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SCREENING ON A SCREEN WITH A VIBRATING SIEVE

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This paper, dedicated to membrane screens with vibrating sieves, is one of the series prepared at the Technical University of Lodz. The membrane screens are the machines with a specific sieve motion, which is forced in points. Only the sieve in the form of a membrane stretched over an immobile riddle, vibrates. This sieve is characterized by a non-uniform distribution of amplitudes on the vibrating surface. This is a property that distinguishes these screens from other industrial screens. In connection with the above mentioned feature, the method of screening is not the same as in other screens. The present paper describes these differences and the methods of their characterization. Results of investigations on the screening efficiency depending on the process capacity are analyzed.

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

INTRODUCTION

This paper is next in the series devoted to screens with vibrating sieves. In the previous papers the screen construction, drive and sieve motion characteristics were discussed, while in the present one the authors wish to present differences in the process of screening as compared to the process carried out in other screens. The most important characteristic feature of membrane screens is the excitation of sieve vibrations by the so-called pushing rods (Szymański, Wodziński 2001). This causes a non-uniform amplitude distribution on the sieve surface. It is known that the sieve vibrations are a driving force of feed motion, i.e. screened material motion, and one of the most significant parameters on which the success of screening depends. The screening is successful if the finer fraction is screened off at the highest efficiency possible. We mean here the so-called recovery or efficiency of the undersize fraction, i.e. the ratio of the mass of undersize particles screened off to the mass of particles of the finer fraction present in the feed.

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$$\eta = \eta_f = \frac{\text{the mass of finer fraction which passed through the mesh}}{\text{total mass of finer fraction in the feed}} \qquad (1)$$

For typical screening the recovery of coarser fraction η_c in the oversize product is 100%, therefore solely η_f can be used for characterization and comparison of screening results.

Usually, the process technology specifies the accepted level of finer fraction that can remain in the oversize product. So, it means that we know the efficiency of screening. This is a basis for designing of screens. One of the methods to determine the sieve surface on which the process is to be performed at a given efficiency, is a model with the discharge function. The authors propose to replace the exponential discharge function by a straight line because of a specific screening in the screens with vibrating sieves.

The screens with vibrating sieves are designed first of all for screening of fine and very fine granular materials. They are characterized by relatively high dynamic factors. That is why in these machines layers on the sieve are well segregated and high screening efficiency is achieved. The screens with vibrating sieves are characterized by high frequency of vibrations and small amplitudes. In the screen tested by the authors, the frequency is 50 Hz and a maximum amplitude is 2 mm. The angle of sieve inclination can be changed in the range from 0 to 35°, i.e. twice as large inclination is obtained as compared to the screens with stable sieves. So large angles and high accelerations induce significant velocities of the material on the sieve, reaching 0.5 to 1.0 m/s (Wodziński 1997).

CONSTRUCTION OF SCREENS WITH VIBRATING SIEVES

Among many design solutions of industrial screens with vibrating sieves the most advantageous seems to be the screen with a driving frame (Fig. 1). This screen was designed and built at Lodz Technical University. It is a subject of the present paper. Figure 1 shows two ways in which the frame drive was designed. The first one is a system driven by a single electromagnetic vibrator placed in the center (broken line), the second one – by two electromagnetic vibrators located on two ends of the driving frame.

In this screen, the driving frame (R_n) is excited to vibrations by a vibrator, or electromagnetic vibrators (WEM) and the frame vibrations are transferred onto the sieve (S) by means of connectors called pushing rods (P). The riddle (R_z) remains immobile. In the tested system, double-action pushing rods that transfer full vibrations onto the sieve were applied (Szymański, Wodziński 2001). This means that the sieve motion is forced on both sides of the equilibrium position (downward and upward). At present, only a few manufacturers in the world produce membrane screens with one-sided excitation, i.e. such where the sieve is only tossed upward. Actually, this facilitates the exchange of sieves but much deteriorates the process of screening. Taking into account a growing durability of sieves produced now, the system with double-sided excitation of the sieve motion seems to be more recommendable.

