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THE OPTIMISATION OF BIOMASS COMBUSTION IN SMALL BOILERS

Summary

Biomass contains chemical energy which is a transformed Sun radiation. This energy can be used in many different ways. One of these is a direct combustion which is the most popular. The direct combustion of biomass is a technology which is well proven in large-scale heat and power generation. However, the situation in the small-scale heat generation is not so good. This paper describes results from the experimental combustion with various kinds of biomass in three different combustion devices. Saw dust is used in the experiment described below. The aim is to choose the best biofuel modification and the best way for its combustion from the point of view of power and emission parameters. As for the so far reached results of the experiment, the best in case of saw dust is the combustion with gasification of saw dust briquettes on stable grate without primary air or pellets in bottom supplied burner.

INTRODUCTION

Renewable energy sources arise due to the Sun radiation falling on the Earth surface. There is a number of energetic sources generated by this way on the Earth. The Sun radiation can be also transformed to another form of energy as is wind energy, water energy and biomass energy. Biomass is defined as a biologic matter in which the radiation energy is transformed through photosynthesis to chemical energy. Efficiency of this transformation is about 1% [Pokorný 1998]. One of the possibilities of how to use this energy is direct combustion. There are two basic groups of combustible biomass which can be used: biowaste and purposely grown biomass.

However, there are two important parameters which makes significant difference between biofuels and fossil fuels: water content and combustible fluid content. Due to this the combustion device must be constructed with regard to these facts and it is not possible to use the systems designed for fossil fuels [Kára and Adamovský 1998]. In case of large-scale power generation the biomass specifities are considered and the technology is solved complexly. There is not a favourable situation in case of small-scale generation. A lot of devices designed for fossil fuel, although unsuitable, are in the use. In these the combustion is ineffective from the point of view of power output and emission limits. Now the question is: What kind of biomass (or its modification) and what kind of combustion technology to use to enhance power effect and minimise emissions?

The aim of the experiment is to evaluate power and emission parameters of selected biofuel under different combustion conditions. Pressed saw dust from soft wood has been used as a fuel in this experiment – briquettes with diameter 90 mm and pellets with diameter 8 mm.

MATERIAL AND METHODS

Combustion devices and possibility of modification

Combustion process was evaluated in three combustion devices – hot water boilers: VARIMATIK VM 45, VERNER V 25 and VIADRUS U22 trademark Czech small-scale boilers.

VARIMATIK VM 45 is primary designed for brown coal and is welded from steel plates and steel tubes. The fuel slides from a fuel reservoir is brought in cycles into the combustion space and burnt on the upper part of rotating cylinder grate. Combustion air is drawn by the help of a fan under the grate. Produced flue gases are directed along the walls of the plate heat exchanger and through the fan into the chimney.

Regulation of fuel supplying cycle (duration of grate rotation and delay) is possible. Total amount of combustion air flow was controlled by clack valve installed in boiler uptake in front of the chimney fan. Access of primary, secondary and tertiary air flow was enabled by way of special nozzles which have been developed. These nozzles distributed air flow into flame jet in parallel or another direction. The amount of all air flows was controlled through air curtain.

VERNER V 25 is constructed as a double-chamber for wood chunks and based on the principle of gasification. The fuel is dried and gasified in the upper chamber with the access of primary air. Generated gas goes through a nozzle, where it is mixed with secondary air, into the lower chamber.

Gas is burnt in the lower chamber which is equipped with stabilising ceramic slab and cooling water jacket – as a first stage of water heating.

The flue gases flow from this space through the tube heat exchanger into the chimney.

The boiler is air pressurised and the air flow is controlled by a clack valve in the outlet of the fan. Equally, it is possible to control the distribution of the air flow: when the access of primary air is open to the upper chamber, it is closed to the ceramic nozzle.

