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CRUDE ORE SCREENING IN COPPER INDUSTRY

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This study was stimulated by the problems with crude ore screening in the "Polska Miedź" SA. company The process of screening preceding ore crushing is performed using screens which do not guarantee a desired process efficiency. The existing single-plane screens do not ensure proper segregation of crude ore layer on the sieve, and consequently, not all particles which represent undersize fraction have a chance to fall into mesh and pass through it.

In this situation the problem should be solved using various means, i.e. a variety of actions should be undertaken to obtain proper characteristics of the screening process. The first one is to propose a new schematic of screening which should be carried out on 4, and in an extreme case on 3 sieve levels. Another action should encompass the application of a linear-elliptic screen. The third innovation can be the use of cascade (stepped) sieves, in particular for two lowest screens on which the proper ore classification is performed. The last one seems to be the application of a feeder which supplies the feed to the sieves of screening machines.

Key words: screening, screen, copper ore, screening efficiency, sieve

INTRODUCTION

In the "Polska Miedź" SA company crude copper ore is classified on sieves after its previous crushing. The crude ore screening is far too much inefficient because of a too high mass flow rate at which ore stream is supplied to screens. A too thick granular layer is formed on the sieves which prevents efficient separation of the undersize fraction from the oversize. A proper mine run classification, according to the present technology, is carried out according to a scheme in which two sieves l_1=40 mm, and l_2=12-16 mm are used.

It is proposed to carry out this task with the use of a modern linear-elliptic screen [Wodzinski 1997] which is a single-plane screen [Banaszewski 1990, Dietrych 1962, Schmidt 1984, Sztaba 1993, Wodziński 1997, 2001], i.e. in which plane motion takes place in the main plane Π of the machine (Fig. 1). The main plane determines cross

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section symmetry of the machine, which is a longitudinal plane perpendicular to the sieve. Sieve trajectories specific for a single-plane screen can be linear, circular, elliptic and complex. The latter are characteristic of drives with double frequency. Single-plane screens, called also vibrating screens (which seems to be incorrect), Wurfsiebe, Schwingsiebmaschinen, etc., are built in Poland and they are considered to be well developed.

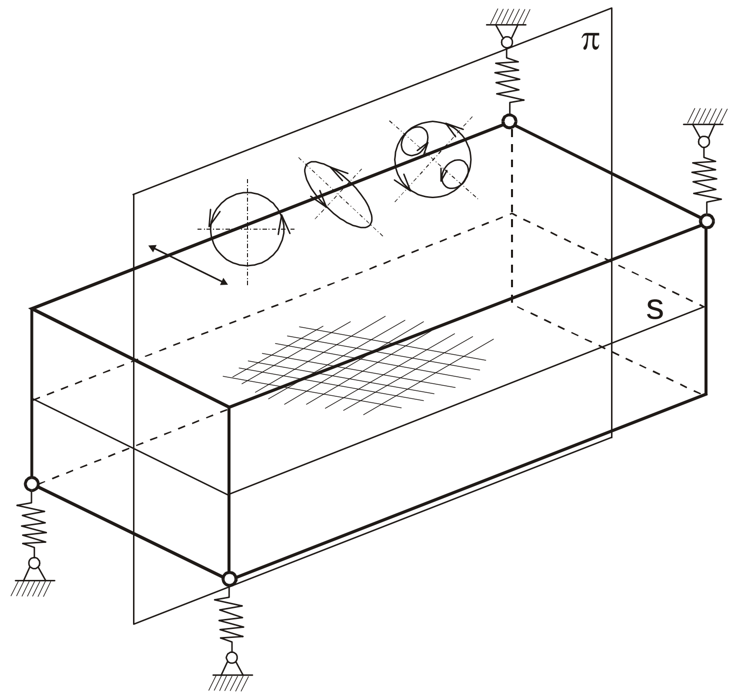

Fig. 1. Single-plane screen

This paper was prepared on the basis of the study on "Modern problems of copper ore processing in Poland" published in the proceedings of a seminar that was held in the headquarters of the "Polska Miedź" SA company on 16 November 2000. It follows from this source (pp. 77-78, 93-99), that the main cause of problems related to copper ore screening is a too big stream of feed Q [t/h, t/h m^2] directed to the process of sieve classification. The problem can be solved in many ways and the situation can be improved only when several conditions are satisfied. These conditions are as follows:
1) application of feeders in the screens,
2) application of a linear-elliptic screen,
3) application of a new schematic of screening,
4) optimised selection of mesh with reference to proper sieves,
5) application of cascade sieves.

SCREENING PROCESS

As mentioned above, the existing screens' efficiency is very insufficient and so the screens do not separate the whole undersize fraction contained in the feed. According to the suggestions of the company "Polska Miedź" SA, crude ore screening should be performed on two sieves (Fig. 2) with mesh dimensions Φ_3=40 mm and Φ_4=12-16 mm. As a result, using this scheme two oversize products X_1 and X_2, and one undersize product Y is obtained. This is an indisputable opinion on the types of sieves which should be used. At present, there is a tendency that polyurethane sieves are applied in mineral raw material processing. Such sieves are extremely resistant to grinding as compared to woven sieves made from metal (wire). However, it should be remembered that the application of polyurethane sieves much decreases the sieve clearance coefficient A_0, defined as the ratio of mesh surface to the surface of the entire sieve. So, if in the case of normalised woven sieves $A_0 \approx 36\%$, in the case of polyurethane sieves $A_0 \approx 10\%$. This means such a proportional decrease of screening efficiency. Thus, the application of polyurethane sieves brings about a significant decrease of screening efficiency when compared to woven sieves which would have been used in the same screen and in the same conditions (e.g. when screening the same feed).

