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EQUATION FOR DETERMINATION OF MINIMUM SPEED OF FLUIDIZATION OF POLYDISPERSED BED OF ANTHRACITIC COAL DUST

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Key Words and Phrases: anthracitic coal dust; construction of a furnace unit of a boiler; minimum speed of fluidization; poly- and monodispersed beds; semi-boiling bed; fluidization; fuel burning.

Abstract: Investigation of a furnace unit and a boiler for burning anthracitic coal dust in the semi-boiling (thermally fluidized) bed have been suggested. On the basis of experimental data the nondimensional equations for determination of minimum speed of fluidization for polydispersed beds of anthracitic coal dust are presented.

Symbols

D_p – equivalent diameter of mixture particles, m;
H_o, H – layer altitude in a fixed state, operating altitude of a bed, m;
d_1, d_2 – diameter of passing and nonpassing screens, m;
u_{mf} – initial (critical) speed of fluidization, m/s;
ν – kinematic viscosity of liquefying medium, m^2/s;
x – fraction of components in mixture;
z – number of components in mixture;
ε_{mf} – minimum fluid voidage;
ρ_s, ρ – density of solid particles and liquefying medium, kg/m^3.

A lot of screenings – anthracitic coal dust – coal particles which are less than 6 mm in size – are formed while enriching the anthracite. Anthracitic coal dust has high calorie content and low cost. Drawing anthracitic coal dust in fuel balance of municipal boiler-houses of small capacity (1…3 MWt) is an important problem for many regions of CIS and in Russia – for Rostov region. An investigation has been made and a construction of a furnace unit and a boiler for burning anthracitic coal dust in semi-boiling (thermally fluidized) bed has been suggested [1]. Such boilers are used in municipal boiler-houses in many towns of Rostov region, e.g., Gucovo, Donetsk, Novoshakhtinsk and other.

Calculated relationships for determination of minimum speed of fluidization of polydispersed bed of anthracitic coal dust are revealed. In monography on fuel burning in the fluidized bed [2] and in number of projects e.g. in [3] while calculating boilers which burn solid fuel in fluidized bed it is suggested to determine a minimum speed of fluidization from known relationship offered by Todes O.M. and his colleagues [4, p.142]:

$$\mathrm{Re}_{emf} = \frac{\mathrm{Ar}}{1400 + 5{,}22 \cdot \sqrt{\mathrm{Ar}}}, \qquad (1)$$

where $\mathrm{Re}_{emf} = \frac{u_{mf} \cdot d_a}{\nu}$ and $\mathrm{Ar} = \frac{g \cdot d_a^3}{\nu^2} \cdot \frac{\rho_s - \rho}{\rho}$, and $d_a = \Phi \cdot D_p$; Φ – form factor.

However, equation (1) is obtained for determination Re_{emf} of monodispersed bed of spherical or round particles at fluid void age at the moment of it transition to fluidized state ε_{mf} = 0,4. Particles of anthracitic coal dust have complex, needle-like form, porosity of anthracitic bed at the moment of it transition to fluidized state ε_{mf} = 0,55 [5], that's why values Re_{emf}, obtained due to relationship (1) can differ from factual ones.

In quoted above paper [5] extensive investigations of fluidization of polydispersed beds of anthracitic coal dust are carried out in the cylindrical unit diameter of which is 102 mm. A wire net is used as an air distributor.

Particles of coal dust have been obtained by grinding pieces of coal up to 6…7 mm in size in a ball mill. The granulated particles have been dispersed with the help of screens and mixtures characteristics of which are given in table 1 have been made up.

Each mixture has been characterized by equivalent diameter determined as

$$D_p = \sum_{z=1}^{z=z} \left(x \cdot d_p \right) \cdot z,$$

where $d_p = \sqrt{d_1 \cdot d_2}$.

Besides, for mixture characterization the index of polydispersion ability has been introduced C_u

$$C_u = \frac{d_{60}}{d_{10}},$$

where d_{60} and d_{10} – diameters of screen holes through which 60 and 10 % of mixture particles pass.

In fig. 1 curves of fluidization of polydispersed mixtures of anthracitic coal dust particles are given [5].