VIADRUS U 22 is constructed as a cast-iron boiler shell which consists of combustion chamber and heat exchanger. Combustion chamber is equipped with bottom fed burner and stabilising ceramic slab above the burner. Fuel is supplied from the reservoir to the cast-iron burner through a screw conveyor. Primary and secondary combustion air is forced into the body of the burner by the fan. Flue gases flow along the plate heat exchanger into the chimney.

The boiler has an air pressurised system with fan and regulation of combustion air flow by way of a clack valve. The regulation of fuel supplying cycle is possible. With regards to the burner construction the distribution of air flow can not be changed.

Testing equipment

Substantial emission and power parameters have been evaluated by the TESTO 33 analysis box. Measuring range: CO 0–20,000 ppm, CO_2 0–20 %, O_2 0–21 %, thermometer – thermocouple Ni-CrNi 0–500°C. The arrangement of testing points is in Figure 1.

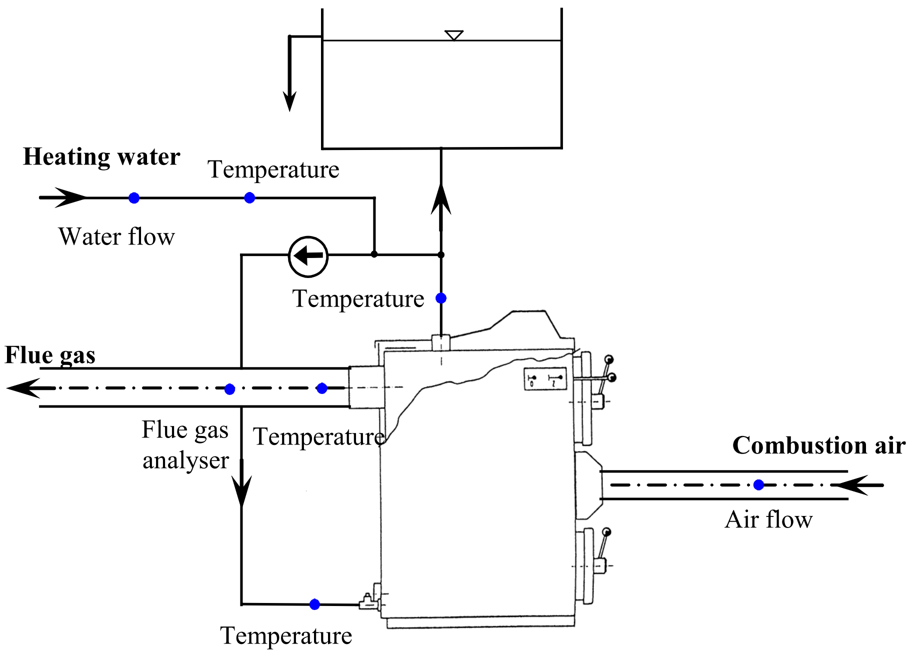

Figure 1. Scheme of testing points

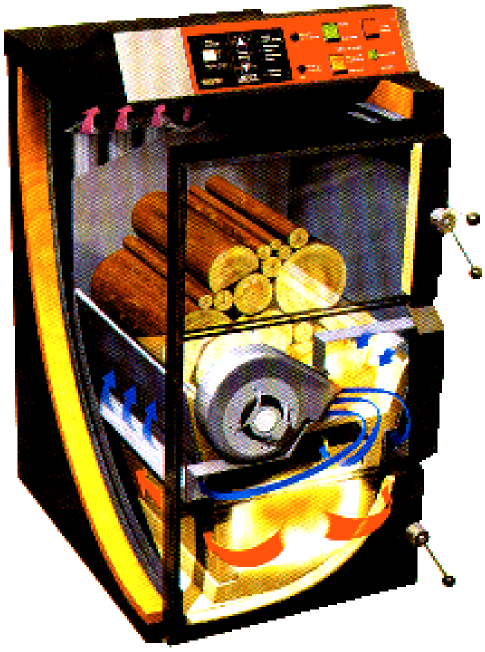

Figure 2. VERNER boiler

RESULTS AND DISCUSSION

The results of the selected emission and power parameters depending on combustion type are demonstrated in the graphs below. Values of emission concentration are given as an average from three single values at steady-state conditions and were corrected to 11% reference content of oxygen.

