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INFLUENCE OF THE TYPE OF HEATING FURNACE ON THE PROCESS OF BURNING BRIQUETTES ROLLED FROM UNCUT RYE STRAW

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Abstract

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In research of Industrial Institute of Agricultural Engineering in Poznan briquetting by the method of the curling to the compaction cereal straw was used. Briquettes from agricultural straw produced by this method are allocated as agricultural biomass combustion for so called small energy. A single briquette is a cylinder of diameter of 85 mm, length of 250-300 mm which are characterized by a high density around 500 kg·m^{-3}. Attempts were made to burn them in two different traditional central heating boilers: Eko Duo 25 with power of 25 kW, STK 22 with power of 22 kW and the one prototype of the rotary grate boiler with power of 25 kW 20 kW produced by PROTECH Sp. z o. o. from Gierałtowice. In research briquettes made from rye straw were used. The study was carried out by observing the combustion process of certain portions of briquettes while making measurements of water temperature at the entrance and exit of the boiler, temperature and gas composition. The study has showed that the total fuel briquettes made from agricultural material excess of air is required and there is a need for frequent, periodic movement of briquettes burning on the boiler grate. Results of gas quality tests have showed that the levels of pollutants do not exceed the legally authorized levels. Results obtained from the combustion of straw briquettes boiler power also do not exceed the values permitted by law.

Keywords: uncat cereal straw, burning, heating furnance, agricultural

List of abbreviations: DHW - domestic hot water

Introduction

Cereal straw is a valuable fuel which fits in a range of energy sources that are renewable sources of energy (Grzybek et al., 2001; Hejft, 2002; Adamczyk and Frąckowiak, 2009; Juliszewski, 2009; Frączek, 2010; Frączek et al., 2011; Lisowski, 2011). The problem of the production and use of renewable energy sources is one of the most important issues of global and European energy policy. The use of straw as a renewable source of energy in Poland is not very significant (Grzybek et al., 2001). This is due to the fact that, compared with other conventional energy carriers, straw as the raw material is rather cumbersome energy material. This material is not uniform, the lower, with respect to unit volume, energy compared to conventional energy sources. To standardize and improve the usefulness of straw for energy purposes it should increase its bulk density, which may be obtained by the concentration of masses of loose straw (Werther et al., 2000; Grzybek et al., 2001; Hejft, 2002; Adamczyk and Frąckowiak, 2009; Juliszewski, 2009; Frączek, 2010; Lisowski, 2011). The Industrial Institute of Agricultural Engineering in Poznan conducts research on the use of briquetting by the method of the curling for compacting uncut cereals straw (Adamczyk and Frąckowiak, 2009; Frączek, 2010). Briquettes produced by this method shall be allocated as biomass burning for so-called low energy. A single briquette is a cylinder of diameter of 85 mm, length of 250-300 mm, and it is characterized by a high density of about 500 kg·m^{-3}, and durability of about 90% (Adamczyk and Frąckowiak, 2009).

When using the straw as fuel in farmer household's boiler should also be pay attention that the quantity of energy obtained per unit of mass is greater than the quantity of energy put into the preparation of fuel for combustion. The calorific value of 1 kg of cereal straw with a moisture content of

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a) b)

