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COAL REPLACEMENT WITH WOOD BIOMASS IN FORM OF BRIQUETTES AND PELLETS IN DISTRICT HEATING SYSTEM OF BELGRADE

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SUMMARY

This paper summarizes results of investigation and analysis of performance of five different coal fuelled heating units of the JKP “Beogradske elektrane” (the Public Utility Company) after replacing the coal with biomass (wood briquettes and pellets). In some cases co-firing biomass with coal (25% and 50% of coal) has been carried out.
For over 30 years „Beogradske elektrane“, responsible for heating and domestic hot water supply to Belgrade, has been active in the fields of energy efficiency and pollution control. During that period JKP “Beogradske elektrane” closed over 1000 coal or heavy oil fuelled local heating units and connected the consumers to district heating systems operating on natural gas, thus substantially improving quality of life by reducing of emissions of pollutants and CO_2. The recent activities with Faculty of Mechanical Engineering in Belgrade have included a joint project on introduction of wood briquettes and pellets instead of using low quality coal in a group of purposely selected heating units. Replacement is “zero investment” project, considering that biomass fuel shape is adjusted to existing boiler and installation, without reconstruction or any changes, with goal to reach maximum efficiency with minimum pollution.
In general, this paper refers to the comparisons of performance of selected coal fuelled boilers of the Belgrade district heating systems when fuelled with wood briquettes or pellets. Result from testing period is show, as well as experience while using more than 16.000 tons of biomass in last four heating season`s at nine different boiler houses / five boiler type`s.

Key words: Biomass, briquette, pellet, coal, substitution, ecology, district heating.

INTRODUCTION

The District Heating Company “Beogradske elektrane” burns up to 10.000 tons of coal per year at the beginning of 21st century. Till 2008. In consumption was decrease to 6.000 tons due to change from coal to natural gas, but on that level it stay. Besides high emissions of SO_2, CO, NO_x and particulates there is a serious problem of ground contamination with coal and ash during transport, handling and storage. This is another important reason for introduction biomass in coal

fuelled boilers and thus further decreasing the consumption of coal and introduction of renewables. The JKP "Beogradske elektrane" has performed investigations on possible utilization of solid biomass in existing boilers, originally fuelled with coal [1-3]. The main goal of these investigations was to analyze possibilities of utilization of biomass without modifying the existing boilers.
The extensive results obtained during the research proved to be very useful for better understanding of performance and operation of coal fuelled boilers when using solid biomass and confirm that the change from coal to briquettes and pellets can be done the way the Utility Company of Belgrade planned.

Following the current heating technology concepts and the high price of fossil fuels, the JKP "Beogradske elektrane" has paid particular attention to energy efficiency increase and the environmental protection and global warming issues by investigating possibilities to introduce renewables for heat production in Belgrade.

During the last 30 years period JKP "Beogradske elektrane" has closed over 1000 coal or oil fuelled local heating units and connected the consumers to district heating systems operating on natural gas, thus substantially improving quality of life in Belgrade by reduction of emissions of pollutants and CO_2 emissions.
In 2006-2008 in Serbia there has been a number of industrial plants that started or were about to start production of biomass briquettes and pellets which could be used for heat production. Based on that fact „Beogradske elektrane"performed research activities of biomass utilization in coal fueled thermal plants in the heating period of 2008. The aim of this research has been to analyze a possibility of direct use of biomass without any modification of boilers that are designed to be solely coal fueled.

TESTING OBJECTS AND METHODOLOGY

A preliminary, detailed analysis of coal fuelled boilers of the Belgrade heating system has been performed. The analysis included type of boilers, design characteristics, combustion air distribution system, type of grates and furnace, thermal power, flue gas cleaning method, coal handling, transport and storage. Particular attention was paid to the selection of districts regarding the number and characteristics of dwellings, public buildings and residential objects, vicinity of the heating units and the local environmental situation. After analysis of the obtained data five heating units which cover all types of coal burning boilers and feeding systems utilized by JKP "Beogradske elektrane" have been chosen for the investigation:

Barajevo heating unit Water-tube boilers, transport of coal by belt-conveyor, steady rate of fuel feeding by a screw conveyor, fan assisted air supply, cyclone particle separator and vicinity of numerous multi-storey residential buildings.
Sremcica heating unit. Hot water boilers, transport of coal by belt-conveyor and elevator, mechanical impulse fuel feeders, fan assisted air supply, cyclone particle separator, wet ash disposal and vicinity of numerous multi-storey residential buildings.
Senjak heating unit. Water-tube boilers, manual feeding of coal bunker, steady rate fuel feeding by a screw conveyor, fan assisted air supply, cyclone particle separator and vicinity of individual residential buildings.
Bogoslovija heating unit. Water-tube boilers, manual fuel feeding of boilers, natural draught air supply, vicinity of multi-storey residential buildings and other specific objects.

