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THE PELLETISING PROCES: THE ASPECTS THAT INFLUENCE DENSTITY OF WOOD PELLETS
PELETOVÁNÍ: ASPEKTY OVLIVŇUJÍCÍ MĚRNOU HMOTNOST DŘEVĚNÝCH PELET

Abstract

Pellets are a modern form of biomass compaction, which offers many opportunities for the development of renewable energies in the 21st century. This paper examined the influence of input parameters on the density of pellets with the use of the real pelletizing machine. Knowledge of the influence of changes in input parameters can effectively affect the output density of pellets so as to maximize and to simultaneously meet the required characteristics of the pellets according to the pellets standards. The building of the measuring point enabled to manufacture our own pellets. Furthermore, were created charts that display the dependence between the density and input factors. The influence of the fraction size and type, humidity content and the type of raw materials and the influence of pressing canal diameter change were examined. Finally, this paper concluded that the output pellets density is very sensitive to changes in input parameters. It is important to use input parameters that contribute to a high concentration of energy per unit volume and the efficient use of machines for production of pellets. As well as it reduces the necessary amount of space for storage.

Abstrakt

Pelety jsou moderní forma zhutnění biomasy, která skýtá mnohé příležitosti pro rozvoj obnovitelné energie 21. století. Tento výzkum se zabýval vlivem vstupních parametrů na výstupní měrnou hmotnost pelet při použití reálného peletovacího lisu. Znalostí vlivů změny vstupních parametrů lisování lze efektivně ovlivnit výstupní měrnou hmotnost pelet tak, aby byla co nejvyšší a aby byly současně splněny požadované charakteristiky pelet dle norem upravujích vlastnosti pelet. Vytvoření měřícího místa nám umožnilo vlastní výrobu pelet. Dále jsme vytvořili grafické závislosti ovlivňující měrnou hustotu pelet. Zahrnuli jsme vliv velikosti a typu frakce suroviny, vlivu vlhkosti suroviny, vliv druhu suroviny a vliv změny průměru lisovacího kanálku. Závěrem našeho výzkumu je, že výstupní měrná hmotnost je velmi citlivá na změnu vstupních parametrů. Při výrobě pelet je důležité používat takové vstupní parametry, které přispívají k dosažení vysoké hodnoty koncentrace energie na jednotku objemu a tím k efektivnímu využívání strojů k produkci a také k snížení objemu prostoru pro skladování.

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1 INTRODUCTION

The population on the Earth is constantly growing. It is closely related to an increased need for energy to meet human needs and development of civilization. This growing demand can be satisfied only by finding a combination of highly efficient and innovative methods of production and energy recovery from natural and secondary sources. With the discovery of nuclear energy questions about the preference of the price, safety, waste management and the risk of diversion of nuclear energy as a weapon have come out [1]. Increased interest in "sustainability fossil and nuclear energy" caused the development of renewable energy. There is an effort to replace fossil fuels with fuels derived from renewable energy sources that are the product of ongoing and recurring stream of energy in nature.

The technology of the wood compaction is one of the ways to convert low-grade waste into valuable fuel [5]. Compaction technology has highly developed in many countries. In Europe it is mainly in Sweden, Denmark, Austria and Germany. Among the hopeful substitute for fossil fuels are pellets.

This paper examined the influence of input parameters on output density of pellets in the production of real pelletizing machine. Many tests have been done in a laboratory with specially made pressing stands. The interest was primarily in the dependences of pellets production under the real conditions. Furthermore the conclusions and recommendations to increase efficiency of biofuels production were drawn. This efficiency is reflected in the achievement of standard density pellets under ideal conditions that eliminate losses. To examine the quality mechanical properties of pellets in terms of compaction are explored [4]. These properties depend on many input, output and production factors. To achieve the standard parameters and max performance is necessary to know the effects of various parameters.

