STANISŁAW CIERPISZ

Institute of Innovative Technologies EMAG

Control systems of coal products discharge from a JIG

The paper presents the development of control systems of coal washing in jigs. Particularly, control of coal products discharge from jigs has been discussed. The aim of control in these systems is to stabilize the separation density at the desired level. The following systems have been evaluated: systems in which water pressure below the screen deck is monitored, systems with metal float, and systems with a radiometric density meter. A comparative analysis of these systems, on the basis of the measurement errors introduced by each method, has been performed. Finally, their advantages and disadvantages have been discussed.

key words: *coal preparation, jigs, process control*

1. INTRODUCTION

Raw fine coal is mostly washed in jigs, whose operation is based on the gravitational stratification of grains of a material subjected to cyclic pulsations in a coal/water medium. During subsequent water pulsations, caused by opening and closing of air valves, the stratification of coal grains takes place due to different velocities of their upward and downward movement. The grains of a low density migrate to upper material layers and the grains of a high density migrate to lower layers. The material is transported on the screen along the jig compartment due to the additional horizontal flow of water. The stratification of grains due to their density is not ideal because the velocity of their upward and downward movement depends also on the grains diameter, shape and fluctuations of the degree of material loosening during each pulsation cycle. The separation of stratified material is performed according to the chosen separation density, which is the density of the layer reporting in half to the upper product (concentrate) and in half to the discharged lower product (refuse).
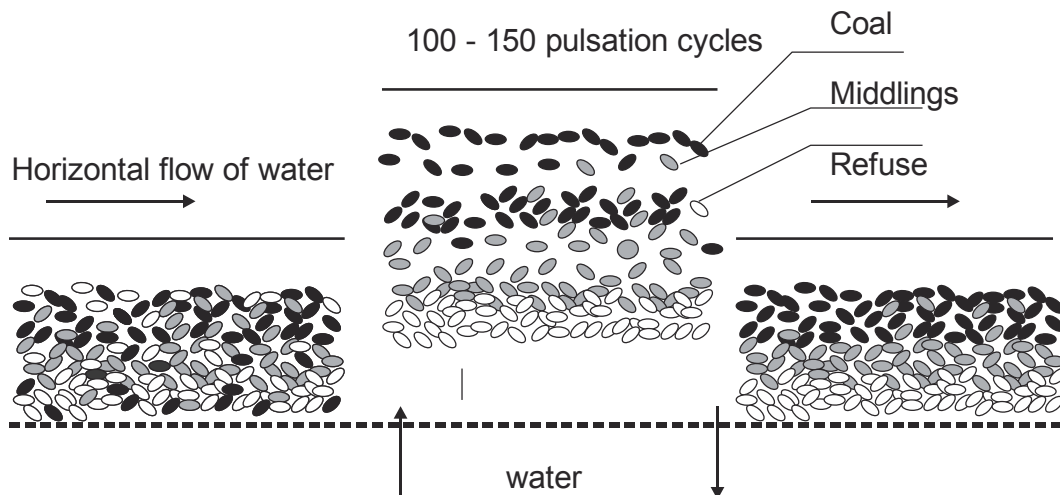

Fig. 1. Illustration of the coal washing process in a JIG

To achieve a proper jig operation it is necessary to adjust continuously the air-pulsation parameters (pressure, shape) to variable load of a jig (tonnage and density composition). It is also necessary to keep the separation density at the desired level by controlling the tonnage of refuse discharged from a jig.

2. CONTROL SYSTEMS OF COAL PRODUCTS DISCHARGE

The most common control system applied in each compartment of a jig is the system of coal products discharge from the jig. The purpose of control in this system is to stabilize the separation density at a pre-determined value by controlling the flow rate of the bottom product. The separation density, which is the density of a material layer at the height of the upper overflow gate and reporting in 50% to upper and bottom products, is measured by indirect methods. The most important methods of material density

measurement applied over the time of the systems development have been based on monitoring of: (a) water pressure in a pipe placed below the screen deck of a jig, (b) position of a metal float of proper shape and density, and (c) absorption of gamma radiation by a medium at the height of the upper overflow gate.

