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## **MOVING PARAMETER RESEARCH OF THE INCLINED MOBILE SURFACE USED FOR MATERIAL SEPARATION**

*Analytical expressions for determination of row of parameters of motion sounding board of oscillation pneumatic separator are presented, that can be used for research of particles moving on the surface of board.*

*Problem and its connection with scientific and practical problems.* It is known, that gravitational processes are the most economic in connection with rather low cost of the used equipment, adjustment simplicity, satisfactory results of works, a wide spectrum of control facilities and automation. Numerous researches of various authors develop theoretical bases of the gravitational division versions, which are well agreed with practice results. Every such a way has the specific features which define parameters of movement and grain mass division with distinguished properties. Mobile inclined planes [1-3] are used in a lot of various material separation processes.

Division is applied to fine granular materials in a thin water layer jetting on a mobile inclined surface – concentration on tables. This method has quite high efficiency for particles sized of 0,1-10 mm [1, 4, 5]. For larger pieces dry separation was widely used lately. Interest to this process has recently renewed again in connection with necessity of preliminary processing of mine rock mass for decrease raw coal ash and quantity of transported gob, and also at a secondary stage of coal measure recycling terrace, that is especially actual in modern conditions. In these processes particle movement depends on some parameters, one of which is moving of the inclined plane providing division.

In this connection an actual scientific – practical problem is consideration of the kinematics circuit of air-operated vibrato separator and connection of moving parameters of its decks with division parameters.

*The analysis of researches and publications.* Use of an air-operated vibrato separation method allows to create small-sized, compact and mobile concentrating complexes with an all-the-year-round work cycle (MOK-CBII). Thus there is an opportunity of process key parameters regulation of enrichment and automated management. The positive factor is independence of water resources and buildings for warehousing high humidity products [6-9].

Development of faculty MDD DNTU promoted fast construction and start-up of factories with a pneumatic enrichment method on mines of Leninsk – Kuznetsk and Prokopevsk in the twentieth century. During this period and later there were 13 concentrating factories and 10 concentrating plants which annually processed more than 30 million ton of coal or about 8 % of all enriched coal in the USSR [4].

## Gravity separation

*Problem statement.* The purpose of this work is parameter research of moving air-operated vibrato separator decks.

*A material statement and results.* Air-operated vibrato separator represents mechatronic system consisting of mechanical, electric parts and a control system. The mechanical separator part is system of the solid bodies connected by special devices, named in mechanics connections (fig. 1).