Mirijevski bulevar heating unit. Steam boilers, manual fuel feeding, natural draught air supply, boiler located inside a big multi-storey residential building.

An in depth experimental research has been done, following a thorough program which was previously conceived. The measured parameters included fuel consumption rate, all relevant fluid flow rates, temperatures, flue gas composition, air coefficient and ash. The fuel consumption rate measurement techniques varied for each type of boilers depending on specific features of the fuel feeding systems. The measurements have been carried out during steady state operation of boilers, keeping in mind that certain unsteadiness cannot be avoided. All measurements have been performed by the Centre for Quality Laboratory of the JKP "Beogradske elektrane". During nights fuel feeding systems and furnaces were cleaned from remains of coal (pellets) and ash.

RESULTS

The selected properties of pellets are given in Table 1.

Table 1. Data of Technical analysis of pellets.

Property	Unit	Value	Method	Limit values by DIN 51731
Moisture	%mass	4.93	DIN 51718	<12.0
Ash	%mass	0.83	DIN 51719	<1.50
Sulfur	%mass	0.03	DIN 51724	<0.08
Lower heating value	kJ/kg	17304	DIN 51900-3	17500-19500
Density	kg/dm^3	1.32	DIN 52182	1.00-1.40

Barajevo heating unit.

Keeping in mind that fuel screw feeders operate at steady regimes the fuel mass flow rate was measured during cold tests. The fuel flow rate was also controlled by number of pellet bags burned in a certain period of time. Interesting photos of testing are shown in Figs. 1-6.

Fig. 1 Pellets in furnace during fuel consumption rate measurements

Fig. 2 Boilers and belt-conveyor.

Table 2 shows the components of flue gases when burning coal.

Table 2 Gas components of flue gases when burning coal.

Parameter	Unit	I	II	III	IV	V	VI	Mean value
O_2	%	13.42	13.8	13.79	14.19	14.67	14.76	14.1
CO	ppm	513	527	534	842	1315	1417	858
NO	ppm	129	113	120	109	88	89	108
NO_2	ppm	19.6	21.9	22.1	26.8	37.2	40.8	28.1
NOx	mg/m3	562	538	566	571	586	595	569.7
SO_2	ppm	197	196	210	207	184	181	195.8
Air coefficient	-	2.8	2.9	2.9	3.1	3.3	3.4	3.1
CO_2	%	6.64	6.31	6.32	5.96	5.54	5.47	6.0
Flue gas temp.	^oC	146.6	146.2	147.4	146.1	143.7	141.7	145.3
η_k	%	86.6	86	85.9	84.8	83.8	83.7	85.1
mCO	kg/h	6	6	7	11	16	18	10.7
mNOx	kg/h	4	3	4	3	3	3	3.3
mSO2	kg/h	7	7	7	7	6	6	6.7

The Bacharach smoke number during tests was about 5.

Pellets combustion showed less dust in the boiler room, no fuel losses from conveyor, easier operation and better working conditions for the personnel.

Fig. 3 Conveyor with pellets.

