THE MATHEMATICAL MODEL OF THE TRACTION FORCE COEFFICIENT OF THE CONVEYOR ON AN AIR CUSHION WITH SLOPING ROUND CHANNELS

Maxim Pronin

Volodymir Dahl East-Ukrainian National University, Lugansk, Ukraine

Summary. Using the methods of ideal liquid aerodynamics and the theory of machines on an air cushion, the mathematical model of the traction force coefficient of the conveyor on an air cushion with sloping round channels is obtained. Compare the results of the modelling and the experimental research of the traction force coefficient of the conveyor on an air cushion with sloping round channels is carried out.
Key words: conveyor, air cushion, traction force

INTRODUCTION

Conveyors on an air cushion with sloping round channels (fig. 1) are a special type of industrial transport, which can be used for:

- transportation of products in the assembling process;
- transportation of loads in warehouses and logistics centres;
- transportation of products through the heating, baking, drying ovens and cooling chambers.

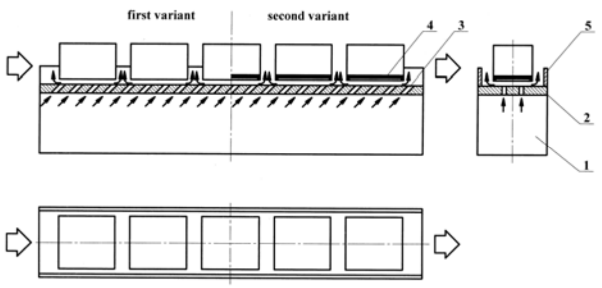

Fig.1. Conveyor on an air cushion with sloping channels: 1 - air receiver; 2 - nozzle; 3 - channel; 4 - pallet; 5 - guide

Despite the existence of such advantages as: the simplicity of construction, high reliability, quiet operation, safety of operation in an explosive environment, the possibility of combining the process of transportation and the thermal processing of loads, wide application of conveyors on an air cushion with sloping round channels do not have. One of the reasons of this fact is the lack of study of these conveyors, in particular their traction qualities, the main indicator of which is the traction force coefficient.

ANALYSIS OF THE PUBLICATIONS. THE AIM AND TASKS OF RESEARCH

Conveyors on an air cushion studied in the scientific works of Bitukov V., Kolodezhnov V. [Bitukov 1979; Bitukov, Kolodezhnov 1979], Khanzhonkov V. [Khanzhonkov 1975, 1981], Pang M. [Pang, Zhang, Ni 2005], Rabochiy G., Redko A., Turushin V. [Redko, Turushin 1997; Turushin, Rabochiy 1978; Rabochiy, Turushin 1983; Turushin, Redko 1997], Song R. [Song, Ni, Zheng, 2006] and other scientists. However, conveyors with sloping channels in these works are not considered.

The scientific works of Lu J., Huang G., Li S. [Lu, Huang 2008; Lu, Huang, Li 2009], Yun L., Bliault A. [Yun, Bliault 2000], Zalewski W. [Zalewski 2003], Zhou J., Guo J., Tang W., Zhang S. [Zhou, Guo, Tang, Zhang 2009; Zhou, Tang, Zhang 2009] are devoted to research of aircraft and ships with support devices on an air cushion. But, taking into account the principle differences between the conveyors and aircraft or ships, use the results of these works to determine the characteristics of the conveyors on an air cushion is not possible.

In work of Złoto T. and Nagorka A. [Zloto, Nagorka 2007] the results of investigation of the pressure distribution of oil film in the variable height gap between the valve plate and cylinder block in the axial piston pump are presented. However, due to the fact that the air and oil have different physical properties, the results of this work may not be used in the study of conveyors on an air cushion.

In work of Dreszer K.A., Pawlowski T., Zagajski P. [Dreszer, Pawlowski, Zagajski 2007] the process of grain relocation with screw conveyors is investigated. Conveyors on an air cushion in these works are not studied.

