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Screens for segregation of mineral waste

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Abstract. The paper presents the results of investigations on classification of different mineral waste on screens with flat screens and rectangular riddles. We developed three different constructions of such screening and subjected them to tests and process examinations aimed to determine their efficiency and productivity on the semi-technical scale. Basing on the presented studies we developed the design assumptions and the industrial screen was constructed for industrial processing of mineral waste.

keywords: screening, screen, sub-sieve, grained material, grain classes

1. Introduction

Processing of mineral waste is of great importance in the economy, first and foremost due to the large amount of waste, as well as their diversity. Mineral wastes are present in many branches of industry, particularly in the mining of coal and rock materials and energy and metallurgy. The vast majority of waste is indeed of a high usable value and the possibility of their use is very broad. Hence, often, instead of "waste" it is reported that there occur raw materials accompanying the extraction of the main mine raw material.

One of the most important unit operations in processing of mineral waste is a screening process (Rogers, 1982; Schmidt, 1984). The most appropriate machines for the implementation of the process are, according to the authors, modern screens of flat screens and rectangular riddles and with a linear flow of the feed. Those machines have been constructed in recent years and examined at the Technical University of Lodz to apply, inter alia, for the treatment of mineral waste.

2. Mineral waste

The area of industrial activity in which the mineral wastes pose the greatest problems is undoubtedly opencast mining. Lignite mining is always the appearance of large quantities of associated minerals, having the nature of mineral waste generated as a result of mining activity. Those minerals constitute a major problem throughout the mining industry, not only in the opencast mining of brown coal, though they occur there the most numerously. Raw materials accompanying lignite mines are applied to various branches of industry. Under conditions of mass occurrence of minerals it is possible to exploit the most valuable varieties being in demand, or there is a chance for their protection by the formation of secondary deposits. Opencast lignite exploitation is associated with handling very large quantities of overburden - sediments lying above the coal bed. Simultaneously, the slopes of the pit mine and in the under-lignite zone rocks and sediments are uncovered – so far inaccessible from the surface. A large amount of sediments and rocks is a commodity of high relevance. The recovery of even 1% of outlay as accompanying minerals is crucial for resource economy of the country, and especially of the central region, where the availability of mineral resources is extremely limited.

Based on several years of research and experience with the screening of various mineral waste, the authors of the present paper believe that the freely vibrating screens with flat screens are most appropriate machinery to perform those processes. There were selected three modern structures such screens, which were tested for their suitability for the segregation of different mineral waste.

3. Screens for classification of mineral waste

The first of the tested machines was a circling and revolving screen - (Fig. 1) being a construction of spatial screen movement of the sieve. It consists of a riddle with 4 screens spread inside, suspended on an elastic spring suspension 5. A feature of the screen is the location of extreme vibrators 2 and 3 being synchronized concurrently or counter-currently cause the movement of the riddle in the plane screens.

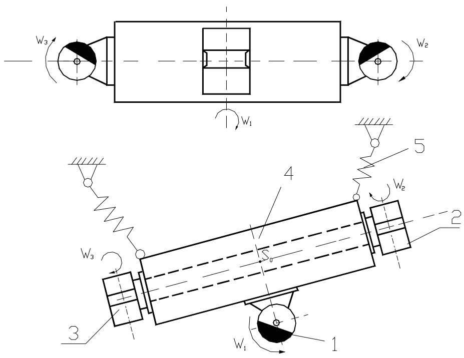

Fig. 1. Circling-and-revolving screen

This movement is applied to the circulating movement caused by a middle vibrator 1 positioned under or the rectangular sieve. This results in a complex spatial movement of the sieve (Fig. 2). Figure 3 shows selected example courses of efficiency curves of circling-and-revolving screen for different drive variants during segregation of typical mineral waste.

Another one-plane screener being characterized by high development potential is the linear-elliptical screen (Fig. 4). It has many elements in common with the other machines discussed here. A characteristic feature of the screen is its drive, made of two rotary vibrators 4 and 5.

