
Bundling Logging Residues with a Modified John Deere B-380 Slash Bundler

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Abstract

A basic problem with processing biomass in the woods is that the machinery must be matched to the final product. If a logging business owner invests in a machine to produce a specific type of biomass product for a limited market, the opportunity for that logging business owner to diversify products to take advantage of market opportunities may also be limited. When woody biomass material is densified into a composite log, the material preserves some of its physical characteristics while controlling transportation costs. Although different types of bundlers and balers are being investigated in the southern states, the John Deere Slash Bundler is one of the few that is commercially available. Studies performed on this machine in 2003 and 2008 resulted in production and cost data for a variety of sites and applications. This project furthers that research by mounting the bundler onto a motorized trailer rather than a forwarder. Because southern logging operations often pile logging residues at the deck, the bundler does not need to be self-propelled for typical logging contractors in the region. This paper describes the equipment modi-

fications and discusses the advantages of this new equipment type.

Introduction

Woody biomass is available in many forms. Logging residues, or slash, are often considered a readily available biomass source because it is produced during typical logging operations. Logging residues may consist of tops, limbs, and unmerchantable material. Since logging residues are a result of other forest operations, the burden of costs for felling and skidding have been borne by traditional forest product removals. Therefore, woody biomass is often considered a by-product with production costs including only processing and transport.

Approximately 2.6 million oven-dry tons of logging residues are generated annually in Alabama as a by-product of conventional harvesting operations (Muehlenfeld, 2003). Cull trees from harvesting operations could readily add another 2.7 million oven-dry tons to this estimate. Depending on the harvesting system employed, these cull trees and residues can be left scattered in the stand, piled throughout the stand, or piled at or near the log landing.

One important characteristic of logging residues is the light, loose, fluffy nature of the raw material. Logging residues need to be processed into a denser form for efficient and economical transport and handling. There are a variety of operational technologies for collecting logging residues. Many of these options create a new set of physical characteristics for the processed biomass (Mitchell and Klepac, 2008). Baling or bundling technologies provide densification while preserving the ability to further comminute [reduce the size and shape] the material to meet the specifications of biomass facilities.

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The John Deere 1490D Slash Bundler is one piece of equipment available today to densify the material. It is commonly used in operations that employ cut-to-length harvesting systems, especially in Europe. In this system, the trees are felled and processed at the stump leaving the residues scattered throughout the stand. Sometimes, the harvester is able to create small piles of logging residues, but these are also scattered through the stand. The John Deere 1490D is mounted on a forwarder chassis to enable the machine to maneuver through a stand to collect and bundle the scattered residues. In a cut-to-length operation, the completed bundles are transported to roadside by a forwarder.

A typical southern logging operation employs a tree-length harvesting system. In this system, trees are felled and skidded to a landing, where they are then delimbed and merchandised. Since the logging debris is concentrated at or near the landing, this type of operation does not require a bundling machine to be mobile within the stand. A prototype bundler has been developed in an attempt to reduce equipment costs. The B-380 bundler has been removed from the forwarder chassis and mounted on a motorized trailer provided by Cutting Systems, Inc. This paper examines various alternatives to processing logging residues and identifies the opportunities that this modified bundling system can bring to typical southern logging operations.

Roadside Biomass Processing Equipment

Chippers and grinders are commonly used to process logging residues into a denser form for transport. They are often stationary machines placed in or near the landing for processing material. A variety of manufacturers produce models that vary by horsepower, in-feed mechanism, number of cutting mechanisms, orientation of blades or teeth to the in-feed, and many other characteristics.

Horizontal and tub grinders comminute many types of woody biomass residues. They can often accept a wide variety of diameters and lengths of material, including stumps. Grinders use a shearing action to comminute woody biomass. As a consequence of the shearing action, the cross-section of material processed with a grinder has a specific roughness (Miu et al. 2006). These rough edges cause the comminuted biomass to stick together when dumped or handled. Screens may be used in grinders to help size the final material before it is conveyed into a chip van or into a pile.

Chippers use the splitting action of knives in the

mechanical treatment process of comminuting woody biomass. The resulting cross section is smooth (Miu, 2006). Disc chippers often have anvils that may be adjusted to help size the final material. The cutting angle of the disc to the in-feed can make it difficult to control chip quality, as smaller limbs can tip upward causing longer chip fiber lengths. The knives on some drum chippers can be adjusted to vary the chip fiber lengths. Screens may be added to some chippers to size the final material.

Different mechanical treatments used to comminute biomass result in different physical properties. These differences could also limit the number of delivery facilities that will accept the material. Biomass specifications may include physical properties due to handling techniques in an end-user facility (Mitchell and Rummer, 2007). In a study of co-milling wood chips with coal, the biomass specification was very narrowly defined, resulting in the development of a prototype chipping machine to process the raw material in one pass (Mitchell and Klepac, 2008).

