THE INFLUENCE OF THE SAWDUST BRIQUETTES GEOMETRIC PARAMETERS ON THE CONVERSION EFFICIENCY

Teodora DEAC, V. ROS, F. MARIASIU, M. DEAC

Technical University of Cluj-Napoca, Cluj-Napoca, B-dul. Muncii, no.103-105, Cluj, Romania
E-mail:Teodora.Deac@arma.utcluj.ro

Abstract: *Sawdust briquettes are characterized by different geometric parameters (length, diameter and geometric form), depending on the briquetting press characteristics. Geometric parameters of the sawdust briquettes have an influence on the energetic conversion. In the present paper we examine the influence of the length of cylindrical sawdust briquettes on the efficiency of their conversion into heat. For this purpose, the energetic efficiency of the conversion process for cylindrical sawdust briquettes in different length and from two different wood species has been analyzed. The efficiency of the conversion process was evaluated as the ratio between the energy resulted at the end of the conversion process and the energy introduced in the system through the solid biofuels used. In order to assess the input biofuel energy, the calorific value of each biofuel was evaluated using the calorific method according to the existing standards Also, a technical analysis of the fuels was performed in order to assess the ash content, the volatile matter and charcoal content. In order to assess the thermal energy obtained in the conversion process, and stored in the thermal agent, a test bench was used, consisting in a boiler with direct combustion and natural draft, radiators for domestic space heating, and a data acquisition system with temperature sensors to establish the thermal agent temperature variations on tour and retour on a complete working cycle. The heat embodied in combustion air was neglected, being considered a limitation of the system, because due to the natural convection of the boiler it could not be evaluated accurately. The sawdust used in experimental research was from two wood species, fir and beech, collected from Apuseni Mountains (fir) and Cluj-Napoca (beech). From the collected sawdust three types of sawdust briquettes were prepared, characterized by the wood species: beech, fir and beech and fir mixed in equal proportions of 50%, their geometrical shape – cylindrical, variable length - 30mm, 50mm and 70mm and constant diameter – 55mm.The results showed an influence of sawdust briquettes length on the conversion efficiency. This is due mainly to the variations in the energy stored in the thermal agent varying with the length of the briquettes. The analysis of energy consumed in the conversion process through fuels shows that it is influenced by the length briquettes use in a very low proportion. This is especially influenced by the different values of the calorific value and energetic density of fuels.*

Key words*: *biomass, conversion efficiency, sawdust briquettes, thermal energy.

INTRODUCTION

Due to climatic conditions and geographical position, Romania has a technical potential of biomass energy from estimated to be 0.318 EJ/year or 88.3 TWh/year [7]. At national level the theoretical potential of biomass is characterized by it's regional distribution. Around 90% of fuel wood and 55% of wood wastes are located in Carpathian Mountains and 54% of agricultural wastes are in South Plain and Moldavia Regions.

The main source of fuel wood and wood wastes is the national forest fund. In 2006 [6], from total area of Romania, about 26.7% (6,382,200 ha) was covered by forests, and the woody biomass potential was estimated at about 6.97×10^{-2} EJ, with a regional distribution. According to Eurostat statistical data [6,7], the available sawdust quantity at national level is about 1.5 million m^3/year, following an increasing trend in recent years, in correlation with the increase in the volume of wood harvested annually.

Thus, sawdust is a viable source of bioenergy, especially in the Apuseni Mountains area, were a significant percentage of the national forests is located.

In the last years, due to the increase in the price of conventional biofuels, and mainly methane gas, in our country, the use of wood boilers has increased both in rural and urban environments.

The statistical data shows that currently about 90% of rural population using biomass as a solid source of heat, particularly wood fuel and wood waste. Also, as a result of an increase in forest found exploitation, the available sawdust quantity has also increased. This has led to an increase in the degree of utilization of sawdust briquettes, of different geometrical shapes and sizes, as a source of thermal energy for wood boilers

Sawdust briquettes are characterized by the different geometric parameters (length, diameter and geometric form), depending on the briquetting press characteristics. The available sawdust briquetting technologies offer the possibility to produce briquettes with different length. Thus, in the present paper we examine the influence of sawdust briquettes length on the efficiency of their conversion into heat.

