Extension of the steel sieve during the spherical gun-powder screening

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Abstract. Influence of the steel sieve extension on screening of the spherical gun-powder was investigated. The objective of this research was to increase the screening productivity and reduce the production downtimes. The sieve's mechanical characteristics – elongation – test was performed on the tensile testing machine ZWICK ROEL 110. Through analysis of results for two sieve types the conclusion was drawn that the steel sieves with the smaller wire diameter are less extended. Their advantage lies in the fact that the cleaning ring, used to deblind the blocked mesh, can come closer to the sieve, due to the smaller clearance between the sieve's opening and the cleaning ring and thus clean it more efficiently. That additionally reduces the possibility for sieve the extension due to the residual gun-powder mass.

1. Introduction

The size distribution of particulate materials is very important in determining their properties (chemical, physical, mechanical etc.) in processes in various branches of industry and in numerous practical engineering operations - mining, metallurgy, dry mortar and artificial sand, production of food powders, chemicals, colorants, paints and pharmaceuticals. The sieves/screens are the oldest and most widely used working elements for separation of solid particles by size. The term screening is usually used for continuous sizing operation, while sieving usually means a batch process.

The aim of mechanical classification (screening) is to divide particulate material into groups of grains according to their sizes. For this purpose, sieves are equipped with either one or several screens. The selection of a correct sieve for a given particulate material determines the course of screening, [1].

A stack of sieves with decreasing mesh size is usually used for materials separation, which can be done in order from the coarse particles to fine, when the process is called the "sifter cascade". If the particles are sifted in a fine to coarse order, by the multiple sieving steps, with each step using a single sieve, such a process is called the reverse sieve method. Of all the elements of the sieving operation, the sieve blinding is considered as the most important and direct controlling factor. It occurs when particles block up and lodge in the sieving mesh, causing reduction of the effective transfer area on the sieve surface, resulting in reduction of the sieving rates (sieving performance or capacity), as well as of the degree of sharpness of particle separation (sieving efficiency).

Many factors have been identified that affect the screening, including the size and shape of particles relative to the aperture of the sieve, the mesh size of the sieve itself, the amount of material...
on the sieve surface, the direction of movement of the sieve, the rate of movement of the material relative to the sieve surface, [2].

Screening machines may be classified based on the direction of the particulate material flow through a screen into two main groups: screens with linear material flow through the machine and screens with either radial or spiral flow of the segregated material through the machine. The second class is based on the design configuration, i.e. circulating and rotary screens, screens with vibrating sieves, circulating screens with vibrating sieves, screens with spatial sieves motion and fluid-flow screening machines. The principal element of a screening machine is the vibrator, i.e. a device that provides the vibrations to the sieve, [3].

Vibrating screens of different types are the main sieving tool for large-scale separation and classification of solid particles by size. The sieving efficiency is an essential indicator for evaluation of the sieving performance. It is hard to be predicted due to the comprehensive effect of many parameters within the particle sieving process with multiple factors that influence the selection or determination of those parameters.

There are numerous researches on the sieving process by the DEM simulations (Discreet/Distinct Element Method) giving qualitative relation between the sieving efficiency and sieving parameters in a vibrating screen such as amplitude, vibration frequency, screen mesh size, particle size, and vibration direction angle has been analyzed, which provides references for in-depth study, [4-5].

The mesh aperture size is an important parameter in evaluation of the sieving efficiency. When the mesh aperture size is small, the sieving efficiency is low due to the lower penetration probability of the fine particles and a greater proportion of fine particles that remain in overflow particles and vice versa, when the mesh aperture size is larger, the sieving efficiency is higher due to the larger penetration probability of the fine particles. However, if the mesh aperture size is too large, the sieving efficiency becomes lower due to the higher penetration probability of the particles whose size is larger than the separation size and undersize particles are mixed with a greater proportion of larger particles, [2].

