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PRELIMINARY EVALUATION OF STEEL-ROLLER ROUND BALER FOR WOODY BIOMASS BALING

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PRELIMINARY EVALUATION OF STEEL-ROLLER ROUND BALER FOR WOODY BIOMASS BALING[1]

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Abstract.-- A round hay baler with little modification was used to bale small-diameter, crushed trees. The trees had been crushed using a series of compression rollers. Bale cores had to be developed by hand before the baler became self-feeding. Windrowed material was packed off the ground by the baler system after a core had been developed.

Biomass harvesting has typically employed portable chippers in conjunction with conventional logging systems that use feller-bunchers and log skidders. On sites with only residuals or small trees, such chipper systems may not be economical because of the difficulty in harvesting these forest biomass components using conventional machines. Some innovative specialized machines have been developed for chipping biomass in the stand or on-site, and then transporting the chips to roadside. However, creating chips for energy use is economical only when high production can be maintained during chipping and forwarding. One alternative is to crush, split and bale biomass at the stump. This concept offers the potentials for easier handling on the site, smaller investment cost, and lower operating cost associated with machines smaller than portable chipper systems.

Harvesting of small woody biomass can be made more efficient by handling such materials in bales or modules. This concept has been applied to agricultural products for many years. Some preliminary research in the baling of woody biomass has been completed in recent years (Jolley 1977, Fridley and Burkhardt 1984, Jenkins 1983, and Stuart and Walbridge 1978). Most of the research has concentrated more on the product and equipment concept rather than on the recovery method.

Jolley (1977) analyzed the concept of densifying slash from harvested forest sites by using a prototype square baler. His work with the baler, a modified agricultural baler, proved that limbs and tops could be compacted into a rectangular cube having a bulk density comparable to that of stacked round wood.

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Stuart and Walbridge (1978) extended the concept with a feasibility analysis of the square baling in conventional harvesting systems. A suggested application was the use of a loader/baler combination at the deck area to recover limbs and tops. Other potential applications were the recovery of limbs and tops at the stump using a mobile baler, recovery of pine thinnings, and recovery of slash from a gate delimber. They listed several advantages of baling: Simplicity, reduced power consumption, low maintenance, field drying, and less storage degradation.

Fridley and Burkhardt (1984) densified forest biomass into large round bales. They used a round hay baler with flexible belts to form the bales in the chamber. The biomass, comprised of cut and uncut tops and limbs, was hand fed into the baler. The authors concluded that the baling concept was a feasible alternative to chipping in the woods, thus solving some forest-material handling problems. Other research has analyzed a modified round baler and modulators for agricultural by-products and forest biomass (Jenkins 1983 and Jenkins et al. 1983).

Residual biomass has form and shape conducive to baling, whereas small-diameter stems alone are more difficult to bale because of their springy characteristics. Recovery of small-diameter stems can be improved by processing that makes them less resilient. One such process involves crushing and splitting the stems (Jones 1982). In this concept, a harvester would cut and process the stems and leave them in windrows for drying. A second machine would modulize or bale the material for low cost transportation to the use-site (Barnett et al. 1986). The development of this concept would lead to the need for a low-cost, woody biomass baling machine.

Baling of young, small-diameter stems may solve problems at unusual site situations, such as rights-of-way, short-rotation plantations, and dense, stagnated stands. Drying and densification of biomass reduces cost for both in-woods and highway transport. This would also provide better burning efficiency than conventional chipping operations do. The potential of producing round bales from processed and dried woody biomass by using a commercially available agricultural baler was evaluated in a study by personnel from Tennessee Valley Authority, Southern Forest Experiment Station, and White's Inc.

OBJECTIVES

The overall objective of the study was to determine the feasibility of baling small woody biomass. A specific objective was to determine if the baler could develop a bale core without assistance, and if not, what assistance was necessary. Another objective was to evaluate the feed system ability to pick up biomass in windrows off the ground.

METHODS AND MATERIALS

Biomass

Stems came from several tree species, including loblolly pine, sweetgum, and oaks. These were segregated by diameter classes. Stems measuring 2.5 to 7.5 cm DBH (diameter breast high) were crushed/split with compression rollers on an experimental test bench machine. The stems were then air-dried several weeks (Ashmore et al. 1987). An additional test was conducted for freshly cut, uncrushed trees of small diameter. At the time of the tests, disc samples were taken from the crushed and uncrushed material to determine the moisture content. Tree lengths ranged from 2.8 to 4.9 m.

Baler

Round balers became commercially available in the early 1970's for agricultural use (Kepner et al. 1978). Baling is accomplished by rotating hay within a chamber, forming a layered roll. The baling chamber is usually a series of flat belts that compensate for the increased length of reach around the bale as the diameter becomes larger. Tensioning of belts helps control the density of the bales. In biomass application, the gaps between the belts allow stems to protrude out of the baling chamber (Fridley and Burkhardt 1984). A newer round baler design consists of a series of powered rotating steel rollers that form the bale chamber. A baler of this type was chosen for the test because the belt type has not been proven feasible for handling long, springy, tree-length material. Also, the belt type is not as rugged as the roller design.

