CHIP AND CHIPLESS WOODWORKING PROCESSES, 11(1): 271–275, 2018
Zvolen, Technical University in Zvolen, ISSN 1339-8350 (online), ISSN 2453-904X (print)

MECHANICAL AND ENERGETIC PROPERTIES OF WOOD PELLETS DEPENDING ON BARK CONTENT

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Abstract
Wood pellets are very used fuel in small heat sources in Europe. This paper deals with mechanical and energetic properties of wood pellets depending on bark content. It evaluates fine material amount and mechanical durability, moisture, volatile, fixed carbon, ash content, carbon, hydrogen, nitrogen and sulfur content, ash fusion temperature, gross calorific value and net calorific value, CO, NOx and OGC and PM concentrations of used wood pellets samples. Wood pellets samples were gradually created with 0%, 5 %, 10 % and 20 % content of bark.

Key words: *wood pellets, bark*

INTRODUCTION

Wood pellets combustion is a very used source of an energy. Poor fuel quality yields high emissions also from new boilers. Bark content in wood pellets influences also the fuel quality (Johansson et al., 2004). It has impact on following parameters: moisture content, ash content, ash fusion temperature, produced emissions and also particulate matter (PM) (Vitázek et al., 2016). High moisture in wood pellets leads to lower net caloric value and causes incomplete combustion in the combustion appliance. High content of bark results in more frequent maintenance of heat sources as bark contains more ash than barkless wood. Increased ash content also generates higher amount of particulate matter, which are very harmful emissions (Filbakk et al., 2011). Particulate matter is solid and liquid material in the atmosphere, mixture of substances consisting of carbon, dust and aerosols (Dzurenda, Pňakovič, 2016)

This paper deals with mechanical and energetic properties of wood pellets depending on bark content. It evaluates fine material amount and mechanical durability measured by using Ligno Tester, moisture, volatile, fixed carbon and ash content determined by using thermogravimetric analyses, carbon, hydrogen, nitrogen and sulfur content determined by using elemental determinator, ash fusion temperature, gross calorific value and net calorific value, CO, NO_x and OGC concentrations measured using by gas analyzer and PM concentrations measured by gravimetric method using by isokinetic automatic sampler. Wood pellets samples were gradually created with 0%, 5 %, 10 % and 20 % content of bark.

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MATERIAL AND METHODS

The samples of wood pellets were produced on a specialized device in an external laboratory for pelletizing. As the input material for pelletizing was used dry spruce wood sawdust. Pellet mill was with capacity of 1000 $kg.h^{-1}$.
Fine material amount and mechanical durability were measured by using Ligno Tester. The Ligno Tester is operated by loading a manually weighed sample of pellets into the test chamber. After the test cycle, the pellets are manually removed and weighed to calculate the fine material amount or mechanical durability. Fines and dust are removed during the test process for a fair and accurate test.
Moisture, volatile, fixed carbon and ash content were determined by using thermogravimetric analyses. 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 (Guan et al., 2016).
The elemental determinator was used to determine carbon, hydrogen, nitrogen and sulfur. 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. 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 (Eksperiandova et al., 2011).
Ash fusion temperature was determined according to STN ISO 540. Ash for testing was prepared in accordance STN ISO 1171. Ash was smashed in bowl to ensure particles less than 0.063 mm. Smashed ash was mixed with distillated water to the paste which is put to the form. Formed ash called test corpuscle must have sharp edges and is glued to templet. Deformed or damaged test corpuscle must be taken out from testing. During testing was a recorded characteristic of temperature, such as:

- Deformation temperature (DT) – test corpuscle has rounds on tip or ends because of starting melting
- Sphere temperature (ST) – test corpuscle has rounds on edges because of starting melting
- Hemisphere temperature (HT) – test corpuscle has about hemispherical shape, height is about the same like basement
- Flow temperature (FT) – ash is flowed on templet which has 1/3 height of test corpuscle at temperature in hemispherical shape

Gross calorific value was determined according to STN EN 14918 using calorimeter LECO AC 500. From gross calorific value was determined net calorific value by relation:

$$Q_i = Q_S - 2{,}453.(M_{ar} + 9H_2)\ (MJ.kg^{-1}) \quad (1)$$

Q_S is net calorific value of fuel, M_{ar} is relative humidity of fuel and H_2 is hydrogen content of fuel.
The samples were burned in a hot water boiler with a rated output of 18 kW. This boiler was tested on an experimental device designed for the measuring of emission production.

Experimental device for testing was built from an experimental boiler, a heat consumption device, a gaseous emission analyzer, a particulate matter analyzer, measuring apparatus to which all measuring instruments are connected and a computer for the processing of measured data. During the measurements constant chimney draft 12 ± 2 Pa via a flue fan is ensured. Its speed is controlled by a frequency regulator. All pellet samples with various bark content were burned at the same operating settings of the boiler.

