TECHNICAL PAPER

PELLETIZING BIO-CARBON

Producing optimal pellet quality with minimal energy consumption and with a minimal wear on parts.

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ABSTRACT

To store and to transport torrefied material safe and at lower costs users request to densify this material by pelletizing. However it has become clear, that this densification process is rather critical and expensive (power consumption and intensive maintenance).

The key factors for successful pelletizing of torrefied material are: controlled recipe conditions; process control; adequate equipment, maintenance and operational skills.

The extra costs of this pelletizing process can only be recovered through lower storage, transport and handling costs of torrefied pelletized material.

CONTEXT OF THE PAPER

This technical paper describes the experience of TorrCoal regarding densification (pelletizing) of torrefied mixed fresh woodchips. Some customers request torrefied material only if is densified, because densified torrefied material can be stored, transported and handled safely and at lower costs.

TORRCOAL

INTRODUCTION

Densifying bio-carbon makes sense in more than one way. The typical bulk density of torrefied biomass lies between 0.25 and 0.35 ton/m³. This poses a logistical challenge. Also, if untreated, torrefied biomass is notoriously self-combustible. Densifying bio-carbon by pelletizing it, doesn't only improve the bulk density (up to 0.7 ton/m³) . It also improves the thermal stability considerably, making it safer to store and transport.

The desired contradiction: Optimal pellet quality produced with minimal energy consumption and with a minimal wear on parts.

Often the same pelletizing equipment for pelletizing wood is used to densify torrefied biomass. That is to say, if one manages to produce pellets from bio-carbon at all.

TorrCoal's experience on this challenge dates back to 2013. It turned out that there are a lot of variables that come in to play to make pelletizing bio-carbon a success.

THE KEY FACTORS FOR SUCCESS FOR PELLETIZING BIO-CARBON.

A pellet mill is a type of extruder. It uses rollers to press the medium through a die that has holes in it. The formed strains are cut by blades to length after the extrusion.

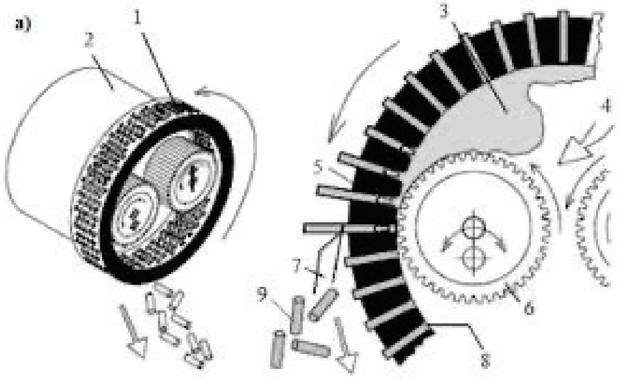
Pellet mills were originally designed to produce animal food from mixed ingredients. The goal was not to densify, but to homogenize nutrition recipes. The end product, pellets, could be easier consumed by live stock. It wasn't for long that farmers owning such mills, discovered that other materials could be pelletized, for instance straw or grass. When coalfired powerplants tried to mitigate their carbon emissions by co-firing biomass, pellet mills suddenly played a huge roll in the logistics of woody biomass.

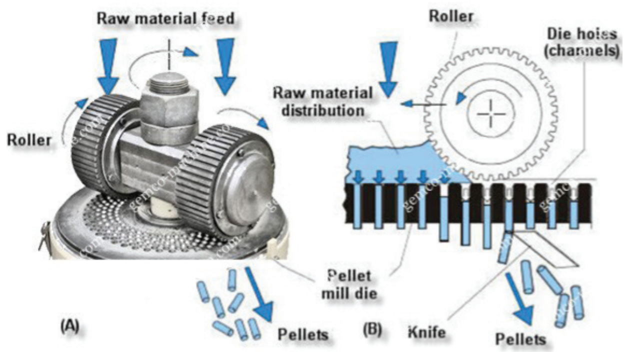
Densifying bio-carbon (which is essentially torrefied biomass) with that same process seemed as the logical next step.

Producing pellets with the same kind of the pelletizing equipment, but with another feedstock, unfortunately means methods and experiences from previous feedstocks aren't necessarily applicable.