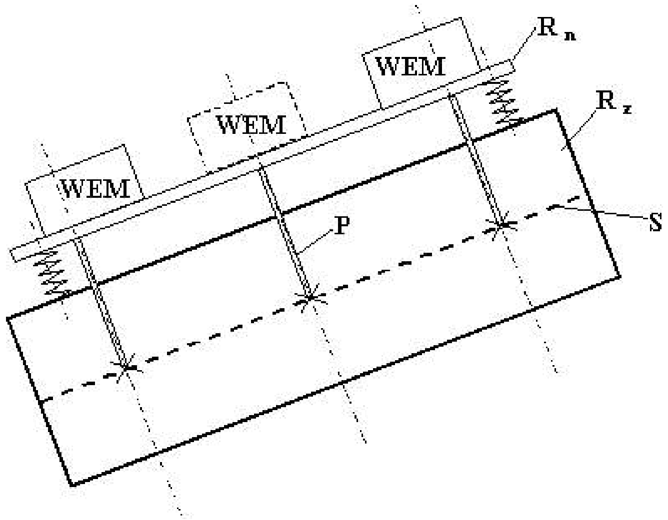

Fig. 1. Frame screen with a vibrating sieve

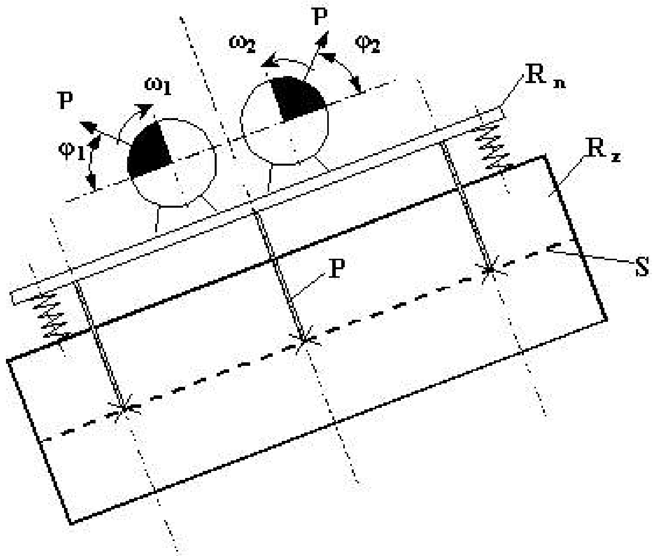

Fig. 2. A system with rotating vibrators

The system with a driving frame is a universal solution, where without any significant changes of design, beside electromagnetic vibrators, two engines with unbalanced shafts can be used (Fig. 2).

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 center of gravity may appear. This is not advantageous and can be eliminated by a system with two electromagnetic vibrators (Szymański, Wodziński 2001).

In the system with two rotary vibrators (unbalanced engines), they work in the conditions of a counter-current self-synchronization. Such driving system guarantees that a linear trajectory of vibrations is obtained, the trajectory being perpendicular to the sieve surface, i.e. to the driving frame as well (Szymański, Wodziński 2001).

THE PROCESS OF SCREENING THIN LAYERS ON VIBRATING SIEVES

Screening on screens with vibrating sieves is carried out with thin material layers. The thickness of material layer on the sieve is as small as possible. It would be ideal if the layer thickness could be equal to the dimension of the particle classified. However, in practice it is assumed that this thickness can reach several diameters of the classified particles.

