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CONSIDERATIONS ON OBTAINING BIOMASS PELLETS

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Abstract: The field of producing solid fuels from biomass has registered a considerable increase, due to the existence of important quantities of biomass that represent an important source of renewable energy. Pellets are one of the most common solid biofuels, being used for both household use and for producing energy. The article presents considerations on the production of pellets from various types of biomass using specially designed equipment and a series of considerations for the best parameters to be used for producing these types of pellets.
Keywords: biomass, pellets, compression, force, renewable energy

INTRODUCTION

The production of pellets, also called granules, from grinded biomass is spread in the field of renewable sources of energy as innovative techniques for environmental protection, especially in Europe. Due to global warming, a phenomenon affecting the entire worldwide population, industries were forced to accelerate and cheapen the large production of pellets used as solid biofuel, by identifying new innovative technical solutions in the field of pelleting machinery (Tumuluru et al., 2010; Voicea et al., 2014).

Pellets represent the biofuel produced from wood or agricultural waste. They are cylindrical granules of standard sizes between Ø-5...8mm (sometimes even up 30 mm) with variable length of approximately 20-50 mm. They have increased mechanical resistance and good combustion characteristics. The pelleting process offers a real possibility of valorising wood waste. Pellets are produced from waste resulted from wood processing, agricultural residues or from energetic plants. Pellets are a non-polluting fuel, because from their combustion, there are no harmful emissions. The mass of one m^3 of pellets weighs approximately 650-700 kg and produces around 3250 kWh of energy. The process of producing pellets is not a complicated one, but it is still complex (Stelte et al., 2012).

It is important that the biofuels are framed by regulation in order to facilitate commercial exchanges of energetic biomass. They refer to terminology, classification, sampling, determining the combustion power, determining particle size distribution and content of chlorine and sulphur. Currently, there are various testing methods for certifying the quality of solid biofuels as well as various practices for characterizing the parameters of these products. The biggest challenge in the case of biomass based fuels refers to the fact that they are not homogenous. Biomass properties differ depending on the raw material.

The main advantages of densifying wood biomass are:

» increasing the density of compressed material (from 80-150 kg / m^3 for straws or 200 kg / m^3 for sawdust to up to 600-700 kg / m3 for final products);
» a higher calorific value and a homogeneous structure of densified products;
» a low moisture content (lower than 10%);
» improved storage characteristics;
» extending the usage period of biomass materials.

MATERIAL AND METHOD

Pellets are produced from industrial dry and untreated wood based waste such as: wood chips, wood dust, saw dust, wood shavings, etc. Wood material can be used from resinous and deciduous trees, from both xylem and bark, and due to the fact that deciduous trees have lower lignin content, they might require additives. Pellets are compact, uniform, easy to store and handle, can be used in automated heating systems, stoves or boilers (Mediavilla et al., 2012; Mani et el., 2006; Kazuei et al.).

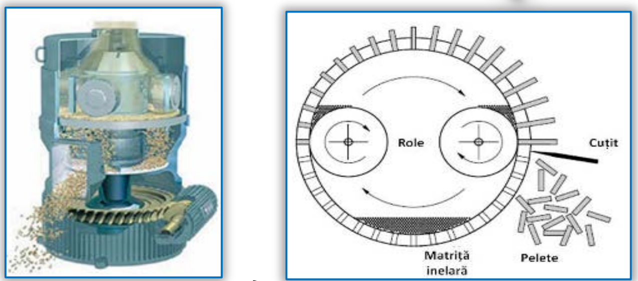
Figure 1. Example of pellets obtained through the densification process

Pellets are produced by grinding sawdust, wood chips, branches, tree bark or parts of agricultural biomass and pressing the material obtained through a die at high pressures. The heat resulted due to friction is enough to soften the lignin in the biomass. When is cooled, lignin becomes rigid and binds the material. The compressed material has the shape on noodles, their section being identical in shape to the one of the pressing channels (Samuelsson et al., 2012; Kaliyan et al., 2010).

The actual densification practically has two stages:

» Compacting the woody material under pressure, in order to reduce its volume and to aggregate the particles of material;
» In the second stage, the lignin is activated by the high pressure and the increased temperature and "glues" the wood particles, thus creating the final product.

The material is pressed in a special die. Due to the high pressure (800-900 bars) and the high temperature that appears during compaction, lignin, the natural binder in wood is melted and helps forming the pellets at the same exact size and shape as the channels in the die. Good quality pellets are produced at adequate pressure and temperature, so it is important to monitor those parameters very carefully.



a) b)

Figure 2. Operating principle of pellet mills (a – flat die; b – ring die) [2]

The two main types of pelleting equipment are: with flat die or with ring die. In the first case, we have a perforated disk on which two or more rollers rotate, compressing the raw material. In the second case, we have a perforated ring (figure 2–a), and the pressing rollers are situated in the interior of ring (figure 2–b).

