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RESEARCHES OVER THE EFFICACY OF THE TECHNOLOGIC PROCESS OF CEREAL STRAW BRIQUETTING

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The work presents the results of the experiments to realize with minimum energy consumption of straw briquttes. Straw briquetting represents an efficient and completely automatic burning solution of this category of bio fuel. The outcome allows recommendations for implementing this technology in the energy of valuing the solid biomass.

Keywords: biomass, straw, briquetting.

1. Introduction

In our country there have been developed burning installations for straw briquettes and implicitly briquetting plants, [1, 2].

Analyzes on the briquetting installations show that the most appropriate one is the extraction press with hydraulic piston.

The piston pumps, when extruding the biomass (exhaust compression) will have to result into a resistant material with a safe form. The piston pumps' capacity is 40-1000 kg/h.

The water content of straws is one of the most effective agents for binding and lubrication. Obviously, the strength and density of briquettes depend on an optimum humidity. Tests indicated that making straw briquettes when the humidity rises above 35% is totally defective. A moisture content of 12-17% is optimal for making briquettes of quality straws, [3, 4].

The particles' size represents another important criterion in briquetting. For briquettes with a diameter from 60 to 120 mm and length of 60-270 mm, tests have shown that an initial granulation of straws of 20-50mm size is optimal.

Presses use a mechanism with a piston that is actuated by a rod mechanical system or by a pneumatic one. Pressure may vary between 7-1300 bars. By pressing, a briquette of a certain form is obtained. This may be cylindrical or prismatic, usually with an inner hole. The inner hole serves to the evacuation of water vapor and volatiles from the compression process. Straw briquette quality is noticeably better at those that have an inner hole.

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The relation for calculating piston pressure was obtained in the following form:

$$p = \frac{a\rho_0}{b}\left[\exp b\left(\frac{\rho}{\rho_0}\right) - 1\right] \tag{1}$$

Where *a, b* are constants that depend on the material. Density after compression was noted with p and p0; density after compression was noted with kg/m3.

This relationship developed in the literature, [1, 5, 7] is of the form:

$$p = \frac{b}{a}\left[\exp a(\rho - \rho_0) - 1\right] \tag{2}$$

For low pressures, density was permitted under the pressure effect:

$$\rho = \alpha + \beta \ln p \tag{3}$$

For the straw briquetting, the relation that matches mostly to the reality, is the one developed in literature, [3, 4, 5] is:

$$p = \frac{a\rho_0}{b} f(r) \tag{4}$$

where *r* is the densification rate.

The constants' values for equation (1) were fixed as: $a = 0.035 \div 0.045$ and $b = 0.47 \div 0.52$.

In Fig. 1, the briquetting station is presented, with its 5 lines arranged in a star, each of them making 60 kg briquettes per hour, [8, 9]. Each line has a 3 kW electric motor and 5 kW electric resistors.

Fig. 1. The Straw Briquetting Station

The briquettes could be cylindrical or polygonal in shape, both having a centerline hole.

The density of the briquettes is 900 ÷ 1000 kg/m^3. The briquettes have an

80 ÷ 110 mm diameter and an 80 ÷ 160 mm length.

These tests were conducted at a briquetting plant station with a production of 50-60 kg/h for a single production line.

During briquetting, the material was heated to 250 ^{o}C through an electrical system, [9, 10].

The briquette has a polygonal shape with the dimensions presented in Figure 2. The weight of a briquette is about 0.61÷0.63 kg.

Briquettes are obtained by compressing the straw and they have a very high density, about 1000 kg/m^3.

The images of briquettes obtain is presented in Figure 3.

The briquetting line for straws presented in Figure 1 is functional at SC E MORARIT of Vaslui County, [8,9].

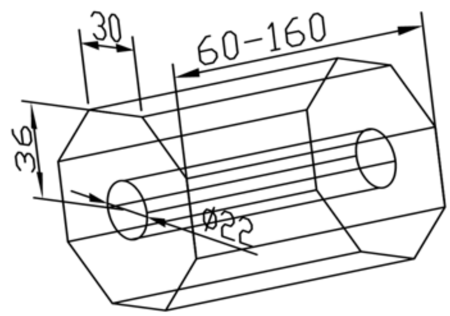

Fig. 2. Briquette geometry

Fig. 3. Images of briquettes

2. Identifying the conditions for cereal straw briquetting

These values have been accepted after several experimental determinations on the briquetting line presented in Fig. 1.

After theoretical and experimental research on establishing the straw briquetting pressure we have adopted the following relation:

$$\rho = \frac{a\rho_0}{b}\left[e^{b(r-1)} - 1\right] \tag{5}$$

Where *p* is the pressure of the piston; ρ_0 is the initial density (kg/m^3); *r* is ratio of densification; *a, b* –constants. The constants' value was fixed as: *a* = 0.035÷0.045 and *b* = 0.47÷0.52

The straw briquetting line in Figure 1 is functional in SC. E. MORARIT, in Vaslui County. There have been performed calculations for different rates of densification. In the calculations there have been considered the following values of the constants: $a=0.04,\ b=0.5$

The initial density depends on humidity and on the straw size before briquetting.

