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ANALYSIS OF SCREENING PROCESS OF CRUSHED BASALT PERFORMED BY A DOUBLE-FREQUENCY SCREEN

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Abstract: This work presents the results of the investigations, devoted to multi-frequency screens, devices being used for the screening process and equipped with two drive vibrators operating at various rotation speeds. The object of this research was to evaluate the efficiency and capacity of a newly designed double-frequency screen to sieve the grained materials, especially those difficult to separate. The experimental double-frequency screen is driven by two inertial drive vibrators operating at various rotation speed, providing complex shaking movement of the screen. In comparison to conventional devices containing vibrators operating at constant rotation speed, the application of this modern double-frequency screen resulted in improving parameters of the screening process.

Keywords: *screening, screen, sieve, grained material, double-frequency screen*

Introduction

The most difficult problem that arises during the screening process is classification of the fine-grained materials containing small grains with cut size (d_{50}) lower than 1 mm. Small grains most easily block the sieve holes lowering the surface area of the sieve (effective area) and also causing difficulties in obtaining a homogeneous and thin enough layer of the material above the sieve. It is usually assumed, that the screening process can be efficient if the layer of grains on the sieve is not thicker than 5-10 average grain diameters (Kanzleiter, 1971; Fischer, 1982). Similar problem arises during the screening process of the grained materials containing large quantities of grains with dimensions approximately equal to the dimensions of the sieve opennings, called grains-difficult-to-separate.

The shape of the grains also plays an important role in the screening process of the grained materials. For instance grains with sharp edges can more easily block the sieve holes, than those spherical in shape. Moreover, the sharp-edged grains can be firmly

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fixed in the sieve holes and resist the intense movements of the screen. In addition, the motion of the sharp-edged grains in the layer of the material on the sieve is hampered, which reduces moving of the grains of the bottom class to the sieve level and passing through the sieve holes. As a result, the efficiency of the screening process of the materials containing grains with sharp edges decreases comparing to those containing grains with other shapes (Rogers, 1982; Schmidt, 1984). It is illustrates in Fig. 1, where the results of the screening process of variously grained materials with the use of a conventional industrial screen equipped with a single-frequency inertial drive vibrator are showed. The lowest efficiency is observed for crushed basalt stone containing sharp-edged grains, whereas higher efficiencies are observed for both sand being composed of irregular grains and agalit composed of spherical grains.

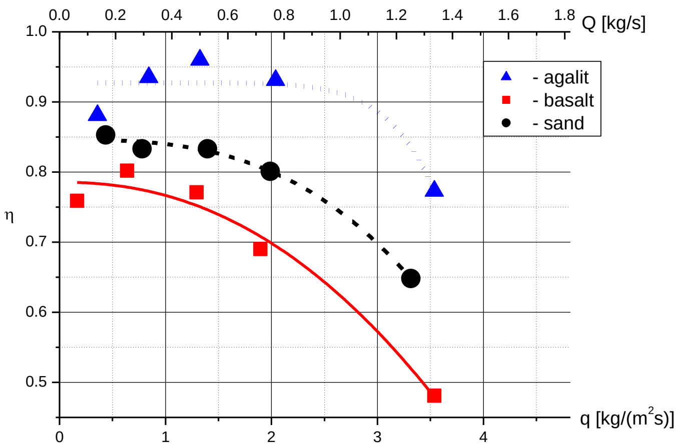

Fig. 1. The efficiency of the screening process performed for the grained materials containing grains with various shapes (*q* – specific capacity, *Q* – total capacity, *η* – efficiency)

The goal of the invention of a new double-frequency screen was to solve the problems mention above by improving conditions of the screening process. Our intention was to find such oscillation paths of the sieve which provide the most efficient separation of grains in the layer on the sieve.

Figure 2 shows the schematic representation of the double-frequency screen offering a wide range of oscillations of the screen with various movement trajectories. Types of movement trajectories and methods of their characterization were already published (Modrzewski and Wodziński, 2010; 2011), whereas this paper describes a continuation of those investigations devoted to the screening process of basalt crushed stone. Basal crushed stone is known to be difficult for the classification by means of a screen as showed above. However, it seems that by using the double-frequency screen possessing unique properties it should be possible to obtain satisfying results.

