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# Evaluation of the Performance Level of Vibration Sorting Machines for Mineral Aggregates

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*Abstract:* - The vibration sorting – classifying machines for mineral aggregates and asphalt mixtures are used for technological fluxes of mineral aggregates crushing and sorting, in adequate exploitation located in riverbed (river ballast), or in quarries (crushed mineral aggregates).

In order to achieve the required performances for concrete and asphalt mixtures, special attention is focused on the vibrating machines, called vibrating screens. These machines have minimum two, and maximum four screens for granular sorting of riverbed and quarry mineral aggregates. This is the right context for the research presented in this paper, focused on establishing the performance level of vibrating screen so that it could fulfill the required specific conditions for its integration in a technological flow. This vibrating machine performances would be optimized by the adequate selection of its specific parameters so that to be competitive with similar equipments on the market and to be fit for integration in continuous technological flow.

*Keywords:* - sorting technology; mineral aggregates; vibrating screen; performance level; specific parameters, stationary vibration.

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## 1. INTRODUCTION

The technical level when operating of the vibration sorting machines for mineral aggregates, called vibrating screens, represents the ratio between functional, constructive and technological parameters values and their reference values, identified either by norms and standards, or by reference documents that producers / users of these equipments provide. In order to assess the performance level of vibrating screen there will be presented both, characteristics defining its technical level and, the performance criterion.

For the technical level of performance there is to be defined the required power for technological vibration regime to keep on, the vibrating machine coefficient and the maximum kinetic energy in stationary regime needed for mechanical sorting – classifying, according to the technical specifications. There are also presented the performance criteria, as specific parametric values able to adequately fit the opportunity and efficiency of vibrating screen in adequate sorting – classifying technology [9, 10].

## 2. EVALUATION OF THE PERFORMANCE LEVEL

The performance level specific to vibration sorting machines stands as the main concept for objective comparison of similar equipments performing same function, made by different producers, aimed at their integration in adequate technological flow.

Considering the previously mentioned, the performance technical level of vibrating screen and the specific parameters values calculated are further unitary presented, so that to characterize the equipment as a whole [1, 3, 4, 5].

### 2.1. Required power for the technological vibration regime

The evaluation of stationary regime vibration power could be determined by relation

$$N = m_0 r \omega^3 R, [W] \quad (1)$$

where:  $m_0$  represents the weight of eccentric elements used for dynamical unbalance, [kg];

$r$  – unbalanced mass eccentricity, [m];

$\omega$  – pulsation of forced vibrations in stationary regime, [s<sup>-1</sup>];

$R$  – the dynamic factor specific to the technological vibration generation system

The dynamic factor,  $R$  is determined by relation:

$$R = r\gamma \sin\varphi + \frac{1}{2}(1 + \gamma \cos\varphi)\mu d, [m] \quad (2)$$

where:  $\gamma = \frac{m_0}{m}$  is the mass factor, (3)

$m$  – whole mass of the vibrating screen, moving, [kg];

$\mu$  – sliding friction coefficient in the vibration shaft bearing;

$d$  – diameter of the bearing relative sliding surface, [m];

$\varphi$  – phase shift angle of the perturbation force from the forced vibration, [rad].

## 2.2. Vibrating machine coefficient

The coefficient of vibrating machine  $\Gamma$  is determined by relation

$$\Gamma = \frac{r\omega^2\gamma}{g \cos \alpha} \quad (4)$$

where:  $\alpha$  is the angle between the screen plane and the horizontal plane

$g$  - gravitational acceleration ( $g=9,81 \text{ m/s}^2$ )

## 2.3. Maximum kinetic energy of the vibrating screen

In the steady regime of the vibrating screen, the kinetic energy is given by:

$$E_{\text{cmax}} = \frac{1}{2} m a^2 \omega^2, \text{ [J]} \quad (5)$$

where:  $a$  is the amplitude of forced vibrations.

## 3. PERFORMANCE CRITERIA

The performance criteria for vibrating screens are defined as power, energy and vibration specific parameters.

