ENERGY CONSUMPTION EVALUATION DURING MECHANICAL PROCESSING OF AGRICULTURAL VEGETAL BIOMASS

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Our century faces a problem that refers to energy consumption and the diminishing supplies of existing fuel. Thus, researchers have been trying to use renewable energy sources and developing new technologies processes of energy production. Lately they can sustain that the most efficient energy source is biogas produced from green energy crops and organized waste matters. In the majority of researches a rise in specific energy consumption together with a lower particle necessity was shown [1, 2, 3, 4]. This paper presents data regarding the energy consumption for mechanical processing of agricultural vegetal biomass (grass of dried hay), respectively for its cutting and then mixing it with liquid (water). Using different paddles we established the power necessary for mixing chopped biomass with water.

Keywords: grinded biomass, mixer, energy consumption, power demand.

1. Introduction

In order for biomass to be transformed into fuel with high energy indexes it is necessary for it firstly to be mechanically processed, this means grinding at certain particle dimensions, after which according to the way of use there can be the following situations: densification with transformation into pellets and briquettes (in the case of fossil fuels), mixing with other types of energetic materials and anaerobe fermentation (for biomass transformation or advanced decomposition of the grinded biomass in order to obtain liquid fuels). In the processes of anaerobe fermentation grinded vegetal biomass is not used alone, in the great majority of cases, but in mixture with other energy materials (animal manure) together making up the bioreactor substrate that in the methanogens phase gives rise to biogas.

Agricultural vegetal biomass from anaerobe reactors can be intentionally introduced or can be found in animal manure either from animal shelters or from

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their food. When biomass is intentionally introduced it is grinded, so it can be homogenized with the rest of the substrate material, even in the case in which biomass reaches in manure as food reserve or from shelter, for a better homogenization a grinding under humidity is necessary. Both in the case when biomass is intentionally introduced, as well as the case where biomass is found in manure, the behavior at grinding and mixing is necessary to understand for size reduction, so that we can estimate the necessary expenses for transforming it into fuel (in this case biogas).

In this paper we present a couple of experimental results obtained regarding energy consumption at mechanical processing of agricultural vegetal biomass (grass or straws), respectively at grinding and water mixing. In the majority of researches a rise in specific energy consumption together with a lower particle necessity was shown [1, 2, 3, 4].

The process of size reduction can be described as a combination of torsion rupture, shearing, stretching, compression, friction resistance recording three indices: particle size, their form, connections from inside the material structure [5, 6, 7]. In the process if size reduction material temperature rises with a few degrees due to tensions at which it is subjected to [8, 9, 10].

Using three different types of stirring and feeding procedures Lemmer et colab. [11], evaluated the efficiency of two different agitation systems. They measured the nutrient distribution in a digester fed with renewable energy crops and animal manure. Samples were taken from a full-scale biogas digester in combination with the electric energy consumption for evaluation. They concluded that are differences in nutrient distribution depending on the investigated agitation system, as well as position and height of the sample in digester. The experimental data shown that electric energy consumption is significantly different for all three agitator setups.

2. Material and method

a. b.

Fig. 1 Grinding apparatus Viking GE 150 and its knife rotor

For identifying dry hay behavior at grinding we used a 3.5 kg quantity obtained manually and naturally dried until 8.3% humidity content. The material was grinded with a vegetal waste grinder Viking GE-150, 2.5 kW power, and 2000 rpm torque. (Fig.1, a).

For determining necessary grinding power we used an ARDUINO system (Fig.2) with data acquisition on a computer. Firstly we determined the current and empty run power, than a load power was analyzed. Grinding time was 11.5 minutes, feeding was done manually (approximately uniform). Thus, for an empty run the average power consumption was of 493.5W, while for a load we obtained an average power of 515.9W, which means a 22.8W only for grinding

