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AIR POLLUTION BURNING DIFFERENT KINDS OF WOOD IN SMALL POWER BOILERS

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Abstract. Experimental investigations have been performed, during which different kinds of wood have been burnt (firewood, wood granules, wood briquettes, sawdust) with the aim to determine the quantities of gases emitted in the air. For the investigation a water boiler burnt by solid fuel with a nominal capacity of 20 kW was applied. For testing gas analyser Testo-350 was used to measure the quantity of gas dispersed into the air (in carbon monoxide – CO and nitrogen oxides – NO_x smoke, the quantity of oxygen – O_2, the smoke temperature of concentrations in the measurement spot). The quantities of harmful gaseous materials have been measured burning different kinds of wood.
The smallest quantities of gaseous materials have been obtained in the process of burning wood granules. The possibility to regulate the combustion process diminishes the gas emission.

Keywords: burning, wood granules, wood briquettes, local fuel, boiler of solid fuel.

1. Introduction

To satisfy the increasing energy demands, more and more organic fuel is burnt and much more gases, causing the greenhouse effect (carbon dioxide, nitrogen oxide, methane, etc.) get into the atmosphere (Vrubliauskas and Pedišius 2005). Consequently, use of local and shifting energy resources has been increasing in recent years.

The need to use shifting energy resources occurred when it was noticed that human activities were making negative effect on the climate's change. Energetics is the major source of gas emission causing the greenhouse effect in Lithuania. It happens so, as carbon dioxide is formed in the process of fuel burning. This gas concentrates in the atmosphere causing the phenomenon of global warming.

Another cause promoting the use of shifting energy resources is that the resources of mined fuel, i.e. coal, petroleum, gas are shrinking.

The development of energy manufacturing from shifting energy resources is the major goal of energy policy of the Republic of Lithuania indicated in the Energetics Law of the Republic of Lithuania (2002). The national energy policy (2007) provides for "aiming at a quantum of shifting energy resources in the primary energy balance in 2010 comprising up to 12% of the total energy input".

Biological fuel is a shifting energy resource making the least negative impact on the environment. This kind of fuel is mined and produced in Lithuania. The industry can lead to the solution of economical and social problems - the decrease of energetic dependence of the state on imported fuel (coal, petroleum, gas), the reduction of pollution of environmental air, establishment of new working places alongside with new sources of revenue in rural districts, and a positive influence on the country's ecological situation (Pedišius 2002).

The most promising shifting energy resource is assorted biological energy. The resources of biological energy involve miscellaneous wood fuel (firewood, shingles, sawdust, wood granules, wood briquettes, grass, straw, grain). Biogas and dumping gas are also ascribed to the types of biological fuel (Developing… 2004). Currently various kinds of wood fuel are most widely used of all types of shifting energy resources in Lithuania.

Carbon dioxide (CO_2), as well as noxious carbon monoxide- carbon (CO), nitrogen oxides (NO_x) and many other compounds are inevitably exuded during each burning process. On the contrary, use of wood fuel for heating has a far less effect on the environment than the use of mined fuel (Manual… 2005). The burning process of wood fuel produces less carbon dioxide (CO_2) and nitrogenous oxides (NO_x) than burning processes of oil products or coals. Furthermore, composition of sulphur dioxide (SO_2) and heavy metals is very low in combustion of these products. CO_2, produced in the burning process of wood fuel, is a part of natural carbon cycle in the nature, therefore it does not count and is equated to a zero (Miško… 2003).

The aim of this study is to confirm experimentally amounts of noxious gas (CO, NO_x) exuded into the environmental air during the processes of combustion and ascertain the optimal type of fuel in the terms of environmental air pollution.

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2. Testing technique

In pursuance of carrying out the experimental investigations, a solid fuel water boiler for the heating of various wood fuel was used. The nominal capacity of the boiler was 20 kW.

A programmable digital controller V 31 was used for monitoring and optimization of granular fuel burning. Wood granules of the diameter of 6–8 mm, extruded from sawdust, are mechanically passed into the boiler's burner for the combustion process. Solid fuel (firewood, coal, etc.) can be loaded into the boiler's burner through an in-load door and burnt inside there.

