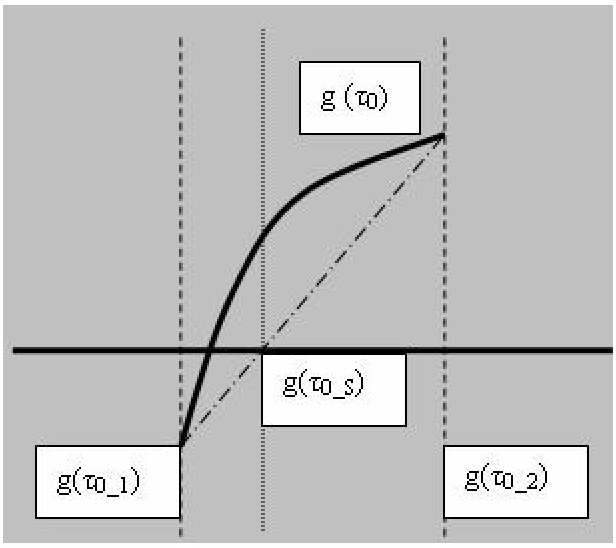

Figure 2. Scheme for exemplifying the false position method

The approximation is done in the interval generated by two values given to the functions within the equations [$g(\tau_{0\_1})$, $g(\tau_{0\_2})$]. Generating the values is done precisely through the programmer, and the root can be determined through linear approximation. After each iteration, the domain shrinks so that the new domain determined by the new values of [$g(\tau_{0\_1})$, $g(\tau_{0\_2})$] contains the root as well. The latter is obtained by replacing $g(\tau_{0\_1})$ or $g(\tau_{0\_2})$, depending on their positive or negative sign with a value calculated with the formula:

$$\tau_{0\_s} = \tau_{0\_1} + \left(\tau_{0\_2} - \tau_{0\_1}\right) \cdot \left(\frac{-g(\tau_{0\_1})}{g(\tau_{0\_2}) - g(\tau_{0\_1})} \right) \tag{10}$$

The calculation programmer for solutions τ_0 of the transcendental equation (9) is the following:

```
function vibrating_movement
clc
%constants
a1= 0.042;
b1=-0.4;
a2=-0.05;
b2=-0.168;
k1=0.1;
km=0.4;
% solving the equation
ind=0;
for c=2.5:0.05:3.3;
   ind=ind+1;
   [tauo_fin] = rezolvare_ecuatie_1(a1,k1,km,b1,c,a2,b2);
   tauo_fin_(ind)=tauo_fin;
   %afisare rezultate finale
end
tauo_fin_
disp('FINISH')
save ('matlabM')
function [tauo_fin] = rezolvare_ecuatie_1(a1,k1,km,b1,c,a2,b2)
%valoare presupusa
tauo_0=pi;
tauo_1=tauo_0;
tauo_2=tauo_0;
% stabilirea lui Z1 si Z2
contor1=0;
while 1
   contor1=contor1+1;
   tauo_2=tauo_2+0.1*tauo_0;
   Z1=a1*sin(k1*tauo_1/sqrt(1+km))+b1*cos(k1*tauo_1/sqrt(1+km))-k1^2/(4+4*km-
k1^2)*cos(2*(tauo_1))-(1+km)/c-(a2*sin(k1*tauo_1)+b2*cos(k1*tauo_1)-k1^2/(4-k1^2)*cos(2*(tauo_1))-1/c);
   Z2=a1*sin(k1*tauo_2/sqrt(1+km))+b1*cos(k1*tauo_2/sqrt(1+km))-
k1^2/(4+4*km+k1^2)*cos(2*(tauo_2))-(1+km)/c-(a2*sin(k1*tauo_2)+b2*cos(k1*tauo_2)-k1^2/(4-
k1^2)*cos(2*(tauo_2))-1/c);
   if Z1*Z2<0
      break
   end
end
%metoda falsei poziii
contor2=0;
while 1
   contor2=contor2+1;
   Z1=a1*sin(k1*tauo_1/sqrt(1+km))+b1*cos(k1*tauo_1/sqrt(1+km))-k1^2/(4+4*km-
k1^2)*cos(2*(tauo_1))-(1+km)/c-(a2*sin(k1*tauo_1)+b2*cos(k1*tauo_1)-k1^2/(4-k1^2)*cos(2*(tauo_1))-1/c);
   Z2=a1*sin(k1*tauo_2/sqrt(1+km))+b1*cos(k1*tauo_2/sqrt(1+km))-
k1^2/(4+4*km+k1^2)*cos(2*(tauo_2))-(1+km)/c-(a2*sin(k1*tauo_2)+b2*cos(k1*tauo_2)-k1^2/(4-
k1^2)*cos(2*(tauo_2))-1/c);
   if abs(Z1)<10^-12
      tauo_s=tauo_1;
      break
   end
```

```
        if abs(Z2)<10^-12
          tauo_s=tauo_2;
          break
        end
        tauo_s=tauo_1+(tauo_2-tauo_1)*(-Z1/(Z2-Z1));
        Zs=a1*sin(k1*tauo_s/sqrt(1+km))+b1*cos(k1*tauo_s/sqrt(1+km))-k1^2/(4+4*km-
k1^2)*cos(2*(tauo_s))-(1+km)/c-(a2*sin(k1*tauo_s)+b2*cos(k1*tauo_s)-k1^2/(4-k1^2)*cos(2*(tauo_s))-1/c);
        if abs(Zs)<10^-12
          tauo_s=tauo_s;
          break
        end
        if Zs*Z1>0
          tauo_1=tauo_s;
        else
          tauo_2=tauo_s;
        end
      end
      %valoarea finala
      tauo_fin=tauo_s;
```

3. CONCLUSION

With the help of this programmer we calculated the values of the lift moment of the material grain lift for values of the throw coefficient from c=2,5 to c=3,3. For each value given to the throw coefficient „c”, the corresponding values of coefficients A_I, B_I, A_{II}, B_{II} were given. The values thus obtained for the throw moment are provided in the table bellow (table 2):

Table 2. The values of the throw moments of the grain on the sieve.

c	2.50	2.55	2.60	2.65	2.70	2.75	2.80	2.85
$\tau_{aruncare}$	**26.855**	**25.608**	**24.645**	**23.747**	**23.186**	**23.008**	**23.404**	**22.738**

Table 2 (continuation)

c	2.90	2.95	3.00	3.05	3.10	3.15	3.20	3.25	3.30
$\tau_{aruncare}$	**22.484**	**22.416**	**22.143**	**21.789**	**21.676**	**21.360**	**21.220**	**20.969**	**21.045**

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