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GABRIEL BOROWSKI*

THE POSSIBILITY OF UTILIZING COAL BRIQUETTES WITH A BIOMASS

A pilot technology for the production of coal briquettes with an additional biomass is presented. Such briquettes may be considered to be an alternative ecological fuel and can be utilized as an energy source. They can be used, provided that some strictly defined technological and ecological criteria are satisfied. Particular criteria are presented and exemplified based on technologies developed in Poland. Attention is paid to the problems of preparing suitable fine-grain mixtures and suitably selected appliances and technology allowing briquettes of an appropriate mechanical durability to be obtained.

1. INTRODUCTION

In developed countries, there is an increasing interest in the combustion of coal and biomass mixtures. There is also an increase in the biomass cultivated for energy. The technologies utilizing renewable energy sources have been known good enough, and some were tested in developed countries. [4], [15]–[17].

The use of mixtures produced by the combination of a biomass with coal dust and mud in an unprocessed form is not effective. This is caused, among other things, by transportation limitations and by the fact that transported crushed raw materials have high volume and low bulk density. Energy carriers, therefore, should be supplied to power engineering plants in a processed form. One of the methods being very frequently applied in order to reduce the volume and to increase a calorific value of power resources is their drying and integrating at the place of acquisition.

Of the known methods of integrating, briquetting is most popular. This method is well known in Poland and often applied to the integration of fine raw materials, including coals and mixtures of coal with various additives [2], [3]. Currently produced briquettes contain fine, brown, hard coal, coke and biomass in the form of sawdust, peat, straw or other raw materials. Such briquettes are produced without any additives

* Lublin University of Technology, Department of Fundamentals of Technology, 20-618 Lublin, ul. Nadbystrzycka 38, Poland.

or with the addition of bonding materials in order to improve their mechanical properties [1].

The aim of the presented paper was to determine the possibility of producing and using briquettes from coal wastes and biomass. The briquettes produced will constitute an ecological source of energy for Polish heating and power generating plants.

2. CHARACTERISTICS OF RAW MATERIALS FOR BRIQUETTE PRODUCTION

In power engineering, all types of organic substances of plant or animal origin that are suitable for combustion are treated as biomass. Biomass of natural origin is characterised by a relatively high calorific value. The calorific value of biomass (in a dry state) approaches 18 500 kJ/kg, being by 17% lower than the calorific value of brown coal. During combustion of pure biomass small amounts of ash are produced (0.5–12.5%). Such ash does not contain hazardous substances and may be used as a mineral fertilizer [6].

Basic components of both hard coal applied in power engineering and of biomass are the same. However, the proportions of individual elements and chemical compounds in coal and biomass are different. Biomass contains, on average, about four times more oxygen, twice as much carbon element, as well as less sulphur and nitrogen. The consequence of these properties is a high content of volatile parts and a high reactivity of biomass [10].

An unfavourable feature of biomass is its high and changeable humidity (dependent on the type of biomass and period of its seasoning). A bulk density of biomass is considerably lower than that of coal, therefore the transport of the former is more expensive and storage yard areas greater.

Compared to coal, biomass is characterised by much higher content of alkaline compounds (especially of potassium), of calcium, higher concentration of phosphorus, and in the case of straw, leaves and wood bark, also by higher content of chlorine, which may lead to an intensified corrosion and accumulation of aggressive wastes in boiler during their direct combustion. A favourable feature of biomass (especially of wood biomass) is its considerably lower amount of ash and sulphur, compared to coal, during combustion [14].

The humidity of biomass of plant origin exceeds 50%. At such a humidity, combustion is possible only in special boilers. Humidity of the biomass combusted in traditional central heating boilers has to be reduced to below 15%. High content of alkaline and chemically aggressive chloride in some ashes from biomass may cause corrosion and accumulation of sediments on the surface of boilers [9].

A very important property of the coal and biomass mixtures is a full additivity of organic substance to both fuels. In this mixture, coal plays the role of a stabiliser in the combustion process. In terms of energy value, 2 tons of biomass are equivalent to 1–1.5 tons of hard coal.

The mixture of coal with biomass is treated as an ecologically friendly fuel. The application of such mixtures limits primarily the emission of SO_2 into atmosphere, hence desulphurisation of fumes is not required [13].