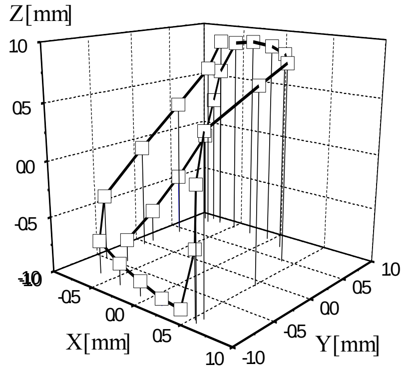

Fig. 2. Example trajectory of circling-and-revolving screen

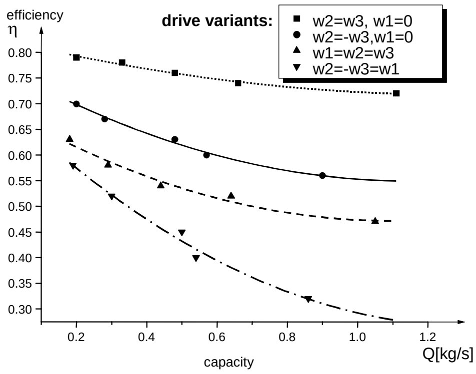

Fig. 3. Efficiency and capacity of circling-and-revolving screen

Vibrators may have identical or different static moments. If those moments are different, it is preferred that the drive shaft with a higher static movement was under the sieve (as low as possible) as shown in Figure 4.

A linear - elliptical screen can be horizontal or slope in the direction of intended movement of the particulate material movement. With the deployment of both vibrators both locations of vibrators ensure the transport of the granular layer along the screen.

Figure 5 shows comparison of theoretical and experimental trajectory of linear-elliptic screen.

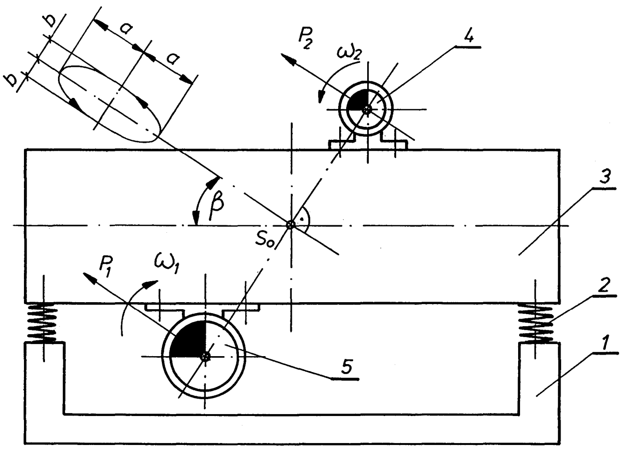

Fig. 4. Linear-elliptic screen

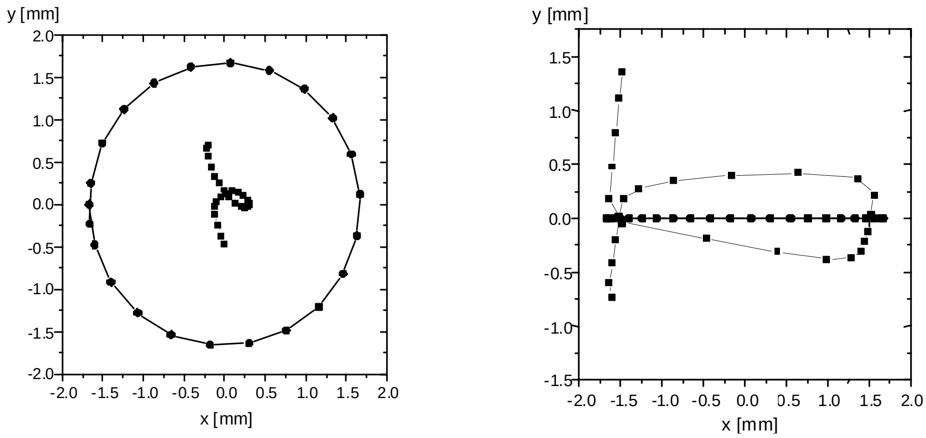

Fig. 5. Comparison of theoretical and experimental trajectory

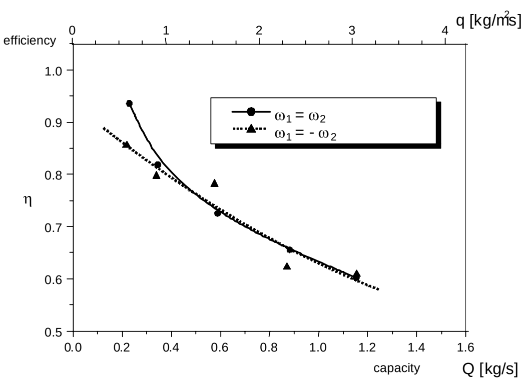

Fig 6. Efficiency curves for different drive vibrators synchronization

Efficiency curves for different drive vibrators synchronization of linear-elliptic screen, during segregation of mineral waste are shown in figure 6.

