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INFLUENCE OF ADDITIVES ON DECREASE OF TEMPERATURE OF SLAG FLOW FROM ENERGY COAL IN WET BOTTOM BOILER

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This paper describes the features of the energy coal combusted in a power plant, its impact on energy production, while the possibility of using natural and secondary raw materials to modify the properties of energy coal. All selected types of additives (fluorspar, de-metallized steelmaking slag (DSS), dolomite, and limestone) in admixture of coal have clearly proved their ability to reduce the pour point of the ash in the laboratory experiments. The highest decrease of the temperature at 5 % of the additive was achieved by fluorspar and dolomite from the temperature of 1 593 °C to the temperature of 1 307 °C. In terms of the economy and the availability of the additives the most suitable seems to be DSS.

Key words: energy coal, raw material, de-metallized steelmaking slag, bottom boiler

INTRODUCTION

Energetics provides heat and power for technological processes in plants. The combustion of anthracite coal poses problems in slag flow resulting in clogging of slag discharge opening. Unmelted ash settles on the bottom of the combustion chamber in layers after cooling showing high strength. In order to remove this layer the boiler has to be shut down, cooled and cleaned up. Such shutdowns of the boiler contribute to shortening of the life and also increase of the expenses for its maintenance [1 - 3].

All industrial enterprises are trying to reduce the production of harmful emissions into the atmosphere. The easiest and best solution is the tightening of the criteria for the purchase of input strategic raw materials and thereby mitigating their impact on the environment. It is not easy to get suitable chemical parameters of coal by purchase. The coal is of Russian origin shipped from several mines and is continuously homogenized as delivered to the storage pit and then delivered directly to the plants in operation by conveyors [4 - 6].

To characterize the problem it was necessary to take a number of chemical - physical analyses of coal, ash, slag, and fly-ash (Table 1). From the analysis the characteristic parameters such as temperature of softening, spherical temperature, hemispherical temperature and flow temperature have been identified. These temperatures and other chemical analysis of coal and slag were determined according to the standards. The viscosity of the liquid coal depends on the chemistry of the slag, in particular on the total content of oxides of iron and CaO + MgO. Oxides SiO_2 and Al_2O_3 increase the viscosity, the related softening point and pour point and "extend" the character of slag [7 - 10].

As to the energy the coal sample in Table 1 conforms to wet bottom boilers requirements but high concentrations of SiO_2 and Al_2O_3, which increase the temperature of the ash flow, were found by chemical analysis of ash (Table 2).

Table 1 **Chemical analysis of coal**

Total water	9,40 %	Hydrogen content in combustible matter	3,96 %
Analytical water	2,00 %	Carbon content in combustible matter	91,60 %
Ash in anhydrous sample	14,60 %	Carbon in original sample	70,80 %
Ash in original sample	13,20 %	Nitrogen content in combustible matter	2,14 %
Volatiles content in combustible matter	11,30 %	Combustion heat content in combustible matter	35,21 MJ·kg^{-1}
Volatiles content in original sample	8,70 %	Heat value in original sample	26,38 MJ·kg^{-1}
Sulphur in anhydrous sample	0,42 %	Heat value in dry sample	29,37 MJ·kg^{-1}
Sulphur in original sample	0,38 %		

Therefore, when determining the basic properties of the coal, it is also necessary to know not only the content of C, H, N, ash, volatile matter, and heating value, or combustion heat, but especially the chemical composition of the ash, which significantly contributes to the characteristics and performance of slag.

During the combustion all the components of the solid fuel – both organic and inorganic – are subjected to high temperatures and may pass through oxidative or

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Table 2 **Chemical composition of ash**

Coal No.	Fe_2O_3 / %	SiO_2 / %	CaO / %	MgO / %	Al_2O_3 / %	MnO / %	P / %
1	8,54	55,37	1,53	0,83	25,67	0,1	0,21
2	5,2	62,21	1,14	0,63	26,29	0,07	0,19
3	5,35	56,78	1,09	0,7	27,6	0,08	0,25
4	5,82	65,67	1,32	0,8	23,83	0,07	0,22
Coal No.	TiO_2 / %	Na_2O / %	K_2O / %	Softening temperature / °C	Spherical temperature / °C	Hemispherical temperature / °C	Flow temperature / °C
1	1,02	1,39	2,03	1 236	1 510	1 521	1 531
2	1,03	1,15	2,01	1 216	1 541	1 551	1 559
3	0,98	1,24	1,85	1 289	1 567	1 577	1 586
4	0,97	0,09	3,12	1 202	1 501	1 514	1 530