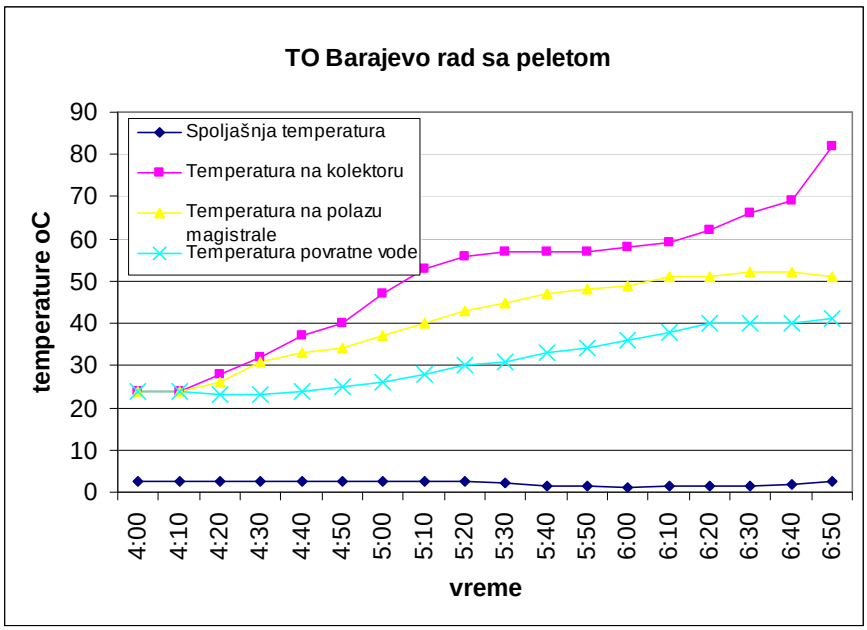

Fig. 4 Characteristic temperatures when burning pellets.

As the investigation showed very good results of emissions and efficiency new testing was performed using mixtures of coal and pellets with 25% and 50% by mass of coal. These mixtures showed good combustion performance. The Bacharach smoke number during tests was between 1 and 2 with 25% of coal, and 3-4 with 50% of coal.

The ash quantity was measured using following procedure: The furnace was complete cleaned and after this preparation 450 kg of fuel was burned. After completing combustion the boiler was shut down and left for 24 hours after which period the ash from furnace and cyclone separator was collected and measured. The obtained results are shown in Table 4.

Table 3 Gas components of flue gases when burning pellets.

Parameter	Unit	I	II	III	IV	V	VI	Mean value
O_2	%	13.9	13.68	13.56	13.6	13.44	13.53	13.6
CO	ppm	323	357	321	312	309	356	329.7
NO	ppm	71	72	73	74	75	75	73.3
NO_2	ppm	3.9	4.1	4.5	4.3	4.8	5.7	4.6
NOx	mg/m3	302	300	299	302	304	309	302.7
SO_2	ppm	0	0	0	0	0	0	0.0
Air coefficient	-	2.96	2.87	2.82	2.84	2.78	2.81	2.8
CO_2	%	6.22	6.41	6.52	6.49	6.62	6.55	6.5
Flue gas temp.	^oC	164.2	164.7	165.4	165.6	166.5	165.8	165.4
η_k	%	83.5	83.9	84.1	84.1	84.3	84.2	84.0
mCO	kg/h	6	6	5	5	5	6	5.5
mNOx	kg/h	2	2	2	2	2	2	2.0
mSO2	kg/h	0	0	0	0	0	0	0.0

Table 4. Ash content.

	Ash (furnace)	Ash (cyclone)	Total
Coal	61 kg	2 kg	63 kg
Pellets	6 kg	< 1kg	< 7 kg

Following the results given in Table 4, the ash content in coal was about 14% by mass and the ash content in pellets about 1.5%. It is interesting to note that the ash and slag formed on the grates during coal combustion made it difficult to control the fuel and air distributions which was not the case when using pellets. On the contrary, the pellet ash was not compact but rather physically unstable and disintegrating easily into dust.

Fig. 5 Combustion of pellets. View from the inspection window.

Fig. 6 Combustion of pellets, view from the open boiler door.

Sremcica heating unit.

The fuel feeding system is of mechanical of impulse type which allows control of number of impulses per minute and the depth of feeding into the furnace. The quantity of combustion air was controlled by fans. The quantity of cooled ash and slag was not possible to measure due to

unsuitable technique for ash/slag collection and disposal, at this heating unit. The operation of boiler was controlled by the SCADA system. Some details are given in Fig. 7.
The boiler performance results are in general similar with those obtained at Barajevo heating unit.

Fig.7 Combustion of pellets and the SCADA control system.

Senjak heating unit.

The boiler of Senjak heating unit is very similar to Barajevo heating unit. The main difference is in the fuel transport systems and boiler capacity. The obtained results are similar with the ones obtained in two previous cases. The composition of flue gases is shown in Fig. 8.

