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MEMBRANE SCREENS WITH VIBRATING SIEVES

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The subject of this paper are screens with vibrating sieves. These machines differ from other industrial screens by the fact that only a sieve itself vibrates, while the riddle stays immobile. Special attention is given to a screen with a driving frame, which was built in Łódź Technical University. The authors give some results of process investigations of this machine. At present, the research is carried out on the sieve dynamics and amplitude distribution. The construction of the screen enables the implementation of rotating vibrators beside the electromagnetic vibrator, so the screen can be used in a wide range of research and industrial applications. The tested screen is built in an industrial scale and is designed for fine-grained materials.

Key words: membrane screen, oversize, particle material, screening, sieve, undersize, vibrating sieve

INTRODUCTION

A characteristic feature of screens with vibrating sieves are vibrations of the sieve itself and of the material being screened, which moves along this sieve. In the classical screens, sieves vibrate along with the riddle whose mass is often bigger than the sieve mass. This is connected with the use of large vibrators which would impart forces high enough. This in turn is related to high power demand necessary to induce vibrations and to high inertia forces which act partly upon the supporting structure. These problems do not occur in the screens with a direct sieve excitation because riddles are immobile in these machines.

Another important feature of the screens with vibrating sieves is an almost unlimited possibility of constructing different variants of these machines. Depending on demand, there can be different arrangements of particular screens, e.g. in a common riddle. Additionally, these machines have a relatively simple construction, they can be made of usual construction materials and they can contain typical elements – sub-assemblies which are taken from other, already existing machines.

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Screens with vibrating sieves are designed first of all for screening of fine- and very fine-grained materials. They have relatively high dynamic factors. In the screen described in this paper the maximum value of the dynamic factor was K=15. Therefore, these machines are characterised by good segregation of a layer on the sieve (the process of stratification) and high screening efficiency. In practice, they reach screening efficiency ranging from 0.9 to 1.0.

The features mentioned above cause that these screens can become very useful in screening fine-grained material. Their disadvantage is a reduced sieve durability and more complicated sieve mounting, as compared to the screens with mobile riddles. However, taking into account the fact that modern woven and polyurethane sieves are very fast, these negative features of screens with vibrating sieves become less annoying.

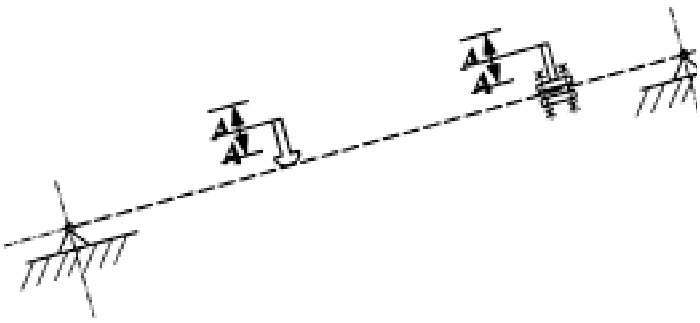


Fig. 1. Principle of vibrating sieve operation

The principle of vibrating sieve operation is shown in Fig. 1. The sieve vibrations are induced by pushing rods. Depending on the method of excitation, single and double-sided screens are distinguished. A characteristic feature of the first type is that the pushing rods induce vibrations through constant or temporary press on one side. The sieve returns to the state of equilibrium due to its resilience.

The double-sided screens impart full vibrations onto the sieve because they are connected to it rigidly. The advantage of such excitement is shown in Fig. 2. An important role in both single- and double-sided screens is played by mesh tension, both in axial and transverse direction.

Attention should be paid to the fact that in the screens with a direct sieve excitation, due to continual sieve vibrations, the effect of removal of particles hard to screen and blocking the mesh from the sieve surface are achieved. The effect of self-cleaning is a very beneficial phenomenon which does not occur, or occurs to a too small extent, in the classical screens where sieves remain immobile.

Two basic designs of the screens are known. In the first one the sieve is driven by electromagnetic vibrators, each connected separately to the sieve by pushing rods. Such a design is shown in Fig. 3.

