REGULARITIES OF OUTFLOW OF BULK MATERIAL FROM HOLES

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The process of outflow of bulk material from holes occurs during various technological processes. Bulk material is extracted from silos intended for storing grain, various building materials (sand, crushed stone, cement), blasted ore is extracted from collapsed blocks under the influence of gravity, etc.

It has been established that during underground mining as a result of the extraction of minerals, the overlying rock blocks move under the influence of gravity, trying to fill the resulting voids, in other words, the process of outflow of bulk material takes place.

Knowledge of the patterns of formation and change of zones in which the movement of rocks occurs is of great practical and scientific interest, since these zones influence the processes of displacement of the earth's surface, deformation and the emergence of areas of high or low rock pressure.

The patterns of movement of particles of bulk material were most fully studied when modeling ore mining processes under collapsed overlying rocks in the works of V.V. Kulikova [1], G.M. Malakhov and other authors.

According to V.V. Kulikov, the outflow of bulk materials occurs from volumes that are close in shape to ellipsoids of revolution (Fig. 1).

The property of the outlet ellipsoid 1 is such that particles located on its surface arrive at the outlet hole simultaneously.

The particles move towards the outlet along parabolic trajectories. In this case, only a certain part of the bulk material moves, which goes through the loosening stage and also has the shape of an ellipsoid of rotation, called loosening ellipsoid 2.

As the bulk material is extracted, the loosening ellipsoid increases, forming a paraboloid - the limiting boundary of the area of influence of the outlet, beyond which the particles remain motionless when any amount of material is extracted.