3. PRODUCTION AND UTILIZATION OF COAL BRIQUETTES WITH A BIOMASS EXEMPLIFIED BY EXISTING TECHNOLOGIES

The briquettes produced by mixing coal and biomass and used in power engineering should bring about a high power effect. These products should also be characterised by a proper mechanical resistance resulting from the conditions of transport and deposition, and the mechanical properties should be preserved during the period of seasoning.

At the University of Science and Technology in Cracow, hotroll briquetting machines were successfully used for integrating fine industrial waste, which allow briquettes of a saddle shape to be obtained and demonstrated many advantages compared to traditional ones [3], [4]. The method was also developed of selecting integration conditions, as well as machines and equipment for briquetting fine materials, including coal [5]. Prior to the process of integrating, the determined portions of crushed components were mixed with bonding additives and the mass was dried to a required humidity. The bonding additives were binding agents improving mechanical properties of briquettes. The following waste raw materials were applied as binding agents: molasses, plant starch, sugar, soda lye, water glass, lime, gypsum and others.

Some advanced attempts to apply coal with biomass were undertaken at the Opole Electric Power Plant [11]. Based on co-combustion tests, the mass fraction of biomass in the mixture with hard coal was determined on the level of 8%. The results of combustion tests confirmed the poor effect of biomass on a chemical composition of the ash obtained. This is due to a considerably lower content of ash in biomass with respect to coal. A slight difference in the mixture composition, however, was responsible for a significant drop in the temperature of the softening of ash components. The ash from the biomass combustion was characterised by lower temperature of softening (within the interval of 750–1000 °C), compared to that of ash from coal (approx. 1000 °C and over). Due to a lower temperature of ash softening during the combustion of the coal and biomass mixture, accumulation of sediments on the surfaces of boilers is faster. The layer of ash deposited in pipes allows new particles to be accumulated more rapidly which leads to a rapid growth of sediment and an increase in its size with respect to the sediments produced as a result of the combustion of coal alone.

The results presented in table 1 show that co-combustion of a crushed wood biomass and coal has a number of advantages, compared to a separate combustion of these fuels [17]. Coal stabilises the combustion process, which facilitates the application of biomass of changeable and high humidity, whereas biomass results in the reduction of the net emission of carbon dioxide, sulphur and other pollutants. Moreover, due to combustion of such mixtures, the concentration of SO_2 and NO_x in fumes decreases, and the content of flammable parts in ash (slag) is reduced as well. These effects were observed in the case of both low power grate furnaces and industrial stoker-fired and fluidised boilers.

Table 1

Selected results of combusting coal and mixtures of coal and wood chips in boilers [17]

Parameters		Unit	Boiler WR-10		Boiler CYMIC-135		Boiler OP-130	
			Coal	Mixtures	Coal	Mixtures	Coal	Mixtures
Total humidity	W_t	%	6.8	7.8	6.3	12.6	9.5	10.7
Volatile parts	V	%	24.8	33.8	26.1	27.3	35.3	37.7
Ash	A	%	8.3	7.1	25.2	28.2	11.8	11.2
Total sulphur	S_t	%	0.38	0.32	1.35	1.02	0.25	0.24
Calorific value	Q_i	kJ/kg	28 405	25 811	22 510	18 766	25 143	24 324
Fuel mass stream flux	B_p	kg/h	1216	1316	19 145	23 382	14 460	12 290
Calorific efficiency of a boiler	Q_k	MW	7.38	7.26	104.62	104.54	90.37	73.77
Efficiency of a boiler	η_k	%	85.2	82.4	87.4	85.79	91.7	91.1
Contents of flammable elements:								
– in slag	$c_ż$	%	33.1	21.2	0.6	0.4	7.0	0.7
– in volatile ash	c_{pl}	%	–	–	18.2	15.9	8.1	8.5

At the Institute of Chemical Processing of Coal, the technology of producing smokeless briquettes was developed for individual households and communal heating [12]. This technology consists in briquetting a mixture of coal with coke by such ecological binding as hydrolysed flour and molasses. A diluted phosphoric acid was added to the mixture, which allows the binding agent to harden. The prepared mixture was delivered onto a double roller press and raw briquettes were produced. They were dried and conditioned, and when the hardening of the binding agent was completed, ready-to-use ecological fuel was obtained.