The last of the tested machines was a two-frequency screen. This machine is schematically shown in Figure 7 with a horizontal variant being presented in Figure 7, however, this machine can also be tilted at an angle α, at $15 - 20^0$. To drive this screen one may apply two rotary vibrators of equal or unequal static moments. The machine can have positioned a differently kinematic axis (eg OK_1 or OK_2 in Figure 7), it depends on the deployment of propulsion vibrators on a riddle. An extremely important parameter characterizing the work of a two-frequency screen is the coefficient of a speed transmission ratio defined as

$$\xi = \frac{\omega_1}{\omega_2} = \frac{n_1}{n_2}\,. \tag{1}$$

This quantity tells us if they differ from each angular velocity (or rotational) of two rotary vibrators. Depending on the applied speed gear ratio and direction of rotation (in line and in the opposite line), one can attain different paths of a vibrating motion for example shown in Figure 8.

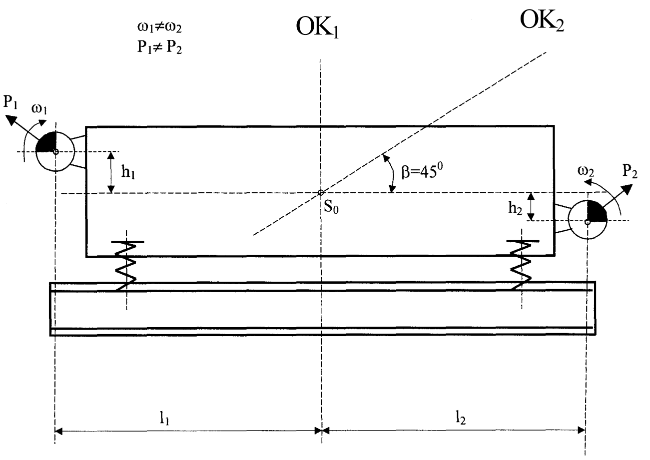

Fig. 7. Double-frequency screen

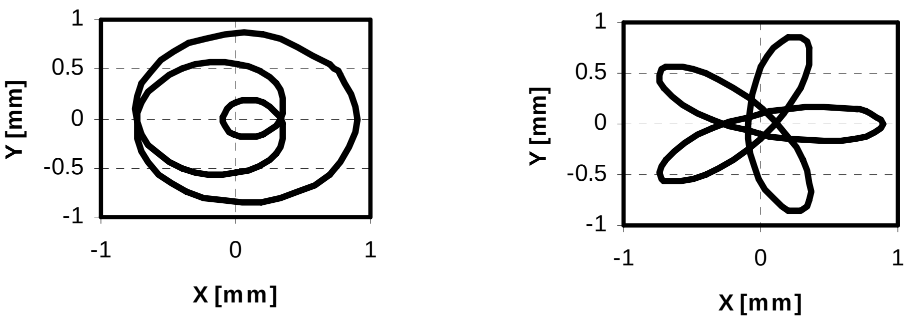

Fig. 8. Example trajectory ($\xi = \frac{1}{3}$ and $\xi = -\frac{1}{3}$)

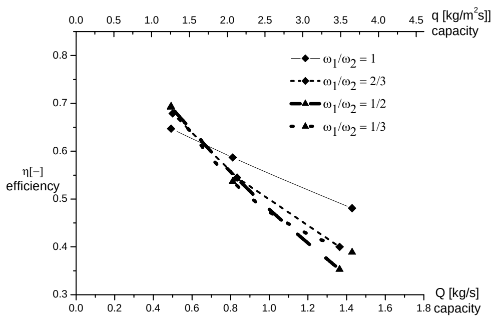

Fig. 9. Efficiency curves for different drive variants

Efficiency and capacity for different drive vibrators variants of double-frequency screen for mineral waste segregation presented figure 9.

Works performed so far were aimed at kinematical and process examinations of screens described above in terms of their suitability for the segregation of different types of mineral waste.

4. Conclusions

As a criterion of assessing the quality of the work mentioned above the screening efficiency and mass efficiency, parameters being crucial for the economy of the process. The research process constitute the only way to achieve the objective that is the optimization of the propulsion system as even the correct operation of mechanical systems does not yet provide a sufficiently good conditions for screening (Fischer, 1982).