CO, NO_x and OGC concentrations in flue gases were measured by a flue gas analyzer ABB AO 2020 with sensor modules Uras 26 with accuracy ≤ 1 % of span and oxygen analyzer module Magnos 206 with accuracy ± 0.5%. The piping for the sampling operations must be incorporated with means for cooling, cleaning and drying flue gas samples.

Particulate matter concentrations were measured by gravimetric method by using of the isokinetic automatic sampler TECORA Isostack Basic. Gravimetric method is given by the standard ISO 9096. It is a manual, single-use method where samples are taken by a probe from flowing gas. Filtration materials are weighed before and after measurements and final mass concentration is calculated from a sample volume. Sampling probes can be placed either directly into hot flow of exhaust gases or outside the flow, where these systems must be heated. Solid particles are collected from flowing gas with the help of the probe. From them an average concentration of flowing gas particles is determined. Exhaust gases were taken from a chimney duct with the help of a three-stage separation impactor. The sampling was conducted at the same speed of exhaust gas flow as in the pipe. Hot gas was led from the pipe through cooling and drying equipment up to the sampling unit. In the cooling equipment exhaust gases were cooled and water vapour was removed from the exhaust gas sample. In the silica gel-water absorption tower residual moisture of exhaust gases was removed.

RESULTS

Table 1 shows results from Ligno Tester. There are stated fine material amount and mechanical durability.

Tab. 1 Results from Ligno Tester

	Fine material amount		Mechanical durability	
Sample	**Value**	**Unit**	**Value**	**Unit**
0 % bark content	0.91	g	97.54	%
5 % bark content	0.95	g	96.25	%
10 % bark content	1.06	g	98.44	%
20 % bark content	0.81	g	97.99	%

Results from thermogravimetric analyzer are showed in the Table 2. We can see values of moisture, volatile, fixed carbon and ash content.

Tab. 2 Results from thermogravimetric analyser

Sample	Moisture	Volatile	Fixed carbon	Ash content	Unit
0 % bark content	6.64	81.84	17.64	0.52	%
5 % bark content	6.81	81.21	18.01	0.77	%
10 % bark content	6.67	80.91	18.16	0.94	%
20 % bark content	7.29	79.83	18.65	1.51	%

Results from elemental determinator are stated in the Table 3, where is carbon, hydrogen, nitrogen and sulfur content.

Tab. 3 Results from elemental determinator

Sample	Carbon	Hydrogen	Nitrogen	Sulfur	Unit
0 % bark content	48.55	6.33	0.13	0.08	%
5 % bark content	49.55	6.01	0.02	0.06	%
10 % bark content	49.49	6.16	0.05	0.05	%
20 % bark content	49.59	6.14	0.06	0.03	%

Table 4 shows results of ash fusion temperature. You can see Deformation temperature (DT), Sphere temperature (ST), Hemisphere temperature (HT) and Flow temperature (FT).

Tab. 4 Results of ash fusion temperature

Sample	DT	ST	HT	FT	Unit
0 % bark content	1320	1400	1420	1475	°C
5 % bark content	1240	1260	1365	1380	°C
10 % bark content	1295	1400	1410	1415	°C
20 % bark content	1180	1200	1210	1315	°C

Gross calorific value and net calorific value are stated in the Table 5.

Tab. 5 Results of gross calorific value and net calorific value

Sample	Gross calorific value	Net calorific value	Unit
0 % bark content	18.96	17.37	MJ/kg
5 % bark content	18.78	17.20	MJ/kg
10 % bark content	18.00	17.04	MJ/kg
20 % bark content	17.01	16.91	MJ/kg

Results from measured emissions are stated in the Table 6.

Tab. 6 Results of measured emissions

Sample	CO	NO_x	OGC	PM	Unit
0 % bark content	795.84	228.55	30.01	35.54	mg/m^3
5 % bark content	1598.11	177.05	13.33	46.41	mg/m^3
10 % bark content	2718.5	149.09	89.48	48.53	mg/m^3
20 % bark content	3613.65	199.88	69.65	57.72	mg/m^3

CONCLUSION

Based on the results, we can conclude that bark content in pellets has an impact on their mechanical and energetic properties. Higher bark content in pellets increases ash content, which can adversely influence combustion process, mainly due to higher ash production during combustion and consequent necessity of more frequent boiler cleaning. But very serious shortcoming is the fact that with higher bark content, ash fusion temperature decreases. Lower ash fusion temperature can cause some problems within combustion process, for example, to lower heat transfer intensity in heat exchangers, to cause corrosion of combustion equipment, to prevent fuel and combustion air supplies, etc. But wood bark has relatively high net calorific value. Therefore, its potential can be energetically used. Attention should be paid to its negative impact on the environment due to higher concentrations of CO, NO_x and PM as mentioned in this article.

Acknowledgements

This work was supported by the projects KEGA 046ŽU-4/2016 "Unconventional systems using renewable energy" and KEGA 033ŽU-4/2018 "Heat sources and pollution of the environment".

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