The experiments were carried out on the grounds of the requirements of Lithuanian standard LST EN 303–5. The amount of the boiler's emission was calculated during the nominal heating capacity. Composition values of carbon monoxide (CO) and nitrogen oxides (NO_x), smoke temperature and values of oxygen (O_2) were being defined throughout the whole investigation period.

Composition values of carbon monoxide (CO) and nitrogen oxides (NO_x), as well as oxygen composition (O_2) in smoke and smoke temperature were being estimated in the measurement places. Hard particles and hydrocarbons were not measured. The estimations of gas products were performed by the smoke analyser Testo-350. Promiles (ppm) on the analyser correspond to a thousandth part of a percent, i.e. they indicate the quantum of the material existing in the air.

Before starting the burning test of firewood, wood briquettes and sawdust, the boiler is heated with full in-load of the fuel (reaching maximum filling height) till it reaches normal working conditions.

The probationary period begins with the accomplishment of the obligatory heating basis.

The probationary period starts counting from the moment when the fuel is placed upon the burning base and finishes at the following in-load. In-load and ignition are reckoned into the testing time.

Before starting the test of granule burning, the boiler is heated till the working temperature using an appropriate amount of fuel. When necessary burning basis is formed, estimations of pollutant compositions are begun.

The fuel parameters used for testing are shown in Table.

3. Testing results and their analysis

Fuel burning is a chemical reaction of its combustible components with oxidiser (air oxygen). In case fuel and oxidiser take different states, system is called heterogeneous.

The speed of burning reaction depends on the chemical constitution of responsive substances, their composition and physical conditions, namely temperature, pressure and volume (Štreimikienė 2004).

Theoretically estimated air quantity necessary for fuel burning is not enough to start the combustion, due to the boiler's technological imperfection and insufficient commixture of fuel and air. That is to say, the amount of air supplied to the boiler is always higher than theoretically calculated amount of air.

The ratio value of air excess depends on the type of fuel, its burning manner, the boiler's design and other factors. It has to be from 1.3 to 1.4 for solid fuel. In the process of burning one should avoid air excess because the higher the excess, the more heat is necessary for its warming. This results in lower burning temperature making the boiler less economical (Švenčianas 2003).

In case the ratio of air excess is too high, not all oxygen is utilized in oxidation reactions or is withdrawn together with smoke.

Alongside the main burning products eliminated during the burning process of fuel, a number of detrimental substances are discarded, i.e. emissions which pollute the environment. Combusting biofuel is considered to be free of emissions. In fact they exist, only their amount is much smaller than burning mined fuel.

Diagrams were made for the analysis of the course of burning process (Figs. 1–5) presenting the results of separate burning processes during the whole period of combustion.

Fig. 1 presents the buning process of wood granules.

In the process of ignition, wood granules fall from the fuel tank into the burner where they are ignited. The main element of the combustible burning mass is coal. It makes the proportion of 50–60% of the wood. The composition of carbon monoxide varies from 127.78 to 343.18 mg/Nm^3 in the burning process of wood granules. The largest composition of CO (343.18 mg/Nm^3) was fixed on the 67th minute of burning. The CO composition varies in a very short interval because the fan blows air into the burning area. Smoke temperature is ≈ 250 °C.

Nitrogen, forming part of the wood structure, in reaction with oxygen becomes oxidized and overpasses the burning products. The composition of nitrogen oxides (NO_x) varies fractionally from 158.52 to 254.94 mg/Nm^3. The highest concentration of 254.94 mg/Nm^3 was fixed on the 54th minute of burning. Smoke temperature was ranging from 212 to 263 °C. The amount of oxygen in smoke was changing from 4.7 till 9.8%.

