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THE EFFECT OF MOISTURE OF THE RAW MATERIAL ON THE PROPERTIES BRIQUETTES FOR ENERGY USE

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Abstract

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At logging and at the subsequent wood and wood semi-products treatment the fine grained loose waste is arising, e.g. wood dust, saw dust, shavings, chips, bark etc. One of possibilities of its meaningful utilization is the briquetting technology, which product are briquettes determined for energetic utilization (combustion). This report contains the results of tests carried out with the aim to assess the influence of moisture on the briquettes final properties. For the tests the platan tree chips of four moisture levels, namely 5.7 %, 7.7 %, 15.7 % and 23.9 % were used. The basic physical-mechanical properties were the evaluation criteria. Following properties were determined: ash amount, gross calorific value, total moisture content, density, rupture force, length, diameter, weight and mechanical durability. From the results of carried out tests it follows that the best properties were reached at briquettes made from chips of moisture 7.7 %. At higher or lower moisture the briquettes properties were sharply failing (namely rupture force and density).

Keywords: wood; wood moisture; briquetting; density; rupture force; mechanical durability

INTRODUCTION

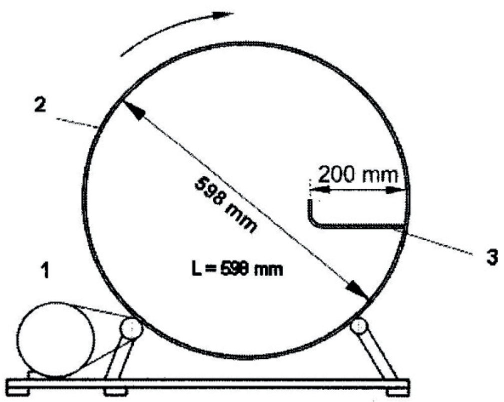
The utilization of wood dust, sawdust, shavings, chips or bark for combustion is without a previous adjustment usually not possible. Therefore for the combustion purpose the above mentioned materials are adapted in order to achieve suitable shape and size, e.g. by briquetting.

Briquetting is a relatively old technology. The first mentions of their use have been published in the first half of the 18th Century. In the last twenty years in the Czech Republic the briquetting technology asserted itself in the field of metallic and non-metallic processing, too. The basis of this method is the high pressure effect on a fine-grained material. Briquettes, most often of cylindrical form and various diameter and length, are the final product. But briquettes can be of various shape, e.g. of cuboid with rounded corners, of hexagonal cuboid etc., according to the design of the press chamber of the used briquetting press.

The use of briquetting technology can bring substantial savings. Waste pressed from flammable materials, e.g. from wood waste (chips, shavings, sawdust, dust, bark), straw, coal, paper, cellulose, tobacco etc. are mostly utilized energetically (by combustion) (Basore, 1929; Punko and Gavrilovich, 2009; Plíštil *et al.*, 2004; Brožek *et al.*, 2012; Sheridan and Berte, 1959; Brožek, 2015a; 2015b). After its compression the waste from combustible materials, e.g. dust collected on air filters, abrasion dust or chips from cutting of metals and their alloys is better usable (Brožek, 2005). After compression the waste volume strongly decreases. This makes easy its handling and decreases costs for transport or storage on a waste disposal site.

The important properties of briquettes and pellets are their mechanical properties, which influence their storage time and handling. The mechanical properties of briquettes (and pellets) (Nováková and Brožek, 2008) determined for combustion are specified in relevant national directives, in the Czech

Republic e.g. by the Directive of Ministry of Environment (DME) No 14/2009, which prescribes the requirements on briquettes from wood waste. The requirements on the briquettes mechanical durability are given in the standard ČSN EN 14961-1 and ČSN EN 15210-2, including the description of the test device (Fig. 1). The requirements on the briquettes strength are included in none of above mentioned directives. But it is very important that briquettes were of adequate cohesiveness in order that at common handling neither crumbling nor falling apart occur (Brožek, 2001a; 2001b; 2013; Brožek and Nováková, 2009).



