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Impact of Pellet Raw Material on the Energy and Environmental Characteristic of Low Power Domestic Stoves

Technical paper

The results of experimental tests for determine thermal and environmental characteristics of low power pellet stove (8.5 kW) for combustion of wood pellets used for household heating are presented in this paper. Test procedure as well as design and manufacturing of test installation were carried out in accordance with the requirements of the applicable European regulation EN 14785 for ovens of this type. Test installation was designed and assembled in the Laboratory for Fuel and Combustion at the University of Belgrade, Faculty of Mechanical Engineering. Tests were conducted for three thermal loads of the stove (minimum, medium and maximum) and three types of test fuel. Used test fuels were produced from beech wood, fir wood and their mixture, which allowed determining impact of pellet raw material on combustion process. Recalculation of test results in accordance with the requirements of a standard provided determination of energy and environmental characteristics of the tested stove and its classification according to the criteria defined by standard EN 14785.

Key words: *pellets, small scale pellet stove, energy and environmental characteristics, raw material*

Introduction

Production of pellets from biomass especially from wood was rather increased in recent years, according to demands from European energy market. Nowadays wood pellets could be used in all areas for energy production from small scale combustion appliances up to large scale energy plants. Using wood pellets for heat production is mainly in households as well as combined heat and power (CHP) production in medium and large energy systems. Advantages like automatic feeding, comfort use and relatively low maintenance costs with high efficiency of combustion process made pellets highly recommended for heat production especially in small scale pellet stoves and boilers for household heating. Enlarged consumption of wood pellets made a possibility for using different raw materials (different wood species and their mixtures) for pellet production.

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Basic aim of the experimental investigations described in this paper was to obtain influence of raw material for wood pellet production on combustion process in small scale pellet stove. During the realization of the experiments three types of wood pellets were used on nominal and reduced thermal loads, and thermal and environmental characteristics of investigated pellet stove were tested.

Experimental tests

All experimental tests in this paper were done on a small scale pellet stove used for heating air in households with declared thermal output of 8.5 kW. Schematic view of vertical cross-section of investigated pellet stove is presented on fig. 1.

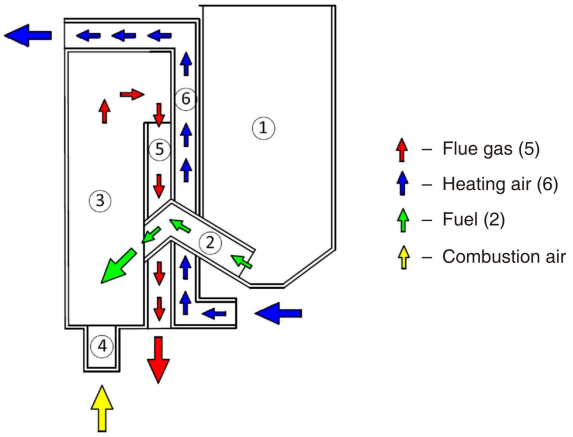

Figure 1. Schematic view of investigated pellet stove
(full color figure is available in electronic version)

Pellets from the built-in reservoir (1) with screw conveyor (2) are inserted from above into the combustion chamber (3) and fall into the burning pot (4), which is perforated from the bottom. Fan for hot gasses suck the flue gas from the combustion chamber providing slight under pressure (5-10 Pa) in it. This under pressure provides draft for airflow required for the combustion process, from the bottom of the burning pot, through circular holes. Flue gasses from the combustion chamber are extracted by exhaust fan through the flue duct (5) to output section of the stove. Second fan introduce the air for room heating through the air duct (6) over heat exchanger and counter flow from flue gasses. This allows heat exchange between hot flue gasses and heated air for room heating.

Test procedure and installation

The test procedure for experimental investigations of pellet stove was defined according to the demands of regulation EN 14785. Experimental tests were conducted for nine experimental regimes of investigated pellet stove. Three test fuels (marked as P_1, P_2, and P_3) and three thermal loads (reduced, medium, and nominal marked as Nominal_TL and Reduced_TL, respectively) were tested.

