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DRUM SCREENS IN MINERAL MINING**

1. Introduction

Drum screens belong to the group of drum machines including also drum granulators, drum mixers (e.g. for granular materials) and other technological equipment. Motion of a granular bed in the drum machine is described by the known analytical relations, where the most important parameter is rotation velocity, called also critical velocity

$$\omega_{kr} = \sqrt{\frac{g}{R}} \left[\frac{\text{rad}}{\text{s}} \right] \text{ or } n_{kr} = \frac{30}{\pi} \sqrt{\frac{g}{R}} - \frac{42.3}{\sqrt{D}} \ [\text{rpm}] \tag{1}$$

R — is the inner radius of the drum and D is its diameter. The velocity of rotations is such a velocity at which forces of gravity and centrifugal force of particles equilibrate and when it is exceeded a simultaneous motion of particles and the drum starts.

The motion of particles in the drum is shown schematically in Figure 1. The layer of granular mineral material is represented by a shaded area, where α is the angle of external friction of material against the drum. During rotary motion the material is elevated at a certain level, determined by angle β ($\beta > \alpha$). This is the so-called angle of elevation which for mineral material is from 40° to 48°. Therefore, many authors [2–4] give a formula to determine the operating speed of a drum screen.

$$n_{rob} = \frac{12}{\sqrt{R}} \ [\text{rpm}] \tag{2}$$

where R is in [m].

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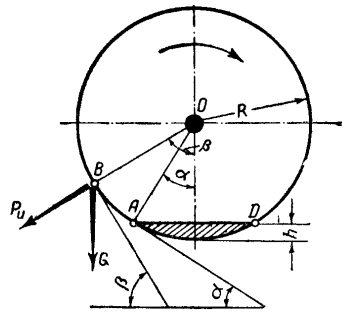
Fig. 1. Lifting of particles in the drum

Table 1 gives diameters and inner radii of drums and critical velocities calculated for them, and also 0.8 n_{kr}, 0.9 n_{kr}, 0.3 n_{kr} and n_{rob}. The drum diameter ranged from 0.5 to 3.0 m, i.e. like in industrial screens.

TABLE 1
Rotational speed and diameters of drum screens

No.	D, m	R, m	n_{kr}, rpm	0.3 n_{kr}	0.8 n_{kr}	0.9 n_{kr}	n_{robr}, rpm
1	0.50	0.250	59.82	17.95	47.86	53.84	24.00
2	0.75	0.375	48.84	14.65	39.07	43.96	19.60
3	1.00	0.500	42.30	12.69	33.84	38.07	16.97
4	1.25	0.625	37.83	11.35	30.26	34.05	15.18
5	1.50	0.750	34.54	10.36	27.63	31.09	13.86
6	1.75	0.875	31.98	9.50	25.58	28.78	12.82
7	2.00	1.000	29.91	8.97	23.93	26.98	12.00
8	2.25	1.125	28.20	8.46	22.56	25.38	11.31
9	2.50	1.250	26.75	8.02	21.40	24.07	10.73
10	2.75	1.375	25.51	7.65	20.41	22.96	10.23
11	3.00	1.500	24.42	7.33	19.54	21.98	9.80

In drum screens 1/6 to 1/8 of the sieve surface is used. This is a serious disadvantage of these screens as compared to screens with flat sieves.

2. Structure and characteristics of drum screens

Figure 2 shows three basic types of drum screens with a central axis (Fig. 2a), with an axis and roller supports (Fig. 2b) and mounted on supports (Fig. 2c). High-speed screens can only be the machines with central axes (pivots) of the screening drum. Low-speed screens can be produced in two other construction variants.
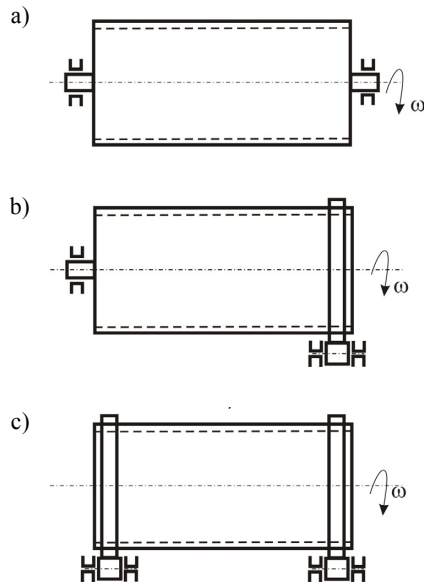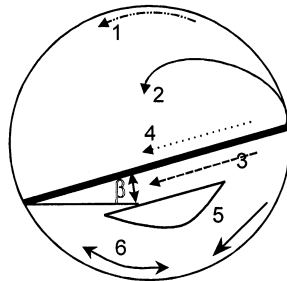
a)