1: *Principle of the durability drum*
1 – motor, 2 – drum, 3 – baffle

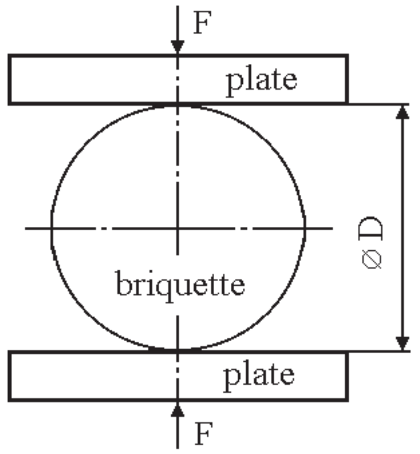
The experimentally simple orientation in the field of briquettes compactness evaluation consists in the determination of briquettes weight loss after the repeated free falls on a firm bottom from the weight of 1 meter (Blahovec, 1982) or 2 meters (Plíštil, 2005).

The briquettes final properties depend on a row of factors. The most important properties are pressed particles size, used pressure and moisture. Many authors engage in the study of properties of briquettes for energy purposes. With regard to the aim of this report it will be put the accent on the initial material moisture influence on the briquettes final properties. The authors of reports agree with the fact that the initial material should be of the definite moisture. Generally speaking briquettes of lower moisture are of lower quality. But at tests made by the author of this report it was determined that at the excessive low moisture the briquettes mechanical properties decrease. It is commonly known that at the increasing moisture the briquettes energy properties and consequently the combustion quality decrease (Plíštil, 2005).

For different materials for briquetting the authors state different values of moisture. Each of below mentioned authors' states in its report only moisture of by him tested materials. For selected energy crops (*Sorghum vulgare* L., *Phalaroides arundinacea* L., *Crambe abyssinica* L., *Fectusa pragensia* L., *Camelina sativa* L., *Miscanthus sinensis* L. *and Carthamus tinctorius* L.) Plíštil *et al.* (2004) states the moisture from 10 % to 16 %. For other energy crops (coriander, crambe, saphlor, sorrel, sorghum, reed canary grass, knotweed, barley straw and rapeseed straw) Plíštil *et al.* (2005) states the moisture values from 9 % to 11 %. For five tested materials (rapeseed oilcake, pine sawdust, Virginia mallow chips, Rape straw and Willow chips) Stolarski *et al.* (2013) states the moisture content from 9.8 % to 18.3 %. Husain *et al.* (2002) states at palm oil residues (shell and fiber) the moisture content of 12 %. Chen *et al.* (2009) recommends the material moisture between 10 % and 15 %. Felfli *et al.* (2011) recommends making briquettes from agro-industrial materials (e.g. rice husk, coffee husk, bagasse, soybean husk or sawdust) at their moisture of 15 %. Tripathi *et al.* (1998) recommends the same moisture value. Brožek (2013) proved that the moisture of over a long period stored briquettes changes namely in dependence on the storage conditions. From the above mentioned information it follows that the majority of authors has experiences about briquetting of materials of moisture between 9 % and 18 %.

MATERIALS AND METHODS

The evaluation of chosen properties (length, diameter, weight, density, rupture force and mechanical durability) of briquettes made from platan chips of the initial material different moisture was the aim of carried out tests. The size of compressed particles was at all tests the same. For the briquetting production the briquetting press of the firm Briklis, type BrikStar 30–12 of the pressure chamber diameter 50 mm was used (manufacturer company Briklis, Czech Republic). The briquetting pressure was for all carried out tests the same, given by the structure and setting of the briquetting press. For tests approximately 40 kg of briquettes were made for each of tested moisture. One half of this amount was used to the durability test (according to CSN EN 14961-1 and CSN EN 15210-2). The advantage of this test is the small time demand (only 5 minutes per one test). But the results can be influenced by one or a few poor quality briquettes in the tested group. The second half was statistically evaluated (Brožek *et al.*, 2012; Brožek and Nováková, 2009). In this way the carried out test make possible the individual evaluation of each briquette in the tested group. Its disadvantage is the high labour demand. The briquettes were numbered, weighted and their length and diameter measured. From the measured values the briquettes density was calculated. Then the briquettes were plate-loading tested using the universal tensile strength testing machine (Fig. 2).