The testing was done under the conditions described in table 1.

Table 1. Description of combustion types

Combustion type	Description
A	VARIMATIK, pellets, only primary air I. under the grate
B	VARIMATIK, pellets, primary air I. under the grate, secondary air II
C	VARIMATIK, pellets, primary air I. under the grate, secondary II + tertiary III air
D	VERNER, briquettes, without primary air
E	VERNER, briquettes, with primary air to upper chamber
F	VIADRUS, pellets, with modified fire feeding cycle

Emission parameters

Carbon monoxide CO is a poisonous gas arising from imperfect burning of carbon contained in the fuel and is a substantial indicator of combustion process quality. Primary cause of its existence is lack of air. Another cause is low temperature in the space where CO as a primary product cannot continue oxidation to CO_2. Both causes mean higher concentration of CO in flue gases. Besides the adverse influence on environment, this means also the loss of energy. Due to the oxidation of CO it should be possible to enhance the heat output.

Maximal concentration (15,846 mg/m^3) has been reached in type A while the lowest in E (669 mg/m^3) and in F (834 mg/m$^{3)}$ (Figure 3).

Nitrogen oxides NO_x arises as a product of air oxidation of nitrogen in the combustion space. This oxidation is realised under high temperatures and it is endothermic. Concentration of NO_x is similar in all cases (about 70 mg/m^3) except C (151 mg/m^3) (figure 3).

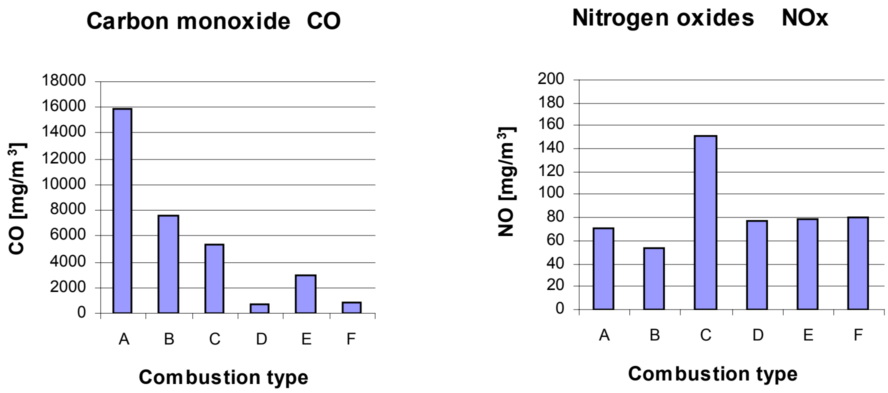

Figure 3. Emission parameters: CO, NO_x

Oxygen: The trend of oxygen concentration looks similar as the excess of air coefficient (Figure 4). It is caused by present air which does not participate in the combustion. Total amount of oxygen in flue gases indicates quality of combustion process too.

Excess of air coefficient: Excess of air is defined as an amount of air which exceeds the theoretical air requirement for complete stoichiometric combustion. It is defined as the actual air/theoretic air ratio. Due to the efficiency of overall process the real combustion must to be done with excess of air. Optimal value of this parameter (about 1.6) was reached with D, E, F (Figure 4).