Hence, in order to increase screening efficiency it is proposed to apply two preliminary sieves whose mesh size would be bigger than that in sieves 3 and 4 (Fig. 2). It is proposed to use grates or polyurethane sieves. The task of sieves 1 and 2 is to "extract" big particles that cause resistance of the layer from the feed as quickly as possible. These particles disturb small particles (undersize fraction) to get near the sieve and then to be screened off. Next, the oversize products from sieves 1, 2 and 3 are joined in one granular stream denoted as X_1.

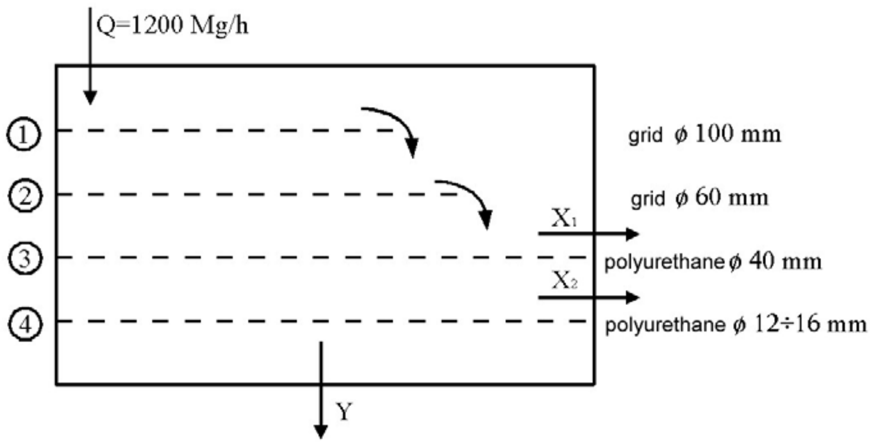

Fig. 2. Schematic of crude ore screening

Selection of mesh size, both for preliminary and proper sieves, should be carried out taking into account diagrams of crude ore particle size distribution: Figs. 3 to 8. Figure 3 shows a diagram of the curve of particle size fractions occurrence frequency in the feed. This diagram is prepared in a normal system. Since this diagram is difficult to interpret, the same function was presented in a two-log system (Fig. 4) and bar diagram of the particle composition of the feed in a one-log system (Fig. 5). Typical granulometric curves of particle size distribution are shown in Fig. 6, where curve P is the curve of sieve residues, and curve R – screening through a sieve. Next, in Fig. 7 the same curves are presented in a one-log system, and in Fig. 8 – in a two-log system.

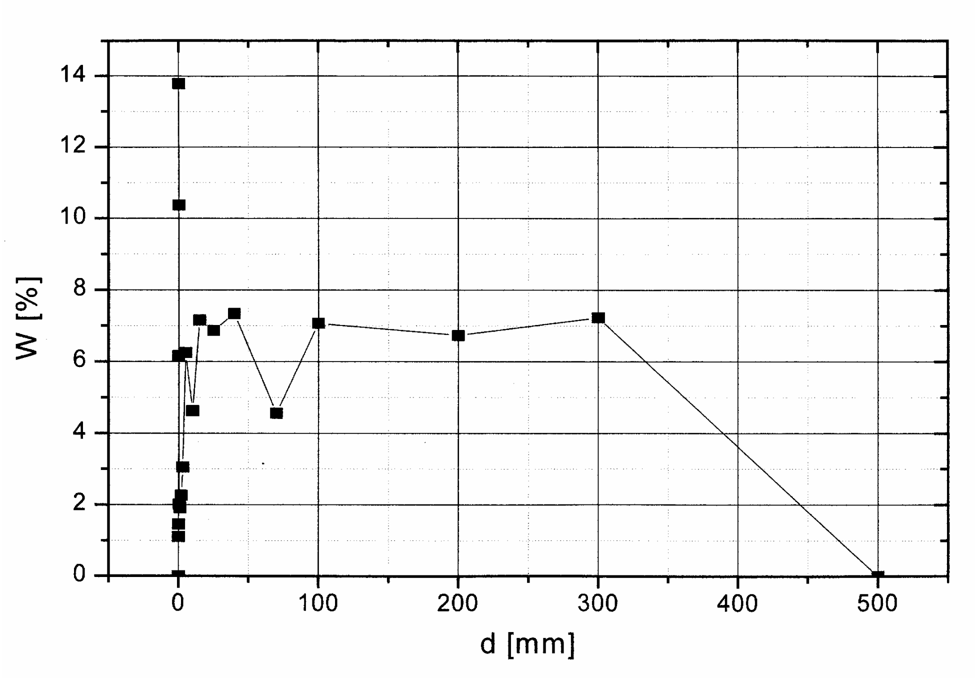

Fig. 3. Diagram of frequency curve for feed size grade fractions

On the basis of the graphic material characteristic mesh sizes (or grate slots) were determined for preliminary sieves 1 and 2. Assuming Φ=100 mm for sieve 1 means that 20% feed (the biggest particles) is separated on it and Φ=60 mm for sieve 2 that further 10% feed is separated. So, on both preliminary sieves 30% feed will be separated and these will be the particles that hamper most seriously the process of screening.

