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Competitiveness of Whole-Tree Bundling in Early Thinnings

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Abstract

In 2007, the first prototype of the Fixteri bundle harvester capable of incorporating whole-tree compaction into the cutting phase was launched by Biotukki Oy. The bundles are hauled by a standard forwarder to the roadside storage, from where pulpwood bundles are transported by a standard timber truck to the end-use facility. At the puplmill, bundle batches are fed into a wood flow consisting of conventional delimbed pulpwood. Separation of the pulp and energy fractions does not take place until the wood reaches the debarking drum. Energy wood bundles are crushed and used for energy generation. In the pre-feasibility study carried out by Metsäteho Oy and the Finnish Forest Research Institute, the required performance level of bundle harvesting (i.e. cutting and bundling) of Scots pine (*Pinus sylvestris* L.) dominated stands was determined by comparing the total supply chain costs with most common pulpwood and energy wood supply chains. The system analysis showed that whole-tree bundling enables the reduction of procurement costs below the current cost level of separate pulpwood and energy wood procurement in early thinnings. The greatest cost-saving potential lies in small-diameter ($d_{1.3}$ = 7–10 cm) first-thinning stands.

Keywords: Costs, Bundling, Integration, Small-diameter wood, Pulpwood, Energy wood, Early thinnings.

1. Background

In Finland, wood production, especially the production of saw and veneer logs, is based on thinnings. Usually two or three commercial thinnings take place before the final cutting. According to the National Forest Programme, the annual need for first thinnings is 250,000 hectares

(Anon. 1999). During the 2000's, however, only 167,000–206,000 hectares have been thinned annually (Juntunen & Herrala-Ylinen 2007, 2008). Consequently, the total area of delayed first thinnings amounts to 600,000 hectares (Korhonen et al. 2007). Based on the latest forest inventories (Korhonen et al. 2007), the target for first thinnings should be increased up to 300,000 hectares per year during the next ten years.

In 2007, 3.0 million m^3 (solid) (6.1 TWh) of forest chips were used in Finland (Ylitalo 2008). Of this amount, 87% was used by energy plants and the remaining portion by small-sized dwellings (Ylitalo 2008). Only one quarter (1.4 TWh) of the commercial forest chips were produced from small-sized trees harvested from early thinnings (Ylitalo 2008). The annual use of forest chips for energy generation is to be increased to 5 million m^3 by 2010, and by 2015 up to 8–12 million m^3 (Anon. 1999, 2003, 2008). Therefore, the harvesting of small-diameter ($d_{1.3}$ <10 cm) wood from young stands must increased three- or even fourfold, compared to the current volumes.

High harvesting costs, resulting from small stem size, low removals and dense undergrowth, is the main problem when harvesting both energy wood and pulpwood from thinnings (e.g. Kärhä et al. 2004, 2005, Kärhä 2006, Laitila 2008, Oikari et al. 2008). In order to increase the volumes harvested from young stands, the harvesting costs have to be significantly reduced (e.g. Kärhä 2007a, Kärhä et al. 2007).

There are several options to combine the procurement of industrial roundwood and energy wood. The integration aims at lower total supply chain costs than in the case of separate procurement of roundwood and energy wood. In Finland, the production of logging residue chips from final fellings is strongly integrated with industrial roundwood procurement. Logging residues are stacked into piles on the felling site by the harvester, and to a certain degree, the same machinery is used for the forest haulage slash and industrial roundwood (Kärhä 2007b).

With regard to first thinnings, integrating the procurement of energy wood into that of pulpwood has been attempted on several occasions during the past decades. For example, separating whole-tree chips into pulpwood and energy wood fractions was tested with the Massahake method (Ahonen & Viinikainen 1993), and the flail delimbing method for debarking and chipping of whole trees (Hakkila & Kalaja 1993). These integration systems designed for first thinnings did not, however, achieve the same success as those of final fellings. In particular, no cost-effective methods for long road transportation distances have so far been found (Kärhä et al. 2007).

