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Studying of Hydrodynamics of the Two-Phase Gushing Forth Layer in the Conic Device

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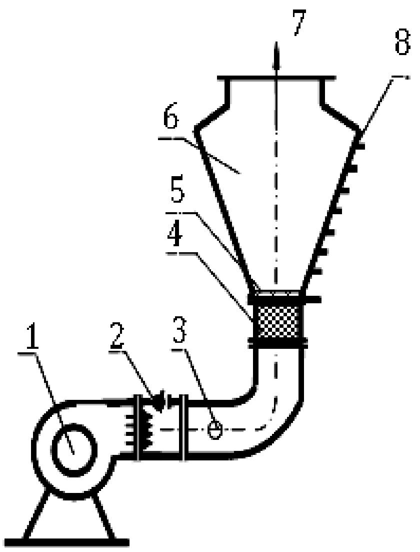
I.INTRODUCTION

Due to the restriction of use of natural gas in big power the question of replacement of natural gas on low-grade brown coal is actual.
One of effective ways of burning of such low-grade coal, in our opinion, is fontaniruyushche — a boiling layer (FKS)[1]. Despite the conducted numerous researches on a gushing forth layer, essence of hydrodynamics of movement gas — a firm particle, are a little opened.

For development of technology of burning of low-grade coal in FKS it is necessary to have and enrich with experimental data, and also techniques of definition of characteristics of such layer. Regularities of heat exchange and fuel burning out in such systems is defined by a created hydrodynamic situation and determination of hydrodynamic parameters of process.

The purpose of this work is determination of regularity of change of pressure of a two-phase stream from an expense of a gas stream, definition of degree of adequacy of the developed analytical dependences by determination of value of resistance of a layer, critical speed and vitaniye speed depending on layer and humidity thickness for model wheat materials, sunflower and peas seeds.

	1 – Fan; 2 – Regulator of consumption of air; 3 – Opening for installation of the measuring device of speed of a stream of air; 4 – Quencher of a vorticose current of air; 5 – Holdinglattice; 6 – The working cameramade of plexiglasss; 7 – Exitforair; 8 – Branch pipes for measurement of speed of a stream and a difference of pressure on sections.

Picture 1.Scheme of experimental installation.

For achievement of a goal the experimental installation which scheme is submitted in fig. 1 was created. Installation consists of the working camera of the conic form 6, made of organic glass for visual supervision over hydrodynamic process. On the chamber 6 case down through each 10 cm are established the union 8 for pressure difference measurement.

The bottom union is placed on an entrance of a gas stream to the camera. In an entrance branch pipe of an airbringing pipe the quencher of pressure head energy from a metal sieve 4 is placed. Diameter entrance an opening makes 10 cm. In the working camera air is forced by means of the pressure head fan 1.The consumption of air in the

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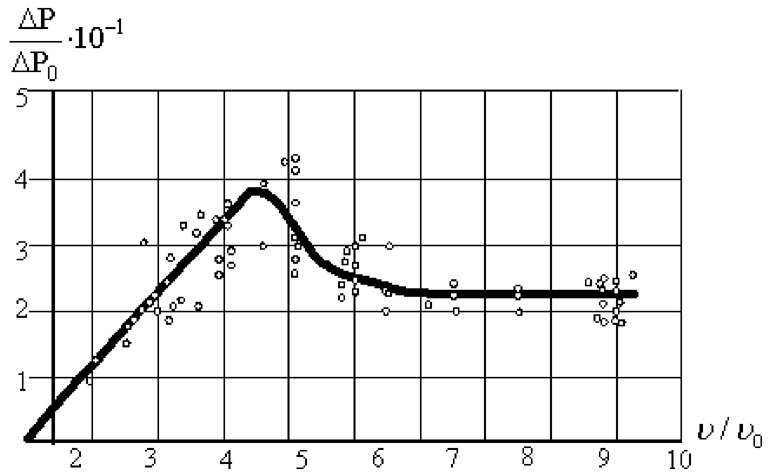
camera is regulated by a special rassekatel 2.For installation of the measuring device the opening 3 is drilled. The expense and speed of an air stream were measured by means of the Testo 405-V1 device. Pressure difference was measured in sections of the camera by means of the multirangemicromanometer with an inclined tube of MMN-2400.