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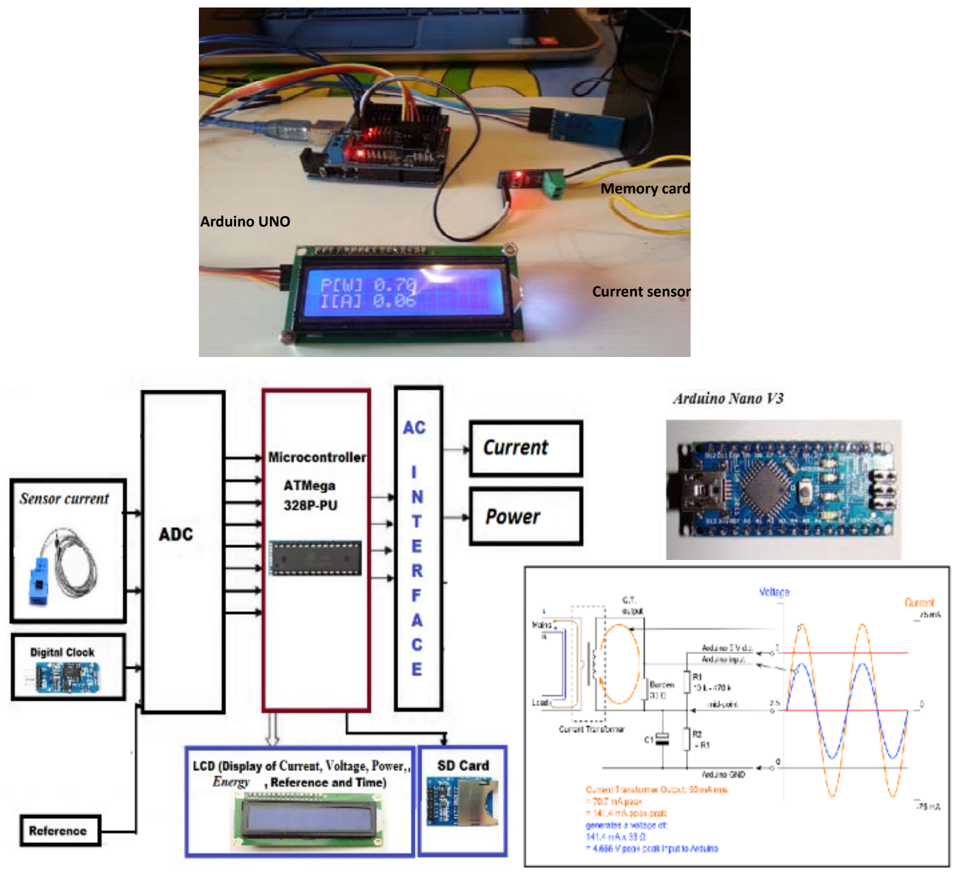

Fig. 2. Data acquisition ARDUINO system

In fig. 3, the graphs of the current and recorded power at load functioning during hey grinding are presented. After grinding, a distribution determination for dimensions was done, with a separation device in air currents with a vertical channel and 3 sedimentation rooms presented in figure 1b. The following values of particle dimensions were found: 2.3% heavy stems, 27.8% particles of 13-18 cm, 48% particles of 7-13cm and 21.3% particles of 1-7cm. Together with the evacuated air through the fan, 0.4% of fine particles and slim stems with 1 cm in lengths were evacuated.

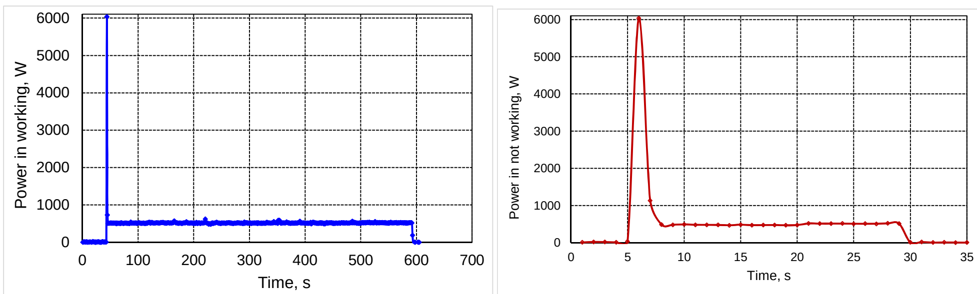

Fig.3. Power consumed by the grinder at a normal load and an empty run

Further experiments were made for water grinding mixture necessary power, using a lab mixer with a mechanical system for liquid solid mixer spin necessary force.

Grinded solid material was introduced in quantities of 0,500 kg, respectively 0,25kw, into 18 liters of water, in the mixer bowl, and left for 30 minutes for humidification.

