

ENERGY EFFICIENCY IMPROVEMENT SYSTEMS WITH PNEUMATIC CHAMBER PUMP

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Abstract. We have proposed a new construction the pump chamber. We have carried out development of a mathematical model of the pump work chamber. On the basis of mathematical modeling we have proved the efficiency of applied design solutions. Adopted by the us constructive solutions to will improve the performance of the pump chamber by 2.34 times.

Economy and Improved utilization of energy resources are among the eight priority areas of the policy of the Russian Federation, approved by Presidential Decree of July 7, 2011 N 899 “On approval of the priority directions of development of science, technology and engineering in the Russian Federation and the list of critical technologies of the Russian Federation” . The main consumers of energy resources are industrial enterprises. The implementation process in many industries require moving large amounts of bulk materials. The share of pneumatic transport accounts for about 30% of all work on the transport of bulk cargo. Pneumatic conveying systems have a number of advantages over traditional means of transport of bulk materials: compactness, high hygiene in indicators, possibility of full automation, the ability to simulation time as the transportation of material to change its status (drying, moisturizing, etc.), easy maintenance [1, 2, 3]. However, the pneumatic transport system have the highest energy consumption per ton of processed material. In some cases, this figure exceeds the energy consumption of traditional modes of transport by 10-15 times. High energy intensity is often associated with errors in the design phase systems, because existing engineering design procedure of pneumatic units does not take into account the specifics of various industries, which leads to lower energy efficiency of pneumatic systems. Therefore, at present it is a very urgent problem of energy efficiency in transport systems, pneumatic transport of bulk materials. In order to enhance the energy efficiency of the pump chamber has been developed mathematical model of two-phase flow and heat transfer (gas-solid). A mathematical model based on the equations of motion, conservation of energy and mass in the production of interpenetrating flows (Euler model) [4, 5]. It is assumed that the bulk material has the properties of pseudo-liquid. The system of differential equations is of the form:

1. The equation of momentum transfer to the solid phase:

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$$\frac{\partial}{\partial t}(\gamma_s \rho_s w_{j,s}) + \frac{\partial}{\partial x_j}(\gamma_s \rho_s w_{j,s} w_{i,s}) = -\gamma_s \frac{\partial p}{\partial x_i} - \frac{\partial p_s}{\partial x_i} + \frac{\partial \tau_{ij,s}}{\partial x_j} + \gamma_s \rho_s g_i + K_{sf}(w_{i,f} - w_{i,s}) \quad (1)$$

2. The equation of momentum transfer fluid:

$$\frac{\partial}{\partial t}(\gamma_f \rho_f w_{j,f}) + \frac{\partial}{\partial x_j}(\gamma_f \rho_f w_{j,f} w_{i,f}) = -\gamma_f \frac{\partial p}{\partial x_i} + \frac{\partial \tau_{ij,f}}{\partial x_j} + \gamma_f \rho_f g_i + K_{fs}(w_{i,s} - w_{i,f}) \quad (3)$$

3. The continuity equation for the solid phase:

$$\frac{\partial}{\partial t}(\gamma_s \rho_s) + \nabla(\gamma_s \rho_s w_s) = 0 \quad (4)$$

4. The continuity equation for the fluid:

$$\frac{\partial}{\partial t}(\gamma_f \rho_f) + \nabla(\gamma_f \rho_f w_f) = 0 \quad (5)$$

5. The equation of conservation of energy

$$\frac{\partial}{\partial t}(\gamma_f \rho_f h_f) + \nabla(\gamma_f \rho_f w_f h_f) = -\gamma_f \frac{\partial p_f}{\partial t} + \frac{\bar{\tau}_f}{\nabla w_f} - \nabla q_f + S_f + \alpha_{fs}(T_s - T_f)F \quad (6)$$

where γ – the bulk concentration; h – enthalpy, J/kg; ρ - density, kg / m³; p - pressure, Pa; w - velocity, m / s; τ - the stress tensor, N / m²; K - coefficient of inter-action phase; α – The heat transfer coefficient, W / (m².°C); S - source term, W; q - heat flux, W; F - heat exchange surface; the indices s and f - the solid phase and the fluid, respectively.