Through trial and error it became clear, that bio-carbon is a more challenging medium to pelletize than for instance wood. But over the years hundreds of tons of bio-carbon pellets have been produced. So it can be done, if specific conditions are met. A lot of experience has been built up, which can help shorten anyone's learning curve on the subject. Pelletizing bio-carbon, will only be successful if following key factors are given sufficient attention:

- Feasible and stable recipe conditions
- Adequate process equipment and process controls.
- Specific Power Consumption (Knowledge and control)
- Die specifications (Compression ratio and steel alloy)
- Operational skills



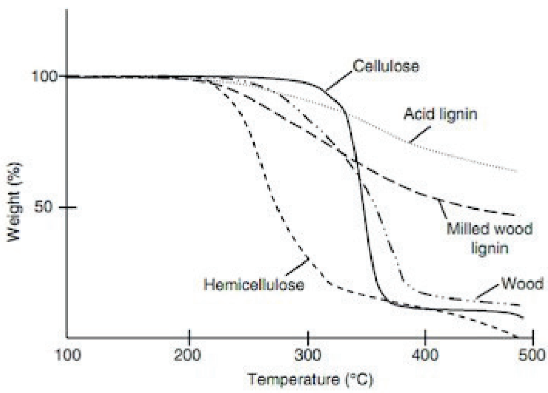


KEY FACTOR 1: FEASIBLE AND STABLE RECIPE CONDITIONS

Pelletizing bio-carbon means absolute control of the recipe. By recipe we mean the composition of the input mix. To have positive results to begin with, it had to be found out what is feasible in terms of the bio-carbon material characteristics vs the desired pellet quality (hardness, moisture etc.). This implied at first that it turned out to be necessary to switch from a continuouss pelletizing process to a batch processing to gain absolute control. This made it possible to analyze and control the input and output streams carefully.

It is important to realize that there is a fundamental difference between pelletizing wood and pelletizing bio-carbon. The ratio hemi-cellulose, cellulose and lignin changes dramatically by the thermal breakdown during torrefaction. The residence time of the biomass and the temperature range during torrefaction determines the amount of hemicellulose and cellulose that is converted into gas. It was concluded that the following conditions need to be in order to make a recipe feasible and stable for pelletizing:

- The bio-carbon used in the recipe is produced at steady process conditions and is homogeneous consistent.
- The higher the conversion rate was during torrefaction, the more of a binding agent should be added afterwards.
- The ash content in the bio-carbon is below an acceptable range.
- The recipe contains enough moisture to act as a lubricant, a cooling agent, and a binder activator (if used) during pelletizing.



"Weight loss in wood cellulose, hemicellulose, and lignin during torrefaction " (Maret- 2012)

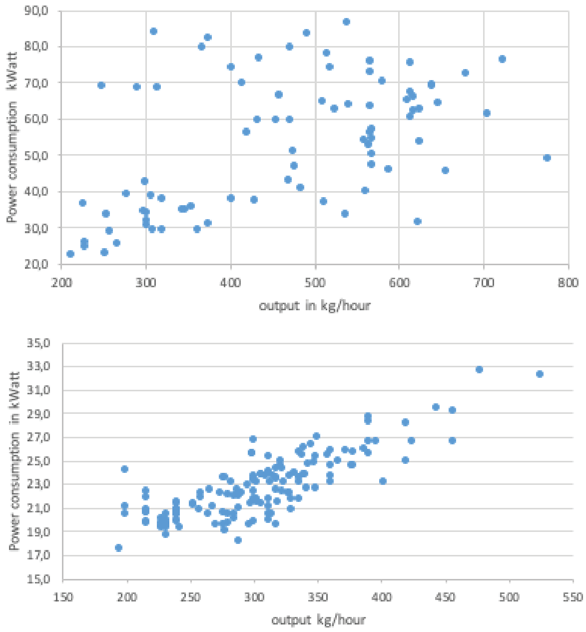
The best pelletizing experiences have been realized with bio-carbon produced around 300°C with an ash content lower than 3%. The degraded binding ability of that bio-carbon was compensated by adding some starch (max 3%). To activate the binding agent and to lubricate and cool the pelletizing process, water was added (max 10%).

KEY FACTOR 2: ADEQUATE PROCESS EQUIPMENT AND PROCESS CONTROLS.

It already became apparent in key factor 1 that the emphasis is on control of the overall process. Next to controlling the composition of the recipe, controlling process conditions also play a main role in the success of pelletizing bio-carbon. It seems apparent, but we discovered that pelletizing bio-carbon is less forgiving than pelletizing other media, given that there are variations in the process. A broad range of equipment and control systems have been tested to reach process stability. In the end the conclusion of all testing is that the following conditions in terms of equipment and process controls have to be met:

- The flow of bio-carbon to the pellet mill is constant in composition (homogeneously mixed with water and the binding agent.)
- The flow of bio-carbon towards the pellet mill is stable in feeding speed.
- The capacity of the feed (t/hr) is also known.
- Temperatures of the mix, the pellet mill and the produced pellets are measured during the process.
- The pressure of the rollers on the die can be controlled and measured during pelletizing.
- The pellets are sufficiently air cooled before storage.

