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# WOOD PELLETS PRODUCTION TECHNOLOGY

**Abstract:** *Increasing environmental concerns, particularly ones concerning the thermal utilization of fossil fuels, have significantly stimulated worldwide R&D work on mitigation of greenhouse gases. Biomass can be regarding as one the most promising "environmental friendly" alternative to fossil fuels. However, handling as well as direct combustion of biomass is restricted due to intrinsic properties of this kind of fuel. Pelleting technology offers possibility of lessening these difficulties. In following paper foundational operations in pelleting process line are described based on the theoretical work and experimental experience of authors.*

**Key words:** pellets, wood pellets, pelleting technology

## INTRODUCTION

Worldwide production of terrestrial biomass has been estimated to be on the order of 200 × $10^{12}$ kg annually, which is approximately five times the energy content of the total worldwide crude oil consumption (via heat of combustion analysis) [1]. Despite these figures wide-spread usage of biomass in developed countries is still insufficient. This could be partly explained by significant investment costs associated with plants for thermal utilization of biomass and partly due to inherent draw-backs of biomass - heterogeneity, low energy density and high moisture content. The latter problems can be overcome by densification technologies i.e. through production of pellets and briquettes with consistent quality (high energy density, low moisture content and homogeneous size and shape). Although the production of pellets and briquettes requires additional energy input, resulting in increased fuel cost, worldwide pellet market (especially EU) has trend of persistent rise. This trend can be easily recognized locally with numerous new pelleting facilities being commissioned every year in Serbia. Exactly that fact motivated authors of this article to transfer some of their field experience and throw the light on essential steps in pellets production technology.

## RAW MATERIAL FOR PELLETS PRODUCTION

Almost any kind of biomass can be regarded as potential raw material for pellet production. However, only pellets produced from woody biomass will be considered in this paper. It is worth noting that most of the pelleting plants operating around the world use wood as a dominant feedstock for pellets production.

Woody biomass is made of three basic components with many trace materials. These are structural natural organic polymers: cellulose, hemicelluloses, and lignin. The most important constituent for pelleting process is lignin. It can be regarded as natural binding agent which keeps the woody particles inside the pellet together. Consequently, the higher the lignin content in wood the more durable pellets are.

Woody feedstock can be distinguished in two broad categories: softwood and hardwood. Typically these two kinds of wood differ in heating value, ash and lignin content. Production of pellets from just one raw material is rather difficult, thereby the producers often use various blends/mixtures of wood species.

The best results in pellets production can be achieved with raw material originating exclusively from wood stem. These pellets are of premium quality (lowest ash content, highest mechanical durability etc.) and conforms to EN 14961 standard "A1 class pellets". Production of this kind of pellets is payable only if raw material is readily available as sawdust. If it comes in any other form, production can be regarded as unprofitable. Surprisingly, in Serbia, as a result of insufficiently developed wood processing industry, most of the pellet plants use the wood logs. This can be explained by their unrealistically low price, but as the market progress and producers start to compete for raw material wood price will rise.

## PELLETS PRODUCTION

It is particularly noteworthy that process steps in actual pelleting facility could differ from what is presented here. Main reasons for this are the type and moisture content of raw material. However, any pelleting plant consists of following process steps:

- Pre-treatment of raw material
- Pelletization
- Post-treatment of produced pellets

### Pre-treatment of raw material

Type of the pre-treatment primarily depends on raw material dimensional characteristics. Simply put, the greater the dimensions of input material the greater the investment and operational costs of pre-treatment. If sawdust is to be used then pre-treatment of raw material is not needed. Thereby, this kind of raw material can be regarded as the most favorable. Due to deficiency of sawdust, especially in Serbia, many

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producers consider and majority of them use log wood. That is the less favorable option resulting in considerably high investment and operational costs. Situation is additionally complicated if class A1 pellets, according to EN 14961-2, are to be produced because debarking need to be included in process line. The removed bark can be used for feeding the furnace for generating hot combustion gases in drying process, but is undesirable as a raw material for pellet production owing to inherent high ash content.