2: *Principle of the plate-loading test*

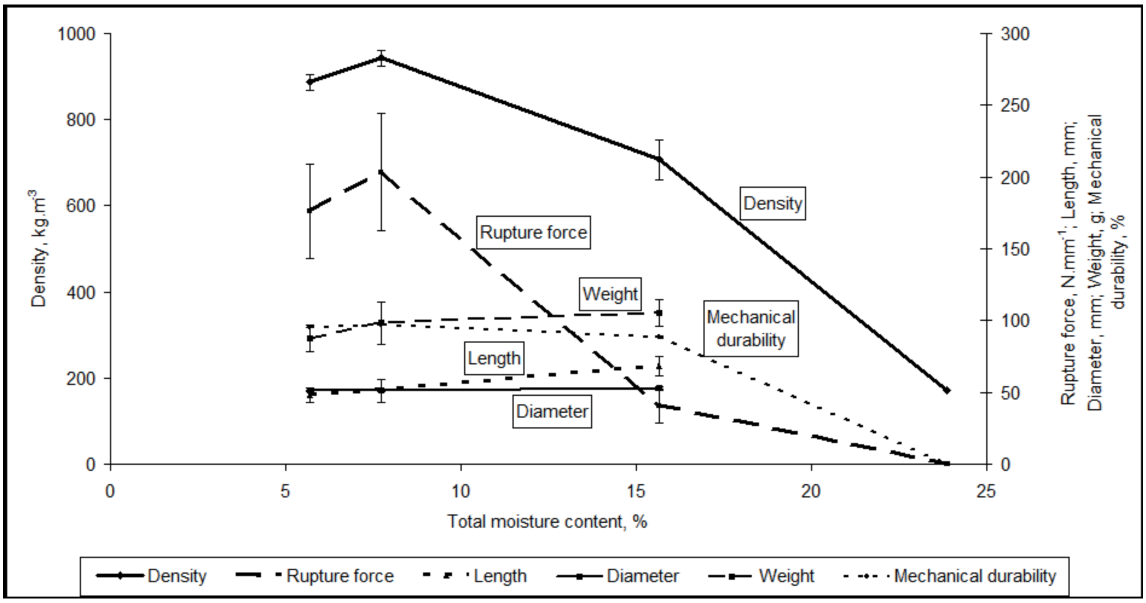
The test is finished at the briquette rupture, which is accompanied with the rapid load decrease. From the load indicator the maximum load is taken down.

With regard to the used technology the briquettes were of different length. Therefore the rupture force was recalculated and it is presented as the force per unit (per 1 mm of a briquette length). Except for this the gross calorific value (according to ČSN EN 14918), ash amount (according to ČSN EN 14775) and total moisture (according to ČSN EN ISO 18134-2) were determined.

RESULTS

The results of carried out tests are presented in Tab. I and Fig 3. The measured values were statistically evaluated. In the Fig. 3 the standard deviation is demonstrated by the line segments.

The gross calorific value of the pressed material (platan chips) was 17.1 MJ·kg^{-1}, ash amount was 1.69 % and the total moisture contents were 5.7 %, 7.7 %, 15.7 % and 23.9 %. The materials of moistures 23.9 % and 15.7 % were dried natural; the materials of moistures 7.7 % and 5.7 % were dried in a drier.



