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Production of particulate matter from the combustion of wood pellets

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Abstract. For production of particulate matters affect more aspects. One of the biggest affect is combustion air volume and it's deviding on primary and secondary part. In this article is described experimental device, on which was investigated affect of combustion air volume on production particulate matters, measuring method, measured and analysed achieved results.

1 Introduction

Air quality significantly affects the status of the environment, human health, as well as individual ecosystems. The biggest problem in air quality at present represents pollution particulate matter (PM particles). Significantly to this contributes combustion biomass, although most particulate pollutants come from transport. One of the main conditions affecting the combustion process is an adequate supply. If we bring in a large number of furnace air temperature drops unburned gases escape and therefore of the energy escapes us. If the supply is insufficient, there is no burning of volatile matter and combustion is complete.

2 Measurements

Use The basic task of emission measurement is to determine the mass concentration pollutants. Measured weights laid pollutant concentrations are in the range from several [mg · m-3] to several [gm-3]. Each measurement must always consists of a status conditions in cross-section measurements, determination of the main components in the exhaust gas, determine the total volumetric flow rate and determine the median concentration of fluid in the gas stream. As the measurement method was used gravimetric method, which is a manual single method of sampling probe of the gas flow. It is based on the Mean concentrations of the collection of one or more points of the cross section, followed by gravimetric measurement evaluation. Solid additives are shed in an external filter. Representative sample is transferred sample probe suitable shape and the correct speed according to isokinetic conditions:

$$w_{s,i} = w_i \rightarrow c_{s,i} = c_i \qquad (1)$$

This equation sets out the requirement that the sampling rate was in the wellhead $w_{s,j}$ [$m.s^{-1}$] the same as the speed w_i [$m.s^{-1}$] gas flow, then the concentration of the wellhead $c_{s,i}$ [$g.m^{-3}$] exhaust flow is equal to the concentration in the stream or [$g.m^{-3}$]. Isokinetic conditions are achieved by controlling.

The aim was to analyze measurements of particulate matter from the combustion of wood pellets in various stoppage primary and secondary air. Measurement was implemented in the boiler nominal output 25kW. This is an automatic boiler with automatic ignition hot. Screw conveyor transports fuel from the hopper to the burner, fuel evenly spread over the surface grid provides diffuser. The air required for combustion is supplied by fan, primary air is supplied to the fuel joints in the grate, and secondary air is fed to the burner holes in the rear wall of the burner. Flow of the flue gas through the heat exchanger, where is transferred heat to the heating water. Cooled exhaust gases going up the chimney outlet port. The technical parameters of the furnace are shown in chart. The measurement was implemented at various stoppage primary and secondary air.

Samples were collected sample probe directly from the chimney. For separation of PM10 and PM2.5 was used a three-stage separator MSSI impactor designed for filtration and separation particulate emissions directly in the chimney. The compact design allows the combined current separation of PM10 and PM2.5. The bottom of the holder is placed on a membrane filter diameter 47 mm. We used wood pellets as fuel with a diameter of 6 cm, a bulk density of 650 kg m^{-3} and calorific 17.5MJ.k[1].

Automatic boiler Verner A251LS (fig. 1 and tab. 1) allows you to change the fan speed in the range from 1 to 7 degree. Prior to measurement on an experimental boiler measured mass flows of air at various stoppage primary and secondary air fan and individual levels. Table 2 shows the mass flow of air at various fan stoppage

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extensions are the primary and secondary air from the manufacturer, which was the primary and secundary element to eject 6.8 cm to 3.1 cm.

Table 1. Technical parameters of the boiler using wood pellets.

Rated power	25 kW
Efficiency	92%
Water tank capacity	85 l
Hopper	240 l
Volume ashtray	18 l
Flue gases temperature at rated power	160 °C
Fuel consumption at rated power	5.8 kg.h^{-1}
Emission class	3
Efficiency class	3

Figure 1. Boiler Verner A251LS.

Table 2. Measured values of mass flow.

fan	primary air [kg.hod^{-1}]	secundary air [kg.hod^{-1}]	total air [kg.hod^{-1}]
1	27.82	2.68	30.50
2	20.92	2.02	22.95
3	68.84	8.20	77.05
4	91.68	12.95	104.63
5	104.16	15.19	119.36
6	120.29	18.22	138.52
7	138.05	21.67	159.72

For quality evaluation of combustion process was content of flue gases measured by flue gases analyser ABB AO 2020 (fig. 2). Advice is assigned on analysis of gaseous pollutants. Gas offtake is one point with inox probe. On inlet of the sample to the offtake pipe is in preserved box heated ceramic filter, captured mechanical dirtiness. Sample continues by offtake pipe to the measuring system. Pipe is heated for noncondensing of the sample. Measured gas is leaded to the refrigerator. In the next step is gas leaded through the valves and filters to the analyser. Analyser ABB AO 2020 is set according the requirements and the nature of measurement. In the case of emission measuring from wood combustion in the fireplace stoves were used measuring advices URAS 26 and MAGNOS 206. For a more accurate analysis of emission and power parameters of the individual settings of intake air into the pellet burner was always measured circa 120 min. During the combustion process of one fuel portion was recorded the following values:

- ambient temperature T_o [°C],
- chimney pressure p_k [Pa],
- flue gases temperature T_k [°C],
- outlet water temperature from the boiler [°C],
- inlet water temperature to the boiler t_r [°C],
- volume flow of heatchange Qvh [m^3.h^{-1}],
- speed of inlet air to the burner [m.s^{-1}]
- temperature of inlet air to the burner [°C]
- constitution of flue gases : oxygen O_2 [%], carbon dioxide CO_2 [%], carbon monoxide CO [ppm], nitrogen oxide NO_x [ppm], sulphur dioxide SO_2 [ppm].

Figure 2. Emissions analyser (ABB).

Samples for analysis of particulate matters (PM) were sampled disposable by probe of TECCORA Company, directly from the chimney. For separation of the particles PM10 (particulate matters in range from 2.5 μm to 10 μm) and PM2.5 (particulate matters smaller than 2.5 μm) was used three- stage separation impactor MSSI intended for filtration and separation of particulate matter directly in the chimney. Combined compact design allows simultaneous separation of PM10 and PM2.5. At the bottom is placed holder for membrane filter diameter of 47 mm. Measurements were carried out at various fan stoppage.

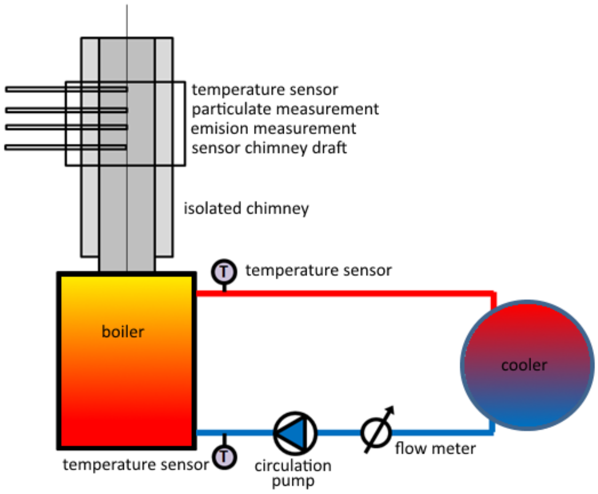

Figure 3. Scheme experimental measurement.

In experimental measurements of the boiler output is set to half (fig. 3). During measurements were recorded at 20 second intervals on the emissions, ambient temperature, exhaust temperature, fuel loss. Interval measurement itself was 30min. Based on measurements of the mass flow of primary and secondary air entering the combustion process in a small heat source is used to manually overfill fan heat source on values: 1,3,6,7. During the measurement of performance and emission parameters of the extensions are fan # 1 to the insufficient supply of air for the combustion process, and therefore used as 3,6,7 The settings. In the picture we can see tar No.2 established the impactor that created the extensions are worth the No.1 fan, respectively, the minimum speed (fig. 4).

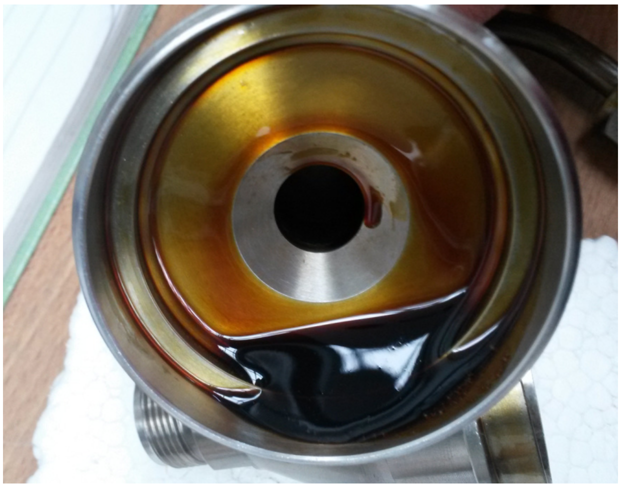

Figure 4. Tar established the impactor.

3 The evaluation of measurement

On the first graph (fig. 5) is showed selected record from one measurement running during 30 min., and affect of combustion at fan setting on speed number 3 on production of individual pollutants and power of small heat source. From the running is possible to observe a significant increasing of all pollutants during fuel metering from the screw feeder to the combustion chamber, while at the same time decreased power. This phenomenon can be observed in all realized combination of primary and secondary mass flow incoming to the combustion process.

