# Influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels

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Received May 27.2014: accepted June 13.2014

S u m m a r y . The mathematical model that determines influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels is obtained and experimentally tested. Using the obtained mathematical model, influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels is investigated.

K e y w o r d s : conveyor, air cushion, lift force, traction force

## INTRODUCTION

At the modern industrial enterprises the main volume of loads transportation is carried out by means of conveyor transport to which, in particular, conveyors on an air cushion with inclined round channels belong. Conveyors on an air cushion with inclined round channels represent one of perspective types of conveyor transport. These conveyors can be used for transportation of loads on separate technological operations in line production (Fig. 1, a), for transportation of loads in warehouses in the course of an order complete set (Fig. 1, b), for transportation of loads through hardening, heating, drying furnaces

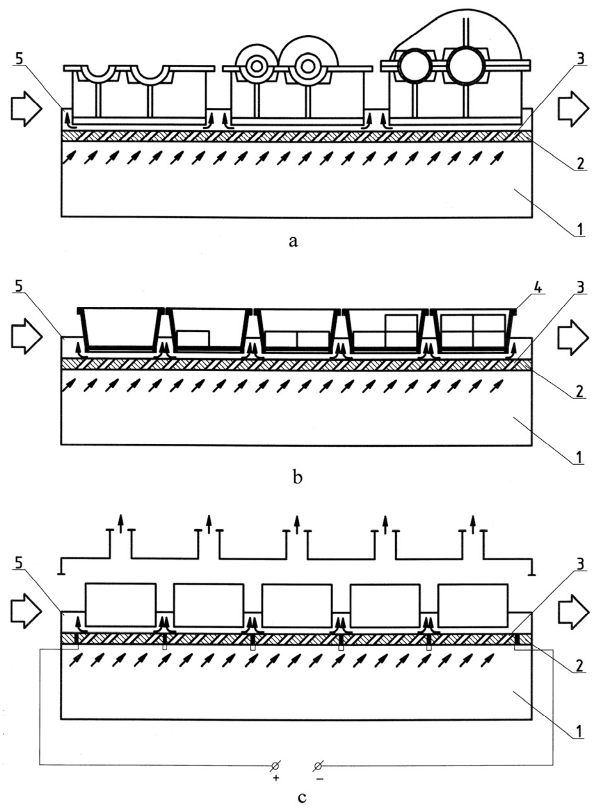


**Fig. 1.** Characteristic examples of use of conveyors on an air cushion with inclined round channels: 1 – air receiver, 2 – nozzle, 3 – channel, 4 – container, 5 – guide

and cooling cameras (Fig. 1, c), and also for other transport and logistic operations which are connected to transportation of piece loads. Owing to absence of a traction organ, and also the drive, conveyors on an air cushion with inclined round channels in comparison with traditional types of conveyors have a row of advantages, somehow: simplicity of construction, the low level of noise, safety of maintenance in an explosive environment, possibility of combination of operations of transportation and heat treatment of loads. However, despite existence of these advantages, conveyors on an air cushion with inclined round channels have rather limited application. This circumstance is connected to small study of these conveyors, in particular, their traction qualities.

## MATERIALS AND METHODS

The simplest theory of the device, made in the form of conveyors on an air cushion, in which the bearing layer is formed by the system of discrete air jets, was proposed by Bobrov V. [1]. A contribution to the development of theory of vehicles on the air cushion was made by Bitukov V., Kolodezhnov V. [2, 3], Khanzhonkov V. [5, 6], Murzinov V. [9], Nechaev G. [10], Pang M. [11], Sarsenova G. [13], Song R. [14], Turushin V. [15-18] and other scientists. But the questions that relate to the study of influence of construction parameters on traction qualities of conveyors on an air cushion with inclined round channels were not studied in the works of these authors.

The research results of aircrafts and ships with support devices on an air cushion are presented in work of Lu J., Huang G., Li S. [7, 8], Yun L., Bliault A. [19], Zalewski W. [20], Zhou J., Guo J., Tang W., Zhang S. [21, 22]. In work of Dreszer K.A., Pawlowski T., Zagajski P. [4] the process of grain transportation by means of screw conveyors is studied. However, the results of this works may not be used in the study of traction qualities of conveyors on an air cushion.

