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Processing Woody Debris Biomass for Co-Milling with Pulverized Coal

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Abstract. *The USDA, Forest Service, Forest Products Lab funds several grants each year for the purpose of studying woody biomass utilization. One selected project proposed removing small diameter stems and unmerchantable woody material from National Forest lands and delivering it to a coal-fired power plant in Alabama for energy conversion. The Alabama Power Company will test the utilization of the woody biomass in one of their energy production facilities to determine the feasibility of this new market. The Talladega National Forest and the Gadsden Steam Plant are serving as the demonstration areas for the project.*

One of the first steps in this project was to select in-woods processing equipment. The biomass fuel to be created in this project must meet unique criteria that differentiate fuel chips created for the power plant from those of typical fuel chips. The wood fuel was to be created from whole-tree chips and co-milled with coal. Biomass specifications were primarily limited by size so that the chips would pass through the current fuel handling system in the plant. In addition, the fuel chips must have edges that are fairly clean and sharp to prevent plugging fuel pathways in the plant. One of the initial steps in the project was to examine output from a variety of in-woods processing equipment to determine which could meet the specifications with one-pass processing. After further review, it was determined that a cutting action, as opposed to a shearing action, was needed to meet the raw *material handling requirements within the plant. Output from a specially equipped horizontal grinder was the final equipment choice.*

Keywords. biomass, forest engineering, harvesting, logging, chipper, grinder

Introduction

Forest-Based Economic Development Services, the CAWACO RC&D Council, and the Talladega National Forest, supported by a grant from USDA Forest Service – Forest Products Lab, are testing the efficiencies of harvesting woody biomass for energy conversion. Concurrently, Alabama Power Company (APC) will test the utilization of woody biomass in one of their energy production facilities to determine the feasibility of this new market. The initial trials at the power plant will require approximately 1,000 tons of biomass to be co-milled, then co-fired, with coal. The Talladega National Forest and APC's Plant Gadsden are serving as the demonstration areas for the project.

APC has six coal-fired power plants in Alabama with a total generating capacity of about 9.5 GW. All of these facilities use similar fuel-handling systems to fire boilers with pulverized coal. Plant Gadsden is the smallest facility with two boilers and a rated capacity of 120MW and has been used for feasibility testing on other renewable feedstocks. If the trials prove to be successful, the power plants could potentially use 800,000 green tons of fuel chips annually (4% mix by energy basis), resulting in displacing 280,000 tons of coal.

During the course of selecting a logging contractor for this project, we found that the output from various types of chippers and grinders are machine-specific. After examining chips from a 3-knife chipper and from a tub grinder, we found that there were more physical characteristics than just size that would need to be controlled for the raw product input to the plant. Initially, a maximum 0.6 cm chip size was requested by the power plant engineers. However, upon further examination of processed biomass, we found that the material cannot have shredded or fuzzy edges because it could "mat", or 'bridge' in the plant's in-feed mechanisms.

Landowners have resources, loggers have a certain mix of equipment, and mills have specific feedstock requirements. We need to understand each of these stages to harvest, process and deliver the appropriate feedstocks to mills and power plants. An initial step of this project is to determine what equipment is needed to process small-diameter wood in the woods into a form suitable for processing in Plant Gadsden. This paper describes the power plant biomass handling requirements, provides a brief overview of previous trials with renewable resource processing at Plant Gadsden, identifies the biomass specifications for fuel chips, reviews the equipment that is typically used in the woods to produce fuel chips, and presents the final equipment selection.

Raw Material Handling

The Gadsden Power Plant serves as the demonstration plant in Alabama for alternative fuel resources. However, eastern grade bituminous coal is the primary feedstock for this 120 MW facility. The coal is stored in an outdoor pile that is moved around by heavy equipment. Conveyors take the coal to fuel bunkers in the plant that feed the material into rolling mill pulverizers. The coal is ground into a very fine particle similar in size to face powder. Once the material is processed, it is blown through a series of pipes to the boiler. There are structures within the pipes, called riffles, that help separate and guide the coal powder. In previous trials, these riffles have proven to limit the physical size of the raw materials. When larger pieces cannot break against or pass through the riffles, they plug the system and material traveling at 90 feet per second packs up behind it. These plugs must be cleared by manual methods.