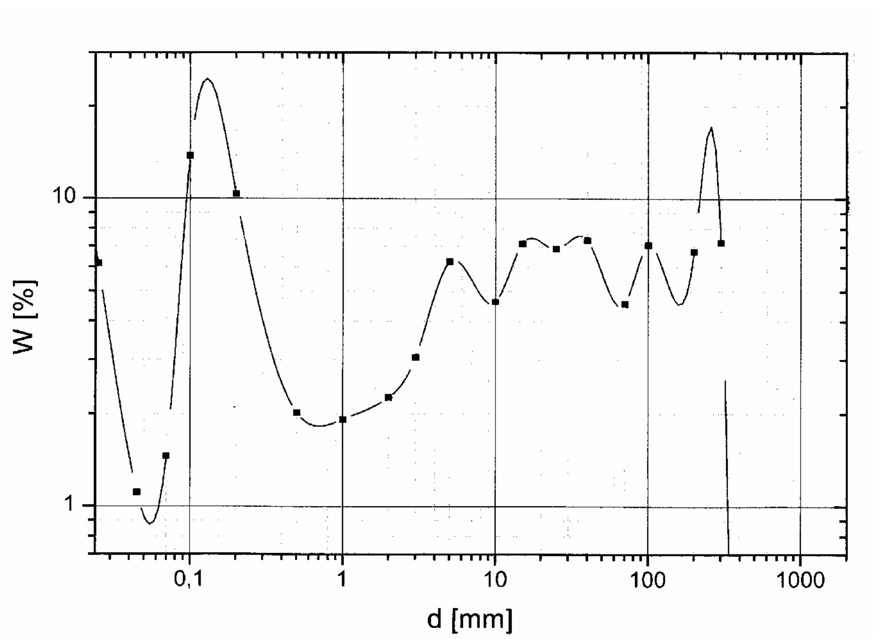

Fig. 4. Diagram of frequency curve for feed size grade fractions

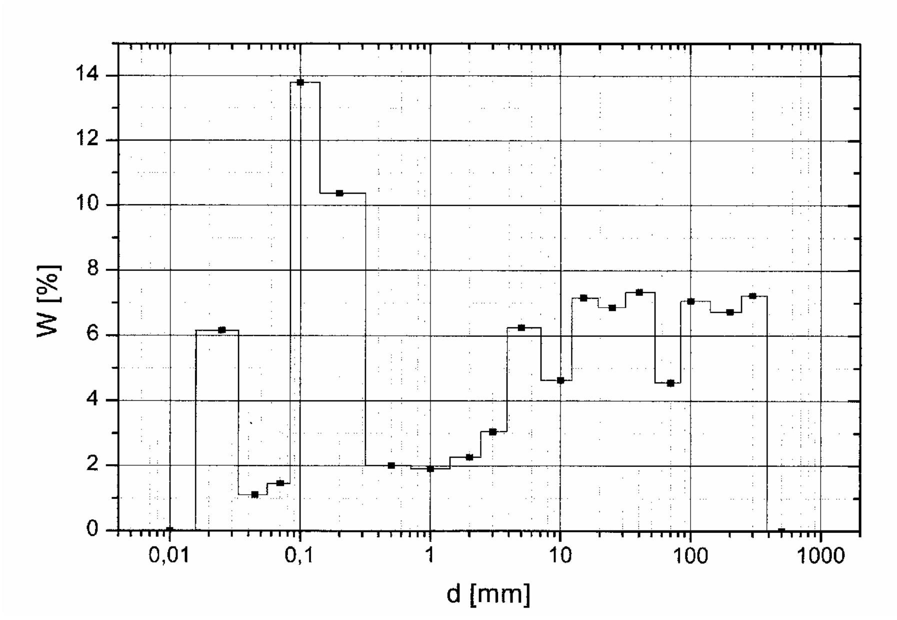

Fig. 5. Bar chart of feed size analysis

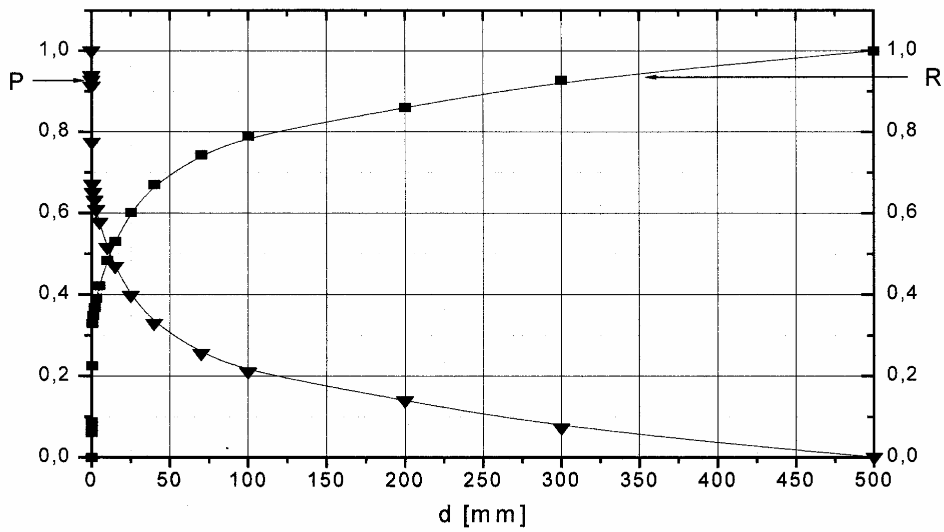

Fig. 6. Particle size distribution of crude ore, P – sieve residue, R – sieve dumping