## Coarse grinding - Chipping

If woody biomass with different dimensional characteristics (i.e. combination of hog fuel, wood shavings, wood chips and log wood) as a raw material is to be used, then the first machine in process line should be chipper.

**Figure 1.** *Drum chipper[2]*

Chippers are used for first, coarse grinding. Presently on the market following types of chippers are available: drum chippers, disc chippers, screw chippers and wheel chippers. Drum chippers are most frequently used because of their robustness and reliability. Huge drum chippers could coarsely grind log wood of up to 1m in diameter. In drum chippers material is chipped by means of horizontally rotating drum with knives arranged transversely. After being chipped material is transported further by fan or belt conveyor.
However, particles size of raw material obtained at the output of chipper are not sufficiently small for production of consistent pellets. Hence, additional grinding is required. The smaller the particles of raw material are, the stronger the pellets will be. However process of fragmentation has economical limits. Too fine grinding will be too expensive. For example, particles of raw material should be below 4 mm for pellets of diameter of 6 mm.
The process of subsequent grinding is performed in hammer mills.

## Fine grinding - Hammer mills

Working principle of hammer mills is shown on fig. 2.
The hammers, with carbide metal coating mounted on huge rotors, "squeeze" raw material particles through screens thus reducing the dimension of original material. The size of output material is determined by the diameter of holes on screen. Hammer mills are usually positioned in peletting plant before the drying section, although the grinding of dry material is more economical. That is because of the fire safety reasons (inflammability of dry wood particles), but some producers neglect this fact and put hammer mills after the dryer.

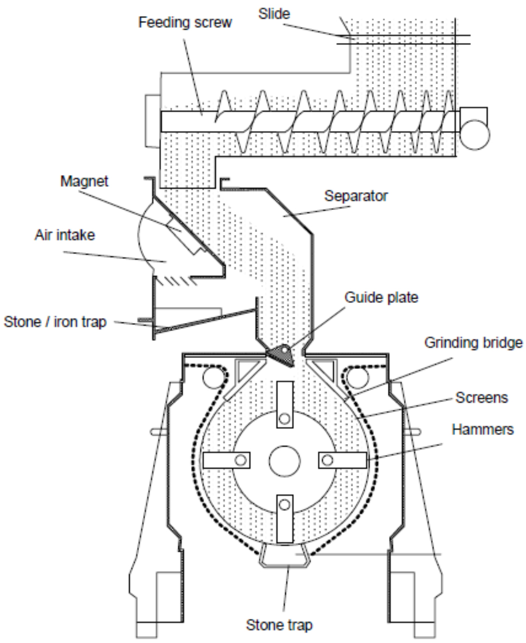


**Figure 2.** *Working principle of hammer mill [3]*

## Drying

As explained earlier, efficient densification of raw material into pellets highly depends on particle size of raw material. Likewise, it depends on moisture content of raw material. Dryers are used for drying/adjusting moister content of raw material. Although most expensive piece of equipment in pelleting plants, dryers are inevitable. Dryers can be divided in two broad categories: natural and forced dryers. Of course the simplest and cheapest form of drying raw material is natural drying. However, experimental trials showed that in this case, optimum moisture content of material can't be achieved. Hence, force dryers are only reliable option. Currently, following types of dryers are available on market: tube bundle dryers, drum dryers, belt dryers, low temperature dryers, superheated steam dryers and fluidized bed dryers. Most frequently used and state-of–the-art in pelleting plants are drum dryers. Consequently, further explanation will be confined to this kind of dryers.
Drum dryers can be directly or indirectly heated. In the case of direct dryers, flue gases (with temperature in range from $350^0$ - $600^0$ C) produced in dedicated furnaces are used as heating medium. Indirect drum dryers have heat exchanger, so heated air (not flue gases) is used for drying raw material. The latter are safer but rather expensive so most of the pelleting plants use former with appropriate spark detection and extinguishing systems.
For generating hot gases, furnaces are used. Different fuels can be used for running these furnaces: natural gas, liquid fuels or what is most economical raw

material for producing pellets (hog fuel, wood chips, shavings, sawdust). Some furnaces are designed to work even with moist feedstock but this is more exception than rule because in most cases efficiency reduces rapidly when dryers work with wet material.

