Different temperature of combustion air for burning of biomass

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Abstract. During the combustion process of renewable fuels are generated pollutants into the atmosphere and have a negative impact on human health. The most monitored pollutants are: particulate matter, carbon monoxide, nitrogen oxides, sulphur dioxide. This paper analyzes the effect of temperature of the primary combustion air to the heat performance and emission parameters of burning biomass. In the second part of the article is evaluated impact of different dendromass to formation of emissions in small heat source. The measured results show that the regulation of the temperature of the combustion air has an effect on concentration of emissions from the combustion of biomass.

Keywords: dendromass, emission, particulate matter, temperature of primary air.
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INTRODUCTION

Nowadays is the effort of many manufacturers of heat sources to achieve the maximum efficiency of energy transformation chemically bound in the fuel to heat. Therefore it is necessary to streamline the combustion process and minimize the formation of emission during combustion. [1,2]

During the combustion process of solid fuels are generated gaseous and particulate pollutants. The aim is to reduce the concentration of these substances to acceptable levels, since the emissions have a significant proportion of air pollution. [4]

The solid particles are entrained with flue gas stream from the combustion chamber of boiler. Particulate matter (PM) consists of soot, inorganic matter (ash) and organic matter (non-volatile flammable). Particles are imported into the flue gas by ash, non-volatile and combustible soot.

Today is the greatest attention paid to the size of particles (aerodynamic diameter) less than 10 μm (PM10), which may penetrate into the respiratory tract. Particles of this fraction are divided into two groups based on different sizes, the mechanism, the composition and behaviour of the atmosphere.

The first group is made up of particles of size below 2.5 μm (fine respirable fraction - PM2,5), arising from chemical reactions nucleation, condensation of gaseous emissions generated at the surface of particles or coagulation of the finest particles.

The second group create particles in the range of the size from 2.5 to 10 μm (coarse fraction – PM2,5 to 10).

Finest particles with a diameter below 2.5 μm (PM2,5) are considered to cause the greatest harm to human health. They deposit deep in the lungs and block the reproduction of cells. [3,5,6]

Various type of wood have different composition and properties such as calorific value, ash melting behavior of temperature, which greatly affects the production of PM.

In this work, experimental measurements were carried out, focused on the formation of PM during combustion of different types of dendromass in a small heat source. The effect of various temperature of the primary combustion air to the emission parameters is also evaluated.

MEASUREMENT OF EMISSION PARAMETERS

Methods for measuring emissions of pollutants can be divided in principle to measuring of particulate matter and gaseous substances. Methods and measurement principles are based on the emission properties of the fluid medium. One of the method for measuring particulate matters is presented below.

Gravimetric method

Gravimetric method is the manual single method with sampling of the flow gas by probe. It is based on determination of the median concentrations by sampling from multiple points of measurements cross-section and their subsequent gravimetric assessment. Solid contaminants are usually separated by an external filter.

Representative sampling is performed by probe suitable shape and the correct speed under isokinetic condition. [7]

Concentration of particulate matter in the flue gas is covered to standard conditions and can be determined for wet, respectively for dry flue gas. Measured volume of sample taken on the volume gas meter should be converted to standard conditions, i.e. 101325 Pa pressure and temperature of 273.15 K (0°C). Therefore, the temperature and pressure of measured sample is measured before gas meter.

The cumulative collection can provide in the cross section average concentration but not concentration profile. Flow velocity, or flow of the sample gas is measured by ensuring of isokinetic, for example by aperture track and a total collected amount of gas by gas meter. [8,9]

In gravimetric method, the taking of representative samples is realized by probe with appropriate shape right from the flowing gas. [10]

To meet the increasing requirements toward the fine particulate determination, the multistage impactor probe was used in these experiments. Impactor separation system is intended to filtrate and separate solid emissions in three-stage impactor. The construction of device allows parallel separation of solid elements PM 10 and PM 2,5 (Figure 1).

