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LIFTING OF FERROMAGNETIC POWDERS

Mironov, V.; Viba, J.

Abstract: *The possibility of use of energy of a pulse electromagnetic field for moving in a vertical pipe magnetic powder materials are discussed. Mathematical models are analysed, taking into account intensity of a pulse electromagnetic field, factors of a powder and its interaction with the surface of pipe and air. Experimental device that includes control and measure system with analysis of parameters by computer is described. A real test of the device is shown.*
Key words: powder, pipe, pulse motion, pulse elevator.

1. MODEL OF DEVICE

The model of device includes vertical tube, powder and special high voltage discharge inductor (IG - impulse generator) (Fig. 1).

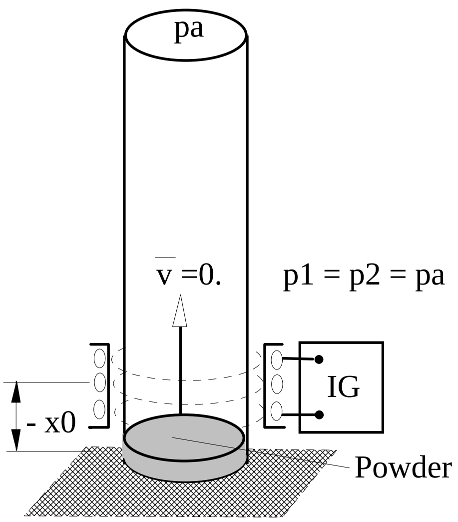

Fig. 1. Model of a device and initial conditions for motion of powder

Motion of powder is described as motion of a centre of mass of powder. This approximation allows to use the theory of pneumatic systems with variable mass in which gas (air) is ideal and heat transfer through the tube does not exist. In addition wave processes may be ignored (Holthunov, 1964; Gerth, 1969; Ashaysky, et. al., 1978; Merkulov & Krivtsov, 1983; Gerth, 1985).
The pulse electromagnetic field is created by an inductor, to which a current is supplied from the pulse electrical generator (Mironov, 1980; Mironov & Kolosov, 2002). As the accumulator of energy condenser is used. The system controls adjustable electromagnetic field parameters.
The mechanical model of system was described from one second order differential equation for motion of porous body centre mass (1) (Mironov & Viba, 1999, 2002, 2003; Bolotin, 1978; Blekhman, 1979):

$$m\ddot{x} = p_1 S_1 - p_2 S_2 - mg - F_T - C_0(\Phi)^2 \, sign\, x; \qquad (1)$$

where x - displacement of centre mass; m - mass; $p_1,\ p_2$ - pressure below and above moving powder; S_1, S_2 - corresponding areas; g - acceleration of free fall; F_T - friction force between tube and powder; Φ - magnetic blow; C_0 - coefficient.
For pressure $p_1,\ p_2$ calculation may be used theory of Gerth, (1969, 1985.) and Holthunov, (1964). Respectively discharge current of inductor may control magnetic force or magnetic blow. In the first approximation discharge current $i(t)$ of inductor equal:

$$i(t) = I_m \cdot e^{-\alpha t} \cdot sin\, \omega\, t. \qquad (2)$$

Here $I_m,\ \alpha$ - constants; ω - angular frequency of discharge current, which may be described as follows

$$\omega = \sqrt{\frac{1}{LC}}, \qquad (3)$$

where L - inductive resistance of discharge circuit, C - capacity of condenser block in discharge time.
The model allows to investigate some real tasks for moving powder upward along the tube (Viba, and Mironov, 1999, 2002.).