b)

c)

Fig. 2. Drum screens

Fig. 3. Types of granular bed motion
(1 — rotation, 2 — falling. 3 — sliding, 4 — rolling, 5 — slip, 6 — wavy motion)

Figure 3 illustrates types of granular bed motion in the drum. Occurrence of any of the presented types of motion depends on the so-called speed factor of a drum screen, i.e. the ratio of angular velocity of a given screen to rotation (critical) velocity for which motion 1 is specific (Fig. 3). In the existing screens the so called operating speed n_{rob} is used (cf. Tab. 1). It is usually 0.3 of the rotation velocity. In such a case the granular bed in the drum moves with motion 3 or 4 (Fig. 3), and sometimes with motion 5 or 6. From the process point of view, we should reach motion 2 (cascading, cataracting). Then process parameters of screening would be optimal. However, we can achieve this motion at the speed factor 0.8 to 0.9, and not 0.3. A solution in which advantageous, cataracting motion of the granular bed can be achieved in the drum is to apply inner baffles that elevate screened material to a certain level, afterwards, the material slides down the baffle and falls to the drum bottom. Similar effects

are obtained when instead of a cylindrical drum, a prism on a regular polygon base, e.g. hexagon, is used. In the currently applied drums, tangential velocity of the sieve cylinder is in the range $u_0 = 0.7$ to 1 m/s.
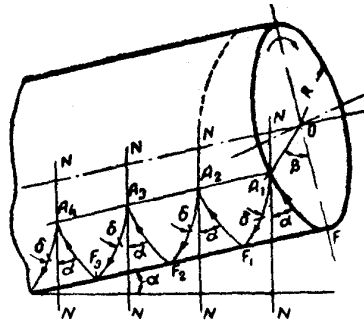

Fig. 4. Particle velocity along the sieve drum

Another important issue that occurs in drum screens is the determination of axial velocity of a granular stream moving along the drum axis. It determines flow capacity of the machine which is necessary in process calculations of the drum machine. A schematic used to identify transport velocity in the drum, is shown in Figure 4. When particles are elevated it moves along line FA, and when they fall down — along line AF. If the angle of drum inclination to the level is α then also α is the angle of inclination of line FA to the level, and angle δ is the angle of inclination of line AF. It is equal to $\delta + \alpha \approx 2\alpha$. Curves FA are the elevation curves, while curves AF — the falling curves. The transport velocity can be calculated from the semi-empirical formula

$$\upsilon = 0.105 Rn \, \mathrm{tg}(2\alpha) \, [\mathrm{m/s}] \tag{3}$$

where drum radius R is given in m, and rotational speed in rpm.

If h is the thickness of granular layer in the drum (cf. Fig. 1) the drum screen capacity is determined by the following formula.

$$Q[\mathrm{Mg/h}] = 0.72 \mu \gamma n \, \mathrm{tg}(2\alpha) \sqrt{R^3 h^3} \tag{4}$$

where loosening coefficient $\mu \approx 0.8$–0.6, parameters R and h are given in m, and specific mass γ in kg/m^3. In practice, it is assumed that h ranges from a double equivalent diameter of average feed particles to the double mesh size. For minerals this is from 1–5 cm to 12–15 cm.