The test installation was designed and constructed in the Fuel and Combustion Laboratory at the Faculty of Mechanical Engineering, according to the demands of regulation EN 14785 (fig. 2). It consists of investigated appliance, weight scale and measurement section for flue gas composition, temperature, and flow. The investigated pellet stove prepared for the test is shown on fig. 3.

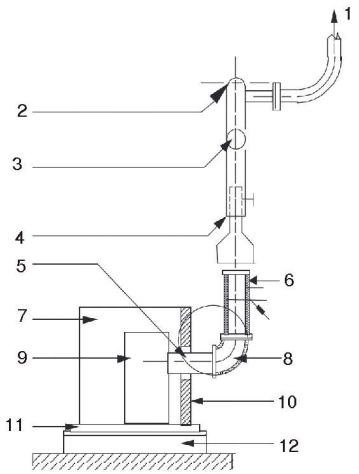

Figure 2. Test installation used for investigations [1] *(1) – exaust to atmosphere, (2) – fan, (3) – adjustable dumper, (4) – adjustable gather, (5) – flue gas connector, (6) – measurement section, (7) – trihedron side wall, (8) – flue gas adaptor – bend, (9) – pellet stove, (10) – trihedron side wall, (11) – trihedron test hearth, (12) – platform scale*

Figure 3. Pellet stove on the test installation

Test fuels

Three different wood pellets were used as test fuels for the experimental investigations. All pellets are produced with same type of pellet press (presses with vertical die), but with different raw materials. Raw materials used for producing test fuels were hard wood represent by beech wood (BW), and soft wood represent by fir wood (FW). Survey of used raw materials for investigated test fuels are presented in tab. 1.

Table 1. Raw materials for test fuels

	P_1	P_2	P_3
Raw material	BW	50% BW + 50% FW	FW

Proximate and ultimate analysis of all test fuels was made according to the regulation EN 14961.

Test results

Results obtained during the experiments were classified in 4 groups:
- fuel analysis,
- combustion process,
- thermal characteristics, and
- environmental characteristics.

Fuel analysis

Analysis of all test fuels was made according to the regulation EN 14961. Proximate analysis was made in the Fuel and Combustion Laboratory and ultimate analysis in the Institute for chemistry, technology and metallurgy – Center for chemistry. The results of proximate and ultimate analysis (only for as received mass) and density (particle and bulk) for all test fuels are given in the tab. 2. All test fuels were classified according to EN 14961-2.

Table 2. Proximate and ultimate analysis of test fuels (as received)

	P_1	P_2	P_23
Proximate analysis			
Total moisture [% mm^{-1}]	6.86	9.85	8.65
Ash [% mm^{-1}]	1.20	1.76	0.96
Combustibles [% mm^{-1}]	92.0	88.4	90.4
Volatiles [% mm^{-1}]	77.1	75.3	76.3
Fixed carbon [% mm^{-1}]	14.9	13.1	14.1
High heating value [$kJkg^{-1}$]	18359	17928	18755
Low heating value [$kJkg^{-1}$]	16801	16265	17051
Ultimate analysis			
Carbon [% mm^{-1}]	44.6	45.39	45.49
Hydrogen [% mm^{-1}]	6.16	6.30	6.61
Nitrogen [% mm^{-1}]	0.17	0.10	0.12
Sulphur [% mm^{-1}]	–	–	–
Oxygen, as the difference [% mm^{-1}]	41.0	36.6	38.2
Physical characteristics			
Density [kgm^{-3}]	1013	1059	1035
Bulk density [kgm^{-3}]	648	688	652
Pellet class*	A2	A2	A1

* According to EN 14961-2

Combustion process

Results of combustion process obtained during experiments and used for determination thermal and environmental characteristics of investigated stove were:
– fuel consumption,
– oxygen (O_2) content in flue gas,
– carbon dioxide (CO_2) content in flue gas, and
– flue gas temperature.