The scientific work of Złoto T. and Nagorka A. [23] is devoted to research of the pressure distribution of oil film in the variable height gap between the valve plate and cylinder block in the axial piston pump. But, physical properties of air and oil are various different. Thus, transferring obtained in this work the results for the case of conveyors on an air cushion with inclined round channels is not possible.

## AIM AND TASKS OF RESEARCH

The aim of our research is analysis of influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels. To achieve this aim it is necessary to solve the following tasks:

– obtainment of mathematical model that determines influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels,

– experimental test of the obtained mathematical model,

– study of the obtained mathematical model.

## RESULTS OF RESEARCH

For load that moves through the conveyor on an air cushion with inclined round channels (Fig. 2.), Newton's second law is:

$$m\vec{a} = \vec{F}_y + \vec{F}_x + \vec{G} + \vec{W}, \qquad (1)$$

where: $m$ – the load mass, $\vec{a}$ – the load acceleration, $\vec{F}_y$ – the lift force, $\vec{F}_x$ – the traction force, $\vec{G}$ – the load weight, $\vec{W}$ – the motion resistance force.

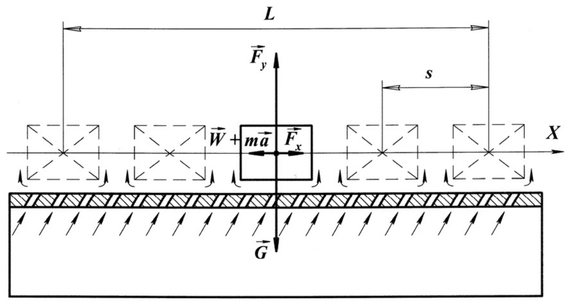


**Fig. 2.** Calculation scheme of the conveyor on an air cushion with inclined round channels

Projecting this equation on the X-axis directed along the trajectory of load, have:

$$ma = F_x - W,$$

from which:

$$F_x = W + ma. \tag{2}$$

Due to the fact that the motion resistance force is determined by the relation:

$$W = wG,$$

mass and weight are connected by the depend:

$$m = G/g,$$

and also that:

$$G = F_y,$$

where: $w$ – the motion resistance force coefficient, $g$ – the free fall acceleration, Eq. 2 can be written in the form:

$$F_x = F_y\left(w + \frac{a}{g}\right). \tag{3}$$

Accepting that the movement of load is uniformly accelerated and that the initial velocity of the load is equal to zero, we obtain:

$$a = \frac{2L}{t^2}, \tag{4}$$

where: $L$ – the conveyor length, $t$ – the time of load transportation.

The time of load transportation can be calculated by the formula:

$$t = \frac{L}{V_a}, \tag{5}$$

where: $V_a$ – the load average velocity.

Substituting Eq. 5 to Eq. 4, we will have:

$$a = \frac{2V_a^2}{L}. \tag{6}$$

It is known that:

$$V_a = \frac{Zs}{3600},$$

where: $Z$ – the hour piece conveying capacity, $s$ – the step between loads. In the case of transportation of loads with little intervals it is possible to consider that $s \approx l$. Taking this into account, we get:

$$V_a = \frac{Zl}{3600}. \tag{7}$$

Substituting Eq. 7 to Eq. 6, finally we obtain:

$$a = \frac{Z^2 l^2}{6{,}48 \cdot 10^6 L}. \tag{8}$$

Because of the Eq.8, the Eq. 3 can be written as:

$$F_x = F_y\left(w + \frac{Z^2 l^2}{6{,}48 \cdot 10^6 Lg}\right)$$

or, having divided right and left parts of this equation for $F_y$:

$$\frac{F_x}{F_y} = w + \frac{Z^2 l^2}{6{,}48 \cdot 10^6 Lg}. \tag{9}$$

The structure of expression, which is in the left part of the Eq. 9, similar to well-known expression of the dynamic factor of the car and, taking into account aerodynamic nature traction and lifting forces, may be called aerodynamic factor of conveyor on air cushion with inclined round channels:

$$A = \frac{F_x}{F_y}. \tag{10}$$

Unlike traction force, aerodynamic factor, which represents the ratio traction force to lift force, allows not only to quantify, but also to compare traction qualities of conveyors on air cushion with inclined round channels.