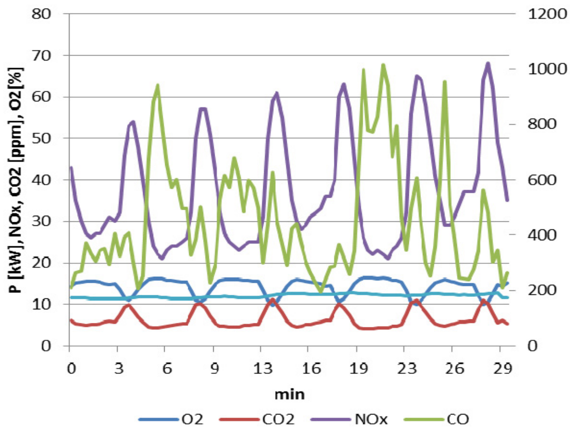

Figure 5. One measurement running during 30 min.

From the perspective of the average values of each combination in primary and secondary mass flow changes can be observed a considerable affect of combustion air amount on combustion quality (fig. 6, 7 ,8). From the perspective of power is the best setting of fan (primary and secondary air setting) on value No 6. Then the experimental small heat source achieves the best efficiency and performance (fig. 6).

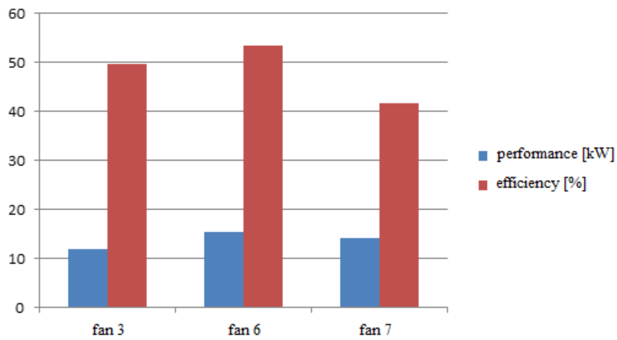

Figure 6. Performance and efficiency.

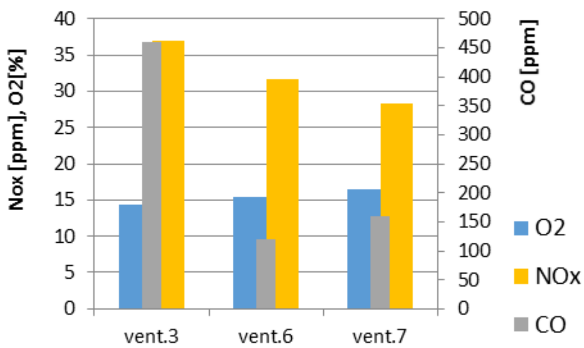

Figure 7. Production of emission

At analyzing of emission by continual measurement wit ABB device (fig.), we observe that for NOx (nitrogen oxides) is preferable to enter to the combustion process with a greater amount of combustion air. For CO emissions of (carbon monoxide) in the exhaust gas it is not true, and also it reiterates the rule, that for the good combustion must be correctly set ratio and intensity of incoming air into the combustion process (fig. 7).

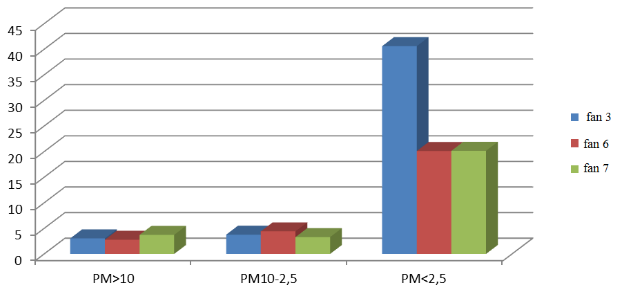

Figure 6. Production of particulate matter.

If we look on the analysis of measured data from the aspect of particulate matter (fig.8), is possible to observe similar process of particulate matters (PM) production with the same variant of combustion like in the previous analysis. From the aspect of PM production we accord least mass number of PM in range 10 µm and more. Similar results were recorded also for PM10 particles, which are in the range of 2.5 µm to 10 µm. Surprisingly was found, that at the combustion of ecological fuels from biomass are most produced smallest particles PM, which are most dangerous for the human body. PM 2.5 are smaller than 2.5 µm. In terms of redistribution and intensity on the formation of PM particles from burning biomass in the process, we observe an increase in the formation of PM at pinching inlet air, or fan settings on value 3. The biggest affect of combustion air pinching was on the creation of PM2.5. Formation of particles larger than PM10 and PM10 was in all variants redistribution and intensity of combustion air into the combustion process approximately the same.

4 Conclusions

From previously conducted preliminary analyzes show that even a slight interference with the process combustion in a small heat source using superstructures intensity entering primary and secondary air can fundamentally affect the quality of combustion and emission performance terms. From these introductory analyses is observed significant fluctuation of pollutants production, dangerous for the human health, producted from the combustion process at incorrect setting of primary and secondary air. From this perspective is important to deal with redistribution and intensity of combustion air and its affect on combustion process, with which we will interest in the next experiments.

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