From previous studies conducted in laboratory conditions on a specially made stands result that the ideal humidity for pressing is 6-12% [4]. Also with the finer granularity of the raw material is achieved better quality of pellets. The influence of the die canal diameter is not mentioned in the previous researches at all. As already mentioned, paper focused on finding the influence of input parameters on the pellets density produced in the real pelletizing machine. These conditions were chosen because in the reality pelletizing does not run under ideal laboratory conditions. Our results are therefore directly linked to the use of real machine and not to a laboratory stand. This is considered as an advantage through which is possible to deduce implications arising directly from the practice of pellets production. The main task was finding these dependencies affect the final pellets density. Influence of the size and type of material fractions, the material humidity in raw material, the type of raw materials and the change in die canal diameter were concluded.

The paper is then structured as follows: First, it clarified the issue of production of pellets. This is followed by a description of the procedure to obtain the necessary data. Research results are further discussed. Finally are drawn consequences and recommendations for future research and practice.

2 BACKGROUND

Biomass is a matter that arises in the natural biological processes. It's organics mass formed by the process of photosynthesis catchment and solar energy conversion. Biofuels are derived from biomass. Briquettes and pellets are biofuels with the highest calorific value of all existing phyto fuels. The briquettes are designated especially for large combustion boilers or manually feeding the fire in the small boilers. Pellets are intended mainly for mechanical automatic combustion. Wood pellets are a product obtained by pressing crushed or ground wood. It is usually the shape of a cylinder with circular cross section. By the pressing process is increased density of raw material. That maximizes the energy content per unit. Pellets have a high calorific value in comparison to sawdust. And it is also low in ash and water. They are resistant to impact, so it can be manipulated with them and automate the process of combustion. Some selected parameters of pellets are in the Table 1.

Table 1 Characteristics of pellets according to the standards [5]

Parameters	Standard		
	German	Austrian	Swedish
	DIN 51 731	Önorm M7135	SS 18 7120
Diameter of the pellet (mm)	4 – 10	4 – 10	< 25
Length of the pellet (mm)	< 50	< 5 × d	< 5 × d
Thermal power (MJ · kg^{-1})	17.5 – 19.5	> 18	> 16.9
Pellet density (kg · dm^{-3})	> 1.0 – 1.4	> 1.12	not set

To produce pellets can be used raw material from deciduous or conifers woods. Conifers total 70 - 95% of wood for the production. The pelletizing is a progressive method of compaction shredded and dried materials through extrusion die [5]. This technology is characterized by the fact that at any one time is made not one but several pressings of pellets, depending on the size of the press and the diameter of canals in the die [5]. Pellets are made either from secondary raw materials or primary cultured exclusively for the production.

2.1 Parameters that can influence pellets quality

To be able to press high quality pellets from different types of wood, it is important to respect the parameters that have influence. In Europe are used primarily these standards: DIN 51731 (Germany), Önorm M7135 (Austria) and 18 7120 (Sweden). Parameters that affect the pellets quality are granularity of the raw material, pressing temperature, the length of the die canal, content and type of binder in the material, pressing speed, material humidity, chemical composition of raw materials, working pressure and type of material [4], [2].

Granularity of raw material - a finer granularity of raw material increases the quality of pellets. It's due to more equal heat transmission through the processed material. Required pressing force also grows with the increase of the fraction size. Homogeneity is also important. With the use of non homogeneous material pellets soon lose the quality and often disintegrate early after pressing due to a mechanical manipulation.

Raw material humidity - ideal value differs. Authors recommend humidity around 6-12 % [4], 10-12 % [3] or 10-13 % [2]. Kott, states that material wetter than 10-12% will significantly reduce long-term quality of final products, even it seems to be easier to pelletize and they seem to be more solid - after a short time, the pellets begin to crumble [3]. He indicates as the max value 18%. Generally, higher water content increases the consumption of energy and decreases the quality of pellets.

Type of the material - can be classed into two categories: deciduous, coniferous trees and hard, medium and soft wood. Coniferous raw material has higher content of lignin so it is easier to make pellets from that. Very good is also soft wood because it is less resistant to mechanical processing than hard wood.