Results of fuel consumption for each experimental regimes (TL_1 – minimum, TL_3 – medium, TL_5 – maximum) are given in tab. 3.

Table 3. Fuel consumption in kg/h for all experimental regimes

	P_1	P_2	P_3
TL_1	0.60	0.61	0.52
TL_3	1.00	0.96	1.02
TL_5	1.70	1.63	1.68

Mean values of O_2 and CO_2 content in flue gas and flue gas temperature during experimental tests are presented in figs. 4, 5, and 6, respectively.

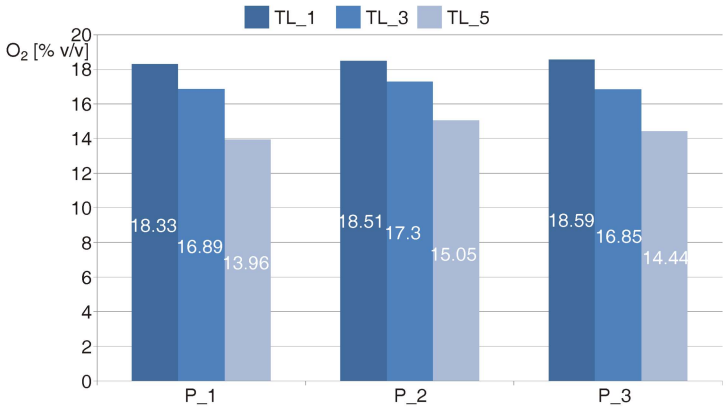

Figure 4. Oxygen content in flue gas for all experimental regimes
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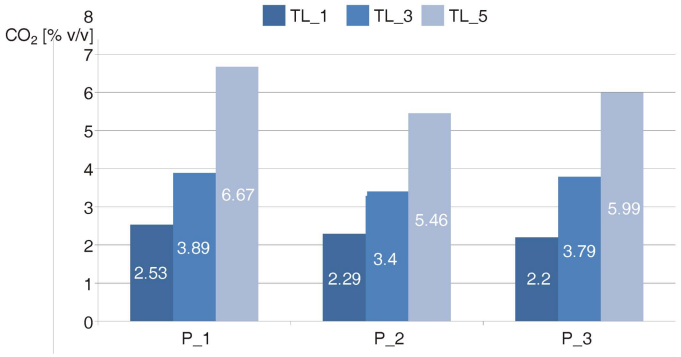

Figure 5. Carbon dioxide content in flue gas for all experimental regimes
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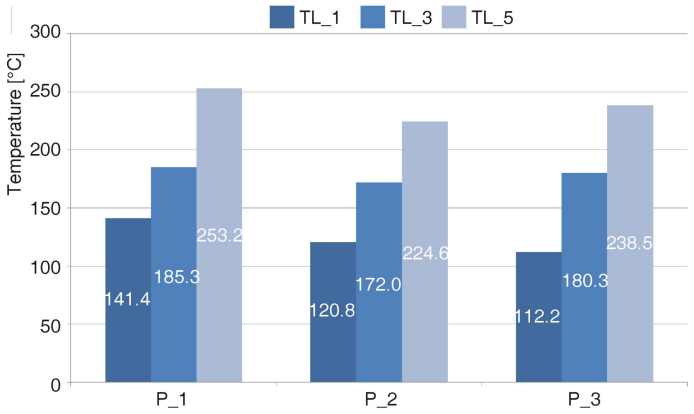

Figure 6. Flue gas temperature for all experimental regimes
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Thermal characteristics

For all experimental regimes, thermal characteristics that were determined during the tests were:

– obtained heat output, and
– total efficiency of the pellet stove.

All calculations of listed thermal characteristics were conducted according procedures defined in EN 14785 and based on obtained experimental results for each firing regime. Results of thermal characteristics from the tests of investigated pellet stove for different test fuels and different thermal loads are given in fig. 7 (obtained heat output) and fig. 8 (total efficiency).