### 3.1. The specific power relative to the static moment of eccentric mass

The ratio between power,  $N$ , and the moment,  $m_0$ , represents the specific power as relation:

$$W = \frac{N}{m_0 r} \quad (6)$$

Considering the relations (1) and (2) it results the relation:

$$W = \omega^3 R, \left[ \frac{W}{kg \cdot m} \right] \quad (7)$$

### 3.2. The specific power relative to the screen sieving surface

The evaluation of specific power when referring to the vibrating screen surface could be done by following the steps below:

$$s = \frac{N}{S_a}, \left[ \frac{W}{m^2} \right] \quad (8)$$

where  $S_a$  is the sieving active surface of the screen, [m<sup>2</sup>]

If we consider the  $k = \frac{m}{S_a}$  parameter, defined as the ratio of uniform distributed mass,  $m$ , in motion, and the sieving active surface,  $S_a$ , then, there results the relation:

$$s = k \cdot \gamma \cdot r \cdot \omega^3 \cdot R \quad (9)$$

### 3.3. Vibrating machine specific coefficient

The machine specific coefficient is defined by relation:

$$\beta = \frac{\Gamma}{\gamma} \quad (10)$$

or, if we consider relation (4), it results:

$$\beta = \frac{r\omega^2}{g \cos \alpha} = \frac{1}{K_0} \quad (11)$$

where  $k_0 = g \cos \alpha$

### 3.4. Vibrations specific energy

This type of energy is defined when referring to the screen mass in motion, as follows:

$$e = \frac{E_{\text{cmax}}}{m}, \left[ \frac{J}{kg} \right] \quad (12)$$

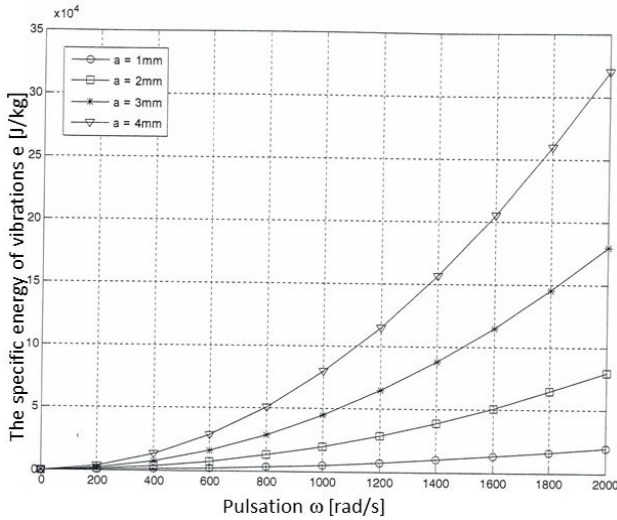
or, considering the definition of  $E_{\text{cmax}}$  in relation (5), results:

$$e = \frac{1}{2} a^2 \omega^2 \quad (13)$$

The graphical representation of relation (13) is shown in figure 1.

It can be noticed that the specific energy of vibrations,  $e$ , directly depends on the pulsation of forced vibrations,  $\omega$ . There is a slow increase of this energy values for each of the considered amplitude values ( $a = 1; 2; 3; 4 \text{ mm}$ ), more of it, the variation of  $e = f(\omega)$  for the amplitude value,  $a = 1$ , is almost linear. This is the case when the increase of

vibrations specific energy is, almost, insignificant. This is why, the increase of vibrations frequency for amplitude discrete values results in significant changes of vibrations energy, but does not significantly influence the sieving process efficiency [2, 6, 7].



**Figure 1.** Variation of the specific energy of vibrations with pulsation

A cylindrical nano shell embedded with a piezoelectric layer and subjected to harmonic excitation ( $f \cos \omega t$ ) shown in Figure 1 where  $f$  and  $\omega$  are the amplitude and angular frequency of the external excitation. The length of nano shell is  $L$ , the geometrical parameters of the cylindrical shell are mid-surface radius  $R$ , thickness of cylindrical shell  $2h_N$  and thickness of piezoelectric material layer  $h_p$ .