Table 1

Mixture notation	D_p, мм	H_o, м	C_u
a	0,970	0,490	1,88
b	0,710	0,275	1,45
c	0,590	0,384	1,18
d	0,418	0,237	1,21
e	0,308	0,306	3,29
f	0,239	0,344	3,27
g–1	0,214	0,263	2,50
h–1	0,167	0,338	3,53

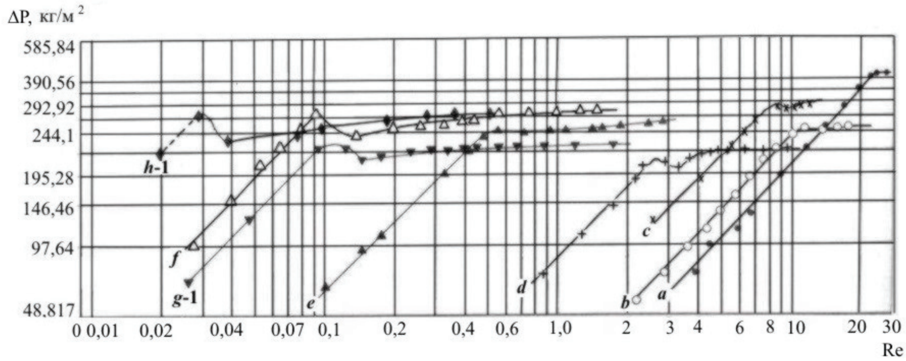

Fig. 1 Curves of fluidization of polydispered mixtures of anthracitic coal dust particles (notation see table 1)

As we can see from fig. 1 for mixtures of particles with equivalent diameter 0,308…0,97 mm curves of fluidization have not peak in the region of transition of bed to fluidized state which is characteristic for fluidization of polydispersed mixtures [4, 6], when with increase of speed of liquefying medium larger particles convert to fluidized state. Curves of fluidization of mixtures of particles with equivalent diameter 0,167…0,239 mm have peak in the region of transition of bed to fluidized state, which is characteristic for fluidization of monodispersed beds. However, mixtures of particles with equivalent diameter within the range of 0,167…0,239 mm are characterized by higher values of polydispersion factor – 2,5…3,53 mm, than mixtures of particles with equivalent diameter 0,308…0,97 mm, which have polydispersion factor – 1,18… 3,29 mm. That's why pressure peak on curves of fluidization of mixtures of smaller particles but with higher degree of polydispersion is connected with more complex character of fluidization of such systems as e.g. with greater force of adhesion.

For generalization of experimental data given in paper [5] it is suggested to use two criteria Re_{emf} and ξ. by analogy with paper [6]. Here ξ – resistance factor in known head loss equation

$$\Delta P = \xi \cdot \frac{u^2 \cdot \rho}{2} \cdot \frac{H}{D_p}.$$

In fig. 2 a relationship is presented, all values $\lg\xi$ and $\lg\mathrm{Re}$ being marked on the plot for each experiment from the beginning of blowing air up to full fluidization – going out on constant pressure differential (for curves *a*, *b*, *c*, *d* and *e* in fig. 1) or up to crossing pressure differential peak (for curves *f*, *g* –1 and *h*–1 in fig. 1).

Fig. 2 displays all these points arranging near the straight line described by equation

$$\lg\xi = -1{,}265 \cdot \lg\mathrm{Re} + 2{,}609.$$

This means that relationship $\xi = f(\mathrm{Re})$ has the form

$$\xi = 406 \cdot \mathrm{Re}^{-1{,}265}. \qquad (2)$$

According to [6] for filtration regime and right up to full fluidization

$$\Delta P = \xi \frac{H}{D_p} \frac{u^2 \rho}{2}. \qquad (3)$$

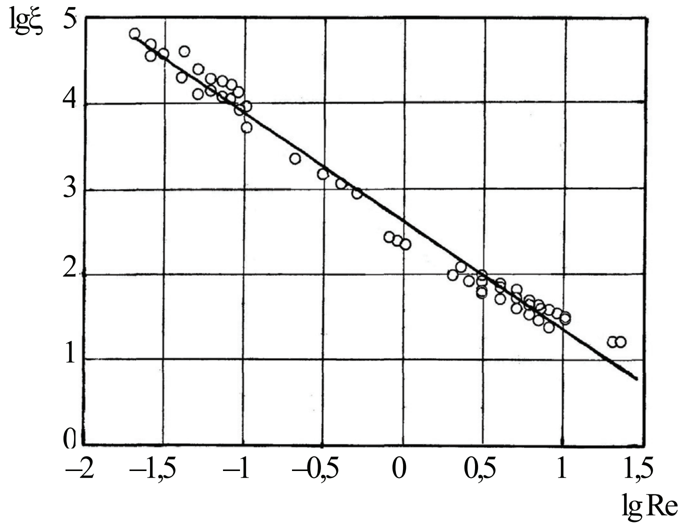

Fig. 2 $\lg\xi - \lg\mathrm{Re}$ **experimental relationship**

for full fluidization

$$\Delta P_{mf} = H_o \cdot g \cdot (\rho_s - \rho) \cdot (1 - \varepsilon_{mf}), \qquad (4)$$