In view of the above we will have:

$$A = w + \frac{Z^2 l^2}{6{,}48 \cdot 10^6 Lg}. \qquad (11)$$

The Eq. 11 is an equation of traction balance of conveyor on air cushion with inclined round channels.

The traction force and lift force are defined as follows:

$$F_x = c_x p_0 S, \qquad (12)$$

$$F_y = c_y p_0 S, \qquad (13)$$

where: $c_x$ – the traction force coefficient, $c_x$ – the lift force coefficient, $p_0$ – the air pressure in the receiver, $S$ – the area of the load support surface. Substituting the Eq. 12 and the Eq. 13 in the Eq. 10,

$$A = \frac{c_x}{c_y}. \qquad (14)$$

Using the results of previously conducted research [12, 16], the Eq. 14 can be represented in the form:

$$A = \frac{64(H+h)^2}{d^2}\left[1-\frac{H+h}{0{,}5d}\left(1-e^{-\frac{0{,}5d}{H+h}}\right)\right]^2 \times \frac{(b+l)^2 h^2 \sin\varphi}{\bar{S}_1 b^2 l^2} : \left(1+\frac{64(H+h)^2}{d^2}\left[1-\frac{H+h}{0{,}5d}\times \left(1-e^{-\frac{0{,}5d}{H+h}}\right)\right]^2 \frac{(b+l)^2 h^2 \cos\varphi}{\bar{S}_1 b^2 l^2} + 2\left\{1-\frac{16}{d^2}\times (H+h)^2\left[1-\frac{H+h}{0{,}5d}\left(1-e^{-\frac{0{,}5d}{H+h}}\right)\right]^2\right\}\times \frac{(b+l)^2}{\bar{S}_1 b^2 l^2} h^2/\cos\varphi\right), \qquad (15)$$

where: $H$ – the depth of the cavity on the side of the load support surface, $h$ – the thickness of an air cushion, $d$ – the diameter of channels, $\bar{S}_1$ – the relative area of channels, $\varphi$ – the incline angle of channels, $b$ – the load width, $l$ – the load length.

The Eq. 15 is the mathematical model that determines influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels.

For validation of the obtained mathematical model an experiment was conducted on test stand (Fig. 3-5).

