MECHANICAL PROPERTIES OF PELLETS FROM SORREL

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Abstract. All-world energy consumption increases rapidly, but resources of fossil fuels (coal, raw oil, natural gas) decrease. Therefore in last years the use of renewable energy sources is still more preferred (wind, water, solar energy). Except these ones the use of biomass in form of briquettes or pellets is proposed. In this paper the test results of mechanical properties of pellets made on the sorrel basis with other additions are published. Effect of the additions sort and amount on pellets mechanical properties was determined. From the results it follows that all tested pellets sorts fulfil the requirements of strength and density and that they are utilizable in practice.

Key words: renewable energy sources, biomass, pellets, palletizing.

Introduction

Today the more comfortable mankind life is ransomed by an expressive energy consumption rise in all forms. The resources of nonrenewable energy sources (coal, raw oil, natural gas) are not unlimited and gradually they use up themselves. But their secure about four fifths of energy consumption. In last ten years periods the renewable energy sources are preferred, e.g. energy of wind, water, solar radiation and biomass. The results of the up to now endeavours about the more wide use of wind and solar energy are not convincing in the conditions of Czech Republic. The possibility of biomass use shows itself to be perspective. But compared with other countries we fall behind. According to published information only several percent of the total consumed energy is produced from biomass. In some countries (Finland) it is up to 25 %. They are several reasons of this fact – from the potential users small knowledge about the biomass use advantages over the higher price compared with some sorts of fossil fuels to the not quite sufficient grants in this field.

Biomass is an organic mass of botanical or animal origin. In principle it can be obtained by two ways – from a biomass which is grown for this purpose or from a waste biomass (e.g. from municipal waste, waste from agricultural basic production or from logging). In the literature a great quantity of vegetal sorts has been published which are suitable for the subsequent power-producing use. They can be classified using several criterions. Products determined for fuel production are often classified [3, 5] according to the vegetative period duration, namely in:

- Annual – prince\`s feather (*Amaranthus sp.*), hemp (*Cannabis sativa*), mallow (*Malva verticillata*), safflower (*Carthamus tinctorius*) etc.,
- Biennial – evening primrose (*Oenothera biennis L.*), white melliot (*Melilotus albus*) etc.,
- Multi-annual and perennial – cup plant (*Silphium* perfoliatum),rowan (*Galega orientalis L.*), topinambour (*Helianthus tuberosus*), deer\`s foot (*Agrostis giganthea*), crown vetch (*Coronilla* varia), elecampane (*Inula helenium*), energy sorrel (*Rumex tianshanicus*), rescuegrass (*Bromus cartharticus*), smooth brome (*Bromus inermis Leysser*), canary grass (*Phalaroides arundinacea L.*) etc.

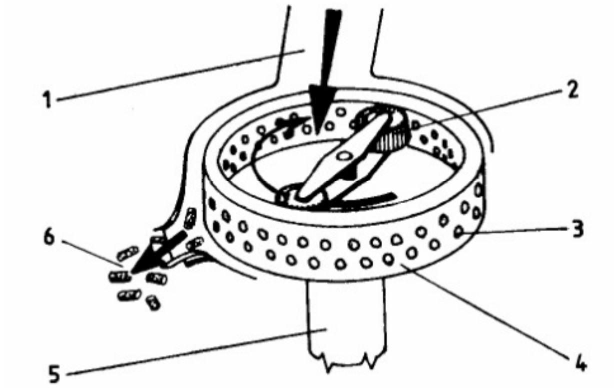
a) b)

Fig. 1. **Briquettes (a) and pellets (b) from wood**

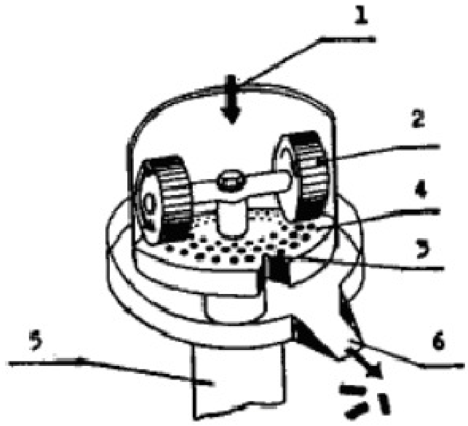
The biomass treatment depends especially on its properties [1, 2, 3, 5]. At present thermochemical (gasifying, combustion), biochemical (methane fermentation, alcoholic fermentation), chemical (esterification) and biological (composting, wastewater treatment) processes are used. Further we will only deal with biomass combustion.

For combustion biomass is formed to a suitable size. Fuels from wood are standardly delivered as logs, bark, split fuelwood, fillings, wood-shavings, briquettes and pellets (Fig. 1); fuels made from power-producing plants are usually delivered as bales, chopped straw, briquettes and pellets [4, 6, 7, 8, 9].

Pellets are granulas of a cylindric form of a diameter 2 to 25 mm, most often about 10 mm. Their length would not exceed 100 mm, usually it is between 5 to 40 mm. Too long or too short pellets can make problems in their transport and combustion. Pellets are made by use of brakers (Fig. 2) by pressing using high pressures. From the power-producing point of view pellets offer many preferences – high calorific value, low water and ash matter content, good freightability. Therefore they can be ecological fuel of future [2].



a) 1 – material feed, 2 – rotating extrusion cylinders, 3 – extrusion holes, 4 – vertical ring matrix, 5 – drive, 6 – pellets discharge



b) 1 – material feed, 2 – rotating extrusion cylinders, 3 – extrusion holes, 4 – horizontal matrix, 5 – drive, 6 – pellets discharge

Fig. 2. **Operating principle of a braker with vertical matrix (a) and with horizontal matrix (b)**

Materials and methods

Mechanical properties of briquettes and pellets are very important. They influence storage ability and possible freightability. Requirements for power-producing briquettes use are determined by pertinent specifications. In Czech Republic the Directions MZP No 14/2003 [10] are valid, which order requirements for briquettes from wood waste. Analogical specifications for briquettes are valid in other European countries, e.g. in Germany DIN 51731 [11], in Austria ÖNORM M 7135 [12], in Sweden SS 187120 and SS 187121 [13], in Switzerland SN 166000 [14] and in Norwegen NS 3165, NS 3166, NS 3167 and NS 6168 [15]. All these standards call for the minimal density of 900 kg.m^{-3}, let us say from 1000 to 1400 kg.m^{-3}. Requirements on strength are never determined. Nevertheless the suitable strength is important so that in usual handling no crush or falling apart occur.

Till this time specifications or standards for pellets properties have not be found by authors of this paper. Therefore requirements for briquettes are used.

For tests pellets of 10 mm diameter of several manufacturers were used. Concrete pellets material identification is presented in Tab. 1. In this stage only pellets containing sorrel were tested. The part of sorrel varied from 26.25 to 100 %. One or two additions were added, namely scorpion shell, canary grass, poplar, bark, straw or coal.

Table 1

Material identification of tested pellets

Specimen number	Material of pellets
1	Sorrel (100 %)
2	Sorrel + scorpion shell (60/40)
3	Sorrel + scorpion shell (50/50)
4	Sorrel + canary grass (75/25)
5	Sorrel + canary grass (50/50)
6	Sorrel + poplar (50/50)
7	Sorrel + bark (75/25)
8	Sorrel + bark (50/50)
9	Sorrel + straw (75/25)
10	Sorrel + straw (50/50)
11	Sorrel + straw (50/50) less water
12	Sorrel + canary grass + bark (66/17/17)
13	Sorrel + canary grass + coal (37.5/12.5/50)
14	Sorrel + canary grass + coal (26.25/8.75/65)
15	Sorrel + bark + coal (37.5 /12.5/50)
16	Sorrel + straw + coal (37.5/12.5/50)

Tests of mechanical properties of pellets were carried out according to technique projected and used by authors already several years for testing of briquettes made from various metallic and nonmetallic materials and waste.

The test is relatively simple. From the pellets supply ten samples for each test were by chance chosen. By preliminary orientation tests it was determined that properties of one supply are not too different. Therefore the more samples use is not purposeful. Then the front surfaces of chosen pellets are squared up by a careful grinding using fine abrasive cloth. Length and diameter of each pellet is measured using calliper (in the middle and close to both ends). Pellets mass is determined by use of technical balance. Then pellets are put between plates of the universal tensile strength testing machine and loaded by compression up to their failure. The operating principle shows Fig. 3.

The test ends at the moment of pellet failure, when the compressive force falls rapidly. The maximum force is read. The supplied pellet, pellets prepared for test (front surfaces squared up) and after the test are shown in Fig. 4.

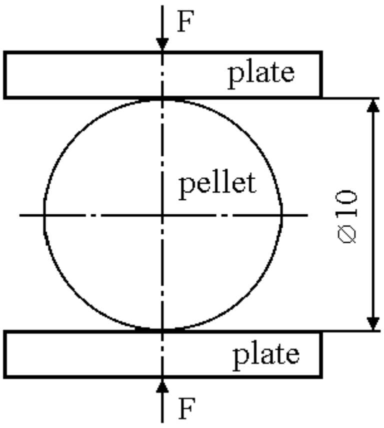


Fig. 3. **Operating principle of pellets strength test**

Fig. 4. **Supplied pellet, pellets prepared for test and after the test**

By above described procedure the obtained data are mathematically evaluated. From the length and the diameter the volume, from the volume and the weight the density, from the length and the force the unit force are calculated. With regard to different tested pellets length the unit of 20 mm length was predetermined.

Results and discussion

The test results are graphically illustrated in Fig. 5.

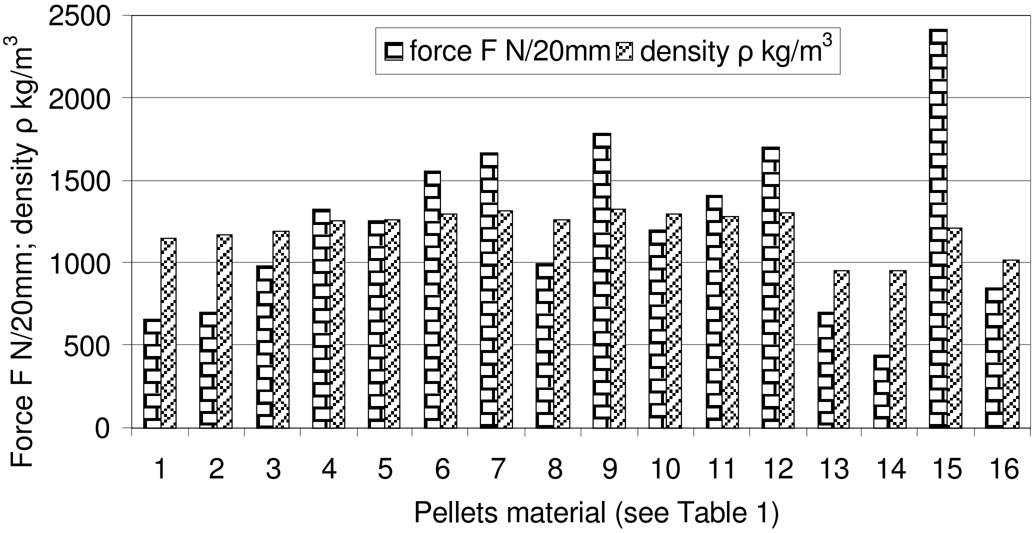


Fig. 5. **Test results**

From results presented in Fig. 5 it follows that the strength characteristics of pellets made only from sorrel (specimen 1) are relatively low. By addition of practically all tested materials they increase (except the specimen 14 with addition of canary grass and coal in the total amount of almost 75 %); the maximal strength increase was reached at the specimen 15 (sorrel + bark + coal), namely almost 3.7 times. The effect of various additions on the destruction force is different. While the scorpion shell amount increase (specimens 2 and 3) from 40 to 50 % evokes the force increase of about 40 %, the canary grass amount increase (specimens 4 and 5) from 25 to 50 % evokes the force decrease of about 6 %. Even more expressive force decrease (almost 70 %) evokes the bark amount increase (specimens 7 and 8) from 25 to 50 %. Also the increase of the straw amount (specimens 9 and 10) acts negatively; the amount increase from 25 to 50 % evokes the force decrease of almost 50 %. But when the pellets are made from material of lower water content, "drier" (specimen 11), the force decrease is milder, namely of about 27 %. At pellets made from three components (specimens 12 up to 16) the highest force was reached at the combination of sorrel + bark + straw (specimen 15), the relatively high force was reached at the combination of sorrel + canary grass + bark (specimen 12). From the test results of specimens 13 and 14 it follows that the increase of coal amount over a specific limit and in this way the amount of sorrel and canary grass decrease evokes the force decrease.

The density of pellets made only from sorrel (specimen 1) corresponds to the requirements. By additions the density of most pellets increases, except specimens 13, 14 and 16. The density of these specimens compared with pellets made only from sorrel decreases. Nevertheless also these pellets correspond to the requirements. By addition of more scorpion shell (specimens 2 and 3) from 40 to 50 % the slight density decrease (about 2 %) occurs, analogous to the canary grass amount increase (specimens 4 and 5) from 25 to 50 %, when the density increase is about 1 %. But the bark amount increase (specimens 7 and 8) from 25 to 50 % evokes the density decrease of about 4 %. The straw amount increase from 25 to 50 % (specimens 9, 10 and 11) is similar, when the density decrease of about 3 % occurs as well as at specimens of lower water content. The highest density of pellets made from three components was determined at the specimen 12 (sorrel + canary grass + bark), high density at the specimen 15 (sorrel + bark + coal). Lower values but still satisfactory were measured at specimens 13 and 14 (sorrel + canary grass + coal in various proportions).

Conclusions

The paper contains the laboratory tests results of mechanical properties of pellets, which were made from sorrel eventually from sorrel and one or two additions. In detail the influence of additions sort and amount on pellets strength and density was studied. It is possible to state that the sort and amount of the addition influences both the density and the strength of pellets. But density varies relatively little while strength values expressively.

After evaluation of all measured values it is possible to say that from the standpoint of corresponding specifications all values are acceptable. Measured values of density (from 950 to 1325 $kg.m^{-3}$) were in the limits determined by specifications for briquettes. Also measured forces for pellets failure were from 440 to 2420 $N.mm^{-1}$. Values of density and strength compared with test results of briquettes and pellets carried out formerly in our department are favorable.

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