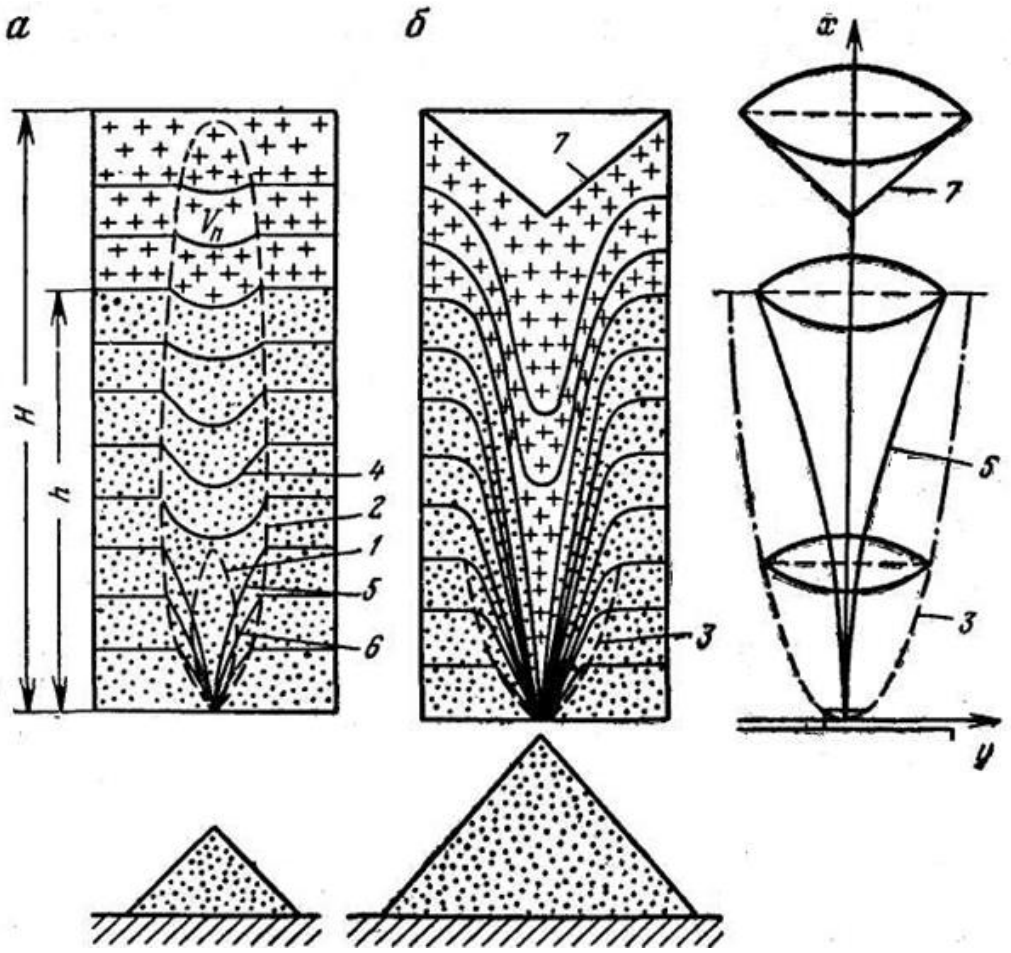

Figure 1. Formation of the release ellipsoid, deflection, penetration, release and destruction funnels: a – the first stage of release; b – exit of the loosening ellipsoid to the surface [1].

In the volume of the loosening ellipsoid, the initially horizontal surfaces take the form of funnels, called deflection funnels 4. When the deflection funnel reaches the outlet, it is called the penetration funnel 5. Subsequently, an outlet funnel 6 is formed. When the loosening ellipsoid reaches the earth's surface, a destruction sinkhole funnel or displacement trough is formed on it 7.

For a mathematical description of the zones of movement of particles of a granular medium, V.V. Kulikov proposed the universal equation

$$y^2 = 2pxk, \tag{1}$$

$$k = 1 - \sqrt{1 - \frac{x^2}{\eta h^2}}, \tag{2}$$

where p – the focal parameter of the parabola, m; η – the coefficient of secondary loosening of rocks in the loosening ellipsoid; h – height of the release ellipsoid, m.

When k = 1, equation (1) turns into the canonical equation of a parabola $y^2 = 2pxk$, while $k \neq 1$ equation (1) is the equation of an ellipse or funnels of deflection, penetration, release.

The focal parameter p is an integral indicator that takes into account the complex of physical and mechanical properties of rocks that affect their flowability or shearability and is therefore called the flowability or shearability indicator [1]. Together with the coefficient of secondary loosening η, the shear index p uniquely determines the shape of the zones of influence of the goaf for specific mining and geological conditions.

An important property of elliptical zones of motion of a discrete medium is the movement of particles along parabolic trajectories, which move from the surface of one ellipsoid to another, located closer to the outlet and occupy a position relative to its vertex, characterized by a constant number. Based on this, the equation for the trajectory of movement of particles of bulk material is obtained

$$y^2 = \frac{xy_0^2}{x_0}, \tag{3}$$

where x_0, y_0 − the initial coordinates of the particle.

When releasing bulk material with a volume q, a loosening zone appears, within the boundaries of which so-called ellipsoids of motion can be distinguished, on the surface of which there are particles of bulk material (Fig. 2). Particles move along trajectories described by equation (3). In this case, particles located on the surface of the ellipsoids of motion move to the surface of the underlying ellipsoids, the volumes of which differ from each other by the volume of the extracted ellipsoid q.

It can be seen from the figure that the velocities of particles when moving from the surface of one ellipsoid to another increase as they approach the outlet, and the differences in the volumes of adjacent ellipsoids remain constant and equal to q.

Knowing the initial coordinates of the particles, it is possible to determine their coordinates after moving as a result of extracting a certain volume of bulk material.

The described scheme of particle movement in the area of influence of the outlet can be successfully used to study the patterns of formation of zones of displacement and deformation resulting from the extraction of bulk materials from containers, predicting ore extraction rates, and displacements of the earth's surface.

Work [2] describes a method for predicting movements of rocks and the earth's surface during underground coal mining, based on the representation of the extracted coal seam in the form of separate zones that initiate the occurrence of areas of movement. As a result of their combined influence, a displacement trough is formed on the earth's surface.

Using the magnitude and direction of particle movement vectors, it is possible to calculate subsidence of the earth's surface, horizontal displacements, inclinations, curvature, tension and compression.