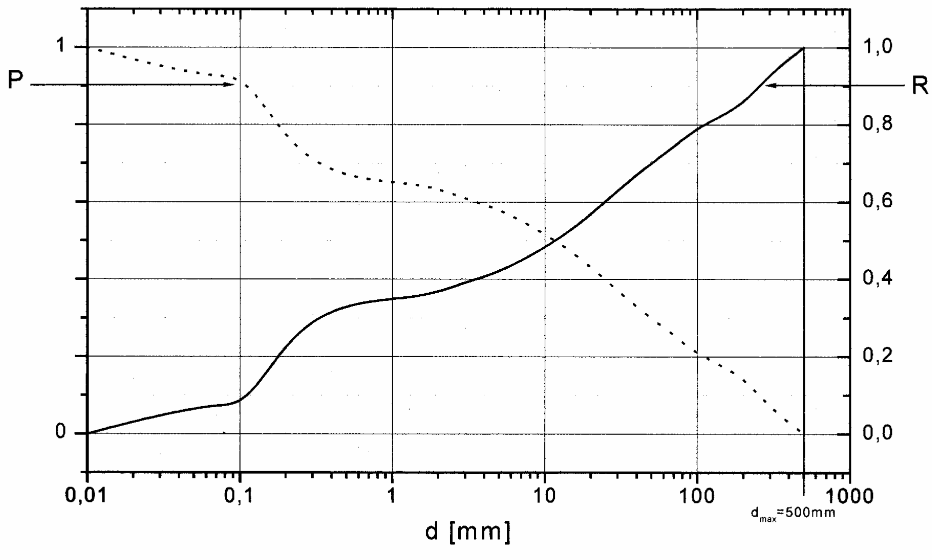

Fig. 7. Particle size distribution of crude ore, P – sieve residue, R – sieve dumping

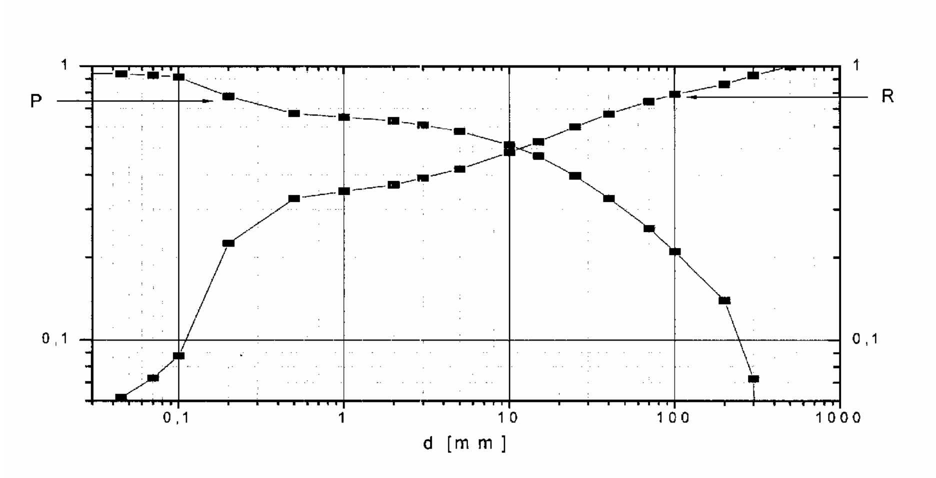

Fig. 8. Particle size distribution of crude ore, P – sieve residue, R – sieve dumping

LINEAR-ELLIPTIC SCREEN

To carry out the process of screening it is proposed to use a modern linear-elliptic screen [Wodziński 1997; Wodziński 2001] that can replace machines working in the ore processing plant. The machine has been described in detail in literature, so here we will deal with it very briefly. A linear-elliptic screen can be either inclined (α=8°-10°) (Fig. 9) or horizontal (α=0°) (Fig. 10).