Figure 10 shows selected example courses of efficiency curves of screens discussed previously. The presented examples concern screening of all kinds of mineral waste. Due to the multiplicity of construction and driving variants of those screens, the total number of such plots attained during the years of research is enormous. The conclusions concerning individual screens, presented in isolation, have been presented in numerous publications (Modrzewski and Wodziński, 2010; Modrzewski and Wodziński, 2011).

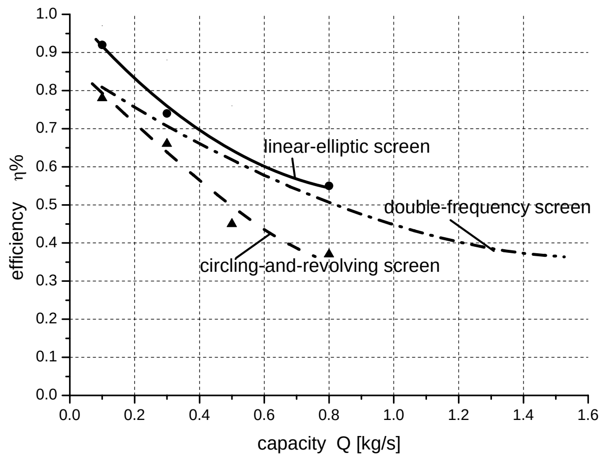

Fig. 10. Comparison of efficiency and capacity of described screens

Based on the investigations one may state that the majority of presented types of screens may find an application to screening both rock aggregates and application to both rock aggregates and mineral waste.

However, in situations where one deals with fine grained materials that are known to impede screening, the most advisable would be a double-frequency screen. Particularly, in situations where the process requires a high efficiency of mass, and as often happens when the processing of waste, a double-frequency screen due to its ability to intense segregation of a layer on the wire ensures a satisfactory performance.

This also happens while screening of relatively thick layers with which typical screens do not succeed. The situation resembles the one which occurs in the case of wet materials. Moisture content significantly hinders the process of screening, yet the majority of minerals and mineral waste is not a dry material . Screening resistance occurring at the time are mainly associated with the resistance of the granular layer and not the passage of grain through a sieve. The resistance of such superbly two-frequency screen due to its distinctive dynamics of the movement of the sieve.

In situations being less cumbersome and thus, for example, when screening of dry materials of larger grains or more oval beans, the best screen is, according to the authors, the linear-elyptical screen. His ability to segregate is slightly smaller than the double-frequency screen but the same design is a bit simpler - especially in the field of electrical control (no alternating current power inverters). This has a positive economic impact, both at the stage of investment and later - operational (lower power consumption).

As for the construction of the spatial motion filters whose representative is the circling and revolving screen it is the least useful for the classification of mineral waste from those screens, at least at the present stage of development of this construction. The reason is too low stiffness of the riddle causing difficulties in ensuring proper motion granular layer on the sieve, and this in turn adversely affects the efficiency and productivity of the process. These machines require the riddles of high stiffness in three mutually perpendicular directions. It is possible to achieve but requires an entirely new design of the riddle and the resignation from its current simple design. A double-frequency screen was constructed in the industrial version. It works in the mining industry and is used for sifting of fine and very fine-grain mineral waste in the mine. The screen is equipped with a three-stage sieve and the vibrating mass is 4500 kg. Schematically, this machine is shown in Figure 11.

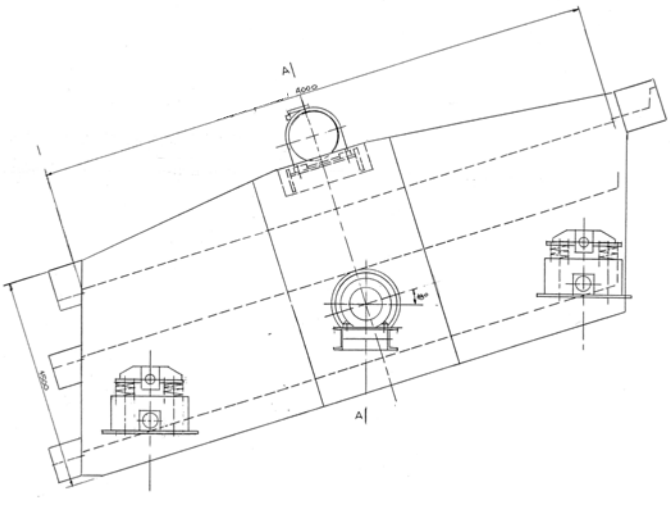

Fig. 11. Industrial double-frequency screen

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