The vibro-sieve consists of the screen, which is fixed to the supporting frames by the cylindrical coil springs and the electro-mechanical vibratory system, which causes mechanical vibrations of the sieve that separates material to factions. The shaft on the rolling bearings is mounted at the screens COG axis and it has two eccentric flywheels at its ends. The following parameters are important for operation of a vibro-sieve: mass of material that is being screened, sieve's vibrations' amplitude, vibrations' frequency, the screens slope angle with respect to horizontal plane and the incoming angle of the excitation force, which acts on the screen. Change of the vibrations' amplitude influences the intensity of screening and this change is achieved by mutual turning of the eccentric flywheels, [6]. Change of the vibrations frequency, on the other hand, influences the quality of the gun-powder screening; it is realized directly by change of the rotational speed of the driving electric motor.

The sieves driving is realized through the electric motor and the belt transmission. Increase of the mass on the screen induces an increase of the electric motor power. Depending on the position along the technological production line, the sieves are divided into the primary and secondary ones.

To obtain the optimal vibro-sieve, a comparison is performed in [7] of the dynamic behavior of the vibro sieve's mathematical models. In the first model, an electric motor with imbalance was used, while in the other model such an electric motor was not used. It was noticed that the biggest deficiency of the system without the motor is just the inability of controlling the particles.

The spherical gun-powder is the nitro-cellulose gun-powder. The basic component is the nitro-cellulose to which the nitroglycerine and stabilizer diphenylamine are added. The whole production process is rigorously controlled, starting from the raw materials, via the semi-finished product up to the finished product, while all the tests are carried out on a daily basis, on the state-of-the-art devices, both in laboratories and on the testing grounds. The production process of the spherical gun-powder must be in accordance with requirements of the following standards: ISO 9001/2015, ISO 14001/2015 [8-9].

The gun-powder separation process, based on geometrical comparison of the shape and size of particles to shape and size of the openings on the sieve's surface is called screening. Machines at
which the separation to fractions is done by mechanical vibrations, according to the granulation sizes, are the vibro-sieves. Number of fractions depends on the number of levels on the vibro-sieve. The screening can be done in the dry conditions or with washing with addition of the washing system.

2. Steel sieves
The steel sieve is presented in Figure 1. Due to the safety reasons, the sieve is shown in the still condition without water. The steel sieve is tightened on a specially made ring with a rim, which is attached to the metal drum using a shaft. There is a metal ring between the metal drum and the steel sieve, which has the role of a scrubber of the stale gun-powder. Technical documentation is not available due to manufacturer protection.

The average sieving area (screen) can be made in different ways and from different materials, depending on the material being sown. For the screening of spherical gun-powder, the most commonly used are steel screens with square or rectangular openings.

![Figure 1. The vibro-sieve.](image)

The sieve represents the wires interlace, which is formed by joining the two systems of wires by weaving, namely by alternate interlacing of the base and weft wires at the right angle. The longitudinal system of wires, which is parallel to the direction of the sieves motion during weaving, is called the base, while the weft is the lateral system of wires, placed at a right angle with respect to base. The interior dimensions of the sieve are combination of the weft wires diameters and their distances. The space formed between the two wires of base and two wires of the weft is called the sieve's eye or the opening, Figure 2.

The variables that define the sieve's dimensions, Figure 2, are: $d$ – the wire diameter, $w$ – the size of the opening, $t$ – the step, $N_0$ – number of wires per cm, $F_0$ – the illuminated area. By knowing these variables, one can calculate the sieve's number, which represents the number of wires and openings, namely, the number of steps per unit length. Generally, there are two numbers: $N_w$ – the weft number and $N_0$ – the base number; only in special cases are those two values equal. In the US and UK the sieve's number value is called the mesh. The sieve geometry is given in Figure 2.

