Coburning of formed fuel with hard coal in the stoker-fired boiler furnace

J.W. WANDRASZ, K. GASKA, M. KOZIOŁ, M. LANDRAT, W. ŚCIERSKI, A.J. WANDRASZ
Department of Technologies and Installations for Waste Management
Silesian University of Technology
PL- 44-100 Gliwice ul. Konarskiego 18A
POLAND
http://www.waste.polsl.pl

Abstract: The paper presents investigation results of the coburning process of two hard coal grades with the formed fuel obtained from plastics acquired from the disassembly of vehicles. The investigations were carried out in the WR-25 type stoker-fired boiler. The main properties of the coburned fuels are specified in the paper; moreover, the concentration and emission values are presented for the main gaseous pollutants: CO, NO, SO_2 and dust.

Key-Words: formed fuels, stoker-fired boilers, coburning, emission, CO, SO_2, NO_x

1 Introduction
1.1 Source of the problem
About 98% of the generated municipal waste mass is deposited in Poland. Apart from the several thermal industrial waste untilization plants and the relatively dense network of the thermal utilization plants for medical waste there is only one thermal municipal waste utilization plant in Poland (in Warsaw) and one sludge icineration plant for sediments from the sewage treatment plant (in Gdynia). Preparations are in progress for development of several such plants more. However, due to the procratedness of the investment processes one can expect their erection in the middle of the nexr decade only.
Therefore, finding solutions making it possible to burn the selected fractions of the municipal waste just now features the important and urgent problem. Such solutions would make utilizing the chemical energy of the waste possible and would also reduce the deposited substance mass. Production of the formed fuels features the group of technologies meeting the requirements above. These technologies make it possible to utilize the selected fractions of waste - both municipal and industrial ones, they make it also possible to compose fules with properties meeting requirements of the particular consumers.
There are several thousand boilers in Poland of the low and average power rating with grate furnaces. Boiler designs of this type are characteristic of a remarkable versatility making it possible to burn in them fuels characteristic of the significantly different properties (e.g., size grade, heating value, combustible fraction, etc.).
Therefore, coburning of the formed fuels with coal in furnaces of the average power rating stoker-fired boilers might be the rational solution of a part of the municipal waste management problems in Poland. Boiler installation would, however, require most often expansion of the combustion gases cleaning systems, limited currently most often to the dust extraction devices.

1.2 Description of investigations
Investigations were carried out on the WR 25 type water heater. Boiler furnace was fitted out with double grate. This was connected with separate air inlets under each grate (from two sides of the boiler). The boiler was in a very good technical condition.
No boiler parameters were changed, except the burned fuel, during the investigations. Boiler load was stabilised by another boiler operation, reacting to load changes, playing the role of the quasi peak boiler.
The main controlled boiler variables assumed the following values during the investigations:
- thicknes of the burned fuel layer – ca. 130 mm;
- average grate travel rate – ca. 4.52 m/h;
- average furnace draft – ca. 8.4 Pa;
- average water flow through the boiler – 299 m^3/h.

The values above were changing in the relatively narrow ranges during the investigations.
Two coal burn tests were carried out within the framework of the presented investigations with coals coming from Piast coal mine (further denoted as „W-I") and from Wujek coal mine (denoted as „W-II").

Concentration and emission values obtained by burning the coals featured the reference values for the analogical values obtained during burning mixes of the formed fuel with coal from Piast coal mine (denoted as „M-I”) and with coal from Wujek coal mine (denoted as „M-II”).
The fraction of the formed fuel dry mass during the coburning of mixes of the formed fuel with coals was ca. 10%. The formed fuel used in the investigations was obtained from plastics acquired from the disassembly of passenger cars.

Measurements of dust emission and of the following gaseous substances were carried out during the investigations: CO, CO_2, O_2, NO, SO_2, and selected hydrocarbons. Moreover, measurements were carried out of streams of the combustion gases and of the air passed under the grate. Measurements of the combustion gases composition and flow rates of the combustion gases streams were carried out immediately behind the combustion chamber (before the combustion gases cleaning devices).
Research topics and range of the measurements and analyzes carried out give occasion to recognize the investigations performed as pioneering on the domestic scale.

2 Characteristics of the burned fuels

2.1 Mix production method

Mixes were produced during the investigations by mixing the formed fuel with coal. Mixing was acquired by raking by the loader.
In Fig. 2.1 the „M-I” mix in the yard is shown. Further homogenization of the mix of the formed fuel with coal was obtained during its transport with the coaling system devices. This resulted especially because of running from the belt conveyor to the bunker and within the bunker itself. As a result the properly homogenized mixes were obtained.

Fig.1 View of the mix of the formed fuel and coal in the yard (M-I mix).

2.2 Properties of fuels and burned mixes

In Table 1 the selected fuel properties of the burned coals, formed fuel, and burned mixes are presented.