For solving the system of equations (1) - (5) the following boundary conditions:

- initial conditions:

$$w'_f(x_I; 0) = 0, \quad w''_f(x_{II}; 0) = 0, \quad w'''_f(x_{III}; 0) = 0, \quad w_{f,s}(x_i; 0) = 0, \quad T_{f,s}(x_i; 0) = T_0, \quad p(x_i; 0) = p_0;$$

- border conditions: $w'_f|_{x_I} = \frac{\dot{V}_I}{f_I}$, $w''_f|_{x_{II}} = \frac{\dot{V}_{II}}{f_{II}}$, $w'''_f|_{x_I} = f(\tau)$, $w_f|_w = w_s|_w = 0$, $p|_{x_I} = f(\tau)$,

$$p|_{x_{II}} = f(\tau), \quad p|_{x_{III}} = p_0, \quad T_f|_{x_I} = T'_f(\tau), \quad T_f|_{x_{II}} = T''_f(\tau), \quad T_s|_{x_{III}} = f(\tau), \quad T_f|_{x_{III}} = f(\tau), \quad T|_w = T_w(\tau);$$

where x_i – coordinate in three dimensional space, \dot{V} – the volume flow of compressed air, f – sectional area, codes of I, II, III - borders on the inlet and outlet computational domain.

Mathematical model of hydrodynamics and heat transfer in two-phase flow is implemented in software and computer system Ansys Fluent [5].

In order to enhance the energy efficiency of the chamber pump (CP) “Монжус” was performed reconstruction of air supplies and the removal of the two-phase mixture. The idea of the reconstruction was to increase the level of turbulence in two-phase flow in the chamber of the pump (see. Figure 2).

Before reconstruction compressed air into a pneumatic chamber is fed via conduit 4 (see. Figure 3a). As is known, the efficiency of the CP layer affects the level of fluidization of the solid material. Use of only one air supply pipe 4 leading to the low level fluidize the bed solids in the pump chamber.

Unloading of the material was carried out after a set pressure in the chamber 3. Thus material-pipe was organized upper unloading material, which results in an emergency operation.

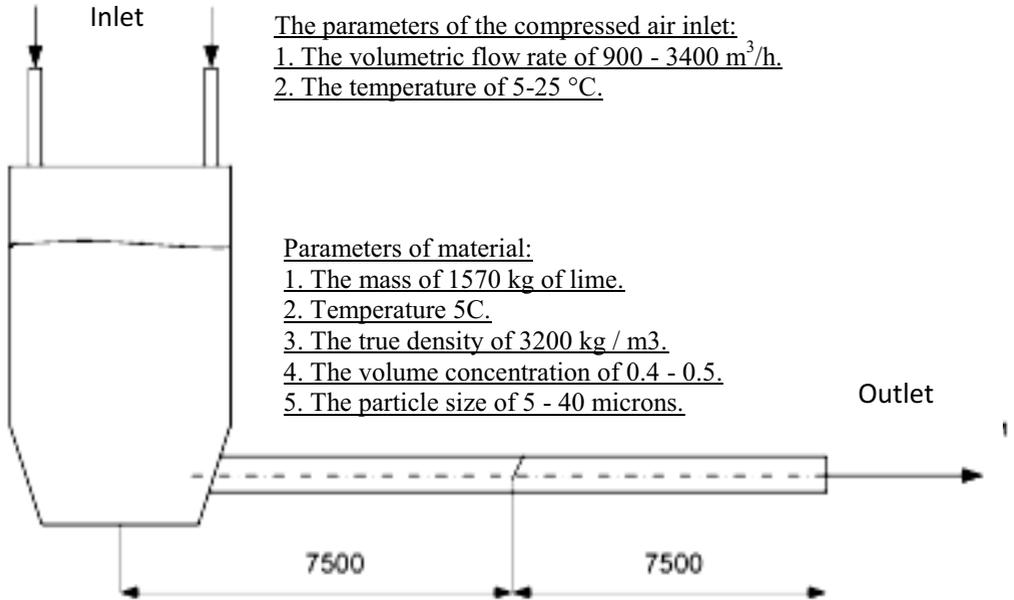


Figure 1. Scheme of the material flow in the pump chamber.