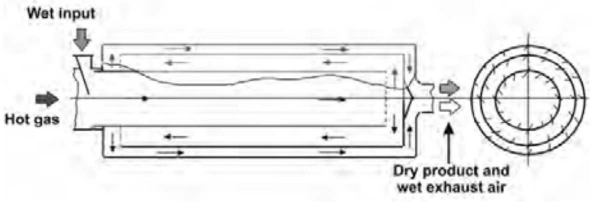


**Figure 3.** *Cross section of a drum dryer with three passes [4]*

Operating principle of three pass drum dryer is shown on figure 3. Drum dryers are of cylindrical shape with multitude of inner flights which are combined in order to lift and shower raw material evenly through the hot air stream while drum rotates. Raw material is drawn in dryer by virtue of negative pressure created by fen on the other end of dryer. Most of the moisture from raw material evaporates in the first pass (in first contact between raw material and stream of hot gases), but two additional passes are usually needed in order to adjust the moisture to required value. Cyclones, positioned at the end of drying section are used for separation of dried material from hot gaseous stream. Dried material is then conveyed to silos for moisture equalization. Process of raw material moisture balancing lasts usually 10 - 24h. This interim storage of raw material also adds to more flexible work of whole plant since it decouples process of drying and pelleting.

Part of the dried material from silos goes to furnace for drying new batches of wet feedstock while the other part continues its way in process.

Before the process of pelleting, particles of dried raw material need to be balanced in size. Separation of fractions and further size reduction is performed in oscillating screens. Particles of dried raw material which suffice dimensional requirements are transported to silos of prepared material. From silos material goes to conditioner. Conditioner is used for adding thin film of water on wood particles in order to alleviate process of binding which is conducted in pelleting machines.

Process usually raises the moisture content of raw material for 2 wt% (w.b.).

There were some experimental trials, documented in [5], on the use of steam explosion reactors in conditioning. Idea is in flash decompression of material after it has been kept on high temperature and pressure. Proposed procedure significantly increases the mechanical durability of produced pellets. However, because of costs being too high, process didn't become the reality in commercial plants.

Pelleting process comes after the processes of grinding, drying, dimensional balancing and conditioning.

## Pelleting process

Wood and biofuel pelleting technology emerged from fodder pelleting. Technology was actually slightly modified in order to enable densification of material with different features.

Currently, two distinctive procedures and consequently milling machines are used for producing pellets: ring and flat die pellet mills. More common are mills with ring dies.

Main elements of pelleting machines, regardless the operating principle, are die and rollers. Pelleting mills with ring die (figure 4) consist of rotating ring die that rotates around the fixed rollers. The incoming raw material is "trapped" in space between roller and die and pressed through die holes (channel).

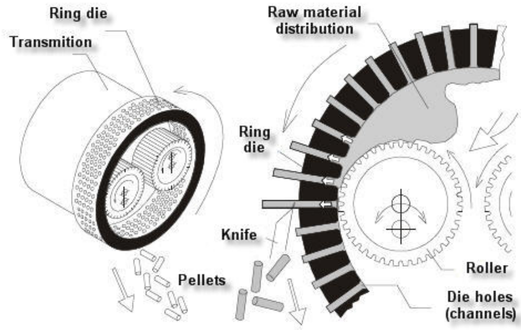


**Figure 4.** *Designs and operating principles of pellet mills-Ring die pellet mill [6]*

In the case of flat die pellet mills, rollers rotate around own axis and around the flat die axis as well (figure 5). Flat die is in horizontal position and material is introduced from above.