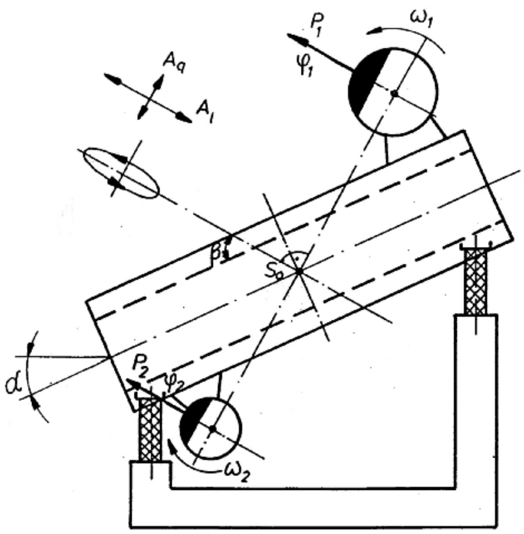

Fig. 9. Inclined linear-elliptic screen

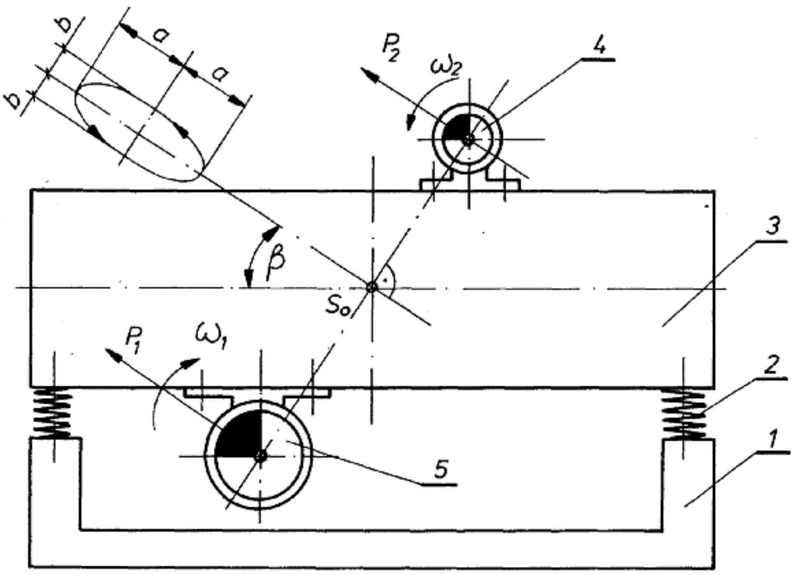

Fig. 10. Horizontal linear-elliptic screen

In both cases the screen is composed of a rectangular riddle, it contains typical elements that are known in other screens, i.e. riddle, springs, main frames, the mechanisms of sieve mounting, the sieves themselves, and also rotary vibrators which drive the screen. As compared to the existing screens, the difference is in drive system configuration (Figs. 9 and 10). If through a centre of mass of the whole riddle S_0 a line of sieve oscillations (the line of driving force action) is drawn and oriented at the angle β to the sieve surface, then the line perpendicular to the line of sieve oscillations in point S_0 is a straight line combining centres of unbalanced shafts that drive the screen. This machine can oscillate in different conditions of drive system operation. The static moments of shafts (or unbalanced engines) can be equal or different. The same refers to rotational speed of drive shafts. Additionally, these shafts can work in the conditions of dynamic concurrent or backward self-synchronisation. So, the linear-elliptic screen can work in different drive systems and consequently move along various trajectories [6]. This is important because the shape of screen trajectory and distribution of oscillation amplitudes on the whole sieve surface determine the screen efficiency.

Figure 11 shows different positions of drive shafts in the linear-elliptic screen. Displacement of shaft axes results in an increase of sieve trajectory angle β. Figure 12 shows different, possible variants of drive system operation in the linear-elliptic screen. Attention is focussed on the application of various static moments of drive shafts, different types of self-synchronisation: concurrent and backward, different values of exciting force (3 values) and different angles of sieve trajectories β.

Subsequent figures show vibrating sieve trajectories in the linear-elliptic screen. The real sieve trajectories are different than the trajectories being a result of calculations (computer simulation), e.g. trajectories of the end and beginning of the sieve (Fig. 13), are straight lines, and their real shape is shown in the figure. The trajectory of sieve centre (Fig. 14) should be circular, its real shape is illustrated in the figure.