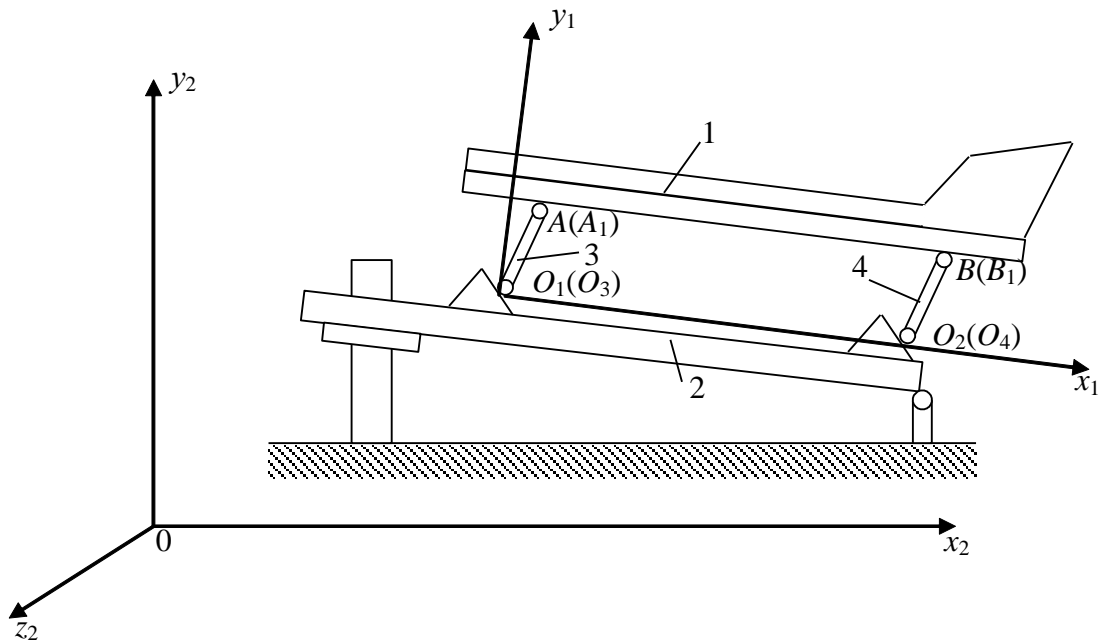


Fig. 1. The constructive circuit of a separator mechanical system

The basic part of a separator – a deck or working body (a body 1). A deck fastens to a frame (a motionless body 2) with the help of four drafts structurally realized as identical cylindrical cores (a body 3, 4, 5, 6). Connection of cores with screen deck and a frame is carried out with the help of cylindrical hinges: cores are connected to a frame with the help of hinges  $O_1$ ,  $O_2$ ,  $O_3$ ,  $O_4$  and with deck by means of hinges  $A$ ,  $B$ ,  $A_1$ ,  $B_1$ . In an equilibrium condition a deck hinged bases on an electromotor axis creating in operating conditions vibrating deck movements. Hinges  $O_1$  and  $O_2$  can move along an inclined plane – frames 2 with the purpose of core inclination corner changes to a straight line which passes through points  $O_1 O_2$  (an axis  $x_1$ ) (fig. 1).

Deck makes plane-parallel movement as the design does not turn around of a vertical axis  $y_2$  and perpendicular to it axis  $x_2$ . Hence, all mechanism sections move equally in planes which are parallel to motionless plane  $Ox_2y_2$ . It is enough to consider movement of one such section. For convenience the section which passes through drafts 3, 4 is chosen. The coordinate system of  $Ox_1y_1$  is inserted into this section plane. Thus the axis  $x_1$  is directed on piece  $O_1O_2$ , parallel a frame and axis  $y_1$  is perpendicular to axes  $x_1$ . The kinematics separator circuit with all values necessary for calculation is submitted on fig. 2.