A description of the baler used in the study is in Table 1. The Claas Rollant 62[1] is an agricultural round hay baler that uses 18 29.8-cm-diameter steel rollers to produce 1.5-m-diameter, high-density hay bales (Figure 1). The baler was equipped with a 1.5-m-wide hay spring tine head with feeder assist rake consisting of strong metal teeth reciprocating in the front of the bottom roller to help pack the material into the baling chamber. It was also equipped with a Rolletex high-speed net wrapping system as well as the more typical twine-tying system for wrapping bales. The baler was powered by a conventional farm tractor with 43-kw pto (power-take-off).

The only modifications to the baler involved the steel rollers, which were too smooth to adequately rotate the biomass within the baling chamber. A single bar, 0.6 cm thick by 2.5 cm wide, was welded to every other roller on the bottom rear quadrant of the baler. These bars were sharpened on the feeding edge to aid the rollers in catching and rotating the biomass.

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[1] The use of tradenames is for the convenience of the reader and is not and endorsement of the USDA Forest Service or Tennessee Valley Authority. Claas of America and White's Inc. do not recommend the Claas Rollant 62 with its present design for this application.

Table 1.--Specifications of equipment.

Item	Specification
Rollant 62 Baler	
Diameter of bale chamber	1.5 m (5.2 ft)
Width of bale chamber	1.2 m (3.9 ft)
No. of rollers	18
Pick-up width	1.5 m (5.1 ft)
Tines per tine bar	18
Tine spacing	7 cm (2.8 in)
Height	2.5 m (8.3 ft)
Width	2.0 m (6.8 ft)
Length	4.4 m (14.5 ft)
Track width	1.8 m (6.0 ft)
Weight	4361 lb (1,980 kg)
Ford 5000 Tractor	
pto power	43 Kw (56.85 hp)
pto speed	540 RPM

RESULTS

The moisture contents of the woody biomass at the time of crushing were 38 percent, dry weight basis, for the crushed; and 89 percent, dry weight basis, for the uncrushed material. The crushed trees were fairly brittle and would break, but they did not separate completely when bent. As expected, the larger diameter trees, 7.5 cm, were much more rigid than the smaller-diameter trees, 2.5 cm. Even though the green trees were flexible, they were too resilient to facilitate initiation of core formation and baling. The small diameter crush material bent easier and broke, enabling the development of a bale core.

The only way to develop a core and get it turning within the baler was by hand feeding. The most successful method was to use small-diameter (2.5 to 5.0 cm) crushed material to develop the core. To help with the initial feeding, the stems were bent manually, causing some breakage of the fibers before feeding into the baler. The material would feed, using positive hand pressure, and loop or fold into the chamber. After feeding enough volume to exert pressure on a sufficient number of rollers, the core would rotate and the bale would develop until its diameter increased to a point where it overcame the spring tension of the chamber door, causing the door to begin to open. When the door gap approached 5 cm, no more material was fed into the baler and the formed bale was wrapped, using Rolletex netting. One attempt was made to use multiple wraps of twine, but this method did not make a secure bale.

