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MONITORING OF COAL SEPARATION IN A JIG USING A RADIOMETRIC DENSITY METER

Stanislaw Cierpisz*, Jaroslaw Joostberens**

**Institute of Innovative Technologies EMAG, Katowice, Poland,*
e-mail: Stanislaw.Cierpisz@polsl.pl,
***Silesian University of Technology, Gliwice, Poland,*
e-mail: Jaroslaw.Joostberens@polsl.pl

Abstract: Application of a radiometric density meter for monitoring of the coal separation process in a jig has been discussed in the paper. The signal from the meter can be used to evaluate the degree of coal grain loosening during cyclic water pulsations and to determine the separation density in a jig. The signal from the radiation detector is highly nonstationary due to stochastic decay of the radiation source and various changes in media density. The paper discusses the optimisation of analogue and discrete filters applied in an electronic circuit of a density meter. The minimum dynamic error of measurement can be achieved in the case of filters with parameters adapting to changes in the measured density. Results of industrial tests of the jig control system with the radiometric density meter have also been presented.

Keywords: density monitoring, radiometric measurements, dynamic errors, optimal filtration, coal preparation

1. INTRODUCTION

Radiometric density meters are widely used in the industry to monitor different technological processes such as, for example, minerals processing or coal beneficiation in heavy media systems or jigs. Application of these instruments to monitor the coal separation process in jigs was discussed in details by Lyman (1991), Loveday & Jonkers (2002) and recently by Cierpisz (2012). Operation of radiometric density meters is mainly based on the method of gamma radiation absorption in which the mean intensity of detected radiation depends on the density of the monitored media.

The measuring head of a radiometric density meter consists of a radiation source (^{60}Co, ^{137}Cs) and a detector usually in the form of a scintillation counter. The review of detectors was presented by Knoll (2000). The output signal from the detector is always a stochastic signal, regardless of the character of the input signal (i.e. density) modulating the intensity of the detected radiation beam. The longer the averaging time, the higher the accuracy of the monitor. At the same time, if the input signal varies, the dynamic error of the measurement is higher. It suggests that for a given shape of the input signal and a given structure of the monitor circuit, one can find an optimal averaging time of input pulses, which gives the minimum dynamic error according to the accepted criteria. Furthermore, this leads to the application of a circuit with an adapting time of input pulses averaging. This problem was discussed by Cierpisz & Heyduk (2001, 2002). If the input signal is, for example, a step function and the density monitor is to reproduce this change, the time of measurement should be short at the beginning of the measurement in order to speed up the reaction of the meter and then it should become longer in order to read out accurately the precise new value of the density.

The problem becomes important when the speed of density variations is high and hence requires short times of measurements. This applies to technological systems of coal separation in a jig where stratification of coal grains due to their densities is performed in a pulsating coal/water bed. The jig separates the coal into two streams based on relative density. These two streams are the coal product with either a discard or a middling product.

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2. TECHNOLOGICAL OBJECTIVE

Raw coal is a mixture of grains with different content of mineral matter (ash content) which determines the calorific value of a grain. The high quality product should consist of grains from the lowest up to the highest elementary ash content (called a "separation elementary ash") – its mean ash content is a weighted mean of all grains reporting to this product. Grains of ash content higher than "a separation elementary ash" report to refuse. In practice, the correlation between the ash content and the density of grains is used and the "separation density" instead of the "separation ash" is on-line monitored to control a coal beneficiation process.

Raw coal is often beneficiated in the gravitational processes where coal grains are stratified according to their densities in a pulsating water/coal medium in jigs as it is shown in Fig. 1. Discussion on this problem has been presented by Lyman (2001), Loveday & Jonkers (2002) and Cierpisz (2012).