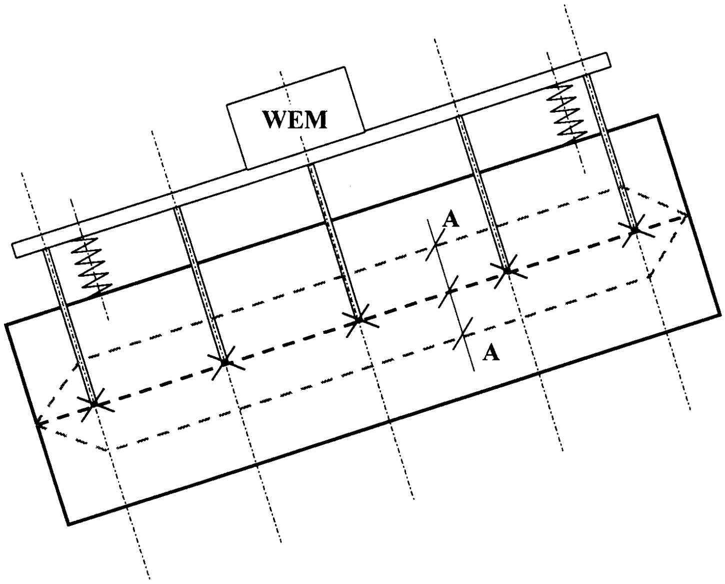
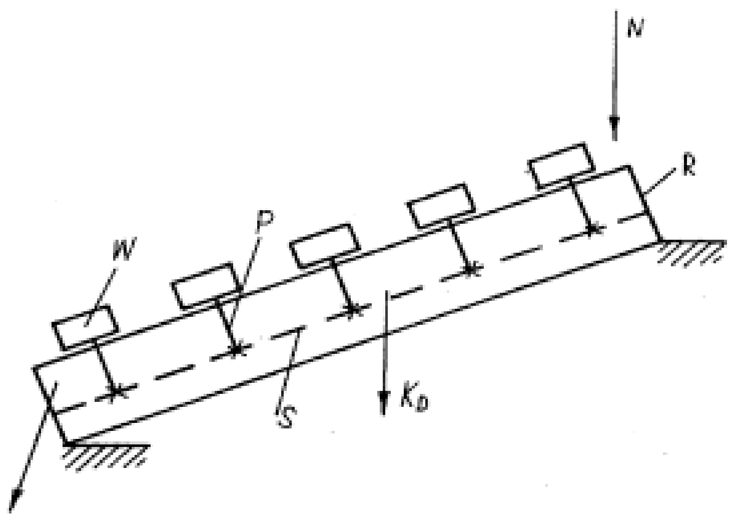


Fig. 2. Advantage of a double-sided excitement

Fig. 3. Screen with single vibrators



K_G– oversize,
K_D– undersize
S – sieve,
W– vibrator,
R – riddle
N – feed,
P– pushing rod

The other basic design solution is a screen with a driving frame illustrated in Fig. 4. Pushing rods are connected to the driving frame which is induced into vibrations by an attachable electromagnetic vibrator. This solution is discussed in the present paper. It is much more advantageous than the one presented earlier because a uniform distribution of amplitudes is obtained for every pushing rod, and additionally, only one electrovibrator can be used. It is also possible to replace the electromagnetic vibrator with rotating vibrators.

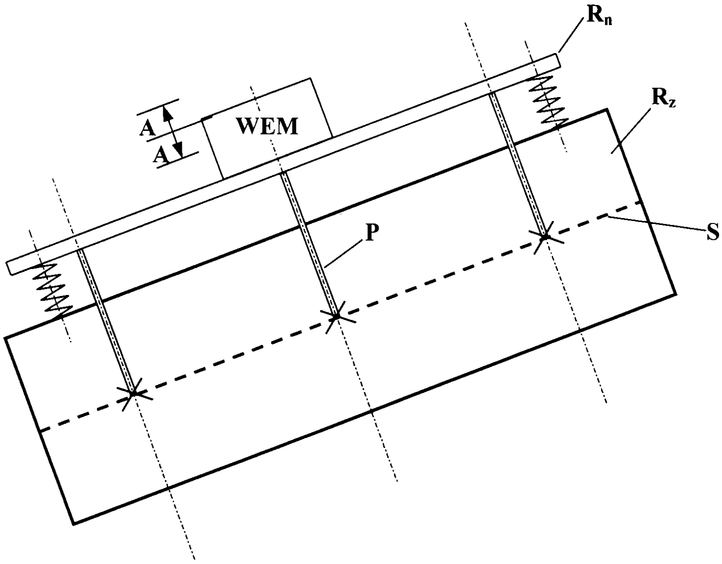


Fig. 4. Screen with a driving frame
WEM – electromagnetic vibrator
R_n – driving frame
R_z – riddle
S – sieve
P – pushing rod