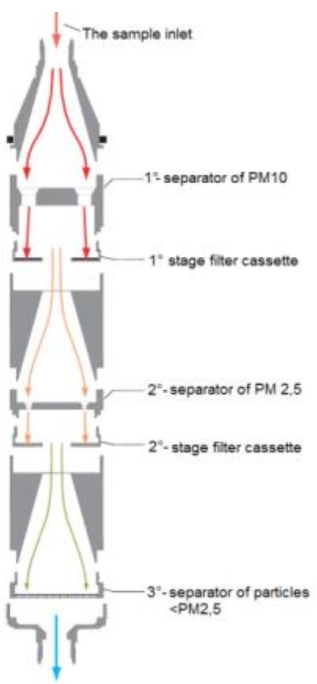

FIGURE 1. Multistage separation impactor.

The advantage of the gravimetric method is its simplicity. In particular, mutual reproducibility and comparability of measurement results regardless of the type of device, the air flow, type of filter material, the suction speed etc.

EXPERIMENTAL MEASUREMENT

As the heat source was used fireplace rated at 6 kW, which is designed for burning of piece wood. Bottom of the combustion chamber is topped with grate and under is the container where the ash falls. Access to the combustion chamber is through the doors that are glazed with high heat resistant glass.

Cooling/heating of combustion air

Changing the temperature of the combustion air inlet was performed on the primary combustion air. The heat exchangers is plugged to pipe of primary air supply for heating/cooling of combustion air. This way is the temperature of the incoming primary combustion air heated/cooled to the desired temperature level. The minimal supply air temperature was - 5 °C and gradually increased up to 40 ° C. The increase in temperature between the measurements was 5 °C and was regulated by the heat exchanger, which is located behind the fan in a duct. Temperature control for the heat exchanger was ensured by circulatory thermostat Julabo F40.

The scheme of experimental stand for the heating/cooling air supply is shown in Figure 2.

In order to evaluate the quality of combustion process, the gas composition was measured by analyzer.

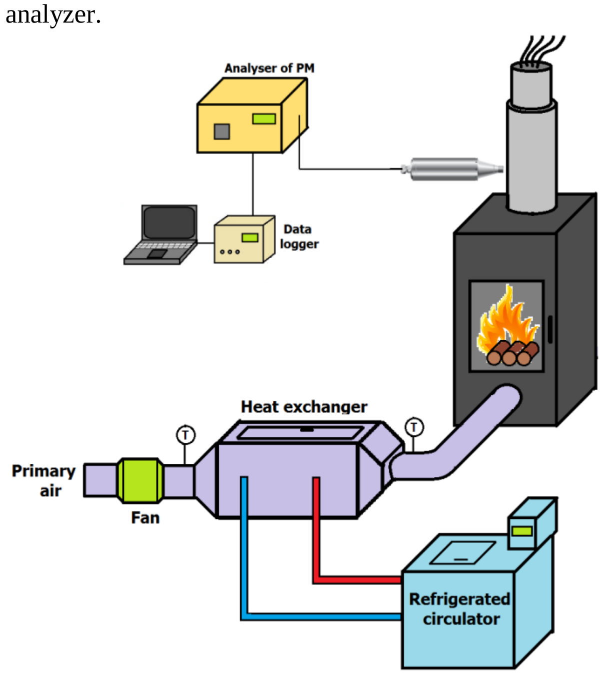

FIGURE 2. Scheme of experimental setup

Dendromass

During the experiment, the different types of wood were tested as well. Every measurement lasted 1 hour and was burned to about 1,5 kg of fuel. For the experimental measurements were used the following types of wood that are listed in Table 1.

TABLE 1. Types of wood and their parameters.

Type of fuel	**Calorific value [MJ/kg]**	**Humidity [%]**
Beech	17,5	7,64
Spruce	19,3	7,87
White birch with bark	28	18,15
White birch without bark	19	18,15

RESULTS AND DISCUSSION

During the measurements were recorded concentrations of following emissions: CO, CO_2, NO and particulate matters in the flue gas.

Effect of air temperature on formation of emissions

The temperature of the primary combustion air supplied to fireplace varied by changing the setting temperature on the refrigerated circulator.

Different temperature of the primary combustion air has impact on formation of emissions.

Figure 3 shows the results of the measurement of carbon dioxide according to the set temperature of the primary combustion air.

