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EVALUATION OF THE MINIMUM VELOCITY OF POLYDISPERSE BED FLUIDIZATION COMPOUNDED OF BIOMASS PELLETS AND THEIR MIXTURES WITH FINE PARTICLES OF COAL

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Abstract

It turned out that the change graphs of the absolute value of dimensionless amplitude of pressure fluctuations against air velocity can be used to evaluate values of the minimum fluidization velocity of polydisperse bed biomass pellets. An experimental verification is reported on the early predicting index of agglomeration in bubbling fluidized bed of biomass pellets and fine coal particles.

Introduction

In recent years, the technology of dispersed material processing in a fluidized bed has been applied in industry mainly for the implementation of combustion technology of different organic products in circulating fluidized beds as well as in a bubbling beds. Thereby, increasing attention is paid to issues of biomass combustion in fluidized bed as well to combustion of a mixture of biomass and fine coal. In the past two years it has aroused interest in the use of non-food biomass (straw, sunflower and rice husk, etc.) as a fuel. However, these types of biomass have a relatively high ash content in comparison to woody biomass with, moreover, low ash melting temperatures. Moreover, the ability of a particular type of biomass during combustion to form on the heating surfaces ash deposits and cause corrosion of these surfaces is directly related to the ability of biomass ash to form slag agglomerates in a combuster of the boiler –Barišić *et al.* (1).

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In a previous study (Isemin *et al.* (2) it has been suggested that these types of biomass should be burned in a form of pellets in the fluidized bed, formed by the pellets itself and by solid products of its combustion (ash and coke residue particles). The results of the experiments have shown that in such a bed the pellets produced of straw and millet husk combust with the same rate as those of wood though the latter contain 8.76 – 19.4 times less ash. The duration of combustion of the same portion of straw pellets in a fluidized bed is 3.74 – 7.01 times less than the duration of combustion of cut straw in a fixed bed. Besides, the movement of agropellets prevents agglomeration and slagging of a boiler furnace. When co-combustion of biopellet and coal (culm) in the boilers of our design is established: at an increase in the proportion of pellets in a mixture of loss of mechanical incompleteness of combustion (including losses from entrainment entrainment of particles) are reduced from 16% (content of pellets in a mixture of 0%) to 10.5 % (content in a mixture of 40% pellets). Content of combustible in the slag with an increase in the proportion biopellet in the mixture is reduced to 7.5% (with a coal burning) to 2.3% (the burning of a mixture containing 40% biopellets).

To calculate the combuster device it is necessary first of all to determine the value of minimum velocity of bed pellet fluidization. However, for large particles of aspherical shape the determination of this value is not possible to make by using a well-known method: a dependance graph of the pressure drop in the bed against velocity of blasted gas through the bed. Punćochář *et al.* (3) is proposed to evaluate the minimum velocity of fluidization carrying out a detailed analysis of random fluctuations of the pressure drop in a bed. On the other hand, Zhang *et al.* (4) proposed to use the statistical characteristics of a random process pulsation pressure drop in a bed for early detection of agglomerates in a fluidized bed .

In summary, the objective of this study is to develop a method for evaluating the minimum fluidization velocity for polydisperse beds of large particles of aspherical shape, and a study of changes in statistical characteristics of random process pulsation pressure drop in the pellets – coal bed.

Methodology and Experimental procedure

Beds of pellets made from winter wheat straw, millet and wheat husk were studied (Table 1). For mixtures, use finely divided coal, which has the following characteristics: particle density 1400 kg/m^3, moisture content 5.3%, the percentage of particles as small as 1 mm – 20.87%, the percentage of particles ranging in size from 1 to 1.2 mm - 61.79%. The height of the fixed bed was 100 - 350 mm.

Table 1 The characteristics of pellets

Name of characteristics	Straw pellets	Millet husk pellet	Sunflower husk pellets
Diameter, mm	7	8	10
Average length of pellets, mm	12.03	20.47	12.17
Diameter ratio of pallets to an length	0.59	0.39	0.89
Bulk density, kg/m^3	490	560	650
Bed porosity in a state of minimum fluidization	0.59	0.55	0.46

The research was conducted in the device with a rectangular cross-section of 194 x 485 mm and a height of 1500 mm (fig. 1). The air velocity was measured by the anemometer «Testo 405-V1» at the outlet of the device. The measurement of the pressure drop fluctuation in a bed was carried out by the differential micromanometer «Testo - 525». The digital signal was sent from the micromanometer «Testo - 525» to a personal computer.