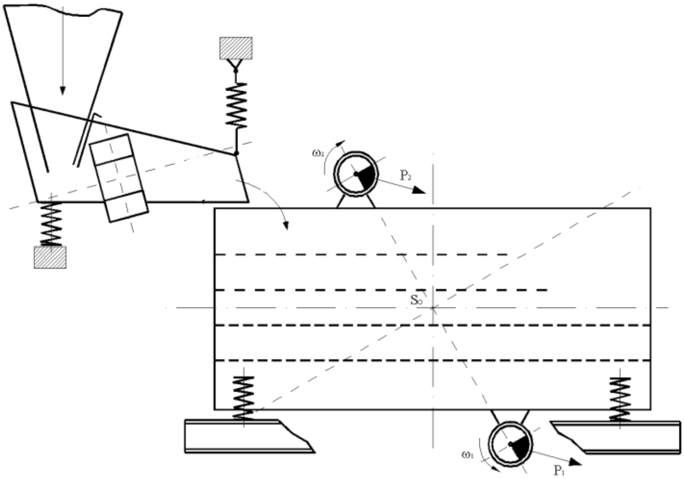

Fig. 2. The double-frequency screen with a feeder

The problems occuring during the application of the double-frequency screen

The construction of the double-frequency screen allows the control of the most of technical parameters of the device including inclination of the sieve (α), driving forces of the vibrators (P_1 and P_2), location of the vibrators (S_0) and, first of all, their rotation speeds (ω_1 and ω_2). By changing the configuration setting a wide range of operating conditions may be applied (Modrzewski and Wodziński, 2011). The best combinations of parameters were selected basing on the results of the measurements.

It is worth to mention that apart from the advantages, application of the double-frequency screens may cause some problems, which are not observed when using a single-frequency screens (Banaszewski, 1990). However in many cases, despite apparently beneficial kinematic conditions (high throwing coefficient, high amplitudes of the screen etc.) the screening process with the application of the double-frequency screens does not occur correctly.

According to the electronic measurements of the screen movements those problems arise when the torsional vibrations of the riddle appear. Those vibrations cannot be seen with naked eyes, however, they can be simply determined by measuring the amplitude of the screen at three different points (Fig. 3 and Fig. 4) (e.g. at the beginning a1, in the middle a2 and at the end a3) in a direction perpendicular to the surface of the screen using the same time scale. When the amplitudes are synchronized no torsional vibrations occur and the screen moves equally along its whole length, and both ends (a1, a3) of the screen have the same amplitudes and trajectories as the centre of the screen (a2). The lack of synchronisation (Fig. 3) means that the amplitudes of the end (a3) and beginning of the screen (a1) are opposite and causes torsional vibrations.