WORKING PRINCIPLE OF THE FLAT DIE RING PELLETING MACHINE

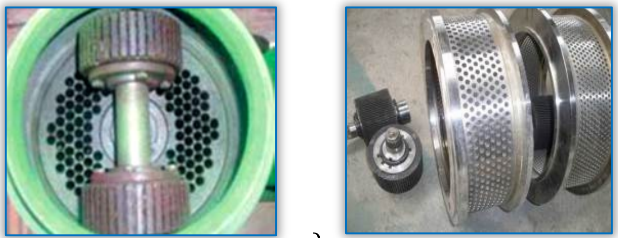
The flat die ring pelleting machine was the first pellet press designed at the beginning of the 20th Century, based on flat dies. Generally, there are two types of flat dies machines on the market, the one with rotating die and the one with rotating rollers. The first type has a stationary roller and the second type has a stationary die. Adopting the vertical principle, the raw material falls due to its own weight in the pelleting room where it is compressed between the rollers and the matrix, forming pellets when passing through the die channels.

WORKING PRINCIPLE OF THE RING DIE RING PELLETING MACHINE

Pelleting machines with ring die are based on a simple operation where the material is distributed on the interior surface of a perforated ring die, in front of each pressing roller, which compresses the material and forces it to pass through the die channels, thus forming pellets.

The actual forming of pellets takes places in "the contact line" between the rollers and the die. All other activities connected to this operation, such as conditioning, cooling, etc. support and enhance the action in that moment in the system. In order to understand the process and to improve transition, quality and aspect, one should have a profound understanding on what happens in the locking point.

The pressing chamber has the shape of channels, the length of a channel being equal to the length of the wall of the die, which is set by its mechanical resistance. As a result of the action of the pressing body, the powdery material, which was previously homogenised and wetted, is forced to pass through the calibrated orifices of the die (is extruded). Characteristic for this densification method is the fact that in the tight space between the working bodies, the material reaches the flowing limit and slides through the die orifices (channels).



a) b)

Figure 3 – Examples of dies and pressing rolls (a – flat die, b – cylindrical die) [2, 15]

The pressing rollers, as the dies, are cylindrical parts that are normally built of tungsten carbide particles or are built as a grooved roller.

Rollers can have cylindrical or cone shape. Roller surfaces can be riffled or can have various shaped imprints. During movement, rollers press the material in the matrix orifices, each channel being active only when it is positioned next to a pressing roller.

The main purpose of rollers is to help the material pass through the die orifices, therefore the shape and the construction of rollers is designed to prevent material from sliding and to offer a roughened surface for a better traction. A pelleting press usually has two or three pressing rollers in its construction.

For obtaining biomass pellets, various types of raw material can be used, such as energy willow, miscanthus, sawdust, etc. These materials are suitable for compaction, because they have a high content of lignin, which is very important for the resistance of pellets in time, lignin acting as a binder when the material is subjected to compression forces within the pressing channels at increased temperatures.

Material properties necessary for densification:

» capacity of flowing and cohesion;
» particle size (if the particles are too fine, it translates in high cohesion, but in reduced flowing; if the particles are too large, the cohesion decreases, but the capacity to flow increases);
» superficial adhesion forces (important for agglomeration and resistance);
» adhesiveness (capacity to adhere);

RESULTS

The process of forming pellets consists in subjecting biomass to high pressures, period when particles are forced to agglomerate. The compression process is usually obtained in three distinct stages. In the first stage, particles rearrange under the action of a low pressure, forming agglomerations. Particles maintain most of their original properties, although the energy is dissipated due to the friction between particles and the machine wall.

During the second stage takes place the plastic and elastic deformation of particles allowing them to flow in smaller spaces, thus increasing the contact surface between particles and, as a result, appear the van der Waals binding forces. Fragile particles can break under pressures leading to mechanical interlocking.

In the final stage, under the high pressures applied in stage two, compression continues until the density of particles is reached. In this stage, particles can reach their melting point and form solid bridges when cooling down. Figure 4 shows the mechanical deformations of biomass during compression.

