Abstract — The pressure properties were investigated with a binary mixture of different density particles using fine coal’s particles and straw pellets in a gas fluidized bed. The minimum fluidizing velocity is determined solely from the measurement in the fluidized bed regime, unlike the traditional method, where experiments in the fixed bed regime are also necessary.

Keywords — Binary particles system, minimum fluidization velocity, pressure fluctuation property.

I. INTRODUCTION

The fluidized bed has more advantages than any other solid handling equipment. Thus, the fluidized bed process is applicable to various industrial processes: as example, for coal and biomass combustion. The technology of coal and biomass co-combustion in a fluidized bed is increasingly frequently applied for the achievement of a better control over a combustion process with a simultaneous decrease in greenhouse gases, ash and sulfur oxides emissions into the atmosphere. Straw can be considered as one of the largest, annually renewed sources of fuel among all other types of biomass.

Low bulk density of straw in the initial condition and necessity for its long distance transportation stimulate to process straw into granules (pellets) which bulk density is 650-750 kg/m³ in comparison to 100-150 kg/m³ of straw in bales.

Fuel combustion can be carried out in a fluidized bed of fine coal loaded with straw pellets. The value of the minimum fluidization velocity of particles forming the bed is required for the calculation of fluidized bed furnaces. However, as it has turned out [1] it is impossible to apply the known method of a minimum fluidization velocity evaluation from the pressure fluctuation versus gas flow rate curve for a pellet bed. The purpose of the present study is to work out the method of the experimental evaluation for the minimum fluidization velocity of a bed compounded of coal particle and biogranules mixtures.

At the first stage of the study the analyses of hydrodynamics of a bed compounded of coal ash particles and pellets were conducted at room temperature. The results of these analyses are stated in the present study.

II. EXPERIMENTAL

Coal particle and straw pellet beds were exposed to the analysis. The fractional compositions of coal were the following: a mass fraction of particles in the size of: up to 1.0 mm – 20.87%; from 1.0 mm to 1.2 mm – 61.79%; from 1.2 mm to 1.5 mm – 5.66%; from 1.5 mm to 1.7 mm – 2.7%; from 1.7 mm to 2.0 mm – 1.81%; from 2.0 mm to 2.5 mm – 1.14%; from 2.5 mm to 3.0 mm – 0.47%; from 3.0 mm to 4.0 mm – 4.07%; more than 4.0 mm – 1.49%. The moisture content of coal particles was 5.35% on the average; the density of coal particles was 1200 kg/m³. Straw pellets had the following characteristics: the granule diameter was 6 mm, the granule average length to diameter ratio was 0.59; the pellet density was 1190 kg/m³, the heating value of straw granules – 15.5 MJ/kg.

The analyses were conducted by means of an apparatus (fig.1) with the rectangular cross-section of 194 mm x 485 mm and height of 1500 mm which was rested upon an air distribution grill with 5% of an open area. The air flow rate was measured by a thermo-anemometer Delta-OHM HD 2103-1 after the air left the apparatus. Not less than 100 measurements of the air flow rate were taken in each experiment. The pressure drop in a bed was measured by means of a differential micromanometer Testo-525 which allowed to take 1200 measurements of pressure drop within 60 seconds. A digital signal from a micromanometer Testo-525 was transmitted to a personal computer for the subsequent processing.
In the course of the pilot experiments it was established that if the content of coal particles in a bed was higher than 40%, the complete segregation of particles by size was evidenced, in this case pellets remained motionless and rested on the air distribution grill. For this reason, the pressure fluctuations were measured in beds containing 100%, 95%, 90%, 85%, 80%, 70%, 65% and 60% of pellets and corresponding amount of coal ash.

The obtained range of random values of the pressure drop in a bed was exposed to a statistical analysis. In addition, we determined the mean value of the pressure drop in a bed $\Delta P_m$ (Pa) during the observation period:

$$\Delta P_m = \frac{\sum \Delta P_i}{N},$$

(1)

where: $\Delta P_i$ – value of pressure drop in a bed (Pa), $N$ – number of measurement in the experiment;

and the root-mean-square deviation of the pressure fluctuation $\sigma$ (Pa):

$$\sigma = \sqrt{\frac{\sum (\Delta P_i - \Delta P_m)^2}{N-1}},$$

(2)

Changes of bed behaviour were recorded by a video camera Panasonic DVC 30. Then each second of the video recording was broken into 50 video shots that allowed to receive consecutive images of bed behaviour in every 0.04 second. As we knew the image scale we could obtain the values of the maximum height of a bed in every 0.04 second and, considering the change of a bed height as a random process, we could also obtain the mean value of the maximum height of a bed during the observation period, the mean value of the relative height of a bed $H_m/H_0$ in the given experiment and the root-mean-square deviation of the relative height of a bed from the dependences which were similar to the dependences introduced above.
straw pellets in the bed.

