EXISTING PERFORMANCE AND OPERATIONAL DATA FOR BRIQUETTING MACHINERY

Waste to Wisdom: Subtask 3.5

Biofuels and Biobased Product Development

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This review will provide an overview of available bulk densification technologies for biomass feedstock available to the U.S. Forest Products industry, with an emphasis on mobile or semi-mobile applications. For the purposes of this review, biomass will be defined as typical forest biomass in North America, e.g. stem wood, or slash (tops and limbs). Mobile, or semi-mobile, refers to the ability, or potential, to operate in-woods, or, in a 'near in-woods' capability. This review recognizes that at this point, there is no densification machinery in North America that is fully mobile (e.g. with wheels or tracks). This assessment will review the strengths and limitations of each of the factory type densification options with an eye to their potential usage in a log landing or other intermediate processing areas.

For the last decade, the growth of the domestic and export wood pellet industry has drawn forestry experts to the possibility of pelletizing in the forest as a logical solution to the inherent low energy dentistry of forest biomass, particularly the sub-commercial biomass, which must be cleared or reduced to facilitate regrowth. As the options for the traditional solution--piled burning--continue to disappear, this problem is both an energy opportunity and a forestry challenge.

Unfortunately, the domestic pelletizing market is almost exclusively a function of residuals. Sawdust from sawmills or other forest product operations, such as hardwood flooring factories, as well as other residuals, are the key to cost effective pelletizing for the domestic market.

Domestic pelletizing systems depend on premium biomass, composed of dry, uniform, small particle sawdust. Any in-forest system would require major capital investment to pre-process the material, and this, while conceptually possible, is a key limit to cost effective in-forest pelletizing.[1]

However, many pellet mills also have developed sidelines of briquetting, and/or densified energy logs. This equipment tends to be adaptable for material which is more coarse, slightly less uniform, and less dry. To date, many of the densified bricks or logs are packaged for consumer sales, which requires a highly cosmetic product, but an industrial brick or log need only maintain its structure sufficient to be transported out of the forest. Less work has been done with densifying torrefied biomass, although one of the machines investigated has had some experience with this type of feedstock.

1 "The capital equipment needed to ***pre-process*** (size reduction and cleaning) harvested biomass will be expensive to purchase and operate. This type of equipment (and cost to operate) is generally not needed in a traditional pellet operation that utilizes sawmill residuals, so this added cost would cause a disadvantage right from the start." Chris Sharron, CEO, West Oregon Wood Products, Inc.

The currently available machines are not designed to be operated outside, or anywhere other than an industrial factory setting. Ocean going sea containers offer the obvious option to both protect these machines and to make them portable. The United States military has developed mobile waste processing technologies for the Joint Deployable Waste to Energy Program that utilize briquetting presses such as those outlined below to compact food waste and garbage for use in mobile energy production.[2] These devices are made mobile, as noted above, by their installation in ocean going sea containers. Consequently, some of the initial considerations in assessing their potential usage will be their physical dimensions and their weight. Equally important, from a practical standpoint, are the issues of feedstock sensitivity; what is the range of particle size and moisture that the machines can tolerate? Finally, the power requirements of the machine are a fundamental factor in any off-grid situation.

The majority of mature densification technologies are European in origin, reflecting the history of extensive biomass utilization in that region. Warning has been given to stay away from machines that have been produced in Southeast Asia, as product quality and manufacturer support at this point has shown to be poor to non-existent. Several of the machines are also used to briquette metal filings and shavings. Some of the machines can be specifically operated for "industrial" quality briquettes as opposed to the more common consumer quality briquettes. Obviously this assessment will focus on industrial quality outputs.

Table 1. The units and their characteristics.