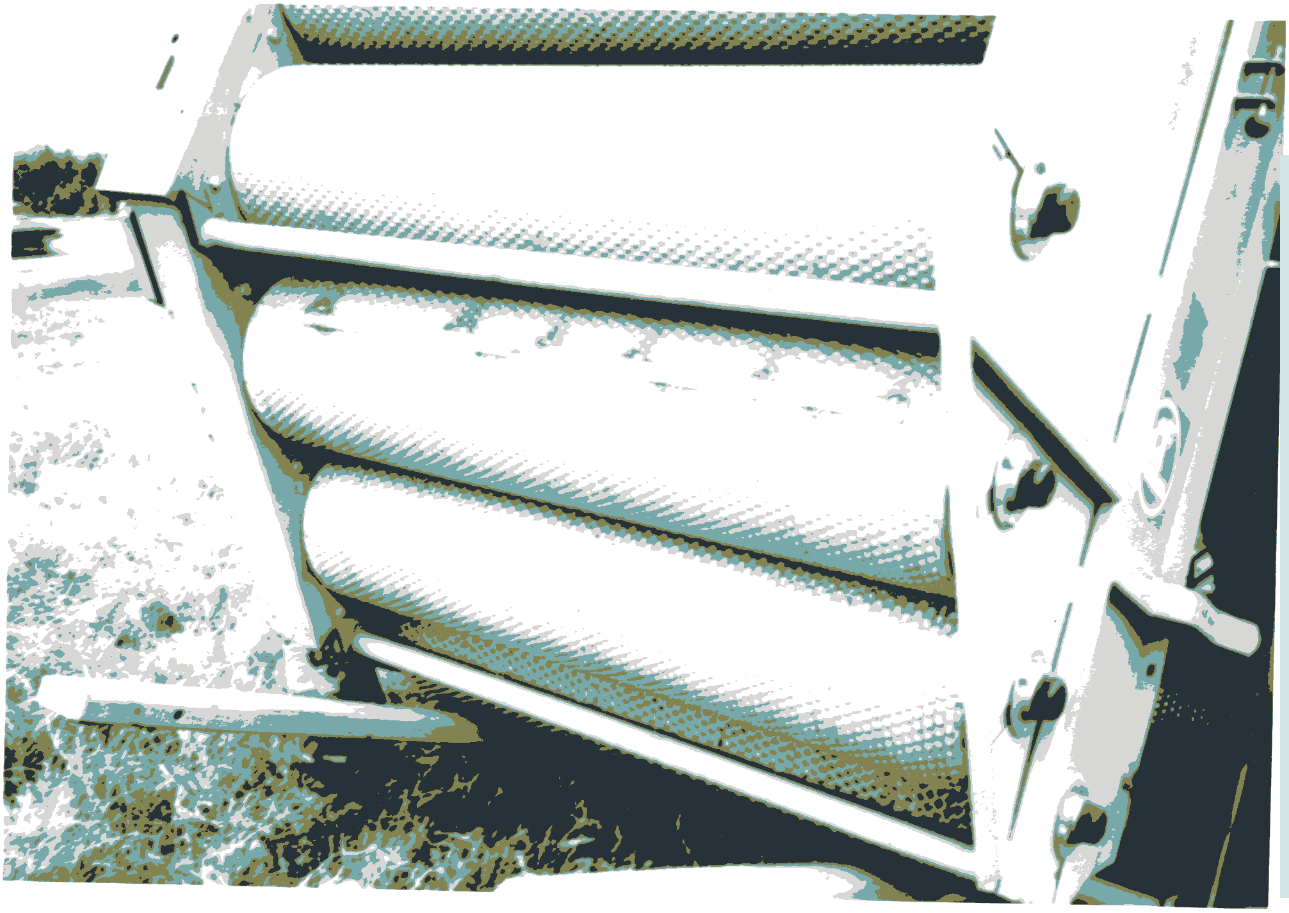

Figure 1. Opened Claas baler with steel rollers in bale chamber.

Methods that were not successful for developing a core were those using green uncrushed material and the larger (7.5 cm) crushed stems. The green material was so resilient that it would not conform to the chamber geometry without some type of applied force. A stronger, positive-feed mechanism might supply the needed force. When the large crushed material was used to try to develop a core, the large butts would stop the rotation of the core after a partial rotation. Modifications to the baler's rollers might help eliminate this problem and cause more complete crushing of the larger stems. In both tests, the stems' butts were fed first. The two materials may have worked better for forming a core if ends of the stems could have been alternated and fed into the baler.

Another test method involved cutting the trees into bolts and feeding the material crosswise into the baler. This method proved unsuccessful because the material would not rotate in the chamber to initiate the core.

After a core was developed and it started rotating, the feeding system became very aggressively self-feeding, and any size stem (up to the tested 7.5 cm DBH) would easily feed into the baler at the rate of approximately 2.4 m per second. Short lengths and chunks also fed easily.

Windrowed material was picked off the ground by the feeding system after a core had been developed (Figure 2). Stems were piled into rows with butts in one direction, some tops of adjacent stems overlapped the butts. Approximately four stems were laid side by side to form the windrow. The tractor straddled the row during baling.

Figure 2. Picking up windrowed biomass top first and baling.

The pick-up mechanism, spring tines, successfully fed the stems -- even 7.5-cm-DBH class -- into the baler when stems were fed first. When stems were oriented butts first, the pickup mechanism was unsuccessful.

It was not readily apparent whether the weight of the butts was too much for the spring tines, or whether the tines were spaced too fat- apart.

Only two bales were made during the test. The first, a partial bale, weighed 213 Kg. The second was a full bale that weighed 324 Kg. The full bale consisted entirely of crushed material with an average moisture content of 38 percent green weight basis. The dry weight was therefore 234 Kg; and with a volume of 2.1 m^3 in the bale chamber, the density was 113.7 OD Kg/m^3. The density of both bales'was greater toward the outer surface, compared to the inner core (Fig. 3). This is d problem that would have to be overcome for an operational system that must obtain nearly uniform density across the diameter of the bale.

Figure 3. Biomass bale with low density center.

CONCLUSIONS

The Claas Rollant 62 with steel rollers was successfully used to bale small-diameter, woody biomass. Crushed stems were hand fed to develop a bale core. Once the bale began rotating, the pickup and infeed system became aggressive enough for self-feeding of stems laid in a windrow.

Based on first observations, it appeared that small, crushed stems were better for developing a bale core. The conventional hay tine pick-up system successfully lifted biomass in windrows if material was gathered tops first. However, for improved production and reliability, additional modifications will have to be made. A more positive infeed system and aggressive rollers are needed for better baling and especially for developing a bale core that does not require manual methods. A future possibility is to have an expanding baling chamber that increases the density of the core and the density of the bale overall.

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