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Influence of fuel quality on boiler work with retort furance

Juliusz Wójcik

Silesian University of Technology, Faculty of Organisation and Management
Institute of Production Engineering
41-800 Zabrze, ul. Roosevelta 26, e-mail: juliusz.stanislaw.wojcik@polsl.pl

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Abstract

In the paper the impact of changes in coal quality on boiler operation with the retort furnace had been discussed. Study used a test for the three types of coal from different mines. Energy and emission studies have shown that even relatively coals not much different with physicochemical parameters, causing a marked change of the efficiency of device operation. Attention was drawn to the growing scale of the problem in the application of fuel significantly deviating from properties of the classical fuel to the retort furnaces. The ways to improve the quality of use of boilers with retort burner have been given.

Introduction

The subject of this publication is to show the impact of fuel quality on the operation of the boiler with a furnace of the STOKER type. Ecological burning of coal is associated with the lowest possible emissions, which include CO, SO_2, NO_x, C_nH_m, polycyclic aromatic hydrocarbons (PAHs). Influence on the amount of impurity emissions has not only the type of fuel burned, but the way it is burning. Minimizing losses due to incomplete and imperfect combustion is essential to the efficient use of fuel. There is thus directly proportional relation between the ecological and economical combustion of coal. More recently, it is (visible) apparent intensification about design of boilers that meet high standards for environmental protection and economic use. This is of great importance in view of the fact that in Poland coal is the main source of energy. The choice of fuel for combustion in boilers with retort is to ensure proper operation consisting of a continuous, uninterrupted operation and the requirements of the energy and emission. Achieving this goal can be providing by tests and combustion evaluation of selected coals that meet certain requirements.

Requirements for coals used into the retort furnaces

The main fuel used in boilers with retort furnace is coal. However, there have been cases of other fuels, which usually act as a supplemental fuel, used extemporaneously. These include pellet [1, 2] and oats [2]. There are also boilers designed to burn a greater range of fuels – so-called multifuel boilers. They are characterized by extensive chamber furnace, where there is beside the retort burner, grate for burning solid fuel briquettes, wood and a large fraction of carbon [3]. The study of the energy and emission retort broilers protocols are conducted based on the basic fuel that is coal, due to the size fraction called peas. Requirements for coals designed for burning in Stoker boilers are provided in table 1.

Table 1. Required physical-chemical parameters of coal for combustion in furnaces of STOKER type

Parameter		Unit	Requirements
The moisture content		%	$W^r_t < 15$
The ash content		%	$4 < A^a < 15$
The volatile components content		%	$28 < V^a < 40$
Temp. of ash melting		ºC	$t_B > 1150$
Sinterability by RI	STOKER boilers with cleaning out ash		< 2
	Classic STOKER boilers		< 5
Granulation		mm	$4 < d_z < 25$
Amount of grain (particles) ($d_z < 4$ mm)		%	< 10

These requirements include not only the correct operation of the combustion in the combustion chamber, but also the proper operation of system of the fuel supply to the retort and combustion waste disposal system (if such a system is used). The main elements of these systems are adequately, feeding device and the screw selector. While the share of total moisture and volume of fraction affects the transport of coal into the retort, its sinterability has an impact on the proper disposal of furnace waste outside of the boiler. All containd in table 1 parameters have affect for correct operation of the combustion process. Description of the combustion process in the retort furnaces is presented in the work [4].

Parameters of the tested fuels

For the combustion tests three coals (carbons) (A, B, C) were used, each coming from different mines. Selected parameters of technical and elemental analysis are shown in table 2, while the sieve analysis results in table 3.

The technical and elemental analysis shows that the coals meet the requirements of table 1. They have comparable calorific values, degree of coalification, content of volatile matter and ash fusion temperature. They differ in moisture content and ash. For carbon "C", the sinterability is close to the limit. The sieve analysis shows that the proportion of small grains in the coal "B" is slightly above allowable value, and generally share of a small fraction in this coal is the greatest.

Table 2. Selected parameters of technical and elemental analysis tested coals [5]

Name	Unit	Coal		
		A	B	C
Content of the complete moisture	%	13.7	11	8.3
Content of the ash	%	4.9	12.6	9
Content of the volatile components	%	31.1	31.2	33
The calorific value	kJ/kg	25,080	24,080	26,076
Sinterability by Rogi (RI)	–	0	0	4
Temperature of melting point of ash	ºC	1240	1240	1300
Content of total sulphur	%	0.77	1.37	0.92
Content of ash sulphur	%	0.43	0.78	0.27
Content of volatile sulphur	%	0.34	0.59	0.65
Content of coal (carbon)	%	72	68.5	70.2
Content of nitrogen	%	1.31	1.27	1.29

