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Optimization of a Radiometric Density Meter for Monitoring of a Coal Separation Process in a Jig

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Abstract: It should be possible to optimize discrete filters applied in an electronic circuit of a radiometric density meter monitoring coal separation processes in a jig. The signal from the meter can be used to (1) evaluate the degree in which coal grains loosen during cyclic water pulsations and (2) to determine the density of the separation layer in the jig. The signal transmitted by the radiation detector is variable due to stochastic decay of the radiation source and changes in media density. The authors present a simulation model of the radiometric meter and discuss results of optimization procedures based on industrial tests.

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

1. INTRODUCTION

Radiometric density meters have been widely used in the mineral separation industry to monitor various technological processes. The application of these instruments to monitor solids concentration in slurry circuits and to control mineral flotation process has been reported by Shoenbrunn et.al. (2002) and Laurilla et.al. (2002). Monitoring of a coal separation process in a jig, with the use of a radiometric density meter has been discussed in detail by Lyman (1991), Loveday & Jonkers (2002) and more recently by Cierpisz (2012). Most radiometric density meters use gamma-ray absorption where the mean intensity of detected radiation depends on the density of the monitored media. Fig. 1 shows the measuring head, which consists of a radiation source and a detector (a scintillation counter) and is applied to monitor the density of a coal/water mixture in a jig.

Fig.1. Measuring head of a radiometric density meter

Various types of detectors used in such systems have been reviewed by Knoll (2000). The output signal from the detector $s(t)$ is usually a non-stationary series of pulses of Poisson distribution. The mean value $n(t)$ of pulses counted over time T is a function of the measured media density modulating the intensity I of the detected radiation beam. Generally, the longer the time of measurement T, the higher the accuracy of the monitor. This holds when the measured density is constant over time. However, when density varies, the dynamic error of measurement increases the longer the time of measurement T. This suggests that for a given shape of the input signal (density), one can find an optimal averaging time T to minimise the dynamic error of measurement according to accepted criteria. Thus, to optimize the measurement, a counter with an adapting time of input pulses averaging might be used.

The problem becomes important when density variations are rapid and require short measurement times. This applies to coal separation jig machines in which stratification of coal grains takes place in a pulsating coal/water bed. This problem was discussed by Cierpisz & Joostberens (2015) in the context of a single pulsation cycle where an adaptive circuit was applied (Fig. 2).

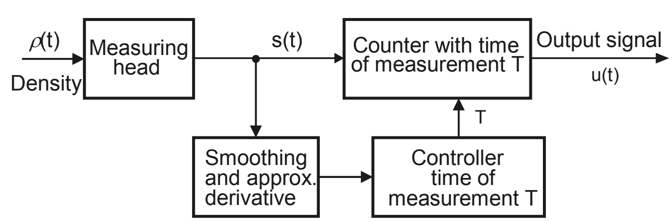

Fig.2. The adaptive filter

When adaptive filters are used to detect changes in density, it is important to determine their optimal parameters. After investigating density variations in the pulsating bed in a jig, we propose specific modifications to the structure of the

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monitoring circuit. The new structure is easier to design and can render better results in many forms of density measurement.

2. TECHNOLOGICAL OBJECTIVE

Raw coal is often beneficiated in gravity separation processes where coal grains are stratified according to their density in a pulsating coal/water medium in jigs (Fig. 3). These processes have been discussed by Lyman (2001), Loveday & Jonkers (2002) and Cierpisz (2012).

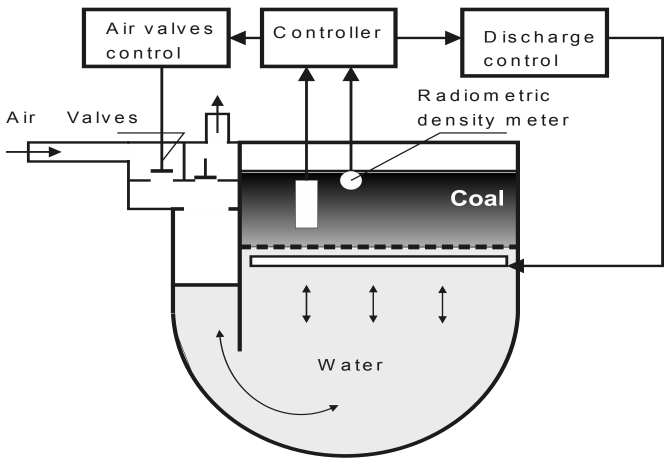

Fig.3. Control system of the coal separation process in a jig where a radiometric meter is used to monitor media density (cross-sectional view of the jig)

During subsequent water pulsations induced by opening and closing air valves, coal stratification occurs as grains of varied density move upwards and downwards with different velocities. Grains of low density (low ash content) migrate to upper layers with grains of high density (high ash content) moving down to lower layers. The material travels horizontally on a screen deck along the jig compartment with the flow of water. Simulation models of fine coal segregation and stratification processes in jigs have been discussed by Srinivasan et al. (1999) and Xia et al. (2007).