Sieving of the gun-powder of the irregular form is a complex process and it influences the efficiency of the sieving if the powder particles size are approximately the same as the sieve's opening size, [10]. It should be said that a vibration sieve is an above resonant sieve with circular vibrations. Due to the increased impact oscillations, when spherical gun-powder is poured onto the vibration sieve, stretching, breaking, damage in some places and, in the worst case, breaking of the sieve occurs. There are several reasons for this extremely negative effect: low mechanical resistance of the sieve, inadequate fixing of the sieve's structure, poor construction and small sieve thickness, low stiffness of the screen, inadequate mounting on the construction, the high impact and vibration load and long-term operation under unfavorable conditions, [11-12]. Therefore, in this paper, the mechanical characteristics of the sieves, i.e. the influence of one of the parameters, is analyzed, which is the stretching (extension) of the steel sieve when the spherical gun-powder is being screened.
3. Experimental setup and results
The two metal single-layered sieves were used in this experiment of the same type - TYPE 110, but with different numeration. Data on the used wire types are given in Table 1. Material for all the wires was WNr. 1.4301. Technical characteristics of the tested sieves are given in Table 2.

Table 1. Basic data on two types of sieves.

|                        | Sieve Type 1 | Sieve Type 2 |
|------------------------|--------------|--------------|
| Base number $N_0$ (wires per cm) | 5            | 30           |
| Base wire diameter (mm)  | 0.5          | 0.15         |
| Weft number $N_w$ (wires per cm) | 5            | 30           |
| Weft wire diameter (mm)  | 0.5          | 0.15         |

Table 2. Technical characteristics of the tested sieves.

|                        |              |
|------------------------|--------------|
| Number of screens (steps) | 2            |
| Single screen area (m²)    | 2.4          |
| Electric engine power (kWh) | 4            |
| Sieve's maximum length (mm) | 2590         |
| Sieve's maximum width (mm)  | 1500         |
| Sieve's maximum height (without a stand) (mm) | 1570         |

The following data were recorded during the test:
- $a_0$ – sample thickness
- $b_0$ – sample width
- $L_0$ – sample length
- $F_{\text{max}}$ – maximum force
- $F_{\text{break}}$ – breaking force
- $\varepsilon_{F_{\text{max}}}$ – extension at maximum force
- $\varepsilon_{F_{\text{break}}}$ – extension at break.

Test results for the sieve of type 1 are given in Table 3 and in Figure 3 and for the sieve of type 2 in Table 4 and Figure 4. Two samples were tested for each sieve type.

Table 3. Test results of the sieve TYPE 110 $N_0$ 5.

| Sample number | $a_0$ (mm) | $b_0$ (mm) | $L_0$ (mm) | $F_{\text{max}}$ (N) | $F_{\text{break}}$ (N) | $\varepsilon_{F_{\text{max}}}$ (%) | $\varepsilon_{F_{\text{break}}}$ (%) |
|---------------|------------|------------|------------|----------------------|-----------------------|---------------------------------|-----------------------------------|
| 1             | 0.3        | 1.1        | 150.20     | 2064.08              | 1928.44               | 21.84                           | 21.56                             |
| 2             | 0.3        | 1.1        | 150.34     | 2218.06              | 2205.97               | 22.17                           | 22.06                             |
Figure 3. The stress-strain diagram for the sieve TYPE 110 N05.

Table 4. Test results of the sieve TYPE 110 N030.

| Sample number | \(a_0\) | \(b_0\) | \(L_0\) | \(F_{\text{max}}\) | \(F_{\text{break}}\) | \(\varepsilon_{\text{break}}\) | \(\varepsilon_{\text{max}}\) |
|---------------|--------|--------|--------|-----------------|-----------------|----------------|----------------|
| 1             | 0.3    | 30     |        | 150.19          | 1077.95         | 969.28         | 6.32           | 6.08           |
| 2             | 0.3    | 30     |        | 150.12          | 1160.74         | 1151.64        | 9.19           | 9.12           |

Figure 4. The stress-strain diagram for the sieve TYPE 110 N030.