This solution enables also the application of many electromagnetic vibrators to the driving frame drive. This system seems to be the most appropriate. A characteristic feature of electromagnetic vibrators is that they can be easily synchronised in the vibrating motion. There is a simultaneous synchronisation which ensures translatory motion of the whole frame and, consequently, the motion of the entire sieve. When one electromagnetic vibrator placed in the axis of symmetry of the screen is used, a risk of torsional vibrations of the frame around the centre of gravity may appear. This is not advantageous because the centre of the sieve will move at small amplitude, and as a result the screened material will be collected in the central part of the screen.

Screens with vibrating sieves are characterised by high frequency of vibrations and small amplitudes. In the screen tested by the authors, the frequency was 50 Hz and maximum amplitude was of the order of 1.5 mm. The angle of inclination of the sieve to the level ranged from 0 to 45^{o}, i.e. the inclination was twice as large as in the case of screens with immobile sieves. Such big values of the angles and high accelerations caused significant velocities of material on the sieve amounting to 0.5 to 1.0 m/s.

A characteristic feature of classification on the screens with vibrating sieves is a thin layer of material on the sieve. Its thickness is equal or twice as large as the stated particle size. This provides very good stratification conditions. High efficiencies reaching 100% can be achieved, which is impossible in the classical screens. The process capacities are also much higher than those obtained in other screens.

Screens with vibrating sieves are able to self-clean the sieves. Vibrations of the sieve surface cause that blocked particles are removed from the mesh. This feature may be a reason why higher process capacities are achieved and causes that these screens are especially suitable for screening of fine- and very fine-grained materials.

The discussed screens with sieves excited directly, and in particular the screens with driving frames, due to their specific construction, i.e. location of an electrovibrator outside the riddle side walls, are very suitable for wet screening.

FLAT SIEVE GEOMETRY

In the classical screens, i.e. the ones with immobile sieves, the layer on the screen is tossed evenly. In the screens with sieves excited directly, due to specific excitement of vibrations, the tossing of material on the sieve surface is different. To approach this phenomenon quantitatively, a description of the vibrating sieve geometry is proposed in Fig.5.

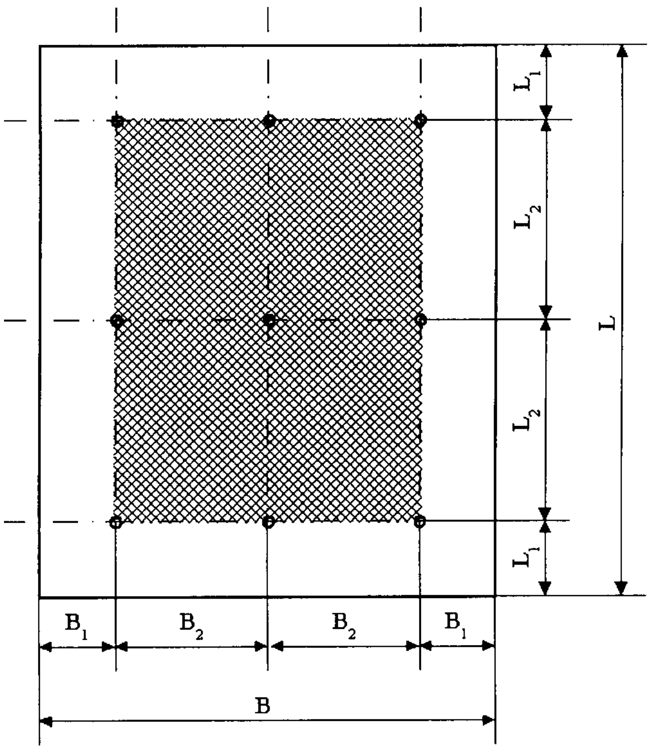


Fig.5. Vibrating sieve geometry

It is obvious that sieves of the screens discussed move only in the plane perpendicular to the sieve surface. However, the amplitude of vibrations is not the same in each point. Because the sieve is mounted on an immobile riddle not the entire sieve surface takes place in the translatory motion. To reflect this phenomenon in model calculations it is necessary to introduce some calculation coefficient.