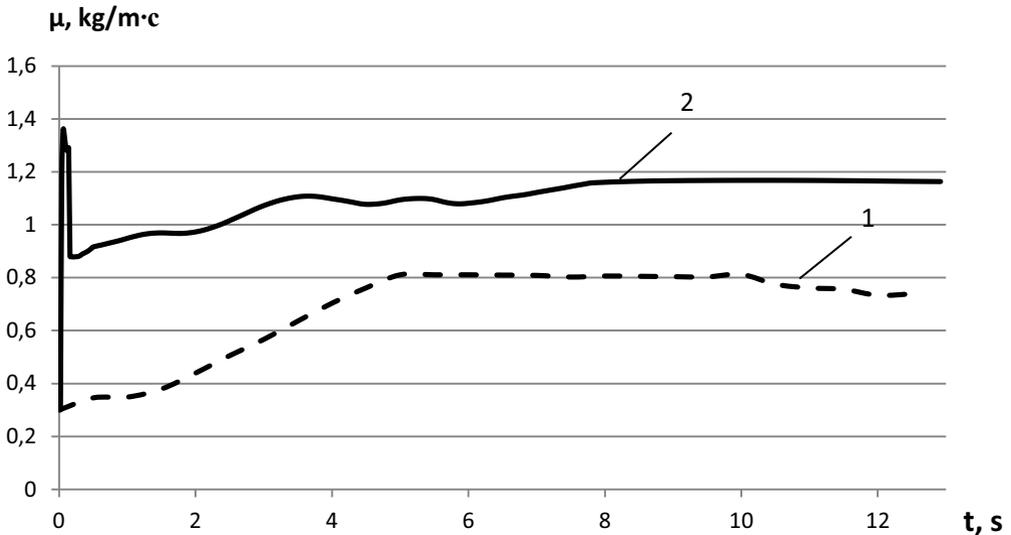


Figure 2. The effective coefficient of turbulent transfer of momentum mixture to (1), and after reconstruction (2).

During reconstruction, firstly it was changed circuit supplying compressed air: setting two feed pipe 4 (Figure 3b), the ends of which are made “L-shaped” bends perpendicularly to the axis CP, allowing not only to increase the degree of fluidization, and set the initial speed material directly inside the chamber pneumatic pump.

Secondly, the scheme has been changed removing material from a pneumatic pump chamber. After reconstruction material-pipe 1 is located at the bottom of the pump chamber, and its diameter is increased from 100 mm to 150 mm. Thus, the material is unloaded from the bottom of the camera in a horizontal direction, thereby reducing traffic congestion and reduce the material emergency work CP.

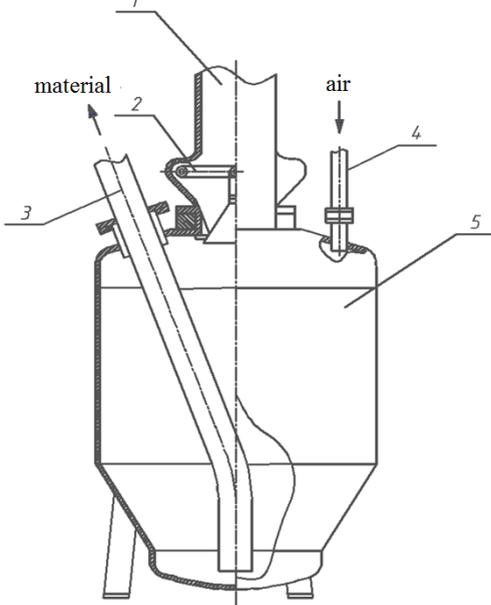


Figure 3a. “Монжус” before reconstruction:
 1 - connection for downloading material;
 2 - charging valve; 3 – material-pipe; 4 - the air;
 5 - chamber pneumatic pump.