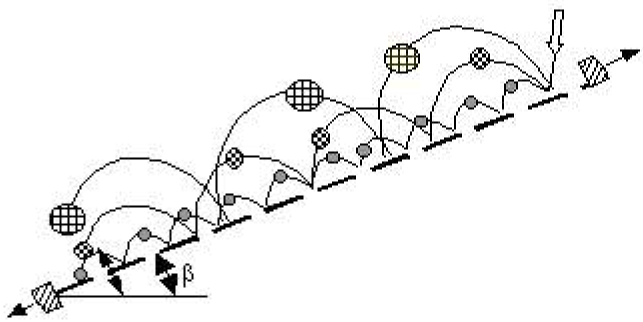

Fig. 3. Behavior of particles in a thin layer

Thin layer screening takes place when material (layer) on the vibrating sieve moves along at high speed, which means that at the same feed rate, the layer thickness decreases. In such conditions there is no segregation resistance during screening, however, individual particles move in a “restrained” way (Fig. 3). This provides very good stratification conditions, which in turn enable very high efficiency reaching 100%.

A MODEL WITH DISCHARGE FUNCTION FOR THE SCREEN WITH VIBRATING SIEVES

In practice, a sieve design is limited to the determination of surfaces of the sieves. In most cases the sieve width and efficiency are imposed and then a designer is to calculate such sieve length that guarantees the desired efficiency. For this purpose a model with discharge function can be used (Sztaba 1993). The external surface of the granular layer screened on the sieve has the shape of an exponential curve (in longitudinal section). This follows from numerous studies on the distribution of the mass of finer fraction screened off from the layer on the sieve, along the sieve. This curve is shown in Fig. 4, in the following reference system: X axis – time or sieve length, Y axis – the height of the layer on the sieve or the mass of material that remained on the sieve.

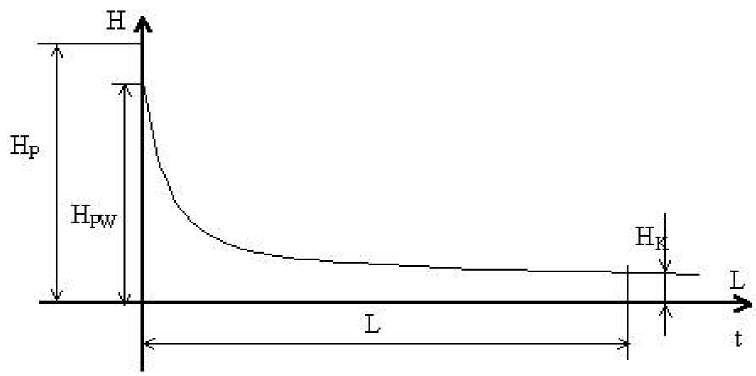

Fig. 4. Discharge function

This shape of the discharge function occurs in thick-layer screening. In the case of thin-layer screening, the authors propose to replace the exponential curve by a straight line (Fig. 5). At the initial stage of the process, in the screen with a vibrating sieve, the layer thickness is equal to several diameters of the classified particles at most. At the final stage of the screening, the layer is equal to the mean diameter of the coarser particles. It is obvious that these are not layers in the exact meaning of the word. Particles move in the way shown in Fig. 3 and by the thickness of these particles we mean a model method of presenting the amount of these particles.

A characteristic feature of the proposed model is an assumption that the real discharge function is replaced by an approximated discharge function which is a straight line. This assumption is possible because in thin-layer screening we observe a relatively small change in the height of the layer on the sieve. The process is carried out so that the layer thickness does not exceed several (2 to 3) diameters of the average particle in the feed.

As in the case of a normal discharge function, we will use the following relations:

$$H = H(L) \tag{2}$$

$$H = H(t) \tag{3}$$

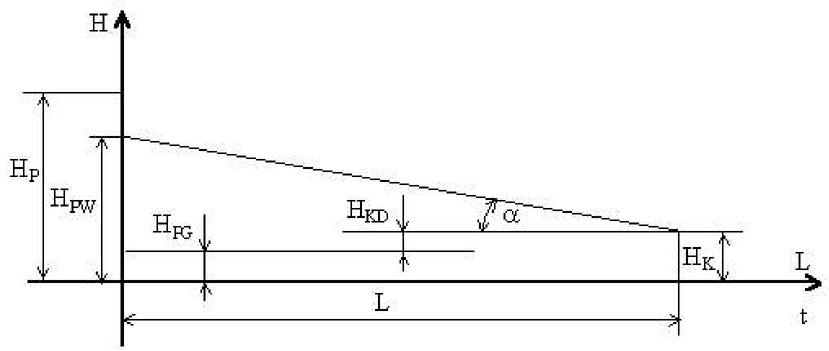

Fig. 5. Discharge function for thin-layer screening

At the beginning of the process (hence, at the beginning of the sieve) the layer heights are: H_P (resulting from the mass flux of feed onto the sieve) and H_{PW} – after the first gravitational discharge, without any machine vibrations. It is obvious that the initial layer thickness H_P is the sum of the initial height of the oversize H_{PG} and undersize product H_{PD}:

$$H_P = H_{PG} + H_{PD} \tag{4}$$

At the end of the sieve, the final height of the oversize fraction stream H_{KG} and the final height of the stream of finer particles that still remained on the sieve H_{KD}. The two values give altogether the value of H_K.

$$H_K = H_{KG} + H_{KD} \tag{5}$$

For a normally working screen, i.e. when the sieve is not damaged and particles of the oversize fraction do not get to the undersize product, the height of the layer of the oversize fraction is the same at the beginning and at the end of the process.

$$H_{KG} = H_{PD} \tag{6}$$

For thin-layer screening, equations (2) and (3) assume the form:

$$H_K = H_{PW} - a \cdot L \tag{7}$$

$$H_K = H_{PW} - a \cdot t \tag{8}$$

These equations are interrelated by the velocity of material layer sliding on the sieve:

$$u_m = L / t \tag{9}$$

In the equations that describe the discharge function there is one empirical factor a (straight line inclination $a = tg\alpha$), which includes:

- machine motion,
- properties of the granular material,
- moisture content of the feed,
- screening efficiency,

and also other parameters which can be considered significant for the process of screening.

At present, research is carried out to justify the applicability of the discharge function in the form of a straight line.

RESULTS OF STUDIES ON THE EFFICIENCY OF THIN-LAYER SCREENING

Below, results of research on the screening efficiency in the screens with vibrating sieves will be discussed. As mentioned in the introduction, the efficiency denotes here the efficiency of the undersize fraction, i.e. the ratio of the mass of material that should be in the undersize product to the mass of material which was actually screened off (Banaszewski 1990).

The investigations were carried out in a frame screen driven by two engines with unbalanced shafts (Fig. 6).

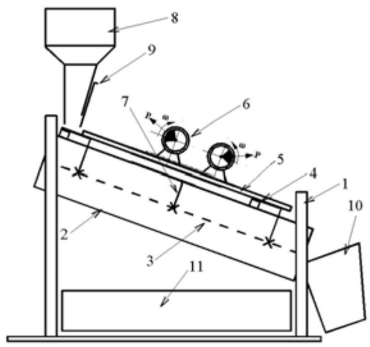

Fig. 6. Experimental setup

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. Inertial vibrators 6 are installed on the driving frame. It is also possible to use electromagnetic vibrator or vibrators. The driving frame is connected 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 coarser fraction is collected to vessel 10, while the finer one to container 11. Dimensions of the tested screen are L = 1500 mm and B = 500 mm. In the case of screening of fine materials this is a typical industrial-scale screen. Such are the sieve surfaces of machines used for screening of fine- and very fine-grained materials.

Two types of material were used in the investigation. These were marble aggregate that represented sharp-edged particles, and agalite representing spherical particles. The tested material was dry, with no transient moisture. Both agalite and aggregate were screened preliminarily, impurities were removed and the material was classified into fractions depending on particle diameters. Half of the material were the particles which represented the undersize fraction. Tests were performed on a sieve of mesh size 0.63 mm. The sieve was inclined at 15°, 20°, 25° and 30° to the level.