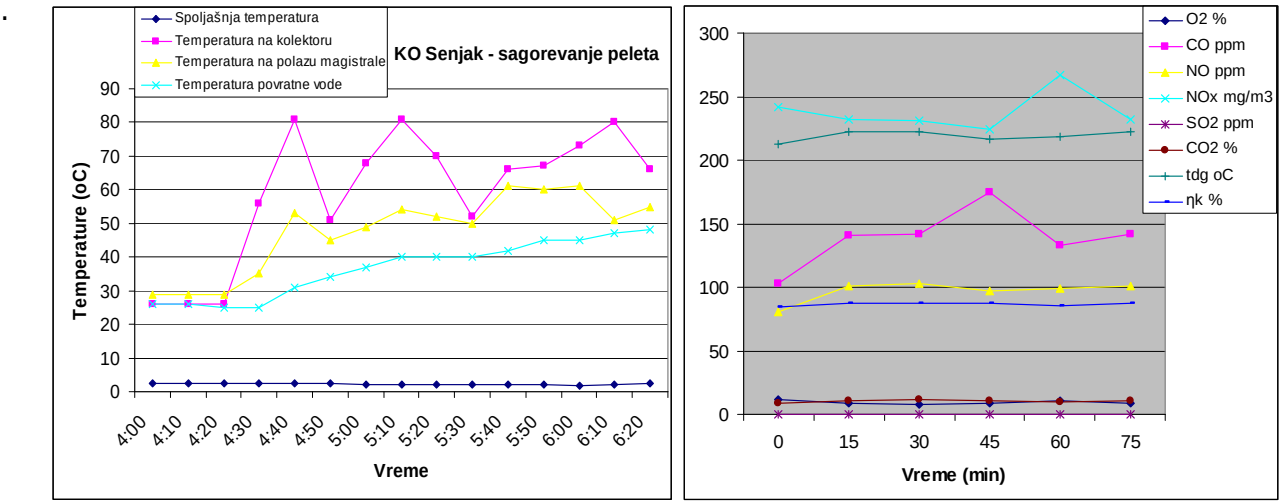

Fig. 8. Temperatures and composition of flue gases.

Bogoslovija and Mirijevski bulevar heating units

The boilers used in Bogoslovija and Mirijevski bulevar heating units are very common in Serbia, primarily because of their simplicity. The fuel feeding is manual and the air flow is controlled by natural draught and by firing flaps at the front end of boiler. The grates' air channels are too wide (40x200 mm) for pallets which can drop into the ash tray. In order to prevent this loss of pellets a pile of coal is purposely put on the grates before each testing with pellets. The upper layer of pellets burns with high flames of dark yellow color with brownish-black tips, Fig. 9. For the reason

of pellet losses into the ash tray wood briquettes are recommended instead of pellets with diameters between 40 and 90 mm and lengths from 150 to 300 mm, as shown in Fig. 10.

Fig. 9 Burning of pellets.

Fig. 10 Burning of briquettes.

After first testing, detailed report with all analysis and calculation was made. Revision of Report was made by Mechanical Faculty of Belgrade University. Board of director of Company make a decision to start using of solid biomass instead of coal in 8 out of 9 heat sources with 22 boilers and 24 MW of installed capacity. In last four heating seasons, in this objects, more than 16.000 tons of biomass was used, saved more than 20.000 tons of CO_2, etc. Some of results reached during testing are improved during massive usage.

CONSLUSIONS

The research and five years of experience of using woody biomass in form of pellets and briquettes, has been followed by detailed analysis which resulted in following important findings:

- Wood briquettes and pellets can be utilized as a substitute for coal for some types of boilers and continuous fuel feeding systems without modifications of boiler sub-systems, except possible minor adjustments for control and operation of boiler.
- The achieved thermal powers when using either coal or biomass do not differ from heating parameters requests.
- There are significant improvements when using biomass in what concerns emissions of gaseous pollutants, ash, particulates and CO_2.
- Ash production is 20 times lower.
- Emission of SO2 is eliminated completely.
- The air supply should be preferably fan assisted.
- Dimensions of briquettes and pellets to be used depend on boiler and grate types and their geometry.
- Storage and handling of briquettes and pellets is much simpler and environmentally friendlier than storage and handling of coal.
- It has been noticed that the personnel enthusiastically accept the change from coal to biomass.

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