By chopping before briquetting, straw will have a size between 2.5÷5 mm.

For a densification from p_0= 200 kg/m^3 to p = 900 kg/m^3, the densification rate will be r = 900:200 = 4.5.

The piston pressure will be: $p = \frac{0{,}04 \cdot 200}{0{,}5}\left[e^{0{,}5(4{,}5-1)} - 1\right] = 76\,\text{bar}$.

If p_0 is set to 150 kg/m^3 and the final density will be 900 kg/m^3, then value of *r* = 900: 150 = 6 and the piston pressure *p* = 134 bar. For a higher densification, characterized by p = 1000 kg/m^3, from p_0 = 150 kg/m^3 the piston pressure increases to p = 190 bar.

Long-term evidence showed that the optimum piston pressure is a value of p = 160 ÷ 180 bar.

During compression straw is heated using a system of electric resistors that have power for briquetting line of 3 kWh. Heating temperature is 250 °C, [12, 13].

The straw density before briquetting depends on their size after chopping and on humidity.

The studies undergone at the briquetting plant station varied chopping sizes resulted in the variation law presented in Fig. 4 and Fig. 5.

Producing the experimental data for straws with humidity between 11 and 20%, allows obtaining a calculating relationship for the density of the straw chopping:

$$\rho = ae^{-bl}, \text{ kg/m}^3 \quad (6)$$

Where $a = 270 \div 290$, $b = (2.9 \div 3.4) \cdot 10^{-3}$ the length of the straws in mm, higher values of the constants belonging to higher values of humidity.

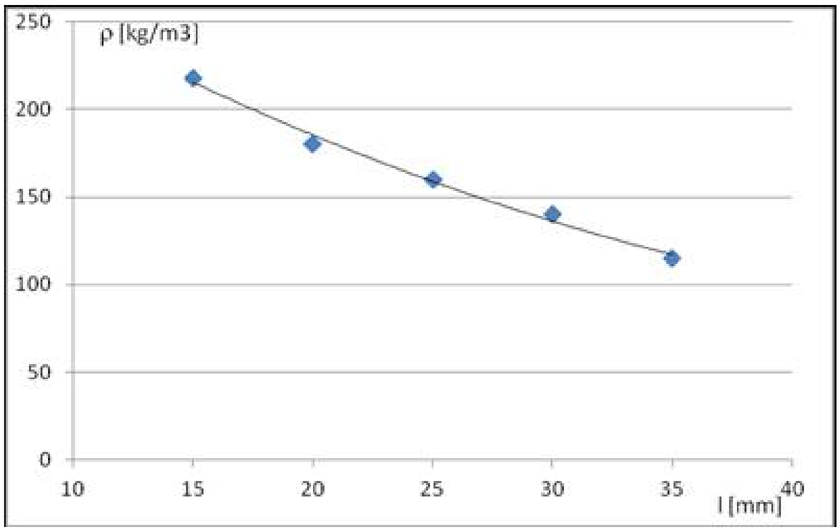

Fig. 4. The relationship between the density and the the size of the straw chopping, humidity W=11.8 %.

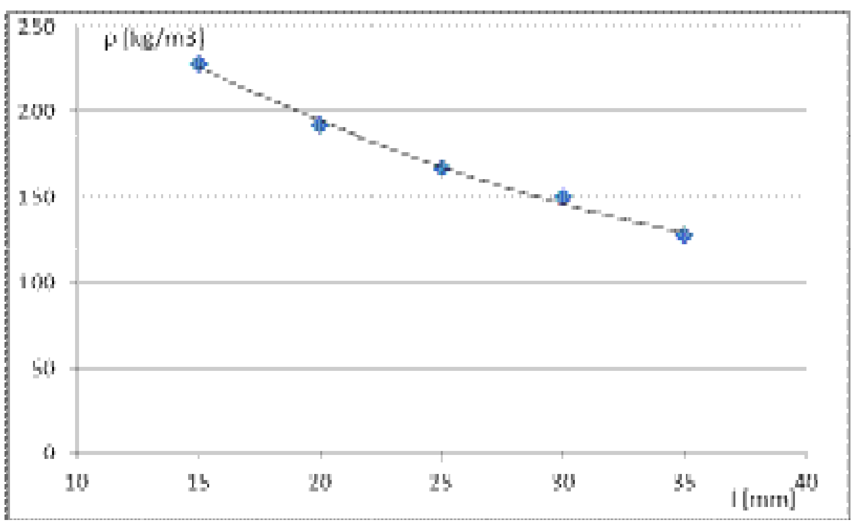

Fig. 5. The relationship between the density and the the size of the straw chopping, humidity W=14.2%.

As for the energy used for chopping the straws, the measures showed a consumption of 22 ÷ 25 kWh/t, for humidity between 11 and 20%. Higher values are reached when humidity increases. At a humidity of 17 - 20%, it was noticed that the consumption of energy was influenced by the sharpness of the cutting equipment.