Authors as firm particles used sunflower seeds after subfrying. Height of a motionless layer varied within 10–25 cm. Results of measurement of numerous serial experiments on pressure differences in a layer are presented in fig. 2.in the form of a «spouting» curve, from where it is visible that with increase in speed of an air stream pressure difference in a motionless layer gradually increases.



Picture2.Spouting curve in the working camera to the initial camera

Regularity of change of pressure drop (filtration) can be described on the following dependence:

$$\frac{\Delta P}{\Delta P_0} = k\frac{\vartheta}{\vartheta_0}, \qquad (1)$$

where: $k = tg\alpha,\ \alpha$ – straight line tilt angle to abscissa axis, depending on a sort of a material and layer thickness; ΔP_0 — pressure difference (Pa) at a speed ϑ_0.

With increase in speed of a stream firm particles start rising with formation of a boiling layer. Thus it is revealed that the layer of seeds iscondensed, since the top part of a layer. At further increase of speed of an air stream such process proceeds to the most lower part, and then all layer rises on some distance from a holding lattice then the razlamyvaniye of the condensed layer begins and the gushing forth layer is formed. Probably, the layer condensed with air at a raising is exempted from a wall limiting it and «breaks». Height of the condensed layer made 20–23 cm. Airbag height between a lattice and a layer made 5–6 cm. Thus, measured pressure difference with big pulsations proceeded to the most critical point of spouting. The maximum value of pressure difference in a gushing forth layer can be described by means of hydrostatic pressure in a look:

$$\Delta P_M = \rho_s gh, \qquad (2)$$

where,

$$\rho_s = \frac{(f_1 + f_2)\rho_1\rho_2}{f_1\rho_2 + f\rho_1}; \quad f_1 + f_2 = 1, \qquad (3)$$

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where: f_1 — concentration of a gas phase; f_2 — concentration of a firm phase; h — height of a motionless layer; g — gravity acceleration; $\rho_1\rho_2$,— density of the corresponding phases. Considering expressions (1), (2) and (3) can be etermined start spouting velocity of the dispersed phase by the following relationship:

$$\vartheta_{s.s} = \frac{\rho_1\ \rho_2 g\ h}{\Delta P_0\left(f_1\rho_2 + f_2\rho_1\right)k}\vartheta_0. \quad (4)$$

From the spouting beginning porosity of a layer increases from 0,4 to 0,6–0,7.Pressure difference starts decreasing to the speed of stable spouting, and it is accompanied by alternate expansion and compression of a gushing forth layer. Such instability of process at the moment leads the beginning of spouting to the scattered pulsations of pressure difference in a layer.

Particles of many disperse materials which are subject to thermal treatment, have the form, considerably different spherical. Existence of a gradient of speed in the cross section of a stream, and also some other the reasons lead to intensive rotation of flying particles and their distribution with various concentration on camera section. Collisions of particles with each other and about a camera wall also have essential impact on nature of movement of a gas-suspension.

For the above conditions of thermal treatment of disperse materials experimentally confirmed analytical settlement dependences were received. However to estimate the error, the made assumptions received for the account at calculation of interesting sizes in the intensified boiling layer for a number of materials very difficult.

Relative speed of gas and material always is more than speeds of a vitaniye of V в.The configuration of the camera and force of interaction arising between particles have impact on nature of movement of particles.

Values of density of gas and its kinematic coefficient of viscosity νrare accepted by constants. From a condition of balance of carrying power and particle gravity for a particle with a spherical form we will write:

$$\Delta PS = \lambda \frac{L}{D}\frac{\rho_2\vartheta_0^2}{2g}S = \frac{\pi d_e^2\rho_M}{6}, \quad (5)$$

where: d_e – the equivalent diameter of a particle of a material; D — diameter of the camera; ϑ_0 — average speed of a vitaniye of particles of a material; S — cross camera sections; ρ_2 , ρ_M - gas and material density;

The equation (5) for particles with the wrong form has an appearance:

$$d_e^2 = \Delta PS = \lambda \frac{L}{D}\frac{\rho_2\vartheta_0^2}{2g}S = \frac{\pi d_e^2\rho_M}{6}, \quad (6)$$

where,

$$d_э = \frac{2\Phi\varepsilon d}{3(1-\varepsilon)};\quad C = \lambda\frac{l}{D};\quad \varepsilon = \frac{V-V_0}{V} \quad (7)$$

Φ— factor of a form of a firm particle, for a cube *Φ = 0,806*, for the cylinder *Φ= 0,96*, for a disk *Φ = 0,32*, for a sphere *Φ = 1; V* — total amount taken by a granular layer; V_0 — volume taken by particles.

