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TECHNOLOGICAL STAND FOR THE DETERMINATION OF THE DIE'S GEOMETRY USED IN BIOMASS PELLET MAKING EQUIPMENT

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Abstract: *The technological stand for determination of the mould's geometry, which are utilized in biomass pellet making equipment's, was developed by Hydraulics and Pneumatics Research Institute-INOE2000, under Contract 264 CI/2018 and now is being included in the Renewable Energy Laboratory. The objective of the project is the development of technical means of research for the optimization of the technical and functional parameters of the biomass pellet production equipment. The stand allows determination of the biomass extrusion forces (wood sawdust and straw resulting as a by-product in strobe technological processes) for different shapes, diameters and depths of the extrusion holes, optimal peripheral speed of the die/roller presses, as well as the physical-mechanical characteristics of the pellets obtained.*

Keywords: *Biomass pelletizing equipment, pellet extruding die*

1. Introduction

The anthropic impact of human activities on environmental factors was manifested in the early 17th century, with the beginning of the industrial age. In the last decades, monitoring of environmental factors has become a concern with increasing interest. It has been found that the anthropic impact modifies the natural environments of fauna and flora, even at great distances from pollution sources, and climatic changes have gained an accelerated character and a stronger impact. Mankind, in order to meet its energy needs, mainly uses fossil fuels. They are inexpensive from the point of view of exploitation, transport and processing technologies because they have reached economic maturity. Disadvantages of using fossil fuels are numerous, with devastating effects on ecosystems and even humans.

Biomass is considered a neutral CO_2 source, because it is part of the natural carbon cycle even if different combustion processes are applied.

The disadvantages of biomass energy resources are: the wide diversity of biomass types, which have different characteristics, low density, high moisture content, all of which contribute to chemical degradation during storage, thus limiting large-scale commercial application.

Applying compression densities, extrusions in properly dimensioned dies at optimum temperatures, one can achieve densities of up to 5 times greater than the initial ones, improving transport and increasing the calorific value.

2. General information about pelletizing processes and pellets

The term **"pellet"** usually designates a small piece of cylindrical material obtained by compressing the original material.

Pelletizing is the industrial process for producing pellets, usually using an extrusion press that presses the raw material by means of rollers through the holes of certain dimensions of an extrusion die.

Biomass pellets used for combustion in heating installations are usually made of wood or straw and have different characteristics depending on the material and its quality. In international regulations, pellets are divided into quality classes with different usage recommendations, depending on their size, ash content and various chemical components. Among the advantages of

using pellets, we can point out that they can be used in automatic feeding systems and that, due to compression they offer a large amount of energy at a reduced volume.
Wood pellets are generally superior to those of straw and are also recommended for use in domestic burners (stoves, boilers, etc.), especially when the ash content is very low (below 0.5%). Usual dimensions are: diameters of 6 to 8 mm and lengths less than 40 mm.
Straw pellets, because of the high ash content and corrosive chemical elements, are recommended for use in industrial plants or specially designed for these pellets. They are similar to wood, from an energy point of view. Pellets can be made from most of wood and straw species without the addition of binders or additives, if suitable equipment's are used.
Pellets are currently a good option for producing thermal energy, which meets the requirements of using "green", "clean" and "renewable" energy, making it an economical and comfortable alternative to fossil fuels. Pellets are cheaper than fossil fuels and are from a renewable resource. Small emissions of carbon dioxide mean that it does not affect the environment, as proof for this is their non-inclusion among the pollutants by the Kyoto Protocol.
The history of pellets begins in the 1970s, in the United States, where their first production plant was built. Over time, due to oil market problems and new pollution requirements, this product along with combustion technologies have taken a special momentum, which has materialized in the rapid development in the market. In recent years, there has been a growing demand for the supply of pellet-based equipment, which means an increase in pellet requirement.
Pellets are produced from wood, sawdust and other wood waste, straw, which are 100% natural materials, chopped and pressed, obtained by pressing without the use of binders. The use of pellets for fuel is in accordance with DIN 51731 and the M 713 ecological standards. Pellets have a high calorific value and high density. Transport, storage and use costs are lower, compared to conventional fuels. 1,8-2Kg of pellets have a calorific value equal to 1 m^3 of gas.

