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SCIENTIFIC SUBSTANTIATION OF THE PROCESS OF MANAGING CRITICAL MODES OF PNEUMATIC TRANSPORTATION FOR FOOD PRODUCTS

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Abstract: The process of managing critical pneumatic conveying modes has been theoretically described, based on the proportional elements and feedback (a current loop of 4–20 mA); the process of destruction of the cluster of products by airwave and controlled decompression has been studied. The process of pneumatic conveying of a small-piece product at the experimental bench system has been examined. As well as the process of moving the material in the product pipeline, which is controlled by compressed air pulses, to maintain the modes of operation.

Keywords: pneumatic conveying, small-piece, excess pressure, feedback, gas suspension.

The aim of this study is to mathematically and physically model the process of the pneumatic conveying of small-piece products, as well as critical modes to ensure the calculation and design of product pipelines with a continuous supply.

Tasks:

– to investigate the process of transporting small-piece products in a working pneumatic pipeline;

– to determine the rational parameters of both the management process and the process of transporting a product in general, as well as to ensure that the required distribution of compressed air pressure at the predefined performance is provided;

– to build a mathematical model of the movement of individual rotating particles to study the process of their collision against the walls of a product pipeline.

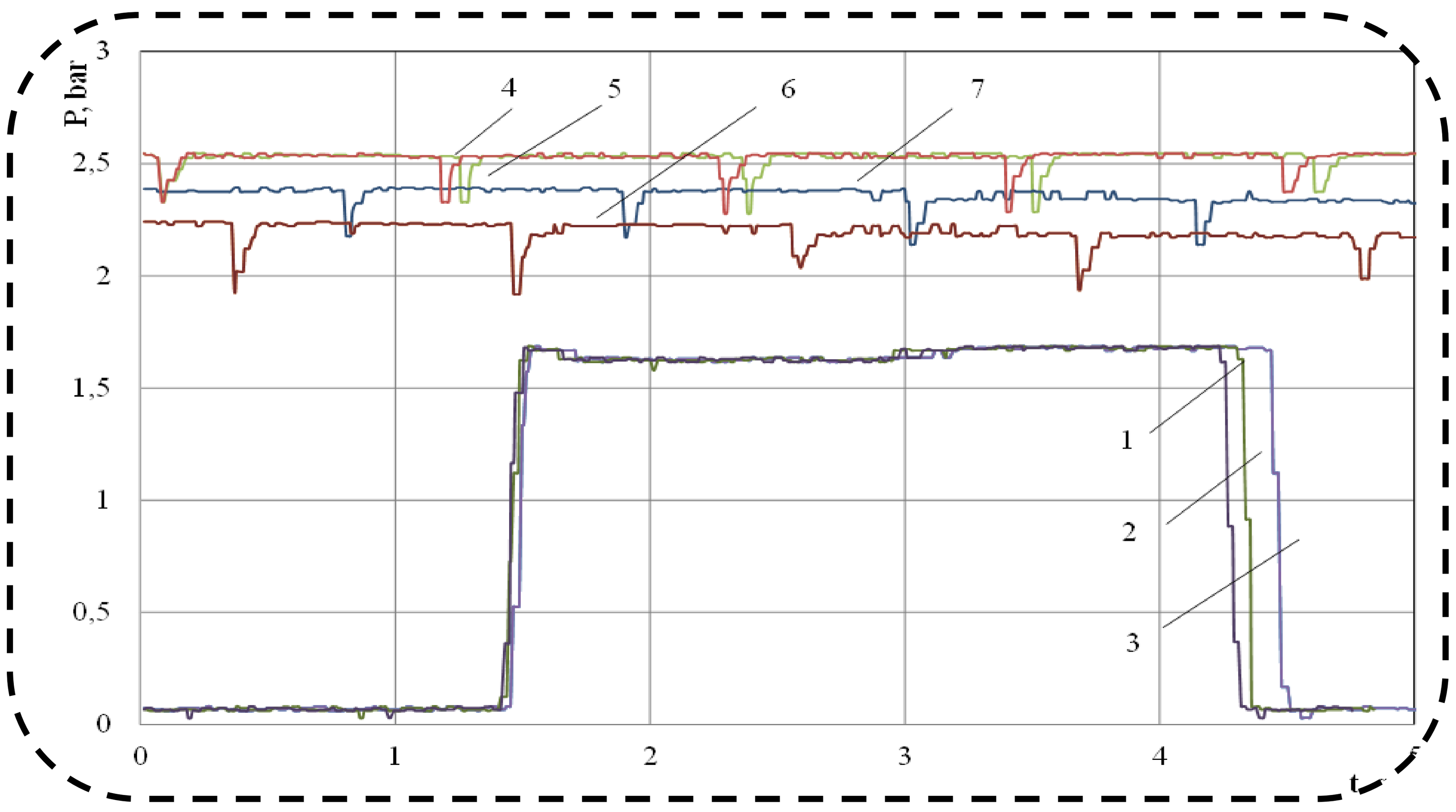
Mathematical model

$$\begin{cases} \frac{4}{3}\pi \cdot r'^3 \cdot \rho' \cdot \frac{du_x}{dt} = D'(v_x - u_x) + G_x + F_x, \\ \frac{4}{3}\pi \cdot r'^3 \cdot \rho' \cdot \frac{du_y}{dt} = D'(v_y - u_y) + G_y + F_y, \\ J \cdot \frac{d\omega}{dt} = -\pi\mu(2\cdot r')^3 \cdot \left(\frac{1}{2}\cdot\frac{\partial v_x}{\partial y} - \omega\right). \end{cases}$$

$$J = \left\{\pi \cdot (2\cdot r')^5 \rho'\right\} / 60.$$

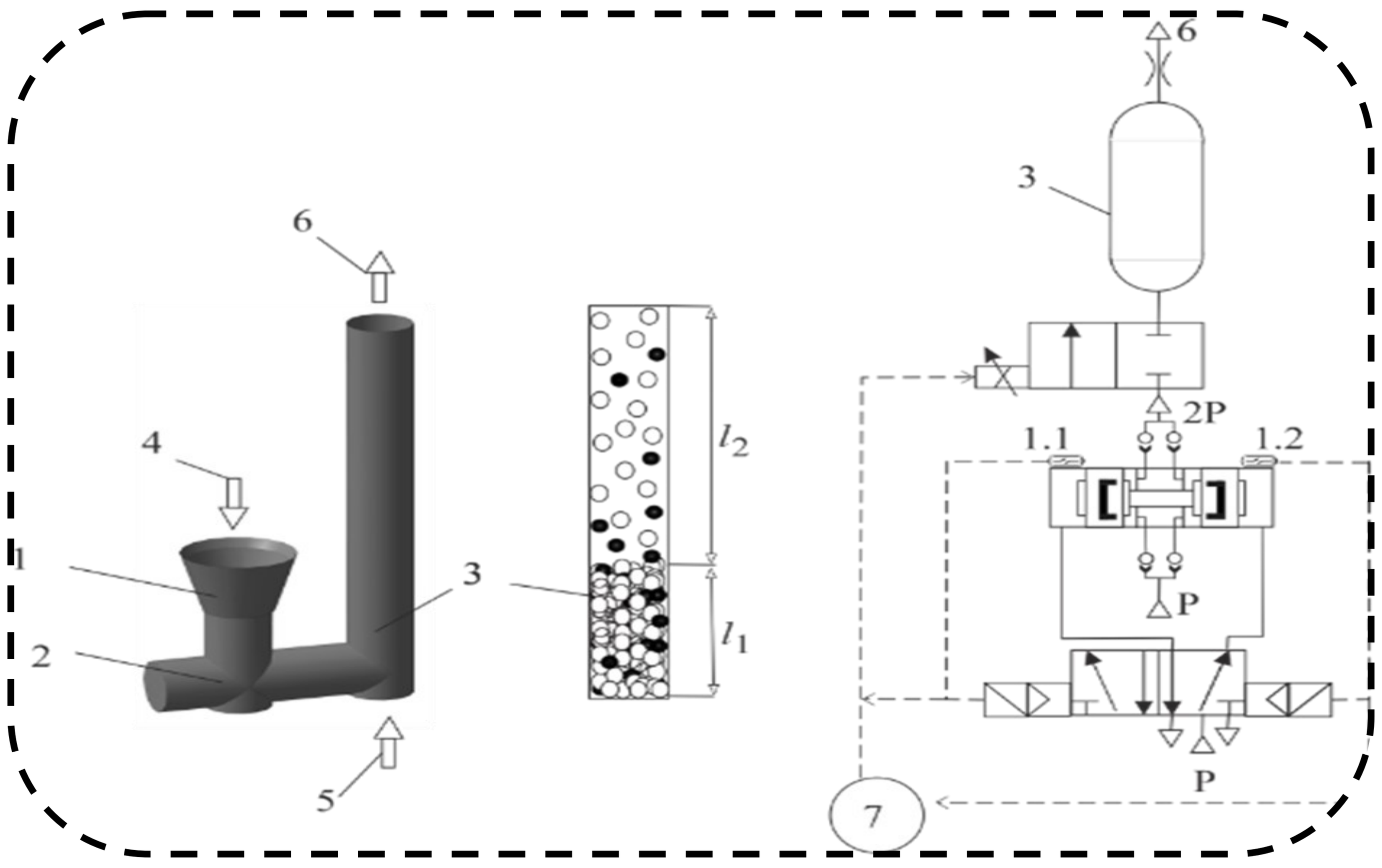
$G=\rho' \cdot g'$ (H); g' – is the vector of the acceleration of gravity. The input parameters of the mathematical model: the radius of the particle is $r`=3\times10^{-3}$ (m); the density of a single particle of a small-piece product is $\rho`=1.24\times10^{-3}$ (kg×m^{-3}); the air density is $\rho`=1.24\times10^{-3}$ (kg×m^{-3}); the acceleration of free fall is $g=9.81$ (m×s^{-2}); the maximum compressed air flow rate is $v_m=20$ (m×s^{-1}); the dynamic viscosity is $\mu=1.82\times10^{-5}$ kg/(m×s); the pipe radius is $b=0.05$ m. In the compressed air flow, the particle is set into a rotational motion, which predetermines the motion equations.