Taking into account (7) equation (6) will register following in a way:

$$C\frac{\rho_{\hat{a}}\vartheta_{B}^2}{4g} = \frac{2\Phi\varepsilon d_i\rho_\mu}{3(1-\varepsilon)}$$

From where, expression of speed of a vitaniyeis defined as:

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$$\vartheta_{\text{B}} = \sqrt{\frac{8g\Phi\varepsilon d_i \rho_\mu}{3(1-\varepsilon)\rho_{\tilde a}\cdot\tilde N}}$$

where: d — settlement diameter.

Experiments were made in the camera of a diffuser form with seeds of grain crops (wheat and peas) which gave the chance to define dependence of change of resistance of a layer on air speed that on character corresponds to results of the research, given in works[1].

The analysis and processing of the obtained data2
gave the chance to receive dependence of critical speed and resistance on layer thickness
–h_0(fig.3 and fig.4).

It should be noted that with increase of initial humidity of W more than 30% relative pressure difference sharply increases. It is connected with increase of mass of particles from moisture (fig. 5).

Change of critical speed from humidity of wheat picture.5 can also be approximated following in a way:

$$\Delta PS = \lambda \frac{L}{D}\frac{\rho_2 \vartheta_0^2}{2g} S = \frac{\pi d_e^2 \rho_M}{6},$$

where: — a, b experimental coefficients depending on thickness of a layer of grain, for example, for thickness of a layer of =100 mm, and = 0,641, b = 0,0089.

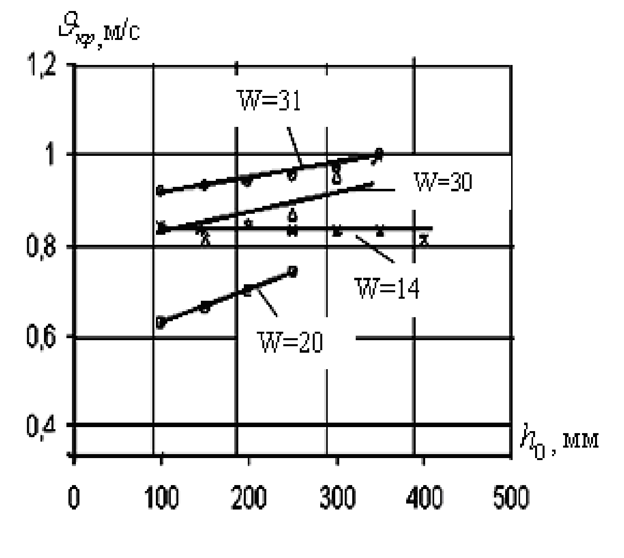

Fig. 3.The schedule of dependence of critical speed of gasses Vcr from thickness of motionless layer (wheat)h_0.

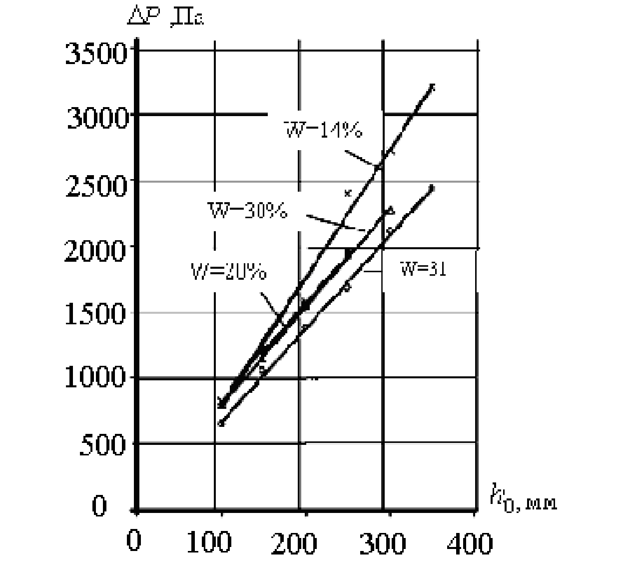

Fig. 4.The schedule of dependence of resistance of a layer of 0 ΔP
from layer height (wheat) h.