MATERIAL AND METHODS

The efficiency of the conversion process was determined as the ratio between the energy resulted at the end of the conversion process and the energy introduced in the system through the solid biofuels used:

$$E_{\mathrm{conv}} = \frac{W_{\mathrm{at}}^{1}}{W_{\mathrm{cb}}^{1}} = \frac{V_{\mathrm{at}} \cdot \rho_{\mathrm{at}} \cdot c \cdot \int \Delta \mathrm{T}_{(\mathrm{i,j})}}{m_{\mathrm{i,j,cb}} \cdot H_{\mathrm{i,j,cb}} \cdot 10^{6}} \cdot 100, [MJ / Kg] \quad (1)$$

where:

E_{conv} is the energy efficiency of the conversion process, [%];

V_{at} – amount of the thermal agent from the boiler, [m^3];

ρ_{at} – thermal agent density, $\rho = 1000$ [kg/m^3] on the temperature range $\Delta T_{(i,j)}$;

c - specific heat of water (c = 4,180 KJ/kgK), on the temperature interval $\Delta T_{(i,j)}$ and V_{at} constant;

$m_{i,j,cb}$ – the amount of the i type sawdust briquettes and j briquettes length (i = 1, 2, 3 and j = 30, 50, 70 mm), [kg];

$H_{i,j,cb}$ – calorific value of the i type of solid biofuels, [MJ/kg];

$\Delta(T_{i,j})$ – the difference between the input thermal agent temperature and the output thermal agent temperature on a complete working cycle.

The heat embodied in combustion air was neglected, being considered a limitation of the system, because due to the natural convection of the boiler it could not be determined accurately. The amount of the solid biofuel i and briquettes length j, $m_{i,j,cb}$ was determined as the average value of the amount of solid biofuel used in each of the experimental test.

The solid biofuel was manually fed in the combustion chamber at the beginning of each experimental test. Fuel calorific value was determined experimentally using the calorimetric method (Table 1).

The difference between the input thermal agent temperature and the output thermal agent temperature on a complete working cycle was determined by monitoring and acquisition of values resulting from the conversion process using a data acquisition system and an experimental installation. $\int \Delta T_{(i,j)}$ is the area between the variation curves of the input and output temperature of the thermal agent, on a complete working cycle.

The same amount of solid biofuel (3 kg ± 100 g), was used for each test. The amount of the solid biofuel was determined through weighing with a digital scale. The weighing precision was 0,001g. Combustion air supply was achieved by opening the ash door with a 2 mm gap and then the door was stuck in this position.

The amount of the combustion air was variable during the operation cycle of the heat generator, being influenced by natural draft of the generator. The variation of thermal agent temperature was recorded automatically using a data acquisition system. The time interval between two consecutive readings was 5 minutes. Also, the external factors with influence on the energy efficiency of conversion process (atmospheric pressure, external temperature, ambient temperature, air humidity) were measured.

A test bench was used to determine the energy efficiency of conversion process. The main components of the experimental installation (Figure 1) were: a boiler with on-grate wood combustion, with a 24 kW thermal capacity; 2 radiators used for domestic space heating; water circulating pump; distributor and heating system and data acquisition system.

The sawdust used in experimental research was from two wood species, fir and beech, collected from Apuseni Mountains (fir) and Cluj-Napoca (beech). From the collected sawdust three types of sawdust briquettes were prepared, characterized by geometric parameters (diameter D, length L, geometrical form), physical and chemical parameters and energetic parameters (Table 1). The value of physical, chemical and energetic parameters of sawdust briquettes was assessed experimentally.