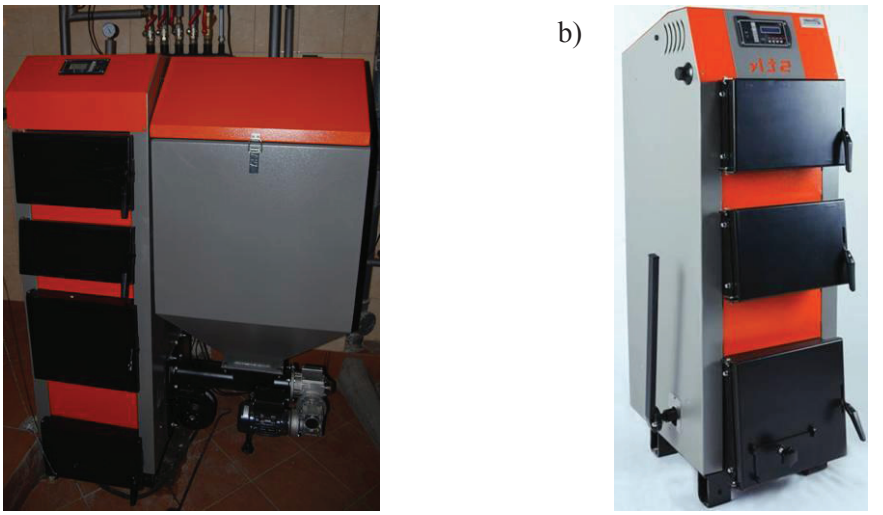

Fig. 1. The central heating boilers. a) Eko Plus DUO 25, b) STK / MS 22

10-15% is 15-18 MJ, which is equivalent to about 4 kWh of energy from its combustion (Werther et al., 2000; Grzybek et al., 2001; Hejft, 2002; Juliszewski, 2009; Frączek, 2010; Lisowski, 2011). This paper contains results of burning tests of the briquettes in three different central heating boilers.

Goal and scope of work

The goal of the tests was to identify and analyze the process of combustion briquettes which are obtained by the method of the curling from uncut cereals straw. The tests of burning process were conducted in a three different types of central heating boilers.

The tests were carried on two conventional central heating boilers for combustion of coal and wood - Eko Plus DUO 25 and STK / MS 22, produced by PROTECH Sp. z o. o. from Gierałtowice, views of which are shown in Figure 1.

The third test was a prototype boiler boiler for combustion briquettes (Figure 2) with a rotating grate (Figure 3). The methods of virtual prototyping have been used to develop it (Szczepaniak, 2011).

Fig. 2. The prototype of central heating boiler with rotating grate during testing

Materials and Methods

The study was conducted on briquettes made from rye straw. The humidity content in the briquettes during the combustion test is between 10 and 15%.

The temperature was measured by the respective thermometers. Exhaust analysis was performed by MRU Portable Exhaust Analyzer - Nova H8.

Straw humidity percentage by weight was determined by drying-weighing. The humidity briquettes were selected at

Fig. 3. View of combustion chamber with rotating grate

random from a partion of intended for incineration, weighed on a laboratory scale WS-21, and then dried for 3 hours at 130°C in the oven. After that time they were removed from the oven and reweighed. Humidity was determined from the known relationship (1):

$$w = \frac{(E - m) \cdot 100}{E} \ [\%] \ , \qquad (1),$$

where: E - initial weight of the sample in g, m - mass of the sample after drying in g.

During the study were determined the DHW temperature, the flue gas temperature and the concentration of some elements and compounds in exhaust.

Results and Discussion

The combustion of briquettes in all tested boilers performed under similar conditions briquetts stream fed to the combustion chamber. It was about 6 $kg \cdot h^{-1}$. Research parameters of boilers and exhaust gas composition were carried out under thermally stabilized conditions.

Analyzing the combustion process briquettes from uncut straw in boilers Eko Plus DUO 25 and STK/MS 22 especialy dedicated to coal in various forms there was observed that it ran a little stable, followed by a very dynamic changes in exhaust parameters. Briquettes burn from the outside, and more compactegd and the more concentrated the center (core) burn more slowly. In densely loaded burning briuetts input appeared craters, through which air enters through the fan flows freely (Figure 4).

It was necessary to periodically, every 10 - 15 minutes, movinge burning briquettes on the grate boiler in order to maintain smooth operation of the combustion process.

In the tested prototype boiler with rotating grate combustion of straw briquettes proceeded steadily. Used, operating continuously during the combustion process, the rotary grate, allow even distribution of briquettes in the combustion chamber and to facilitate their exact burnout. The combustion process was carried out with a considerable excess air ratio λ measured values contained between 2.5 and 3.5. Despite the significant value of the excess air has been observed, that briquettes burning process it was an incomplete. The exhaust outlet duct could be seen hovering presence of solids. Further increasing of the amount of injected air to the combustion chamber lead to a decrease in efficiency obtained in both combustion and boiler.

Average values of the basic parameters of the boilers during combustion of straw pellets are shown in Table 1.

The most important parameter characterized work of boiler is quick to obtain, and long-term maintenance of an adequate level of output. A reflection of this parameter is the level of DHW flowing from the boiler to the heating system. As a result of combustion of cereal straw briquettes leaving the water temperature of the tested heating boilers included for all types of between 40 and 80°C. Its volatility, after the 50 – 60°C was negligible. Obtained and maintained the level of the DHW temperature allows maintaining the desired temperature in heated rooms.