Thus, the received results of research of model disperse materials give the chance to estimate energy expenses at IBL (the intensified boiling layer) at the beginning of thermal processes (drying, gasification, burning, etc.) falling on a certain productivity of production and to choose the fan.

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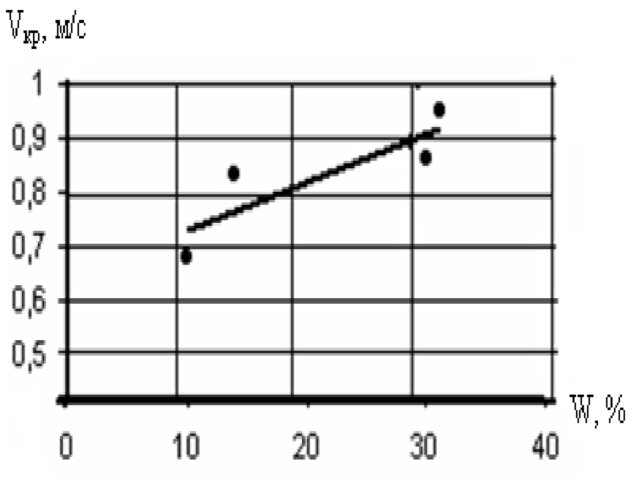

Fig. 5.The schedule of dependence of change of critical speed Vcr from humidity of grain W-.Points-experiment; The continuous line –the theory

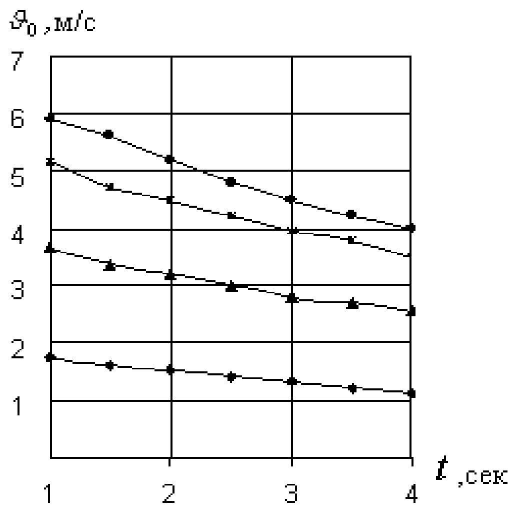

Fig 6.Dependence of change of speed of gasses of mix on time: ϑ_0= 2; ϑ_0= 3; ϑ_0= 4; ϑ_0= 5.(К = 0,35)

Movement of a stream of liquid (gas) through a motionless disperse layer is a difficult non-stationary pulsing current. At speed increase the stream of liquid sets firm particles in motion. Nature of movement of liquid through a motionless layer significantly differs in comparison with a usual whirl. At movement through a motionless layer the speed of pulsations can exceed considerably even average speed. Such phenomenon considerably complicates processing and the analysis of obtained experimental data at liquid movement in a motionless layer of a disperse material[1].

It is known that the geometrical form of firm particles of a disperse material differs from a sphere form. Collisions of particles with each other and about a wall of the camera have essential impact on nature of movement of a gas-suspension.

Rakhmatullin H. A. it is proved that in uniformly — the porous environment volume and superficial porosity represent part of the unit of volume, taken by this gas, and the sum of all coefficients of porosity is equal to unit:

$$m_w \rho_i = \rho_c \text{ и } m_S \rho_i = \rho_c ,$$

or

$$\frac{\rho_1}{\rho_{1i}} + \frac{\rho_2}{\rho_{2i}} + ... + \frac{\rho_N}{\rho_{Ni}} = 1 \text{ or } f_{1i} + f_{2i} + ... + f_n = 1,$$

where: mw — volume porosity; ms– superficial porosity; ρ_c– average density; ρ_1 – the true density of some liquid which moves in the porous environment; fn — concentration of liquid with n-oh phase.