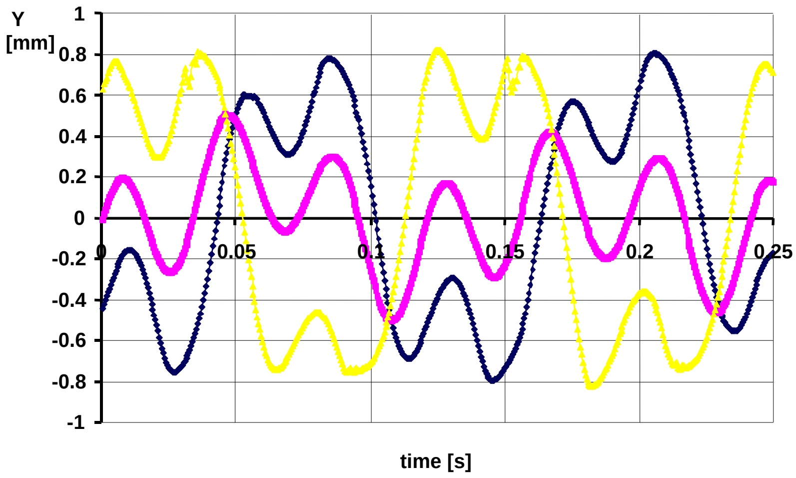

Fig. 3. The amplitudes of the screen in the presence of torsional vibrations

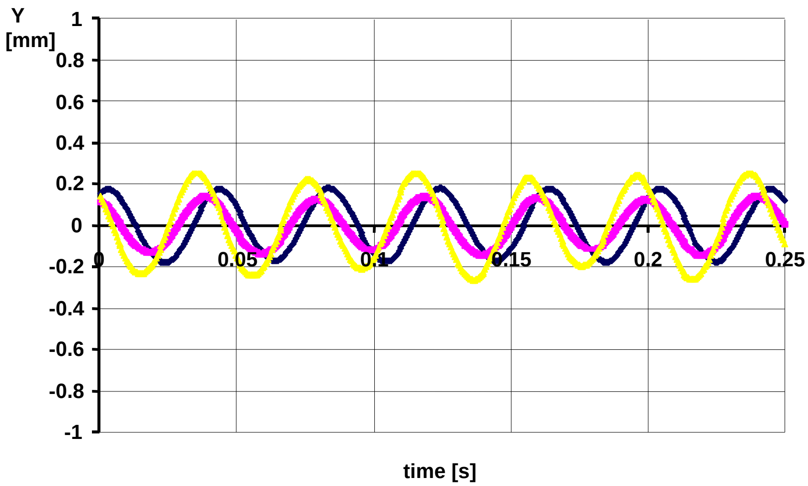

Fig. 4. The amplitude of the screen in the absence of torsion vibrations

Based on experimental data collected for the screening process of basalt crushed stone, one may conclude that even a small contribution of torsional vibrations to the screen motion can cause significant problems. As a consequence of the presence of torsional vibrations the grained material is accumulated in the central part of the screen causing a partial or complete blockage of the screening process.

In the less serious case the layer of the grained material formed at the presence of torsional vibrations becomes thicker in the central part of the screen (Fig. 5) than in other parts and vividly differs from an optimal profile forming in the absence of torsional vibrations (Fig. 6), described by an exponential curve. The accumulation of the grained material in the central part of the screen, even if does not lead to the stopping of the process, causes the lowering of the overall efficiency of the screening. So, those parameter combinations that cause torsional vibration were discarded at the stage of the process investigation.

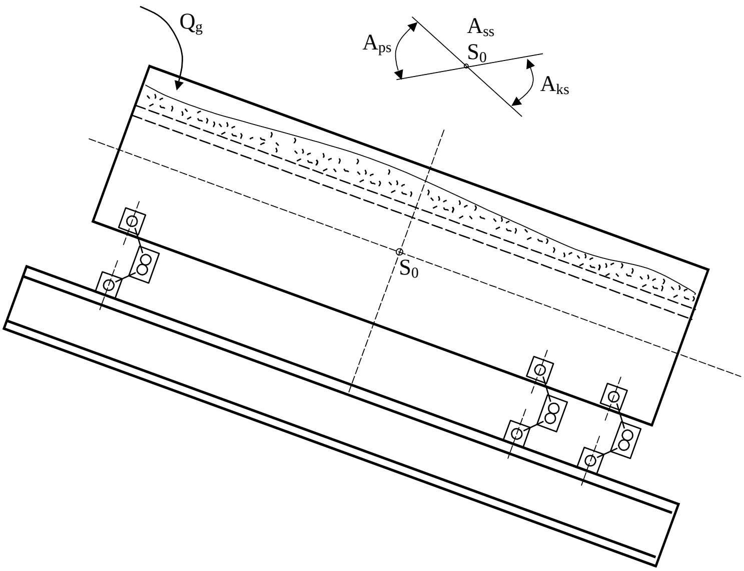

Fig. 5. The layer of the grained material formed on the double-frequency screen in the presence of torsional vibrations

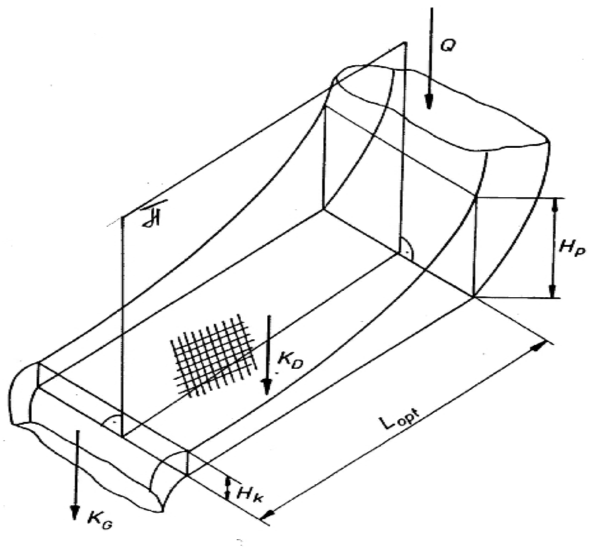

Fig. 6. The profile of the layer of the grained material on the screen in the absence of torsional vibrations