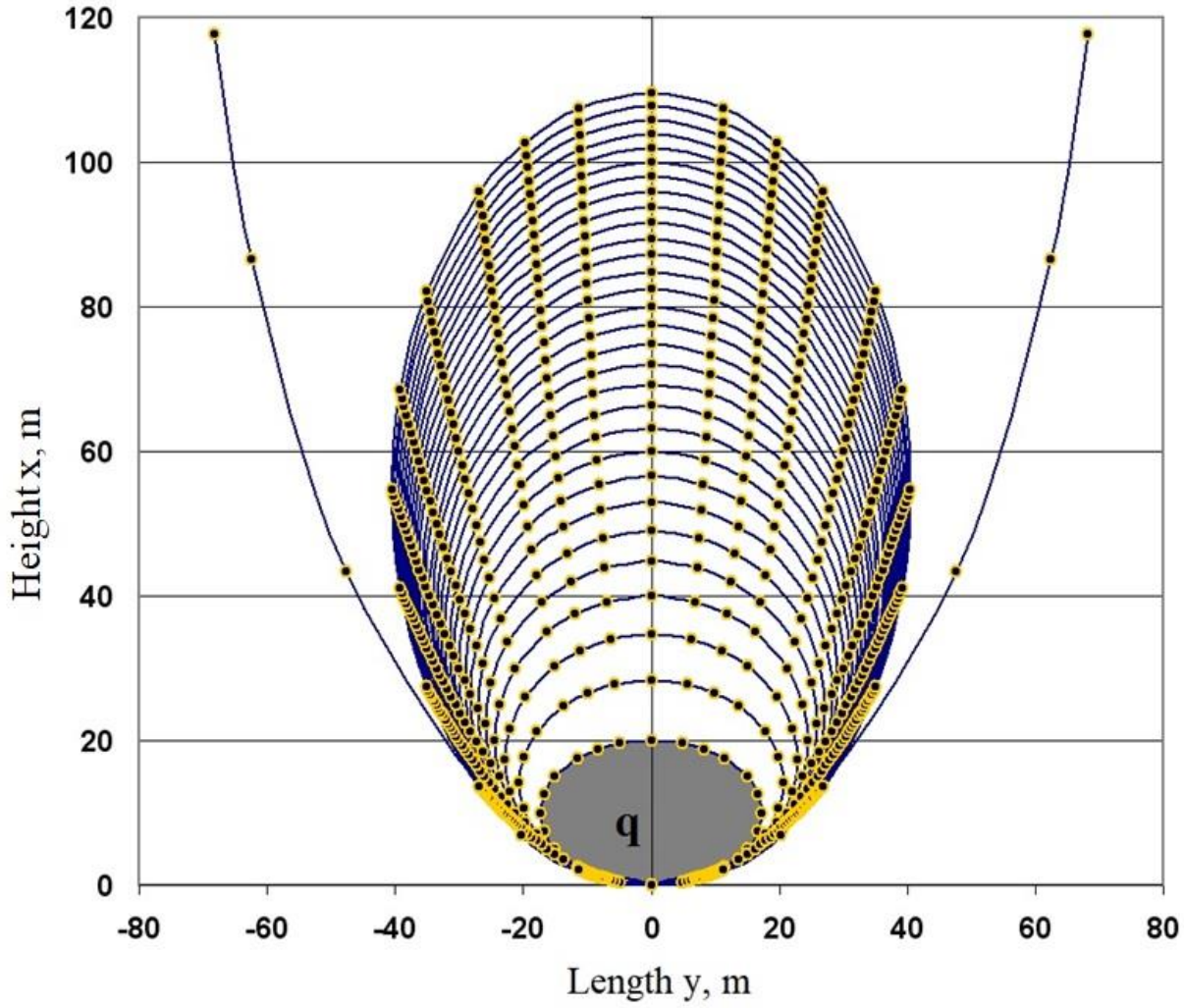

Figure 2. Trajectories of movement of particles of bulk material during the transition from ellipsoid to ellipsoid during the outflow process.

Thus, knowing the patterns of movement of particles of bulk material, it is possible to study the processes that occur during the flow of grain or building materials from containers, the extraction of ore from collapsed blocks, and the displacements of rocks and the earth's surface.

References:

1. Kulikov V V 1980 Discharge of Ore [Vypusk rudy – in Russian] (Moscow: Nedra).

2. Kodunov B A 1991 Method for predicting displacements of rocks and the earth's surface during underground mining of coal deposits [Metod prohnozyrovanyia sdvyzhenyi hornykh porod y zemnoi poverkhnosty pry podzemnoi razrabotke uholnykh mestorozhdenyi – in Russian] J. Uhol 2 54 – 56.