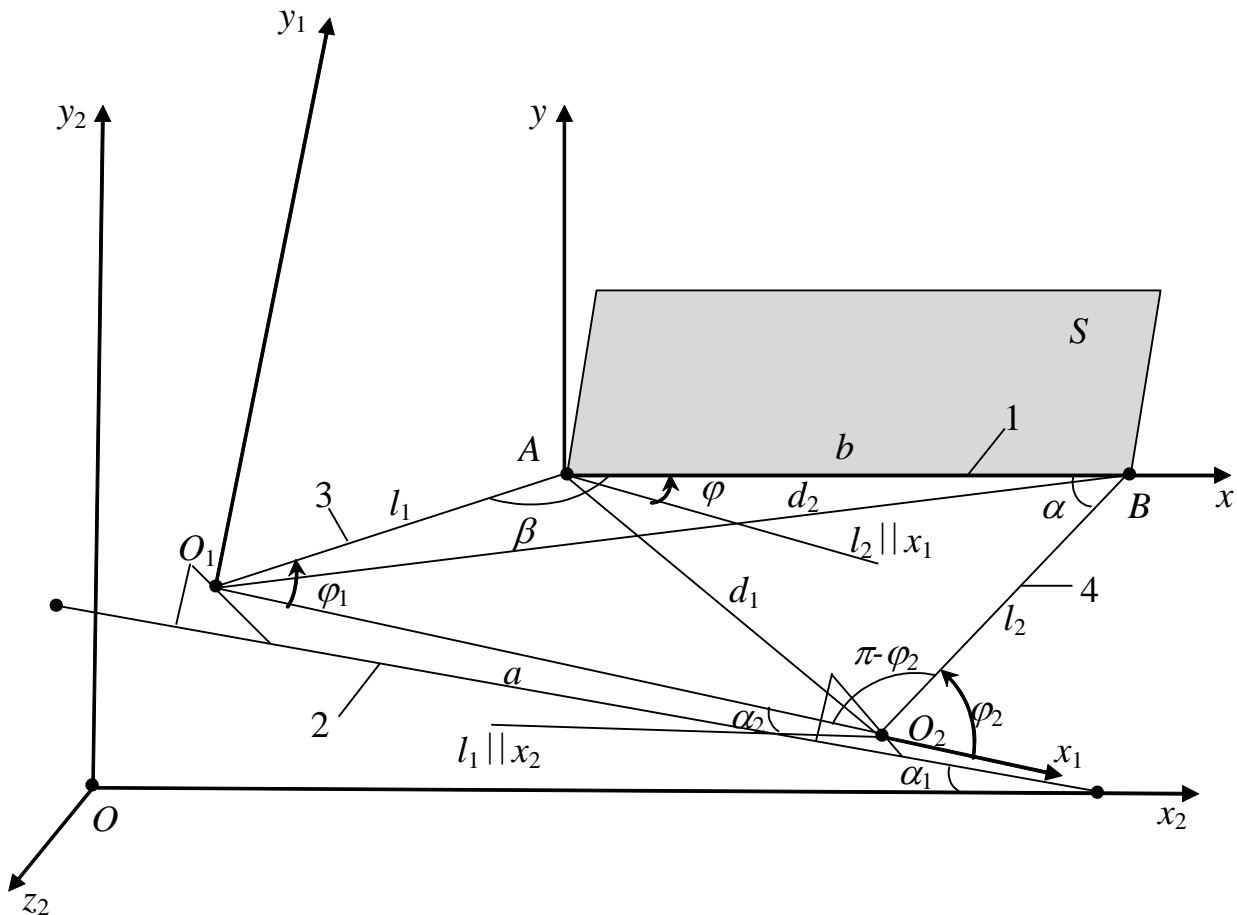


Fig. 2. The kinematics separator circuit

For the definition of deck movement and the equations of its movement it is necessary to consider deck movement in the received coordinate system. Because deck makes flat movement, it is enough to consider movement of its section  $S$  in plane  $O_1x_1y_1$  (fig. 2). It is possible to set flat figure movement with the help of its pole coordinates and a turn corner around of a pole. The point  $A$  is chosen as a pole. Its coordinate in motionless coordinate system  $O_1x_1y_1$  are designated as  $x_A, y_A$  and are determined on dependences:

$$x_A = l_1 \cdot \cos \varphi_1;$$

$$y_A = l_1 \cdot \sin \varphi_1, \quad (1)$$

where  $l_1$  – length of core  $O_1A$ ;  $\varphi_1$  – a corner formed by core  $O_1A$  with an axis  $x_1$  ( $\varphi_1 = \angle AO_1O_2$ ).

The mobile system of coordinates  $Axy$ , which axis  $x$  is directed on lines  $AB$  and an axis  $y$  is perpendicular to it, is connected to plane  $S$ . The corner formed by an axis  $x$  (or  $AB$ ) and a straight line  $l_2$  parallel  $x_1$ , is designated as  $\varphi$ . At the mechanism movement the coordinate  $x_A, y_A, \varphi$  are functions of time  $t$ :

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$$x_A = x_A(t); \quad y_A = y_A(t); \quad \varphi = \varphi(t). \quad (2)$$

The equations (2) represent the equations of the deck movement law.

For parameter calculations the following designations for distances and corners are accepted:  $l_1 = O_1A$  – length of tag 3 (a core  $O_1A$ );  $l_2 = O_2B$  – length of tag 4 (a core  $O_2B$ );  $a = O_1O_2$  is a distance between hinges  $O_1$  and  $O_2$ ;  $b = AB$  is a distance between hinges  $A$  and  $B$ ;  $d_1 = O_2A$ ,  $d_2 = O_1B$  are diagonals of quadrangle  $O_1ABO_2$ ;  $\varphi_2$  is a corner formed by core  $O_2B$  with an axis  $x_1$ ;  $\alpha_1$  is a corner formed by a frame 2 with axis  $x_2$ ;  $\alpha_2$  is a corner between axes  $x_1$  and  $x_2$ ;  $\alpha = \angle ABO_2$ ;  $\beta = \angle O_1AB$ ;  $\alpha_2$ ;

Рассматриваемая механическая система является системой с одной степенью свободы, ее положение можно задать с помощью угла. Координаты полюса  $A$  вычисляются через значение угла  $\varphi_1$  с помощью соотношений (1).