where H_o and ε_{mf} – bed altitude and its voidage at the moment of it transition to fluidized state.

Taking into account that at the moment of fluidization $\Delta P_{(3)} = \Delta P_{(4)}$ and with regard for (2) we obtain the following after some simple transformation:

$$\mathrm{Re}_{emf}^{0,735} = 0{,}0049 \cdot \mathrm{Ar} \cdot (1 - \varepsilon_{mf}).$$

or

$$\mathrm{Re}_{emf} = \left[0{,}0049 \cdot \mathrm{Ar} \cdot (1 - \varepsilon_{mf})\right]^{1,36}, \qquad (5)$$

for anthracitic coal dust $\varepsilon_{mf} \approx 0{,}55$ and it slightly depends on D_p [5].

Values [5] measured and (1) and (5) relation calculated are given in table 2 $\mathrm{Re}_{кр}$.

Table 2

Mixture notation	D_p, mm	d_a, mm ($D_p \Phi$)*	Ar	Re_{emf} from [5]	Re_{emf} from (1)	Re_{emf} from (5)
a	0,97	0,64	11161,7	30,0	5,72	77,97
b	0,71	0,47	4420,39	15,0	2,53	22,12
c	0,59	0,39	2525,3	10,0	1,52	10,32
d	0,418	0,27	843,7	4,5	0,54	2,33
e	0,308	0,2	340,7	0,6	0,23	0,68
f	0,239	0,16	170,34	0,2	0,12	0,26
g-1	0,214	0,14	115,0	0,15	0,08	0,16
h-1	0,167	0,11	55,36	0,04	0,04	0,06

* Φ = 0,66 [4, p. 80]

As we can see from table 2 on the average values Re_{emf} estimated on (1) are to values measured on [5] as 1:4 (relationship (1) decreases Re_{emf} approximately 4 times as much), and values Re_{emf} measured on [5], are to values Re_{emf} estimated on (5), as 1:1,48. I.e. estimation on formula (5) is 2,7 times as exact as on formula (1).

Tinned equation (5) was used for the calculation of device for the incineration anthracite dust coal.

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Уравнение для определения минимальной скорости псевдоожижения полидисперсного слоя антрацитового штыба

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Ключевые слова и фразы: антрацитовый штыб; конструкция топочного устройства котла; минимальная скорость псевдоожижения; поли- и монодисперсный слои; полукипящий слой; псевдоожижение; сжигание топлива.

Аннотация: Проведены исследования топочного устройства котла для сжигания антрацитового штыба в полукипящем (термопсевдоожиженном) слое. На основе экспериментальных данных представлены критериальные уравнения для определения минимальной скорости псевдоожижения для полидисперсных слоев антрацитового штыба.

Gleichung für die Bestimmung der Minimalgeschwindigkeit der Pseudoverflüssigung der Polydispersschichte von Anthrazitstaubkohle

Zusammenfassung: Es sind die Untersuchungen der Feuerungsanlage des Kessels für das Verbrennen der Anthrazitstaubkohle in der halbsiedenden (thermopseudoverflüssigten) Schichte durchgeführt. Aufgrund der Experimentalangaben sind die Kriterialgleichungen für die Bestimmung der Minimalgeschwindigkeit der Pseudoverflüssigung für die Polydispersschichte von Anthrazitstaubkohle vorgestellt.

Equation pour la définition de la vitesse minimale de la pseudo-fluidification de la couche polydispersée de la charbonnaille d'anthracite

Résumé: Sont effectuées les études du foyer pour l'échauffement de la charbonnaille d'anthracite dans une couche thermopseudofluidifiée. A la base des données expérimentales sont présentées les équations pour la définition de la vitesse minimale de la pseudo-fluidification de la couche polydispersée de la charbonnaille d'anthracite.