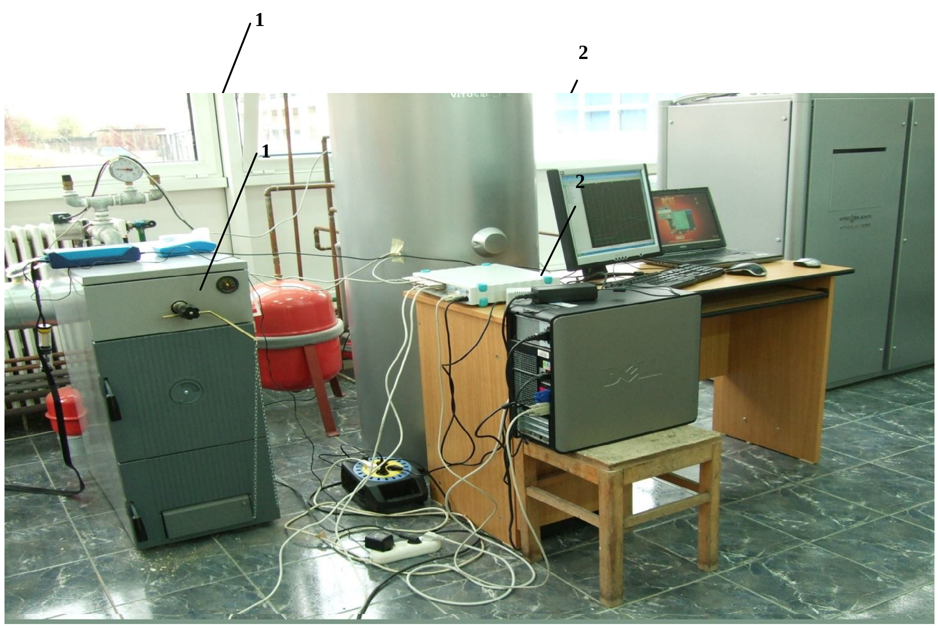

Figure 1. Test bench: 1 – boiler and heating system; 2 – data acquisition system

RESULTS AND DISCUSSIONS

The results of the experimental tests are showed in figures 2 and 3.

Comparative analysis of the useful energy stored in the thermal agent (Figure 2) reveals that it is influenced by the length of sawdust briquettes used. The analysis indicates significant differences between the values obtained using the same fuel with different lengths of briquettes (33.35 MJ for fuel 1, L = 70 mm and 22.01 MJ for L = 30 mm).

The calorific value and energy density having different value for each type of fuel (15,988 MJ/kg for fuel 1 and 17,9054 MJ/kg for fuel 3) led to different values of the energy embodied in heat agent.

This explains the minor difference between the values obtained for the energy stored in the same type of fuel, but with different lengths of sawdust briquettes. This assertion is demonstrated by the values obtained for the energy used with fuel 2, L=70 mm (53,65 MJ) and L = 50 mm (53.63 MJ). Using experimental data, the energy efficiency of the conversion process for each experimental test was assessed. The results are shown in Figure 4.

Table 1.

The main characteristics of sawdust briquettes used in experimental research

Fuel	Geometric parameters of the cilindrical sawdust briquettes		Humidity	Technical analysis			Elemental composition			High calorific value	Lower calorific value
	D [mm]	L [mm]	W_t [%]	V^{mc} [%]	A^a [%]	C^f_a [%]	C [%]	H [%]	O [%]	H_s [MJ/kg]	H_i [MJ/kg]
Fuel 1 (fir)	55	30	7,042	70,4685	2,065	20,4240	45,0730	5,4311	39,7518	17,268	15,988
		50									
		70									
Fuel 2 (beech)	55	30	7,06	67,4081	4,1136	21,4182	44,3141	5,2931	38,5974	19,377	18,125
		50									
		70									
Fuel 3 (fir+beech)	55	30	6,784	70,3498	2,8238	20,04232	44,7761	5,4039	39,5794	19,174	17,905
		50									
		70									

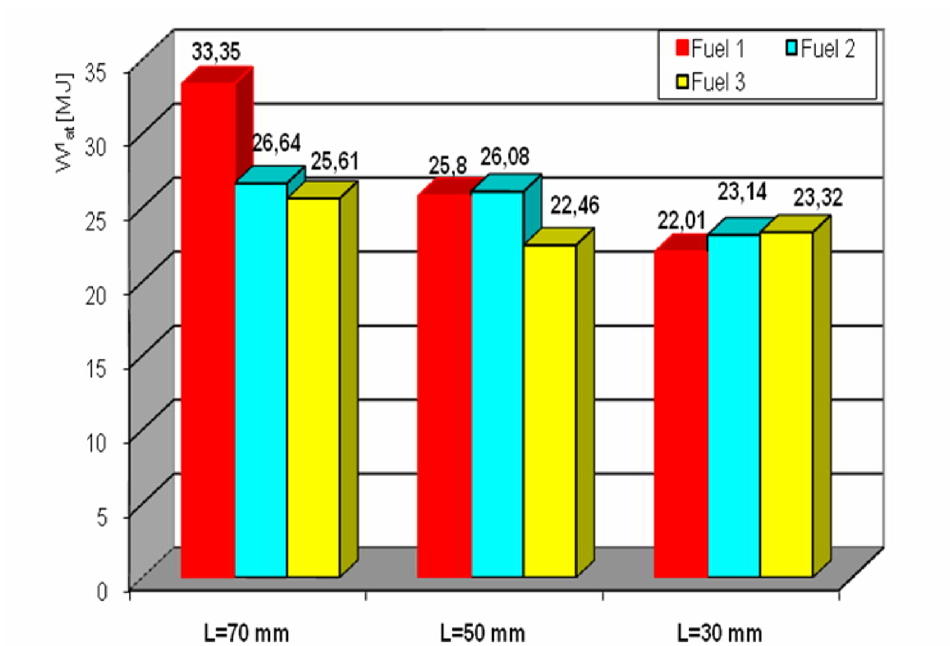

Figure 2. The variation of useful energy with fuel category
and sawdust briquettes length