Table 3 **Chemical composition of mixtures**

Sample	Fe_2O_3 / wt. %	SiO_2 / wt. %	CaO / wt. %	MgO / wt. %	Al_2O_3 / wt. %	MnO / wt. %	P_2O_5 / wt. %	TiO_2 / wt. %	Na_2O / wt. %	K_2O / wt. %
Coal	7,82	59,12	1,92	0,74	23,85	0,10	0,59	0,92	0,41	2,57
Coal + 1 % fluorspar	7,86	57,15	5,66	0,69	23,09	0,10	0,57	0,85	0,46	2,49
Coal + 3 % fluorspar	6,66	49,07	11,47	0,56	18,58	0,08	0,49	0,73	0,39	2,05
Coal + 5 % fluorspar	5,87	42,26	19,11	0,48	16,24	0,19	0,41	0,67	0,02	1,78
Coal + 1 % limestone	7,39	55,36	6,01	0,78	22,15	0,09	0,55	0,80	0,36	2,21
Coal + 3 % limestone	6,86	51,59	10,28	0,97	20,55	0,09	0,53	0,86	0,40	2,23
Coal + 5 % limestone	6,47	47,63	18,10	1,19	19,47	0,09	0,50	0,67	0,24	1,90
Coal + 1 % dolomite	7,36	56,40	2,82	1,51	23,87	0,09	0,59	0,80	0,38	2,44
Coal + 3 % dolomite	6,63	51,14	6,60	4,08	20,97	0,09	0,52	0,83	0,37	2,23
Coal + 5 % dolomite	6,69	48,54	10,51	6,40	20,51	0,09	0,50	0,68	0,28	1,97
Coal + 1 % DSS	9,02	57,31	4,60	1,27	22,79	0,27	0,59	0,93	0,50	2,29
Coal + 3 % DSS	11,62	51,40	8,31	2,41	20,08	0,66	0,61	0,86	0,50	2,23
Coal + 5 % DSS	12,88	45,77	11,21	3,08	17,95	0,90	0,59	0,77	0,38	1,77

reducing environment. The transit time of the particles through the combustion furnace at high temperature is short (1 - 3 seconds). During this time they melt and reactions occur in the liquid phase or only in the surface part. As a result, the ashes consist, in addition to mineral residues, of the remains of the original or by thermal process converted coal to varying degrees.

The measured values (Table 2) indicate that the coal samples do not meet the conditions of ash flow. In order to change these conditions dosing of additives fluorspar, limestone, dolomite and de-metallized steelmaking slag was proposed. In the first stage of laboratory tests the concentration of 1 %, 3 %, and 5% of the additives mixed with the energy coal were been proposed. The chemical composition of the ash from these samples is shown in Table 3. The coal powder was mixed with the above quantities of the additives. The coal samples with additives were ignited and then the pour point of the resulting ash was determined

Characteristic temperatures of the mixed samples with various additives are given in Table 4. The obtained results of laboratory tests indicate that the addition of selected types of additives lowers the concentration of SiO_2 and Al_2O_3 (these components increase the flow point of ash) and increases the concentration of CaO and MgO in the ashes (these components decrease the pour point of the ashes). At 5 % of the DSS, fluorspar, and dolomite the required temperature of ash pour point, i.e. the pour point below 1 350 °C, were achieved.

CHEMICAL AND PHYSICAL PROPERTIES OF THE ADDITIVES

Fluorspar

Chunk, metallurgical fluorspar is a product of treatment of the basic raw material of natural fluorspar to the desired properties. Treatment consists in adjusting the lower and upper limit of the grain size distribution by sieving and milling the oversize fraction to the desired particle size. Physical properties of fluorspar are: specific weight of 3,14 $kg \cdot dm^{-3}$, bulk density of 1,55 to 1,67 $kg \cdot dm^{-3}$, flow temperature of 1 348 °C.

De-metallized steelmaking slag

DSS produced by a steelworks, is an artificial melt formed as a by-product of steel production in the converter which solidifies in crystalline form after casting and rapid cooling in a thin layer. DSS is produced as a product of the cooled steel slag, and the free iron is removed by magnetic separation of metal particles and the slag is sorted into the fractions of 0 - 16, 16 - 45, and 16 - 63 mm. The flow temperature of DSS is 1 362 °C .

CONCLUSION

All selected types of additives (fluorspar, DSS, dolomite, and limestone) in admixture of coal have clearly

Table 4 **Flow temperatures of mixtures**

Sample	Flow temperature / °C	Softening temperature / °C	Spherical temperature / °C	Hemispherical temperature / °C
Coal	1 593	1 222	1 489	1 527
Coal + 1 % fluorspar	1 455	1 240	1 348	1 379
Coal + 3 % fluorspar	1 364	1 245	1 278	1 310
Coal + 5 % fluorspar	1 307	1 183	1 207	1 223
Coal + 1 % limestone	1 428	1 250	1 323	1 343
Coal + 3 % limestone	1 383	1 253	1 282	1 314
Coal + 5 % limestone	1 388	1 249	1 269	1 290
Coal + 1 % dolomite	1 529	1 229	1 363	1 417
Coal + 3 % dolomite	1 367	1 224	1 275	1 291
Coal + 5 % dolomite	1 308	1 218	1 236	1 250
Coal + 1 % DSS	1 428	1 236	1 333	1 359
Coal + 3 % DSS	1 349	1 224	1 267	1 286
Coal + 5 % DSS	1 338	1 205	1 255	1 266

Table 5 **Qualitative parameters of DSS**

Fe total	18,0 – 30,0
SiO_2	8,0 – 11,5
MgO/ free MgO	Max 11,0/0,40
Al_2O_3	0,5 – 8,0
CaO/ free CaO	40 – 60/ 4,5 – 10
S total	0,40 – 0,065
P_2O_5	0,6 – 1,2
Basicity CaO/ SiO_2	3,5 – 5
Chrome	0,07 – 0,15
Mercury	0,002 – 0,03

proved their ability to reduce the pour point of the ash in the laboratory experiments. The highest decrease of the temperature at 5 % of the additive was achieved by fluorspar and dolomite from the temperature of 1 593 °C to the temperature of 1 307 °C. In terms of the economy and the availability of the additives the most suitable seems to be DSS.

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