Properties of Briquettes from Recovered Paper and Board

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Abstract

Worldwide increasing energy demand is today permanently covered by a majority of non-renewable energy sources, namely by coal, crude oil and natural gas. This causes the rapid decline of their reserves and the time gets near when they will be run out. Therefore in last years the exploitation of renewable energy sources is permanently preferred. One of alternative fuel forms is the fuel on the basis of paper waste. In this paper the results of tests are published, which were carried out using six sorts of recovered paper and board (group and grade 1.05, 1.07, 2.01, 2.05, 2.07 and 2.08 according to ČSN EN 643), pressed in form of briquettes. During the tests following briquettes parameters were watched: moisture content, ash amount, length and diameter, weight, density, rupture force and mechanical durability. It was proved that briquettes made from recovered paper and board are compared with briquettes from wood waste are of high density, high mechanical durability and for their rupture the relatively high force is necessary. But at the same time they have high ash amount and low combustion heat.

Key words: renewable energy sources, recovered paper and board, briquetting, properties of briquettes, mechanical durability

Introduction

Today the comfortable life is paid with the expressive consumption of energy in its all forms. The non-renewable energy sources reserves are limited and they exhaust. Nevertheless they supply about four fifths of energy consumption. But in last decades the renewable energy sources are preferred. One of alternative forms of fuel, made from renewable sources, is the fuel on the basis of paper waste. First of all it is recommended to recycle this raw material – to use it as a material (McKinney, 1995). But in several last years it is a paper waste surplus on the world market and therefore the interest of specialized firms in this raw material decreases. Besides not every paper waste is apt for recycling. E.g. chancery paper, exercise-book paper, magazine paper, newspaper, boxes, cartoons or boards are suitable. E.g. wet, greasy or otherwise polluted paper or coverings from paper and another material (e.g. besides paper coverings Tetra-pak contain aluminum or polyethylene foil, too) are not suitable. Energetic use becomes an interesting alternative and it is certainly more suitable than the paper waste disposal. Besides it is necessary to keep in mind that cellulose fibers progressively lose their original properties. Therefore the paper recycling can be repeated only 5 or 6 times. Then the raw material is unusable (Kupsa, 2009; Tymich, 2011; Tymich, Lešikar, 2011).

Paper is a flexible, sufficiently consistent mass, made mostly from vegetable substance and finished in form of thin sheets. Doubtless it is one of materials without which our everyday life is unimaginable. History of its production is old and at the same time interesting, too. Already more than 5000 years ago the parchment paper was produced in Egypt from medullas of cypress-grass (*Cyperus Papyrus*) stems. The production was relatively demanding and therefore the price was high. At the beginning of the 2nd century in China the paper production was significantly developed, as the rests of silk and hemp were used as the initial raw material. Later the cotton and flax waste was utilized. In the same way the hand-made paper is produced up to the present day. The modern industrial paper production is a relatively complicated process. In principle two steps concur – the paper pulp production and the paper production (internet source 1, 2012; internet source 2, 2012).

The fuel briquettes are mostly of circular section, eventually of square, rectangular or hexagonal section with rounded corners. The briquettes size depends above all on the used press type. Cylindrical briquettes are most often of 50 mm, 65 mm or 90 mm diameter, briquettes in form of blocks are usually of 100 x 150 mm section. The briquette length is proportional to the material quantity in the press chamber. The length of cylindrical briquettes is most often 0.5 to 1.5 of their diameter, of block form briquettes about 65 mm (Basore, 1929, Sheridan, Berte, 1929, Plistil et al 2004). Besides the shape of briquettes the combustible materials are processed in the shape of pellets [Plistil, 2005, Novakova, Brozek, 2008, Punko, Gavrilovich, 2009].

But the briquetting technology is not limited only to non-metallic materials [Brozek, 2001a, Brozek, 2011, Brozek, Novakova, 2011, Brozek et al, 2012, Brozek, 2013, Kupsa, 2009, Novakova, Brozek, 2009]. It is used also for processing of chips resulting from metallic materials machining be it on the ferrous basis (steel, cast iron) [Brozek, 2001b] or on the non-ferrous basis [Brozek, Novakova, 2010]. In this case the waste volume reduction, handling facilitation or possibility of its as following material utilization are the main aims.