The tests performed to date at the Polish Power Engineering Concern (covering, among others, the Katowice Power Plant, Jaworzno III/II, and the Power Plants in Siersza and Bielsko-Biała) prove that co-combustion of properly prepared biomass (up to 5%) with fine coal and silt is possible in a way practically not involving cash [8]. In the case of co-combustion of biomass whose content is higher than 5%, there are necessary technological lines that would provide loading of this fuel to the boiler in a way independent of coal. In such a way, it is possible to increase the content of biomass from 10 to 15% of the calorific value of a fuel flux. In fluidised boilers, co-combustion of biomass with coal is highly efficient. It should be noted that during the combustion process in these boilers, briquetting or granulating the mixture is not necessary.

At the "Ekokarbotech" enterprise, the technology of producing coal–biomass briquettes was developed. In such briquettes, biomass made approx. 20 percentage by weight.

A mixture of fine coal and silt was applied as coal load. The binding agent added to the mixture was starch, resulting in higher resistance of briquettes. The briquettes obtained were characterised by high water resistance. The process of their combustion was similar to the combustion of coal of the nut or pea type. The calorific value of briquettes ranged from 19 to 26 MJ/kg. Due to a proper mixing of biomass and coal in briquette, the biomass subjected to gasification had porous spaces which allowed the air to penetrate them. This improved the coal combustion and reduced emission of toxic gases.

4. MATERIALS AND METHODS

It is recommended that the process of briquetting a coal–biomass mixture on an industrial scale should be performed in roll presses. Roll briquetting machines enable the briquetting of fine-grained substances in a continuous way.

The briquetting machines produced by "Komarek" (USA) have the rollers placed both horizontally – one beside the other, and vertically – one on the top of the other. The forming rings may be exchangeable or integrated permanently with the rollers, which allows the heating or cooling of the forming surfaces with water. These briquetting machines are equipped with various types of bins for loading the material. In the case of materials difficult to briquette, the bins with screw gear mechanisms are applied, often equipped with a heating system enabling drying the mixture. Bins with a device mechanically crushing the grains of the mixture are used as well.

At the University of Science and Technology in Cracow the method of a proper selection of a briquetting machine, depending on the kind of integrated fine-grained materials [5], was developed. For the briquetting of coal, the LPW 1200 briquetting machine was applied. The main components of this machine are two rollers, each with a diameter of 1200 mm on average, placed side by side on a horizontal surface. One roller is positioned permanently, the other is a slidable one, which enables regulation of the rolling slot by means of a hydraulic servo. Both rollers revolve in opposite directions. The rollers are equipped with forming rings shaping the briquettes. The best results were obtained using forming rings that enable the production of briquettes in the shape of a "saddle". The briquetting material was loaded by a gravitation bin.

In their natural forms, not all fine-grained materials show good vulnerability to integrating in the presses for briquetting. Therefore, some actions are undertaken to change the properties of the material subjected to briquetting. These activities are concentrated on:

- selection of a proper granular composition;
- elimination of undesired admixtures and pollutants;
- determination of the most advantageous range of humidity of the material;
- determination of the type and content of the binding material;
- selection of the type of briquetting machine and briquetting parameters.

In my own studies of the process of integration of fine-grained materials, the factors associated with the preparation of the material played an important role [2], [3]. The preparation of the material for briquetting consisted in the blending of the determined amounts of components and in drying the mixture. At Lublin University of Technology and the University of Science and Technology in Kraków, common studies were conducted on the vulnerability of metal fine industrial wastes to integration. Briquettes of good quality were obtained by adding ca. 8% of molasses as a binding agent. Mean mass of briquette amounts to 24.6 g and its volume is 8.5×10^{-6} m^3. In order to average and to dry the mixture, a laboratory Z-mixer with a mantle heated to about 80 °C was applied. Two portions of the material were prepared for the studies of humidity within the range of 2.0–7.4%. Wastes were briquetted in punch and roll presses, then the resistance of the products obtained, both fresh and seasoned, was tested (table 2). The briquettes obtained met standards determined for metallurgy, thus could be used for smelting in steel making furnaces.