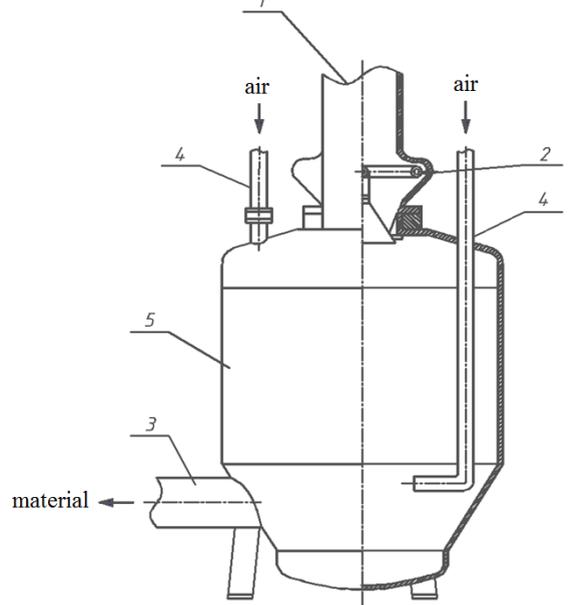


Figure 3b. “Монжус” after reconstruction:
 1 - connection for downloading material;
 2 - charging valve; 3 – material-pipe; 4 - the air;
 5 - chamber pneumatic pump.

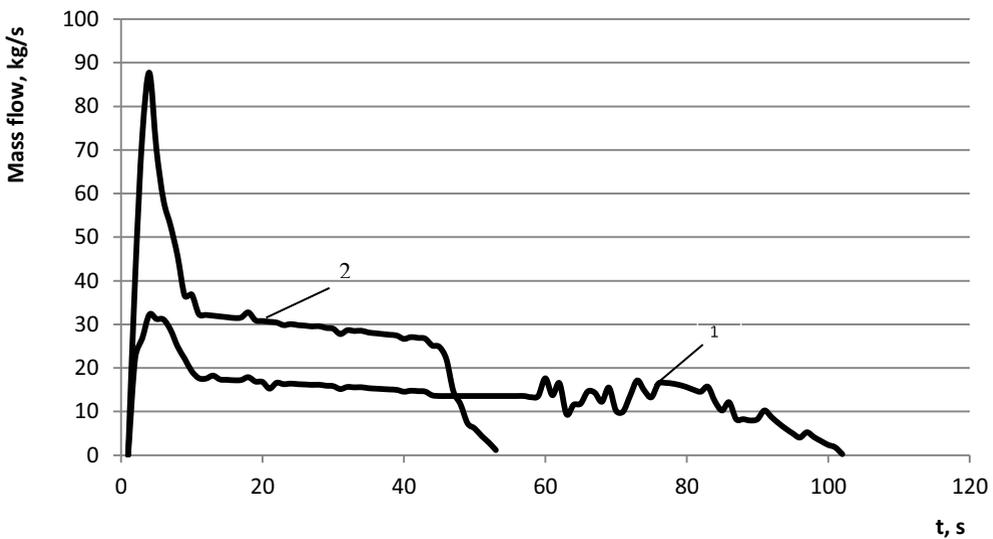


Figure 4. The mass flow of the material after the pump chamber: 1 - before the reconstruction, 2 - after reconstruction.

Analysis Figure 4 shows that the reshaped chamber pump (Figure 3b), the mass flow rate of material in the discharge cycle up and emptying the pump chamber is smaller than the original embodiment (Figure 3a). Performance CN to reconstruction of 54.7 t/h (on the passport 40 - 60 t/h), and after the reconstruction - 128 t/h.

Conclusion

1. The mathematical model of pneumatic transport of bulk materials, taking into account the size of the particles, the compressibility of the gas, the interaction of particles with each other, the gas and the walls material-pipe.

2. On the basis of variant calculations on a mathematical model of fluid dynamics and heat transfer in two-phase flows, the reconstruction of the chamber, which has increased its productivity by 2.34 times.

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