Taking the above into account, the aim of this article is to obtain a mathematical model of the traction force coefficient of the conveyor on an air cushion with sloping round channels. To achieve this aim it is necessary to solve the following tasks:

- mathematical modelling of the traction force coefficient of the conveyor on an air cushion with sloping round channels;
- experimental checking of the results of the mathematical modelling.

THE DECISION OF THE RESEARCH TASKS

The traction force, which acts on the load, transported by conveyor on an air cushion with sloping round channels, can be determined with the help of the law of conservation of momentum for the volume of the liquid, limited control contour 1-2-3-4-5-6-7-8-1 (fig. 2). Using the theory of machines on an air cushion [Khanzhonkov 1972], in the projection on the X-axis have:

$$F_x = \rho V_{1a}^2 S_1 n_1 \sin\varphi , \qquad (1)$$

where: ρ - the air density; V_{1a} - the average velocity of the air in the channel outlets; S_1 - the cross-sectional area of the channel; n_1 - the number of channels situated under the load; φ - the slope angle of channels to the vertical line.

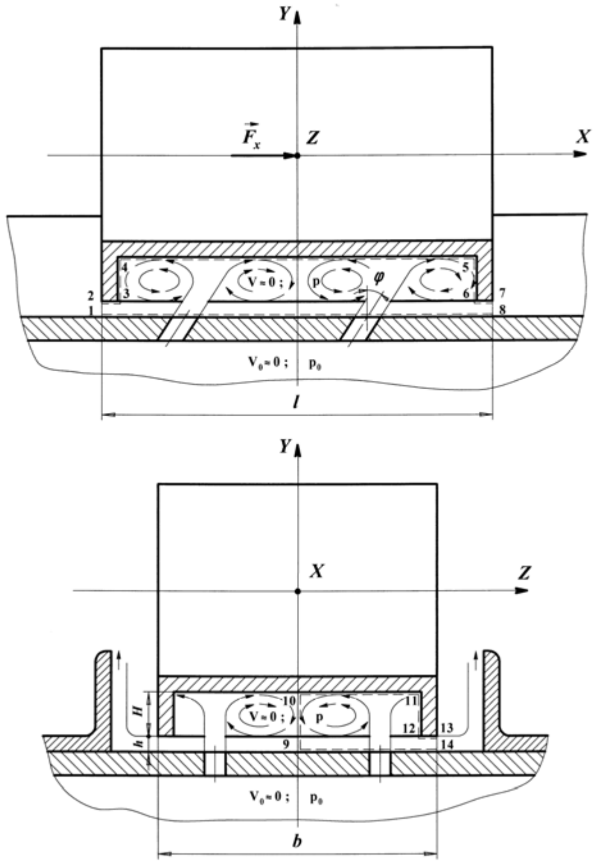

Fig. 2. Calculation scheme of the conveyor on an air cushion with sloping round channels

On the basis of the Bernoulli equation for the flow in the channel outlet can be found:

$$p_{1a} + \frac{\rho V_{1a}^2}{2} = p + \frac{\rho V_1^2}{2} ,$$

where: p_{1a} - the average pressure in the channel outlets; p - the pressure in an air cushion; V_1 - the speed of the airflow around the edge of the channel outlet.

Accepting

$$V_{1a} = \alpha_1 V_1 , \qquad (2)$$

where: α_1 - coefficient, which takes into account the uneven distribution of speed in the channel outlet; can be obtained:

$$p_{1a} = p + \left(1-\alpha_1^2\right)\frac{\rho V_1^2}{2} . \qquad (3)$$

Substituting the expressions (2) and (3) in equation (1) and accepting

$$S_1 n_1 = \overline{S}_1 S , \qquad (4)$$

will have:

$$F_x = \rho \alpha_1^2 V_1^2 \bar{S}_1 S \sin \varphi , \qquad (5)$$

where: $\bar{S}_1$ - the relative area of channels; S - the area of the support surface of the load.

Using the Bernoulli equation, for the part of the flow from the receiver to the channel outlet can be found:

$$p_0 = p + \frac{\rho V_1^2}{2} . \qquad (6)$$

where: p_0 - the air pressure in the receiver.