The briquettes mechanical properties are very important. They influence expressively e.g. the storage ability. By author it was experimentally proved (Brozek, Novakova, 2011; Brozek, 2013) that at storage the briquettes mechanical properties decrease. The decrease depends above all on the storage conditions and storage time. The adequate mechanical properties level influences also the possible handling from their production, packing and sale to the incineration at the final user.

Material and Methods

In the Czech Republic the demands on the briquettes properties are prescribed by the Directive of Ministry of the Environment Nr. 14-2009. It requires the briquettes minimum density of 900 kg·m^{-3}. The briquettes strength requirements are not prescribed. Nevertheless for operational reasons the adequate compactness is very important in

order that at a common handling neither crumbling nor disintegration occur. The briquettes minimum gross calorific value must be 17 MJ.kg^{-1}, the total moisture content max. 10 per cent by weight and the ash content max 1.5%.

But the above mentioned Directive concerns to briquettes made from wood waste, alternatively to wood waste with maximum 20% of vegetable waste. Although it is a case of a different material, briquettes from paper waste are evaluated according to these technical requirements. In the Czech Republic the special technical requirements for briquettes from paper waste still do not exist.

The properties of briquettes made from six different sorts of recovered paper and board were watched (according to ČSN EN 643, 2002), namely old corrugated containers (group 1, grade 05), telephone books (group 1, grade 07), newspapers (group 2, grade 01), sorted office paper (group 2, grade 05), white woodfree books (group 2, grade 07) and coloured woodfree magazines (group 2, grade 08). Before briquetting all samples were shredded using shredder of cross cut 4 x 18 mm.

Ahead of briquetting the moisture content (according to ČSN EN 14774-2, 2010), ash amount (according to ČSN EN 14775, 2010) and gross calorific value (according to ČSN EN 14918, 2010) were determined.

Then the raw material was without other treatment briquetted using the briquetting press type "BrikStar 30-12" (Briklis, Malšice, Czech Republic) (internet source 3, 2012) of 50 mm pressure chamber diameter. From each material at least 50 pieces of briquettes were made, what made possible to carry out the measured values statistical evaluation.

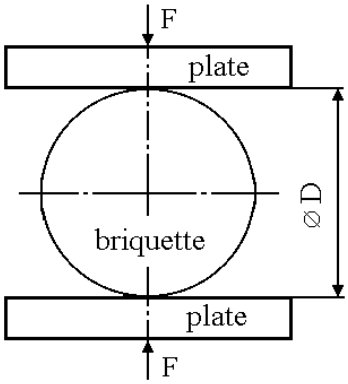

Figure 1. **Principle of the rupture test**

The tests of briquettes mechanical properties were carried out according to the method used by author during several years for testing of briquettes made from different nonmetallic (Brožek, 2001a, Brožek, 2011, Brožek et al, 2012; Brožek, 2013) and metallic (Brožek, 2001b, Brožek, Nováková, 2010) materials. The method of operation is relatively simple. Using the slide caliper the diameter and length of each briquette are measured. By weighing their weight is determined. Then the briquettes are placed between the plates of the universal tensile testing machine and continuously loaded till to the briquette rupture. The method of operation is presented in Fig. 1. The test is finished at the briquette rupture, which is accompanied with the rapid load decrease. From the load indicator the maximum load is noted down.

By the above mentioned method obtained values are mathematically evaluated. From diameter and length volume, next from volume and weight density and from length and force for rupture needed for destruction per unit of length are calculated. Using the unit of length the influence of briquettes different length is eliminated.

The determination of the mechanical durability of briquettes (according to CSN EN 14961-1, 2010 and CSN EN 15210-2, 2011) was the part of carried out tests.

Results and Discussion

Results of carried out tests are presented in following table and figures. Tab. 1 presents the properties of tested papers ahead of briquetting (moisture content, ash amount and gross calorific value). Fig. 2 presents results of length measurements, Fig. 3 presents results of diameter measurements, Fig. 4 presents results of weight measurements, Fig. 5 contains results of calculated briquettes density and Fig. 6 presents results of rupture force measurements. In all these figures the standard deviation is demonstrated by the line segments.