The stratification of grains due to their density is not ideal. Their upward and downward movement also depends on their diameters, shape and the way in which the material loosens within a given pulsation cycle. Material is separated according to a 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). For detailed description of this technology see Cierpisz & Joostberens (2015).

Optimal conditions for coal separation are defined in terms of (1) optimal stratification of material according to grain density and (2) maintaining constant separation density in the jig. They require that the profile of changes in density over each pulsation cycle be stabilized. To achieve best monitoring and control results, radiometric density monitors should reproduce changes in medium density with the minimum error.

Fig. 4 shows a typical dynamic change in coal/water density during one cycle of the separation process. The solid line represents the signal from the density meter and the dashed line represents the expected real variations in density. Samples were taken every 50 ms. Initially, when the inlet valve is opened, the bed is lifted as a mass. Then the material gradually loosens. When the inlet valve closes the whole mass on the bed falls down and compresses.

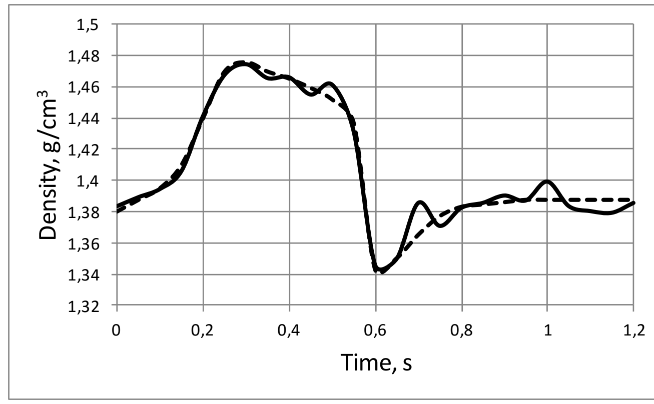

Fig.4. Change in the medium density over a single pulsation cycle (1.2 s); (solid line – signal from the density meter sampled every 50 ms, dashed line – expected real density change)

If the raw coal feed to the jig rapidly increases in mass flow rate, it is possible that the material only moves up without loosening the upper part of the bed. Conversely, if the mass flow rate of the feed rapidly decreases, the material may not reach its compressed state. The range of the density change is ca. +0.2 g/cm^3 to -0.1 g/cm^3 around its steady value (1.2–1.7 g/cm^3). It is in the first part (50-70%) of the cycle that the conditions of separation should be stabilised over feed variations, as this phase is characterised by significant variations in the density of the bed (Cierpisz 2012). However, the separation density measured when the material is compressed also varies due to feed fluctuations and operation of the refuse discharge gate. Predictably, these two processes have contrasting dynamics (Fig. 5).

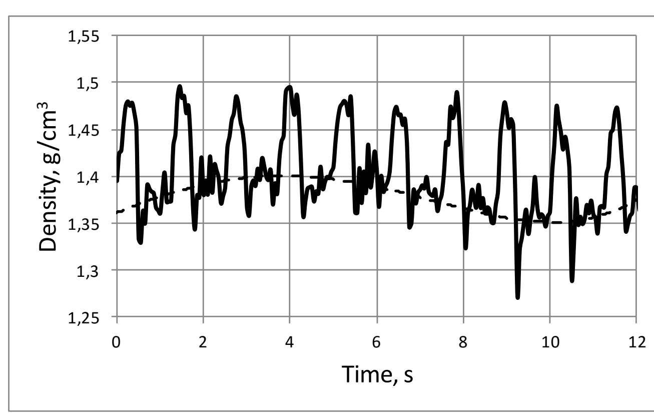

Fig.5. Changes in media density over a longer period of time (solid line); dashed line represents separation density (when material is compressed)

The slope of the function for the dynamic density change over a single pulsation cycle is ca. 1.0-2.0 g/cm^3 s, whereas for the separation density (dashed line) it is $(0.1 \div 0.5) \times 10^{-2}$ g/cm^3 s. This suggests that the density change identified in a single pulsation cycle could be used to estimate the optimal filter