Fuel	U. M.	Fuel price (lei/u.m.)	Calorific power (KWh / u.m.)	Efficiency	Price (lei/kWh)
Natural gas	KWh	0.169	1	90	0.132
Electrical energy	KWh	0.580	1	99	0.535
Pellet	kg	0.790	5.1	91	0.153
Wood 20% moisture	kg	0.344	3.6	70	0.097

Good quality pellets have smooth and uniform surface, are the same size and do not crumble. In order to control the quality of the pellets, one method is to put them in water: good quality pellets remain on the surface of the water, poor quality pellets sink into the water.
Advantages of using wood pellets in thermal power plants:

- They are a clean energy source
- Provides high autonomy of the boiler; Depending on the volume of the pellet storage, it can be reached a period of refuelling between 2-3 days up to 30-60 days
- Pellet plant automation also increases autonomy and efficiency, by modifying power according to thermal demand
- Pellets are part of the category of fuels considered as CO_2 neutral
- Smoke emission resulting from combustion is very low
- Re resulting ash is in small quantities (in the case of the use of quality pellets) and can be used as a natural fertilizer
- The operating costs reported at the same power obtained from an condensing gas boiler are approximately identical
- Burning efficiency is higher compared to wood use as fuel
- The pellets storage space is relatively low: 1.2-1.5 m^3
- Pellets are more efficient than firewood because they are higher calorific value; also represents a cheaper energy than that obtained from traditional fossil fuels (coal or oil)

- In case of using poor quality of high moisture pellets, more ash and slag is produced, this decreases the boiler efficiency require more frequent cleaning and maintenance

3. Die for pellet presses

The most important piece of the pellets press is the die. According to the size of the die, the diameter and the depth of the holes, the produced pellets have different dimensions and hardness's. The dies can be used for the production of straw pellets, sawdust, hay, mixed fodder, garbage, beep pulp, peat and other materials.
There are two variants of pellet presses: ring die and flat die. Ring presses with ring die [1] are made in two constructive variants.
In the first embodiment, the die rotates and the pressing rollers are entrained by the friction forces that develop upon contact between them and the extrusion material.
The second method assumes that the ring die is fixed, and the presser rolls are rotating driven by a by a common shaft.
Mainly, the first option is used. The ring-shaped movable die rotates, while the pressing rollers compress the radial material radially through the die holes as in fig. 1.

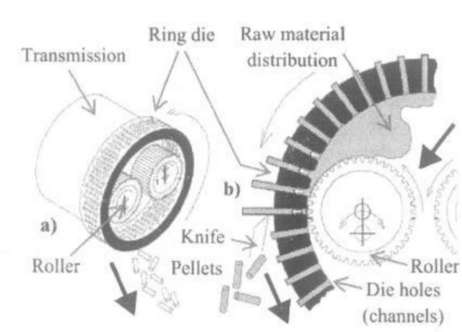


Fig. 1. Rotary ring die chamber with fixed press rollers

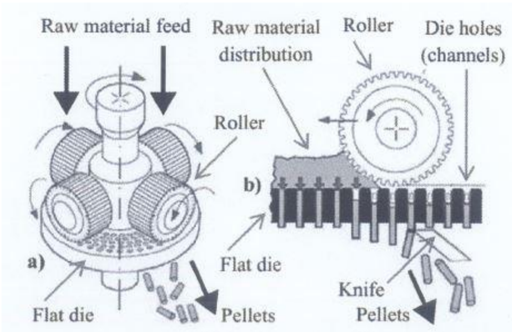


Fig. 2. Flat and fixed die chember with rotating press rollers

Also, in the case of the pellet press with flat die (fig.2) there are two constructive-functional types.
The first variant consists of a stationary die on which the pressing rollers rotate, and the second variant with the stationary press rollers and the rotating die. In this type of pellet press, the raw material is fed upward, falls on the die and on the rollers, thus pressing the raw material by means of the pressing rollers through the die holes.
For the biomass palletisation process, the most important components of the press are the die, the press rolls and the pellet cutting knife. During the pelletizing process, the raw material enters the press chamber and it is equally distributed on the die. On this, a thin layer of high density raw material is formed by rotating the press rollers or the die. The pressure rollers exert a strong pressure on the compressed biomass layer, causing it to penetrate into the die holes. By continuing this process, the biomass is extruded and cut with a knife at the desired size.
A determining characteristic for the formation of quality pellets is the ration between the hole diameter and its depth in the die (the space that biomass is forced to cover during the extrusion process). In wood pelletizing (chip or sawdust), press rations are 3:1 – 5:1.
The ring die has many radially drilled channels.
The annular die has many radially drilled channels. Depending on the selected material, different diameters and channel lengths are selected. Due to the intense friction between the die and rollers, heat is produced which slightly reduces the moisture content of the material (1-2%).
The two main advantages of the pellet ring are low wearing and low energy consumption.
The die components are made of hardened stainless steel in vacuum; the diameter of the holes is 1.8 to 14 mm and the depth of the holes from 55 to 104 mm.