Fig. 2 shows the dependences of the pressure drop on the air flow rate in the bed, for different bed mixtures. A dark line on the diagrams indicates the range of the air flow rate values at which the process of bed fluidization $U_{mf}$ begins and the bed becomes completely fluidized $U_{mf}$.

The value of the minimum fluidization velocity decreases with the increase of a coal particle fraction in a mixture: the minimum fluidization velocity is 2.4 m/s for a 100% pellet bed, 2.1 m/s – for a bed with 15% of coal particles and 1.75 m/s – for a bed with 45% of coal particles.

Fig. 3 shows the dependences $\sigma = f(U)$. For mixtures with 80-100% of pellet content the dependence diagram $\sigma = f(U)$ can be divided into three portions: the portion where $\sigma \approx 0$, the portion where a weak increase of $\sigma$ is observed with the increase of $U$, and the portion where a fast increase of $\sigma$ is observed with the increase of $U$.

Fig. 4 shows the reduction of a bed relative height is observed with the increase of a pellet fraction from 55 to 80%: the bed with 80% of pellets practically doesn’t expand, while the maximum height of a fluidized bed of the bed with 55% of pellets twice exceeds the height of a fixed bed. The relative height of a bed starts to increase again with the increase of a pellet fraction in a mixture: the maximum height of a fluidized bed of pellets 1.5 times exceeds the height of a fixed bed.

For mixtures with granule content lower than 80%, the first portion is practically absent on the diagram, but the 2-nd and 3-d are shown distinctly. The comparison of figure 3 with the results of the visual observation allows to draw the conclusion that the value of the air flow rate corresponding to

the transition of the dependence $\sigma = f(U)$ from the first portion on the curve to the second is the velocity when the fluidization just begins. The air flow rate corresponding to the transition of the dependence $\sigma = f(U)$ from the second portion on the curve to the third one is the velocity when a bed becomes completely fluidized. Hence, the dependence diagram $\sigma = f(U)$ can be applied for the experimental evaluation of $U_{mf}$.

As fig. 4 shows, the reduction of a bed relative height is observed with the increase of a pellet fraction from 55 to 80%: the bed with 80% of pellets practically doesn’t expand, while the maximum height of a fluidized bed of the bed with 55% of pellets twice exceeds the height of a fixed bed. The relative height of a bed starts to increase again with the increase of a pellet fraction in a mixture: the maximum height of a fluidized bed of pellets 1.5 times exceeds the height of a fixed bed.
of a pellet portion from 55 to 80% we can observe the decrease of $\sigma H$, i.e. the frequency of formation and sizes of air bubbles decrease with the increase of a biogranules portion. With a further increase of a pellet portion in a bed, larger air bubbles start to form (1), and their eruption results in more violent fluctuations of the upper limit of a bed that cause the increase of $\sigma H$.

- It has been shown that the increase of a biogranules fraction in a mixture leads on the whole to the reduction of a bed relative height and to the decrease of frequency of the formation and sizes of air bubbles that should diminish a fuel loss from mechanical and chemical incompleteness of combustion.
- We have suggested the method of the evaluation of the minimum fluidization velocity in a bed compounded of a mixture of coal and biogranules particles from the root-mean-square deviation of pressure fluctuation versus air flow rate curve.

**Fig. 5 dependence of root-mean-square deviation of the bed relative height value on the average value of flow velocity for different mixtures. On the graphs indicate the content of straw pellets in the bed.**

The reduction of the relative height of a bed with the increase of a pellet portion results in the increase of the separation space height in a furnace and lets the furnace and boiler dimensions remain the same that should lead to the reduction of fuel loss with entrainment.

**IV. CONCLUSIONS**

From the results of this study, the following conclusions can be drawn:
- Hydrodynamic features of the transition into a fluidized condition of the bed compounded of small particles of coal and biogranules have been studied.

**REFERENCES**