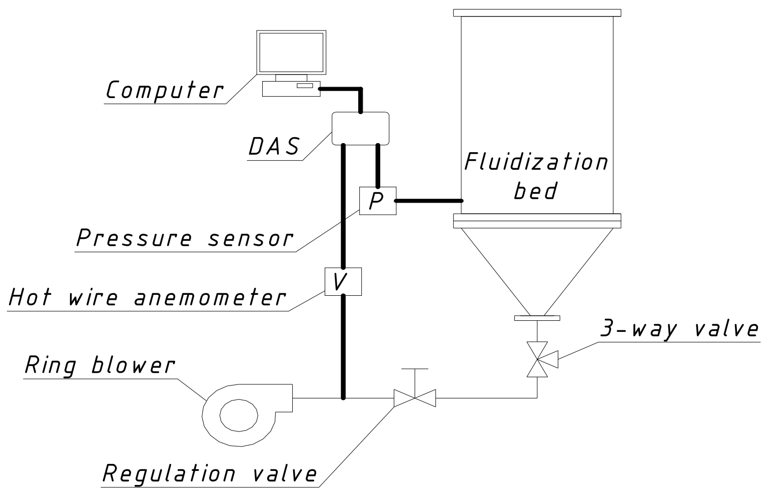

Fig. 1. – Scheme of an experimental device

In the pilot tests it was found that, the measurements of pressure fluctuations should be made in every 0.05 s within 60 seconds without reducing the accuracy of measurements of more than 10%. Thus, the pressure drop measurements were made at the frequency of 20 Hz, whereas according Li *et al.* (5, 6), the dominant frequency of fluctuation in a bed of large particles does not exceed 3 Hz.

The obtained set of casual values of pressure drop in a bed was exposed to the statistical processing. Thus the following values were determined: 1) the average value of pressure drop in a bed during the time of visual examination ($P_m = \Sigma P_i/N$,), 2) root-mean-square deviation of pressure fluctuations ($\sigma = [\Sigma (P_i - P_m)^2 / N]^{½}$), 3) dimensionless amplitude of pressure fluctuations ($\delta = \sigma/Pm$), .4) absolute value of change of dimensionless amplitude of pressure drop ($\Delta\delta = \delta_I - \delta_{i-1}$). Besides the changes of a bed state were filmed with Panasonic DVC 30 video camera. Then each second of a video shooting was broken into 25 video shots that allowed to get the successive pictures of the change of a bed state in every 0,04 second.

Results and discussion

Figure 2 shows the dependence of mathematical expectation of pressure drop in a bed on the air velocity blown through the bed.

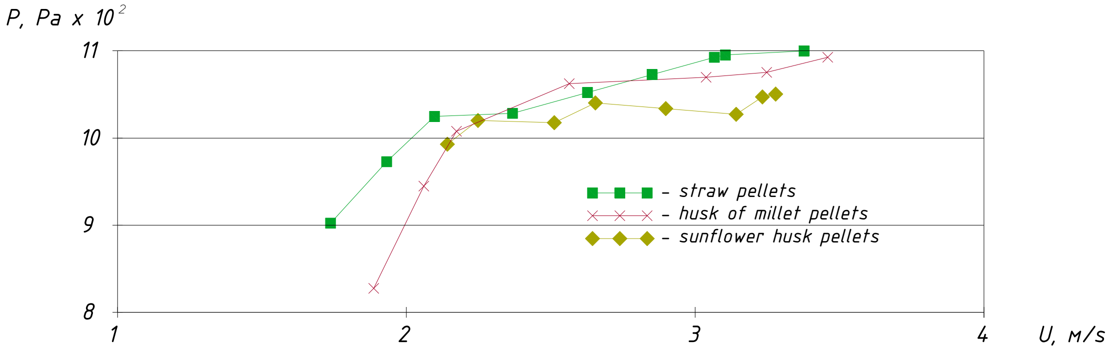

Fig. 2. – Dependence of pressure drop in a bed on the air velocity blown through a bed

According to Fig. 2, the complete fluidization of straw, millet and sunflower husk pellets occurs when the air velocities is 2.4 m/s, 2.6 m/s, 2.3 m/s correspondingly.