Previous Trials

Plant Gadsden has performed trials using other alternative fuels, including switchgrass (Panicum virgatum), hardwood sawdust, and pine pulp chips. The plant processed switchgrass fibers up to 2.54 cm in length with acceptable burn times. In addition, the coal input could be decreased by the addition of up to 10% switchgrass (by energy basis) without problems. But, this co-firing required additional costs because the switchgrass had different handling properties than coal. Its low bulk density and fibrous nature required a separate grinding process and separate handling pipes to feed the material to the burners (co-firing). The process also required adding water to the switchgrass for dust abatement. Because there is no way to reduce the moisture in the material handling process, the added moisture results in a 0.5 to 1.0% rate loss in the plant. Separate storage was also needed because the coal bunkers plugged when feeding a blend of switchgrass and coal. The addition of switchgrass as an alternative fuel would require a capital investment of grinders, pipe supply lines, and storage facilities for each of the power plants.

In another trial at Plant Gadsden, hardwood sawdust was mixed with coal at a rate of 4-6% (by energy basis) without causing any problems within the system. The sawdust was co-milled with the coal and there weren't any residues left in the pulverizer. However, there are other customers competing for sawdust. If the power plant were to use sawdust, the increased demand for the raw product could raise the price which would make sawdust less economical.

Pulp chips measuring 2.54 cm in length have also been used in trials at Plant Gadsden. This size chip clogged in the system and the riffles couldn't break the oversized particles. So, further investigations of wood chip sizes for co-milling with coal at Plant Gadsden are needed.

Biomass Specifications

A common problem with handling any size of wood chips is material flow. Wood chips in gravity-feed systems have a tendency to bridge, "rat-hole", plug, and cause all sorts of problems. The common solution is to make wood into a pellet form where it flows better and doesn't bridge. Pelletizing wood, however, adds an extra processing cost. The flow problem usually occurs with 100% wood, but still occurs when wood is mixed with coal. Once an appropriate fuel chip size is determined, plant engineers can vary the mix of wood to coal to provide the best material flow. The material handling criteria is important because if a plug occurs, it could cause the power plant to shut down. Plant engineers can't afford the down time to clean it out, so they set fairly stringent material specifications early in the trial process.

Based on the previous trials using sawdust and wood chips, plant engineers decided that they needed a unique size of fuel chips that is not currently available in Alabama. The size needed is somewhere between sawdust and 0.6 cm in thickness to pass through the plant's existing processes and infrastructure. Particle size also has to be small enough to be completely burned before exiting the burner. The blend of coal and wood chips must pass through the bunker without plugging, process through the pulverizer (co-milling), and pass through the riffles before entering the burner (co-firing). The coal and wood chips must be mixed on the storage pile with existing equipment at the plant before entering the bunkers.

Because of the existing infrastructure limitations, the fuel chip specifications for these six power plants in Alabama would create a market for a new product. The fuel chips needed by the power plant would be differentiated from those used at pulp mills in Alabama due to the unique size and physical characteristic requirements. The size of the chips produced for use by the power plant would usually meet the specifications for pulp mill fuel chips, but the reverse would not be true. These power plant fuel specifications are critical because the economic impact of fuel-handling problems in a large utility plant is so significant.

Equipment Selection

There are different technologies available to reduce wood into smaller particles. In order to meet the fuel specifications of the power plant, three types of equipment were considered: disc chipper, horizontal grinder, and tub grinder. Many chippers and grinders offer options such as screens and sizers to further control the characteristics of the output. In the initial investigation, plant engineers first considered output from each type of equipment.

Figure 1. Re-ground whole-tree chips from tub grinder (left), whole-tree chips from chipper (right).