Table 1. **Properties of tested papers**

Sample designation	Moisture content %	Ash amount %	Gross calorific value MJ·kg^{-1}
1.05	5.5	13.9	15.5
1.07	6.1	2.9	16,2
2.01	4.6	30.1	11,7
2.05	4.3	22.8	14.5
2.07	4.6	21.6	18,0
2.08	5.3	11.0	18.0

From the results presented in Tab. 1 it follows that the moisture content at all tested materials ranged in the relatively low level, from 4.3% (sample 2.05) to 6.1% (sample 1.07).

From the point of view of the ash amount (Tab. 1) between six tested materials the significant differences exist. The lowest ash amount was determined at the sample 1.07 (2.9%). At the next two samples (2.08 and 1.05) the ash amount was higher than 10%, at the next two samples (2.07 and 2.05) the ash amount was higher than 20%. The highest ash amount (30.1%) was determined at the sample 2.01.

The gross calorific values (Tab. 1) ranged from 11.7 (sample 2.01) to 18.0 (samples 2.07 and 2.08) MJ·kg^{-1}. From this point of view only the samples 2.07 and 2.08 met the requirements.

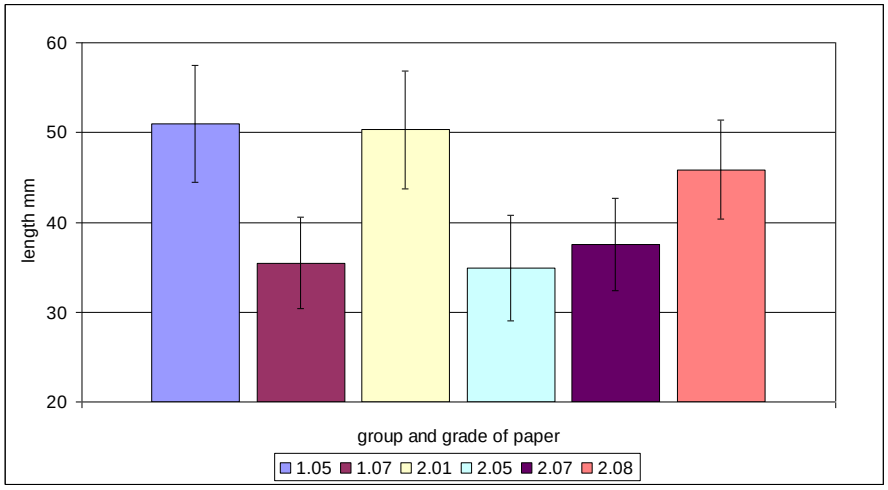

Figure 2. **Test results – briquettes length**

From the results published in Fig. 2 it is evident that the average length of briquettes made from all six sorts of paper waste is in the relatively wide range from 34.9 mm (sample 2.05) to 51.0 mm (sample 1.05).