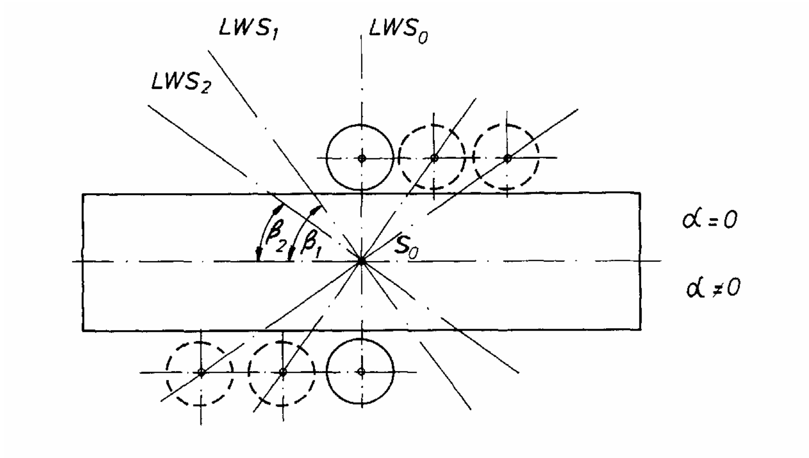

Fig. 11. Position of drive shaft axes in a linear-elliptic screen

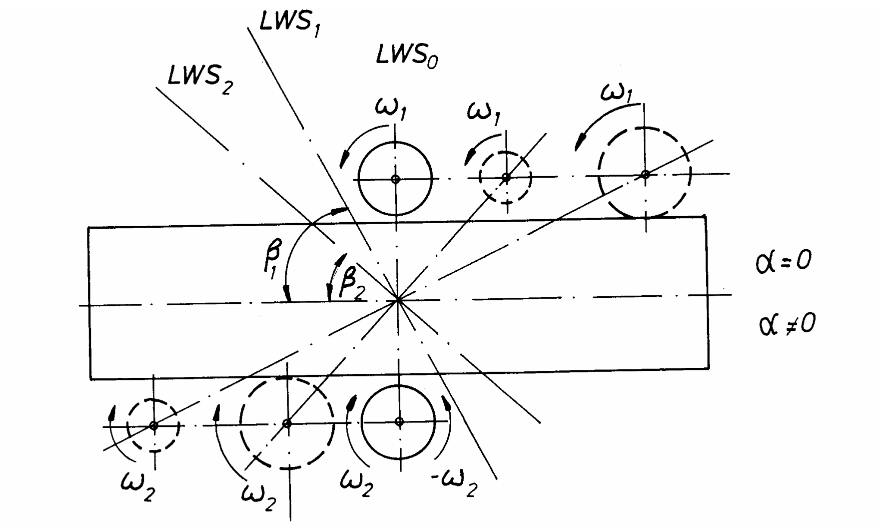

Fig. 12. Types of drive system operation in the linear-elliptic screen

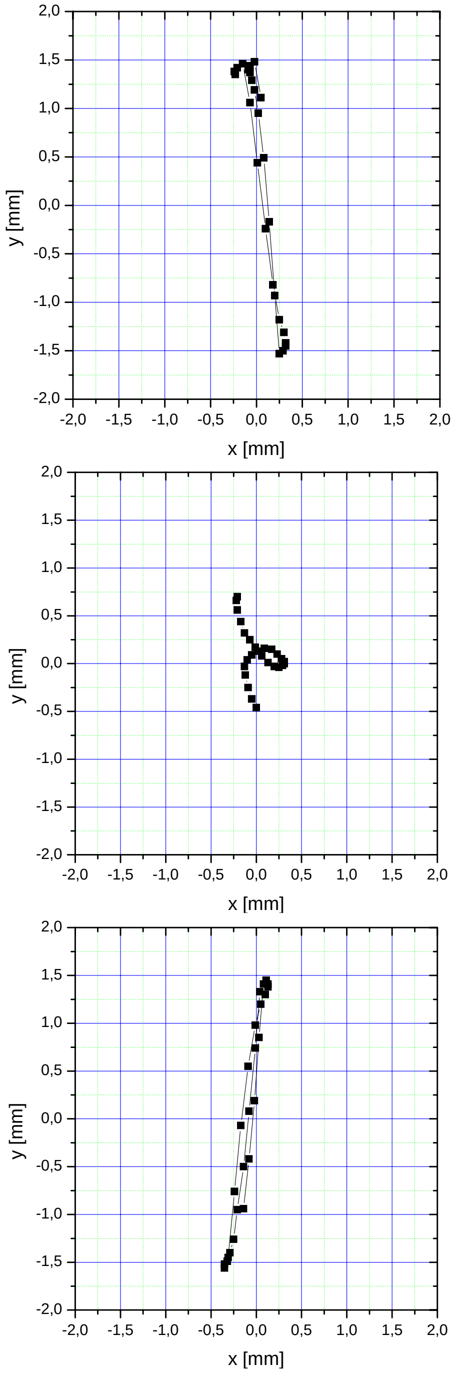

Fig. 13. Screen trajectories for medium force and co-current synchronisation

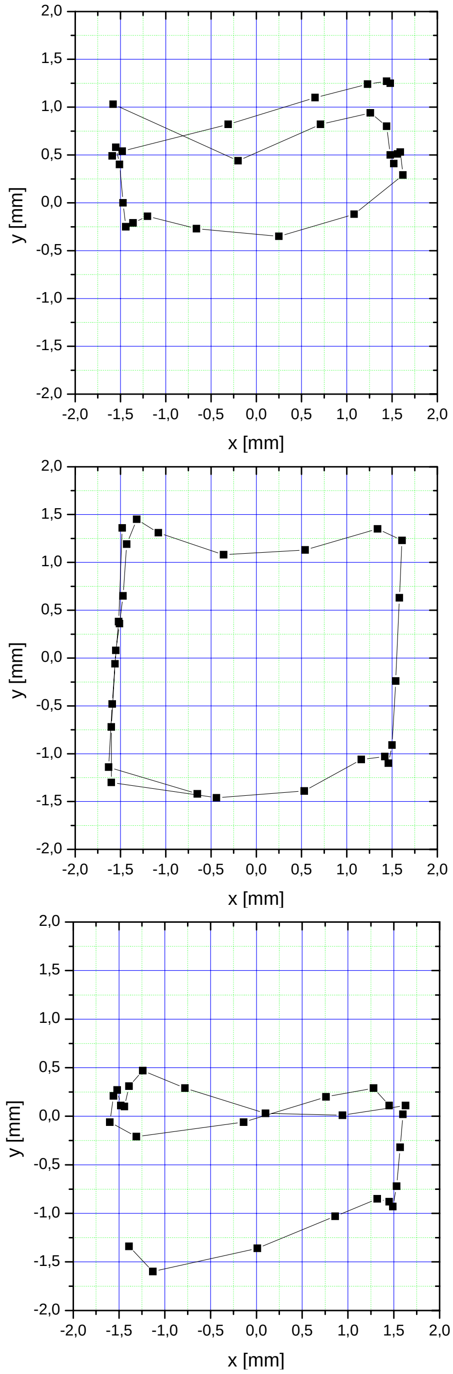

Fig. 14. Screen trajectories for maximum force and co-current synchronisation

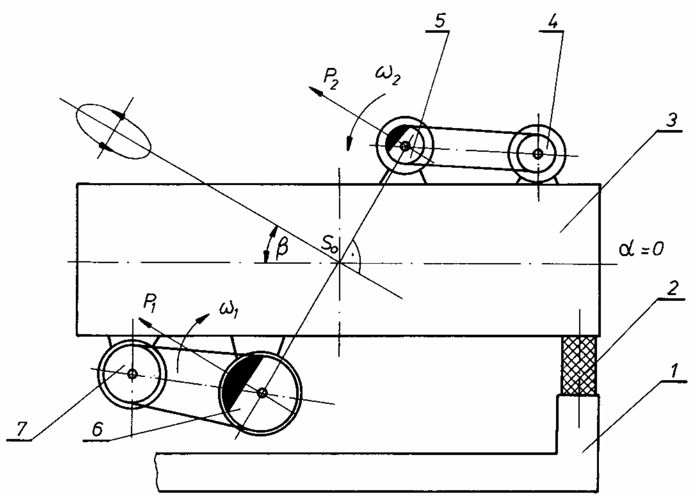

Fig. 15. Variant of a linear-elliptic screen with drive engines on the riddle

Figure 15 illustrates design solutions of the linear-elliptic screen different from the existing ones, in which drive engines were located immediately on the riddle. However, the most proper solution of the drive system is shown in Figs. 16, 17 and 18. This is a so-called module drive system where constant (known) modules of unbalanced shafts are used. Electric drive engines are on immobile frames mounted on a common base with a supporting frame of the screen. Elastic shafts are used for driving. They combine unbalanced modules with each other and with a drive engine. Elements shown in Figs. 16-18 are known from other constructions of screens and they have been thoroughly verified in industrial practice.