Low-compacting grade feedstocks require longer holes for pressing and vice versa. The temperature of the biomass that reaches into the die holes increases as the depth of the hole increases, thus enhancing the hardening of the pellet. The pelletizing process requires a continuous supply of homogeneous raw material, sufficiently shredded, with a humidity of 8-12%. Another feature of the extrusion process is the peripheral speed of the press rollers. From the practice it has been found that a speed of about 2.5 m/s allows the production of quality pellets. The layer of high density raw material, formed between the die and the press rolls, must have a thickness of 0.5 - 1 mm.

The production process [2] The ground material is fed into the device, (fig. 3), where it is evenly distributed on the die by the dispensers. Two rollers compress the material by pressing it through the radial channels of the die. An adjustable blade then cuts the pellets at a fixed length. Hot pellets are then transported to the cooler.

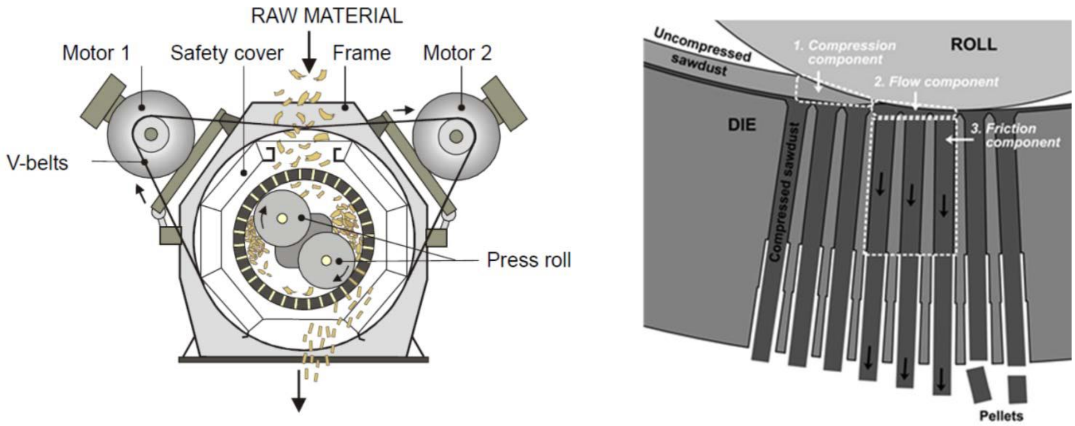


Fig. 3. The process of manufacturing pellets with rotary ring presses and fixed pressing rollers

Fig. 4 illustrates the palletisation process and a die bore. Niels, Douglas, Torben and Claus [3] presented the palletisation process in detail using the circular die. It can be seen how the biomass descends into the pelletizing chamber and is extruded through the cylindrical pressing channels. The die is a cylinder that varies in size between 150-250 mm, with an inner diameter of 800 mm and an outside diameter of 1 m. In the solution they choose, the cylindrical (right) holes have a 60 degree conicity to help the extrusion process and to prevent premature wear of the die. The length of the active part may vary between 30 and 70 mm.

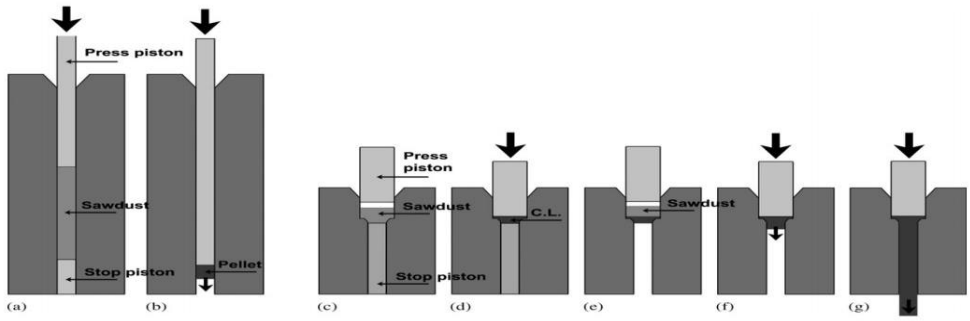


Fig. 4. Two bores and test procedures (a-b) Friction and compression analysis; (c-f) Flow analysis; (g) Continuous pelleting process