Mixing system was firstly composed out of a simple propeller (two sides), with interior diameter of 15mm and exterior diameter of 100mm, and then by rectangular sides of different dimensions (table 1). Mixing system propeller type is replaced directly from the apparatus, while the sides are mounted on the corresponding system with the help of two screws, the grip orifice is at 35mm from the rotation vertical axis.

Dynamometer arm recorded force was read every time, later we calculated the torsion moment and necessary power for spinning the mix system used. Torsion moment at drive shaft was calculated with the relation:

$$\mathrm{M} = \mathrm{F} \cdot \mathrm{r} \qquad (1)$$

in which: F – necessary force for the spin of the mixing system (given by the indication of the measuring system dynamometer indication), in kg, multiplied with gravitational acceleration g, în m/s^2); r – force arm (from construction r = 0.11 m). Mechanical power P_m necessary for mix homogenization was measured with the relation:

$$P_m = \mathrm{M} \cdot \omega \qquad (2)$$

Positions of the pallet mass center towards the axis of rotation were calculated, for all four types of pallet of the mixing system, respectively lateral surface (table 1).

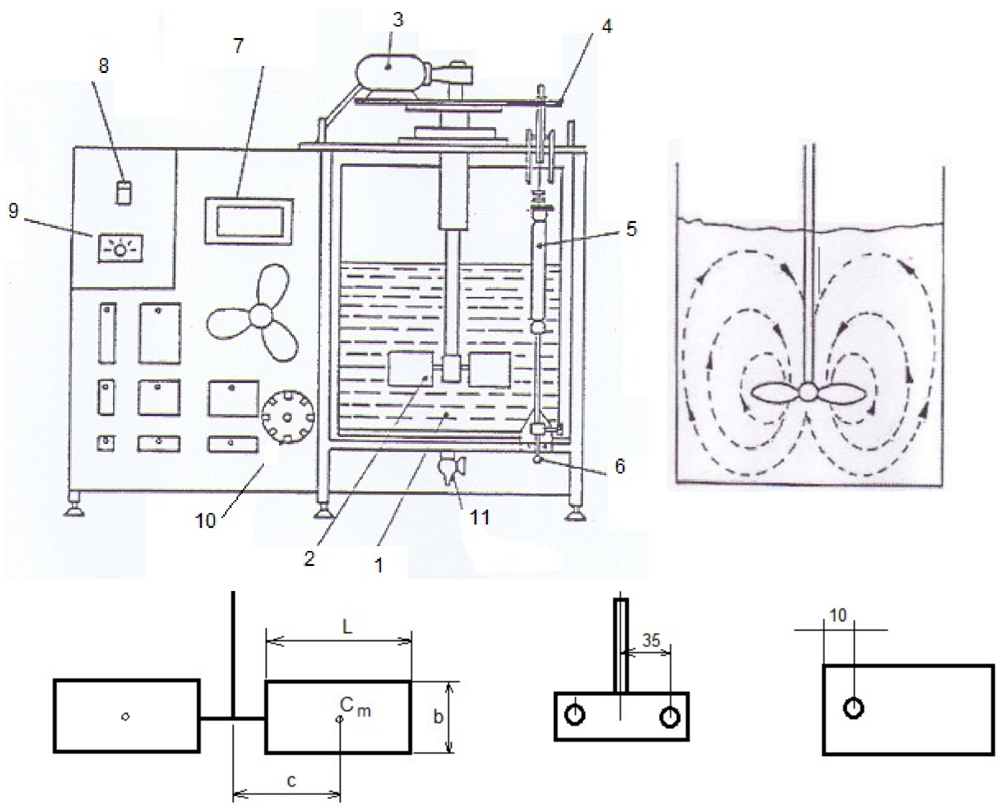

Fig. 4. Armfield CEK mixer, mixing system and the base dimensions of the sides
1. vessel; 2. homogenizing paddles; 3. motor electric; 4. dynamometer arm; 5. balance; 6. balance adjustment; 7. speed indicator; 8. on/off switch; 9. speed controller; 10. instrument panel; 11. drain valve

3. Results and discussion

At the start of the experiment a solid material empty space was formed around the propeller without homogenization. For 465 rpm, the recorded force for the measuring system was relatively small, 150g, an insignificant value for consideration.