Description	RUF	Di Piu/SUNOMI	C.F. Nielsen	Weima
Process type	RUF 200- mold type, pre-charger press, hydraulic	MB 50- Mechanical	BPU 2500- Mechanical	HD 600- Hydraulic
Machine wt. (kg)	2800	2200	3300	900
Machine Dimensions (mm)	1800x1600 x2000	2600x1100 x2400	3150x1275 x2300	2280x1820 x1445
Briquette Diameter (mm)	150x60x70-100	50	50	60
Start-Up Electrical Demand (kW)	NA	24kW (10 Seconds following startup)	65kW (Startup)	NA

2 "Lessons Learned from Past Demonstrations". Leigh Knowlton Combat Feeding Directorate, Expeditionary Basing & Collective Protection Directorate, US Army Natic Soldier RD&E Center. Accessed on March 2, 2015. Available at https://community.apan.org/cfs-file.ashx/__key/telligent-evolution-components-attachments/13-9358-00-00-00-12-82-39/JDW2E_5F00_NSRDEC_5F00_Lessons_2D00_Learned_5F00_v20130909.pdf

Average Electrical draw (kW)	11 kW	12 kW	14 kW	11 kW
Electrical consumption per production (kWh/tonne)	60	40	40	110
Max allowable moisture content (%)	15.00%	14%	6-16%	18%
Recommended moisture content (%)	<12%	10-14%	10-12%	<15%
Max allowable particle size for continuous consumption (mm)	50.8	12	20x5x3	15.875
Recommended particle size for continuous consumption (mm)	<50.8	1-12	20x5x3	<12.7
Max allowable particle size for intermittent consumption (mm)	152.4	12	20x5x3	19.05
Max allowable feedstock ash content (%)	NA*	NA	NA, 17% (Rice Husk)	NA
Recommended feedstock ash content (%)	NA	NA	0.40%	NA
Production Capacity (kg/h)	200	300	350	100
Bulk dry density of product (kg/dm^3)	.99-1.05	1.25-1.30	1-1.1	1

W2W, PFI, Task 2 - Summarize the review of existing densification equipment and suitability for transportation and outdoor operation. Provide a recommendation of which manufacturer and machine to use for testing under the Waste to Wisdom Project.

A review of existing densification equipment that is currently available in the commercial marketplace highlighted four major companies ("RUF", "sunomi, llc", "C. F. Nielsen", and "Weima"). Each company produces a variety of briquetting machines, but the chosen appliances for this study are the "RUF 200", "BRIK MB 50", "BPU 2500", and the "HD 600", respectively. These were chosen to represent the best machines based on the requirements outlined in the previous section. The two most common types of densification equipment currently on the market are hydraulic presses and mechanical presses. The selection above contains two of each type: the RUF 200 and Weima's HD 600 are both hydraulic presses, while Di Piu's BRIK MB 50 and C. F. Nielsen's BPU 2500 are mechanical. The trade-offs between the two types will be explored more in the following section.

Current Technologies

All of the machines in the provided list have some similar primary components. There is a hopper that can be fed manually or via a conveyor belt. In this storage area, feedstock material is fed into the pressing component of the machine via an auger. Typically there is an agitator attached to the hopper that aids in this process. Once in the pressing component the feedstock is either hammered through a metal cone called a die (mechanical presses) or slowly pressed into a form (hydraulic presses). The speed of this process and the post-pressing processes are completely different for the different methods and will be detailed separately in the following paragraphs.

Hydraulic Presses

Hydraulic presses rely on fluid driven pistons. Typically speaking, there are two of these, one that pre-presses the material vertically and a second that applies horizontal pressure to produce the final product. The pressure in the system can be electronically adjusted at any time, via computer controls, without interrupting operation. Durability and safety are both maximized by using a hydraulic press as there are few moving parts, and no parts that move at a high velocity.

Since hydraulic devices use a form (also known as a cast) rather than a die, there is very little friction and thus little heat in this process. This yields added benefits, which include reduced risk of fire, elimination of long cooling lines, and less wear and tear on the machines. Since heat due to friction is not present in these devices, they themselves do not need to be cooled, which allows them to be operated around the clock for months at a time.