A large surface and a sufficiently big amount of oxygen, which is provided in the form of air, are necessary for good firewood burning. The coal existent in the composition of wood reacts with the air oxygen. When firewood burns in insufficient amount of oxygen, the incompletely burned gas is formed, i.e. carbon monoxide

Characteristics of the tested fuel

Properties/Type of fuel	Birch firewood	Wood granules	Wood briquettes	Sawdust
Caloric content (kJ/kg)	15 059	17 660	17 610	12 570
Amount of sulphur (%)	0.09	0.06	0.07	0.08
Humidity (%)	18	6-7	6.8	30
Ash-content (%)	1	0.49	0.66	1

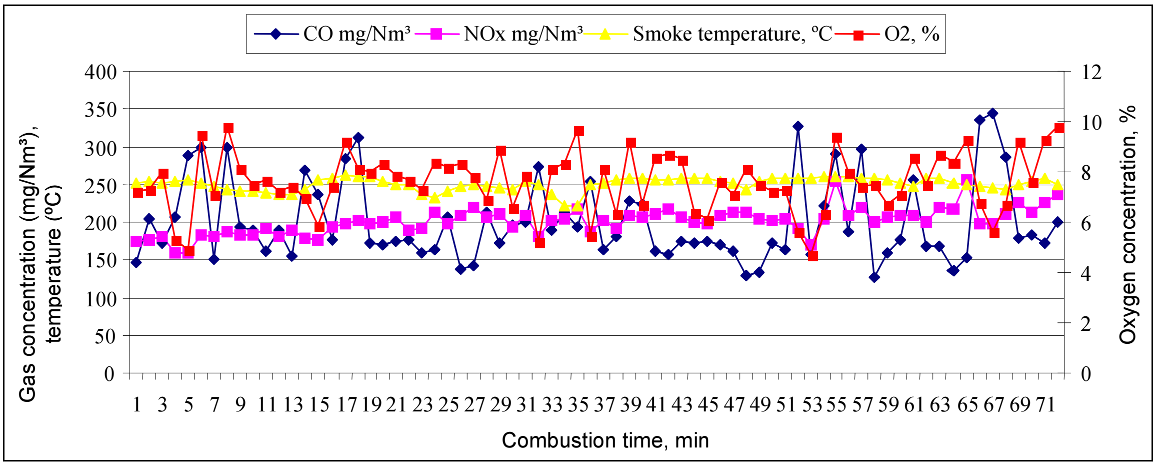

Fig. 1. Change of composition and temperature of smoke burning wood granules

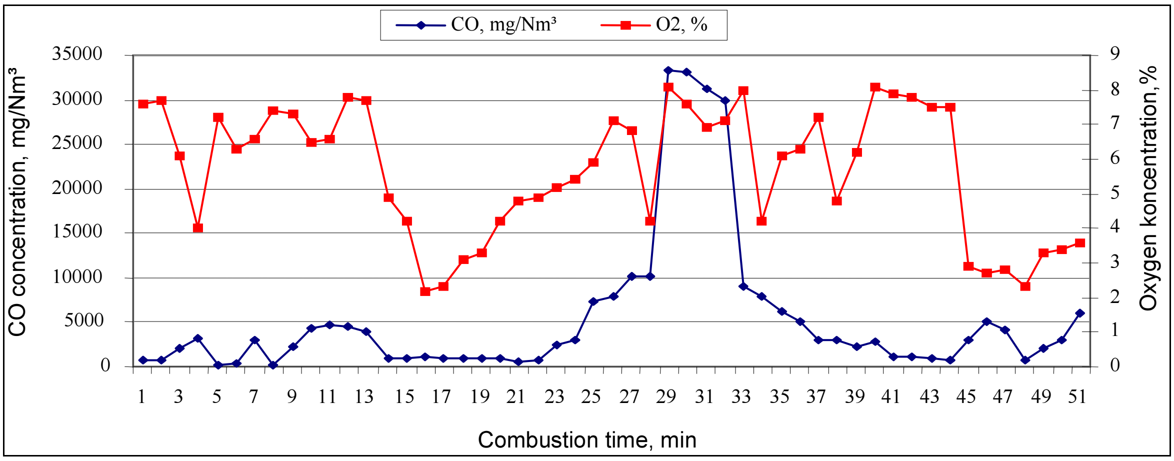

Fig. 2. Change of composition of smoke burning fire-wood

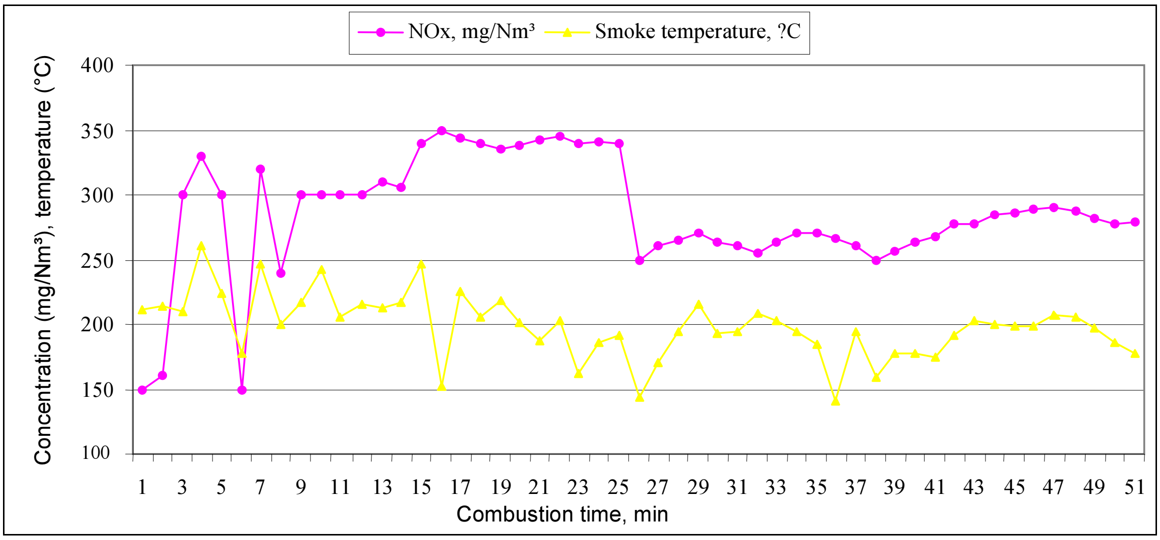

Fig. 3. Change of composition and temperature of smoke burning fire-wood

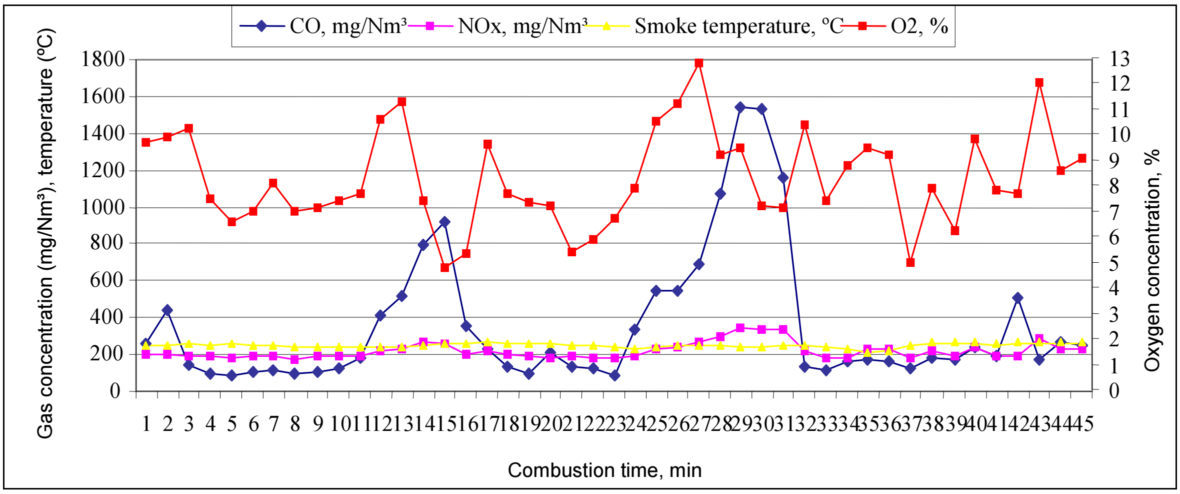

Fig. 4. Change of composition and temperature of smoke burning wood briquettes