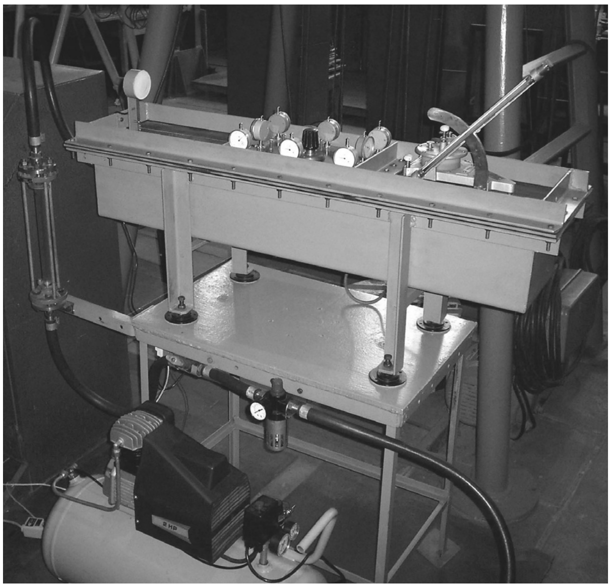

**Fig. 3.** Test stand for research of conveyors on an air cushion with inclined round channels

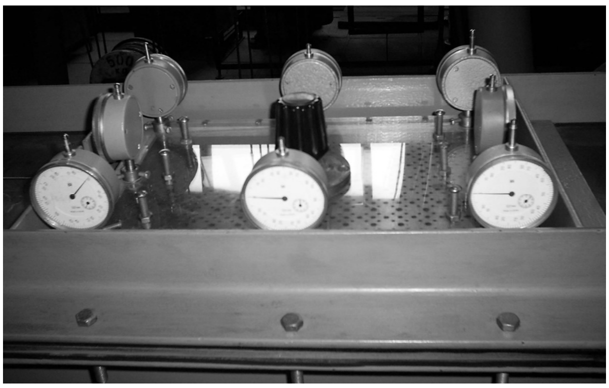

**Fig. 4.** Platform, which simulates the transported load

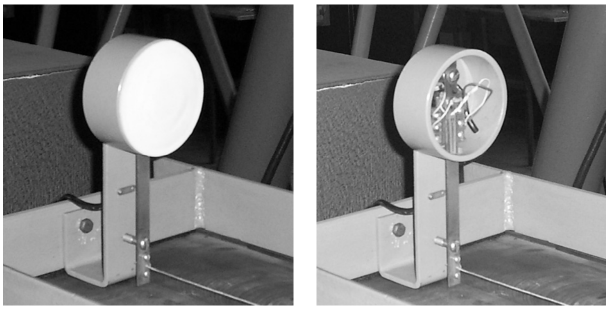

**Fig. 5.** General view of the strain gauge

In the result of conducted experiment the following empirical model was obtained:

$$
\begin{aligned}
A = &-2394{,}7\cdot10^{-6} + 7893{,}3\cdot10^{-6}h + \\
&+39{,}6\cdot10^{-6}\varphi + 227{,}0\cdot10^{-6}d + \\
&+1020{,}0\cdot10^{-6}\overline{S}_1 + 655{,}3\cdot10^{-6}H + \\
&+209{,}3\cdot10^{-6}h\varphi - 1480{,}0\cdot10^{-6}hd - \\
&-6720{,}0\cdot10^{-6}h\overline{S}_1 + 3533{,}3\cdot10^{-6}hH - \\
&-17{,}5\cdot10^{-6}\varphi d - 58{,}8\cdot10^{-6}\varphi\overline{S}_1 + \\
&+45{,}4\cdot10^{-6}\varphi H + 716{,}0\cdot10^{-6}d\overline{S}_1 - \\
&-262{,}0\cdot10^{-6}dH - 1656{,}0\cdot10^{-6}\overline{S}_1 H\ ,
\end{aligned}
$$

where: $h$ – the thickness of an air cushion in the range from 0.2 to 0.5 mm, $\varphi$ – the incline angle of channels in the range from 10 to 30 degrees, $d$ – the diameter of channels in the range from 2 to 4 mm, $\overline{S}_1$ – the relative area of channels in the range from 0.5 to 1.0 %, $H$ – the depth of the cavity on the side of the load support surface in the range from 0 to 1 mm.

The results of the modelling and experimental research of the aerodynamic factor of conveyor on air cushion with inclined round channels are presented in Fig. 6-8 (the modelling results are shown as a dotted line, the results of the experiment are shown a solid line). As you can see, the differences between the modelled and experimental values of the aerodynamic factor do not exceed 11 %.

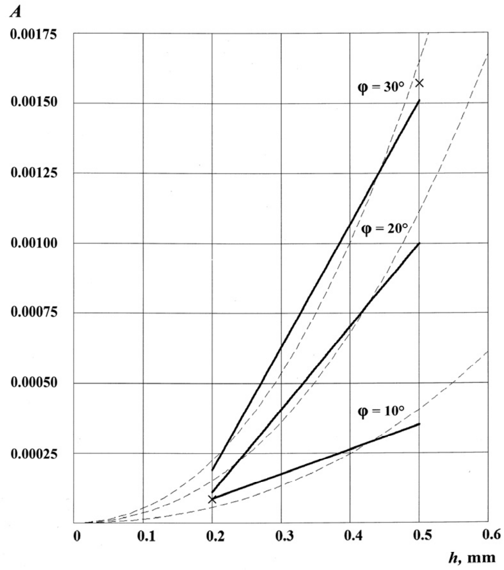


**Fig. 6.** The modelled and experimental values of the aerodynamic factor when $d$ = 4 mm, $\overline{S}_1$ = 1 %, $H$ = 1 mm