Results are given in the form of diagrams illustrating the dependence of screening capacity on process efficiency $\eta=f(Q)$. The efficiency was selected so as to carry out the process as a thin-layer screening.

Figures 7 and 8 show curves $\eta=f(Q)$ for angles of sieve inclination given above for agalite, and for marble aggregate, respectively.

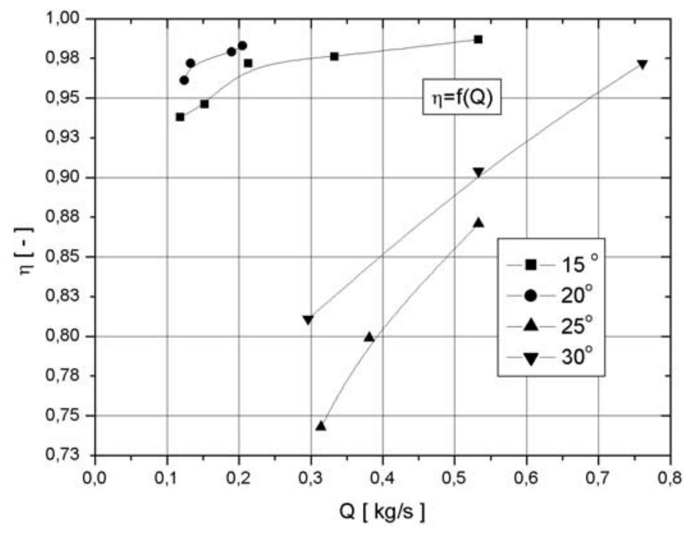

Fig. 7. Dependence of screening efficiency on capacity for agalite

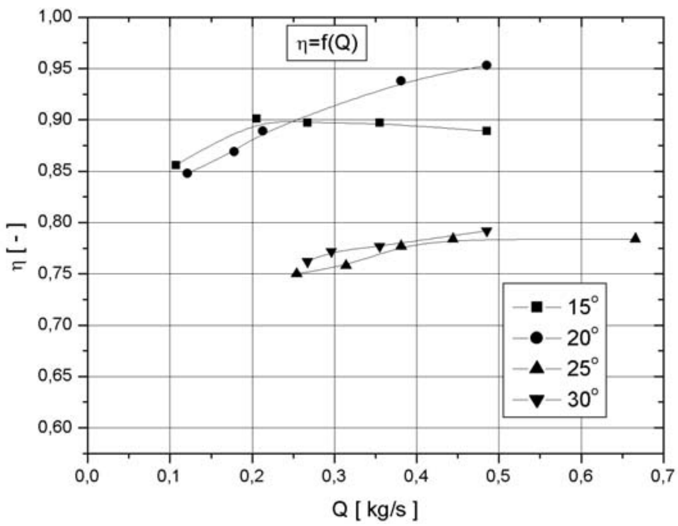

Fig. 8. Dependence of screening efficiency on capacity for marble aggregate

CONCLUSIONS

The aim of the above presented research was to determine experimentally the operating parameters of a frame screen with a vibrating sieve in the process of industrial screening of loose materials with model particle shapes. The subject of studies were two parameters: screening efficiency and capacity. These parameters determine the process; they also form a basis for defining the criterion of estimation of the device operation quality.

The analysis of results leads to the following detailed conclusions:

1. The character of curves shown in the diagrams suggests that high screening efficiency can be achieved at properly chosen process parameters.
2. An increase of efficiency in some cases may provide the evidence that at a further growth of process efficiency, a point will be reached that corresponds to a maximum screening efficiency. The screening should be carried out for such conditions.
3. Also the angle of sieve inclination is an important factor that determines if the screening is correct.
4. It follows from the presented graphs that the conditions of grain classification should be determined taking into account the type of material screened. Different shapes of screened particles have different abilities of passing through the mesh.
5. It is possible to achieve high screening efficiency when the sieve, while vibrating in a non-uniform way on its whole surface, has an ability of self-cleaning, i.e. to release blocked particles.