Regulation EN 14785 does not have strict limits for the nominal heat output of pellet stove. However, total efficiency is defined and according to this regulation shall be at least 75% at nominal heat output and 70% at reduced heat output.

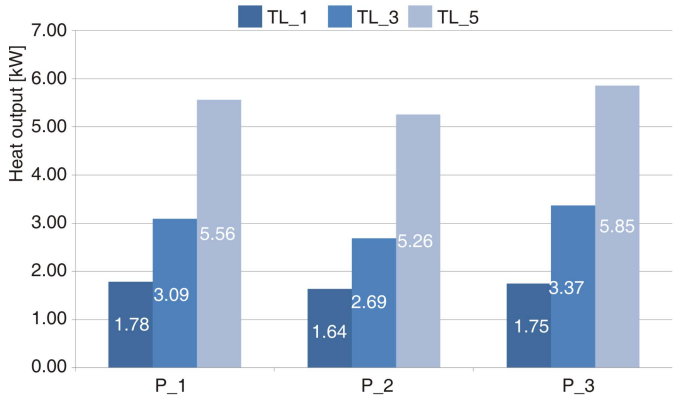

Figure 7. Obtained heat outputs for all experimental regimes
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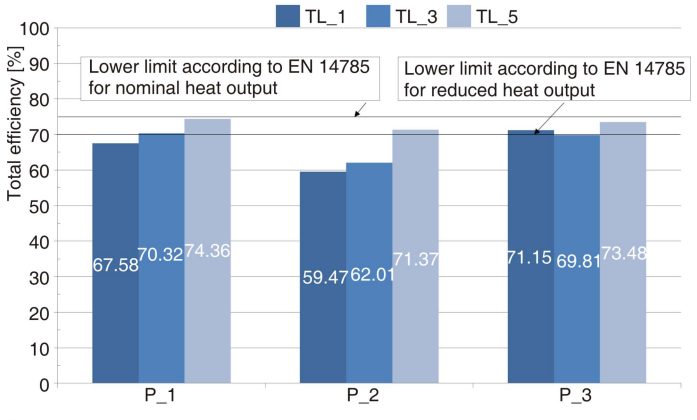

Figure 8. Total efficiency for all experimental regimes
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Environmental characteristics

Under environmental characteristics only CO emission level is defined by the regulation EN 14785. According this standard, during testing, maximum permitted mean CO concentration based on 13% of O_2 content in flue gas can be 0.04% v/v (500 mg/m^3) at nominal heat output and 0,06% v/v (750 mg/m^3) at reduced heat output.

Results of CO emissions (calculated on 13 %v/v O_2 content in flue gas) from the tests of investigated pellet stove for different fuel types and different thermal loads are given in fig. 9.

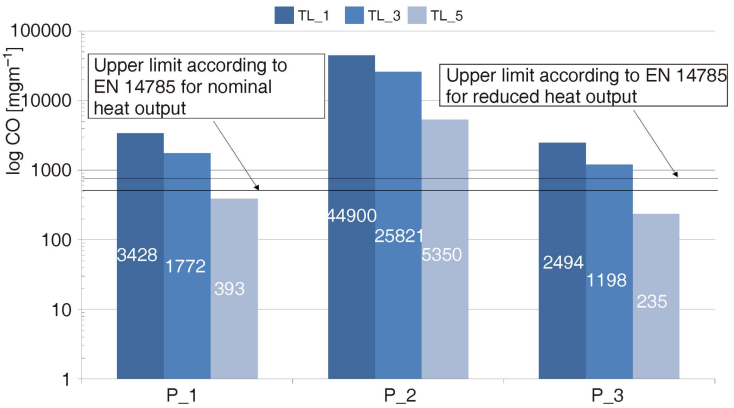

Figure 9. CO emission for all experimental regimes
(full color figure is available in electronic version)

Conclusions

Using wood pellets for heat production in small scale pellet stoves and boilers could be increased significantly. The importance of this type of heating appliances is em-

phasized by the all advantages using pellets especially for household heating. European regulation EN 14785 has brought clear test procedures and strict limits for heating appliances fired with this type of solid biofuel.