However, the visual observations show that when air velocity is 2.4 m/s, two heterogeneous streams are seen in a straw pellet bed. These streams come to the surface of a bed, while the rest of the bed remains motionless (Fig. 3 a). i.e. the fluidization process of straw pellet bed begins at this air velocity.

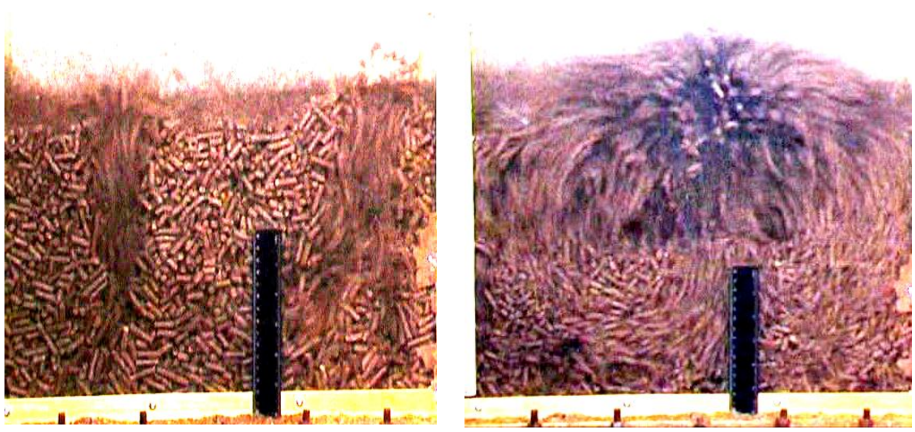

Fig. 3. - The state of straw pellets beds when the air velocity is 2.4 m/s (a) and 3.09 m/s (b).

The bed of sunflower pellets also begins to fluidize at the air velocity of 2.3 m/s: three jets break through it - two at the sides and one in the center, and the remaining mass of the pellet bed is motionless. It is also applied to the millet husk bed: two vertical streams break through the bed near the walls at the full height at the air velocity 2.6 m/s, but the rest of the bed is motionless. The complete fluidization of the bed of straw pellets, millet husk, sunflower husk takes place when the air velocity is 3.09 m/s (Fig. 3 b), 3.24 m/s, 3.14 m/s correspondingly.

For the same reasons, the dependence $\Delta P = f(U)$ can not be used to evaluate the minimum velocity of fluidization. However, it turned out that the graphs of $\Delta\delta$ can be used to evaluate the the minimum fluidization velocity of the pellet bed.(Fig. 4). Indeed, the monotonous increase of $\Delta\delta$ is observed in the pellet bed until the bed becomes completely fluidized. When the pellet bed is fully fluidized, the absolute value of $\Delta\delta$ drops abruptly. The same drop occurs in the pellet bed of the millet husk at the air velocity equal to 3.2 m/s, in the pellet bed of straw at the air velocity equal to 3.0 m/s, in the pellet bed of the sunflower husk at the air velocity equal to 3.1 m/s. All this is consistent with the results of visual observations.

It should be noted that the change pattern of $\Delta\delta = f(U)$ is identical for the pellets with the different ratio of the diameter to the average length. Therefore the graphs of this dependence can be used to evaluate the minimum fluidization velocity of large cylindrical particles.