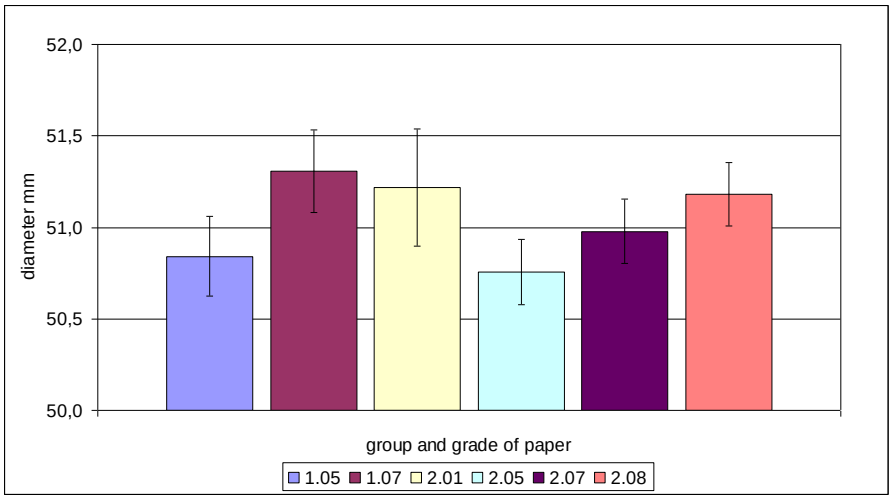

Figure 3. **Test results – briquettes diameter**

From results published in Fig. 3 it is evident that briquettes made from all six tested materials enlarged their diameter compared to the diameter of the pressure chamber diameter (50 mm). The enlargement was relatively small and for all tested materials it ranged from 0.8 mm (samples 2.05 and 1.05) to 1.3 mm (sample 1.07).

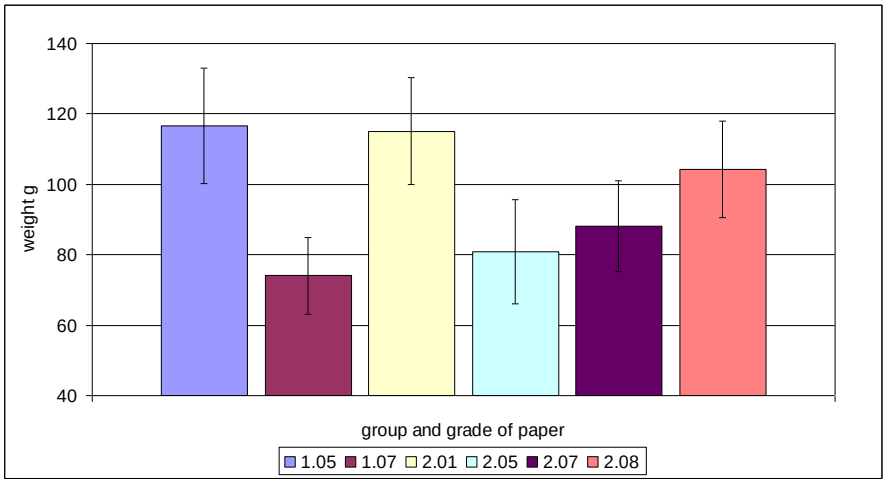

Figure 4. **Test results – briquettes weight**

From results published in Fig. 4 it is evident that the briquettes weight ranged relatively widely from 74.0 g (sample 1.07) to 116.6 g (sample 1.05).

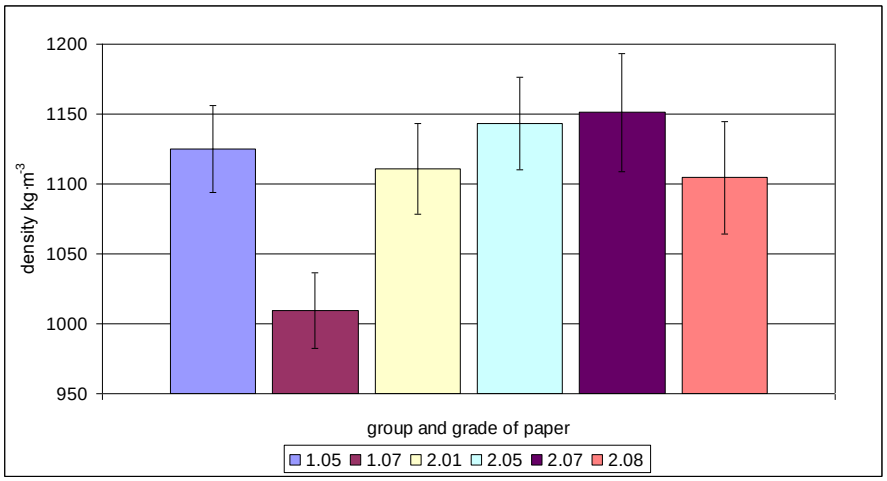

Figure 5. **Test results – briquettes density**

From results published in Fig. 5 it is evident that the briquettes density ranges relatively widely from 1009 kg·m^{-3} (sample 1.07) to 1151 kg·m^{-3} (sample 2.07).