The diameter of the canal in pressing die - can affect the final density. There were found experiments dealing just with the length of the canal in the literature [4], [2]. Therefore it was seen as a gap in this area which should be explored.

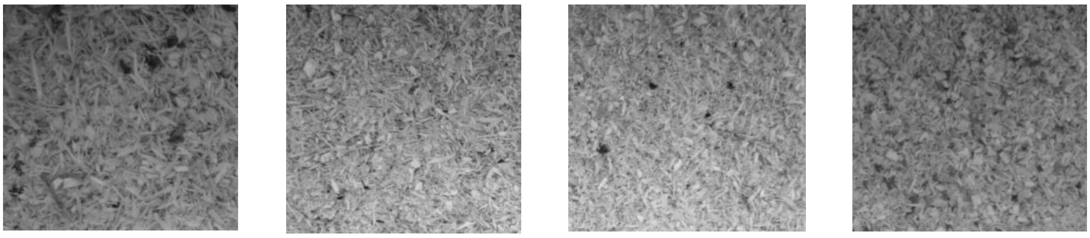
3 METHODOLOGY

For the experimental tests were used spruce chips from the trees about 80 years old and hazel chips, ten years old, the Moravia-Silesian Region. Pellets were produced at the pelletizing machine JGE 120 Economy. Subsequent evaluation was made according to standard ČSN P CEN/TS – 15405. The whole research was conducted in a laboratory environment at 21 º C. All tests, except test of the influence of the canal diameter, were performed with a die with the 4 mm diameter of the canals. All samples were stabilized 24 hours. After this step was measured the density of the pellets that were chosen as the sample, Figure 1.

Figure 1 Pellets (left – diameter 6 mm, right – diameter 4 mm).

The first test was aimed to determine the influence of material humidity. The material was divided into three size fractions: fine size of 0-2 mm, medium (0-4 mm with dust particles) and coarse (2-4 mm, without dust particles), Figure 2 a), b) c). The humidity test was done with the material humidity of 15 % and fine fraction size. Desired material humidity was reached by residual drying or humidification of the raw material. Pellets are made from material with humidity of 10, 15, 20, 25 and 30%. To measure the humidity hygrometer was used specially designed to detect humidity in wood chips. Specific density was measured according mentioned standard.

The second test was focused on exploring impact of the size of the material fraction. The raw material with the humidity of 20% was used to produce three sets of samples, namely samples from fine, medium and coarse size of the material fraction.



a) spruce chips coarse fraction <2 – 4> mm	b) spruce chips medium fraction (0 – 4) mm	c) spruce chips fine fraction <0 – 2) mm	d) hazel chips fine fraction <0 – 2) mm

Figure 2 Fractions of the raw material used.

Thirdly was made test focused on the influence of the change of the material. Two woods were chosen, deciduous-hazel (Figure 2 d) and coniferous-spruce. Raw material had 15 % of humidity and fine size of the fraction. Samples were made of both woods and pellets density was measured according to the standard.

Last was monitored the influence of the change of the die canal diameter. It was realized by the use of two pressing dies. One was with the canal of diameter 4 mm and other 6 mm.

4 RESULTS AND DISCUSSION

The objective of this article was to investigate the specific density dependence on the selected three inputs factors and one production factor.