2.1. Systems with the water pressure measurement

Control systems with the water pressure measurement were developed in Great Britain and France in 1950-60. In Great Britain these systems were designed by ACCO (Automatic Coal Cleaning Company) and by RMDE Bretby (Hirst Automatic Refuse Control). The operation principle of such a system is presented in Fig. 2. The measuring element in this system is a tube whose lower part is placed just below the screen deck of the jig. The level of water in this tube moves with pulsations of a coal/water medium and its position is proportional to the water pressure below the screen deck.
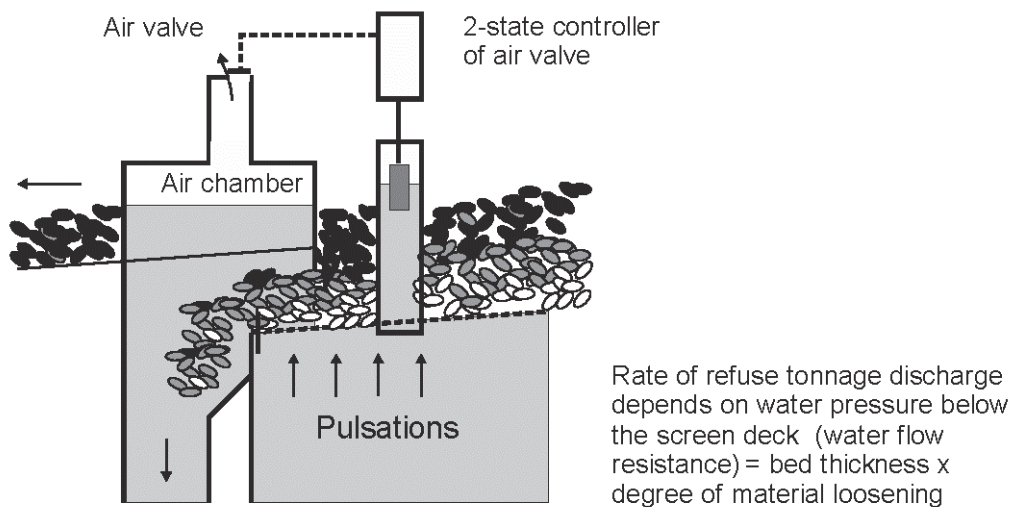

Fig. 2. Refuse discharge control system designed by ACCO [8]

The water pressure below the screen deck depends on the material movement upwards or downwards and on the water flow resistance which, in turn, depends on the amount (thickness) of the bed and its loosening in each cycle of pulsations. The water pressure water reaches its maximum just before the bed is loosened (fluidized state of the bed). At this moment the water pressure is determined by the pressure drop along the compressed (and moving upwards) bed and the movement (acceleration) of water. The pressure drop depends on the thickness of the bed and the degree of its compression (loosening) and hence the pressure measurement is not an accurate measure of the amount of material in the bed if the pulsation

varies too. The water level in the tube is measured by a float whose upper position opens the air valve in the air chamber increasing the discharge of the bottom product. When the float reaches its lower position, the air valve closes and reduces water pulsations between the upper and lower refuse gates.

The water pressure meter below the screen deck, modified by Bermen company [8], is shown in Fig. 3.

In this system, the measuring tube is separated from the jig compartment by a membrane, and pressure changes, transferred by the liquid in the pipe, are measured by an electro-pneumatic transducer. In this arrangement, the pressure signal is used to adjust the tonnage of the bottom product and, at the same time, to

control the tonnage of heavy fraction in the feed to the jig. A block diagram of the system stabilizing the ton-