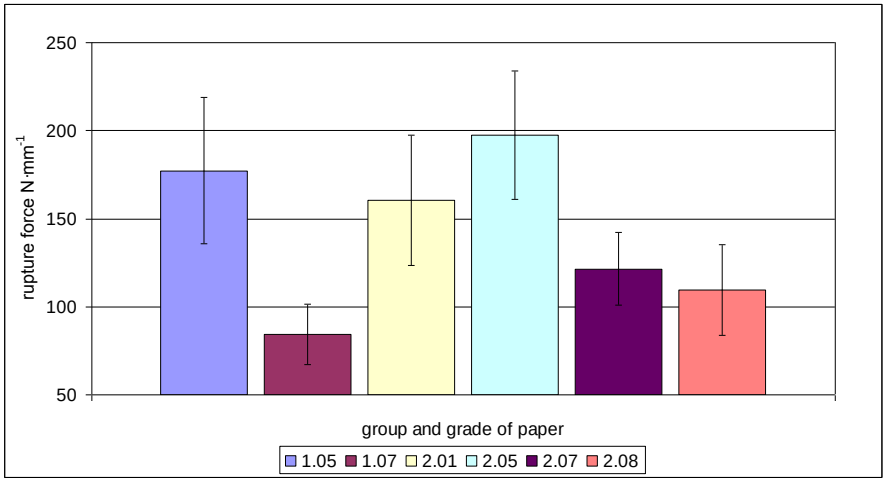

Figure 6. **Test results – rupture force for briquette destruction**

From the results published in Fig. 6 it is evident that the rupture force of the briquettes made from paper ranges relatively widely from 84 N·mm^{-1} (sample 1.06) to 198 N·mm^{-1} (sample 3.05). From this point of view briquettes were not similar.

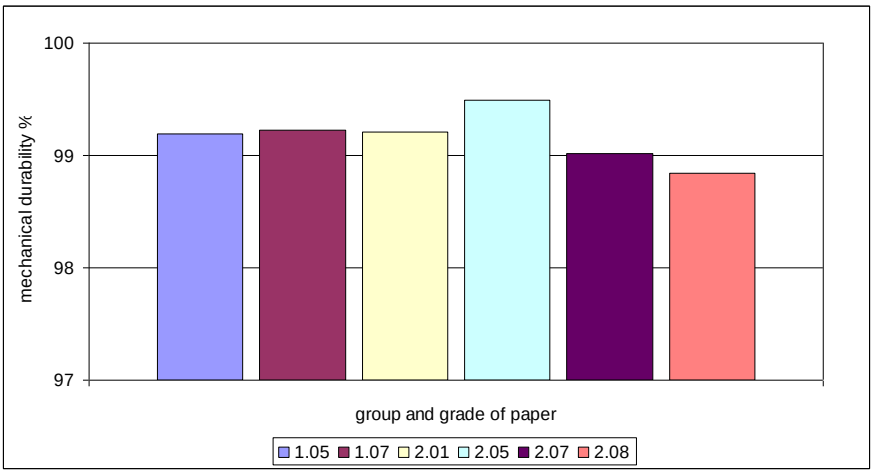

Figure 7. **Test results – mechanical durability**

As it follows from Fig. 7 the mechanical durability of all briquettes is very high. The value just below 99% was determined at the sample 2.08; the values over 99% were found at all next samples.

