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ANALYSIS OF PARTICULATE MATTER FROM THE COMBUSTION OF WOOD CHIPS

Michal Holubčík – Nikola Kantová – Jozef Jandačka – Milan Malcho

Abstract

One of the most watched emissions from combustion processes are particulate matter (PM). It is a mixture of particles consisting of carbon, ammonium, metals, organic materials, nitrates and sulfates. These emissions are important in terms of danger to human health when they are inhaled. With decreasing diameter of the dust particles increases their degree of danger. The article deals about analysis of PM from the combustion of wood chips. There were analyzed PM obtained from heat source for combustion of wood chips with nominal thermal power 2.3 MW. The first performed analysis was particle size distribution determination. In this work it was performed thermo gravimetric analysis where the moisture, volatile, fixed carbon and ash content were obtained. During elemental analysis were detected carbon (C), hydrogen (H), nitrogen (N) and sulfur (S) content in PM. There was obtained that PM consist mainly from the ash but they also consist C, H and N.

Key words: *particulate matter, thermo gravimetric analysis, elemental analysis, particle size distribution, wood chips*

INTRODUCTION

Emissions have a significant proportion of air pollution. It may be gaseous substances as well as particulate matter, which can arise from natural or anthropogenic sources. Natural sources are dust from natural sources, usually large areas of land with little or no vegetation, methane emitted by the digestion of food by animals, radon gas from radioactive decay within the Earth's crust, smoke and carbon monoxide from wildfires, vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days and volcanic activity, which produce sulfur, chlorine, and ash particulates (Jandačka et al. 2015).

Anthropogenic sources (human activity) mostly related to burning different kinds of fuel. These are mainly chemicals, dust and controlled burn practices in agriculture and forestry management, fumes from paint, hair spray, varnish, aerosol sprays and other solvents, waste deposition in landfills, which generate methane, military, such as nuclear weapons, toxic gases, germ warfare and rocketry, motor vehicles, marine vessels, aircrafts, and of course Stationary Sources of emissions, including smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices (Who, 2013). This may be biomass-fired heat sources.

University of Zilina, Univerzitna 8215/1, 010 26 Zilina, Slovakia
e-mail: michal.holubcik@fstroj.uniza.sk

Particulate (dust) matters in the atmosphere are a mixture of substances consisting of carbon, dust and aerosols. We meet with the concepts of: particulate matter (PM), solid aerosols, hard aerosols, airborne dust. In foreign literature then suspended particulate matter (SPM), total suspended particles (TSP), black smoke, etc (Dzurenda and Pňakovič, 2016).

Into the atmosphere where we can in terms of particle size and chemical composition to meet with them in the form of complex heterogeneous mixture are receiving from various sources, which can be divided into three basic categories. These are stationary sources (local furnaces, incineration plants, agricultural activities, logging and mining, chemical production), mobile sources (road, rail, sea and air transport) and sources of indoor air pollution (smoking, burning, cooking, cleaning, release from internal and other materials). The percentage of particulate matter from a wide range of sources is as follows: road transport (25 %), industrial processes without combustion (24 %), industrial plants with combustion devices (17 %), waste incineration plants and domestic heating (16 %) and fuel-energy industry (15 %). In addition to these categories, which include anthropogenic sources of air pollution are also participating natural resources (land erosion, volcanic activity, pollen, spores, bacteria) (Zhuo et al. 2009).

Suspended particles according to the character of creation can be divided into primary particles directly emitted by the source and the secondary particles generated during the chemical reaction between oxygen in the atmosphere, water vapor and reactive components (ozone, hydroxyl and nitrate radicals, SO_2, NO_X) (Yao et al. 2009).

Sources of suspended particulate matter, together with other conditions such as inputs into the atmosphere, the mechanism of formation, transformation of particles in the air, the distance from the source and meteorological conditions predetermine the amount of particles (particle number or mass of particulates per cubic meter of air), their specific physical (shape, size, electrical charge, particle size and solubility) and chemical properties (organic and inorganic components). The basic building blocks of particulate emissions from transport include elemental carbon (soot), organic matter (HCs, PAHs and their alkyl, nitro, oxo-and chloric-derivatives, aldehydes, organic acids, PCBs, OCPs, PCDDs / Fs) , metals (Pb, Pt, Cd, As, Cu, Zn, etc.), acid condensates, nitrates, ammonium, sulfate and others (Villeneuve et al. 2012).

From physical properties of the emitted particles is crucial especially the representation of individual particle size fractions, including very fine, fine and coarse fractions. Particle size and composition related to the effects of particles on human health and the possible risks posed to exposed populations (Lázár et al. 2015).

