The use of reed briquettes in a domestic heat

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Abstract: - In this paper the combustion performance of briquettes made from pure reed in a domestic heating boiler is presented. The boiler is designed to work with wood logs and briquettes made from sawdust. The combustion technique used is the reverse combustion. The main combustion parameters (CO and NOx emissions, flue gas temperature, air excess, combustion efficiency) have been analyzed. The results have shown a very good behavior of reed briquettes in the domestic heating boiler with reverse combustion.

Key-Words: - reed, briquettes, combustion, domestic heating boiler, pollution, thermodynamic efficiency

1 Introduction
The Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources provides principles under which Member States must ensure that the share of renewable in the EU final energy consumption reaches at least 20% by 2020 to 1990 levels. Also, it sets binding national targets for each Member State. In the face of Europe’s increasing dependency on fossil fuels, using biomass is one of the key ways of ensuring the security of supply and sustainable energy in Europe. The Biomass Action Plan sets out a series of Community actions aimed in particular at increasing the demand for biomass, improving supply, overcoming technical barriers and developing research.

Biomass is the third largest primary energy resource in the world, after coal and oil [7]. The biomass represents two thirds of the Renewable Energy Sources in Europe. Biomass for heating accounts for 96% of the renewable used for heating. Biomass materials with high energy potential include agricultural residues and residues from forest-related activities. Residues from forest-related activities (excluding wood fuel) account for 65% of the biomass energy potential whereas 33% comes from residues of agricultural crops [7].

Agricultural residues are among Romania’s major potential energy sources. Estimates based on available statistical data and the results of experimental studies suggest that the annual agricultural residue potential is about 4799·10³ tep. This is equal to 63% of the total biomass quantity. Romania has one of the largest expanse of reed in the world (about 2 million ha).

Combustion technologies produce about 90% of energy from biomass, converting the biomass fuels in various forms of useful energy such as hot air, hot water, steam and electricity.

Unlike the solid fossil fuels, the biomass combustion is more problematic due to alkali metals and chlorine content and the higher ash content. Improvements could be operated at the fuel preparation stage, adding some specific anti-slagging agents (e.g. kaolin) or mixing straw with sawdust so as to present final characteristic more convenient with regard to combustion and ash issues. For heating boilers of lower power (<200 kW) the solution to combustion and ash issues consists in mixing straw with sawdust operated at the fuel preparation stage so as the present final characteristic more convenient with the meet of a European standards.

The interest in using more efficient boilers in rural areas, user friendly and environmental friendly is increasing. In a boiler with reverse combustion known also as down-draught boiler or boiler with gasification the combustion process occurs in two steps. Through separation of devolatilization and char combustion phases, the mixing of fuel gas and secondary combustion air is improved leading to higher combustion temperatures and reduced emissions from incomplete combustion.

Recent published research studies on the use of reed as fuel in the form of pellets, or mixed with wood residues in laboratory or industrial facilities [2, 3]. The goal of this study is to test the combustion of briquettes made from reed in a down-draught boiler with a power of 40 kW for domestic heating.
2 Experiments

The boiler has two combustion chamber separated by a refractory plate (Figure 1). The plate has slots provided with holes for secondary air supply. In this kind of boiler the combustion process occurs in two phases. The first phase-volatiles combustion occurs in the secondary chamber and the second phase – char combustion takes place in the primary chamber. In this way, mixing combustibles gases with secondary air is enhanced leading to reduced emissions from incomplete combustion. While the flue gases are guided down they transfer their heat to the water space and then flow from the bottom to the chimney.

The obtained results are compared with those obtained for fuels recommended by the boiler manufacturer: acacia log and briquette produced from sawdust.

The briquettes have a diameter of 7 cm and 15 cm length. The draught had almost the same value (≈3 Pa) during all tests and the load was 10 kg for each test. The fuels properties are shown in Table 1.

The temperature, CO, CO$_2$, NO$_x$ and O$_2$ concentrations in flue gas, the combustion efficiency and the excess air ratio ($\lambda$) were analyzed using the Eurotron Ecoline 4000 gas analyzer. The test rig includes also thermocouples to measure the temperature in the combustion chambers and the Riken analyzer for CO content in the fuel gas (Figure 1).

The boiler was tested according to the European Standard SR EN 12809:2003/A1:2005/AC:2008 – Residential independent boilers fired by solid fuel – nominal heat output up to 50 kW – requirements and test methods.

![Fig.1. Scheme of the 40 kW down-draught boiler.](image)

Table 1. Fuel properties.

<table>
<thead>
<tr>
<th>Fuel sample</th>
<th>Ultimate analysis (wt% of wet fuel with ash)</th>
<th>Lower heating value [kJ/kg]</th>
<th>Energy density [GJ/m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td>1. Acacia log</td>
<td>48.4</td>
<td>5.5</td>
<td>0.6</td>
</tr>
<tr>
<td>2. Reed briquettes</td>
<td>49.6</td>
<td>6.0</td>
<td>0.9</td>
</tr>
<tr>
<td>3. Sawdust briquettes</td>
<td>50.0</td>
<td>5.9</td>
<td>1.8</td>
</tr>
</tbody>
</table>
3 Results and discussion

The time dependence of the combustion efficiency NO\textsubscript{x} and CO emissions, O\textsubscript{2} concentrations in flue gas and excess air ratio are shown in Figures 2, 3 and 4. The combustion efficiency decreases in time for all fuel samples due to the increase of excess air ratio. This happens because the fuel composition varies continuously as a function of burnout degree. The lower reactivity of char as compared to the volatile fraction and the constant air flow rate lead to a lower fuel consumption rate and a larger amount of excess air. One may conclude that the boiler should be equipped with a system to optimize the amount and distribution of air between the combustion chambers. It can be seen the influence of the HHV on combustion efficiency. The highest carbon content in fuel leads to the highest combustion efficiency. The CO emission is high for all fuels despite the high excess air ratio. This could be explained by lower level of combustion temperature. The highest CO emission is obtained for acacia logs and the minimum CO emission for saw dust briquettes. The highest NO\textsubscript{x} emission corresponds to the fuel with the highest content of N (saw dust). The trend of NO\textsubscript{x} emission is to decrease in time as the N from fuel is consumed and the combustion temperature decreases.

The O\textsubscript{2} content in flue gas increases during the combustion process for all fuel samples due to the fact that the flow of air introduced into furnace is not adjusted well to the combustion conditions (Fig.4).
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4 Conclusion

The behaviour of the briquettes made from reed in the 40 kW with reverse combustion is similar to that of the wood logs and sawdust briquettes recommended by the boiler manufacturer. The maximum combustion efficiency was obtained for sawdust briquettes. The combustion efficiency decreases in time for all fuel samples due the increase of excess air ratio as the air flow introduced into furnace is not adjusted well to the combustion conditions. The largest emission of CO (about 2\%) was obtained for acacia logs. The largest emission of NO\textsubscript{x} corresponds to briquette made from sawdust and has a value of 400 ppm.

References:
