PROPERTIES EVALUATION OF BRIQUETTES MADE USING DIFFERENT BRIQUETTE PRESSES

Milan Brozek, Alexandra Novakova
Czech University of Life Sciences Prague
brozek@tf.czu.cz, novakovaa@tf.czu.cz

Abstract. The contribution contains the results of performance tests carried out with the aim to evaluate objectively the quality of briquettes made by the use of two different briquette presses and also in this way to assess the used briquette presses quality. Two briquette presses of firm Briklis were tested, namely the type BrikStar 50 of 65 mm press chamber diameter and the type BrikStar 30 of 50 mm press chamber diameter. For production of fuel briquettes four different materials were used, namely sorted office paper in form of shreds of dimensions 4x18 mm, from white wood-free books in the same shred dimensions, from lime wood chips without bark and from pine wood shavings without bark. All fuel briquettes were made using the automated operation of both briquette presses. From statistical evaluation of the carried out tests it follows that using the briquette press of 65 mm press chamber diameter it is possible to produce quality fuel briquettes only from shreds from office paper and from white wood-free books in form of shreds. The properties of fuel briquettes made from pine wood chips are although worse, but they are still suitable. Briquettes made from lime wood chips do not fulfill the Directive demands. Using the briquette press of 50 mm press chamber diameter the suitable fuel briquettes were made from all four tested materials.

Keywords: quality of briquettes, briquette press, paper, wood, properties of fuel briquettes.

Introduction

Heating using fuel briquettes today in the Czech Republic is still relatively financially advantageous. The year-long costs for family house (consumption 80 GJ·year^{-1}) at wood chips heating are about 20 000 CZK (740 EUR), at firewood heating about 21 920 CZK (811 EUR). The heating using wood waste is a bit more expensive: using pellets 28 800 CZK (1065 EUR), briquettes 30 120 CZK (1115 EUR). In the pellet and briquette price their production costs are included. The year-long heating costs using brown coal are about 28 680 CZK (1062 EUR), hard coal about 32 110 CZK (1188 EUR), natural gas about 27 210 CZK (1007 EUR) and electric power about 55 030 CZK (2037 EUR) [1] (for information: January 15, 2016 the exchange rate was 1 EUR = 27.0200 CZK and 1 USD = 24.7560 CZK).

The fuel briquettes are mostly of circular section, eventually of square, rectangular or hexagonal section with rounded corners. The briquette 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 [2-5]. Besides the shape of briquettes, the combustible materials are processed in the shape of pellets [6; 7].

But the briquetting technology is not limited only to non-metallic materials. It is used also for processing of chips resulting from metallic material machining be it on the ferrous basis (steel, cast iron) or on the non-ferrous basis [8]. In this case the waste volume reduction, handling facilitation or possibility of it as the following material utilization are the main aims.

The briquette mechanical properties are very important. They influence expressively, e.g., the storage ability. By the author it was experimentally proved [9-11] that during storage the briquette mechanical properties decrease. The decrease depends above all on the storage conditions and the storage time. The adequate mechanical properties level is influenced also by the possible handling from their production, packing and sale to the incineration at the final user.

From the results of before published works [12-15] it follows that briquettes made from recovered paper and board compared with briquettes from wood waste have a low moisture content, high density, high mechanical durability and for their rupture relatively high force is necessary. But at the same time they have a high ash amount and low gross calorific value.

Other works studying the briquette and pellet properties exist, too. But they engage in other materials than paper waste, primarily in briquettes made from wood waste [2; 7; 16; 17], from energy

plants [4; 5; 18], or from alternative fuels [7]. 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 the dissimilarity of the tested materials.

From the before made tests [10] it univocally follows that from the mechanical properties view fuel briquettes of various quality are marketed in the Czech Republic. Therefore, the experiment was arranged, which should prove the used briquette press influence on the final briquette properties.

Material and methods

On fuel briquettes a row of requirements is demanded, which are specified in relevant international and national standards and directives, above all :

- specifications and classes of solid biofuels are determined in the standard CSN EN 14961-1,
- mechanical durability is determined in the standard CSN EN 15210-2.

At fuel briquette energetic properties, gross calorific value, calorific value, moisture content, ash amount and properties, contents of chemical elements, chemical composition of combustion products etc., but also mechanical properties, density, strength, crumbling, damage at handling etc., are considered. In the Czech Republic the demands on briquette properties are determined by the Directive of the Ministry of Environment No. 14/2009. For briquettes made from wood waste this Directive requires the density of at least 900 $kg \cdot m^{-3}$, gross calorific value at least of 17 $MJ \cdot kg^{-1}$, moisture content max. 10 % by weight and ash amount max. 1.5 %. The requirements on the briquette strength are not included in the Directive. But it is very important that briquettes are of adequate cohesiveness in order that at common handling neither crumbling nor falling apart occur. In the Czech Republic no requirements on fuel briquettes from paper waste are determined.

The aim of the experiments was to evaluate the properties of fuel briquettes made from four different materials using two different briquetting presses and also in this way to assess their quality. The tested briquettes were made from sorted office paper (group 2, grade 05 according to ČSN EN 643) in form of shreds of dimensions 4 x 18 mm, from white wood-free books (group 2, grade 07 according to CSN EN 643) in form of shreds of dimensions 4 x 18 mm, from lime wood chips without bark and from pine wood shavings without bark.

Two briquette presses of firm Briklis were tested, namely the type BrikStar CS 25 of 65 mm press chamber diameter and the type BrikStar 30-12 of 50 mm press chamber diameter. All fuel briquettes were made at automated operation.

After sampling the briquettes were numbered, weighted and their length and diameter measured. Then single briquettes were loaded by pressure using the universal tensile strength testing machine (Fig. 1). The rupture force at the split testing was determined.

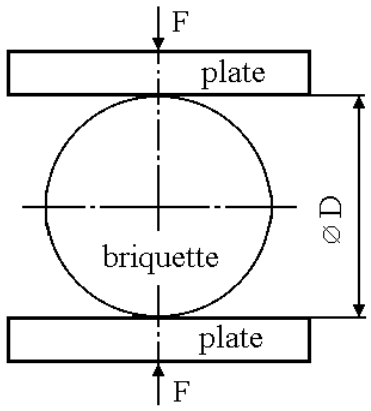

Fig. 1. **Principle of the briquette strength test**

From the measured values the briquettes density was calculated. With regard to the production technology the briquettes are of different length. Therefore, their rupture force was recalculated and it is presented as the force per unit.

Moreover, the above mentioned parameter gross calorific value, moisture content and ash amount were determined.

Results

The test results are presented in the following figures and tables. For evaluation of the fuel briquette quality using two types of briquetting presses the own criterion was used – relation between the rupture force and density [6; 12; 16]. Fig. 2 presents the relation between the rupture force and density for briquettes of 65 mm diameter. Fig. 3 presents the same relation for briquettes of 50 mm diameter. In both figures small marks quote single results, big marks – average values. Table 1 presents the determined values of gross calorific value (according to ČSN EN 14918), moisture content (according to ČSN EN 14774-2) and ash amount (according to ČSN EN 14775) of the used materials. The statistical evaluation of the measured values is presented in Table 2.

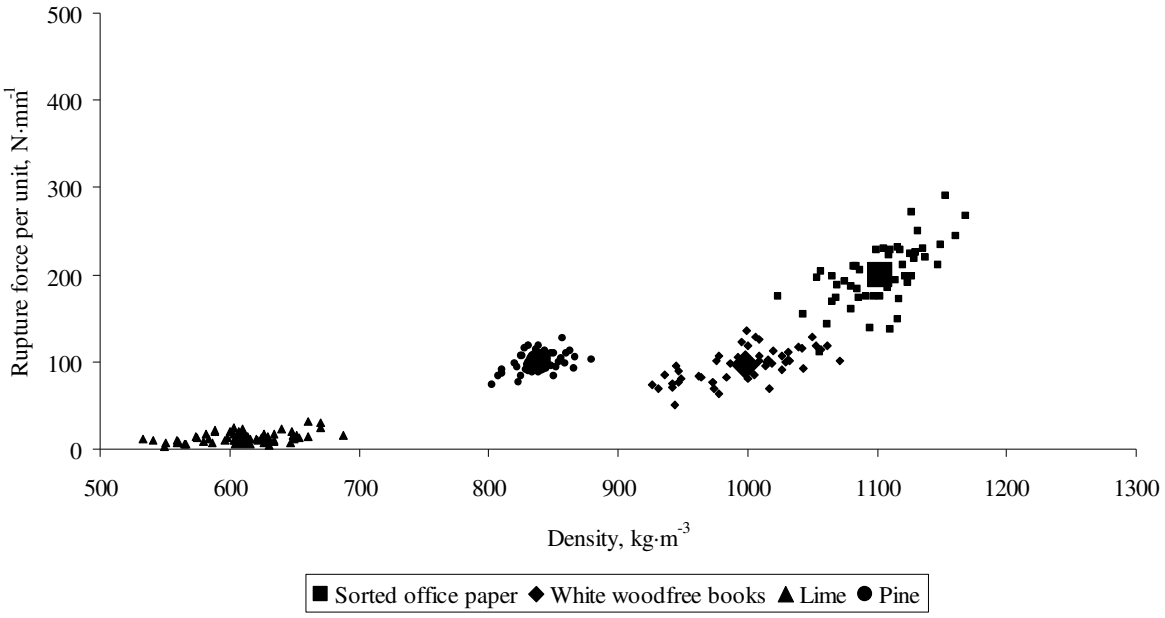

Fig. 2. **Relation between rupture force and density for fuel briquettes of 65 mm** diameter

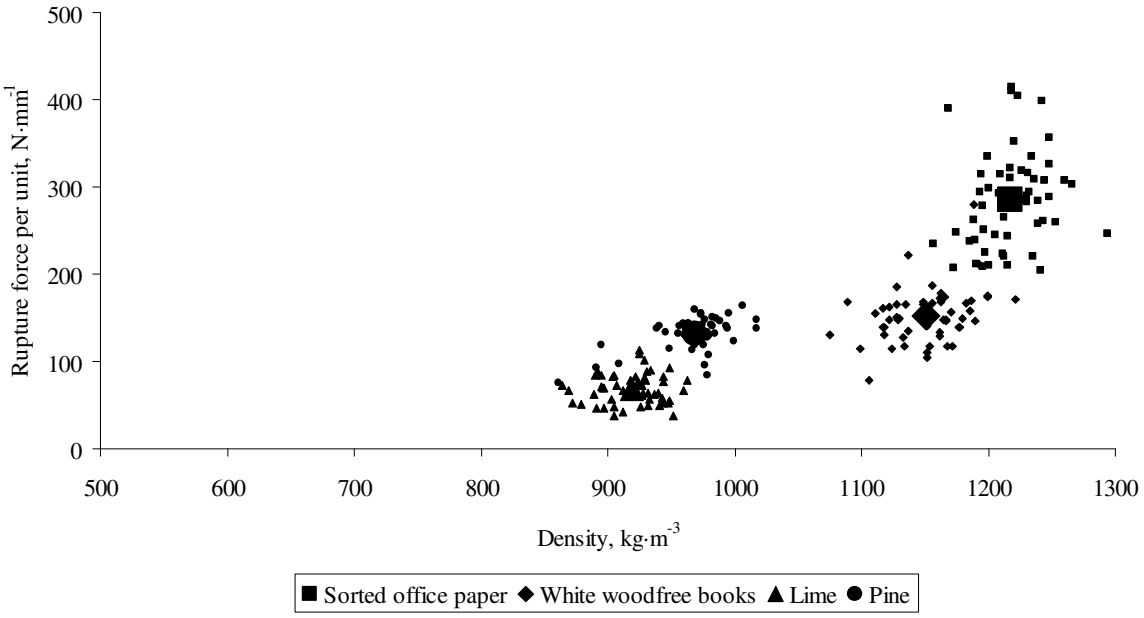

Fig. 3. **Relation between rupture force and density for fuel briquettes of 50 mm diameter**

Table 1

Test results

Sample	Gross calorific value, $MJ \cdot kg^{-1}$	Moisture content, %	Ash amount, %
Sorted office paper, shreds	14.1	5.4	23.2
White wood-free books, shreds	18.0	6.0	23.1
Lime, chips	21.1	7.1	0.7
Pine, shavings	20.3	8.5	0.6

Table 2

Test results

Sample	Length, mm	Diameter, mm	Weight, g	Density, $kg \cdot m^{-3}$	Rupture force per unit, $N \cdot mm^{-1}$	Mechanical durability, %
Diameter 65 mm, sorted office paper, shreds	47.09±6.06	65.56±0.17	175.3±24.3	1102.0±30.2	199.6±34.0	98.9
Diameter 65 mm, white wood-free books, shreds	46.57±5.79	66.11±0.27	159.6±21.1	997.5±36.9	96.4±18.7	96.0
Diameter 65 mm, lime, chips	92.51±17.08	67.01±0.83	199.7±40.9	610.3±35.7	13.7±6.0	37.8
Diameter 65 mm, pine, shavings	47.66±4.07	66.50±0.18	138.9±12.0	838.9±15.0	99.5±10.5	92.5
Diameter 50 mm, sorted office paper, shreds	49.73±5.01	50.66±0.13	122.0±12.1	1217.7±26.1	284.9±54.6	99.4
Diameter 50 mm, white wood-free books, shreds	49.84±5.68	50.80±0.32	116.2±13.7	1150.3±29.9	152.9±30.5	98.2
Diameter 50 mm, lime, chips	64.02±5.83	50.65±0.42	118.6±11.2	919.4±22.9	68.3±16.8	89.4
Diameter 50 mm, pine, shavings	53.83±2.70	51.15±0.20	107.1±6.2	968.4±27.4	132.0±17.8	97.5

Discussion

The requirements on fuel briquettes made from wood waste are determined by the Directive 16/2009. In the Czech Republic a similar document for fuel briquettes made from paper waste does not exist. Therefore, the technical requirements were borrowed and all briquettes were evaluated according to the same conditions.

From Table 1 it follows that from the point of view of the gross calorific value only the wood waste (lime wood chips and pine wood shavings) satisfied. The paper waste (shreds made from sorted office paper and from white wood-free books) did not meet these requirements. From the point of view of the moisture content all four tested materials met the requirements. From the point of view of the ash amount only the wood waste met the requirements. At the paper waste the determined values exceeded substantially the limit. But from the paper waste fuel briquettes are produced only in the case when the paper waste cannot be recycled (e.g., owing to pollution) [15].

From Table 2 it follows that the briquettes made using the briquette press of 50 mm press chamber diameter are at three tested materials only minimally longer (from 6 to 13 %) than using the press of 65 mm press chamber diameter, with the exception of the briquettes made from lime wood chips, which are of 44 % longer than the briquettes made using the briquette press of 50 mm press chamber diameter.

The diameter of all fuel briquettes made from all four materials using both briquette presses is mildly larger (at 50 mm press chamber the diameter is in average of 1.6 %, at 65 mm press chamber the diameter is in average of 2.0 %) compared with the press chamber diameter.

In accordance with the prediction it was confirmed that the briquettes made using the briquette press of 65 mm press chamber diameter have at all briquetted materials higher density (from 30 to

68 %) compared with the briquettes made using the briquette press of 50 mm press chamber diameter. It is evident that it is connected with their bigger volume although they have lower density.

Density of the briquettes made using the press of 50 mm press chamber diameter is in average of 14 % (from 10 to 15 %) higher than of the briquettes made using the press of 65 mm press chamber diameter. Only at the briquettes made from lime wood chips it is higher of 51 %.

This fact is connected with the briquette press design. Both presses use the same source of hydraulic oil for hydraulics. The difference is in the compression force, which is higher at the press chamber of lower diameter.

The rupture force of the fuel briquettes made using the press of 50 mm press chamber diameter is on average of 40 % higher than the rupture force needed using the press of 65 mm press chamber diameter. Only at the briquettes made from lime wood chips the rupture force is five times higher.

It is connected with higher compression pressure, when the made briquettes have higher cohesiveness and therefore the rupture force is higher.

Mechanical durability of the briquettes made using the press of 50 mm press chamber diameter is on average 98.4 % (from 97.5 to 99.4 %), of the briquettes made using the press of 65 mm press chamber diameter in average 95.8 % (from 92.5 to 98.9 %). As well as at the foregoing properties also here the briquettes from lime wood chips have considerably different properties. At the briquettes of 65 mm diameter there is a very low value of durability (only 37.8 %), at the briquettes of 50 mm diameter the value of 89.4 % was determined.

The maximum mechanical durability regardless of the press chamber diameter was determined at the briquettes from sorted office paper. These briquettes had also the highest density and destruction force of all tested materials. The lowest durability was determined at the briquettes from lime wood chips. These briquettes had both low density and low rupture force, too.

Conclusions

The contribution contains the laboratory test results of fuel briquettes made from four different materials using two different briquette presses, namely sorted office paper in form of shreds of dimensions 4x18 mm, from white wood-free books in the same shreds dimensions, from lime wood chips without bark and from pine wood shavings without bark. For briquette production two types of briquette presses of firm Briklis of 50 and 65 mm press chamber diameters were used.

From statistical evaluation of the carried out tests it follows that using the briquette press of 65 mm press chamber diameter it is possible to produce quality fuel briquettes only from sorted office paper shreds (density 1102.0 $kg \cdot m^{-3}$) and from white wood-free books shreds (density 997.5 $kg \cdot m^{-3}$). The briquettes made from lime chips (density 610.3 $kg \cdot m^{-3}$) and from pine shaving (838.9 $kg \cdot m^{-3}$) did not meet the Directive requirements. Using the briquette press of 50 mm press chamber diameter the quality fuel briquettes were made from all four tested materials (density from 919.4 to 1217.7 $kg \cdot m^{-3}$).

Acknowledgement

The work was supported by the internal research project of the Faculty of Engineering IGA 2016: 31140/1312/3107 “Influence of feedstock specific mechanical parameters and type of storage conditions on final quality of briquettes from waste biomass”.

References

1. Basore C.A. Fuel Briquettes from Southern Pine Sawdust. Auburn: Alabama Polytechnic Institute, 1929. 30 p.
2. Sheridan E.T., Berte V. C. Fuel-briquetting and Packaged-fuel Plants in the United States that Reported. Washington: U. S. Government Printing Office, 1959. 7 p.
3. Plíštil D., Brožek M., Malaťák J., Heneman P. Heating briquettes from energy crops. Research in. Agricultural Engineering, 50, 2004. pp 136-139.
4. Plíštil D. Briketování a paketování (Briquetting and packeting). [Ph.D. Thesis]. Praha: ČZU, 2005. 169 p.

5. Nováková A., Brožek M. Mechanical properties of pellets from sorrel. 7th International Scientific Conference "Engineering for Rural Development". May 29-30, 2008, Jelgava, Latvia, pp. 265-269.
6. Kolářová M. Vlastnosti pelet a briket pro energetické využití (Properties of pellets and briquettes for energy use). [Ph.D. Thesis]. Praha: ČZU, 2011. 144 p.
7. Brožek M., Nováková A,. Briquetting of chips from nonferrous metal. 9th International Scientific Conference "Engineering for Rural Development". May 27-28, 2010. Jelgava, Latvia, pp. 236-241.
8. Brožek M., Nováková A. Influence of storage on briquettes mechanical properties. Ecology and farming technologies: Agro-engineering approaches. May 17-19, 2011. Saint-Petersburg-Pavlovsk, Russia, pp. 225-232.
9. Brožek M. Influence of storage on briquettes mechanical properties. Scientia Agriculturae Bohemica, 45, 2014, pp. 175-179.
10. Brožek M. Study of briquettes properties at their long-time storage. Journal of Forest Science, vol. 59, 2013, pp. 101-106.
11. Brožek M. Properties of briquettes from paper waste. Manufacturing Technology, vol. 13, 2013, pp. 138-142.
12. Brožek, M.: Properties of briquettes from recovered paper and board. The Sixth International Scientific Conference "Rural Development 2013". November 28-29, 2013. Akademija, Lithuania, pp. 25-30.
13. Brožek M., Nováková A. Briquettes from recovered paper and board. 12th International Scientific Conference "Engineering for Rural Development". May 24-25, 2013. Jelgava, Latvia, pp. 488-493.
14. McKinney R.W.J. (Ed.). Technology of Paper Recycling. London: Blackie Academic & Professional, 1995. XIV, 401 p.
15. Brožek M., Nováková A., Kolářová M. Quality evaluation of briquettes made from wood waste. Research in Agricultural Engineering, vol. 58, 2012, pp. 30-35.
16. Brožek M. Quality evaluation of briquettes made from biomass. The Fifth International Scientific Conference "Rural Development 2011". November 24-25, 2011. Akademija, Lithuania, pp. 308-313.
17. Kakitis A., Nulle I., Ancans D. Durability of the arranged structure biomass briquettes. 9th International Scientific Conference "Engineering for Rural Development". 2010, Jelgava, Latvia, pp. 285-289.