Table 1 Fractions of the combustible and incombustible parts in the burned mixes.

Parameter	W-I	W-II	Formed fuel	M-I*	M-II*
Humidity, %	8.46	822	52.34	16.76	16.57
Fraction of combustible parts, %	86.67	86.79	92.66	87.27	87.38
Fraction of combustible parts, %	27.09	29.82	30.95	27.48	29.93
Elementary composition, %					
carbon	68.00	71.55	55.12	66.71	69.91
hydrogen	3.19	3.90	6.57	3.53	4.17
sulphur	0.49	0.48	0.31	0.47	0.47
chlorine	2054.8	1628.1	990.9	2041.3	1911.1
Heating value, kJ/kg	21 149	24 299	8 905	18 830	21 385
Heating value of the fuel dry mass, kJ/kg	23 334	26 700	21 431	23 144	26 173

*- parameter values calculated based on determination results obtained for coals and the formed fuel

Humidity of coals differed relatively negligibly. On the other hand humidity of the former fuel exceeded more than six times humidity of the burned coals. This was caused by storing the formed fuel in the yard where it was exposed to precipitation. Due to its properties it absorbed the remarkable amount of moisture (more than the burned coals).

The significant humidity of the formed fuel caused reduction, on the average by about 60%, of the heating value of the real fuel mass compared to the value of this parameter recalculated to the dry mass. The heating value of the formed fuel was from 2.4 to 2.7 times lower than in coals after recalculation to the real mass.

The formed fuel used was characteristic of the higher fraction of the combustible parts of about 6.5% than the coals used. The formed fuel was characteristic of the fraction of the volatiles comparable to the one revealed in the coals.

The lowest sulphur fraction was revealed in the formed fuel - 0.31%. Its value for the coals was similar and was nearly 0.5% on average.

In case of chlorine, its highest concentration was revealed in W-I coal. In the W-II coal its concentration was revealed to be smaller by 20% than in the W-I one. Concentration of this element was revealed to be 60% less in the formed fuel than in the W-I coal.

3 Burning process run

Observation of the bolier operation was carried out during the investigation, and especially of the burning process on the grate.

Remarkable differences between burning process runs of the coals used were observed. Swelling was observed clearly of the burned fuel layer in case of burning the W-II coal.

No changes were observed of the burned fuel layer bahaviour during burning mixes on the grate compared to conditions observed during burning of coals used to make them. The thick layer of the burned fuel prevented formation of empty areas on the grate due to, e.g., quicker burning out of the formed fuel elements.

The boiler achieved a similar efficiency during burning of both coals, of about 13-14 MW. During burning of the both investigated fuel mixes the achieved boiler efficiency was only ca. 10 MW. Therefore, feeding the fuel mix with the other boiler settings unchanged caused nearly 30% drop of its efficiency.

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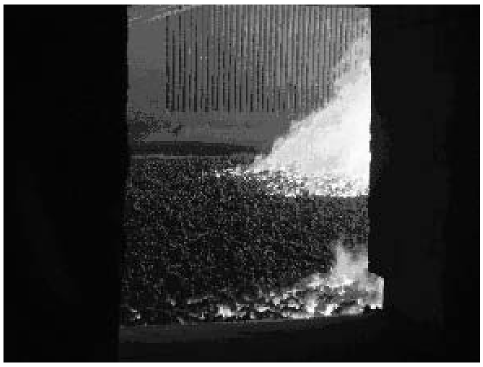

Fig. 2 View of the burned fuel („W-II") on the grate

4 Analysis of the combustion gases composition

4.1 Results of the measurements of concentrations and emissions

Average values of the measured gases during the investigations are presented in Table 2.

Measurement results of concentrations are presented recalculated into the constant, 11% content of O_2, and in case of SO_2, NO, and CO are given in mg/m^3_n of dry combustion gases. Moreover, the average emission values are presented in Table 2 in mg/s.

Table 2 Summary results of the average concentrations and temporary emission values of the selected gaseous pollutants

Parameter	CO	NO	SO_2
Unit	mg/m^3_n		
W-I	33.2	125.0	941.3
M-I	77.8	99.7	769.0
W-II	49.7	129.0	804.6
M-II	67.6	106.5	760.8
Unit	mg/m^3_n at 11% O_2		
W-I	29.8	109.15	823.2
M-I	92.9	116.45	915.7
W-II	42.3	111.8	692.1
M-II	76.2	119.5	850.8
Unit	mg/s		
W-I	324.5	1192.0	8985.5
M-I	846.0	1067.5	8350.5
W-II	481.0	1264.0	7844.5
M-II	764.5	1193.5	8486.0

The following was found out during the investigations:

- during burning of mixes the concentration of oxygen in combustion gases was higher by 30% than revealed during burning of coals used for their composition;
- during burning of mixes the average concentrations of NO (recalculated to 11% of O_2 in combustion gases) were higher by

7% compared to concentrations observed during burning of coals;

- ♦ reduced average NO emissions:
  - – by more than 10% in case of burning the M-I mix, compared to the W-I one,
  - – by more than 5% in case of burning the M-II mix, compared to the W-II one,
- ♦ increased average SO_2 concentrations (at 11% concentration of O_2 in combustion gases):
  - – by more than 11% in case of burning the M-I mix, compared to the W-I one,
  - – by more than 23% in case of burning the M-II mix, compared to the W-II one,
- ♦ reduced by 7% average SO_2 emission in case of burning the M-I mix compared to the W-I one; however, the increase by 8% was observed of this emission in case if burning the M-II mix compared to the W-II one;
- ♦ in case of CO the increase of both the average concentrations and the average emissions was revealed:
  - - concentrations by more than 3.1 times in case of burning the M-I mix compared to the W-I one, and by more than 1.8 times in case of burning the M-II mix compared to the W-II one,
  - - concentrations by more than 2.6 times in case of burning the M-I mix compared to the W-I one, and by more than 1.6 times in case of burning the M-II mix compared to the W-II one.

In case of SO_2 the average emission revealed during burning the M-II mix was still lower than the average emission observed during burning of the W-I coal. Pertinently to the nearly identical fractions of sulphur in the burned coals changes in emission levels should be explained by the different extent of burning the fuels out in the boiler. Increase of the SO_2 emission in case of burning the M-II mix compared to the W-II one results from the exceptionally low emission of this compound during burning of the M-II coal. This emission was 6-15% lower during burning this coal than in case of burning other fuels.

In Table 3 measurement results of the combustion gases dustiness are presented. Values of both concetrations and emissions are given in this table. Dustiness of the combustion gases and the stream of the transported dust before the cyclone system assumed random values (in case of the W-I/M-I comparizon it was bigger for W-I, and in case of the W-II/M-II comparizon it was bigger for M-II). Dustiness of the combustion gases after the cyclone system was always lower in case of the burned mixes than during burning the coals, and:

- – for the W-I/M-I system the difference in dustiness was ca. 20%,
- – for the W-II/M-II system the difference in dustiness was ca. 50%.

Table 3 Summary results of the combustion gases dustiness measurements.

Parameter	W-I		W-II	
Measurement location in respect to the cyclone system	before	after	before	after
Dustiness of combustion gases, g/m^3_n	0.0903	0.0279	0.1492	0.0329
Mass of the dust carried with the combustion gases (after cyclones – emission, g/s)	0.798	0.288	1.479	0.386
	M-I		M-II	
Measurement location in respect to the cyclone system	before	after	before	after
Dustiness of combustion gases, g/m^3_n	0.0544	0.0226	0.2101	0.0173
Mass of the dust carried with the combustion gases (after cyclones – emission, g/s)	0.496	0.240	2.001	0.228

Dust emission was lower in both cases for the burned mixes than in case of burning of the relevant coals, and:

- – for the W-I/M-I system the difference in dustiness was ca. 17%,
- – for the W-II/M-II system the difference in dustiness was ca. 40%.

No changes of the combustible and volatile parts fractions were revealed by the analyses carried out in slags produced by burning the mixes, compared to slags produced by burning the relevant coals. In case of the W-II coal and the M-II mix more than twofold increase was revealed of the combustible parts fraction compared to the W-I coal and the M-I mix.

Adding the formed fuel resulted, in the test conditions, in the remarkable (more than 30%) increase if the volatile parts fraction in the slags.

As regards the combustible parts, no connection was revealed between adding the formed fuel and their fraction in ashes collected from the cyclones. Adding the formed fuel caused reduction of the volatile parts fraction in the ashes in the test conditions. The observed fraction reductions were from several to more than 50% (relative values).

5 Conclusions and final comments

Investigations carried out revealed the possibility to burn the formed fuels based on the selected waste fractions in furnaces of the stoker-fired boilers. It was found out, resulting from the investigations that protection of the formed fuel from getting moist is important (more than in case of coals).

Burning of mixes with 10% fraction of the formed fuel dry mass with humidity above 50% caused the boiler efficiency reduction of ca. 30%. Reduction of the boiler efficiency was, among others, the result of the 20% decrease of the heating value of the burned fuel.

The fact that the flame does not move to the boiler front (under the ignition arch and the coal gate) may be recognised as an advantageous effect of the fuel getting moist.

The increased concentrations of oxygen in the combustion gases result from the quicker burning out of the formed fule and from forming the empty areas on the grate making air flow possible. The significant growth of the CO emission should be explained by the same phenomenon and by the lower temperature in the combustion chamber.