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THE EFFECT OF SETTING THE OPERATING CONDITIONS OF THE SAMPLING DEVICE ON THE REPRESENTATIVE SAMPLE OF COAL

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ABSTRACT

Currently, emphasis is placed on the efficiency of process technology in the production of energy. Large energy corporations are forced to develop new and optimize existing technologies to reduce emission limits. In coal and biomass combustion technologies, it is important to continually monitor and evaluate the quality of input material. A sampling device is used to obtain a representative sample of the fuel from the continuous conveying process. In this research work, the effect of setting the operating conditions of the rotating sampling device for coal, which is intended for combustion is investigated. From the operating tests, it was found that the different settings of the sampling device (velocity, dimensional parameters) influence the quality and quantity of a representative sample of coal taken from the belt conveyor of the technological line.

Keywords: Coal; Sample; Sampling device.

1 INTRODUCTION

Reducing the energy consumption of production processes is one of the key issues of today's technological development. Due to the development of new technologies, process systems are introduced or optimized in energy companies in order to eliminate emission limits related to combustion of coal, biomass or other fuels. In combustion of coal or biomass it is important to have up-to-date and detailed information on the quality of the fuel sample entering the combustion chamber. For collecting a representative sample of fuel from a continuous transport process, different types of sampling devices are used [1–4]. In most cases, fuel samples are collected directly even several times per shift [5]. The aim is to maintain and control the high quality of coal in relation to the fuel market prices and other aspects affecting the environment [6,7].

This research task is focused on taking a representative sample of coal using a rotary sampling device. Rotary sampling device is currently used in several coal-fired power plants. The operating conditions in this experiment corresponded to the real operation in the power plants. The collected coal sample was subjected to an analysis that assessed the quality of coal and compared the particle size distribution of material entering the sampling device with the output sample. The particle size distribution of the coal sample directly affects the ash content after the combustion process. The required split ratio i_d was also monitored, which is defined as the result of division of mass of the output sample m_s by the mass of the input material m_i entering the sampling device, see Equation 1. The optimal split ratio of the sampling device is $i_d=0.1$. The second analysis focused on assessing the quality of coal in terms of calorific value and ash content after the combustion process. This analysis is not included in the present study. Innovation in sampling devices seeks to solve problem of automated sampling operations. The research is focused on assessing the correct sampling of fuel according to the operator's requirements, depending on the various operating conditions of the sampling device.

$$i_d = \frac{m_s}{m_i} \tag{1}$$

2 MATERIALS AND METHODS

For the experimental measurement on the rotary sampling device, coal with the designation "Coal-A" was used, see Fig. 1. A sample of coal was taken directly from real operation in a cogeneration plant where the same type of rotary sampling device is used to collect a representative sample of coal for analysis. The particle size distribution of the collected coal was measured using opto-electric-granulometer CAMSIZER. CAMSIZER is a device for measuring the size and shape of grains of free-flowing bulk materials in the particle size distribution from 0 mm to 30 mm. The device includes a planar light source, a feeder, two CCD cameras for generation of bulk material images, a cleaning unit and a computer equipped with evaluation software.

Figure 1. *Sample of Coal-A*

The rotary sampling device consists of three functional sections. The first section includes the space where the material enters onto rotary blades, which evenly spread the material along the static plate. The static plate includes an opening through which the material is dropped into the second section, i.e. a rotary disk. The rotary disk may include one, two or more openings of adjustable size. In our case, there were two symmetrically located openings in the rotary disk with surface area of 0.008 m^2 each. The material either passes to a third section (Output-waste) or into an outlet pipe from which a representative sample of coal (Output-sample) is obtained. The outlet pipe is positioned directly below the static opening of the first section. Between the static opening and the outlet pipe, the rotary disk with two openings rotates. Collection of a representative sample of coal takes place only when the openings in the rotary disk align with the openings of the static plate and the outlet pipe. In the third section of the device, there are two rotary blades which ensure gradual discharge of waste material from the sampling device. Fig. 2 shows a model of the rotary sampling device.