The first factor was the humidity in the raw material. The result is that the maximum density was achieved by using spruce with a humidity content of about 15 %. The value of the pellets density was 1.277 kg·dm^{-3}. This value meets most European standards. This result is slightly different from the results of the other authors 6-12 % [4], 10-12 % [3], 10 -13 % [2] and 10-15 % [6]. It is probably due to the fact that it was used the real machine which has different working temperature than laboratory stands. The result depends on die material and geometry of the canals, the raw material used for pressing and on the magnitude of the rollers pressure on the top of the die. These factors influence the size of the friction that arises during the pressing and generates heat. It results that the humidity content of our material was before the entry of the die canals dried to the lower value than 15 %. The rollers and also the top of the die had relatively high temperature. This could cause the drying of material before entry to the pressing canals. So the value of the humidity of the raw material before the loading to the feed hopper may be around 15 %, but closely to entering the pressing canals around 12 %. With the use of material with the humidity of 10% there was a rapid lowering in the quality of pellets. Density decreased to 0.909 kg·dm^{-3}. With the use of higher content of humidity and that were 20, 25 and 30 %, there was a gradual decline in density and quality. Due to a higher content of the water in these pellets, they became very sensitive to mechanical manipulation after a short time. On the basis of that it results that different content of humidity in the raw material is needed for individual machines and dies. Therefore it is appropriate to test the specific machine and not rely on the results of testing conducted on the laboratory stand. The results are outlined in the Figure 3.

Furthermore, it was investigated the influence of the size and type of the spruce chips fractions. From previous research is known that the fine fraction has a large contribution to the quality of pellets. Three types of the fraction were used: fine, medium and coarse. Used humidity was 20%. The density of pellets produced from the fine fraction was 1, 254 kg·dm^{-3}, with the medium decreased to 1,146 kg·dm^{-3} and with the coarse to 1, 12 kg·dm^{-3}. The reason is that with the use of the coarse fraction, which contained chips of the size 2-4 mm without dust particles, there was a worse heat transfer and therefore worse release of lignin. Also, this material is more difficult to pelletize because it is more difficult to organize larger chunks of chips in the compression canal. Pellets from coarse fractions had rougher surface. Pellets from the fine fraction had a smooth-regular surface. The results are outlined in the Figure 4.

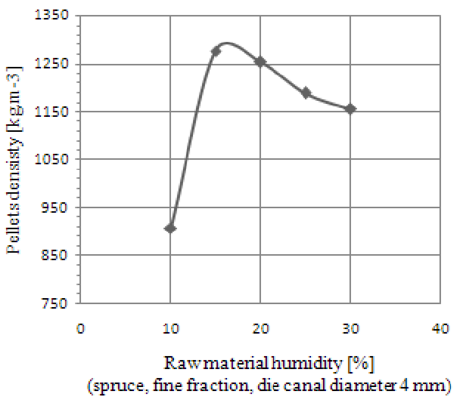


Figure 3 The pellets density dependence on the raw material humidity.

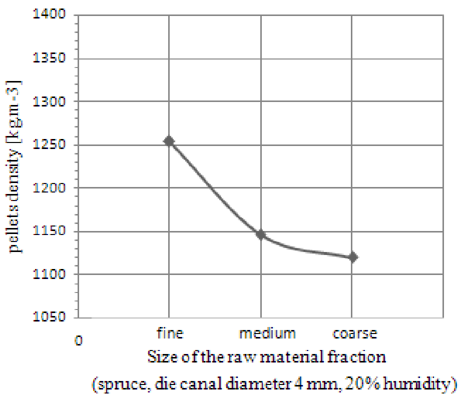


Figure 4 The pellets density dependence on the fraction type and size of the raw material.

Hazel (deciduous) and spruce (coniferous) wood were chosen to investigate the influence of the material. Both belong to the group with the soft wood. Surprising was, that pellets from hazel chips with the humidity of 15 % had very good quality. However, their length was in comparison to pine pellets much shorter. Achieved density of spruce chips was 1.277 kg·dm^{-3}and hazel chips 1.268 kg·dm^{-3}, Figure 5. The reason for high values of both materials is the use of appropriate fraction - a fine and appropriate use of humidity – 15 %. In conclusion it results that pellets made from the chips from coniferous trees have higher quality than pellets made from the chips from deciduous trees. It is due to a higher amount of the lignin in coniferous trees.