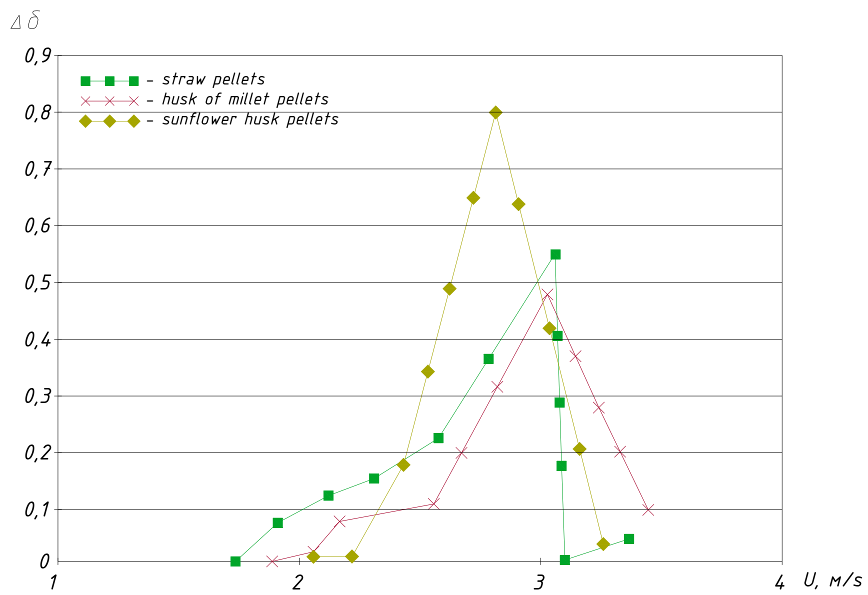

Fig. 4 – The dependence graphs of Δδ excess according to the air velocity.

When fluidization mixture biopellet and fine coal curves pressure drop in a bed on the velocity of air blown through the bed strongly the importance of air velocity at which the bed becomes fluidized state. As expected, the higher the proportion of fine coal in the mixture, the lower the air velocity bed becomes fully fluidized (full fluidization of the mixture of pellets and coal occurs when the air velocity equal to 2,7 m/s at the content in a mixture of 20%, with the velocity of 2.24 m/s at the content of 50% coal and air at a velocity of 2.03 m/s at the content in a mixture of 80% of coal).

The sharp decrease in values σ and δ of statistical characteristics of a random process of changing the pressure drop in a bed consisting of biopellet and coal, is when a concentration of and pellets in a mixture of 50% (fig. 5 a and b). As is known, the bubbles in the beds strongly influence the pressure fluctuation - Leu and Lan (7). On the other hand, it is the movement of gas bubbles determines the intensity of motion of particles that make up the bed. Reducing the value of σ and δ means that, if the content in a mixture of 50% of pellets and more, the intensity of particle motion decreases and increases the probability of formation of slag agglomerates.

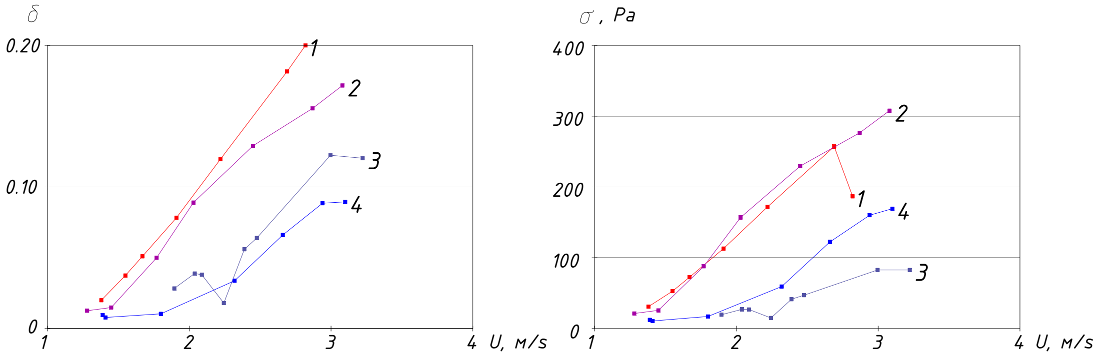

Fig. 5. The dependence graphs of δ (a) and σ (b) excess according to the air velocity (1 – culm100%, 2 – culm 80%, straw pellets 20%, 3 – culm 50%, straw pellets 50%, 4 – culm 20%, straw pellets 80%).

Conclusion

Studies have shown that existing methods of estimating values for the minimum fluidization velocity for a polydisperse layer of cylindrical pellets are not suitable. A new method of evaluation of the velocity - change the dimensionless amplitude of pulsation pressure drop in the layer. Thus obtained values of minimum fluidization velocity bed pellets exactly correspond to the values of this velocity, derived from visual observations. Adding pellets in fluidized bed of fine coal reduces the value of the minimum air velocity at which this bed is transferred in a fluidized state. The intensity of pulsations of pressure differential decreases rapidly when the content in a bed of 50% pellets. Consequently, at this concentration biopellet in the mixture increases the probability of formation of agglomerates in a bed of slag.

Acknowledgments

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