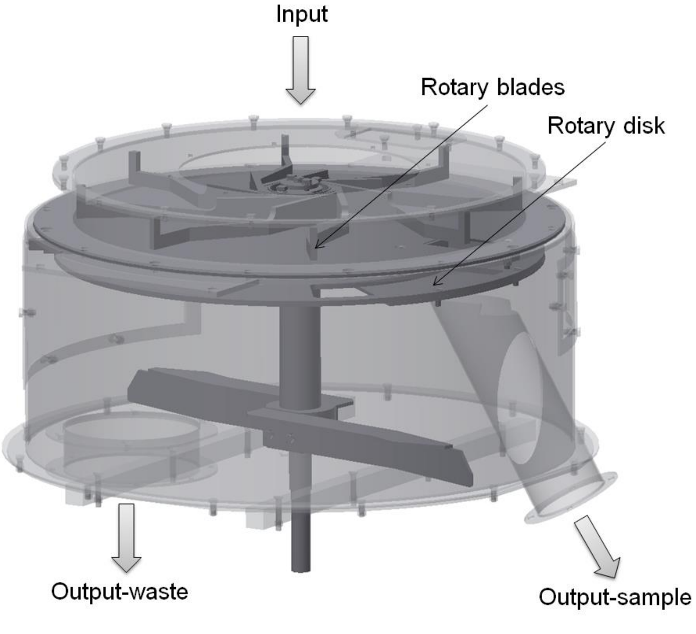

Figure 2. *Rotary sampling device model*

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For the experimental measurement, a measuring station assembly consisting of a belt feeder 1, a rotary sampling device 2, a strain gauge weight sensor for samples 3, a strain gauge weight sensor for waste material 4, and a computer for storing and evaluating the measured data 5 was used. The assembly of the measuring station is shown in Fig. 3. During the experiments, the feed capacity of the belt feeder was set to 0.25kg $kg \cdot s^{-1}$. The input coal mass was 10 kg and was constant for all experiments. The experiments were performed for the three following rotational speeds of the sampling device: 10 rpm, 29 rpm, 45 rpm. Both strain gauge weight sensors continuously recorded the flow of the output from the sampling device. The obtained representative coal sample was further subjected to the analysis described in the introductory part of this article. As the first step, the actual split ratio was determined based on the actual sample size, followed by the measurement of particle size distribution.

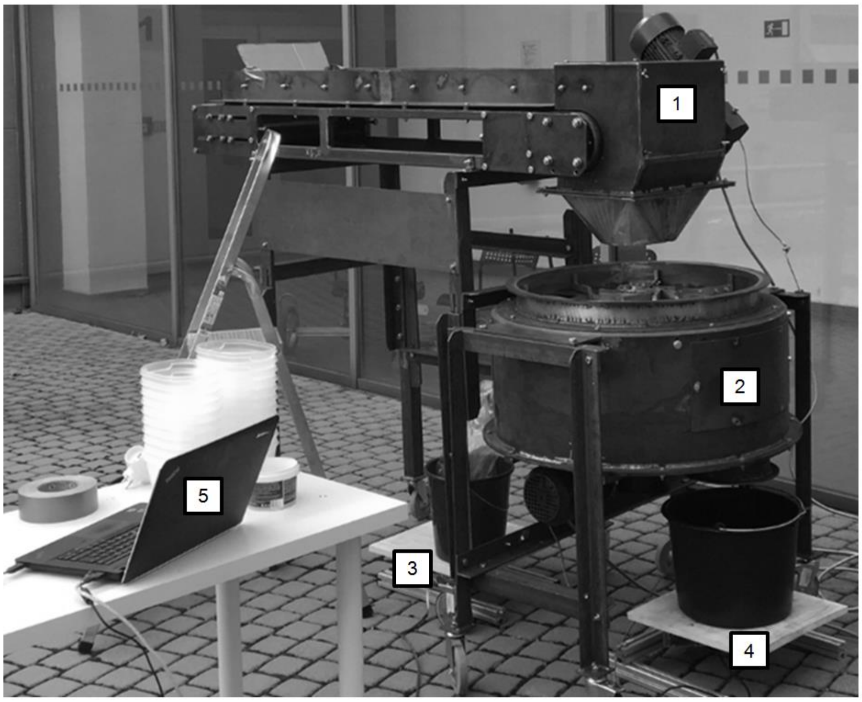

Figure 3. *Assembly of the measuring station*

3 RESULTS AND DISCUSSION

The experiments were carried out for three different rotational speeds of the sampling device, which were set by adjusting the rotation frequency of the drive. Fig. 4 shows the obtained average values of mass distribution for both sample and waste materials after the splitting process for the individual rotational speeds of the sampling device. The sum of the Output-Sample and Output-Waste masses showed that the result did not match the input quantity of the material. In the splitting process, a partial loss of the input material occurs as the material gets stuck in the so-called “dead zones” of the splitting device. A certain amount of material was also lost at the inlet and two outlets from the sampling device. From a series of measurements for the individual rotational speeds of the sampling device, average material losses were determined as follows: 10 rpm = 0.22 kg, for 29 rpm = 0.14 kg and for 45 rpm = 0.15 kg. It should be noted that the average values of the material losses recorded in the individual measurements did not deviate considerably. The split ratio i_d was determined from the obtained mass readings. The split ratio is defined as the result of a division of output sample mass m_s by the mass of the input material *mi* entering the sampling device, see Equation 1. It was determined that rotational speed of the sampling device which was set at 29 rpm was the closest to the required split ratio $i_d=0.1$.