When larger pallets were used for experiments (62x43mm), by using 100rpm we recorded a force F=750g for driving the solid material and homogenizing liquid-water mixture

For a quantity of 0.250 kg of vegetal grinded mass introduced in the mixer bowl, using the four systems for agitation, the recorded data for dynamometer force are represented in table 1.

Table 1

Characteristics of stirrer pallets and recorded force at mixer dynamometer for 0.250 kg vegetal grinded matter, 200 rpm at stirrer drive

Stirrer type		L ($mx10^{-3}$)	b ($mx10^{-3}$)	Blade area S, ($m^2 \cdot 10^{-4}$)	Centre of mass c, ($m \cdot 10^{-3}$)	S·c, ($m^2 \cdot 10^{-7}$)	Dynamometer force, (kg)
P0	Propeller	-	-	7.5	30	22.5	0.08
P1	Small blade	62	21	13.02	87	113.274	0.23
P2	Middle blade	76	24	18.24	100	182.4	0.455
P3	Big blade	62	43	26.66	87	231.942	0.38

Experimental data were done in Microcal Origin 8.0. Curves of regression for multiple mathematical functions expressed with 3-5 relations were graphically drawn:

- logistic function:

$$y = a + \frac{b-a}{1+(x/c)^d} \tag{3}$$

- parabolic function:

$$y = a + \frac{b}{x} \tag{4}$$

- exponential function

$$y = \exp\left(a + \frac{b}{x^2}\right) \tag{5}$$

- linear function $y = a + bx$ (6)

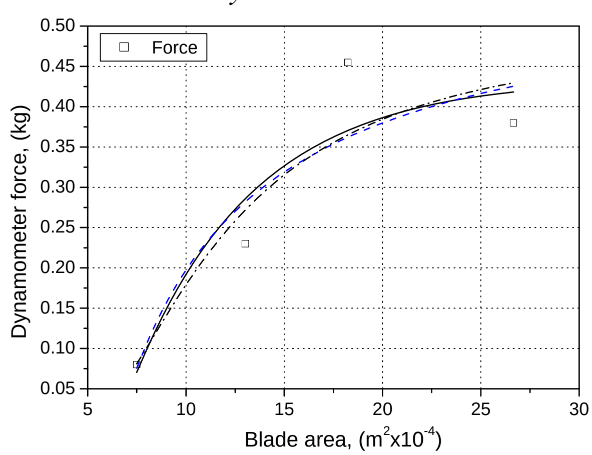

Fig. 5. Dynamometer force vs. blade area for 200 rpm at mixer shaft
——— logistic function; – —– parabolic function; –·–· – exponential function

So, for expressing dynamometer force as a function of paddle lateral surface the mathematical relation coefficients are given in table 2, including values of correlation coefficient R^2.

Table 2

Values of the parameters of equation values that best describe R^2

	Dynamometer force vs. Blade area					Dynamometer force vs. S·c				
	a	b	c	d	R^2	a	b	c	D	R^2
Eq. (3)	0.435	-0.804	854.46	140.76	0.858	0.574	$3.03\cdot10^{-3}$	$-6.4\cdot10^{7}$	$-3.6\cdot10^{5}$	0.871
Eq. (4)	0.564	-3.652	-	-	0.838	0.405	-7.525	-	-	0.756
Eq. (5)	0.701	-101.93	-	-	0.852	-0.991	-889.14	-	-	0.726
Eq. (6)						0.056	$1.68\cdot10^{-3}$	-	-	0.839

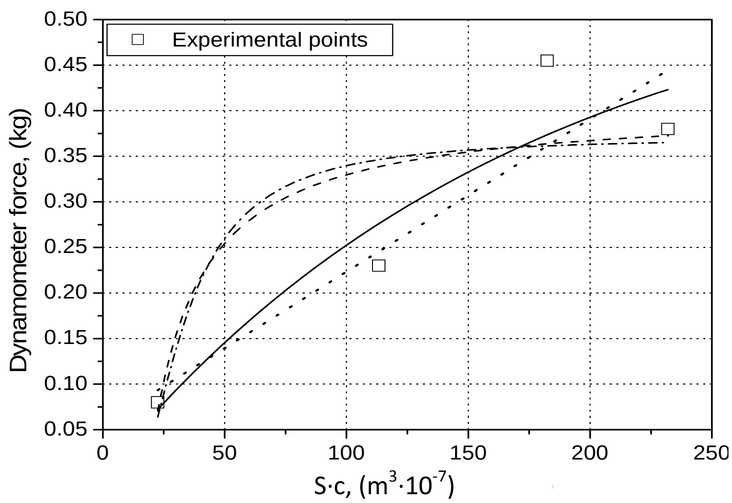

Fig. 6. Dynamometer force vs. *S·c* for 200 rpm at mixer shaft

——logistic function; – – – parabolic linear; – · – · – exponential function; ····· linear function