Table 3. Sieve analysis results of tested coals [5]

Grain class	Coal		
	A	B	C
[mm]	[%]	[%]	[%]
> 25	–	–	–
(25, 10)	95.5	41.3	63.8
(10, 5)	1.7	35.9	25.3
(5, 3.15)	0.3	11.4	4.3
< 3.15	2.5	11.4	6.6
Sum	100	100	100

Tests of coal combustion in a boiler with a capacity of 25 kW

Combustion tests were used to determine the effect of burned coal type on the emissions, on the amount of heat loss mainly due to incomplete and imperfect combustion, on the property remains of grate (trails, caking). The duration of each test was 4 hours, so results can be considered reliable. Table 4 shows the characteristic parameters of the reference to a fuel gas, fumes and combustion wastes according to each burning coals. The temperature and gas composition were measured at the nozzle outlet of gas in the boiler.

In table 5 parameters of the thermal performance of the boiler when burning tested coals are shown.

Table 4. The test results of combustion of coals A, B, C in the boiler 25 kW CRE [5]

Factor	Specification		Unit	Coal		
Fuel	Type, assortment			A	B	C
	Consumption in the unit of time		kg/h	4.73	5.24	5.37
Exhaust	Temperature		ºC	274.81	286.79	260.81
	Composition	CO_2	%	7.74	7.31	9,33
		O_2	%	12.24	12.75	10.28
		CO	mg/m^3	122.79	957.02	552.04
		SO_2	mg/m^3	531.12	872.73	971.78
		NO	mg/m^3	315.43	163.68	333.78
		Dust	mg/m^3	43.11	338.68	129.99
		Organic substances	mg/m^3	17.40	88.45	29.12
		B(a)p	µg/m^3	147.41	362.45	152.40
Grate waste	Mass stream		kg/h	0.20	0,25	0.74
	The content of combustible		%	29.40	26.40	48.40

Table 5. Size and thermal XSAir for the boiler CRE 25 KW while burning tested coals

Parameter	Unit	Burning coal		
		A	B	C
Useful thermal power	kW	24.69	24.91	26.98
Power fed with fuel	kW	32.92	35.03	38.92
Chimney loss	%	24.39	27.64	18.99
Loss of incomplete combustion	%	0.08	0.70	0.30
Loss of imperfect combustion	%	1.65	1.74	8.47
Thermal efficiency	%	75.00	71.10	69.33
Excess air ratio	–	2.46	2.50	1.93

Assessing the process of burning tested coals the following factors were taken into account: emissions of pollution into the air, especially: CO, organic compounds and polycyclic aromatic hydrocarbons (PAHs), the state remains scraper (possibility of tracking or caking).

Analyzing the results of measurements and thermal calculations should be noted that the parameters of the emission during combustion of carbon "B" are definitely the least favorable. For this coal, relatively high are heat losses as a result of incomplete combustion what is evidenced by the high carbon monoxide emissions. Equally high is the emission of dust. Coal "B" is also characterized by the highest emissions of organic compounds and PAHs. The representative of polycyclic aromatic hydrocarbons is benzo-alpha-pyrene – B(a)p, a substance with particularly dangerous effects on living organisms.

During coal combustion "B" we are dealing with the formation of slag forming smoke flue above the furnace and flowing into the ash chamber. This phenomenon is detrimental to the Stoker type boilers, especially with mechanical waste disposal of grates. The main reason for the unfavorable operation of the boiler during coal "B" combustion is a relatively high proportion of ash in coal output. Although, the share of minerals in coal "B" is below the limit (Tab. 1), yet it is seen that the effect of the ash in coal is significant on the combustion process. This dependence is shown in figure 1 with respect to CO, organic matter, and B (a) p.

Emission parameters of coal "A" and "C" are similar. They differ in the properties of the grate residues. In the case of coal "C" residue of grate did not take a form of slag or lumps. Its consistency was loose dust and papules, which crumbled under slight pressure. The grate residue of coal "A" consisted only of dust and of fine particles underburnt. This is due to the nature of the combustion of this coal. Burning in the bed grains has a tendency to "plow", as a result of it detached particles burn