The first chips examined were from a Precision 1858 whole-tree 3-knife disc chipper. The raw product used was whole-tree small-diameter pine trees from a pre-commercial thinning operation. Fuel chips from this machine resulted in an unacceptable end product. The first problem was that the chip fibers were oriented mostly lengthwise. Since the disc is oriented at an angle to the end of the tree stems, it created chips with long fibers. When these longer chips reach the riffles in the plant’s pipes, they will not pass through or break, causing plugging to occur at the riffles. The second problem occurred when handling small diameter material. The small branches and small stems tilted upward before being chipped resulting in longer chips. In addition, the thickness and width of the chips could not be adequately controlled with this machine.

There are number of contractors in Alabama that own equipment capable of producing fuel chips of the quality preferred by pulp mills. Although additional handling may increase the cost of producing the fuel chips, secondary processing was an alternative explored because of the availability of existing in-woods chipping equipment. Fuel chips from the Precision 1858 were resized by processing them through a ProGrind 2000 tub grinder (Figure 1). The output from this secondary operation met the size and fiber orientation requirements, but a new problem surfaced. The edges of the fuel chips were not sharp or clean. The grinder created fuzzy fibers on the edges of the chips that caused the wood particles to stick together. This new property would cause unacceptable handling problems within the plant.

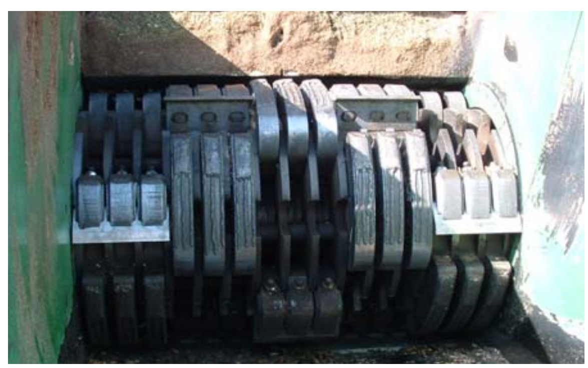

Figure 2. Modified ProGrind H-3045 drum

Horizontal grinders were also considered. The fiber orientation and chip length could be more readily controlled with the horizontal drum as opposed to a chipper disc mounted at an angle. However, the comminution action is by grinder teeth rather than knives, resulting in fibrous edges.

The comparable physical difference in the edges of the fuel chips from these types of machines is due to differences between cutting and shearing of the raw material (Miu et. al., 2006). The 3-knife chipper uses sharp knives to cut the raw material. Tub and horizontal grinders rely on shearing or tearing, to reduce the size of wood, resulting in rougher surfaces. These rougher surfaces and their tendency to stick together are unacceptable for the power plant's use.

Figure 3. Cutting blades

Because of the different physical characteristics between fuel chips created by the different machines, the initial investigation resulted in selecting a cutting action, rather than a shearing action, to make fuel chips for the power plant. However, the disc chipper output was deemed unacceptable because of the long chips. These results led to the development of a unique chipper that combined horizontal grinding action with knife-type cutting blades (Figure 2). Precision-Husky, a local manufacturer, built and modified a 2007 ProGrind H-3045 horizontal grinder by replacing the coarse shredding hammers with flat cutting blades (Figure 3). This configuration provides good in-feed and a perpendicular material alignment at the cutting drum. The comminution occurs by slicing rather than shredding and a clean chip is produced. Using whole trees and one-pass processing, this type of machine should be able to create fuel chips that meet the size and physical characteristics required by the power plant. Initial trial runs with whole-tree pine thinning material are promising.

Conclusion

Power plants may have very narrow specification ranges for fuel chips. The specifications discussed in this article are for co-milling and co-firing wood fuel chips with coal. There are several equipment options that rely on different types of communition actions resulting in different physical characteristics of the final fuel chip product. This project focused on one-pass processing of whole trees in the woods without any additional screening at the power plant.

In the fall of 2007, a time-and-motion study will be conducted on the horizontal drum chipper to determine the cost of producing the fuel chips. Combustion and material handling trials will be run at the power plant using a variety of fuel chip sizes and a variety of proportions of wood to coal to determine the optimal mix for handling and mill efficiency.

References

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