A screen construction with a driving frame offered a possibility of applying different configurations of the driving system. The frame screen discussed in the paper, because of a simple construction, can be used in almost all industrial conditions.

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This study is next in a series devoted to membrane screens and is part of the research program on „The classification of granular materials" carried out within Basic Research Project no. Dz.St.12.

Szymański T., Wodński P., *Proces przesiewania na przesiewaczu z sitem drgającym*, Physicochemical Problems of Mineral Processing, 37 (2003) 27-36 (w jęz. ang.).

Niniejszy artykuł dotyczy przesiewaczy membranowych z sitem drgającym i jest kolejną pracą z tego cyklu, wykonywaną w Politechnice Łódzkiej. Przesiewacze membranowe są to maszyny o specyficznym ruchu sita, bowiem wymuszany jest punktowo ruch samego sita, przeponowo rozpiętego w nieruchomym rzeszocie. Sito to charakteryzuje się nierównomiernym rozkładem amplitudy na powierzchni drgającej. Jest to cecha wyróżniająca tego typu przesiewacze od innych spotykanych w przemyśle. W związku z wyżej wymienioną cechą sposób prowadzenia procesu przesiewania nie jest taki sam jak na innych przesiewaczach. Poniższy artykuł dotyczy tychże różnic, jak również sposobu ich opisu. W artykule przedstawiono wyniki badań nad skutecznością przesiewania w zależności od wydajności procesu. Znamienną cechą klasyfikacji na przesiewaczach z sitami drgającymi jest cienka warstwa materiału na sicie, której grubość równa jest wymiarowi ziarna podziałowego lub jest najwyżej dwukrotnie większa. Stwarza to bardzo korzystne warunki dla przebiegu klasyfikacji. Dlatego uzyskuje się bardzo wysokie sprawności, dochodzące do 100%, co nie jest możliwe do osiągnięcia na przesiewaczach klasycznych. Również wydajności procesu są znacznie większe od osiąganych na innych maszynach przesiewających. W artykule przedstawiony został nowy sposób opisu procesu przesiewania na przesiewaczach z sitami drgającymi. Dla przesiewania cienkowarstwowego, autorzy poniższego artykułu proponują zastąpić eksponencjalną krzywą wysypu - linią prostą. Na sicie przesiewacza z sitem drgającym w początkowym okresie procesu znajduje się warstwa o grubości równej co najwyżej kilku wymiarom ziarna podziałowego. Natomiast w końcowym etapie przesiewania warstwa o grubości równej średniemu wymiarowi ziaren klasy górnej. Spośród wielu rozwiązań konstrukcyjnych przesiewaczy z sitami drgającymi najbardziej korzystny wydaje się układ z ramą napędową, który opracowany został w Politechnice Łódzkiej. W przesiewaczu tym rama napędowa wzbudzana jest do drgań, które z kolei przenoszone są na sito za pomocą łączników zwanych popychaczami. W badanych układach zastosowano popychacze dwustronnego działania, które charakteryzują się tym, że przenoszą pełne drgania na sito przesiewacza. Układ z ramą napędową jest rozwiązaniem uniwersalnym, w którym bez większych zmian konstrukcyjnych można zastosować jeden lub dwa wibratory elektromagnetyczne, jak również napęd składający się z dwóch silników z wałami niewyważonymi pracujących w synchronizacji przeciwbieżnej. Zalety i uniwersalność budowy przesiewacza ramowego powodują, że może on znaleźć i znajduje szerokie zastosowanie w przemyśle. Rezultaty badań mogą być bezpośrednio wykorzystane do celów projektowych, ponieważ omawiany przesiewacz jest wykonany w skali przemysłowej dla materiałów drobno uziarnionych.