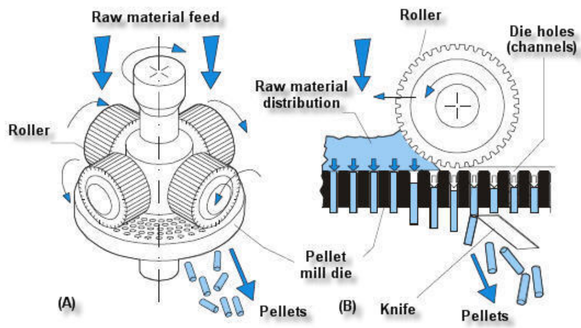


**Figure 5.** *Designs and operating principles of pellet mills-Flat die pellet mill [6]*

Even distribution of raw material in the space between die and rollers is essential in order to get the pellets of proper quality.

Produced pellets leave the pelleting mill as infinite string, so special knives positioned on the perimeter of pellet mill lid are needed in order to cut this string into pieces of acceptable length (usually less than 40 mm).

Pelleting mills differentiate according to: press ratio, quantity of die holes (channels) and the inside area of channels [6]. Press ratio represents the ratio between the diameter and length of hole and it highly depends on type of raw material used. In the case of woody biomass it is in the range of 1:3 to 1:5.

## Post treatment - Cooling

Temperature of pellets leaving the pellet mill is usually in the range of 80-130$^0$C. Products with such high temperature are not appropriate for further handling (i.e. packing). That is the reason why cooling stage is essential. In addition, cooling process improves mechanical durability and reduces moisture content of produced pellets by some 2 wt% (w.b.). Pellets are usually transported from pelleting machine to cooler via bucket elevator.

**Figure 6.** *Countercurrent pellet cooler [7]*

Coolers with counter flow of pellets and cooling medium are most common. In this arrangement dry cold air enters the cooler at the bottom side, while the pellets enter the cooler from the opposite, top side. Cold air collects the heat and moisture released from pellets and leaves the cooler. On opposite, pellets cool down and continue their way to packaging section.

## Pellets handling

There are few handling options for produced pellets. The straightforward option is to transport pellets internally to silos of finished commodities and then unload pellets to specially designed trucks (figure 7). However, this kind of pellet delivery exists only in countries with developed pellet market and significant number of household users (for example in Scandinavia, Germany, Austria).

The other option is bag packaging. Pellets can be packed in smaller bags (10 – 25 kg) or in big "Jumbo" reusable bags containing 1 - 1.5 $m^3$ of pellets.

**Figure 7.** *Simultaneous pellets loading of pneumatic truck from silo and loading of loose pellets to the tractor trailer [8]*

The former are used in households while the latter are intended for industrial customers.

Producers usually pack small bags on pallets and then wrap the whole package with plastic foil. It is very important to provide good sealing of bags since pellets are highly hygroscopic and are prone to disintegration in the presence of water.

## CONCLUSION

Densification technologies provide practical options for overcoming some of the inherent drawbacks of biomass (moisture content and low energy density being the most important). Pelleting can be regarding as one of the well established densification procedure, gaining increasing popularity and acceptance in recent years. This is primarily due to pellets dimensions (appropriate for automatic feeding), durability and consistent and standardized quality. In this paper fundamental process steps in producing wood pellets were described. However, it is noteworthy that actual process can differ from ones depicted in this article, since it highly depends on kind of the raw material to be used, planned investment and available land for plant set up.

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## BIOGRAPHY

**Milan Protic** was born in Nis, Serbia, in 1979.

He received the diploma in Mechanical engineering and Mphil degree in Environmental engineering from the Faculty of Mechanical Engineering and Faculty of Occupational Safety, University of Nis, respectively.

His research interests covers diverse renewable energy systems with particular focus on biomass densification and combustion technologies. He got CEI award "From Research to Enterprise" and participated in several internationally and nationally funded research project. One of the recent projects was Technological Project for Pelleting Plant – Forest enterprises d.o.o. in Pukovac, Serbia with capacity of 4 t/h.

He presently works as teaching assistant at the University of Nis, Faculty of Occupational Safety.