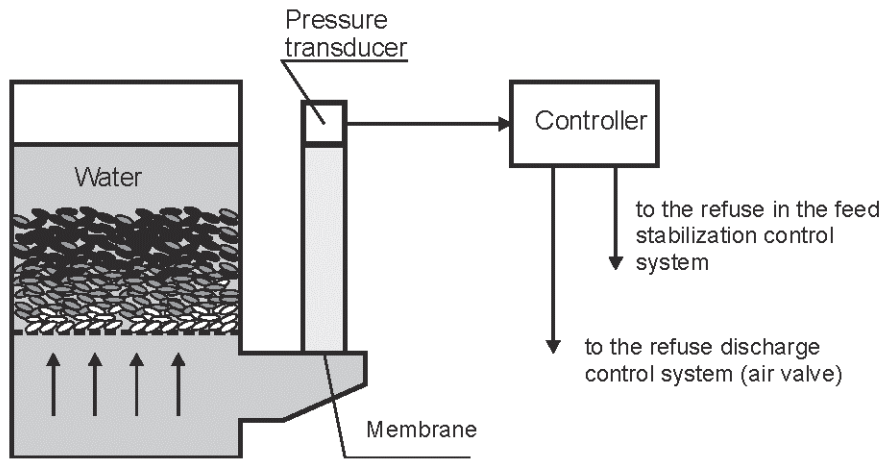nage of heavy fraction (underflow) is shown in Fig. 4.

Fig. 3. Modified measurement of water pressure in the refuse discharge control system
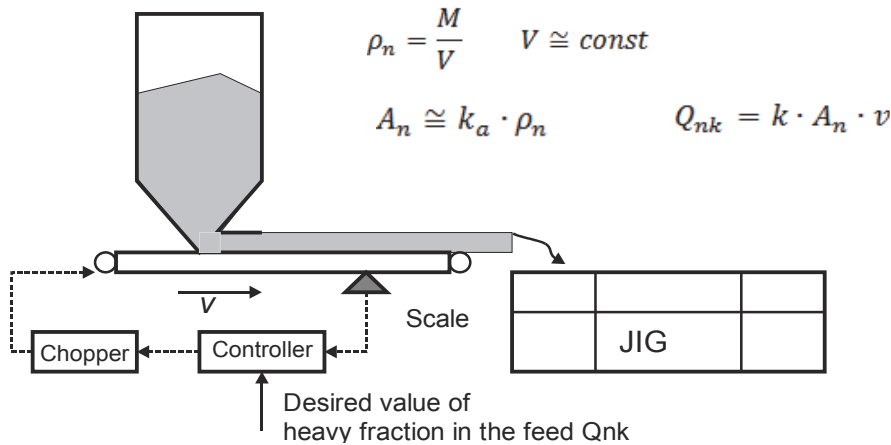

$$\rho_n = \frac{M}{V} \qquad V \cong const$$

$$A_n \cong k_a \cdot \rho_n \qquad Q_{nk} = k \cdot A_n \cdot v$$

Fig. 4. Stabilization of refuse tonnage in the feed to a jig

The correlation between ash content in coal and its bulk density is used in this system. Constant thickness of the coal layer has to be ensured on the belt conveyor which closes the outlet of the bunker. In this case, the mass of the material on the unit length of the belt is proportional approximately to its bulk density and this, in turn, to ash content in coal. Constant tonnage of heavy fraction (refuse) in the feed can be achieved by controlling the speed of the belt by the signal of ash content in the feed. Thus, the stable load of the jig by the heavy fraction (refuse) can be ensured. It should be noted that this way of control gives good results, first of all, in one compartment jigs.

2.2. Systems with a float

In parallel with the pressure measurement methods, systems with a metal float have been designed. The float applied in these systems should, in principle, measure the position of the material layer having a density corre-

sponding to the parameters of the float, as shown in Fig. 5. The float, in presence of water pulsations, can be considered as a large grain of chosen density taking the location of the layer of grains of the same settling velocity. The density of the monitored layer is selected by changing the density of the float with the "weights" imposed on the float stem. In newer systems, the choice of density of the layer (separation density) is accomplished by the change (ΔH) of the desired position of the float (of set density) in the electronic system.