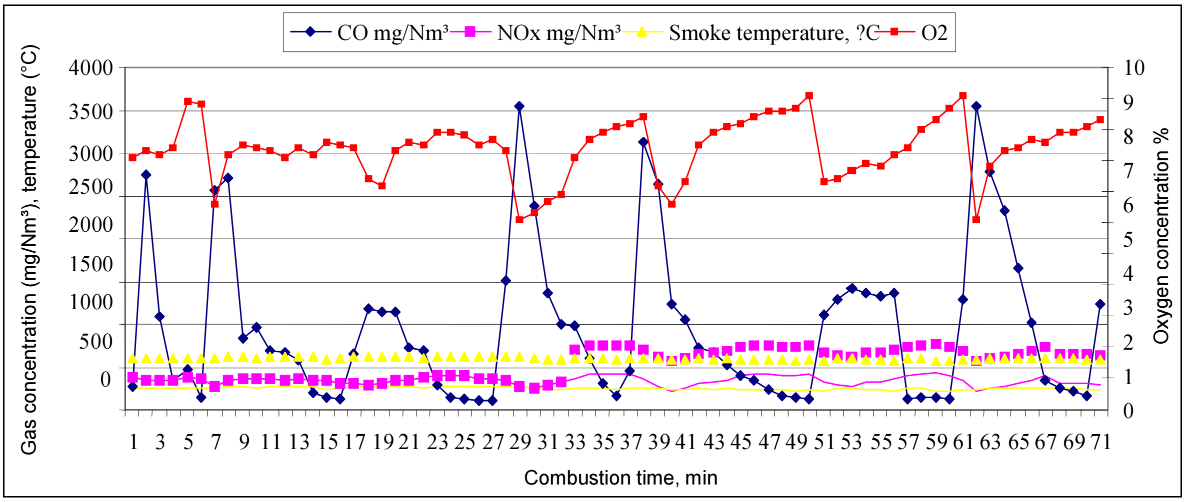

Fig. 5. Change of composition and temperature of smoke burning sawdust

(Defanas *et al.* 2001). Fig. 2 shows that the burning process of firewood is very unstable. The reason is, that during the burning process of firewood it is very difficult to control the burning process as well as the supply of air into the combustion chamber which is controlled by the primary and the secondary bolts. Because of the uneven firewood burning process, CO smoke constitution varies at a very wide range – from 200 to 33253 mg/Nm^3. The highest concentration of carbon monoxide (33253 mg/Nm^3) was fixed on the 31st minute of burning. The least was recorded on the fifth minute – 200 mg/Nm^3.

Temperature of smoke and composition of NO_x were fluctuating over a period of time during the combustion, i.e. temperature of smoke was ranging between 140 and 261 °C, whereas concentration of nitrogen oxides was ranging between 150 and 350 mg/Nm^3 (Fig. 3).

As the figures show, burning process of wood briquettes (Fig. 4) was similar to the burning process of firewood. It was due to the uneven supply of oxygen to the combustion chamber and high leaps of composition of carbon monoxide ranging between 82,03 and 1546,15 mg/Nm^3. The composition rise was determined by the temperature decrease in the combustion chamber (Kavaliauskas and Katinas 2004). Concentration of nitrogen oxides and temperature of smoke were very similar to the previous cases (from 173.52 mg/Nm^3 to 345.35 mg/Nm^3). When sawdust is burning, a bigger amount of carbon monoxide is emitted in the air because sawdust is powdery and in the process of burning small surface area is exposed to oxygen. The fuel burning results in smouldering and incomplete combustion.

CO gets in the atmosphere or part of unburnt fuel remains in ash (Štreimikienė and Bubeliene 2005). Thus the environment is exposed to pollution, and the boiler to durability and efficiency decrease. Carbon monoxide concentrations varied from 109.96 to 3549.53 mg/Nm^3. Smoke temperature and concentration of nitrogen oxides remained stable – 172–256 °C and 212.74–430.98 mg/Nm^3.