A serious problem in drum screens is power required to put the drum in rotary motion. Figure 5 shows characteristics of the drum screen which are necessary to identify the drive power. We assume that the coefficient of mineral friction against the drum is $f = 0.4$, and the coefficient of friction of pivots of support rollers is $f1 = 0.1$, rolling friction coefficient of the rollers on the drum circumference is $k = 0.5$ mm, angle $\varphi = 35°$, while the ρ/r radii ratio is 0.25.
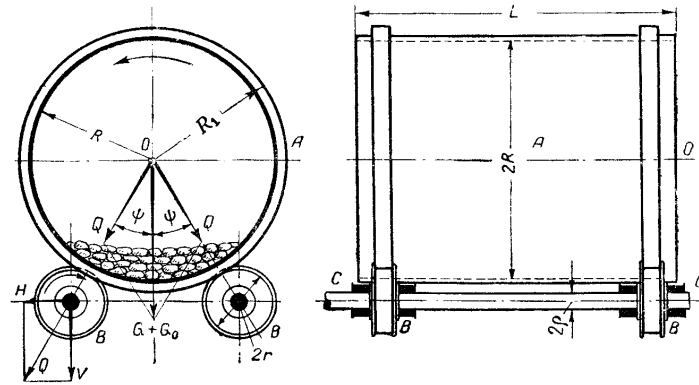
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Fig. 5. Determination of power required by screen drive

Power required to put the screen in rotary motion is

$$N = \frac{R \cdot n \left(G + 13 G_0 \right)}{21\,500} \ [\text{kM}]$$

(5)

where:

G — total drum weight, kG;

G_0 — weight of aggregates in the drum, kG;

R — drum radius, m;

N — drum revolutions, rpm.

Formula (5) was quoted in the original version [2–4] and that is why MKS units were used in it.

Capacity of screens is determined using a diagram shown in Figure 6. Screening capacity in Mg/h is drawn on the axis of abscissae, while on the axis of ordinates the diameter of round mesh is given in mm. Particular lines are valid for drum diameter in m. The whole diagram was prepared for 1 running meter of the drum length. In the case of minerals, the drum diameter is determined from the empirical formula

$$D = 20.23 \sqrt{\frac{Q}{\gamma}}$$

(6)

where:

D — drum diameter, m;

Q — capacity, Mg/h;

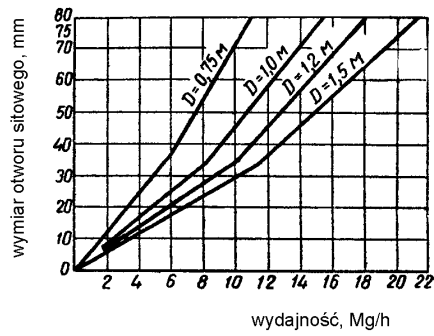γ — specific gravity, g/cm^3.

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Fig. 6. Determination of screen capacity

3. Design solutions of drum screens

Table 2 shows parameters characteristic of drum screens used in mineral processing.

TABLE 2

Parameters of drum screens

| $D \times L$ drum, mm	Q, capacity; $d = 75$ mm		Power, kM	N, rpm	Screen weight, Mg
	Initial screening	Accurate screening			
600 × 1800	18	8	3	26	1.36
600 × 3600	40	18	4	26	1.67
800 × 2400	36	16	4	22	2.54
800 × 4200	72	32	5	22	2.85
1000 × 3000	60	27	8	18	3.60
1000 × 6000	125	60	12	18	4.85
1000 × 6000	90	40	10	16	5.90
1200 × 6000	165	77	14	16	7.09
1500 × 3600	110	50	12	14	9.52
1500 × 6000	230	105	18	14	12.70
1800 × 4200	230	77	16	12	13.60
1800 × 7200	270	135	20	12	18.14
2100 × 4200	230	115	20	10	18.14
2100 × 9000	450	230	25	10	23.58
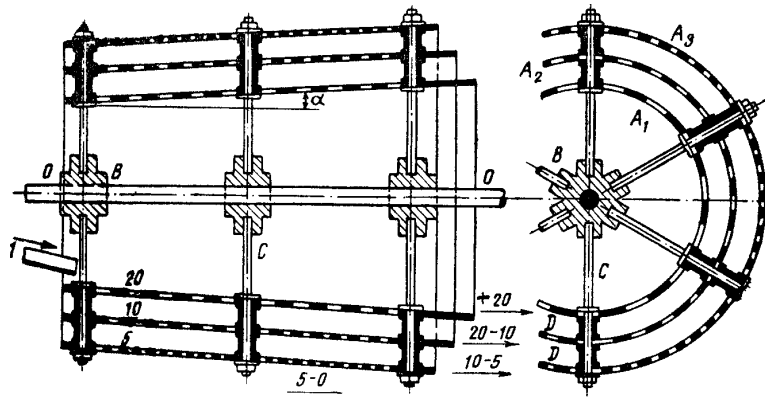
Fig. 7. Conical co-axial sieves