During the tests of burning briquettes made by the method of the curling from uncut straw the analysis of exhaust was also performed. There was measured exhaust gas temperature at the outlet from the boiler, during the whole period for the boiler combustion Eko Duo ranged from 140 to 240°C,

Fig. 4. View briquettes burning in the combustion chamber of the boiler at the time of the study

Table 1
Average values of selected parameters of the tested boilers

The boiler type	Average water temperature at the outlet of the boiler	Average flue gas temperature	The average size of the chimney draught
	ºC	ºC	hPa
Eko Plus DUO 25	71.0	282.4	0.33
STK/MS 22	43.5	-	0.25
Boiler with rotating grate	66.5	239.0	0.26

and for a boiler with rotating grate - from 224 to 254°C. For boiler STK/MS measurements were performed.

As already mentioned for the proper conduct of the combustion of briquettes for traditional boilers had to be cyclical (different for each test boiler) to move a burning lode. Such a process influenced by the high level of CO in the exhaust (Table 2). In the case of the prototype boiler with rotating grate CO concentrations ranged from 75-693 ppm. Similar combustion of straw can be found for example in (Hardy et al., 2010).

Compared the mean values of concentrations of this compound to compound contained in the harmonized standard EN 12809, which is admittedly relating for coal combustion values. It was noted that in the case of combustion of straw briquettes boilers obtained in the test concentrations of CO allow the classification of subject's boilers class 1. In turn, the level of CO in the exhaust gas emitted by the boiler of a prototype rotary grate allows including it in class 3.

Combustion of straw, and hence the briquettes formed of it, that it was complete, should be with high redundancy O_2. During combustion tests carried out with the briquettes redundancy air, wherein the oxygen concentration in the exhaust gas varied between 10 - 20% by volume (Table 2).

Cereal straw contains a considerable amount of potassium, and therefore has a low melting point (approx. 900°C) (Werther et al., 2000; Korylewski, 2008; Juliszewski, 2009; Matuszek and Zawistowski, 2009; Frączek et al., 2011). For this reason, it is important to control the temperature of combustion briquettes, which should not exceed the melting point of the ash. The excess will lead to the formation of agglomerates (slag) from the resulting ash after burning straw.

During the tests the combustion briquettes from uncut cereals straw followed by temporary changes in temperature (above the melting point of ash), which caused a certain amount of sintering (slag) from the ash of burnt briquettes. This phenomenon occurred most heavily in the oven with rotating grate. As a result, sintered together with the ashes get into the swing grid (transmission), causing interference with the working of the mechanism. This adversely affected the course of the combustion process. Figure 5 shows the ash remaining after burning portion briquettes.

Fig. 5. The ash remaining after a briquettes portion burning. Source: Photo by Frackowiak

Conclusion

The carried out tests of the combustion briquettes formed by the method of the curling from the uncut cereals straw enabled to determine the future direction of research and eliminate no appropriate parameters boilers models.

Obtained as a result of burning briquettes outlet temperature of the domestic hot water (DHW) which feed a heating system is between 40 and 80°C. Its volatility, after the 50 – 60°C was negligible.

Combustion of in conventional boilers was not effective. On the other hand, analyzing the results of the combustion briquettes in a prototype central heating boiler fitted with a rotary grate observed that enforced automatic continuous mixing of the grid is the right solution for the furnace burning briquettes from straw collapsed. However, the combustion process was not complete, even though a large excess of air carried by air blower (λ values contained between 2.5 and 3.5). The result of incomplete combustion of briquettes was the presence of solids in the exhaust in the flue gas outlet duct.

Table 2
Average levels of certain chemical elements and compounds in the exhaust

The boiler type	Average levels				λ
	O_2	CO	CO_2	NO_x	
	%	$mg \cdot m^{-3}$	%	$mg \cdot m^{-3}$	-
Eko Plus DUO 25	15.8	2684	5.0	109	5.91
STK/MS 22	14.7	818	6.1	157	4.27
Boiler with rotating grate	14.1	693	4.3	98.2	3.00

During the study, the combustion temperature exceeds the melting point of the ash grate, which led to the formation of agglomerates (slag), which hinder proper functioning of the rotary grate mechanism.

In the case of combustion briquettes from cereal straw in tested conventional boilers resulting concentrations of CO, allow the classification this tested standard coal-fired boilers for class 1 and the level of concentration of CO for the boiler with rotating grate allows to qualify it to class 3.

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