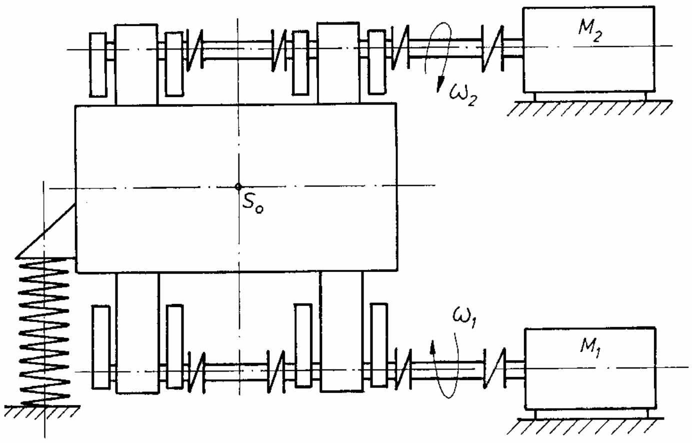

Fig. 16. Drive system of the linear-elliptic screen with stable engines

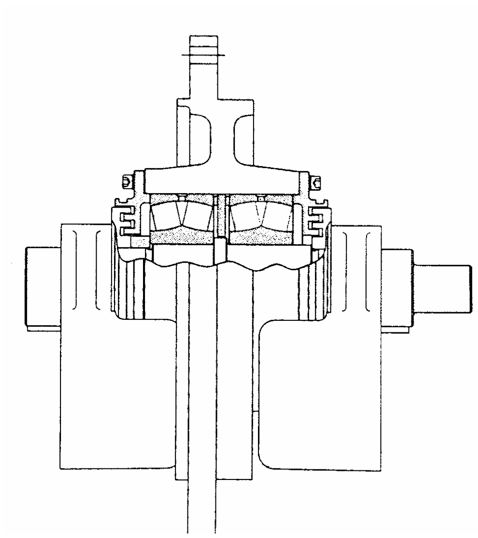

Fig. 17. Vibrating module

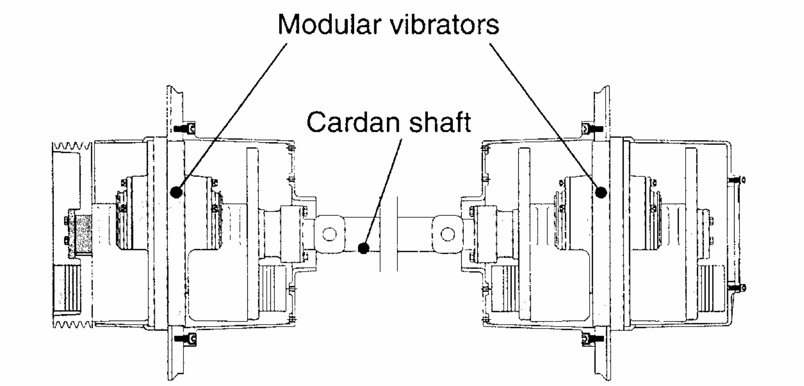

Fig. 18. Module drive

In Poland it is believed that particularly big machines (e.g. screens working in mining and processing industries) should be driven by unbalanced shafts, with bearings directly in sides of the screen riddle. Also in the case of a linear-elliptic screen this solution is possible (Fig. 19), and additionally it was proposed to apply a cascade sieve. The cascade sieves can be one-sided (Fig. 20) or two-sided (Fig. 21). An advantage of the cascade sieve is screening of the feed which is additionally mixed and hence small particles that constitute undersize fraction, can find their way to the sieve more easily which is a condition to pass through the mesh. In segments SO_{AB}, SO_{CD}, SO_{EF} the most intensive feed discharge from the layer on the sieve takes place because this is the initial segment of the kinetic curve of screening, i.e. a so-called outflow function.

