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REDUCING THE AERODYNAMIC NOISE GENERATED BY A PNEUMATIC CONVEYOR USING THE ADAPTIVE SYSTEM OF AIR CUSHION THICKNESS CONTROL

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***Abstract**: The article describes the sources of aerodynamic noise generated inside an air cushion as applicable to industrial conveyor systems. The relationship between aerodynamic noise level and the air-space thickness is shown. The method of stabilizing the air-space thickness is proposed to reduce the level of aerodynamic noise.*

***Keywords:** Aerodynamic noise, air cushion, turbulence, adaptive control system*

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1. INTRODUCTION

Transport operations involved with different product manufacturing process flows at industrial facilities have a significant impact on addressing production problems. In modern manufacturing, transport systems play a significant part. Therefore, their improvement, the use of new methods of moving products, efficiency is one of the directions of production development.

Compared to mechanical conveyor systems, the conveyors with air cushions have a number of advantages [1]. These include the lack of moving mechanical elements, the possibility to implement simple product flow control methods, non--contact transportation, fire and explosion safety, and combining product transportation with various handling processes. However, when addressing pneumatic conveyors through the lens of increasing environmental requirements, certain defects can be identified. Many pneumatic conveyors without air-cushion thickness control systems ping high-level aerodynamic noise [2, 3]. For many industries, this is not acceptable. In addition, these pneumatic conveyors consume a large amount of compressed air. All this limits the scope of application of pneumatic conveyors with air cushion.

To increase the attractiveness of pneumatic conveyors as production vehicles, a mechanical system for controlling the thickness of the air cushion was developed [4, 5]. Thanks to this control system, the aerodynamic noise of the pneumatic conveyors was significantly reduced and the consumption of compressed air was reduced. From the point of view of energy costs, such pneumatic conveyors are low-cost.

The control of the thickness of the air cushion provides a differentiated creation of an air cushion under the transported products, that is, the sections of the pneumatic conveyor, free from products, have closed nozzles. In addition, the thickness of the air cushion is stabilized and does not depend on the weight of the products being moved [6, 7, 8].

2. EXPERIMENTAL DETERMINATION OF NOISE LEVEL

The main source of aerodynamic noise generated in such conveyor systems is the jet flows of air supplied from the feeding nozzles arranged below the conveyed products. An experimental assembly of a pneumatic conveyor section was designed to determine the aerodynamic noise level as shown in Fig. 1. The basic dimensions of the assembly are as follows:

Weight of one product $\boldsymbol{G}$ = 0.21 N.
Number of products $\boldsymbol{n}$ = 4.
Product width $\boldsymbol{B}$ = 0.0125 m.
Product length $2 \cdot \boldsymbol{R}$= 0.04 m.
Air density $\boldsymbol{\rho}$ = 1.29 kg/m^3.
Air viscosity $\boldsymbol{\mu}$ =$1.73 \cdot 10^{-5}$ Pa $\cdot$ s.
Nozzle width $\boldsymbol{\delta}$ = 0.0005 m.

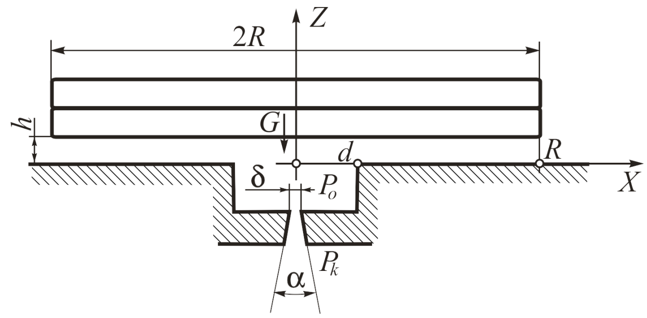

*Fig. 1: Diagram of an experimental assembly of a pneumatic conveyor section for determining the level of aerodynamic noise and the thickness of the air cushion. Two products are installed above the nozzle. **G** - weight of the product on the air cushion; P_0 - excessive pressure in the pocket; P_k - excessive pressure in the pneumatic chamber; **h** - the thickness of the air cushion*