### 3.5. Vibrations intensity

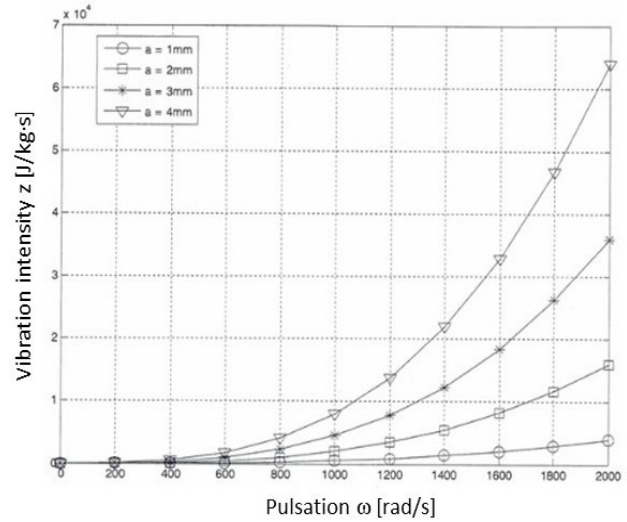
The variable  $z$  is defined as the ratio of vibrations squared maximum,  $a_{\max}^2$  and pulsation  $\omega$ :

$$z = \frac{a_{\max}^2}{\omega} = \frac{(a\omega^2)^2}{\omega} = a^2\omega^3 \quad (14)$$

If we consider relation (13), it results:

$$z = 2\omega e, \left[ \frac{J}{kg \cdot s} \right] \quad (15)$$

The graphical representation of relation (15) is shown in the figure that follows.



**Figure 2.** Variation of vibration intensity with pulsation

The graph in figure 2 evidences a fast increase of  $z$  variable,  $z = f(\omega)$ , for the values of vibrations amplitude similar to the previously mentioned ones - see also the graph in figure 1.

### 3.6. Vibrations efficacy

There is defined the product of vibrations intensity,  $z$  and the period of regime vibrations  $T$ :

$$E = zT \quad (16)$$

or, considering (14) and

$$T = \frac{2\pi}{\omega} \quad (17)$$

it results:

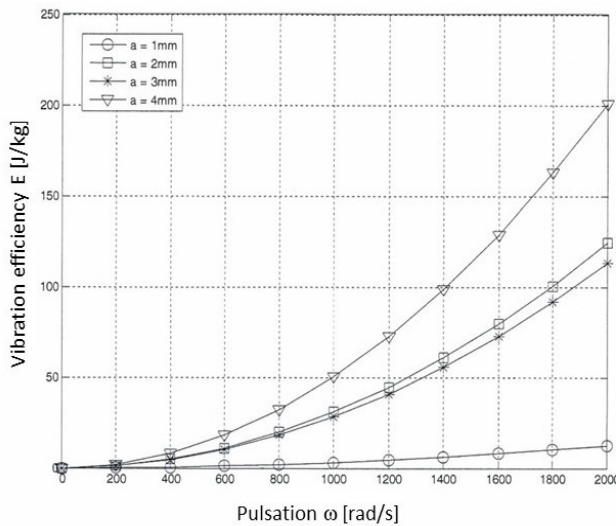
$$E = a^2\omega^3 \cdot \frac{2\pi}{\omega} = 2\pi a^2\omega^2 \quad (18)$$

If we consider relation (13), then it results:

$$E = 4\pi e, \left[ \frac{J}{kg} \right] \quad (19)$$

The graphical representation of relation (19) is shown in figure 3.

It is to be noticed that the efficacy of vibrations,  $E$ , is slow increasing while the pulsation values increase, for the same values of the amplitude, still there is a higher increase than in the case of specific energy (fig.1).



**Figure 3.** Variation of vibration efficiency with pulsation

One supplementary notice should be on the amplitude values,  $a=2$  mm and  $a=3$  mm, when the graphs are so very close and the differences are not significant.

With the origin of coordinate system located on the middle surface of nano-shell, the coordinates of a typical point in the axial, circumferential and radius directions are described by  $x$ ,  $\theta$ , and  $z$ , respectively.