Picture 6 shows the pressure for realizing a certain density for briquettes in a strong connection to the initial density of the straw cutting.

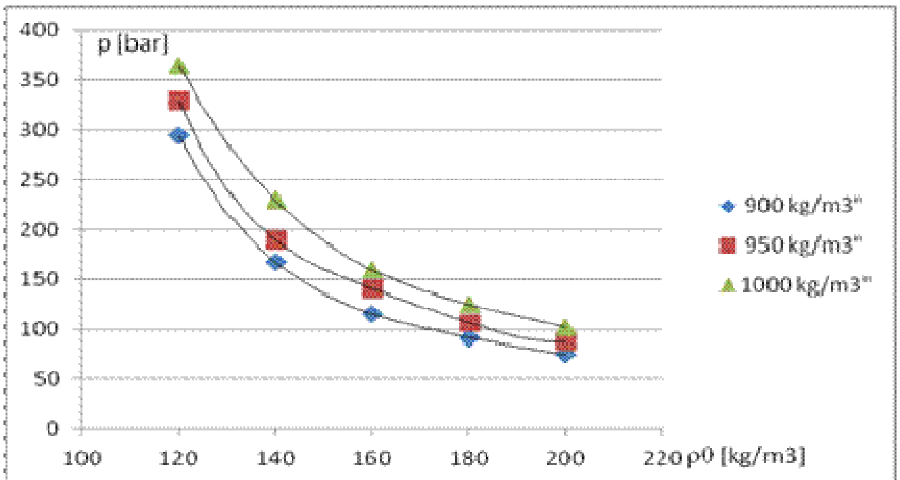

Fig. 6. Pressure briquetting variation connected to the initial density of the biomass

In Fig. 7 shows the humidity variation over the briquetting pressure, for a cutting size of 20 ÷25 mm.

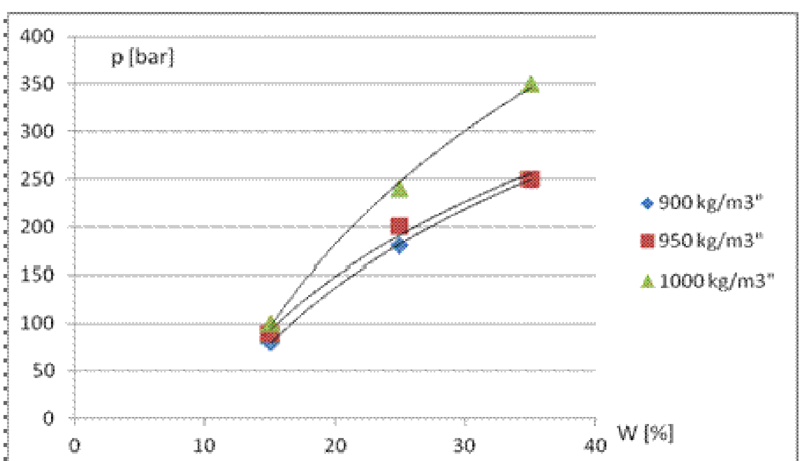

Fig. 7. Pressure variation for briquetting based on humidity (experimentally determined).

The consumed power increases by the increasing density law at compaction,

$$P \cong \rho^{c}, \text{kW} \qquad (7)$$

This confirms other reaserchers conclusions, [1, 5, 6, 7] that envisaged the biomass heating at 225 – 2500C leads to a higher densification than a cool compaction.

The experiments have identified the temperature of 200 ^{0}C as a preheating minimum .Heating below this temperature increases the consumed power/ input.

For a compaction pressure over 15 bar a plastic contortion is necessary .That is realized both by preheating and by increasing the pressure over 300 bar.

3. Conclusions

The researches took place at a briquetting plant station- SC Morărit E – Huşi the briquettes used here are energetically used at copper plants with thermal power between 100 and 400 kW. These plants being completely automatic require strict conditions considering the quality of the straw briquettes.

The experiments have certified an optimum heating temperature of 220 – 250^{0}C.

This aspect was also highlighted by other researches, [1, 3, 6, 7]. The most efficient heating was realized by electrical resistance in the final stage of briquetting. For a line of 60 kg/h, the necessary input was 3 kW.

The power for compression is proportional with the pressure by the law: $P \cong p^{c}$, kW ,where p is the pressure of the piston in bar , c is a coefficient with the value c = 0,84 ÷ 0,89.

Using the data from Fig. 5, it results as economic to realize briquettes with an initial density of over 160 kg/m^3.

The experiments have identified a minimum of preheating at briquetting at a value of 200 ^{0}C.Temperatures under this value lead to significant increases of the input.The necessary plastic contortion for an efficient briquetting, if it is not realized by heating increasing the pressure at values over 300 bar.

For humidity an optimum value was highlighted. This phenomenon is presented for all biomass categories in the specialized literature.

For cereal straws, the experiments have showed as optimum a humidity of 11 – 20%. Over 35% humidity, the cereal straw briquetting process becomes not applicable.

Acknowledgments

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