The screening process of basalt crushed stone

Basalt crushed stone with grain size ranging from 0 to 2 mm (Table 1) was selected for the examination of the double-frequency screen. The cut size (d_{50}) of the sieved material was equal to 0.63 mm. The fraction of grains difficult to sieve, i.e. with the dimensions approximately equal to 0.63 mm, in the initial grained material was ca. 45% (including upper and bottom classes). Besides a large content of grains difficult to sieve, the grained material was also composed of grains with sharp edges, therefore it had to be classified as an exceptionally difficult to sieve.

Preliminary experiments on the examination of the double-frequency screen using different grained materials, e.g. sand were described in previous papers (Modrzewski and Wodziński, 2010; 2011), where a detailed information on the parameters of the double-frequency screen was also included. Current experiments were conducted using basalt crushed stone and applying the same operating conditions, such as:

- inclination of the screen 0–20^o (α),
- alignment of the vibrators (S_0),
- driving force generated by the vibrators (P_1 and P_2),
- rotation speed of the drive vibrators (ω_1 and ω_2).

Table 1. Granulometric composition of the initial grained material

Grain size *d* [mm]	Percentage share U [%]	
0.2	11.25	
0.4	16.25	50
0.63	22.5	
0.85	22.5	
1	16.25	50
2	11.25	

The screening process was tested by changing the configuration of operating conditions. The mass of the upper and bottom parts was measured for each configuration. Then, the efficiency (η), total capacity (Q) and specific capacity (q) (per unit of screen surface area) (Sztaba 1993) of the screening process were calculated. The efficiency of the screening process was calculated according to the equation:

$$\eta = \frac{m_d}{m_n K_d} \quad (1)$$

where: m_d – the mass of the product collected under the sieve [kg],
m_n – the mass of the initial grained material [kg],
K_d – the percentage of the bottom class in the initial grained material

The results of investigations were presented as the relation between efficiency and capacity. About two hundred various experiments were carried out changing the configuration, which however was only a part of possible combinations of parameters. Unpromising results, especially those obtained in the presence of torsional vibrations were not taken into consideration.

A major criterion for the evaluation of the efficiency-capacity relations was the efficiency of the screening process, which should be naturally as high as possible. The most representative results are displayed in Figure 7 which shows how the efficiency, capacity and specific capacity changes with various speed ratios of both vibrators, e.g. 1:1, 2:3, 1:2, 1:3.

The curves were plotted using experimental data recorded for applying rotations in the same direction. The rotations in the opposite directions caused torsional vibrations. Therefore the results were not taken into consideration for the reason described above. High efficiency, about 0.9 was achieved using the optimal gear ratio of 2:3, which may fully satisfy industry standards.