According to results of combustion process for investigated small scale pellet stove obtained from the tests made completely by demands of EN 14785, which are presented in this paper, it can be concluded that:

– total efficiency required by EN 14785 for nominal heat output (more than 75%) was not achieved for neither experimental regime;
– total efficiency required by EN 14785 for reduced heat output (more than 70%) was achieved for maximum thermal load (TL_5) with all test fuels, for medium thermal load (TL_3) with test fuel (P_1) and for minimum thermal load (TL_1) with test fuel (P_3);
– total efficiency for other thermal loads for this two test fuels was slightly below this limit,
– CO emission limit for the nominal heat output (less than 500 mg/m3 at 13% O_2) was achieved only for maximum thermal load (TL_5) with test fuels (P_1) and (P_3). With other test fuels and for other thermal loads this demand of EN 14785 was not fulfilled;
– CO emission for test fuel (P_2) was higher for all thermal loads it has varied from 5350 mg/m^3 to 44900 mg/m^3.

Obtained results from experimental tests (according to standard EN 14785) presented in this paper have proved the impact of raw materials and their mixtures for pellet production, on the energy (the most interesting for consumers) and environmental characteristics of the investigated pellet stove. All of these experimental tests were perfomed for fixed stove construction (chosen small scale pellet stove available on the Serbian market) and under the same combustion conditions (the amount of fresh air flow rate due to the regulation systems for chosen thermal load). Also according to obtained results for thermal output and total efficiency it is possible to make an improvement of investigated stove construction and combustion process. These facts will be the subject of further investigations of the authors.

References

[1] ***, ONORM EN 14785:2006. Residential space heating appliances fired by wood pellets – Requirements and test methods, Osterreichisches Normunginstitut, Wien
[2] Manić, N., Jovanović, V., Stojiljković, D., Results of Experimental Investigation According to EN 14785 (2011), *Proceedings,* 10th International Conference DEMI 2011, Banja Luka, BIH, pp. 538-549
[3] Stojiljković, D., *et al*., Investigations of Combustion Process in Stove Fired on Biomass, *Journal of Mechanical Engineering, 51* (2005), 7-8, 426-430
[4] Verma , V. K., *et al*., Performance of a Domestic Pellet Boiler as a Function, *Biomass and Bioenergy, l35* (2011), 1, 272-279

Апстракт

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Утицај сировине за производњу пелета на енергетске и еколошке карактеристике пећи мале снаге за загревање домаћинстава

У раду су приказани резултати експерименталних испитивања енергетских и еколошких карактеристика пећи мале снаге (8,5 kW) за сагоревање дрвених пелета која се користи за загревање домаћинстава. Целокупни поступак испитивања као и пројектовање и израда испитне инсталације извршена су у складу са захтевима важећег Европског прописа EN 14785 за ову врсту пећи. Експериментална инсталација је пројектована и изведена у Лабораторији за горива и сагоревање Машинског факултета Универзитета у Београду. Испитивања су обављена за три топлотна оптерећења пећи (минимално, средње и максимално) и са три врсте испитног горива. Као испитна горива коришћени су пелети произведени од буковог дрвета, чамовине и њихове мешавине, чиме је омогућено одређивање утицаја сировине за производњу пелета на процес сагоревања. Обрадом резултата испитивања у складу са захтевима стандарда омогућено је одређивање енергетских и еколошких карактеристика испитиване пећи и њена класификација према критеријумима дефинисаним стандардом EN 14758.

Кључне речи: *пелети, пећ мале снаге на пелете, енергетске и еколошке карактеристике, сировине*

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