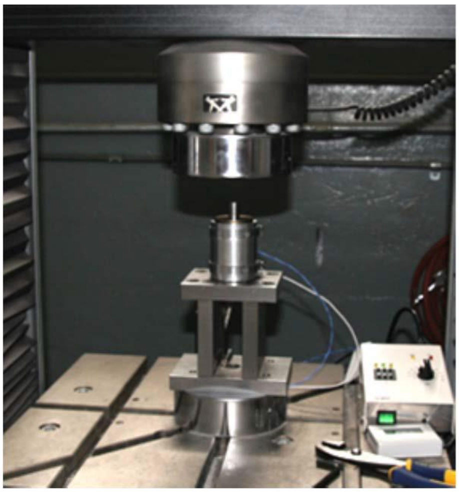
The authors present in an intuitive way the procedures for determining compression forces and friction, from die boreholes. They insist more on analysing different sources of biomass, moisture content, and temperatures in the palletisation process. The tests were carried out by introducing pistons, with a force of up to 200 kN, connected to a data acquisition system. A coil system has

been installed around the die to heat it at different temperatures, thus adjusting the bore temperature.
In Fig. 4-a-b is illustrated friction and compression. The bore diameter used is 8 mm; the saw dust was introduced with a force of 15 kN, at a compression speed of 127 mm/min and a holding time of 10 seconds.
After the force was removed, the plunger was extracted and the pellet was pushed at a speed of 127 mm/min until it was out of the canal. After 24 hours of cooling, at a temperature of 20-25 ° C, the pellet resistance was determined.
In FIG. 4 c-f were simulated and determined the flows from the bore of a commercial die, with a diameter of 8 mm and a cone at the beginning of the 2.5 mm deep pressure chamber, made at an angle of 60°. In these determinations sawdust was used. In all determinations the extrusion was done at temperatures of 60, 75, 85, 95, 105, 115, 125, 135, 145 and 160°C.
The results of the determinations led the authors to the conclusion of the need to study the die bores in order to determine the effects of the compression forces, friction and temperature on the pellet quality.

4. Stands for the determination of the technical and functional parameters of pellet presses

Four parameters are tracked on the stands designed to experiment with the active parts of the world-wide pelleting presses (Danish Technological Institute) [3], fig. 5, for each type of biomass:

- The needed force for the extrusion of the biomass into the die with single hole, respectively with multiple holes;
- The static and dynamic friction forces generated at the contact between the active piece of the press (die or roller press, depending on the construction variant) with the high density material and small thickness formed between them in the extrusion process;
- Resistance to compression of the obtained pellets;
- The density of the pellets.



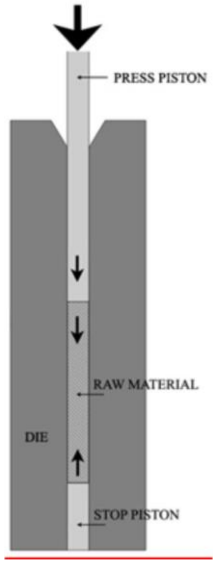


Fig. 5. Stand for determination of extrusion force (single hole die)

The diagram of fig. 6 shows the variation of the parameters: the compressive force and the density of the extruded material along the extrusion bore.

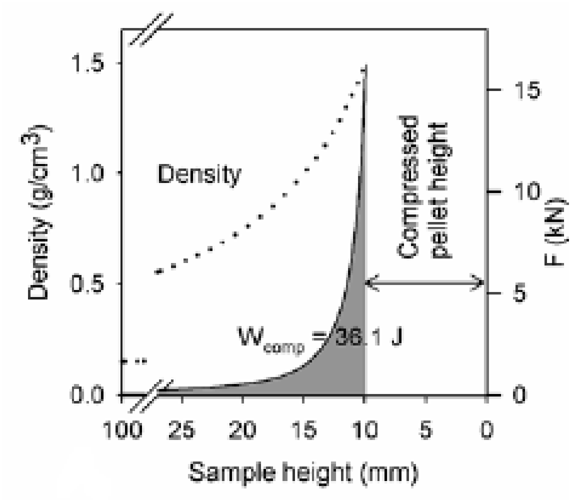


Fig. 6. Variation of the compression force and pellet density along the extrusion bore

The quality of the pellets is appreciated by their behavior under the action of a compression force, fig. 7.