2. A novel technology for young stands

Compacting logging residues into cylindrical bundles was a breakthrough, which enabled cost-efficient operation in the case of extended forest haulage and long-distance transportation (Asikainen et al. 2001, Kärhä et al. 2004, Kärhä & Vartiamäki 2006). Transferring bundling technology into thinnings was only recently considered a complex technological and economic problem, to which there is not a solution in a view (Hakkila 2004). Three years ago, however, forest machine entrepreneur Pasi Romo from Biotukki Oy (www.biotukki.fi) constructed the first prototype of the Fixteri whole-tree bundler capable of cutting and bundling of small-diameter tree in dense thinning stands. The bundles produced by the bundler are approximately 0.5 m^3 in solid volume. The weight of the bundling unit is about 5.5 tonnes. The first bundler was mounted on the rear end of a Valmet 801 Combi harwarder, but it can also be installed onto other base machines.

The work cycle of a harwarder-based whole-tree bundler is as follows:

- The trees are felled and accumulated into bundles with an accumulating harvester head. Thereafter, the bunch of whole trees is lifted onto the feeding table of the bundler (Fig. 1).
- The feeding rolls pull the stems into the feeding chamber of the bundling unit.
- The stems fed into the feeding chamber are cut to a length of 2.6 metres with a chain saw installed at the chamber gate.
- The stems sections are lifted from the feeding chamber into intermediate storage above.
- A sensor detects the amount of wood in the intermediate storage, in which the trees are compacted. When the storage is full, the bundle is lifted into the compressing chamber above for the final compaction and wrapping with sisal string (Fig. 2).
- After wrapping, the bundle is dropped down along the strip road (Fig. 3).

Except for placing bunches onto the feeding table, the bundling process is autonomous, enabling simultaneous cutting and accumulation of subsequent bunches.

Figure 1. The first prototype of the Fixteri whole-tree bundler taking wood onto the feeding system of the bundler. Photos: Metsäteho Oy / Kalle Kärhä.

Figure 2. The accumulated bundle is lifted into the compressing chamber, in which it is compressed and wrapped using sisal string.

Figure 3. The compressed and wrapped bundle is dropped along the strip road.

In addition to bundles with pulpwood-dimensioned trees, separate energy wood bundles composing of undersized trees and undesirable tree species can be produced (Fig. 4). The bundles are hauled by standard forwarder to roadside storage, from where pulpwood bundles are transported by standard timber truck to the pulp mill (Fig. 5). Separation of the pulpwood and energy wood fractions takes place in the debarking drum. The pulpwood bundles are fed into the debarking process as blends with conventional delimbed pulpwood harvested from first thinnings. Bundles containing only energy wood are delivered to the heating and power plant for energy generation (Fig. 5).

Figure 4. Pulpwood bundle (left) and energy wood bundle.

Figure 5. The whole-tree bundling system.

The results from whole-tree bundling experiments indicate that the machine concept is viable in terms of its basic technical solutions (Jylhä & Laitila 2007). Furthermore, encouraging results from debarking and pulping of bundled Scots pine (*Pinus sylvestris* L.) sections harvested from first thinning have been obtained (Jylhä & Keskinen 2006).

3. Pre-feasibility study

Competitiveness of the bundling system was evaluated based on a system analysis, in which the total supply chain costs of the following procurement chains were compared:

- Separate procurement of pulpwood (cutting with single trees)
- Separate procurement of energy wood (whole-tree chips):
  - Roadside chipping
  - Chipping at plant
- Integrated procurement of pulpwood and energy wood:
  - Whole-tree bundling
  - Loose whole trees.

The cost calculations indicated that whole-tree bundling enables undercutting the current costs of the separate procurement of industrial pulpwood and energy wood from first-thinning stands (Fig. 6). The greatest cost-saving potential lies in small-diameter ($d_{1.3}$ = 7–10 cm) first-thinning stands, which are currently relatively unprofitable sites when applying conventional procurement systems with separate pulpwood harvesting applying single-tree harvesting.