We will work out the equation of movement of firm particles in a gas-suspension layer, accepting that liquid (gas) with an initial speed creates a porous layer of a gas-suspension. The layer has the mass of m which the gravity of a layer of P and force of resistance$R=\nu\vartheta^2$directed down concerning movement of gas affects. We will enter designations in the following look

$$\frac{\nu}{\mathrm{P}} = K^2$$

Where ν– the coefficient depending on average density of the environment on its surface of S, perpendicular to the direction of movement of gas.

Then $\nu = \phi \rho S$ $\nu\rho=\Phi s.$

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Dependence of change of average speed of a particle in set time of t will be defined from the following ratio:

$$\vartheta = \frac{K\,\vartheta_0 - tg\left(K\,g\,t\right)}{K\left[1 + K\,\vartheta_0\,tg\left(K\,g\,t\right)\right]}$$

The maximum height of lifting of a particle, it agrees[1]has an appearance:

$$h = \frac{\ln\left(1 + K^2\,\vartheta_0^2\right)}{2K^2\,g}$$

For determination of speed of a stream of a gas-suspension in time and the maximum height of lifting of firm particles pilot researches in the device with fontaniruyushche-boiling layers are conducted.

As a disperse material used sunflower seeds with humidity of 10–20%. Height of a motionless layer of a disperse material changed within 10–80 cm. The received results show (fig. 6) that dependence of change of speed of a gas-suspension on time strongly depends on coefficient *K*. At values K= 0,35 value of speed sharply decreases in time to *K=1* value. With increase in values to *K= 25* the pulsation of speed of a gas-suspension with the value, increased to 50% of average speed is observed. This phenomenon is explained by that the coefficient ν strongly depends on superficial porosity (section S surface). When porosity of a layer grows, value of coefficient increases also Kthat characterizes growth of a pulsation of speed.The schedule of change of height of the maximum lifting of firm particles from initial speed and resistance coefficient K is submitted in fig.7.that coherence of experimental and settlement and theoretical data shows.

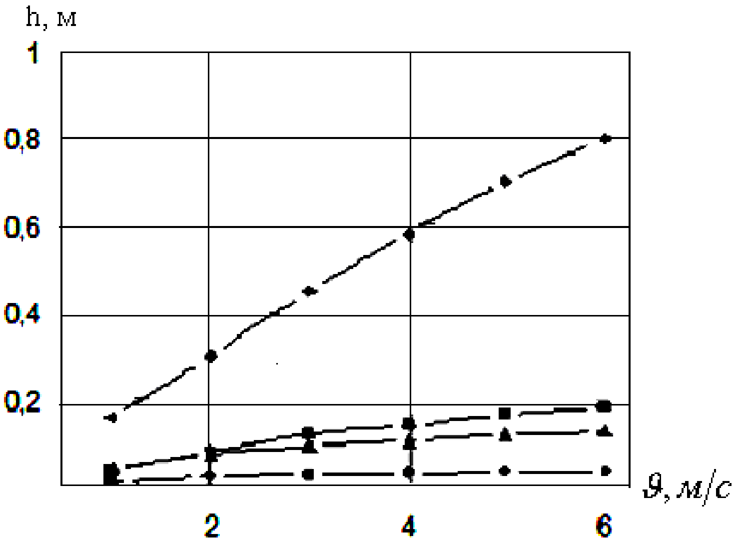

Fig 7.Dependence of change of height of a layer of hon the speed of gasses of mix ϑ: *K= 0,35*; *K= 1; K= 2; K= 3*

The phenomenon of a pulsation happens to the beginning of processes of boiling or spouting of a disperse layer. From a certain value*K*there are interpenetrating movements of a stream of a gas-suspension. Thus there is a phenomenon of a difference of speed of gas and a firm particle. In such cases interaction force between gas and firm particles is considered. For the description of movements of such character the classical fundamentals of hydrodynamics applied at interpenetrating movements of squeezed environments are used[2].

Thus, it is possible to draw a conclusion that process of movement of liquid through a layer of firm particles has difficult character. Without acceptance of certain coefficients there are difficulties in the mathematical description of processes with active hydrodynamics therefore authors settlement experimentally defined the corresponding coefficient *K*.

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