The height of the float is relatively large (approx. 200-400 mm) as compared to the thickness of the coal bed (300-500 mm) and this creates some measuring problems. For this reason, the rate of the float downward movement can vary in relation to the particle settling the velocity of the selected layer. The average density of the medium in the space around the float (in loosened state) is different (and may vary) from that for a single grain. This effect is illustrated in Fig. 6 and Fig. 7. Changes in the density

distribution of the material in the jig bed influence the position of the float, relative to the position of the selected layer. It can be seen that the change

of the position is greater for floats with greater heights (50% and 70% of the bed), and are up to 15 mm (D. Kowol [10]).
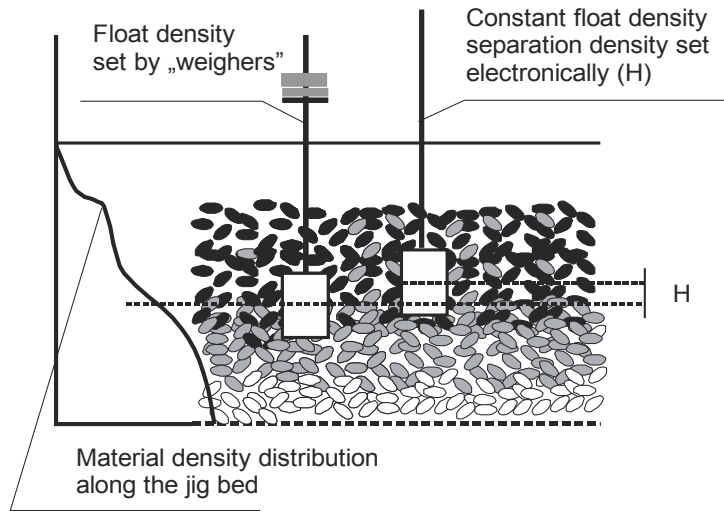

Fig. 5. Application of a float for monitoring of the position of a coal layer of chosen density
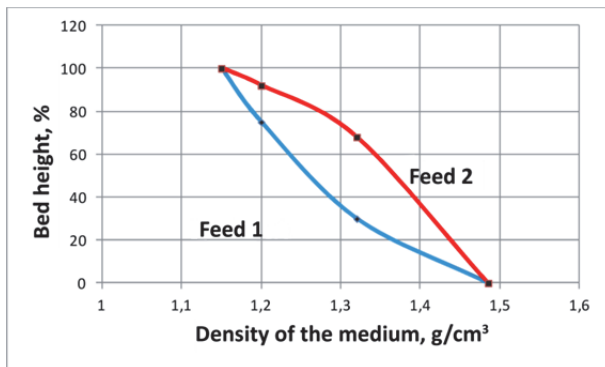

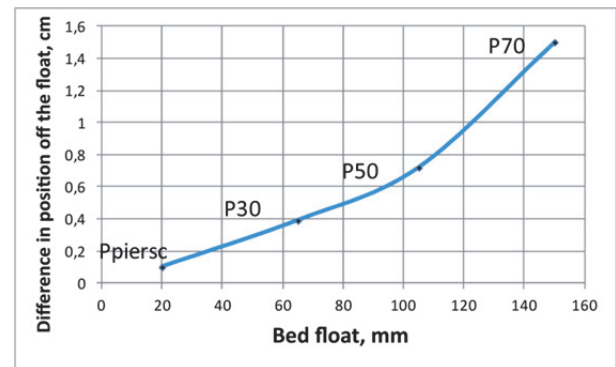*Fig. 6. Two types of density distribution in a jig bed*

Fig. 7. Influence of change in the density distribution of a jig bed on the position of the float in relation to the chosen material layer

These changes are likely to be even larger in industrial conditions (20-30 mm).

Fig. 8 shows the possibility of the errors caused by changes in the position of the float with a set density (Fig. 5).

If the float position is different from the position of the overflow upper gate, then, due to changes in the density distribution, additional errors in determination of separation density can be expected. Examples of control systems with floats as measuring devices have been presented in Fig. 9a, b, c.