In figs. 5 and 6, curves of variation force measured by the dynamometer and pallet surface respectively dynamometer measured force are presented. From table 2 we can observe the fact that the biggest value of the coefficient of correlation is R^2=0.858, and was registered for the logistic function in the case of force at dynamometer in function with the lateral paddle surface. For the case of force at dynamometer in function to *S.c.* the value of correlation coefficient R^2 was registered for logistic function 0.871.

4. Conclusions

Through experimental researches we could conclude the fact that only through the process of biomass processing by grinding we need such a power with approximately 5% bigger than the average power recorded for an apparatus empty run. Also, analyzing the stirrer system used during the paper we could observe the significant differences between dynamometer registered forces. The smallest was recorded for the propeller type mixer 0.08kw, and the biggest for the middle size pallet mixer 0.455kg. Our experimental results can be used as a starting point for new experimental research regarding power demand during mixtures formed from chopped biomass and liquid and also regarding the energy consumption during biomass cutting process.

Acknowledgements

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R E F E R E N C E S

[1]. *S. Mani, L. G. Tabil, and S. Sokhansanj*. Grinding performance and physical properties of selected biomass, ASAE Paper No. 02-6175, St. Joseph, Mich.: ASAE, 2002.

[2]. *S. Mani, L. G. Tabil, and S. Sokhansanj*. Grinding performance and physical properties of wheat and barley straws, corn stover and switchgrass. Biomass and Bioenergy 27, pp 339-352, 2004a.

[3]. *S. Mani, L. G. Tabil, and S. Sokhansanj.* Mechanical properties of corn stover grind, Trans. ASAE 47: 1983-1990, 2004b.

[4]. *Gh. Voicu, G. Moiceanu, G. Paraschiv* – Miscanthus stalk behavior at shear cutting with V cutting blades, at different sharpening angles, U.P.B Sci. Bull., 2013, Series D, Vol. 75, Iss. 3 ISSN 1454 – 2358, , pp. 257 – 270, 2013;

[5]. *P. Lopo,* „The right grinding solution for you: roll, horizontal or vertical", Feed Management, 2002, 53(3):23-26;

[6]. *J.A. Müller* – „Comminution of Organic Material. Chemie Engineering Technology", 26(2), pp. 207–217, 2003;

[7]. *S. Nikolov*, „Modeling and simulation of particle breakage in impact crushers", Int. Journal of Mineral Processing, 24(S): pp.219 – 225, 2004;

[8]. *G. Moiceanu, P. Voicu, G. Paraschiv, G. Voicu*- Miscanthus Behaviour regarding shear cutting with straight knives with different edge angles, Enviromental Engineering and Management Journal, 2014;

[9]. *G. Moiceanu, P. Voicu, G. Paraschiv, Gh. Voicu, M. Chițoiu* – Miscanthus plant energy consumption during grinding with a lab mill Grindomix GM 200, 2nd International Conference on Thermal Equipment, Renewable Energy and Rural Development, TE-RE-RD 2013, 20 - 22 June 2013, ISSN 1843 –3359, Olăneşti, România, pp. 203-209, 2013;

[10]. *G. Moiceanu, G. Paraschiv, Gh. Voicu, M. Dincă, M. Chițoiu*. Comparative analysis of energy comsumption at grinding multiple types of vegetal biomass, Second International Conference on NATURAL AND ANTHROPIC RISKS ICNAR 2014, 04-07 June 2014, Bacau, Romania

[11]. *Lemmer A., Naegele H.J., Sondermann J.,* How efficient are agitators in biogazdigesters? Determination of the efficiency of submersible motor mixers and incline agitatorsbymeasuringnutrientdistribution in full-scale agriculturalbiogazdigesters, Energies, 6, 6255-6273, 2013.