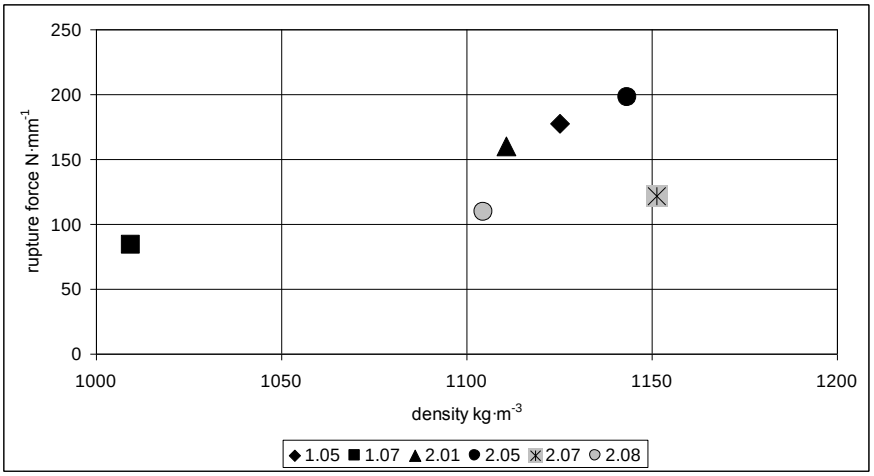

Figure 8. **Test results – relationship between rupture force and density**

The graphical representation of the briquettes rupture force and density is shown in Fig. 8. It is evident that the highest density was determined at briquettes made from sample 2.07 (white woodfree books). The highest rupture force was determined at the briquettes made from the paper 2.05 (sorted office paper).

From Fig. 8 it follows also that the properties of the briquettes made from five materials (1.05, 2.01, 2.05, 2.07 and 2.08) were relatively similar. The briquettes made from telephone books (1.07) were a bit deviating. Despite this fact it is possible to state that also these briquettes accommodated the requirements on the mechanical properties.

The comparison of obtained results with other works is in this case difficult. The author actually knows only one published work (Novakova, Brozek, 2011) studying properties of briquettes made from paper waste. For briquetting the cuttings of two different sorts of newspaper were used (dimensions: width about 3 to 10 mm, average length about 300 mm), and common shredded chancery paper, made using two types of shredders (longitudinal cut 3 x 300 mm and cross cut 3 x 30 mm). For briquetting the press type "BrikStar 50" (Briklis, Malsice, Czech Republic) of the pressure chamber diameter 65 mm was used. From the published results it follows that briquettes made from shredded chancery paper are of higher mechanical properties (density about 1045 $kg \cdot m^{-3}$, rupture force at the use of longitudinal cut about 126 $N \cdot mm^{-1}$, at the use of cross-cut 172 $N \cdot mm^{-1}$) than briquettes made from newspaper shavings (density about 790 $kg \cdot mm^{-3}$, rupture force about 45 $N.mm^{-1}$). By the results comparison we find that at the use of briquetting press of smaller pressure chamber diameter the briquettes density and rupture force increase considerably.

Other works, studying the briquettes and pellets properties, exist, too. But they engage in other materials than paper waste, primarily in briquettes made from wood waste (Basore 1929; Brozek et al.: 2012; Brozek, 2013; Sheridan, Berte, 1959), from energy plants (Kakitis et al., 2010; Plistil et al., 2004; Plistil et al., 2005), or from alternative fuels (Kolarova, 2011). Their authors concentrate primarily on energy properties, but not on mechanical properties. Therefore the comparison of their results gained at the use of briquettes from paper waste is not possible owing to tested materials dissimilarity.

Conclusion

In the paper the results of briquettes mechanical properties are published. Briquettes were made from six sorts of recovered paper and board (according to ČSN EN 643, 2002), namely old corrugated containers (group 1, grade 05), telephone books (group 1, grade 07), newspapers (group 2, grade 01), sorted office paper (group 2, grade 05), white woodfree books (group 2, grade 07) and coloured woodfree magazines (group 2, grade 08). Before briquetting all samples were shredded using shredder of cross cut 4 x 18 mm. These materials were pressed without any admixtures.

Ahead of briquetting the paper properties (moisture content, ash amount and gross calorific value) were determined. For briquetting the briquetting press type "BrikStar 30-12" of the pressure chamber diameter 50 mm was used. Briquettes were judged from several standpoints – length, diameter, weight, density, mechanical durability and rupture force using plate-loading test.

After evaluation of all measured values it is possible to say that all briquettes made from six sorts of recovered paper and board are from the user's view suitable. Briquettes technical parameters were objectively determined using above mentioned tests, adopted from methods for testing of briquettes made from wood waste. Compared with briquettes from wood waste briquettes from paper waste are of considerably higher density, mechanical durability and rupture force. But combustion heat of all sorts of paper waste is lower than combustion heat of wood waste and contemporarily ash amount is many times higher.

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