Chippers and grinders are often high capital investments. If a machine is purchased to meet the narrowly defined biomass specifications of one facility, with an associated high operational cost, the owner may be accepting some risk to their operation. For example, if the end-user facility has high inventories, deliveries will be disrupted. In this instance, the equipment owner could cease production until inventory controls are loosened, or the deliveries could be diverted to another facility. However, the delivered price at another facility may not cover the higher cost of producing biomass to meet a specific, stringent standard. For instance, the comminution cost of producing short-fiber, dirty chips with a prototype machine was found to be approximately \$5.42/green ton (Mitchell and Klepac, 2008), while the cost of producing biomass chips with a commercially available disc chipper was \$3.37/green ton (Mitchell and Gallagher, 2007).

Transportation delays can often occur in biomass processing operations that use chippers or grinders. Chippers and grinders typically load their processed output directly into chip vans. Delays often occur in operations due to chip van availability (Mitzel, 2007). When a chip van isn't on site, chippers are in a non-productive mode while waiting for another chip van to arrive. Of course, the processed material can be piled on the ground, but this would require additional handling to pick up the material and load it when a van returns, and the chipper would have to be idled during the re-handling phase of the operation. These transportation and processing delays can be avoided

by the use of bundling or baling equipment because they can process logging residues without a transport vehicle on site.

Equipment for Bundling or Baling Biomass

Bundling and baling biomass is another option for compressing logging residues into a denser product for transportation and hauling efficiencies. There are a few different types. Some are already in production by a manufacturer and others are in the field demonstration phase. Three different types will be summarized in this section: a “composite log” bundle machine, a square bundle machine, and a round bundle machine.

The first machine in this review is the John Deere 1490D Slash Bundler. It is commercially available and has been sold in the European markets for several years. A few of these machines have been sold in the United States. As mentioned earlier, this machine consists of the B-380 bundler mounted on a forwarder. Rummer et al. (2007) describes the operation as follows:

In operation, the operator collects residues with the crane and places them in the in-feed deck. Four compression rollers pull the material into the bundling unit and perform initial packing. Behind the feed rollers, two sets of compaction frames alternate grasping and sliding to move the compacted bundle through a wrapping unit. The bundles are simply wrapped with standard baling twine at selected intervals in one continuous string. As the wrapped bundle comes out of the machine and reaches a preset length, the cut-off saw activates, dropping the completed bundle to one side.

Production studies were performed (Rummer et al. 2007) using the 1490D Slash Bundler in the western United States (Idaho, Oregon, Montana, and California). The bundler collected post-harvest logging residues and small unmerchantable stems that were scattered throughout the stands, some in piles (Figure 1). During these studies, production rates varied from a high of 24 bundles/hr to a low of 5 bundles/hr. Var-



Figure 1. Composite log bundles from the John Deere 1490D Slash Bundler.

iables impacting production between the test locations included site conditions (including the openness of the stand for maneuvering), slash arrangement, terrain, and operator. Production rates were highest where bundled residues were primarily limbs and tops. Where larger whole trees were included in the bundles due to market conditions, the production was slowed due to aligning and bunching the stems before feeding them into the bundler. Production could be increased if advance harvest planning and operations include alignment of residues and tops in concentrated piles or bunches to facilitate bundling.

Another type of machine is one that bales biomass into large square bales (Figure 2). The initial prototype machine was built in early 2008 by engineers at Forest Concepts, LLC. Dooley et al (2008) describes the operation as follows:

... the loader picks up biomass from the ground and places it into a top-loading in-feed section. During bale compression the two finger-grates close to pack biomass into the chamber and form the top surface of the baler. Completed bales are ejected out the curb side of the baler to facilitate tying and lifting by the loader.

Production studies are not yet published on this machine. However, field trails proved that completed



Figure 2. Square bale from Forest Concepts, LLC prototype baler.

bales could be further processed by horizontal or tub grinders. Five end-user facilities commented that baled biomass would be easier and less costly to handle and process than bulk comminuted biomass (Dooley et al, 2008). The prototype is trailer-mounted, so the residues must be concentrated in an area near the trailer. Developers indicate that this machine is designed for woody biomass collection in urban and suburban environments where slash is brought to the unit.