The control system with one actuator and with a fixed position of the upper overflow gate has been presented in Fig. 9a. Such systems are used widely abroad [11, 12]. The control system with one actuator and the moving upper overflow gate is shown in Fig. 9b. In this system, there is a mechanical coupling of the refuse discharge slot and the upper overflow gate.
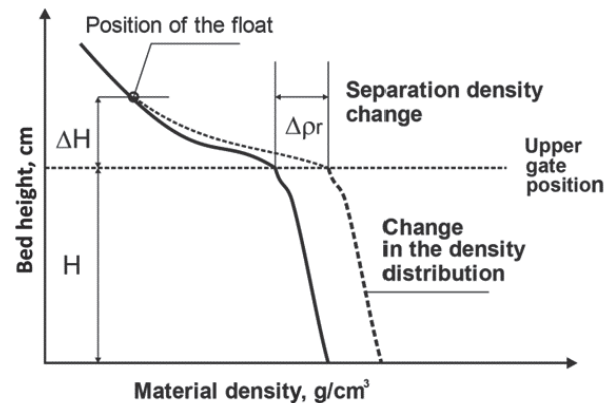

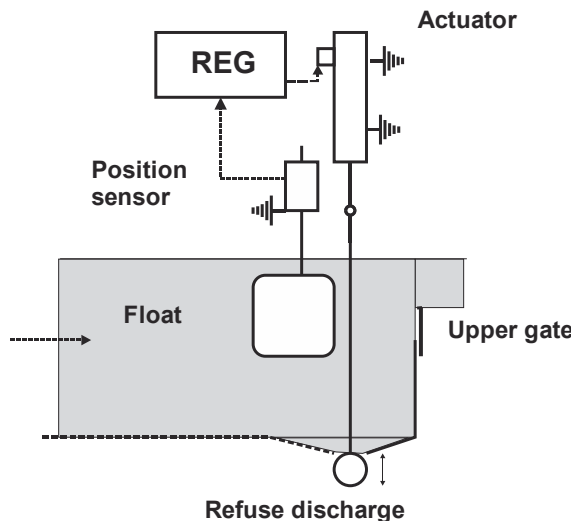*Fig. 8. Errors of density measurements due to the change in the desired position of a float*

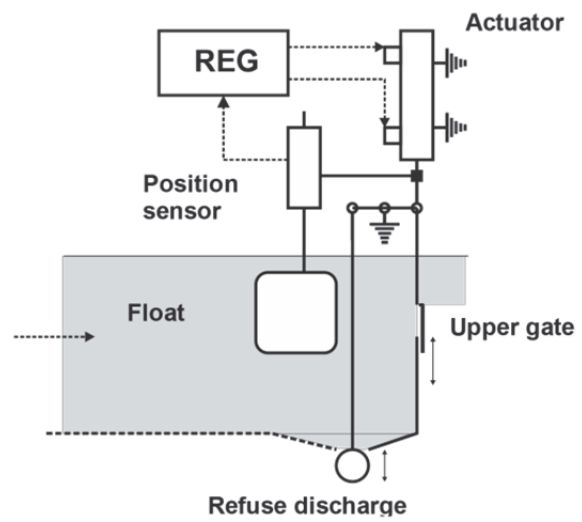Fig. 9a. Products discharge control system
– fixed upper gate

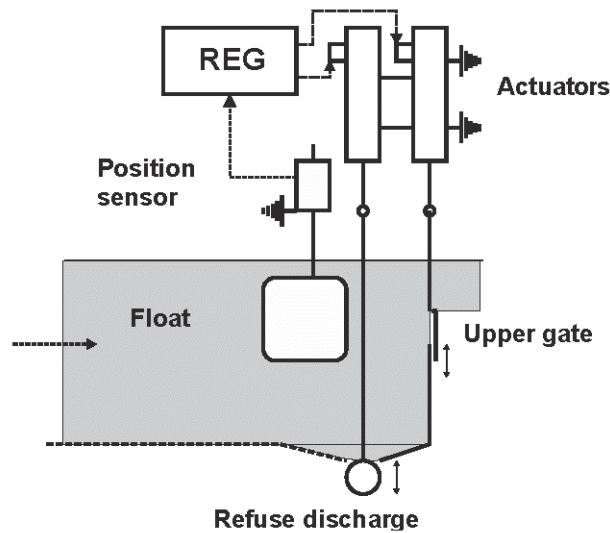Fig. 9b.Control system with moving upper gate
– one actuator

Fig. 9c. Control system with a moving upper gate – two actuators

The idea behind this approach is to speed up the re-action of the system and to reach faster the desired separation density in case of significant changes in the feed tonnage. At the same time the thickness of the bed varies and a consequent change in the degree of the material loosening appears, which requires, for this reason, an adjustment in the air pulse shape.