The pressure in the air cushion can be determined with the help of the law of conservation of momentum for the volume of the liquid, limited control contour 9-10-11-12-13-14-9 (fig. 2). In the projection on the Z-axis have:

$$\rho V_2^2 hl = p(H + h)l - pHl ,$$

whence it follows:

$$p = \rho V_2^2 ,$$

where : V_2 - the speed of the air, coming out from under the load; h - the thickness of the air cushion; H - the depth of the cavity on the side of the support surface of the load. Then the expression (6) will have the form:

$$p_0 = \rho V_2^2 + \frac{\rho V_1^2}{2} . \qquad (7)$$

The construction of the conveyor gives grounds to assert that

$$V_1 S_1 n_1 = V_2 S_2 = V_2 \Pi h ,$$

where: S_2 - the area of the output slit; Π - the perimeter of the load; whence, taking into account the expression (4) and designated $\bar{S}_2 = \frac{\Pi h}{\bar{S}_1 S}$,

$$V_2 = \frac{V_1}{\bar{S}_2} ,$$

where: $\bar{S}_2$ - the relative area of the output slit.

In view of the foregoing, equation (7) can be represented as:

$$p_0 = \left(\frac{2 + \bar{S}_2^2}{\bar{S}_2^2} \right) \frac{\rho V_1^2}{2} . \qquad (8)$$

Generally, the traction force can be determined as follows:

$$F_x = c_x p_0 S , \qquad (9)$$

where: c_x - the traction force coefficient. Substituting the expression (5) and (8) in the relationship (9) and solving the resulting equation on c_x, find a formula of the traction force coefficient:

$$c_x = \frac{2\alpha_1^2 \bar{S}_1 \bar{S}_2^2 \sin \varphi}{2 + \bar{S}_2^2} . \qquad (10)$$

In accordance with the [Turushin, Pronin 2007]

$$\alpha_1 \approx 4 \frac{H + h}{d} \left[1 - 2 \frac{H + h}{d} \left(1 - e^{-0,5 \frac{d}{H + h}} \right) \right] , \qquad (11)$$

where: d - the diameter of the channels. Substituting the expression (11) to equation (10), and also considering that

$$\bar{S}_2 = \frac{\Pi h}{\bar{S}_1 S} = \frac{2(b + l)h}{\bar{S}_1 bl} ,$$

where: b - width of load; l - length of load; will have:

$$c_x = \frac{64 \frac{(H + h)^2}{d^2} \left[1 - 2 \frac{H + h}{d} \left(1 - e^{-0,5 \frac{d}{H + h}} \right) \right]^2}{1 + 2 \frac{(b + l)^2}{\bar{S}_1^2 b^2 l^2} h^2} \times$$

$$\times \frac{(b + l)^2}{\bar{S}_1 b^2 l^2} h^2 \sin \varphi . \qquad (12)$$

Expression (12) is a mathematical model of the traction force coefficient of the conveyor on an air cushion with sloping round channels.

The results of the modelling and experimental research of the traction force coefficient of the conveyor on an air cushion with sloping round channels [Turushin, Pronin 2006] are presented in fig. 3-6 (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 traction force coefficient is in the range of 0.9 - 14 % , which indicates a satisfactory accuracy of the obtained model.

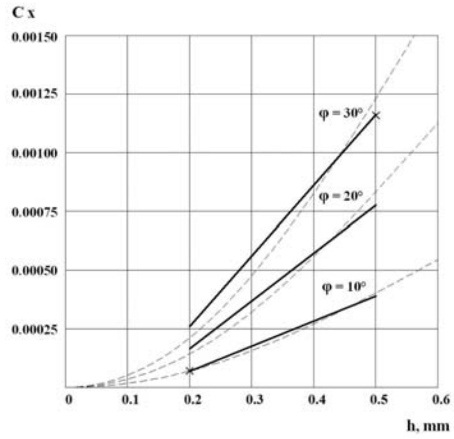

Fig. 3. The modelled and experimental values of the traction force coefficient when $d = 4$ mm , $\overline{S}_1 = 1$ % , $H = 1$ mm