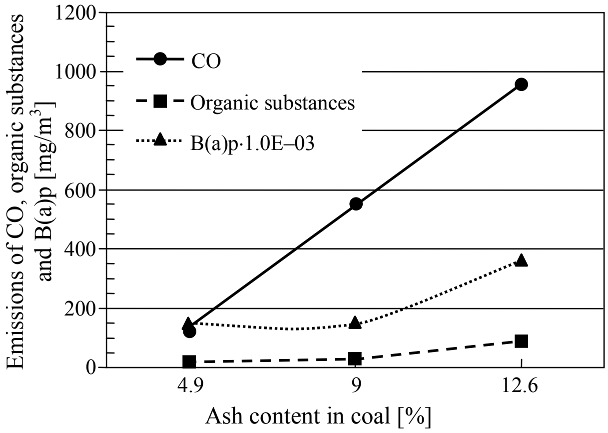

Fig. 1. Influence of ash participation in coal on the emission into atmosphere pollutants substances

themselves in the area of homogeneous reactions. Phenomenon is accompanied by a large dustiness of combustion chamber. Because of it, there are dust sticks to the walls of a heat exchanger, and thus, over time, it is reduce the energy exchange between exhaust gases and the heating factor.

Figure 2 shows the burning of coal "A" in a boiler with a capacity of 150 kW. It has been shown and described above the specificity of the burning coal in the tested boiler is similar to shown in figure 2.

Fig. 2. The occurrence of "pollination" of the combustion chamber during coal "A" combustion, in the boiler with a capacity of 150 kW

Discussion

Test studies of coal combustion in the boiler with the retort combustion were preceded by proper setting of the speed of the fuel supply and air to the combustion chamber. Selection of parameters of the working boiler during combustion of the given fuel is a process very tedious and lengthy due to the thermal inertia of the device and the inertia in the determination of new operating points in the combustion chamber. Working point of the device assumed to be optimal when emition of the CO into the atmosphere reached minimum value. The control system of the boiler does not include the type of fuel burned, only synchronizes the operation of systems: the fuel supply, air supply, disposal of waste combustion, the flow of heating factor and security systems. Thus, change the type of burned fuel forces to carry out the test of control combustion. Boiler's manufacturers often give the so--called, universal control range of the boiler when burning eko-pea coal [6]. However, it is questionable whether such an adjustment provides for low emissions and high energy efficiency of the boiler, which is administered in advertising folders. There are known microprocessors control equipment functioning of the retort boiler, which have stored in permanent memory operating characteristics of given boiler for the various types of coals. An example is the eco system MAX 700R Individual Fuzzy Logic [7]. This system analyzes the evolution of the CO in the exhaust. The approach to solve the problem of controlling the operation of the boiler is suggested that the operation of the boiler can run with good results.

Another solution is the driver control eCoal.pl [8]. According to the manufacturer driver sets the optimum amount of air needed for combustion of fuel, on the basis of measurements of gas temperature at the nozzle outlet of the boiler. It seems that taking into account only the temperature of exhaust gases at the outlet from the boiler does not fully guarantee its correct operation. The advantage of this controller driver is a programmable temperature of heating factor on a daily or weekly period.

Performed study shows that for very similar type of coal, combustion process can be considerably different, which in turn translates into energy efficiency of the whole device. It is not difficult to imagine changes of the combustion process forced by use of fuel substantially different from the primary fuel, such as during combustion of coal dust, a mixture of fine coal and oats or burning pellets [1, 2]. There are new design solutions for retort burners suitable for burning fuel which parameters differ significantly from those contained in table 1. An example is the type of burner BRUCER [9]. Modernized its fuel transportation system and the additional nozzles systems allow combustion of fine coal. But the biggest efficiency of fuel combustion provides typical fuel for retort's burners.

Conclusions

Influence of coal type on the operation of the boiler with the retort burner can be very pronounced. In order to ensure proper operation of the device there are two possible solutions.

The first is to carry out the selection of carbon and systematizing it in the series. Selection of coal requires a complete knowledge of the characteristics of the fuel not only in terms of physicochemical properties, but also formed from the ashes. This is due to the complex nature of coal, its composition and diversity of processes occurring during its combustion [10, 11].

In contents of these facts, the process of selecting adequate coal to the specific type of furnace should be conducted with the following steps:

a) the initial selection of coals based on their classification according to PN;
b) determination of the physicochemical properties of coals (technical and elemental analysis) with respect to their sinterability parameter, and the determination of ash melting temperature;
c) carrying out the energy and the emission test.

Paying attention to the development of combustion technology based on the retort's furnaces, there is a need for studies of coals from a number of mines to prevent accidental use of fuels. This is necessary to provide the broad base of security of the coal for boilers.

The second solution, which refers mainly to the individual user, is to rely on fixed constant possibly high-quality fuel delivered from a single supplier. Any change in the type of fuel will have to be associated with long-term selection of boiler operating parameters. For less experienced users the choice of appropriate parameters can take weeks. It is advised to use microprocessor control systems devices, what unfortunately is associated with additional costs. These systems can be very useful, then the additional investment will be recouped very quickly by the smaller amount of fuel burned.

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