3: *Results of experiments (the standard deviation is demonstrated by the line segments)*

I: *Results of experiment*

Total moisture content, %	Density, kg.m^{-3}	Rupture force, N.mm^{-1}	Length, mm	Diameter, mm	Weight, g	Mechanical durability, %
5.7	887.0 ± 18.8	176.1 ± 32.9	48.23 ± 4.91	51.07 ± 0.24	87.6 ± 9.2	95.5 ± 0.1
7.7	942.5 ± 18.7	203.4 ± 40.6	51.04 ± 7.66	51.02 ± 0.26	98.3 ± 14.9	96.7 ± 0.0
15.7	707.2 ± 45.8	40.6 ± 11.8	68.15 ± 6.45	52.84 ± 1.02	105.4 ± 9.0	88.9 ± 0.1
23.9	170.1 ± 0.8	x	x	x	x	x

DISCUSSION

From the test results (Tab. I and Fig. 3) it follows that the briquettes made from materials of different moisture have significantly different properties. From chips of the highest moisture (23.9 %) it was not possible to make any briquette. Although the material was pressed into the pressure chamber, either no briquettes were created (the material "ran") or their strength was minimal and even at careful handling they were falling into pieces. Briquettes, which were suitable for tests, were possible to produce only from material of moistures 5.7 %, 7.7 % and 15.7 %.

As it is evident from Tab. I and Fig. 3, the briquettes properties depend significantly on moisture of the material used for their production. From the examined properties density and rupture force are most influenced by the briquettes material moisture. Both these properties reach their maximum at the moisture before compressing of 7.7 %. The briquettes density is 943 $kg \cdot m^{-3}$, rupture force 203 $N \cdot mm^{-1}$.At the use of the drier material (5.7 %) as well of the moister material (15.7 %) the values of these properties rapid decrease. At the briquettes made from the material of moisture 5.7 % the density decrease was of about 6 %, the rupture force decrease was of about 13 %. At the briquettes made from the material of moisture 15.7 % the density decrease was of about 25 %, the rupture force decrease was of about 80 %. For the briquettes quality evaluation it is possible to recommend as the optimal parameter the rupture force, alternatively the density of produced briquettes. The briquettes length, diameter and weight mildly increase with the increasing moisture of the pressed material. Briquettes made from chips of moisture 7.7 % have the highest mechanical durability (DU = 96.7 %). But on moisture this parameter depends only in a low extent. For briquettes made from material of the moisture 5.7 % the value of DU is 95.5 %, of the moisture 15.7 % it is 88.9 %. From this it follows that in practice the most used parameter – mechanical durability – is for the evaluation of briquettes quality not optimal.

CONCLUSION

This report contains the laboratory tests results of the platan tree chips briquetting at different initial moisture. For briquetting the briquetting press Briklis type BrikStar 30-12 of the pressure chamber diameter 50 mm was used. At the tests evaluation it was determined that it is impossible to produce briquettes from the material of the highest tested moisture (23.9 %). It managed to produce briquettes from the materials of next three tested moistures (5.7 %, 7.7 % and 15.7 %). As it is evident from the results in Tab. I and Fig. 3, the properties of briquettes made from material of different moisture are quite different. The total moisture content influences most rupture force and density. On the contrary the values of briquettes diameter, length and weight are only mildly dependent. Mechanical durability is on the pressed material moisture practically independent. Besides the above mentioned six parameters gross calorific value and ash amount were determined.

In conclusion it is possible to state that the results of the carried out tests fill in the previous results of other authors works. Mostly they recommend the material moisture before briquetting between 0 % and 18 %. But from our tests it follows that for the briquetting production it is better to use material of the lower moisture (up to about 12 %). Using material of higher moisture a sharply decrease in rupture force and also density occurs.

For the briquettes quality evaluation it is possible to recommend the parameter rupture force, alternatively density. On the contrary it is impossible to recommend the parameter mechanical durability, because at the moisture change of the initial material it changes minimally.

Acknowledgements

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