This role can be played by a surface module m_p. It denotes part of the sieve which performs translatory, linear vibrating motion. This value is a ratio of the surface subjected to full excitement to the overall sieve surface.

$$m_p = \frac{F_d}{F_s} \tag{1}$$

where :

F_d – vibrating surface

F_s – total surface

$$m_p = m_l \cdot m_b \tag{2}$$

where:

m_l – longitudinal module

m_b – transverse module

Taking into account symbols from Fig. 5, the formulae describing the above values have the form

$$m_l = \frac{(n-1)l_{2l}}{L} \tag{3}$$

$$m_b = \frac{(n_b-1)b_2}{B} \tag{4}$$

where:

n_l – the number of pushing rods in the longitudinal direction

n_b – the number of pushing rods in the transverse direction

In conclusion, the surface module of the screen with a vibrating sieve has the form:

$$m_p = \frac{(n_b-1)b_2 \cdot (n_l-1)l_2}{B \cdot L} \tag{5}$$

The values of b_2 and l_2 in the above formula depend on process parameters and in particular on the mesh size and thickness of the layer on the sieve.

CHARAKTERISTIC FEATURES OF SIEVE MOTION IN THE SCREENS WITH VIBRATING SIEVES

As seen in Fig. 6, in the screens with vibrating sieves there are so-called membrane amplitudes A_m at distances between the pushing rods. This follows from the fact that the sieve is flexible and vibrates like a membrane. Besides, because the sieves are mounted on the immobile riddles, the amplitude increases from zero to the value of vibration amplitude of the pushing rods. This is reflected by a surface module discussed in the previous section. The sieve motion was proposed to be described by a membrane equation, however the authors of this paper are of the opinion that typical membrane equations cannot be applied because specific excitement of vibrations occurs in several points on the sieve surface.

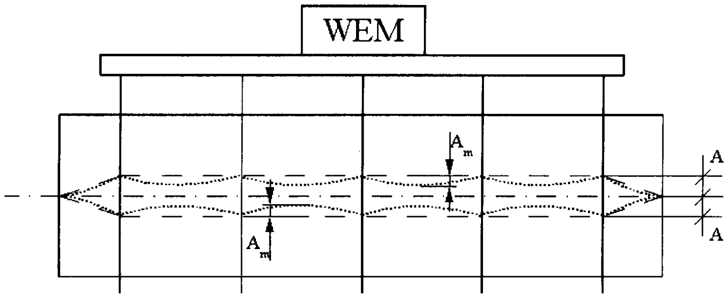


Fig. 6. Membrane amplitudes of the vibrating sieve

In the description of dynamics of the screen with a vibrating sieve we use a dynamic model shown in Fig. 7.

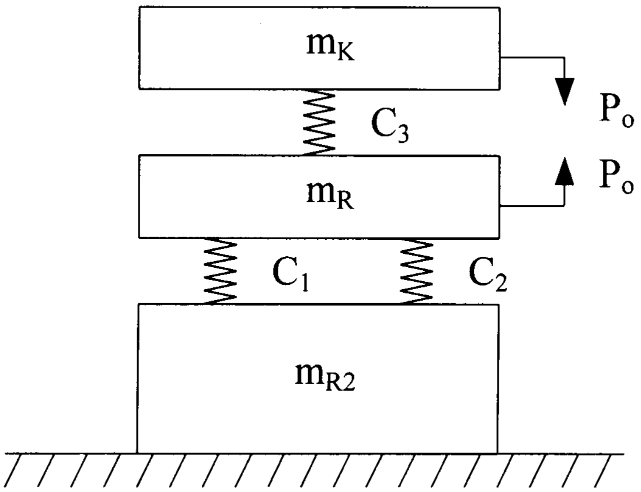


Fig. 7. Dynamic model of a screen with vibrating sieve
m_{R2} – immobile riddle mass
m_R – driving frame mass
m_K – mass of the vibrator anchor
C_1 – flexibility of the driving frame suspension
C_2 – mesh elasticity
C_3 – elasticity of inner elements of the vibrator
P_0 – exciting force induced by the vibrator coil

This system is characterised by variable flexibility constant C_2. During the screen operation the sieve is “elongated” (deformed), which leads inevitably to changes in the sieve elasticity. So, to make typical dynamic calculations of the vibrating system is difficult because:

- Rigidity of the sieve mounted on the riddle cannot be determined – each time we can expect a different tension.
- The sieve during operation is deformed which can change significantly rigidity C_2.