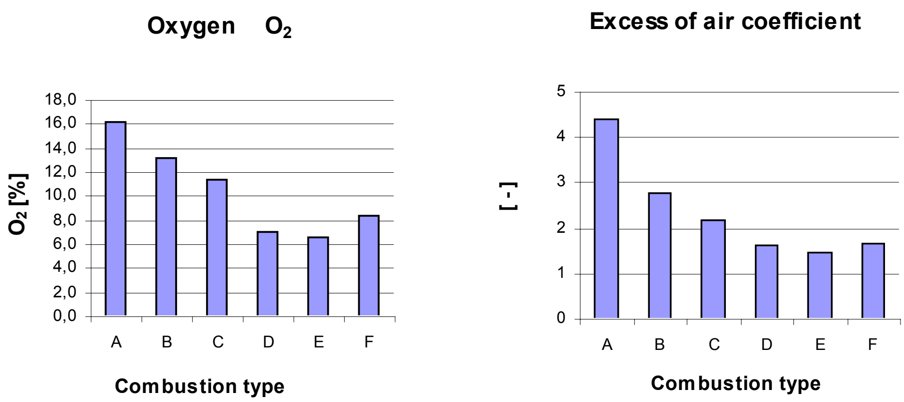

Figure 4. Emission parameters O_2, excess of air

Power parameters

Flue gas temperature and chimney loss are important values from the point of view of thermal efficiency of a boiler. High temperature together with high O_2 content means loss of heat energy and lower efficiency. It is also important for improvement or development of heat exchanger. Optimal temperature values have been reached with B,C and F (figure 5). Unfavourable results with D, E are probably caused by smaller heat exchanger designed for another fuel, i.e., chunk wood with moisture content and lower heat value than briquettes.

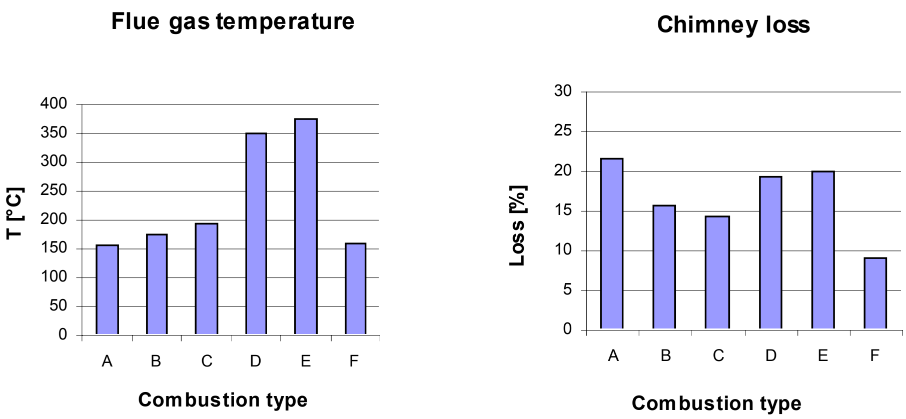

Figure 5. Power parameters

CONCLUSION

Specificity of biomass based fuels mentioned above requires special combustion device. Burning process passes in several steps: 1) fuel drying, 2) pyrolysis and gasification, 3) gas burning, 4) burning of solid parts on grate. Biomass belongs among fuels which are called “long flame fuels”. With regard to this it is necessary to construct the combustion space larger, with addition of secondary air and equipped with stabilising elements (ceramic slab, etc.). These elements accumulate the heat and keep the temperature at the optimum level (about 900°C) to enable finishing oxidation to CO_2 since this reaction passes under temperature higher than 850 °C. When the temperature is lower, air cannot perform the reaction but only dilutes flue gases. These basic demands are fulfilled in cases D, E, F and so the emission of CO is the lowest in these cases.

Air flow settings have been necessary in all types of combustion to ensure the optimal excess of air and lower O_2 content in flue gases. The regulation was provided by clack valves situated in every fan. In the devices equipped with automatic fire feeding it was necessary to improve the fuel supplying cycle, especially in VARIMATIK device which is primary designed for coal combustion. As the most suitable in case A and C there was chosen the feeding/delay cycle of 1.0/10 sec, and in case B 1.5/15 sec. In case F, the best choice was 10 sec feeding and 35 sec delay. The presented results were obtained under these settings.

Most of problems were detected in VARIMATIK which is not equipped with stabilising parts and has no additional secondary air which is necessary. Also the present arrangement of the rotating grate is not the proper solution. On the other hand in VERNER device, due to the high flue gas temperature, larger heat exchanger for this fuel is required.

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