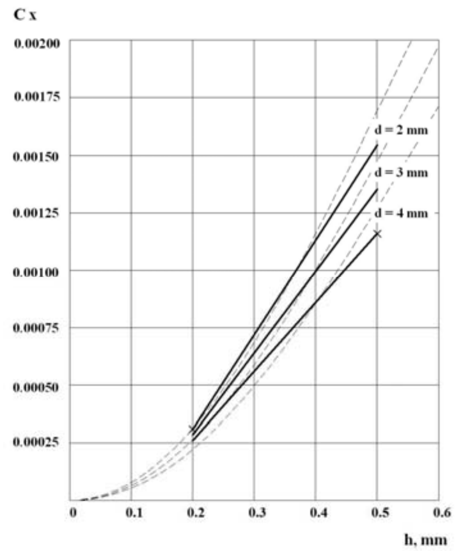

Fig. 4. The modelled and experimental values of the traction force coefficient when $\varphi = 30^\circ$, $\overline{S}_1 = 1$ % , $H = 1$ mm

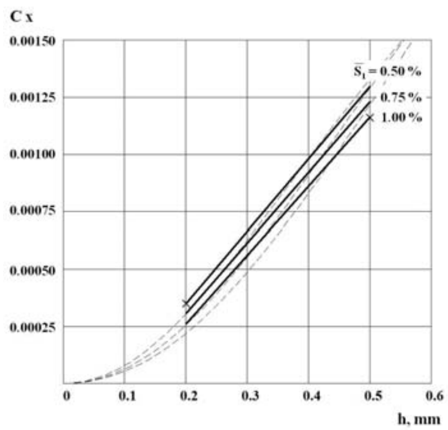

Fig. 5. The modelled and experimental values of the traction force coefficient when $\varphi = 30^\circ$, $d = 4$ mm , $H = 1$ mm

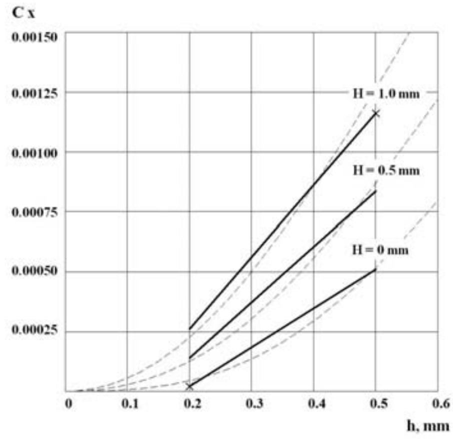

Fig. 6. The modelled and experimental values of the traction force coefficient when $\varphi = 30^\circ$, $d = 4$ mm , $\overline{S}_1 = 1$ %

CONCLUSIONS

1. The mathematical model of the traction force coefficient of the conveyor on an air cushion with sloping round channels is obtained. The model takes into account the character of the velocity distribution in the channel outlets, as well as the possible presence of the load box-shaped support surface, which ensures the high accuracy of the model and its universality in relation to the configuration of a load support surface.
2. The obtained mathematical model of the traction force coefficient of the conveyor on an air cushion with sloping round channels adequately displays the data of the experiment. The modelling results differ from the results of the experiment for not more than 14 %.

REFERENCES

1. **Bitukov V.K., 1979.:** Conveyor with air cushion. Mechanization and automation of production. 10, 3 - 5.
2. **Bitukov V.K., Kolodezhnov V.N., 1979.:** Conveyors with air interlayer for transportation of cargoes. Material handling equipment. 30, 50.
3. **Dreszer K.A., Pawlowski T., Zagajski P., 2007.:** The process of grain relocation with screw conveyors. TEKA Kom. Mot. Energ. Roln. OL PAN. 7, 86 - 96.
4. **Khanzhonkov V.I., 1981.:** Aerodynamic calculation of bearing system with a gas cushion for thermal processing of metal strip. The technology of light alloys. 10, 61- 69.
5. **Khanzhonkov V.I., 1972.:** Aerodynamics of machines on the air cushion. Mashinostroyeniye. Moscow.
6. **Khanzhonkov V.I., 1975.:** The aerodynamic characteristics of the carrier system with air cushion for the strip of metal. The technology of light alloys. 7, 55-62.

7. **Lu J., Huang G., 2008.:** The Course Stability of an Air Cushion Vehicle. Shanghai Jiaotong University. Chinese edition. V. 42. 6, 914- 918.
8. **Lu J., Huang G., Li S., 2009.:** A study of maneuvering control for an air cushion vehicle based on back propagation neural network. Shanghai Jiaotong University. Science. V. 14. 4, 482- 485.
9. **Pang M., Zhang S., Ni X., 2005.:** Distributing Law of Air Cushion Parameter in Air Cushion Belt Conveyor. Jiangsu Polytechnic University. V. 17 (4), 27-29.
10. **Rabochiy G.M., Turushin V.A., 1983.:** Definition of lift force contactless devices with air suspension. Izvestiya Vuzov. Mashinostroyeniye. 7, 79 - 83.
11. **Redko A.M., Turushin V.A., 1997.:** The dependence of the capacity of the conveyors on the air cushion on the design parameters. EUSU Publisher. Lugansk.
12. **Song R., Ni X., Zheng X., 2006.:** Current Situation and Development of Air Cushion Belt Conveyor. Jiangsu Polytechnic University. V 18 (2), 61-64.
13. **Turushin V.A., Pronin M.A., 2006.:** The experimental researches of the undriving air cushion conveyors with inclined feeding canals. EUNU Visnik. 7(101) , 189 - 192.
14. **Turushin V.A., Pronin M.A., 2007.:** The analysis of efficiency of the movement of loads by undriving conveyors on an air cushion with sloping feed channels. EUNU Visnik. 3(109) , 172 - 176.
15. **Turushin V.A., Rabochiy G.M., 1978.:** Experimental research of the support of the conveyor belt on an air cushion. Mine and quarry transport. Nedra. Moscow, 118 - 121.
16. **Turushin V.A., Redko A.M., 1997.:** Influence of design parameters of the main characteristics of the conveyors on the air cushion. EUSU Publisher. Lugansk.
17. **Yun L., Bliault A., 2000.:** Theory and design of air cushion craft. Yun and A.Bliault. London.
18. **Zalewski W., 2003.:** Air cushion creation methods in various types of hovercrafts, hovercrafts skirt design. Prace. Instytut Lotnictwa. V. 176, 17-20.
19. **Zhou J., Guo J., Tang W., Zhang S., 2009.:** Nonlinear FEM Simulation of Air Cushion Vehicle (ACV) Skirt Joint Under Tension Loading. Naval Engineers Journal. V. 121. 2, 91- 98.
20. **Zhou J., Tang W., Zhang S., 2009.:** Sea keeping analysis of air cushion vehicle with different wave angles under the operation resistance. Shanghai Jiaotong University. Science. V. 14. 4, 471- 475.
21. **Zloto T., Nagorka A., 2007.:**. Analysis of the pressure distribution of oil film in the variable height gap between the valve plate and cylinder block in the axial piston pump. TEKA Kom. Mot. Energ. Roln. OL PAN. 7, 293 - 301.

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ КОЭФФИЦИЕНТА ТЯГОВОЙ СИЛЫ КОНВЕЙЕРА НА ВОЗДУШНОЙ ПОДУШКЕ С НАКЛОННЫМИ КРУГЛЫМИ КАНАЛАМИ

Максим Пронин

Аннотация. Используя методы аэродинамики идеальной жидкости и положения теории аппаратов на воздушной подушке, получена математическая модель коэффициента тяговой силы конвейера на воздушной подушке с наклонными круглыми каналами. Проведено сравнение результатов моделирования и экспериментального исследования коэффициента тяговой силы конвейера на воздушной подушке с наклонными круглыми каналами.

Ключевые слова: конвейер, воздушная подушка, тяговая сила