So, it is postulated not to consider the parameter C_2 at all, the more that the driving system is usually designed for high exciting forces and the value of C_2 is in this case negligibly small. The screen operation depends first of all on C_1 and C_3, while the effect of the sieve elasticity is negligible as compared to other values and consequently it is omitted.

At present, the research is carried out on the amplitude distribution on the vibrating sieve surface. The measuring devices include piezoelectric sensors, an integrating circuit and a computer with an A/D converter PCL-818 HD. Under the influence of acceleration the sensors produce a voltage signal which is then transmitted to the integrating circuit. The sensor parameters are as follows:

- Acceleration 10 $mV/m/s^2$
- Velocity 10 mV/mm/s
- Deflection 10 mV/μm.

The voltage signal produced by the sensors is integrated twice, and as a result the value of deflection of the tested point on the sieve is obtained. These signals are acquired by the A/D card and logged in the computer. The system is calibrated by a manual tastograph. The correctness of readings of the whole measuring system must be checked because the signals obtained from the sensors are double-integrated.

After the measurements of amplitude distribution on the whole vibrating sieve surface, the authors tried to describe the phenomenon mathematically and then by relating it to the vibrating sieve geometry, to develop a correlation suitable for model calculations of screens with immediate sieve excitation.

EXPERIMENTAL RIG

In the nearest future also process investigations of the screen with vibrating sieves will be carried out. An experimental rig constructed for this purpose is shown in Fig.8.

Supporting structure 1 is the machine frame. Riddle 2 inclined at different angles which remains immobile during the screen operation is mounted in the frame. Sieve 3 is stretched on the riddle. Flat springs 4, on which driving frame 5 rests, are mounted on the riddle. Attachable electromagnetic vibrator 6 is installed on the driving frame. It is also possible to use an inertial vibrator. The driving frame is combined to the sieve by means of rigid pushing rods 7. The feed is in tank 8 with valve 9 which controls the size of the discharge hole. The oversize is collected to vessel 10, while the undersize to container 11.

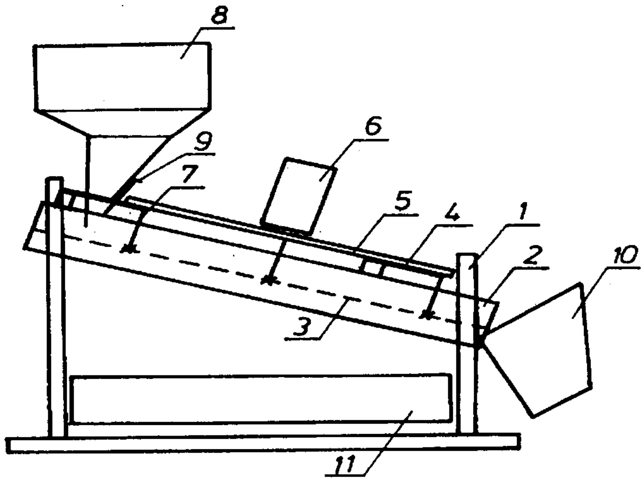


Fig. 8. Experimental rig for process investigations

RESULTS AND DISCUSSION

In this section some characteristic results of investigations for frame screen with a vibrating sieve were presented. These studies were carried out in the Institute of Chemical Engineering, Łódź Technical University in the 70's (Wodziński 1981). The authors of this paper intend to repeat the process investigations for the presented screen in order to verify them, and in particular to compare values characteristic for the screening process with those obtained in the present studies.

Below, diagrams presenting the following relations are shown:

$\eta = F(Q)$ – screening efficiency as a function of capacity for irregular particles – sand (Figs. 9 and 10), and for sharp-edged particles –agglomerates (Figs. 11 and 12).

