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Review paper

COAL CLEANING BEFORE COMBUSTION – PRACTICE AND EXPERIENCE IN SERBIA

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Abstract: The paper gives review of international and domestice experience in Serbia in the field of coal cleaning prior to combustion in thermal power plants. Also, the paper highlighted the problem of combustion low rank lignite from open pit mine in thermal power plants and considering this problem from the aspect of mineral processing. The results of laboratory tests aimed to establish the possibility of cleaning of lignite from Tamnava Zapadno polje, showed the beneficial upgrading of the 70% of run-of-mine coal with simple screening. It has been confirmed that by simple process of coal cleaning can be removed about 30% of tailings, which mostly consist of mineral impurities. The final obtained products have satisfactory quality (lower contents of ash and higher calorific values).

Keywords: Lignite, Coal cleaning, Coal quality, Thermal power plants

1 INTRODUCTION

Coal plays a vital role in electricity generation worldwide. Coal-fired power plants currently fuel 37% of global electricity and data from IEA show that coal will still generate 22% of the world's electricity in 2040, retaining coal's position as the single largest source of electricity worldwide (Word Coal Association, 2022). Public Enterprise Electric Power Industry of Serbia (EPS) is the most reliable power system support of Serbia. The mean annual generation between 2010 and 2020 was 34.896 GWh of electricity. The capacities for generation of electricity operated by EPS total to 7.855 MW. EPS thermal power plants generate about 70% of electricity in Serbia, while about 30% is generated in 16 hydropower plants (EPS, 2022a).

Coal produced in mining basin Kolubara in Serbia provides about 53% of electricity in EPS, and coal from Kostolac open pit provides 17% of electricity production. Total coal production of coal in EPS in 2020 amounted to 39.1 million tons. Mining basin Kolubara produces an average of 29 to 30 million tons of coal. Kostolac coal basin produces an average of about 9 million tons of coal (EPS, 2022b). From 9 underground mines that

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operate within JP PEU Resavica is produced about 500.000 tons of high-quality coal per year. However, this coal participates with about 1.3% in total electricity production (JP PEU Resavica, 2022).

Based on all the above mentioned, it is obviously that coal from surface mining will be the main source of energy in Serbia in the future.

All coals contain noncombustible mineral matter which residue after coal has been burned is called ash. From the standpoint of coal cleaning, impurities occurring in coal may be classified as ash-forming and the sulfur-containing impurities, which both can be subdivided into inherent impurities and extraneous impurities. The inherent impurities are inseparably combined with the coal, while the extraneous impurities are segregated. Ash-forming material organically combined with the coal is considered inherent mineral matter. Extraneous mineral matter is ash-forming material from detritial matter and consists usually of slate, shale, sandstone, limestone or clay or other extraneous mineral matter from the roof and floor of the mine. All extraneous matter can be removed, i.e. separated physically with various method (Hower and Parekh, 1991).

The goal of coal preparation is to maximize the value of the coal material by separating the coal from the waste impurities to shipment to the end consumer (Noble and Luttrell, 2015).

The processes of coal preparation include coarse and intermediate coal cleaning (in dense medium vessels and dense medium cyclones) and fine and ultrafine coal cleaning (in spirals, water-only-cyclones, teeter-bed separators, conventional and column flotation cells). For coarse and intermediate size classes, crushing and screening is efficient methods for size reduction and classification. Grizzlies, inclined vibratory screens, high frequency screens and banana screens are often utilized for screening, while hammer mills, sizers and jaw crushers are the most popular machines for crushing (Bethell and Luttrell, 2004; Noble and Luttrell, 2015; Waymel and Hatt, 1988).

Thermal power plants have the capacities of boilers designed for a certain quality of coals. It is generally known, and confirmed through the paper of other authors, that combustion of coal with higher calorific values, lower ash and moisture contents, enables high boiler efficiency (Bureska, 2017; Harikrishnan et al., 2016; Saxena, 2013; Waymel and Hatt, 1988).

In the structure on pathway of the coal heat energy flow from deposit to the delivered electricity, only 24% of available energy is delivered to the users, while 15% of available energy went to exploitation losses, 10% to coal cleaning waste, only 3% to inefficiency of the cleaning process, 48% to inefficiency of the combustion process and 2% to line losses (Gluskoter et al., 2009). So, it is extremely important to maintain the constant values of the basic quality parameters of coal delivered to thermal power plants and, also, to precisely defined tolerances of these parameters (Harikrishnan et al., 2016).

The lower quality of coal, in addition to reducing the efficiency of boiler in thermal power plants, imposes other problems: complex disposal requirements of ash and slag, transport of large quantities of materials, environmental problem (air quality, soil, etc.). This problem is often viewed one-sided, i.e., from the aspect of coal recovery from the deposit, without considering the consequences that lower quality coal has in the combustion process. Relating to this, homogenization is one of the ways to solve these problems. However, although the process of homogenization makes uniform the quality of coal, the problem is not solved, because the impurities presented in the coal for combustion to the thermal power plant are not removed this way. A serious analysis of that problem is necessary, especially from the aspect of mineral processing.