Last was examined the influence of the die canal diameter. Diameter was changed from the value 4 mm to 6 mm. Since it was impossible to make pellets on the die with the diameter of 6mm - wood side, it was used the manufacturer's recommendation: to use the agro side of the die (aimed for straw, grain, etc.). The important can be the difference in the diameter of the canal and diameter of the entry slope of the die. The canal diameter of 6 mm - agro side has longer and larger difference in these two diameters. In conclusion due to this geometric fact a greater compression is possible. With the use of 6 mm canal was pellets density 1.233 kg·dm^{-3} and with the 4 mm it was 1.277 kg·dm^{-3}. It seems that this difference is due to the possibility of heat transfer.

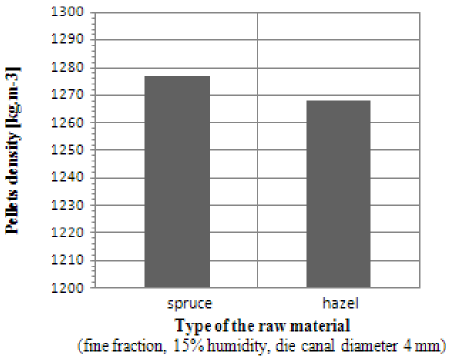


Figure 5 The pellets density dependence on the type of material.

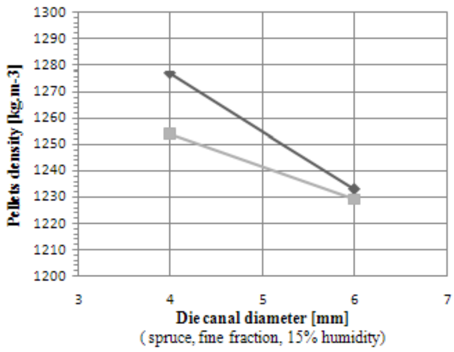


Figure 6 The pellets density dependence on the canal diamater in the die.

The heat transfer in the 6mm canal was worse, so the resulted density is lower. Also difficulties with the use of 6 mm canal on agro-side occurred. When die became warmer, material was more dried. This caused stoppage in the canals. Pressure force of the rolls was not high enough. Force was not able to overcome frictional forces in the canals. It relates to a particular machine - 120 JGE Economy and the dies that were made for that type of machine. It results that die material and geometry is very sensitive and difficult to design. Results are displayed on the Figure 6.

5 SUMMARY

The aim of this article was to examine the influence of input parameters on output density of pellets in the production of real pelletizing machine. Four factors were chosen. Three input factors: raw material humidity, the shape and granularity of material and the type of the material. One production factor was: the change in die canal diameter. To achieve standard parameters and maximum performance it is necessary to know the effects of various parameters.

The results show that the ideal material humidity for pelletizing is around 15 %. The most appropriate is fine fraction of material containing the dust particles, allowing good heat transfer necessary to achieve quality surface pellets. From the perspective of selecting suitable material for pelletizing are better coniferous trees due to higher lignin content. The last factor which has been studied was the effect of die canal diameter. Here arises the recommendation to pay special attention for the geometric and material design of the die. Crucial is the ratio of the slope part of the canal and canal diameter. Important is also the angle of the slope part of the canal.

In the previous studies conducted in laboratory conditions on a specially made stands are recommended following values of the material humidity: 6-12 % [4], 10-12 % 10-12 % [3], 10 -13 % [2] and 10-15 % [6]. It is obvious that with finer material fractions is achieved better quality of pellets and that coniferous trees are due to the higher content of lignin more suitable. The direct influence of die canal diameter is not mentioned by researchers.

The important fact is the test was performed on the machine JGE 120 Economy. The results showed that the content of humidity in the initial material is to some extent influenced by the warming up the machine. Therefore, the results were influenced by the use of a specific machine: JGE 120 Economy. However, the facts proved the existence of an ideal area for the pelletizing. This ideal area can differ for each individual machine.

It results that pelletizing is by no means a simple matter. Pellets will be promising biofuels in the future. It is therefore important to focus on the design of machines that facilitate the production and it is important to have very good knowledge of all factors that may affect the production of pellets.

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