The efficiency is meant here as the screening efficiency (undersize), i.e. the ratio of the amount of undersize which was screened off to that one which should be screened off during ideal screening to the amount of undersize in the feed (eq. 6).

$$\eta = \frac{m_d}{x \cdot m} \tag{6}$$

where: m_d – mass of the screened material
x – undersize fraction in the feed
m – feed mass

Materials used in the experiments were dry, devoid of moisture. Both sand and agglomerates were screened, separated from impurities and fractionated in the whole range of particle size. The sand mixture contained particles of the size 0.1-10.0 mm, while marble agglomerates 0.1-5.0 mm.

Symbols used in the diagrams:

η– screening efficiency [–]
Q– screening capacity [kg/s]
α– angle of inclination of the sieve to level [°]
l– mesh size [mm]
K– dynamic factor [–]

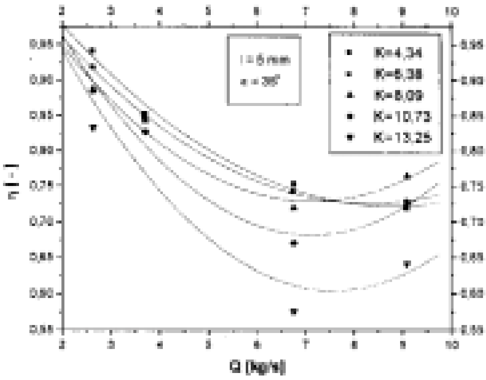


Fig. 9 Screening efficiency as a function of capacity for irregular particles

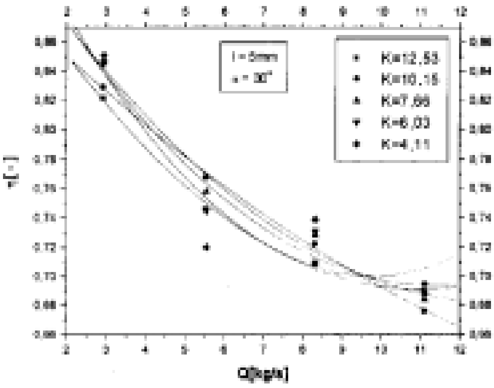


Fig. 10 Screening efficiency as a function of capacity for irregular particles

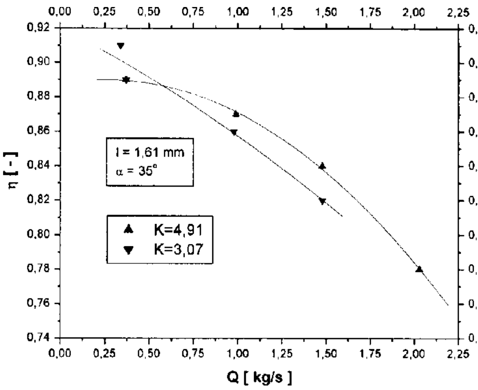


Fig. 11. Screening efficiency as a function of capacity for sharp-edged particles

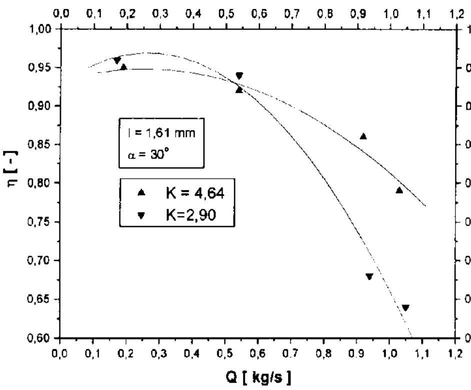


Fig. 12. Screening efficiency as a function of capacity for sharp-edged particles

CONCLUSIONS

Screens with driving sieves have the following characteristics:

1. High capacities of the screening process.
2. A possibility to choose the number of construction variants, especially in the case when different sieves inclined at different angles are used.
3. Self-cleaning of mesh by removal of particles which block it.
4. Simple servicing in the case when an electromagnetic vibrator is used as a drive.
5. Low energy demand of the screen, caused by much smaller vibrating masses (in relation to the screens with mobile riddles). This is connected also with an advantageous dynamics of the machine.

Due to a simple construction the frame screen discussed in this paper can be used in every industrial conditions. It can be made of generally available intermediate products. In this case there are no problems with high inertia forces transferred by the drive and suspension. There is no impact of dynamic vibrating masses on the base on which the machine is placed.

Screens with vibrating sieves are designed for fine screening in a wide range from 20-40 μm to about 10 mm and as such they can find application in many industrial branches.

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