Measured data are shown in Tab. 1 specifying aerodynamic noise levels (L_1, L_2, L_3, L_4) and air cushion (h_1, h_2, h_3, h_4) thicknesses. The index shown in the designation of noise level and air cushion thickness indicates the number of installed products. The air cushion thickness was determined by equation (1) [9, 10]. Only the value of the aerodynamic noise level was experimentally determined using the OKTAVA-110A sound level meter at various values of the excessive pressure in the pneumatic chamber.

$$h = \left[3 \cdot \mu \frac{B \cdot \delta}{G \cdot n} \left(4R^2 - \frac{\delta^2}{2} \right) \sqrt{\frac{2}{\rho} \left[P_k - \frac{G \cdot n}{B\left(2R + \frac{\delta}{2}\right)} \right]} \right]^{1/3} \quad (1)$$

	P_k, Pa	L_1, dB(A)	h_1, mm	L_2, dB(A)	h_2, mm	L_3, dB(A)	h_3, mm	L_4, dB(A)	h_4, mm
1	2666	46.5	0.527	41.5	0.404	34.8	0.338	35.4	0.29
2	5332	52.4	0.6	51.8	0.469	49.7	0.403	49	0.36
3	7998	56	0.645	55.6	0.507	54.6	0.438	55	0.394
4	10664	58.7	0.678	57.8	0.534	57.4	0.463	58	0.418
5	13330	60	0.705	59.2	0.556	58.8	0.483	59.5	0.436
6	15996	61	0.727	60	0.574	60	0.499	60.7	0.452
7	18662	61.6	0.746	61.2	0.59	61.5	0.514	61.5	0.465
8	21328	62.5	0.764	62.2	0.604	62.3	0.526	62	0.476
9	23994	63.5	0.779	63	0.616	63	0.537	63.2	0.486
10	26660	64.5	0.793	63.8	0.628	64	0.547	64.6	0.496
11	29326	65.5	0.806	64.2	0.638	64.5	0.556	65.2	0.504
12	31992	66.5	0.818	64.8	0.648	65.3	0.565	65.3	0.512
13	34658	67.5	0.829	65.2	0.657	65.8	0.572	65.5	0.519
14	37324	68.2	0.839	65.8	0.665	65.8	0.58	66	0.526
15	39990	69.5	0.849	66.3	0.673	65.8	0.587	66	0.532

Tab. 1: The level of aerodynamic noise and the thickness of the air cushion at various values of excessive pressure in the pneumatic chamber of the pneumatic conveyor.

Based on experimental data of Tab. 1. a graph was plotted of the dependence of the level of aerodynamic noise of a single flat airstream on the thickness of the air cushion. formed by the working nozzle at different weights of the product (Fig. 2).

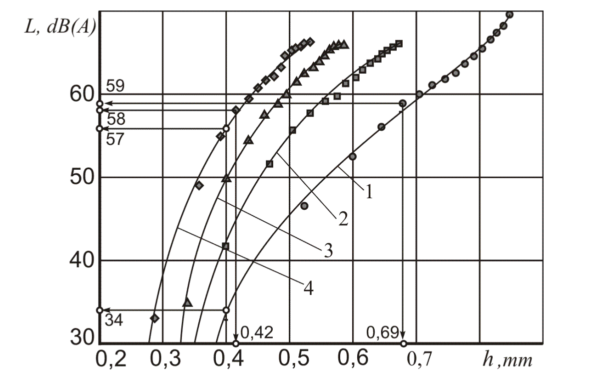

Fig. 2: Experimental values of aerodynamic noise level depending on the air cushion thickness. 1 – one product installed at the experimental assembly; 2 – two products installed at the experimental assembly; 3 – three products installed at the experimental assembly; 4 – four products installed at the experimental assembly

For example. two points are marked on the graph with arrows. corresponding to the same pressures in the pneumatic chamber of the pneumatic conveyor. One point is four products above the nozzle have an air cushion thickness of 0.42 mm and an aerodynamic noise level of 58 dB (A). The second point is one product above the nozzle has an air cushion thickness of 0.69 mm and an aerodynamic noise level of 59 dB (A). But if you reduce the thickness of the air cushion to 0.4 mm. then in the first case. the aerodynamic noise level will decrease by 1 dB (A) and become 57 dB (A). For the second case. the aerodynamic noise level will decrease by 23 dB (A) and amount to 34 dB (A). So. the air cushion under a lightweight product is noisier. but when the air-cushion thickness is reduced to 0.4 mm. its noise level will decrease by 23 dB (A). These experimental data show. that if the thickness of the air cushion is kept constant. the noise of the air cushion under lightweight products will be almost soundless.