2. PRACTICAL MODELLING

Practice of modelling shows that equation of motion (1) may be changed and separated into two steps (Fig.1. - 3.).
First step includes modelling of rapid process for magnetic circuit with small displacement of powder by approximate equation (4):

$$m\ddot{x} = p_1 S_1 - p_2 S_2 + F_m. \qquad (4)$$

Here F_m - magnetic force from inductor that approximately equal:

$$F_m = \mu_0 \mu\, k \left(\frac{|i(t)|}{n_1} \right) \frac{r}{z}, \qquad (5)$$

here μ_0 - magnet constant; μ - magnetic penetrability of powder; k - coefficient of connection between inductor and powder; $n1$ - number of wind of inductor helix; middle radius of inductor helix; z - distance between helix and short circuit wind.

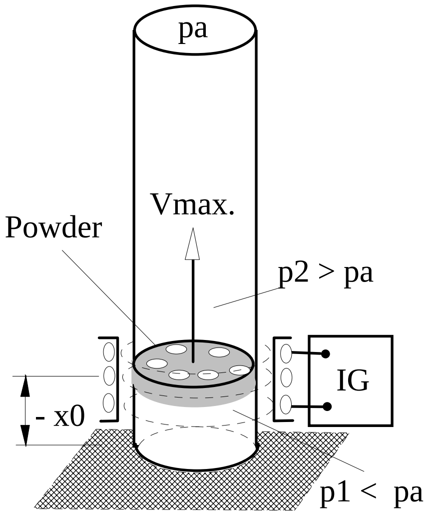

Fig. 2. Motion of powder at the end of electro magnetic field action

Second step includes motion of powder with initial position and velocity obtained in the first step by next equation (6):

$$m\ddot{x} = p_1 S_1 - p_2 S_2 - mg - F_T \,. \qquad (6)$$

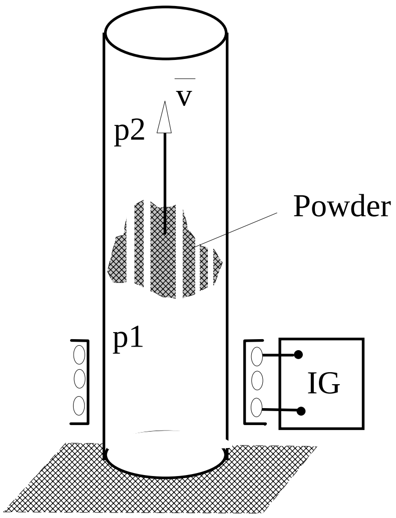

Fig. 3. Flying motion of powder along the tube

Experimental device includes control and measure system with analysis of parameters by computer.

Experimental measurement of discharge current of inductor in the first step in time domain is shown in Fig. 4. Respectively mathematical approximation of discharge current of inductor is shown in Fig. 5.

Examples of modelling results are shown in Fig. 6. - 8.

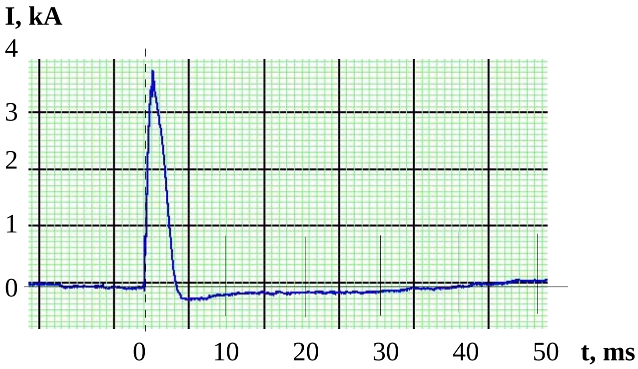

Fig. 4. Discharge current of inductor in the first step in time domain (Voltage 900 V; Current $i(t)_{max}$ = 4 kA; Time of discharge T = 2,5 ms).

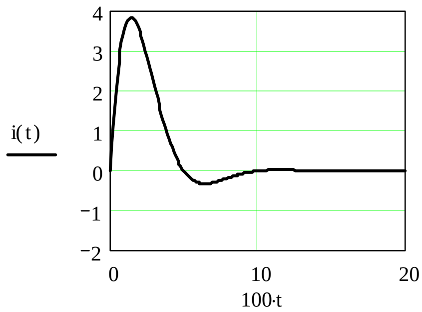

Fig. 5. Mathematical approximation of discharge current by formula (2).