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 behavior 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. Their main sources are coal, fuel, wood, chemical production, transformation NO_X and SO_2 in the atmosphere (nucleation) and the conversion of organic matter. The basic composition of these substances is dominated by sulfates, nitrates, ammonium, elemental carbon, organic compounds and metals (Nosek et al. 2012). These particles remain in the atmosphere for a long time, which allows them to transport long distances in air flow. The second group of particles are in the range of the size from 2.5 to 10 μm (coarse fraction – PM2,5 to 10). These particles formed by mechanical abrasion (crushing, grinding surface) and swirling of dust. Their main sources are the various industrial dusts in mining in quarry industry, construction activities, transport, land management, and so on.

This fraction also includes various biotic particles such as bacteria, pollen, plant particles (Geffertová and Geffert, 2011).

The article deals about analysis of PM obtained from heat source for combustion of wood chips. There were determined particle size distribution, moisture, volatile, fixed carbon and ash content, carbon (C), hydrogen (H), nitrogen (N) and sulfur (S) content in PM.

MATERIAL AND EXPERIMENT METHODOLOGY

There were analyzed PM obtained from heat source for combustion of wood chips with nominal thermal power 2.3 MW. This heat source is used for heat supply for residential and public buildings in the downtown area of Dolny Kubin. PM samples were taken from the cyclone separator during the combustion of wood chips made from the mix of spruce, oak and beech wood. The moisture content of the wood chips was 29.17 % and calorific value was 12.27 $MJ.kg^{-1}$.

Particulate matter size distribution was determined by using of vibratory sieve shaker machine. This machine is suitable for dry and wet sieving. Their patented electromagnetic drive produces a 3-D throwing motion which ensures optimum use of the open sieve area and lets the sample move equally over the whole sieving surface. There were used sieves with the size of mesh 500 μm, 250 μm, 150 μm, 100 μm, 50 μm and 20 μm.

Moisture, volatile, fixed carbon and ash content were determined by using of thermo gravimetric analyses. Thermo gravimetric analyzer is used to determine the composition of organic, inorganic, and synthetic materials. It measures weight loss as a function of temperature in a controlled environment. The instrument consists of a computer and a multiple sample furnace that allows up to 19 samples to be analyzed simultaneously. After an analysis method has been selected, empty crucibles are loaded into the furnace carousel. The analysis method controls the carousel, furnace, and balance operation. On completion of crucible tare, each crucible is presented to the operator for sample loading. The starting sample weight is measured and stored automatically. Once all the crucibles have been loaded, analysis begins. The weight loss of each sample is monitored and the furnace temperature is controlled according to the selected analysis method. The percent weight loss for each sample is reported at the end of each analysis step.

The elemental determinator is used to determine carbon, hydrogen, nitrogen and sulfur in organic matrices. The instrument utilizes a combustion technique and provides a result within 4.5 minutes for all the elements being determined. A pre-weighed and encapsulated sample is placed in the instrument's loader where the sample will be transferred to the instrument's purge chamber directly above the furnace, eliminating the atmospheric gases from the transfer process. The sample is then introduced to the primary furnace containing only pure oxygen, resulting in a rapid and complete combustion (oxidation) of the sample. Carbon, hydrogen and nitrogen present in the sample are oxidized to carbon dioxide (CO_2), water (H_2O), and NO respectively, and are swept by the oxygen carrier through a secondary furnace for further oxidation and particulate removal. The combination gases are then collected in a vessel known as ballast for equilibration. Then they pass into a helium carrier gas. Separate optimized non-dispersive infrared (NDIR) cells are utilized for the detection of H_2O and CO_2 ensuring the rapid analysis time of the system. The NO gases are passed through a reduction tube filled with copper to reduce the gases to N and remove any excess oxygen present from the combustion process. Sulfur content was determined in the second module. Analysis begins as a sample is weighed into a combustion boat and placed in the furnace with pure oxygen typically regulated at 1350 °C. Sulfur within the sample is

evolved from the sample and forms SO_2. The sample gases exiting the furnace are first swept through the boat stop to the back of the inner combustion tube, then forward between the inner and outer combustion tubes.
All tested parameters were realized 3 times and the results are average values.

RESULTS AND DISCUSSION

Particulate matter from biomass size distribution of analyzed sample is shown on fig. 1. The largest amounts of PM are in the size range 50 – 100 μm and 20 – 50 μm. The lowest amount of PM is in the size range over 500 μm.