Выразим угол  $\varphi$  через угол  $\varphi_1$ :

The examined mechanical system is system with one degree of freedom, it is possible to set its position with the help of  $\varphi_1$  corner. A pole  $A$  coordinates are calculated by means of corner  $\varphi_1$  value with the help of ratio (1).

Let's express corner  $\varphi$  through corner  $\varphi_1$ :

$$\varphi = \varphi_1 - (\pi - \beta). \quad (3)$$

Corner  $\beta$  can be determined from triangle  $O_1AB$  under the cosine theorem:

$$d_2^2 = l_1^2 + b^2 - 2l_1b \cos \beta.$$

From triangle  $\Delta O_1BO_2$  on the cosine theorem it is received:

$$d_2^2 = l_2^2 + a^2 + 2l_2a \cos \varphi_2.$$

From last two ratio it follows, that

$$l_1^2 + b^2 - 2l_1b \cos \beta = l_2^2 + a^2 + 2l_2a \cos \varphi_2$$

From this equation it is expressed  $\cos \beta$  from  $\cos \varphi_2$ :

$$\cos \beta = a_1 - a_2 \cos \varphi_2, \quad (4)$$

where

$$a_1 = \frac{b^2 - a^2 + l_2^2 - l_1^2}{2l_2b} \quad a_2 = \frac{al_1}{bl_2} \quad (5)$$

In that particular case, when cores  $O_1A$  and  $O_1B$  have identical length ( $l_1 = l_2 = l$ ), we get:

$$a_1 = \frac{b^2 - a^2}{2lb} \quad ; \quad a_2 = \frac{a}{b} \quad (6)$$

Then

$$\beta = \arccos(a_1 - a_2 \cos \varphi_2) \quad (7)$$

Further it is necessary to express a corner  $\varphi_2$  through a corner  $\varphi_1$ . It is necessary to establish connection between corners  $\varphi_2$  and  $\varphi_1$  and the sizes of a design. On property of quadrangle  $O_1O_2BA$  corners:

$$\varphi_1 + \alpha + \beta + \pi - \varphi_2 = 2\pi,$$

or

$$\varphi_1 - \varphi_2 + \alpha + \beta = \pi \quad (8)$$

Let's calculate corner  $a$ . From triangle  $O_2AB$  under the cosine theorem we have:

$$d_1^2 = l_2^2 + b^2 - 2l_2b \cos \alpha$$

From triangle  $O_1O_2A$  under the cosine theorem:

$$d_1^2 = l_1^2 + a^2 - 2l_1a \cos \varphi_1$$

From last two ratio it follows, that:

$$l_2^2 + b^2 - 2l_2b \cos \alpha = l_1^2 + a^2 - 2l_1a \cos \varphi_1$$

From this equation it is easy to express  $\cos \alpha$  from  $\cos \varphi_1$ .

$$\cos \alpha = a_1 + a_2 \cos \varphi_1 \quad (9)$$

Then corner  $a$  is defined as:

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$$\alpha = \arccos( a_1 + a_2 \cos \varphi_1 ) . \quad (10)$$

Let's substitute values of corners  $\alpha$ ,  $\beta$  according to (7), (10) in the equation (8):

$$\varphi_1 - \varphi_2 + \arccos( a_1 + a_2 \cos \varphi_1 ) + \arccos( a_1 + a_2 \cos \varphi_2 ) = \pi . \quad (11)$$

If we use an auxiliary corner  $\varphi_2'$  □

$$\varphi_2' = \pi - \varphi_2 , \quad (12)$$

then equation (11) can be written down as:

$$\varphi_1 + \arccos( a_1 + a_2 \cos \varphi_1 ) + \varphi_2' + \arccos( a_1 + a_2 \cos \varphi_2' ) = 2\pi . \quad (13)$$