4. Discussion of results and conclusions

From obtained results one can see that the sieve of type 1, i.e. TYPE 110 N05, has bigger extension for about 50 % and 50 % bigger breaking force that the sieve of type 2, i.e. TYPE 110 N030. This corresponds to the results from the technical practice that it is necessary to use the sieves with the smaller extension %. The reason for this requirement, namely for the sieve to have as small extension (stretching) as possible, lies in the fact that this guarantees better screening (sifting). The system with rinsing of the sieve with water under compression, which is usual in sieving the gun-powder, can cause the blinding (clogging) of the sieve's openings, creating a powder residue, what has as a consequence reducing of the sieving area, thus decreasing the sieving efficiency. In addition, the gun-powder residue increases the load on the sieve, thus causing its additional stretching. The stretched
sieve does not lie in a single plane with the whole surface, i.e. a certain portion of its area is inclined with respect to the original surface, what additionally aggravates the screening. As the openings are reduced due to inclination, the percentage of the screened gun-powder is decreased. Thus, one can conclude that out of the two tested sieves, the better one to be used is the sieve with the smaller wire diameter and the higher number, i.e. the sieve of type 2 - TYPE 110 N030.

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References
[1] Liu K S 2009 Some factors affecting sieving performance and efficiency, Powder Technology 193(2) 208-213
[2] Zhang B, Gong J, Yuan W, Fu J and Yi H 2016 Intelligent Prediction of Sieving Efficiency in Vibrating Screens, Shock and Vibration 2016 Article ID 9175417, 7 pages
[3] Lawinska K, Modrzewski R 2017 Analysis of sieve holes blocking in a vibrating screen and a rotary and drum screen, Physicochemical Problems of Minerals Processing 53(2) 812-828
[4] Grozubinsky V, Sultanovitch E and Lin I J 1998 Efficiency of solid particle screening as a function of screen slot size, particle size, and duration of screening, International Journal of Mineral Processing 52(4) 261-272
[5] Chen Y H and Tong X 2010 Modeling screening efficiency with vibrational parameters based on DEM 3D simulation, Mining Science and Technology 20(4) 615-620
[6] Bojic N and Stojanovic N 2017 Key performance indicators for production of the screens for paper and pulp industry, XXII international symposium in the field of pulp, paper, packaging and graphics, Zlatibor, Serbia, June 13 - 16, 59-62
[7] Bojic N and Stojanovic N 2018 Risk management of steel and plastic wires used for construction of formatted and dried sieves, XXIII international symposium in the field of pulp, paper, packaging and graphics, Zlatibor, Serbia, June 19 - 22, 101-106
[8] Djokovic J M, Tanikić D I, Nikolić R R and Kalinović S M 2017 Screening efficiency analysis of vibrosieves with the circular vibrations, Civil and Environmental Engineering 13(1) 77-83
[9] Milisavljević J, Ćirić I, Petrović E and Djekić P 2011 Mathematical models behavior of vibrating sieve with and without electric motor with imbalance, 28th Danubia-Adria Symposium on Advances in Experimental Mechanics, Siofok, Hungary, Sept. 28 - Oct. 01, 239-241
[10] Trumić M S and Trumić M Ž 2012 Analysis of Sieving Kinetics of Mineral and Secondary raw Materials, 7th Symposium Recycling Technologies and Sustainable Development, Soko Banja, Serbia, Sept. 5 - 7, 50-55 (In Serbian)
[11] Bojić N V, Nikolić R, Jugović B Z, Jugović Z S and Gvozdenović M 2013 Uniaxial tension of drying sieves, Chemical Industry 67(4) 655-662
[12] Bojic N, Nikolic R, Banic M and Hadzima B 2018 Evaluation of mechanical properties of the two PVC conveyor belts, Communications 20(4) 47-51