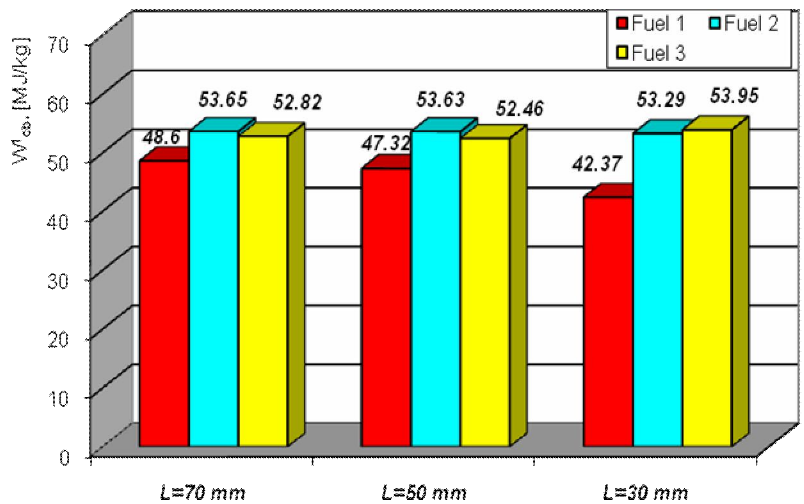

Figure 3. The variation of the consumed energy with fuel category
and sawdust briquettes length

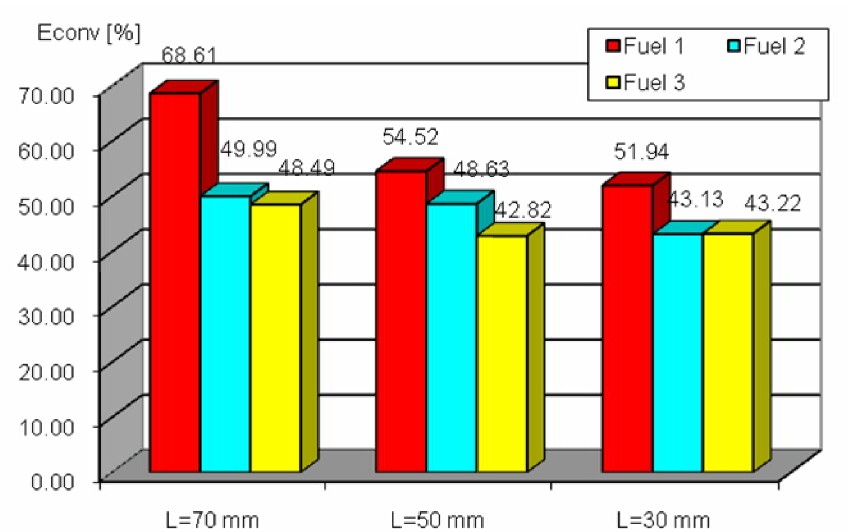

Figure 4. The variation of the efficiency of energy conversion process
with fuel category and sawdust briquettes length

Comparative analysis of the energy efficiency values of the conversion briquettes process (E_{conv}), obtained in the same experimental conditions, indicates a variation of these values with the sawdust briquettes length variation.

Data analysis (Figure 4) shows significant differences from the same type of fuel with different lengths of briquettes: for fuel 1 and briquettes length L = 50mm, the energy efficiency of conversion process was evaluated at 68,61% and respectively 51,94 % for L= 30 mm.

CONCLUSIONS

The main objective of the research was to analyze the influence of sawdust briquettes length on the conversion process efficiency of these into thermal energy. In this research sawdust briquettes from fir, beech and fir and beech mixed, with three different lengths were used together with a boiler with natural draft and manual fuel feeding.

The conversion efficiency was evaluated as the ratio between the useful energy embodied in the thermal agent and the energy brought into the system through the utilized fuel.

The experimental results showed an influence of the sawdust briquetting length on the energy efficiency of conversion process. We have observed a decrease of the energy efficiency of the conversion process when the briquettes length decreases. This is due mainly to the energy stored in the thermal agent depending on the length of the briquettes. The maximum values for the energy efficiency were obtained for the maximum length of the briquettes used in the experiment.

The analysis of energy consumed in the conversion process through fuels shows that it is influenced by the length of the briquettes in a very low proportion. The energy utilized is mainly influenced by the calorific value and energetic density of fuels.

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