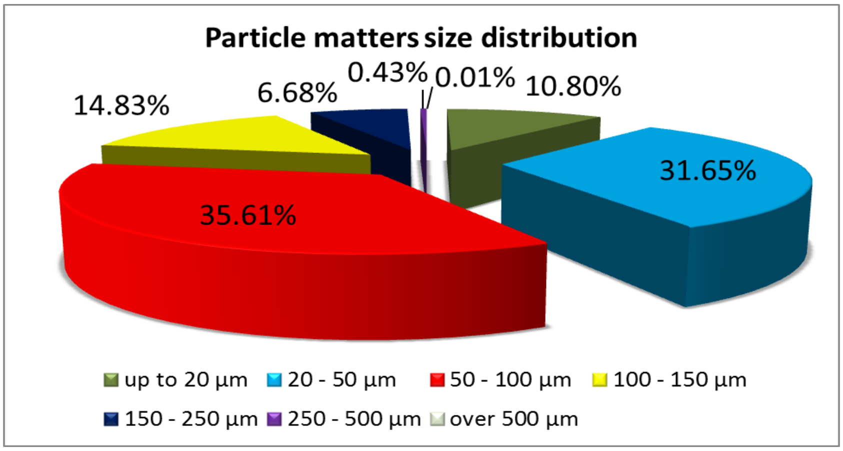

Fig. 1 Particulate matter from biomass size distribution

Results of the thermo gravimetric and elemental analysis of PM from biomass are shown in the tab. 1. Moisture content of PM from biomass was very low. Moisture of all tested PM samples was under value 0.2 %. This moisture in PM could be caused by moisture in flue gas and by air humidity which PM could absorb during manipulation. Volatile content of PM from biomass was 7.07 %. Fixed carbon content of PM from biomass was 2.35 %. These values of volatile and fixed carbon content could be caused by unburned combustible in obtained PM. These values also related with elemental analysis. The largest part of PM created ash (90.57 %). The elemental analysis shows that PM contains 8.63 % of carbon (C), 0.41 % of hydrogen (H) and 2.36 % of nitrogen (N). Sulfur in PM was not detected.

Tab. 1 Results of the thermo gravimetric and elemental analysis of PM from biomass

Parameter	Value	Variation	Unit
Moisture content	0.1414	±0.03909	%
Volatile content	7.07	±0.035	$\%_{\text{dry state}}$
Fixed carbon content	2.35	±0.866	$\%_{\text{dry state}}$
Ash content	90.57	±0.901	$\%_{\text{dry state}}$
C content	8.63	±0.441	%
H content	0.41	±0.1068	%
N content	2.36	±0.242	%
S content	0.0	±0	%

Based on the observation of the PM samples by using of stereomicroscope it can be estimated that each PM particle has geometrically irregular shape. With most of the particles have a fibrous shape, e.g. like shape, fiber, rod or needles. One dimension of the three-dimensional coordinate system should be significantly larger than the remaining two (fig. 2).

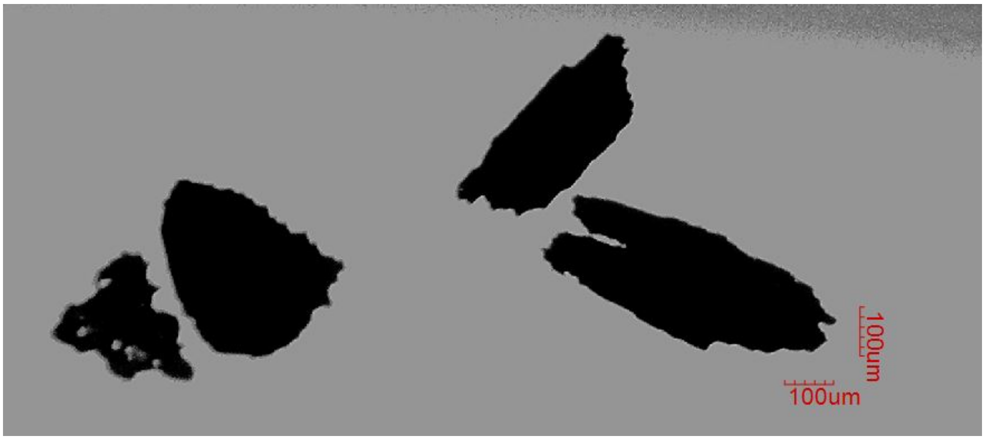

Fig. 2 PM from biomass samples magnified under the stereomicroscope

CONCLUSION

Knowing the causes of PM creation and its chemical composition is important for their elimination and for proposals of their creation reduction during biomass combustion. In this work they were analyzed individual PM samples from biomass combustion. PM size distribution showed that the most of particles has size in dimensions between 20 – 100 μm. Thermo gravimetric analysis showed that PM contains mostly ash and almost 10 % of volatiles and fixed carbon. Elemental analysis showed that tested PM contained 8.63 % of carbon, 0.41 % of hydrogen, 2.36 % of nitrogen and no sulfur. Stereo microscope observation of the samples showed that most of particles have geometrically irregular shape, the majority of which have the form of fibers, rods or needles.

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