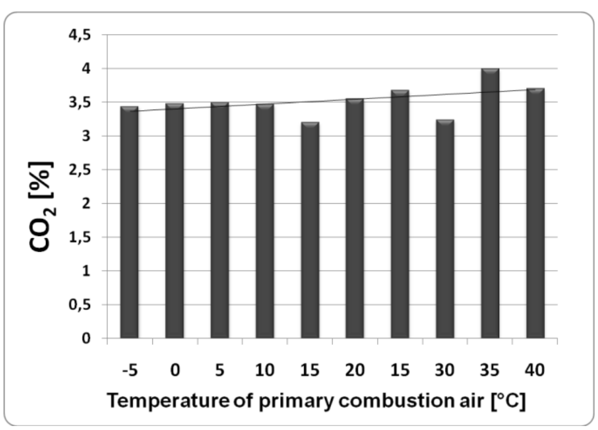

FIGURE 3. Average CO_2 emissions depending on the temperature change of the primary combustion air

The highest average CO_2 were recorded at 35 °C of inlet air, while at 15 °C of supplied air was registered the lowest average value of 3.20%. Carbon dioxide formation has a trend to increase with increasing temperature of the primary combustion air.

Figure 4 shows the results of the measurement of carbon monoxide.

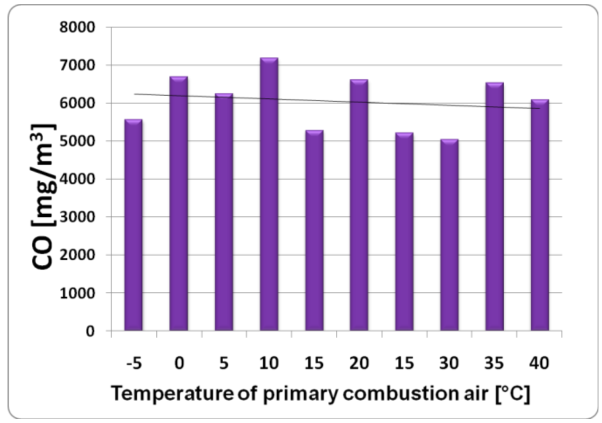

FIGURE 4. Average CO emissions depending on the temperature change of the primary combustion air

The highest average value reached 7193mg.m^{-3} of CO and were recorded at 10 °C inlet air, while at 30 °C supply air reached the lowest average value of 5051mg.m^{-3}. The results indicates, that formation of carbon monoxide has trend to decrease with increasing temperature of the primary combustion air.

Dependence of NOx formation on the different temperature of the primary combustion air to the experimental heat source shows Figure 5.

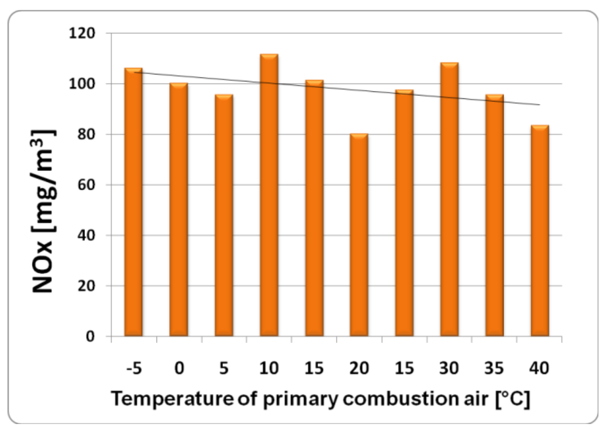

FIGURE 5. Average NOx emissions depending on the temperature change of the primary combustion air

The highest average values of the measured NOx (111.65 mg.m^{-3}) was achieved at 10 °C, the lowest average values were measured at 20 °C with a value of

80.16 mg.m^{-3}. NOx production has a trend to decrease with increasing temperature of the primary combustion air.

The results PM concentration depending on the temperature of primary combustion air are shown in Figure 6 and 7.