Sieves of drum screens can be not only cylindrical but also conical, as shown in Figures 7 and 9. The use of a conical sieve enables screening of granular material along the sieve, at the inclination of its axis $\alpha = 0$ (horizontal screen axis). Additionally, in the case of conical and cascade sieves (Fig. 8), a speed factor changes in one screen which is advantageous, because at the end of the drum the feed is partly screened off and has a changed particle size distribution. In the screened material most of particles are big, as majority of very fine ones have already been screened off.
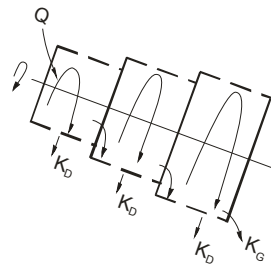
Fig. 8. Schematic of a cascade drum screen
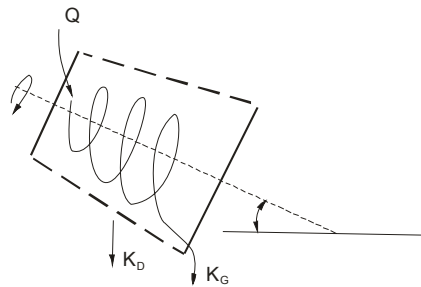
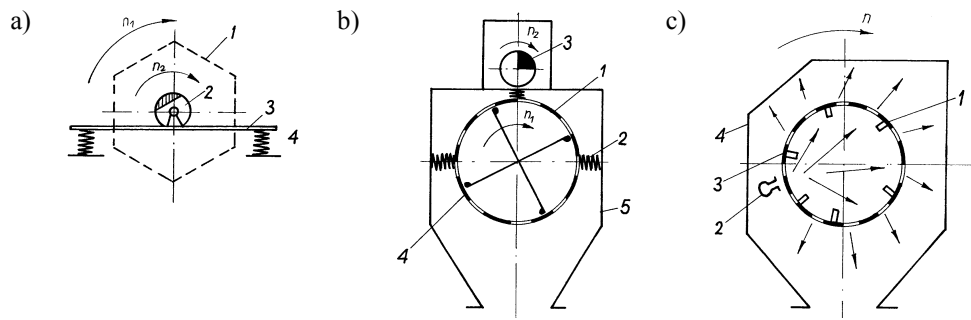**Fig. 9.** Schematic of a conical drum screen

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Fig. 10. Drum screens

Other modifications of drum screens are shown in Figure 10. Well known are drums in the form of prisms with the base of regular polygons, e.g. hexagon — Figure 10a. Additionally, to such a drum screen vibrating drive was connected, which ensured vibrations of the drum axis. Another type of the drum screen is illustrated in Figure 10b, where beside vibrations of the whole screen, there is a motion of the cross cleaning drum and supporting the screening process. In some cases, e.g. screening of fine-grained materials, mesh cleaning is effected by blowing air into the drum (Fig. 10c).

4. Conclusions

Drum screens can be used in both dry and wet processes. Interesting is the result of studies on industrial drum screens, obtained for mineral aggregate screening. It appeared that wet screening, at maintaining all characteristic values of the process, gives about 1.7 times higher process efficiency than dry screening.

It can be assumed that for rock material dry screening efficiency in the drum screen is 6.5 Mg per 24 h from 1 m^2 of sieve surface. This value refers to 1 mm mesh diameter. In the case of wet screening the efficiency is 11 Mg per 24 h and 1 m^2, at 1 mm mesh. At bigger mesh the efficiency grows proportionally.

The angle of drum axis inclination is from 1° to 14°, but most frequently from 4° to 7°. Screening efficiency in industrial screening of rock material in drum machines is in the range η = 40 to 60%.

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