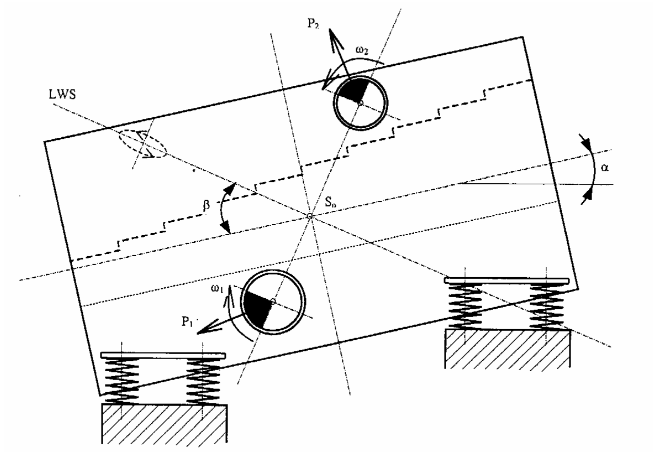

Fig. 19. Linear-elliptic screen with a stepped sieve

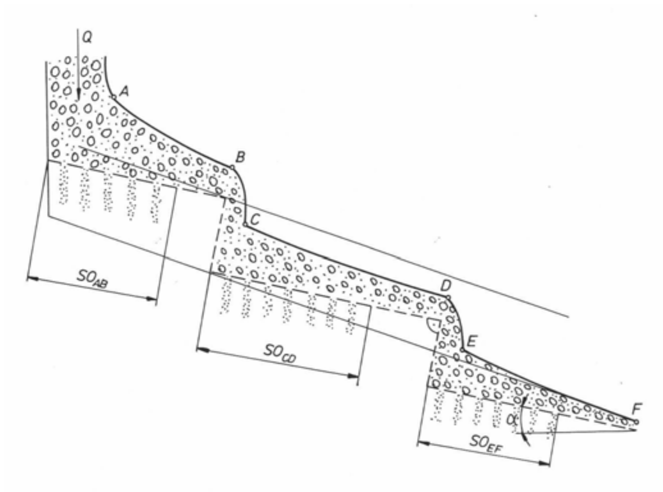

Fig. 20. One-sided cascade sieve

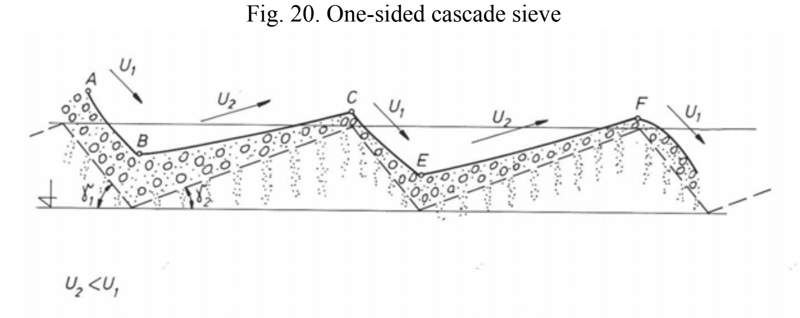

Fig. 21. Two-sided cascade sieve

Screening on a two-sided cascade sieve (Fig. 21) is performed on both surfaces of the cascade. On the AB segment of discharge curve, material moves at velocity u_1, and on the segment BC – u_2, and so on. A cascade placed in this way constitutes an "obstacle" for small particles which due to low kinetic energy cannot leap over the step and are held up. Owing to this, the probability that they will be screened off increases.

As we can see, the linear-elliptic screen is a universal screen in which advantage is taken of experience gained so far in the area of constructing and exploiting screening machines. This screen is characterised by a relatively uniform arrangement of vibrating masses, a feature unknown in the constructions known so far.

SUPPLY OF FEED TO THE SCREEN

The methods of feed supply to the screen were discussed in literature [Wodziński 2001]. One of possible design variants of such a feeder (with a horizontal trough) was also shown. The feeder can be driven by:

1. an electromagnetic vibrator placed usually below the feed transporting trough,
2. one rotating vibrator (in such a case the trough must be inclined),
3. two backward-synchronised rotating vibrators (unbalanced engines). Then, the most advantageous arrangement of the vibrators is on the side walls of the feeder (Fig. 22).

Design recommendations obligatory for mines referring to such feeders (Fig. 22) were discussed [Wodzyński 2001] and presented in a feeder schematic diagram.

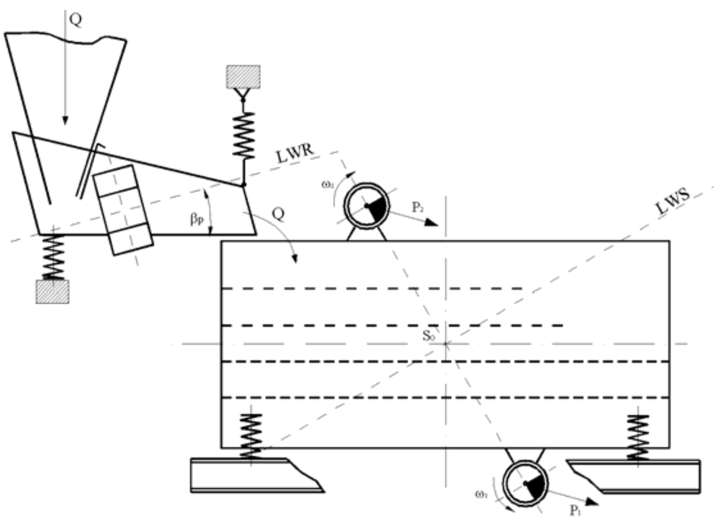

Fig. 22. Screen with a feeder

CONCLUSIONS

1. On the basis of the analysis of the state of the art in the area of crude ore screening in the "Polska Miedź" SA company, a linear-elliptic screen with a new sieve system was proposed.
2. There is still an open problem of optimal selection of mesh size and sieves to carry out the process of ore screening before crushing.
3. An important issue is a correct feed supply to the screen and this problem refers to almost all screening processes, in particular on rectangular sieves and with linear flow of material through the screen.

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Bodźcem do powstania niniejszego opracowania były problemy, jakie są związane z procesem przesiewania rudy surowej w KGHM "Polska Miedź" SA. Proces przesiewania poprzedzający kruszenie rudy, jest realizowany na przesiewaczach, nie zapewniających wymaganej skutecznej wydajności procesowej. Istniejące przesiewacze jednopłaszczyznowe nie zapewniają odpowiedniej segregacji warstwy rudy surowej na sicie, a co za tym idzie nie wszystkie ziarna reprezentujące swym wymiarem klasę dolną, mają szansę wpaść w otwory sitowe i następnie przejść przez te otwory.

W tej sytuacji rozwiązanie problemu powinno być prowadzone wielotorowo, tzn. powinny być wykonane różne działania, które razem doprowadzą do uzyskania właściwych charakterystyk procesu przesiewania. Pierwszym z nich jest zaproponowanie nowego schematu procesu przesiewania, który powinien być prowadzony na 4, a w skrajnym przypadku na 3 pokładach sitowych. Drugim działaniem powinno być zastosowanie przesiewacza liniowo-eliptycznego. Trzecią innowacją może być zastosowanie kaskadowych (schodkowych) pokładów sitowych, w szczególności dla dwóch najniższych sit, na których odbywa się właściwa klasyfikacja rudy. Ostatnim wydaje się być zastosowanie podajnika zasilającego, podającego nadawę na sita maszyn przesiewających.