The briquette resulting from hydraulic processes has been compacted as one solid entity. As opposed to the layering which occurs in a mechanical press, the product is both more durable and does not accordion during its combustion.

The RUF model was designed to utilize tree bark as its primary feedstock and can accommodate biomass feedstock up to six inches long which can be composed of highly corrosive (high ash content) material. Thus, a broader range of biomass that can be utilized by this machine and a severe reduction in pre-processing realized. It is evident based on the footprint of the machine, its higher output capacity, and less electrical demand per weight of product, that the RUF 200 is the more preferred of the two hydraulic machines (see Table 1 above).

Mechanical Presses

Mechanical presses, driven by electric rather than hydraulic motors, have the benefit of utilizing their inertial force during operation. This, in theory, reduces the overall energy use but requires a significant increase in start-up power supply (about ten seconds at three to six times the average power demand). Based on the data presented in Table 1, it is obvious that this process does not actually cut down on average electricity required, but negatively affects the mechanical press' ability to operate in an off-grid setting. The inertial force comes from the continuous, rapid rotation of a massive flywheel (typically about 250RPM).

The flywheel shaft is connected to a plunger which presses raw material through a conical die once per rotation. The counter pressure can only be adjusted by installing a die with a different length or conicity, thus limiting the amount of control over a specific product. As the cycle period is constant and does not depend on the amount of material fed into the press, it is typical for manufacturers to maximize productivity by maximizing the input of feedstock into each pressing cycle. While this negatively impacts the density and durability of the product, it is not a concern for this study as we are interested in "industrial" as opposed to "consumer" quality product.

When the feedstock is pressed into the die, heat is created due to the friction. While the heat supports the chemical bonding of the lignin (natural bonding agent) with the wood particles and thus a durable product, it is deemed a negative attribute in this study due to the fact that long cooling lines are then required to cool the product before processing continues. These lines typically run the length of the manufacturing facility before the product is cool enough to be processed for packaging (cut to final length). The pressing cycle also creates substantial wear on the machine. The amount of wear is determined by the amount of contaminants (e.g. ash content) that is present in the feedstock. For larger machines it has been characterized that if the wood has less than five percent ash content, then the cost for service and replacement parts due to wear will be around $1.12 per produced ton. This increases to around $5.61 per ton when the ash content is around 16% (the approximate ash content of rice husk). Therefore, materials such as bark and leafy matter are some of the most costly material to process in this type of machine.

One of the only positive attributes of the mechanical presses is their production rate. The mechanical presses in this study average to be approximately twice as productive as the hydraulic ones (345 kg/hr as opposed to 150 kg/hr). This also makes the MB 50 and the BPU 2500 both competitive when electrical consumption per ton produced is considered.

Densification of Torrefied Biomass

Of all the machines in this study, only the Di Piu MB 50 has been used to successfully densify torrefied wood. In order for this to be achieved, the torrefied feedstock material must still contain some of the original lignin to act as the natural binder. "In this, we are all walking a very narrow line between the increase of the heat value of the wood through the method of torrefaction on one side, and the cost of the equipment and energy to achieve the goal of a torrefied product that can be transported, packaged, and sold at a profit on the other side."[3] A value added process for doing this has yet to be realized.

While none of the Hydraulic presses claim to be able to densify torrefied feedstock, it can be assumed that mildly torrefied biomass feedstock can be utilized. As this is mostly uncharted territory, further testing must be done to identify the scope of possibilities.

Conclusion

After considering the cumulative benefits and drawbacks of each of the machines, it is easy to conclude that the RUF 200 is the best test machine for use in the Waste to Wisdom Project. The reduced wear and electrical demand, added safety and feedstock capabilities, and the freedom from a long cooling line, make the hydraulic presses the best type of machine for outdoor, mobile processing. The RUF 200 was already outlined to be the best of the studied hydraulic presses, it is clearly the best choice overall.

RUF 200

3 Checchi, Giordano. "Densification of torrefied wood." Message to John Crouch. 22 February, 2015. E-mail.