4. Comparable pollution analysis

As final part of the investigation process, comparative pollution analysis was carried out based on the experimental evidence. Carbon monoxide formation in the process of combusting different kinds of fuel is presented in Figs. 6 and 7.

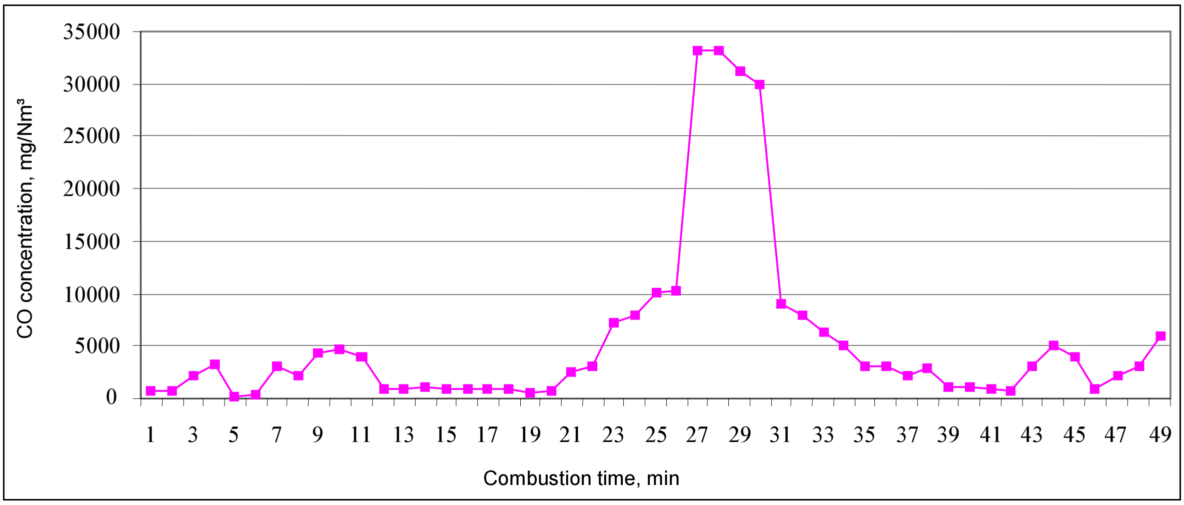

Fig. 6. Concentration of carbon monoxide in smoke burning fire-wood

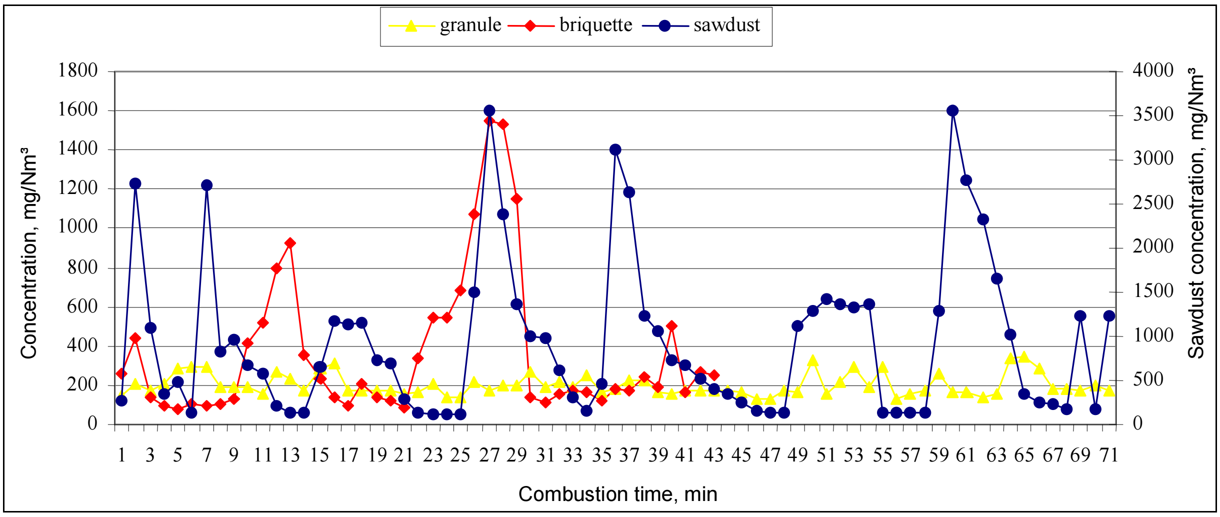

Fig. 7. Concentration of carbon monoxide in smoke burning granules, briquettes and sawdust