The productivity of the bundle harvester, however, will have to be raised well above 50% of that of conventional feller-buncher (Fig. 6). This means, for example, that the performance of bundle harvesting must exceed 4.6 m^3 (9.2 bundles) per effective hour (E_0, excluding delays) with bundle size of 0.5 m^3, when the breast height diameter (DBH) of the trees to be removed is 7 cm. In the case of trees with DBHs of 11 and 13 cm, the productivities must exceed 7.6 and 8.7 m^3/E_0-hour (15.1 and 17.4 bundles/E_0-h), respectively.

Cost savings with the procurement system based on whole-tree bundling can be achieved especially in the case of relatively long forest haulage and road transportation distances. When whole-tree bundling is applied to the harvesting of energy wood ($d_{1.3}$ <7 cm) only, significant cost savings are not achieved (Fig. 6).

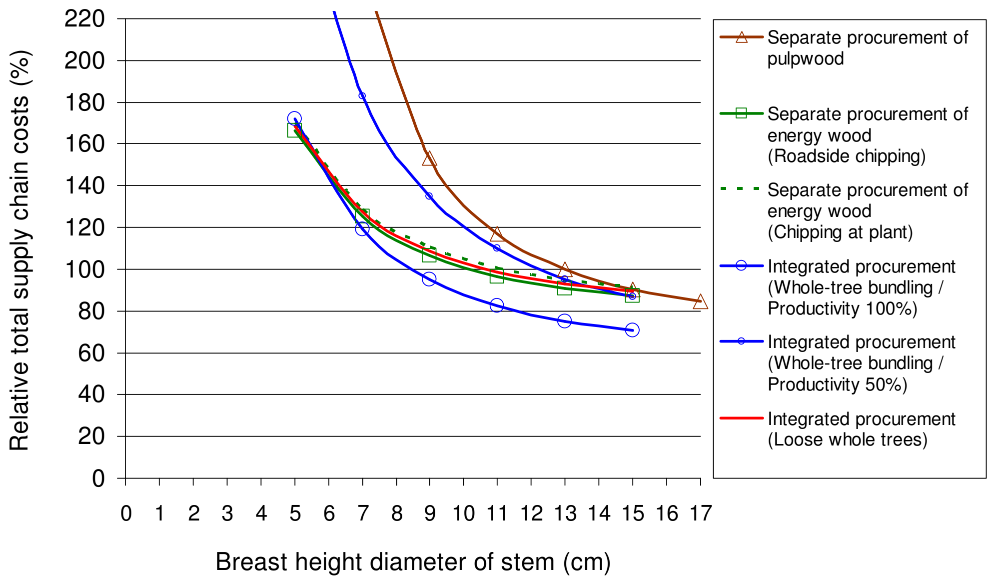

Figure 6. Relative total supply chain costs of wood harvested in early thinnings as a function of stem size. Calculations were made assuming two (100% and 50%) productivity levels for whole-tree bundling compared to feller-buncher. Forest haulage distance was 250 m and road transportation distance 100 km.

4. Further development work required

The low engine power of the four-cylinder harwarder used as a base machine, as well as the lack of grapple feeding system, were the main causal agents for the relatively low performance of the first prototype of bundle-harvester. Bundling unit in itself did not limit production (Jylhä & Laitila 2007). Along with improved interaction between felling and bundling processes, quicker functions, and improved working techniques, competitive productivity levels can be achieved. These bottlenecks were eliminated from the second version of the bundle-harvester, which is currently being tested.

With the felling heads (Naarva-Grip 1500-40E, Nisula 280E) tested with the first prototype, it was necessary to lay the felled wood bunch on the ground and to take a new grip before feeding it into the bundling unit. Despite these improvements, the purchase price and operating costs of the base machine of bundler should be kept at reasonable level.

Metsäteho Oy and the Finnish Forest Research Institute will carry out further time studies and economic analyses on the whole-tree bundling system in 2008–2009. The R&D project is funded by the National Technology Agency (Tekes) and the Finnish forest industries.

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