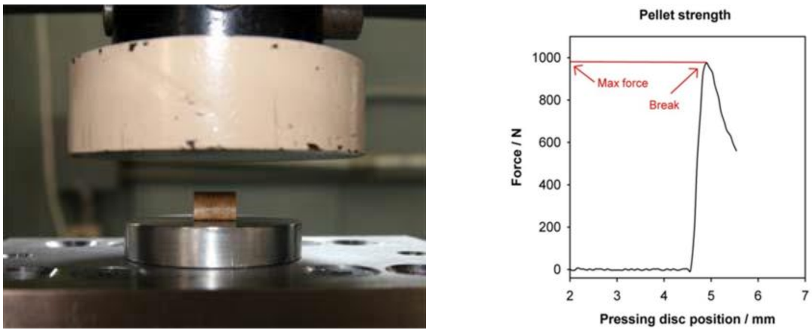


Fig. 7. Determination of pellet quality by compression

The pellet is placed perpendicular to its axis and crushed, resulting in the force-distance curve.
The density of pellets is determined by measurements (length, diameter and weight) and the application of the known calculation formula.
After the analysis of the technical-functional parameters performed on the single press (single hole mold) and the multi-hole pellet press (used in the pelleting process) there is a good correlation shown in fig. 8.

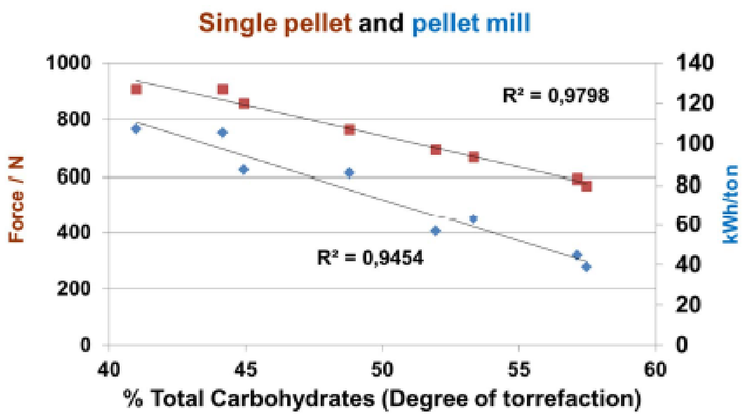


Fig. 8. The correlation between the technical and functional parameters of a single and multiple presses

The stand that was built withing the project, Fig. 9, consists of a rigid resistance frame, a traverse that can be moved on two columns and fixed in the desired working position, a plate solidarized with the hydraulic cylinder on which the single extrusion die is mounted.

Fig. 9. Technological stand for the determination of the die geometry used in biomass pellet making equipment

On the traverse is mounted a force transducer and the pressing piston of the extruded material in the die.
The hole in the die and the pressing piston are perfectly coaxial in order to avoid the occurrence of radial forces, during the extrusion test.
The pressing of the material is done by vertically moving the plate with the die towords the pressing piston.
To highlight the effect of the extrusion temperature on the compression force, the die may be heated with electrical resistors.
The hydraulic power supply of the actuating cylinder is done by an own group.
The technical parameters of the extrusion process (compressive force, friction forces) are determined on a set of single hole molds with different geometric parameters of hole diameter, its shape (circular or truncated press chamber), depth of the hole , mold temperature.
The data subject to experimentation is acquired using a data acquisition system.

5. Conclusions

1. The objective of the project is the development of technical means of research for the optimization of the technical-functional parameters of the biomass pellet production equipment in order to increase the energetic efficiency of the palletisation process;
2. On the stands dedicated to this purpose, made at world level, the following parameters are determined:
- The need for the extrusion of the biomass into the die with the single hole, respectively with multiple holes;
- The static and dynamic friction forces generated at the contact between the active piece of the press (die or roller press, depending on the construction variant) with the high-density material and the small thickness formed between them in the extrusion process;
- Resistance to compression of the pellets obtained;
- Density of pellets;
-Influence of torrefaction in the quality of pellets [4].

3. The stand made within the project meets the technical and functional requirements imposed on the stands of the components of the pelletizing presses.

Acknowledgments

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