The system presented in Fig. 9c has two actuators to independently control the refuse discharge slot and the position of the upper overflow gate. In this ar-rangement, it is possible to quickly change the posi-tion of the upper gate, followed by a gradual return to a preset position.

2.3. Radiometric control systems

The development of application of radiometric methods for measuring the separation density in a jig could be observed in recent years. The first attempt to use a radiometric density meter to adjust the bot-tom product discharge was conducted by D. Bartelt [1] in 1964. Bartelt achieved very positive results in the application of the density meter in a control sys-tem to reduce the imperfection of the machine down to 0.06 for coal of 120-10 mm grain size . This type of a control system was also studied in Australia [11] in the years 1989 - 1995 (JKMRC). A block scheme of "JigScan" developed by the JKMRC [6, 12] is presented in Fig. 10.

Research on radiometric systems for process con-trol in jigs has been carried out in EMAG since 2009. The block scheme of the experimental system tested in the Rydultowy mine in 2010-11 is shown in Fig. 11. In this system, a radiometric density meter, placed at a height of the upper overflow gate, was used to correct the float control system operation in a cascade loop. The use of the density meter enabled also to study the distribution of the material density

with the height of the bed, and to examine dynamic changes in the density of the material during its loosening in each pulsation cycle. A comparison of the effects of stabilization of the separation density in a float system and with the radiometric measurement showed that fluctuations in the separation density can be reduced to $\pm\,0.015$ g / cm^3 in the latter case.
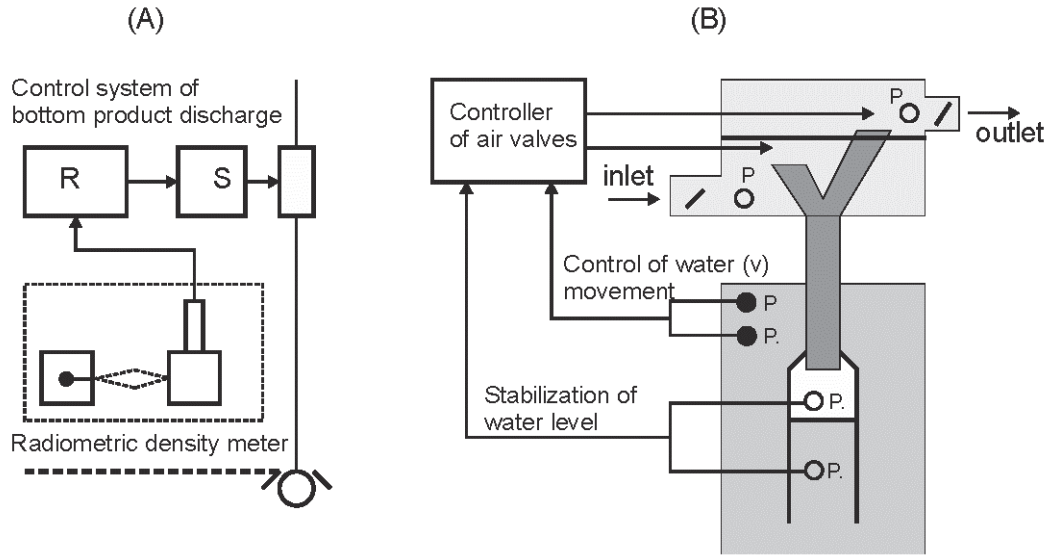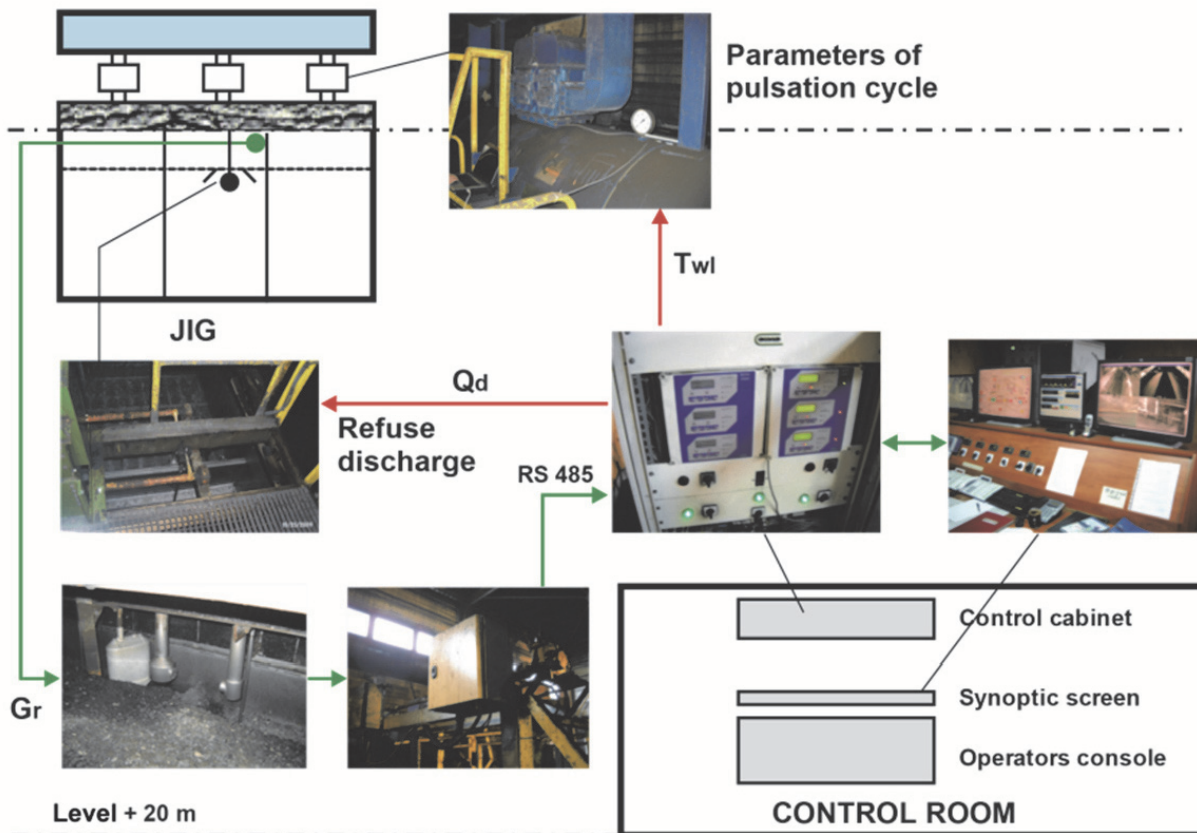