A third type of baling equipment creates round bales in a single pass operation. The original version of the FLD Bio-baler shreds and bales severed material. This modified New Holland BR740 must be towed as it is not built on a prime mover platform. Unlike the previous bundler and baler described, this machine severs standing material using a mulching head, shreds the material, then processes it into round bales. When the bale is complete, either netting or bale twine is wrapped around the exterior and the bale is released from the unit. The cutting head of this machine is currently under development by FLD Biomass Technology to add a lifting mechanism at the front of the mulching head to pick up scattered logging residues. The shredded output may be similar to that from a grinder as the prototype used hammer teeth commonly found on mulching machines. Future versions of the machine may have optional cutting blades. In initial testing of the prototype unit, the cost range was \$37-\$43/ton of baled biomass (Canto et al,

2008). An advantage of the round bales over loose chipped or ground biomass is the additional compaction and ease of transport, which is similar to round bales in agricultural crops. When compared to other biomass compaction systems, this machine is at a disadvantage because it does not preserve the end-user values for processing the raw material to a particular specification.

This review indicates that if an in-woods operation is to retain the physical properties of logging residues, the material must not be chipped or ground. Compression and compaction technologies can densify woody biomass while retain-

ing the value of being further comminuted to meet end-user facility specifications.

The Trailer-Mounted John Deere B-380 Slash Bundler

The John Deere 1490D Slash Bundler has been modified by researchers at Auburn University to take advantage of concentrated logging residues on typical southern logging operations. Since mobility is not needed in this application, the B-380 Bundler has been removed from the forwarder and mounted on a trailer (Figure 3). Cutting Systems Inc. provided a motorized trailer to serve as the power unit for the bundler. This heavyweight trailer was originally designed to support a delimber, so it is applicable in the forest environment. The trailer's design makes it easy to move the unit on the landing with a skidder or log loader grapple.

The size and shape of the composite log bundles can make this compaction method a reasonable option. Finished bundles can be piled by a log loader as another product sort on the landing. Alternatively, if the landing arrangement doesn't allow for this space, a grapple skidder or mobile loader could move bundles aside. In addition, the bundler can be programmed to automatically cut a specified length. Bundles can be cut to length to fit between the bolsters on a log trailer. This is an especially attractive feature as four-bolster trailers are common on many southeast-

ern logging operations. It is expected that transportation efficiencies will arise as log trailers can be used for hauling bundles or other traditional forest products. In-woods truck turnaround times should be efficient for loading bundles because the loading phase is separate from the bundle processing phase.

Operational efficiencies in the field are yet to be determined. The original assumption was that the modified bundler would operate on a landing with one log loader sorting traditional forest products and feeding the bundler as slash management is needed. This assumption includes the use of a pull-through delimber on the log loader or similar device that can delimb and top material so that logging residues are readily available and within reach for the log loader to feed the bundler.

Delimbing gates are often used in pulpwood operations in southern logging operations. Transporting residues from the delimbing gate to the bundler could be an additional expense. Spinelli and Hartsough (2001) describe efficiencies of using a front end loader to transport multi-stemmed *Eucalyptus camaldulensis* a distance of approximately 656 feet to the landing. Efficiencies documented for use of the front end loader included the ability to pick up stems that were arranged in a windrow pattern. This forwarding activity was facilitated by the use of forks over a grapple. In addition, forks of the front end loader were better equipped than a skidder for moving residues around on the landing. With a trailer-mounted bundler, the use of a log loader for additional slash movement and arrangement may be an option if residues are concentrated around a delimbing gate, similar to a windrow pattern or pile.

In a more recent analysis of the John Deere 1490D Slash Bundler, Patterson et al (2008) reported production rates from their time and motion study that ranged from 23 to 36 bundles/hr. The rates are



Figure 3. Trailer-mounted B-380 Bundler.

higher in this study as compared to Rummer (2007) because the machine produced composite bundles by moving around slash piles on three separate landings, and the residues were not scattered through the stands. Delays occurred when bundles were dropped onto each other because the machine did not travel very far to create each bundle. When bundles accumulated around the machine, the operator had to stop bundling and use the boom to move bundles away from the machine.

Production rates for the modified unit are expected to be similar to those from the most recent study (Patterson et al, 2008). Production differences between the first study and the modified unit are expected because the slash will be concentrated at or near the landing. The log loader will feed the bundler as residues accumulate on the landing. While the modified version will not be mobile, the log loader will move bundles away from the primary working area. This should reduce the impact of bundles accumulating around the working unit, as was reported as a delay in the second study. Field trials during the late summer/fall 2009 will identify production elements and rates that may differ from previous studies due to differences in landing configurations and operation of the bundler.

Summary

The development of the trailer-mounted modified bundler could add another tool choice for logging residue collection. Land managers need equipment options to meet requirements of various logging systems and biomass facilities across the United States. Chippers, grinders, balers, and bundles can process logging residues into a variety of products that can be uniquely different from each other.

This first phase of this project has been completed by mounting the bundler on a motorized trailer. The second phase will address production rates and costs, and worksite management.

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