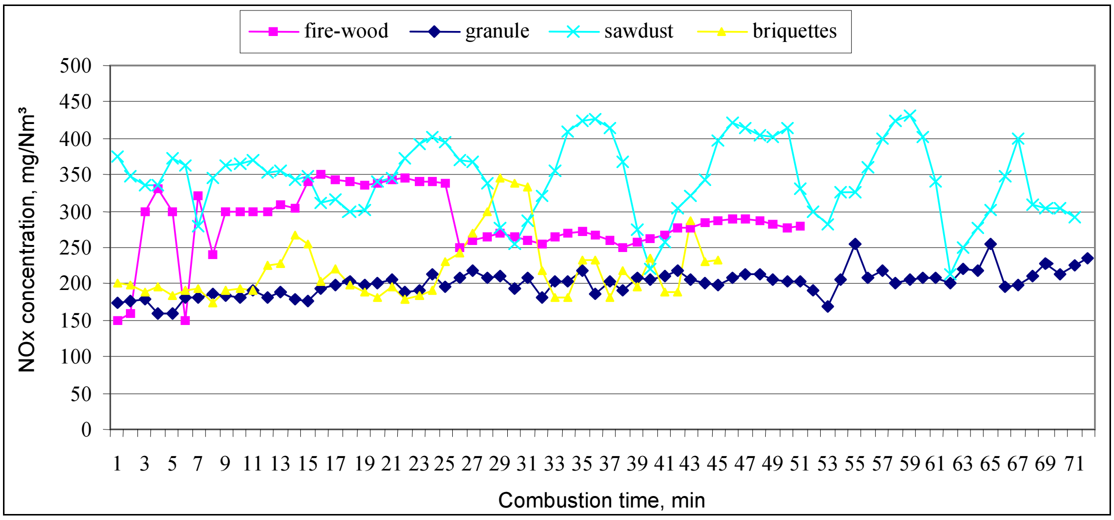

Fig. 8. Concentration of nitrogen oxides in smoke

Formation of carbon monoxide can be determined by several factors. One of them is moisture of solid fuel. Combusting moist fuel results in smouldering, therefore, more of CO is formed. Most CO was formed when firewood was burning – average CO concentration was 5368 mg/Nm^3, and the biggest 33253 mg/Nm^3. As the quantity of oxygen in the moment of combustion was sufficient, that could have happened because firewood slumped into the burning chamber.

It was also noticed that the least carbon monoxide was emitted burning granules (200 mg/Nm^3) – 27 times less than burning firewood (Fig. 7).

Burning sawdust discharges CO 4.7 times more than granules, and 2.7 times more than briquettes. Wood briquettes discharge 15 times less CO than firewood and 2.7 times less than sawdust. Maximum CO concentration variations were established combusting firewood and lowest CO concentration variation was registered when wood granules were combusting.Therefore, to improve the sawdust's combustion it is recommended to mix it and other kinds of fuel.

Emission of nitrogen oxides is determined by fuel composition (Jankauskas 2004). Nitrogen makes 0.2% of wood. During fuel combustion nitrogen does not emit heat and passes to combusting products, therefore, it is undesirable element of fuel (Kugelevičius *et al.* 2005). Quantity of nitrogen oxides is determined by the temperature of combustion. Having decreased the temperature in the centre of torch, quantity of oxidized air nitrogen as well as quantity of nitrogen oxides decrease. Quantity of nitrogen oxides is also influenced by concentration of free oxygen: having decreased its emission of nitrogen oxides decreases as well. Most nitrogen oxides are emitted combusting sawdust (344 mg/Nm^3), and least – wood granules (201 mg/Nm^3) (Fig. 8). Combusting other kinds of fuel nitrogenoxides are emitted in smaller amounts than combusting sawdust: granules 1.7 times, briquettes 1.6 times and firewood 1.2 times less than sawdust. Most concentration variations during the burning were established when sawdust was combusting, and least – burning wood granules.