Fig. 10.Control system of "Jigscan" (A) – stabilization of separation density, (B) – control of the degree of material loosening

Gr - separation density, Qd - refuse tonnage, t/h, Twl - time of air inlet, s.

Fig. 11. Illustration of the experimental system in the Rydultowy mine

3. SUMMARY

Control systems of products discharge in jigs were modified over the last few years. The aim of the control in all systems was to stabilize the separation density at a desired value in the presence of disturbances occurring mainly in the form of changes in the tonnage and quality of the feed. The first measurement methods introduced in the control systems were based on measurements of water pressure below the screen deck of a jig, and then metal floats were used.

Measurement of water pressure allowed for the approximate evaluation of the amount of material in the bed of the jig and therefore to stabilize the thickness of the bed in the presence of disturbances. Although the density of separation in this case was not measured directly, the control system allowed some reduction of the density fluctuations in comparison with a system without any adjustments. Some progress was achieved after using floats in control systems, which appeared to be better devices to monitor the separation density in jigs. However, in float systems, errors of separation density measurements are high due to fluctuations of the degree of material loosening which influences the position of the float in the compressed state of the material. Radiometric methods applied to measure the density of the material layer at the height of the overflow upper gate give best results as regards the separation parameters stabilization, similar to those achieved in a heavy media process.

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The article was reviewed by two independent reviewers.