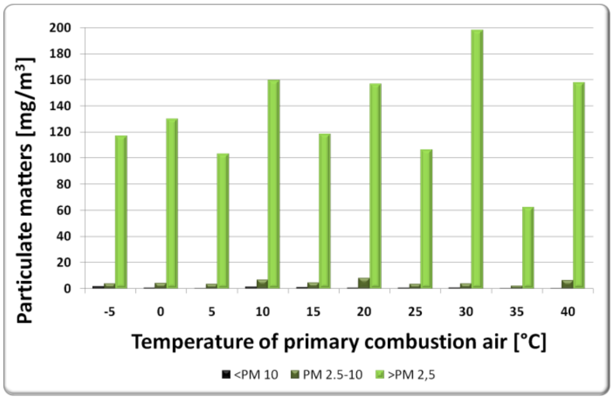

FIGURE 6. The measured values of particulate matter depending on the temperature

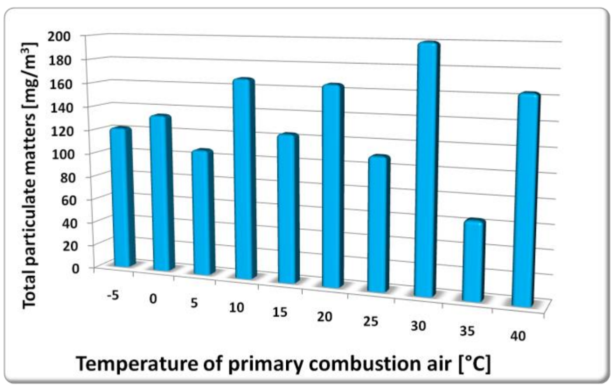

FIGURE 7. The measured values of particulate matter depending on the temperature

Measurement of particulate matter with a change of temperature of combustion air has reached the maximum concentration of 202 mg.m^{-3}. Minimum concentration of PM emission was generated at 35 °C of combustion air.

Different types of dendromass

The second part of the work deals about the effect of different dendromass to formation of solid particles. Generation of emissions is largely influenced by type of fuel that is burned in heat source. Every fuel has different properties and chemical composition, which ultimately affects the combustion process, the amount of actual emissions and ash content. During the experimental measurements were secured the same combustion conditions, i.e. uniform supply of primary, secondary and tertiary air, the same pressure in chimney (12 Pa) and a maximum dose of 1.5 kg of fuel.

Particulate measurement were conducted on all types of wood for 30 minutes. During this time, the individual samples collected PM that were captured the filter. These were subsequently stripped of moisture and weighed. Concentrations of particulate matter were determined by difference weight of the filter before and after the measurement. The highest amount of particulate matter was observed in measurements of white birch with bark and beech (Fig. 8).

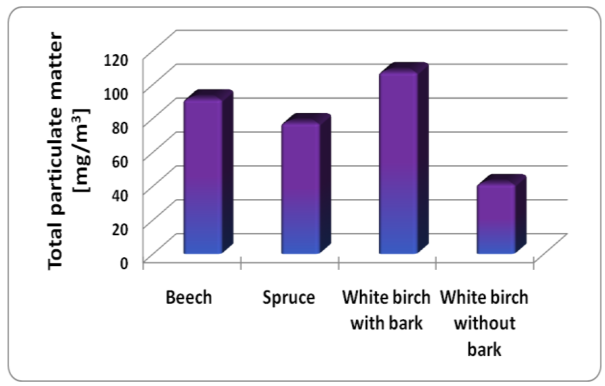

FIGURE 8. Concentrations of PM for different types of dendromass

CONLUSIONS

The aim of this work was to demonstrate an impact of the primary combustion air temperature to emissions parameters.

Presented results of emissions depending on the temperature of the primary combustion air do not indicate the most suitable setting of temperature. For each type of emission has been reached the lowest value at different temperatures of the primary combustion air.

From the experimental measurements of solid emissions is clear that in terms of the lowest value of PM is preferred to supply the primary combustion air into the combustion process at a temperature of 35 °C

It can be argued that the production of carbon monoxide (CO) decreases with increasing temperature at the expense of higher production of carbon dioxide (CO_2). The formation of CO is influenced by several factors and therefore its different concentration during the measurements cannot be attributed to changing temperatures of the combustion air.

In this research work was carried out analysis of the impact of different types of dendromass to the formation of particulate matters during the combustion process. The results of measurements indicates that the type of fuel has a considerable influence on the combustion process and the formation of particulate matters. This phenomenon is largely influenced by the different properties and chemical composition of different types of dendromass.

In the case of birch without bark, the lowest values of PM were measured, suggesting that the bark of firewood has a significant proportion on the formation of solids particles.

The measured results show that the type of firewood affects emission parameters of the heat source.

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