3. METHOD OF REDUCING AERODYNAMIC NOISE

One of the methods of reducing aerodynamic noise in a pneumatic conveyor can be the use of the adaptive system of automatic air-cushion thickness control. The purpose of this control system is to stabilize the thickness of the air cushion. Pneumatic conveyor [5] with the function of stabilizing the thickness of the air cushion due to automatic regulation creates a noticeable reduction in the level of aerodynamic noise. as well as reduces the consumption of compressed air. Structurally. the pneumatic conveyor is made in such a way. that changes in the weight of the transported product lead to a change in the nozzle area. supplying air under the product. At the same time. the thickness of the air cushion remains constant. The scheme of the pneumatic conveyor structure is shown in Fig. 3.

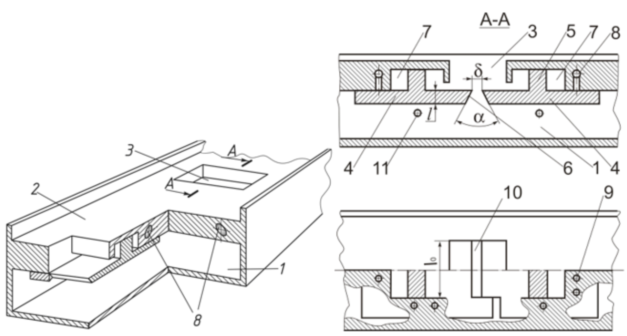

Fig. 3: Pneumatic conveyor with automatic air-cushion thickness stabilization. The symbols are defined in Tab. 2

1 – pneumatic chamber	2 – load-bearing panel
3 – rectangular holes	4 – movable plates
5 – protruding part	6 – end surface of movable plate
7 – control cubicle	8 – gas lubrication supply channel
9 – gas lubrication nozzle	10 – nozzle
11 – bearing plug.	

Tab. 2: Definition of symbols shown in Fig. 3.

The operation of the pneumatic conveyor is as follows. Compressed air is supplied to the pneumatic chamber 1. In the absence of products on the carrier panel 2 in the pockets of rectangular openings 3. the movable plates 4 will be pressed against each other. There will be almost no compressed air consumption. When products appear on the pneumatic conveyor. the state of the pneumatic conveyor will change. The products will block the rectangular openings 3. in which excessive pressure will appear due to the not tightly pressed plates 4. This excessive pressure will affect the projections 5 of the plates 4. Plates 4 will begin to move drift away from each other. forming a slotted opening 10. through which air will begin to intensively flow under the product. creating an air cushion. However. the shape of the edge of the plates 4 has a certain inclination. Due to this. the edges of the plates 4 form a conical channel with a taper angle . which determines the thickness of the air cushion. A flow is formed in the conical channel. which has a pressure less. than the pressure in the pneumatic chamber. A force will begin to affect the plates 4. tending to press the plates 4 against each other. Thus. two oppositely directed forces will affect the movable plates 4: the force. applied to the projections 5. and the force. applied to the conical ends of the plates 4. The balance of these forces will ensure such a position of the plates 4 relative to each other. that the formed nozzle 10 will create an air cushion of a given thickness under the product.

Thus. an automatic control system is obtained. in which the weight of the product is taken into account through the pressure in the air cushion. and this pressure will change the nozzle area 10. ensuring a given thickness of the air cushion.

The positive operation of the air cushion thickness stabilization system is ensured by the fact. that the control chamber 7 is connected to the atmosphere. To move the plates 4. gas lubricant is used. which is supplied through channel 8 and goes under the plates 4 through nozzle 9.

4. CONCLUSION

The relation between the level of aerodynamic noise of the pneumatic conveyor and the thickness of the air cushion was experimentally revealed. It is shown. that with an increase in the thickness of the air cushion. the level of aerodynamic noise increases significantly. A diagram of a pneumatic conveyor is shown. that provides stabilization of the thickness of the air cushion. This stabilization allows to get a reduction in the aerodynamic noise level of more than 20 dB (A).

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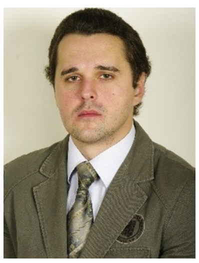

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