A great level of detail has been spent on sufficient mixing the recipe. Measurement and control of the the flow through the pelletizing process and monitoring all process values such as all electric power consumptions, the applied force of the rollers on the die and process temperatures of equipment and the produced pellets have been put in place.



The difference between two different kind of our tested pellet mills. Notice the seemingly lack of control on the top diagram. The bottom diagram is the result of an added adjustable hydraulic roller pressure system.

KEY FACTOR 3: SPECIFIC POWER CONSUMPTION (KNOWLEDGE AND CONTROL)

In theory, anything can be compressed or densified, if enough force is applied. Key is doing it as efficiently as possible. The amount of force a pellet mill needs to do this for a certain kind of product is expressed in electrical consumption per weight unit: (kilo)Watt per ton (kW/t).

Specific Power Consumption depends on the type of materials, but also on the recipe.

There are general values for well know materials. For instance;

- Animal feeds have specific power consumption of 10-15 kW/ton;
- Wood flakes have a specific power consumption of 65-75 kW/ton

To calculate the specific power consumption, the pellet mill's electric motor needs a watt meter and the throughput volume of the product must be determined accurately.

The pellet mill's electric motor did not have a Watt meter originally. Only Amperage could be monitored. However it was possible to calculate the Wattage of our 400V 3 phase motor with the formula: $P=U*I*\sqrt{3}*\cos\Phi$. Currently the frequency converter that controls the electric motor, has a direct output that provides the Wattage of the engine. There is no direct weighing system that is linked with pelletizing. The feeding screw is controlled by a frequency converter. The relationship was determined through the percentages in screw speed with the actual capacity in volume. A periodically check of these values was done. It was found that it is important to monitor the trend of the Specific Power Consumption to safeguard performance and quality.

The Specific Power Consumption of pelletizing our bio-carbon ranges between 85-95 kW/ton.

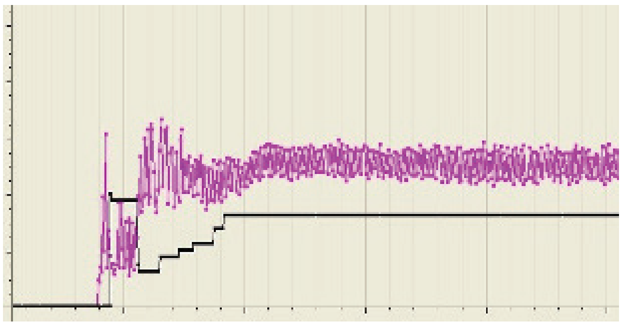
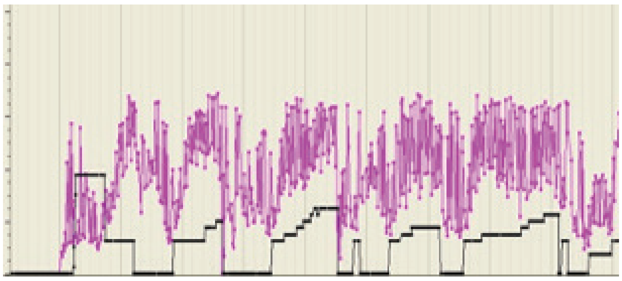


Figure: a "perfect run".

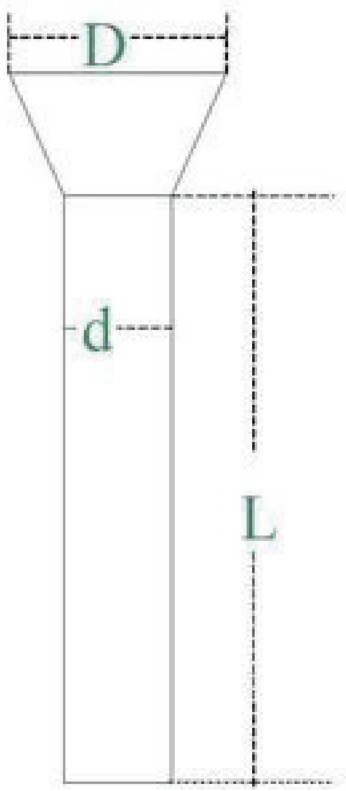


Purple trend shows the power consumption of the pellet mill. The black trend shows the feed screw speed. The erratic power swings in the right side figure, are a clear indication there is either something wrong with the recipe, with the die, or with the roller pressure.

KEY FACTOR 4: DIE SPECIFICATIONS (COMPRESSION RATIO AND USED STEEL ALLOY)

Pelletizers use steel rollers to press the medium through a steel die. There is a relation between the compression length and the diameter of die holes to end up with the desired pellet quality. Compression ratio is the relation between hole size (d) and compression length (L). Wood on average has a compression ratio of 1:6.