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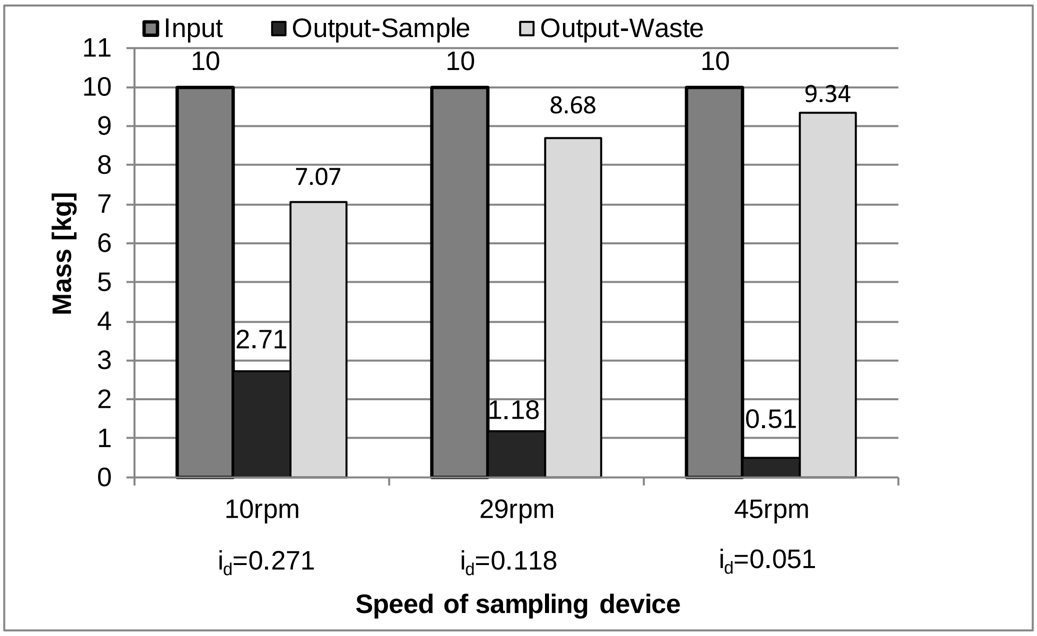

Figure 4. *Efficiency of the sampling device as a function of its speed*

The second parameter considered was a comparison of the particle size distribution of the input material with Output-Sample. The aim was to determine whether any separation of a certain fraction of coal occurs due to the setting of the rotational speed of the sampling device. Table 1 summarizes the average particle size distribution of *Coal A* for all experiments performed. The results were compared according to the cumulative distribution Q3 in 10 %, 50 % and 90 %. By comparing the particle size results in the individual cumulative distribution rows for Input and Sample (Output-Sample), it was found that partial degradation of the input material occurs during the splitting process. Degradation of the material may be caused by gaps between the rotating and static parts of the sampling device where the material may fall during the separation process. No significant variation of degradation effects related to the rotation speed of the sampling device was found.

Table 1. *Particle size distribution of Coal-A*

Cumulative distribution Q3 [%]	**Particle size X [mm]**					
	10 rpm		29 rpm		45 rpm	
	Input	Sample	Input	Sample	Input	Sample
10	0.299	0.312	0.328	0.310	0.407	0.230
50	1.083	1.004	1.371	1.169	1.594	0.770
90	4.984	3.523	5.835	3.947	4.185	2.861

4 CONCLUSION

Based on the measured results, it was found that the setting of the operating parameters of the sampling device informs the desired separation efficiency and the quality of the representative sample obtained. Required split ratio $i_d=0.1$ was achieved for the rotational speed of 29 rpm. Setting the rotational speed of the sampling device to 10 rpm led to $i_d=0.271$ while rotational speed of 45 rpm showed split ratio $i_d=0.051$. In the assessment of segregation during the splitting process, it was found that there was no segregation but the degradation of particles was observed. This was confirmed by comparing the results of the particle size distribution of input material

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(Input), sample material (Output-sample) and waste material (Output-waste). Degradation of the material may be caused by gaps between the rotating and static parts of the sampling device where the material may fall during the separation process. The device was optimized and the settings of the operating conditions of the sampling process were changed based on the obtained results.

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NOMENCLATURE

Symbols used

i_d	split ratio	(-)
m_i	mass of input material	(kg)
m_s	mass of output sample	(kg)
Q_3	cumulative distribution	(%)
X	particle size	(mm)

Abbreviations

CCD	charge-coupled device

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