Coal processing before combustion significantly affects the reduction in generation of fly and bottom ash, by-products of flue gas desulfurization and other pollutants generated during coal combustion. Cleaning or preparing of coal is most often carried out on the mine site prior to the transport to the thermal power plant and represents the first step in the entire energy cycle. Several technical and prefeasibility studies have evaluated the possibility and viability of pre-combustion of lignite cleaning in Serbia, but none of the proposed and promising processes were not implemented in practice. The aim of this paper is to consider the needs for cleaning of lignite as burning coal and to point out the advantages and importance of cleaning of our coals, or individual parts of the coal deposits before combustion in thermal power plants. So, in this paper we would like to highlight how a simple dry screening process of coal after primary crushing can provide improved quality regarding ash content and calorific values by removing fine particles containing unwanted impurities.

2 INTERNATIONAL AND DOMESTIC PRACTICE

Related international literature indicates determined trends of the introduction of coal cleaning before combustion in thermal power plants because of several advantages that include improved and more consistent coal quality, lower transport costs, reduced capacity of fuel- associated equipment, lessen deposition, corrosion, erosion, and enhanced net TPP heat rate (Burnard et al., 2014).

According to published data, about 40% of coal is being cleaned in South Africa prior combustion in TPP’s, India at the moment cleans about 30% of coal with the tendency to reach over 60% in the near future by building new capacities, in Russia about 35% of coal is cleaned, while in China about 25% of coal is subjected to cleaning processes before sending to TPP’s (Fedorova et al., 2015; Zhenia, 2013). These data are related to coal that is burned in existing conventional thermal power plants with efficiency considerably lower than in the contemporary combustion technologies (Supercritical, Ultra supercritical, Circulating Fluidized Bed, and Integrated Gasification Combined Cycle).

In the United States, more than 30% of the thermal coal is treated using various coal preparation processes that remove unwanted impurities from coal, such as ash, sulphur and moisture, and increase the calorific value of coal in order to improve overall combustion efficiency of the boiler. Coal preparation greatly depends on the relative proportion and differences of composite particles (coal and waste rock) and it usually impossible to physically separate all the organic matter from inorganic impurities (Gluskoter et al., 2009).

Coals from mines in Serbia, both from underground and surface mining, in the aim to obtain final products are treated by simple processes (crushing and screening) or complex cleaning processes (usually by gravity concentration in a suspension of magnetite or quartz sand or by Parnaby process in autogenous suspension). The selection of the applied process depends on the type of coal and its quality, exploitation capacity, purpose, and quality of the obtained final products (ash content, calorific value, moisture, size fraction, etc.) and other factors. Coals from underground and surface mining, especially from surface mining, intended for combustion in thermal power plants, are not cleaned often. These coals are treated only by simple processes such as crushing and screening, reducing to the appropriate size fraction and then sent to the thermal power plant. In addition to required size fraction, these coals must also satisfy the requirements of thermal power plants for calorific values, ash and moisture contents.

The Tamnava coal preparation plant aims to prepare raw coal from surface mining for combustion in thermal power plants. Due to the nature of the deposit and the structure of the coal layer, selective coal mining at the Tamnava surface mine is difficult. Lignite i.e., burning coal from mass coal mining sent to the Nikola Tesla thermal power plants in Obrenovac. This coal has lower quality because of presence of high content of clay, quartz sand and other mineral impurities. The new crushing line was introduced aimed at increasing the capacity and obtaining coal of satisfactory size fraction, while the homogenization process was introduced with the aim of making uniform the quality of coal.

In eastern part of the Kolubara coal basin, there are three exploitation fields: Tamnava – East field, whose exploitation has been finished, Tamnava – West field and the Radljevo field. According to data from the exploration works, almost 21% of the coal in the Tamnava Zapadno polje does not satisfy the required quality in relation to lower calorific value (LCV) by the thermal power plants in Obrenovac. The estimated average quality of coal at Tamnava Zapadno polje has a downward trend, consequently at the end of the exploitation it is expected that ash content will be around 18.5% and LCV (Lower calorific value) below 7 GJ/t (Average total sulphur content is less than 0.6%). The same applies to coal from other open pits, where at Južno polje average ash content is expected to increase to over 17.7% and LCV will drop to less than 7 GJ/t and at Radljevo average ash content in coal will increase over time to over 19% and LCV will decrease to below 6.5 GJ/t. This is supported by the fact that in the tender for the construction of the new thermal power plant Kolubara B, the adopted projected values are 18.36% of ash and LCV of 6.7 GJ / t (Rudarski institut, 2011). Today, the situation is especially interesting in certain parts of the deposit where there are significant reserves of coal finely impregnated with tailings. Reserves of this coal are estimated at 10 million tons, and lower calorific value (LCV) is below 6000 kJ/kg, which is significantly lower than the requirements of thermal power plants.