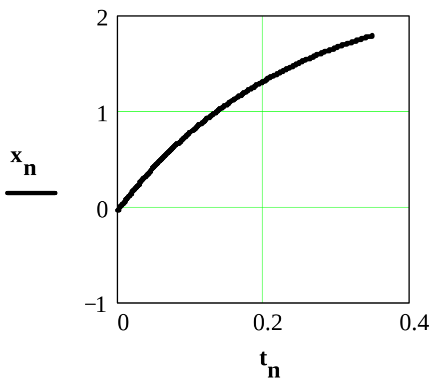

Fig.6. Displacement of powder in the second step

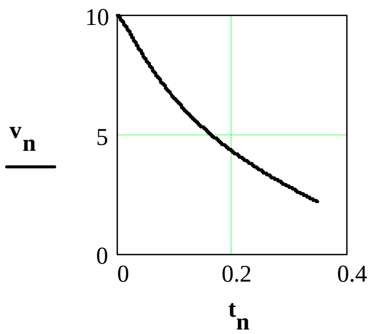

Fig. 7. Velocity of powder in time domain

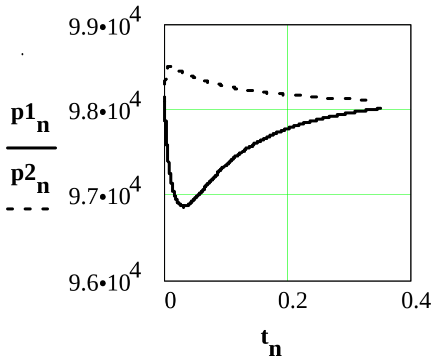

Fig. 8. Pressure below and above moving powder

The tests of the device (with the maximal energy of the generator 400 J and the productivity 3 kg mass in one minute to rise of iron powder on height 2 m) is made (Fig. 9).
The experimental device - electromagnetic-pulse elevator with one control action, intended for vertical pulse moving of iron powders is described. The influence of the basic parameters of the generator of the device and coil, mass of a powder portion and its properties, status of a surface of a pipe, pressure of air in it and other factors on character of process of transportation of a powder and its productivity is established. From experimental investigation some physical parameters of interaction of powder with air and surface of pipe for mathematical models are found out. It allows inventing and designing a new device in the great range of dimension.

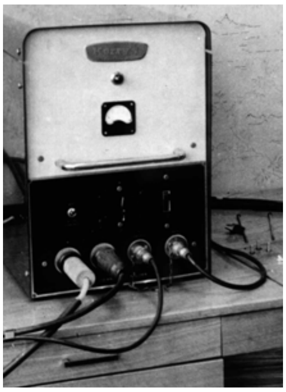

Fig. 9. The experimental pulse generator for vertical lifting of iron M20/80 powder (C = 57 500 μF, U = 160 V, W = 0,736 kJ, H = 1,5 m, Q = 3 kg/min).

The basic advantages of the new device for moving of ferro-magnetic powder materials are – absence of mechanical driven parts; – simplicity of the device; – possibility to control motion along the pipe; – automatic capture of powders.
The research has shown opportunities of effective vertical moving of powder materials with the purpose of their hashing, sorting and transportation. The ways of increase of productivity and reliability of the device are determined. The influence of properties of powders and parameters of the unit contour on moving processes of materials in a pulse electromagnetic field is investigated.
Various kinds of iron powders move in pulse magnetic field with different efficiency. Influence is rendered of powder size, its cleanliness of powders and other factors (Fig 10).