5. Conclusions

During the experimental research, burning different kinds of wood fuel – sawdust, wood granules, wood briquettes and firewood, the following was established:

Most carbon monoxide is formed combusting firewood (average CO concentration was 5368 mg/Nm^3), and least – burning wood granules, which is 27 times less than combusting firewood. Least fluctuation of CO concentration was observed combusting wood granules, and most – burning firewood.

Most nitrogen oxides (NO_x) were discharged combusting sawdust (344 mg/Nm^3), and least – wood granules (201 mg/Nm^3), that is 1.7 times less. Briquettes (220 mg/Nm^3) and firewood (285 mg/Nm^3) take medium position in respect to nitrogen oxides. Maximum concentration fluctuations during the burning process were established combusting sawdust, and minimum – wood granules.

In comparison to other kinds of wood fuel burning granules form least gaseous products. Possibility to control combustion process reduces quantity of discharged gases.

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APLINKOS ORO TARŠA DEGINANT SKIRTINGAS MEDIENOS KURO RŪŠIS MAŽO GALINGUMO KATILUOSE

I. Gimbutaitė, Z. Venckus

S a n t r a u k a

Eksperimentinių tyrimų metu buvo deginamas įvairių rūšių medienos kuras – malkos, granulės, briketai ir pjuvenos, siekiant nustatyti degimo metu į aplinkos orą išsiskiriančių dujų kiekius. Tyrimams naudotas kietojo kuro vandens šildymo katilas, skirtas įvairioms patalpoms šildyti, kurio nominalusis galingumas 20 kW. Bandymo metu dujų analizatoriumi *Testo*-350 išmatuotos degimo metu į aplinkos orą išsiskiriančių dujų – anglies monoksido (CO), azoto oksidų (NO_x) koncentracijos dūmuose, deguonies (O_2) kiekis, taip pat dūmų temperatūra koncentracijų matavimo vietoje. Išanalizuoti išsiskyrusių degimo metu dujinių teršalų kiekiai deginant skirtingas medienos kuro rūšis.
Mažiausiai dujinių medžiagų, palyginti su kitomis medienos kuro rūšimis, susidaro deginant granules. Galimybė reguliuoti granulių degimo procesą sumažina išmetamų dujų kiekį.

Reikšminiai žodžiai: degimas, medienos briketai, medienos granulės, vietinis kuras, kietojo kuro katilai.

ЗАГРЯЗНЕНИЕ АТМОСФЕРНОГО ВОЗДУХА ГАЗОВЫМИ ВЫБРОСАМИ ПРИ СЖИГАНИИ РАЗЛИЧНЫХ ВИДОВ ДРЕВЕСНОГО ТОПЛИВА В КОТЛАХ НЕБОЛЬШОЙ МОЩНОСТИ

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Р е з ю м е

Проведены экспериментальные исследования сжигания различных видов древесного топлива – дров, гранул, брикетов, опилок – с целью установить количество попадающих в атмосферу газовых выбросов, образующихся во время сжигания. Для эксперимента использован водяной котел, подогреваемый твердым топливом. Мощность котла – 20 kW. Газовые выбросы, попадающие в атмосферу в процессе горения, измерялись газовым анализатором Testo-350. Установлены концентрации CO и NO_x в дымовом потоке, количество O_2, температура дыма в местах измерения концентраций. Проанализированы количественные показатели газовых выбросов, образовавшихся при сжигании различных видов древесины. Наименьшее количество газовых выбросов по сравнению с другими видами древесного топлива образуется при сжигании древесных гранул. Возможность регулировать процесс сжигания гранул уменьшает эмиссию газов.

Ключевые слова: сжигание древесины, древесные гранулы, древесные брикеты.

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