It is clear that coal processing can have an important role in the electrical power supply chain by providing higher-quality fuel for TPP's in Serbia.

3 MATERIALS AND METHODS

For these investigations two representative coal samples were obtained from the open pit mine Tamnava Zapadno polje during excavation of the first withdrawal cut. Raw coals were sent to the plant by belt conveying system and samples were taken from the belt conveyer after crushing to -60 mm. These samples of coal, for thermal power plant in Obrenovac were taken in different periods of time and they were different relating to quality, i.e., ash contents and calorific values, so marked as sample 1 and sample 2. These samples represent burning coal for thermal power plant in Obrenovac.

The samples of coal, marked as sample 1 and sample 2, were screen by dry procedure on laboratory screens with 5 mm opening. Products of screening (oversize fraction -60+5 mm and undersize fraction -5+0 mm) were dried, measured, and prepared for analysis.

4 RESULTS AND DISCUSSION

Results of dry screening of samples 1 and 2 are shown in Table 1 and Table 2, respectively.

Table 1 Results of dry screening of sample 1

Products Size fraction (mm)	Mass %	Ash %	Ash distribution %	LCV GJ/t	LCV distribution %
-60+5 mm	70.4	14.33	57.39	12.31	85.44
-5+0 mm	29.6	25.30	42.61	4.99	14.56
Feed	100.0	17.18	100.00	9.85	100.00

Table 2 Results of dry screening of sample 2

Products Size fraction (mm)	Mass %	Ash %	Ash distribution %	LCV GJ/t	LCV distribution %
-60+5 mm	70.92	21.68	59.59	6.39	83.17
-5+0 mm	29.08	35.85	40.41	3.22	16.83
Feed	100.00	25.80	100.00	5.46	100.00

It can be seen from Table 1 and 2 that oversize products, size fractions -60+5 mm, obtained by dry screening, have both higher calorific values (LCV) than raw coals. Primary crushing of raw low grade coal leads to concentration of waste minerals in fine fractions, which results in the increase of ash content and the decrease of LCV in those fractions. By screening of size fraction -60+0 mm on 5 mm screen about 70% of oversize fraction can be obtained with 14.33% and 21.68% of ashes and LCV of 12.31 GJ/t and 6.39 GJ/t. Undersize fraction -5+0 mm contained 25.3% and 35.85% of ashes and LCV of 4.99 GJ/t and 3.22 GJ/t. About 85% and 83% of the heat (calorific values) will be separated in the oversize fractions. The screening results clearly indicate that it is possible to achieve satisfactory and continuous coal quality with LCV over 6.10 GJ/t (in the case of low-grade sample 2) for the supply of TPP in Obrenovac, while removing unwanted impurities that concentrates in fine fractions. The presence of tailings is evident in undersize fractions (-5+0 mm) due to the higher ash content and significantly less calorific values in relation to raw coal. It is possible to remove by screening about 30% of coal (in undersize fractions).

5 CONCLUSION

World experience shows that coal cleaning significantly affects different aspects of coal combustion in thermal power plants, among which are the efficiency and performance of the combustion process, the costs of maintenance and transport of coal, disposal of waste materials generated by combustion and mitigation of environmental degradation, especially air pollution. In addition to increasing the reliability of the operation of the thermal power plant, better and uniformed fuel quality enables the higher production of electricity with the same amount of coal due to higher calorific value, which can cover the costs of coal cleaning. It also significantly reduces the pollution of the environment both in terms of the amount of suspended particles and gases with greenhouse effects that are emitted into the atmosphere.

Simple experimental tests have shown that it is possible to successfully clean lignite i.e., burning coal of size fraction -60+0 mm from the Tamnava Zapadno polje in Mining basin Kolubara. Cleaning of burning coal is performed by screening as simple process. According to the distribution, about 83-85% of heat and about 57-59% of ashes will be separated in these products. In this way, it is possible to remove by mass about 30% of coal (in undersize fraction) as tailings. Taking into consideration that tailings in lignite are consisted of mineral impurities, mainly quartz sand and clays, these impurities could be removed in industrial conditions by simple and cheap processes: quartz sand by previous dry screening on vibratory screen, and clays by wet processes (disintegration, desliming and washing). Removal of these impurities can be done in the process of coal preparation and before the crushing. In industrial conditions, it is not realistic to expect that all amount of coal could be cleaned, but individual parts of coal layers in deposit where it is not possible to selectively excavate tailings, could certainly be subjected to some cleaning process, i.e., coal could be planned for cleaning. This solution requires minimal investment in vibratory screens, wastewater thickener and allocation of space necessary for disposal of fine fraction, which share will go up to 30%. To be more precise, Tamnava coal preparation plant with annual capacity of over 16 million tons can treat, with minor reconstruction, the low-grade portions of coal thus removing up to 4.8 million t/yr of coal with LCV slightly over 3 GJ/t.

Considering the results of these tests, it is obviously that cleaning of coal from the surface mining is becoming a necessity, and not just one of the possibilities.

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