Experimental data on changes in pressure in the pneumatic conveying channel of the bench under the following modes:



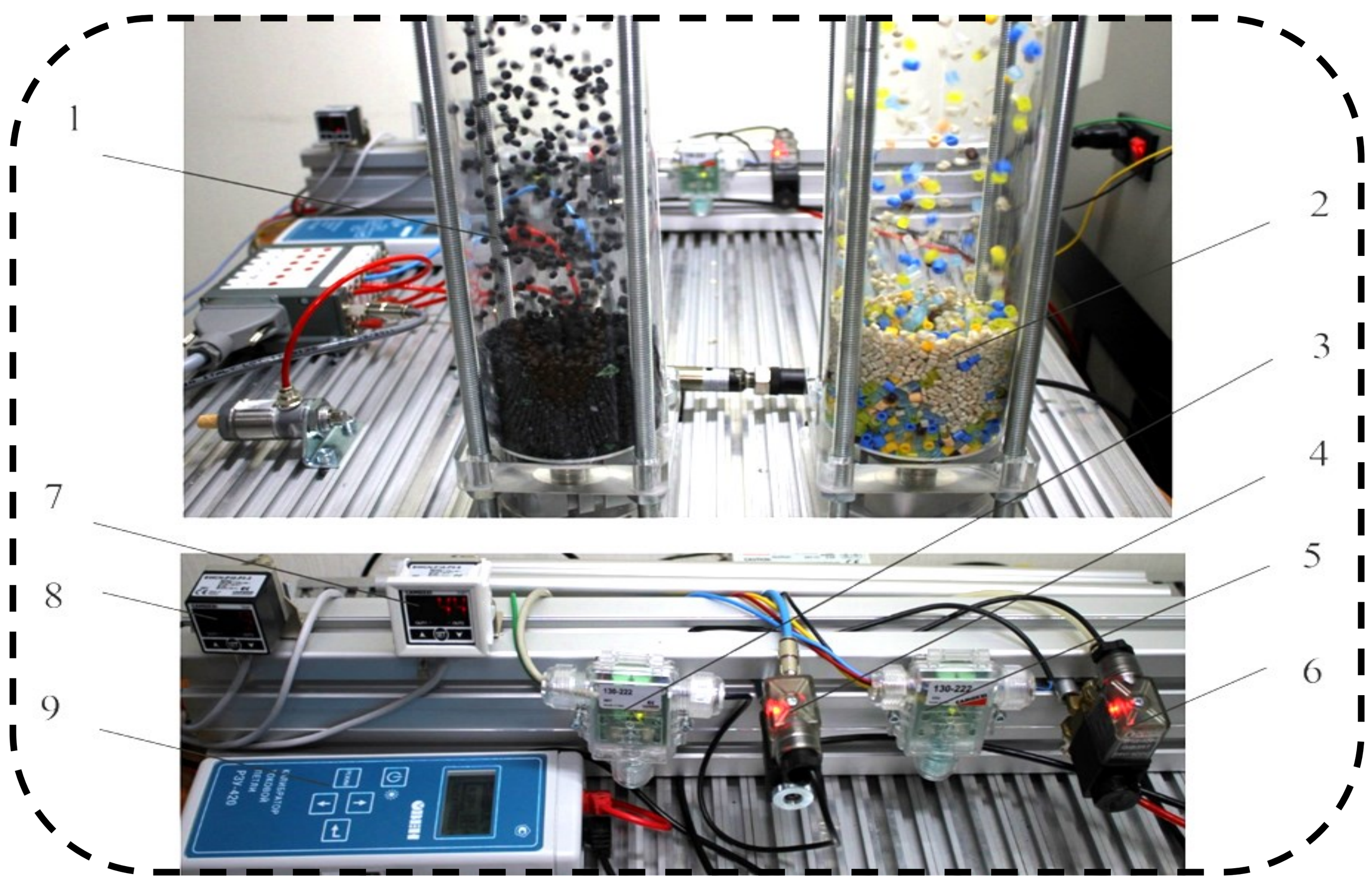
1 – Imax..Imin=4.1..19.9 mA, air supply frequency air supply frequency 0.3 Hz; 2 – Imax..Imin=4.1..19.9 mA, air supply frequency 0.35 Hz; 3 – Imax..Imin=4.1..19.9 mA, air supply frequency 0.37 Hz; 4 – Imax..Imin=12.0..19.9 mA, air supply frequency 0.6 Hz; 5 – Imax..Imin=12.0..19.9 mA, air supply frequency 0.75 Hz; 6 – Imax..Imin=12.0..19.9 mA, air supply frequency 0.5 Hz; 7 – Imax..Imin=12.0..19.9 mA, air supply frequency 1 Hz

Schematic transportation of small-piece products in the pneumatic conveying technological module:



1 – loading bunker, 2 – supply zone of a product by an auger feeder, 3 – vertical transporting channel; 4 – product, 5 – compressed air; 6 – gas suspension (air, small-piece product), 7 – electro-pneumatic control unit; P – main pressure of compressed air (MPa), 2P – double pressure at the outlet of the booster; 1.1., 1.2. – reed sensors; l1, l2 – the length of the acceleration and stabilization sections (m)

Experimental bench for studying the critical pneumatic conveying regimes of small-piece food products:



1, 2 – vertical transporting channels; 3, 5 – control drivers of the proportional supply of compressed air pulse; 4, 6 – proportional electromagnetic distributors of direct action 2/2; 7, 8 – electronic vacuum/pressure relays with analog output; 9 – programming device for setting the law of signal change 4...20 mA

Conclusion:

1. We have obtained results from the experimental and theoretical studies of the process of transporting small-piece products in a working pneumatic product pipeline. The pressure in the working system is in the range of 2..4 bar, the flow speed is up to 20 m/s.

2. A control signal transmission scheme has been developed for the pulsed supply of compressed air in the vertical pipeline, taking into consideration the introduction of elements of the proportional pneumatic equipment (analog signal, 4.20 mA).

References