Because the counterpressure is based on friction, material choice of the die also plays an important role, as does the angle of the inlet. Dies come in different steel alloys. Die producers harden steel and use additives such as chromium to improve their die characteristics. The inlet angle guides the material into the hole, but is also the first parameter subjected to wear by friction and first to be damage by roller contact.



Compression length (L) and inlet (D)

Rollers and dies are the most exchanged parts on a pellet mill. And therefore, next to power consumption, the most costly part of pelletizing. The challenge is to find the specs that create balance between optimal Specific Power Consumption for bio-carbon, while minimizing wear. It seems attractive to start off with thicker dies to compensate for the wear and then revising the bore periodically. However it turned out that this has its limitations: Increase in die thickness will automatically result in increase of compression length. As a result the friction and the specific power consumption will also rise unwantedly.

Pelletizing bio-carbon has been realized successfully in several diameters and on different types of pellet mills with and we used a range of different steel alloys. The following specs have evolved as a guideline (flat die pellet mill):

- hole size 6mm, compression ratio 1:4 (chromium steel die)
- hole size 8mm, compression ratio 1:3.5 (chromium steel die)
- hole size 10mm, compression ratio 1:3 (chromium steel die)

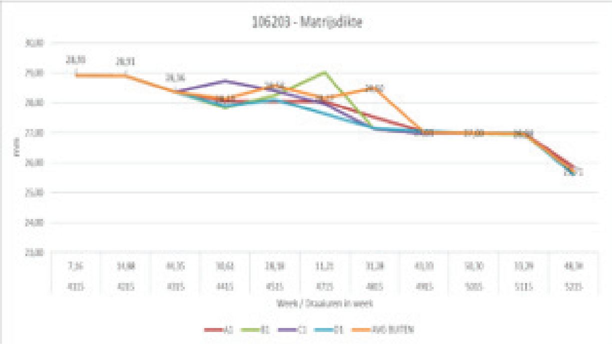
Noticeable wear of the bore itself (increase in diameter) during the lifetime of the die was not identified.

KEY FACTOR 5: OPERATIONAL SKILLS

The description of key factors 1 - 4 show the variety of underlying variables that all need to be in order to succeed in pelletizing bio-carbon. And although much can be automated in the pelletizing process, human interaction is still needed to cope with unwanted changes. Changes need to be detected as soon as possible and correctly interpreted to take the necessary action. This means that operators need sufficient knowledge and experience. Operators need to understand the influences of key factors 1 - 4 and the way to correct them. Furthermore they fully need to understand the pellet mill itself. The machine manual can be a useful tool. Use of an experienced trainer could save time and costly mistakes. Training can often be done by the pellet mill supplier, or at the pellet mill manufacturer's site. Finally the right methodology and registration tools need to be in place to gain quality in work and build a track record.

In the beginning there was little experience with pelletizing and the way bio-carbon would behave in the process. Underestimating the complexity and lack of a systematic method, implied there was little success in the first pelletizing attempts. After organizing properly, learning all the ins and outs of the equipment, consulting the die manufacturer and carefully recording all variables, the process became a success.

The 4 listed key factors are monitored and verified periodically through measurements or inspections. All in compliance with the guidelines of the pellet mill manufacturer. The product flow is analysed in all the different stages of the pelletizing process.



Example of the recorded die thickness / die wear.

CONCLUSION

To store, transport and handle torrefied material safe and at lower costs users request to densify this material by pelletizing. The bulk density of torrefied material increases from about 0,25 ton/m³ to 0,70 ton/m³ by pelletizing.

However it has become clear, that this densification process is rather critical and expensive (power consumption and intensive maintenance). The specific power consumption of pelletizing ranges between 85 – 95 kWatt/ton. Especially intensive wear of dies, rollers and bearing of shafts means frequent maintenance.

The key factors for successful pelletizing of torrefied material are: controlled recipe conditions; process control; right adequate equipment, maintenance and operational skills.

The torrefaction process must be carried out in a very controlled manner. Stable recipe conditions are required (addition of right amount of binder and water to the torrefied material). Good condition of the die, rollers and bearings is absolutely required. Human interaction in the right way is needed if unwanted changes are observed. This means that operators need sufficient knowledge and experience to correct.

This all mean extra costs of the pelletizing process and these can only be recovered through lower storage, transport and handling costs of the torrefied and pelletized material.

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Waste to Carbon: Densification of Torrefied Refuse-Derived Fuel
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The Proof-of-the-Concept of Application of Pelletization for Mitigation of Volatile Organic Compounds Emissions from Carbonized Refuse-Derived Fuel
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