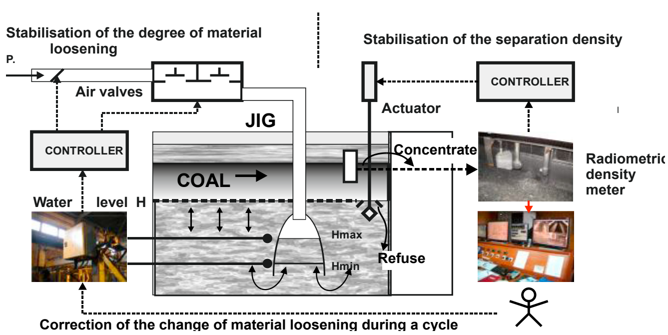

Fig. 1. Control system of the coal separation process with the radiometric monitor of separation density

During the subsequent water pulsations, caused by opening and closing of air valves, the stratification of coal grains takes place due to their different velocity of movement upwards and downwards. Grains of a low density migrate to upper material layers and 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 their velocity of movement upwards and downwards depends also on grain diameters, shape and variations in the process of material loosening during the pulsation cycle. Separation of stratified material is performed according to the chosen separation density, which is the density of a layer reporting in half to the upper product (concentrate) and in half to the discharged lower product (refuse). Refuse is removed through the discharge gate and concentrate overflows the splitting gate. The quality of products is determined by the density of a separation layer. Its position should be monitored on-line and kept at the splitting gate level regardless of the changes in the tonnage of the feed or changes in the washability characteristics of raw coal. The position of a separation layer is usually measured by a metal float of the relevant shape and density.

The desired position of the float is stabilized by controlling the amount of a lower product discharged through a bottom gate. Float is not an accurate indicator of the position of the selected density layer, especially during the changes in the amount of the feed and its grain density composition. In new experimental systems, floats are being replaced by more accurate radiometric density meters which can monitor the process of material loosening/compressing during each cycle of coal/water pulsations. The output signal from a radiometric meter can be used for two purposes:

a) to stabilize the shape of density dynamic changes,
b) to stabilise the separation density measured during the compressed state of material at the end of a cycle.

The typical dynamic change in coal/water density during one cycle of the separation process has been shown in Fig. 2. At first, while the inlet air valve is opened, the material rises upwards without loosening the upper part of the coal bed. Then the material reaches gradually its loose state, the inlet valve closes and the grains of material fall down to the compressed state at the end of the cycle. The outlet air valve opens to speed-up the material compressing. Then the outlet valve closes to ensure the same hydraulic conditions for the next cycle.

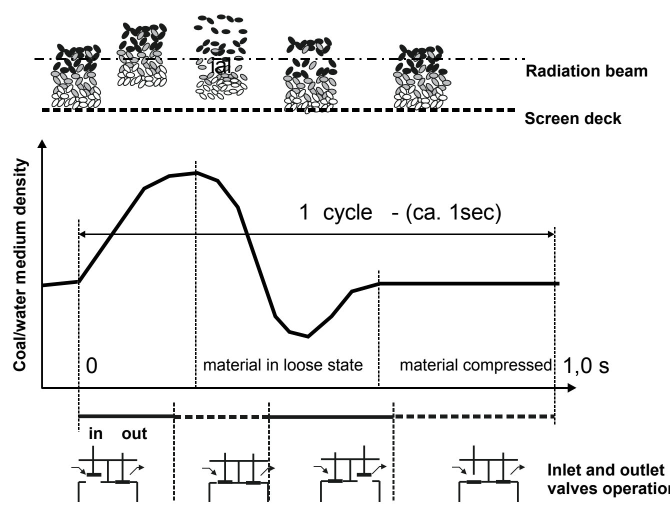

Fig. 2. Changes in the medium density over a single cycle of pulsations

The shape of density changes at the bed level where the concentrate overflows the upper discharge gate varies due to variations in the feed tonnage or grain density composition and fluctuations in air pressure in an air collector. To achieve best conditions for coal separation in terms of optimal stratification of material grains according to their density and constant separation density in a jig, the shape of density changes over each cycle of pulsations should be stabilized. The radiometric density monitor should reproduce changes in