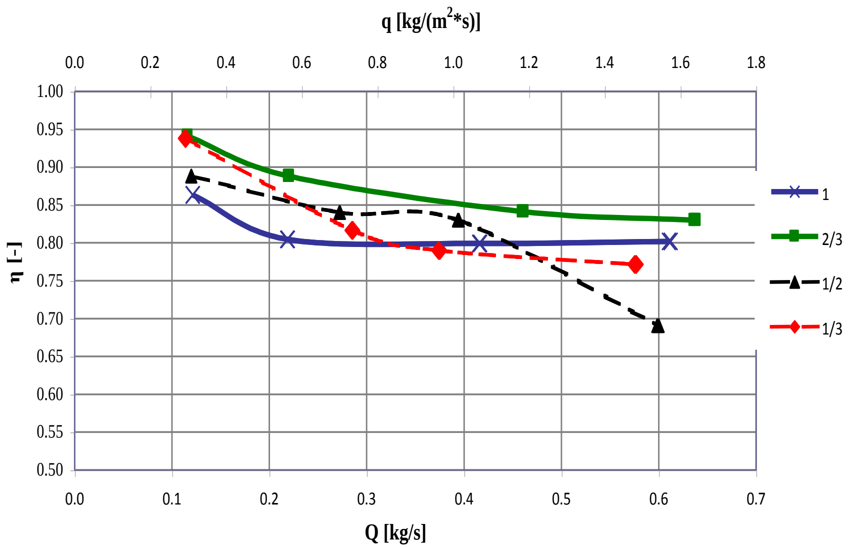

Fig. 7. The comparison of the efficiency (η), capacity (Q) and specific capacity (q) calculated for various gear ratios

Figure 8 displays the comparison of results obtained for various arrangements of the vibrators on the screen, e.g. keeping minimum distance (the vibrators positioned one over the other) or maximum distance between vibrators. It shows that the location of the vibrator on the screen had no influence on the efficiency of the screening process. The values obtained for the minimum distance between vibrators were similar to those obtained for the maximum distance.

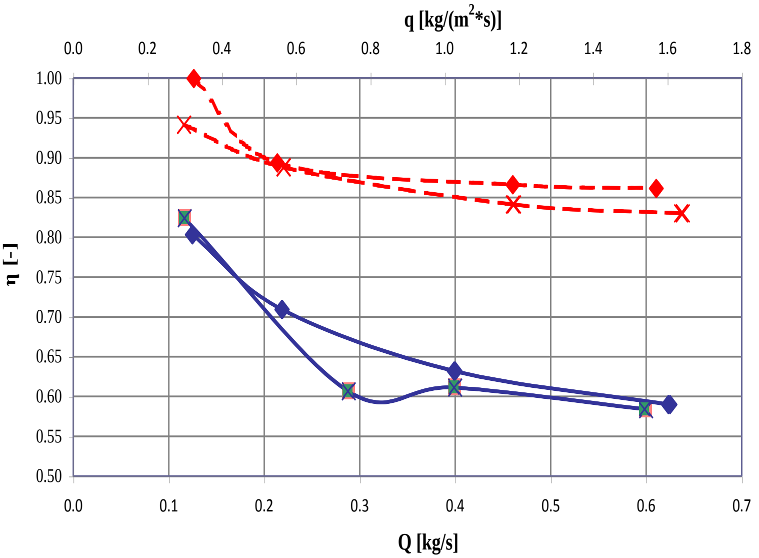

Fig. 8. The influence of location and rotation direction of the vibrators on the efficiency of the screening process

Figure 8 also shows the influence of various rotation directions of the vibrators on the efficiency of the screening process. Dashed red lines represent the data collected using rotations in the same direction, whereas solid blue lines are related to the data collected using rotations in the opposite direction. A high efficiency (ca. 0.9) was achieved setting the rotations in the same direction. By applying the rotations in the opposite directions a low efficiency (ca. 0.6–0.7) was achieved, which is insufficient for industry standards. All results shown in Figure 8 are based on the data collected using gear ratio of 2:3.

Conclusions

Based on experimental results obtained for basalt crushed stone one may conclude that the double-frequency screen can be successfully applied for the screening process of the grained materials especially those difficult to separate. However, certain unfavourable operating conditions described above must be avoided whilst using this device.

However, the regression analysis of the process, for the applied process evaluation criterion, the efficiency, does not lead to the unequivocal conclusions, because of large number of complicated dynamic parameters that also influence each other. For example, it is impossible to determine solely the effect of inclination of the screen on efficiency of the screening process because such effect may differ or even be opposite for different sets of parameters, depending on dynamic factors. Similar mutual interferences may be observed for other operating conditions and dynamic factors.

The results for all investigated sets of parameters cannot be fully presented in so this paper, however a few basic suggestions for designing and operating the double-frequency screen may be provided:

- both vibrators should rotate in the same direction to avoid the appearance of torsional vibrations,
- the vibrators should be fixed with a minimum distance, e.g. one should be located above the other, to reduce the risk of generating torsional vibrations,
- depending on the type of the vibrator, driving force should be set to a maximum possible value,
- it is strongly recommended to apply the speed ratio of 2:3, which offers stable trajectories and high efficiency.

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