Table 2

Resistance of roll press briquettes to compression and drop [2]

Humidity of material (%)	Resistance to compression (kN/m^2)		Resistance to drop (%)	
	Fresh briquette	Seasoned briquette	Fresh briquette	Seasoned briquette
2.0	2.42×10^4	3.98×10^4	96.55	97.80
3.2	2.66×10^4	4.08×10^4	98.16	99.57
4.5	2.96×10^4	4.53×10^4	99.50	99.85
5.2	3.17×10^4	4.69×10^4	99.52	99.78
6.5	2.68×10^4	4.12×10^4	96.50	98.65
7.4	2.34×10^4	3.74×10^4	86.33	93.50

The mechanical properties of briquettes were determined based on their resistance to gravitaty drop and the compressive strength. The resistance of briquette to gravitaty drop is evaluated on the basis of the percentage loss of mass after at least three drops of portions of briquettes from a height of 2.0 m onto a steel plate.

A compressive strength destroying briquette depends on its type and is determined experimentally. The method of measuring this strength consists in compressing briquette placed between flat surfaces of a testing tool, until it is destroyed. The studies should be carried out with an endurance machine, e.g., ZWICK Z100, which enables a continuous measurement of compression and translocation of the punch, registering data on a computer.

5. RESULTS AND CONCLUSIONS

The attempts to combust briquettes made of coal with biomass in power installations produced a series of positive ecological and economic effects. In order to implement briquetting of these raw materials on an industrial scale, we have to solve a number of various problems. Considering the possibility of producing and using coal–biomass briquettes and making use of my own experience in the technology of integrating fine-grained materials, further research activities are planned, which can be itemized as follows:

1. Analysis of vulnerability to material in briquetting presses.
2. Selection of binding additives.
3. Selection of roll press and forming system.
4. Determination of the parameters of briquetting.
5. Assessing the effect of humidity of the material on briquetting.
6. Analysis of mechanical properties of briquettes.
7. Testing water resistance of briquettes.
8. Microscopic analysis of the structure of briquettes.
9. Evaluation of the usefulness of briquettes in power engineering.
10. Analysis of economic and ecological effects of the combustion of briquettes.

The results of a future research and pilot trials will allow the design of an industrial technological line for briquetting the mixtures of coal and biomass. The implementation of the developed method of the production of briquettes will enable benefits to be obtained, resulting in a decrease in the use of raw materials and in a considerable decrease in natural environment pollution.

Considering the results of experimental studies, and exploitation trials with briquettes made of coal and biomass, the following conclusions can be drawn:

1. Briquettes used as a fuel satisfy the standards of environmental protection, especially in terms of low emission of hazardous substances into the atmosphere.
2. Prior to the process of briquetting, it is necessary to obtain a proper humidity and consistency of the mixture by enriching it with a specified amount of binding agent.
3. It is recommended that a roll press equipped with a changeable forming system and gravity batch be used for briquetting.
4. The quality of the briquettes obtained should be confirmed by suitable tests.
5. For a mass production of briquettes it is necessary to develop a concept for an industrial technological line.
6. The effective use of briquettes for power engineering requires a complex economic and ecological analysis.

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MOŻLIWOŚCI WYKORZYSTANIA BRYKIETÓW WĘGLA Z BIOMASĄ

Opisano rozwój badań i pilotażowych wdrożeń technologii wytwarzania brykietów węglowych z dodatkiem biomasy. Brykiety takie są zaliczane do ekologicznych paliw alternatywnych i mogą być wykorzystane w energetyce pod warunkiem, że spełniają ściśle określone kryteria technologiczne oraz ekologiczne. Poszczególne kryteria zostały przedstawione i omówione na przykładach istniejących w kraju rozwiązań. Zwrócono uwagę na problematykę odpowiedniego przygotowania mieszanki drobnoziarnistej oraz doboru odpowiednich urządzeń i technologii umożliwiających uzyskanie wyrobów o odpowiedniej wytrzymałości mechanicznej. Określono kierunki dalszych prac badawczych umożliwiających poznanie wielu zjawisk towarzyszących procesowi formowania tego typu brykietów i wpływających na ich jakość.