The equation (11) or (12) is the equation of connection between corners  $\varphi_1$  and  $\varphi_2$  in the implicit form:

$$F( \varphi_1, \varphi_2 ) = 0 . \quad (14)$$

For the further researches it is convenient to have explicit connection of corners:

$$\varphi_2 = f_1( \varphi_1 ) . \quad (15)$$

For this problem decision we write down a ratio (13) as:

$$\varphi_2 + \beta = 2\pi - ( \varphi_1 + \alpha ) . \quad (16)$$

From equality of corners their cosine equality follows also:

$$\cos( \varphi_2' + \beta ) = \cos( \varphi_1 + \alpha ) \quad (17)$$

or

$$\cos \varphi_2' \cos \beta - \sin \varphi_2' \sin \beta = c , \quad (18)$$

where

$$c = \cos(\varphi_1 + \alpha) \quad (19)$$

Having calculated

$$\cos \beta = a_1 + a_2 \cos \varphi_2', \quad \sin \beta = \sqrt{1 - (a_1 + a_2 \cos \varphi_2')^2} \quad (20)$$

and having designated

$$x = \cos \varphi_2', \quad (21)$$

we write down ratio (18) as

$$x(a_1 + a_2 x) - \sqrt{(1 - x^2)(1 - (a_1 + a_2 x)^2)} = c \quad (22)$$

Let's get rid of the equation irrationality:

$$\sqrt{(1 - x^2)(1 - (a_1 + a_2 x)^2)} = c - (a_1 + a_2 x)x,$$

$$(1 - x^2)(1 - (a_1 + a_2 x)^2) = c^2 - 2c(a_1 + a_2 x)x + (a_1 + a_2 x)^2 x^2,$$

$$1 - x^2 - (a_1 + a_2 x)^2 + x^2(a_1 + a_2 x)^2 - c^2 + 2c(a_1 + a_2 x)x - (a_1 + a_2 x)^2 x^2 = 0$$

or

$$(a_2^2 - 2ca_2 + 1)x^2 + 2a_1(a_2 - c)x + a_1^2 + c^2 - 1 = 0 \quad (23)$$

Roots of a quadratic equation (23) are determined as:

$$x_{1,2} = \frac{a_1(c - a_2) \pm \sqrt{D}}{a_2^2 - 2ca_2 - 1}$$

As  $x = \cos \varphi_2' \leq 0$ , the negative root is chosen only:

$$\cos \varphi_2' = \frac{a_1(c - a_2) - \sqrt{D}}{a_2^2 - 2ca_2 - 1} \quad (24)$$

From this equation we find explicit dependence of a corner  $\varphi_2$  on  $\varphi_1$ :

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$$\varphi_2 = \pi - \arccos \left( \frac{a_1(c - a_2) - \sqrt{(c^2 - 1)(a_1^2 - a_2^2 + 2ca_2 - 1)}}{a_2^2 - 2ca_2 - 1} \right), \quad (25)$$

where

$$c = \cos(\varphi_1 + \arccos(a_1 + a_2 \cos \varphi_1)), \quad (26)$$

or  $c = \cos \varphi_1 (a_1 + a_2 \cos \varphi_1) - \sin \varphi_1 \sin(a_1 + a_2 \cos \varphi_1),$

or  $c = \cos \varphi_1 (a_1 + a_2 \cos \varphi_1) - \sqrt{(1 - \cos^2 \varphi_1)(1 - (a_1 + a_2 \cos \varphi_1)^2)},$

or

$$c = y(a_1 + a_2 y) - \sqrt{(1 - y^2)(1 - (a_1 + a_2 y)^2)}, \quad (27)$$

where

$$y = \cos \varphi_1. \quad (28)$$

Finally connection between corners  $\varphi$  and  $\varphi_1$  is received.

$$\varphi = \pi + \varphi_1 + \arccos(a_1 - a_2 \cos \varphi_2), \quad (29)$$

where according to (25)

$$\varphi_2 = f_1(\varphi_1), \quad (30)$$

$$f_1(\varphi_1) = \pi - \arccos \left( \frac{a_1(c - a_2) - \sqrt{(c^2 - 1)(a_1^2 - a_2^2 + 2ca_2 - 1)}}{a_2^2 - 2ca_2 - 1} \right), \quad (31)$$

$$c = y(a_1 + a_2 y) - \sqrt{(1 - y^2)(1 - (a_1 + a_2 y)^2)}, \quad (32)$$

$$y = \cos \varphi_1. \quad (33)$$

*Conclusions and directions of the further researches.* The carrying out analytical researches of deck movements and the equations of its movement in the chosen system of coordinates have allowed to receive expressions for definition of some para-



meters which can be used at studying moving grains on a surface decks. The further researches is necessary to direct on getting of expressions for speed definition of a pole decks and its angular speed, and also on an establishment of movement deck parameter connection with various material division parameters on an inclined mobile surface.

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