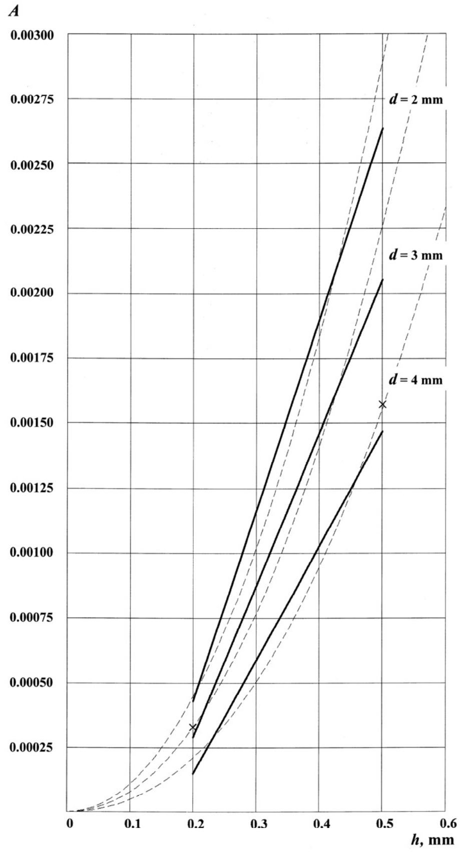


**Fig. 7.** The modelled and experimental values of the aerodynamic factor when $\varphi = 30^\circ$, $\overline{S}_1$ = 1 %, $H$ = 1 mm

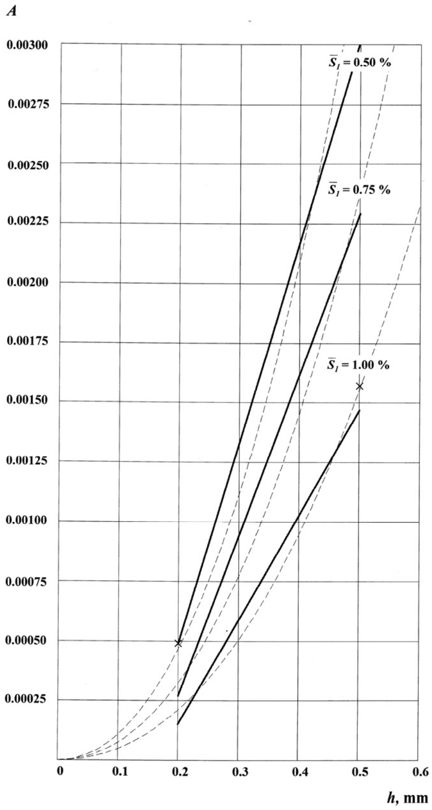


**Fig. 8.** The modelled and experimental values of aerodynamic factor when $\varphi = 30^\circ$, $d = 4$ mm, $H = 1$ mm

The analysis of the graphs, which are presented in Fig. 6-8, allows to conclude that the traction qualities of conveyor on air cushion with inclined round channels increase with increasing incline angle of channels and decrease with increasing diameter of channels and relative square of channel.

## CONCLUSIONS

1. In the first on the basis of Newton's second law the mathematical model that determines influence of construction parameters on traction qualities of conveyor on an air cushion with inclined round channels is obtained. The mathematical model establishes the functional relationship between incline angle of channels, diameter of channels, relative square of channels and aerodynamic factor of conveyor on an air cushion with inclined round channels.
2. The obtained mathematical model adequately displays the data of the experiment. The modelling results differ from the results of the experiment for not more than 11 %.
3. The aerodynamic factor which is a criterion for conveyor on an air cushion with inclined round channels increases with increasing incline angle of channels and decreases with increasing diameter of channels and relative square of channel.

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## ВЛИЯНИЕ ПАРАМЕТРОВ КОНСТРУКЦИИ НА ТЯГОВЫЕ КАЧЕСТВА КОНВЕЙЕРОВ НА ВОЗДУШНОЙ ПОДУШКЕ С НАКЛОННЫМИ КРУГЛЫМИ КАНАЛАМИ

*Максим Пронин, Евгений Шапран*

Аннотация. Получена и экспериментально проверена математическая модель, определяющая влияние параметров конструкции на тяговые качества конвейеров на воздушной подушке с наклонными круглыми каналами. Используя полученную математическую модель, проанализировано влияние параметров конструкции на тяговые качества конвейеров на воздушной подушке с наклонными круглыми каналами.

Ключевые слова: конвейер, воздушная подушка, подъемная сила, тяговая сила