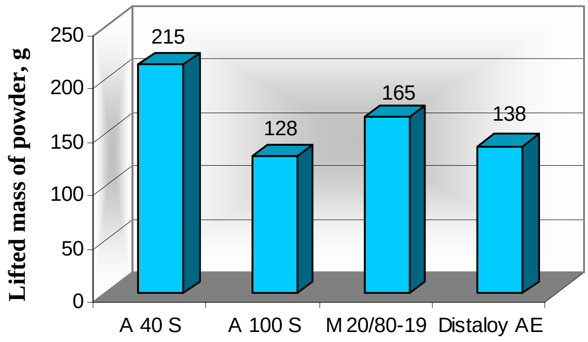

Fig. 10. Influence of kinds of iron powders on the lifted mass of Höganäs powders (2002)
■ The maximal lifted mass of powder on 1 m (g)
Device – CD-500; Inductor – flat, 3-line, n = 25

At automatic following pulses it is established, that with increasing speed following of pulse size of digit current falls, and consequently the volume of a lifted powder is reduced (Fig. 11).

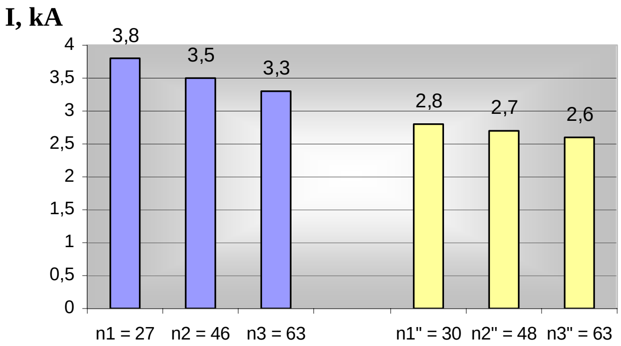

Fig. 11. Changes of I_{max} from number of following of pulses and for two kinds of inductors.

Quantity of the lifted powder (m_p) depends also of initial material quantity (M_0). It is possible to see on fig. 12. a, b that there are areas where the lifted mass is maximal and minimal. Specification of it will be a subject of the further researches.
a)

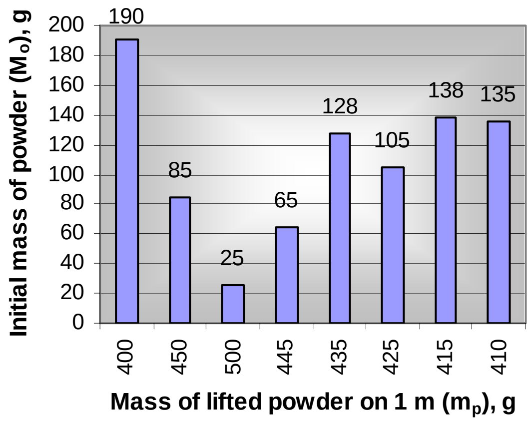

Fig. 12. a. Influence of initial mass of powder M_0 on final lifted mass m_0.

b)

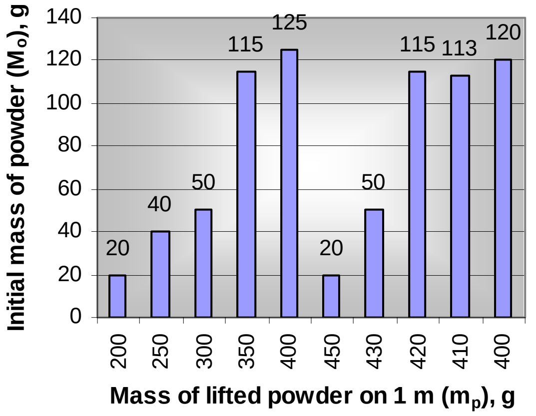

Fig. 12. b. Influence of initial mass of powder M_0 on final lifted mass m_0.
a) Distaloy AE; b) ASC 100-29.

3. CONCLUSION

Electromagnetic - pulse elevator has good prospects in the field of powder metallurgy for its use during moving, mixing and processing of powders and also for submission of powders in the form at pressing.

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