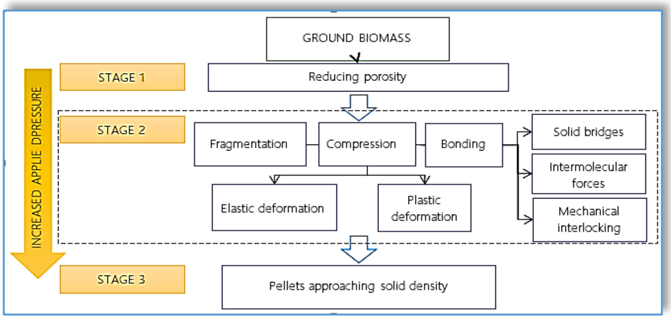


Figure 4 - Deformation mechanisms of powder particles under compression [12]

Understanding some of the major chemical changes that take place during processing of biomass can be useful in understanding their compaction behaviour. As the densification of biomass is coupled with process variables like temperature, pressure, die geometry and mechanisms of densification, changes in these variables will bring about significant changes in the chemical composition of the biomass by the mechanisms known as interaction reactions.

In table 1 are shown the recommended values of some of the most important parameters of the densification process.

Table 1. Recommended values for the parameters of the densification process

Parameter	Biomass type	Recommended value
Die Temperature	woody	80-90º
	agricultural	80-90º
Moisture	woody	6-12%
	agricultural	10-20%
Granulation	woody	0.5-5 mm
	agricultural	0.5-6 mm
Percentage of fines	woody	10-20
	agricultural	10-12

The quality of densified biomass is given partly by the type of raw material and partly by the process variables. Process variables refer to those parameters inherent to the pelleting machine, respectively: temperature, pressure, die size, die speed, the distance between the die and pressing roller, etc.

– Temperature – quality attributes such as durability and bulk density are significantly influenced by die temperature. A higher die temperature can reduce the pressure needed to compress the material and will also increase the durability of pellets.
– Pressure – pressure play a very important part in the quality of pellets. It is necessary to find an optimal pressure depending on the type of material used for compression. A pressure higher than the optimal one can cause breaks in the final product due to a sudden expansion immediately after the pellets exit the die. Also, after a certain value, an increase of pressure will not offer any significant gain in the cohesion (binding) of pellets and it would only increase the production costs.
– Applying high enough temperatures and pressures during densification can develop solid bridges through the diffusion of molecule from one particle to another in the contact points, thus increasing density and resistance.
– Die geometry and speed – die geometry refers to its sizes and shape. These attributes can affect both the quantity of material that can pelleted, but also the energy necessary for compression and influences the properties of the final product, such as moisture, bulk density and durability.
– Pelleting machines are built of a die characterized by the length / diameter ratio (L/D). Length refers to

depth of the die (the length of channels in the die) and the diameter refers to the diameter of the perforations (orifices, channels) in the die. Usually, durability increases along with increasing the L/D ration, due to the increase of friction forces caused by the increased friction between the material and die. However, a ration that is to big will block the die and will strangle the pelleting machine.

- Distance between pressing rollers and the die – the distances between the pressing rollers and the die refers to the space between the die and the roller that forces the material to pass through the die. Usually, the distance should be between 1.5 and 2.5 mm. increasing the distance would lead to a significantly reduced resistance and durability of pellets.
- A very important structural parameter is represented by the conicalness of the pressing channels. The conicalness has a significant impact on the final quality of the product obtained by pressing, but also on the construction of pressing machines.
- Geometry of the pressing chamber - each geometry has its specific shape that affects the distribution of pressures in the pressing chamber and also the final quality of pellets. Each shape of the pressing chamber is suited for certain types of materials. Therefore, it is necessary to research the influence of the construction parameters of pressing chambers on the biomass densification process and on the quality of products resulted. The research and optimizing of the pressing chamber for biomass compaction will allow designing a compaction process that is energetically efficient, leading to obtaining high quality products (Križan et al., 2012).
- Additives - besides the variables of the process, the use of an additive for the particles of biomass could have a positive effect on the resistance of pellets. Starch, proteins, fibres, fat / oil, lignosulfonate, bentonite and modified cellulose have proven to positively influence the durability of densified products (Byoung et al., 2014).

CONCLUSIONS

The densification of biomass offers a real alternative to the use of fossil fuels. Also, it represents a method of using all the biomass materials that otherwise would go to waste. Densification is a relatively new method of processing biomass and still requires research and improvement.

Biomass densification can be achieved by using two types of equipment:

» Flat fie pelleting machine;
» Ring die pelleting machine.

Both types have their advantages. The flat die pelleting machine is recommended for smaller producers as it has smaller capacities, smaller size and weight, is very compact and has low energy consumption. The ring die machine is recommended for large scale producers because they have higher capacities, experience low wear and are very effective in term of energy use.

The field of producing biomass pellets still offers a multitude of possibilities for improvement and optimizing, both regarding the construction of equipment, but also for the composition of biomass mixes prepared for pelleting.

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