### 3.7. Superficial density of vibrations energy

This variable is defined as the ratio of maximum kinetic energy and whole surface of the sieving screen:

$$\delta_V = \frac{E_{cmax}}{S}, \left[ \frac{J}{m^2} \right] \quad (20)$$

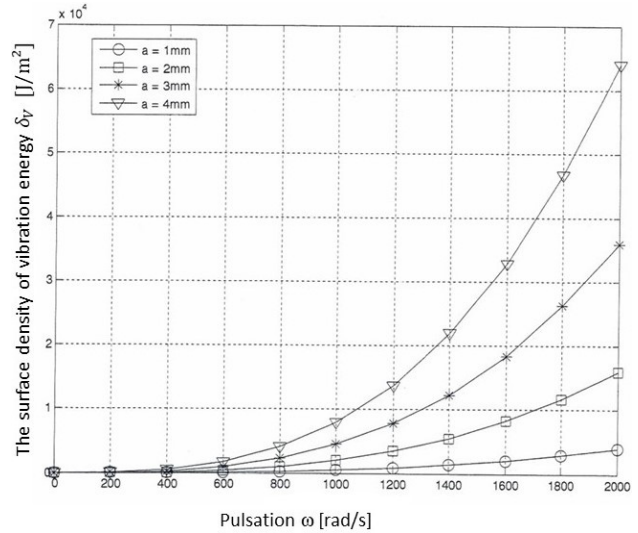
Considering relations (15) and (9) we get:

$$\delta = \frac{1}{2} \frac{ma^2\omega^2}{m} k \quad (21)$$

if we consider, also, the definition relation of  $e$  (13) it results:

$$\delta_V = ke \quad (22)$$

The graphical representation of relation (22) is shown in figure 4.

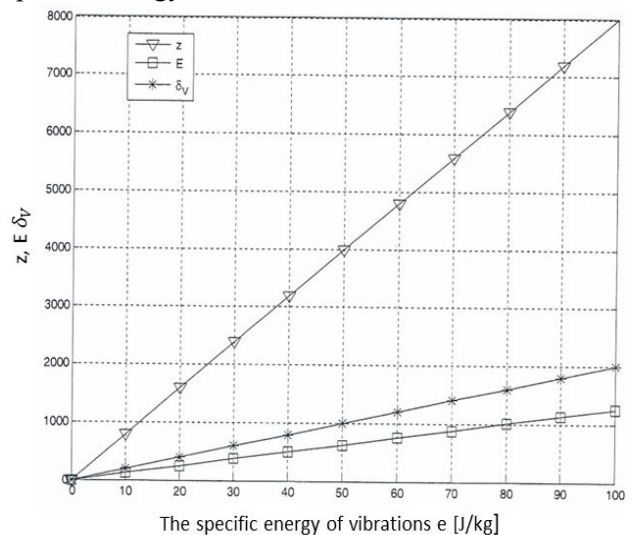


**Figure 4.** Variation of the surface density of vibrations with pulsation

As in the case of intensity  $z$ , this variation graph evidences a fast increase of the  $\delta_V$  parameter, once the pulsation values increase. The graphs look almost the same for the coefficient value,  $k=1$  (relation 22).

## 6. CONCLUSION

a) The increase of amplitude does significantly influence the specific intensity of vibrations, the evolution of vibrations efficacy and, most of all, the specific energy.



**Figure 4.** Comparative evolution of some previously presented criteria

b) For an efficient sieving, a low value for the screen opening,  $d_s$  (1.7mm), require low vibrations amplitude and high frequency, while a large screen opening require high vibrations amplitude and low frequency. This is why the conclusion that a significant increase of intensity, and thus, of

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vibrations superficial density do significantly influence the sorting efficiency and the quality of sieved products.

c) The above presented relations stand as criteria for right comparisons and evaluation of the vibrating screen in these equipments type, according to the data in figure 5.

d) It can be noticed the linear variation of  $z$ ,  $E$  and  $\delta_V$  criteria, function of the vibrations specific energy variation,  $e$ . From the point of view of evaluation assessment of the vibrations influence on the sieving process it is seen that vibrations efficacy,  $E$ , and vibrations density,  $\delta_V$ , stand as two criteria with same similarity degree.

e) The vibrations intensity and specific energy,  $e$ , are in direct correlation and both depend on the angular velocity (pulsation),  $\omega$ . This fact points to the conclusion that by applying the vibrations intensity as evaluation criterion of performance level for vibrating screen, it leads to finer analysis of their performance and sieving process optimization when considering the sieving efficiency,  $\varepsilon$ .

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