Demo Report 1 – Two stage grinding of woody biomass – D4.3.1

Dissemination Level

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Uppsala, July 29, 2013

INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
1. Introduction

The wood energy market continues to evolve throughout Europe and future growth largely depends upon the trade-off associated with investment in alternative heating/electrical systems and the cost (economic, environmental, and ecological) of alternative energy supply systems relative to existing fossil fuel based systems. Renewable energy is an important part of the Swedish and Finish energy budgets. Most of this is based on forest biomass, mainly in the form of industrial residues and by-products from the forest industry. These sources are almost fully utilised today, and therefore a growing share of the biomass used consists of primary forest fuels, mainly in the form of tops and branches from final felling, a.k.a. logging residues (Björheden 2011). Thinning of small trees and extraction of stumps are two other sources for primary forest fuels with a large theoretical potential to increase future biomass harvesting in Sweden (Anon. 2008). Stumps are a large potential source for forest energy and the Swedish Forest Agency estimates the potential to 4.2 million oven dry tonnes of harvestable stumps when ecological and technical restrictions to stump harvest has been taken into account (Anon. 2008).

Both logging residues and stumps are bulky materials leading to low load utilisation on trucks transporting these materials to the heating plants. One way to remedy this problem is to comminute the material on the landing, as this will increase the density and homogeneity of the material (Björheden 2008). This enables the use of chip trucks that, due to their lighter weight, have a higher legal pay load than trucks for loose residues and are able to fully utilise that load weight. Chipping residues at the landing results in the lowest total costs when the chips are transported medium to long distances, even though the chipping can be done more efficiently at a plant or at a terminal using a large stationary machine. Swedish fuel suppliers are well aware of this and chip 80 per cent of the residues at roadside landings. Similarly, comminution of stumps at the landing has the potential to increase load weights and thus reduce transport costs (von Hofsten and Granlund 2010). By grinding stumps to a coarse fraction, e.g. a target size of 200 mm or more, it is possible to sieve the material after grinding and get rid of a large proportion of the soil contaminants that reduce the heating value of the stumps (Fogdestam et. al. 2012).

The goal of the demonstration was to show the possibilities of two-stage grinding system to interested stakeholders, and study the performance and fuel consumption for the grinder as well as the quality of the hog fuel produced.

2. Materials and Methods

A demonstration and study of a Doppstadt 3060 Büffel was made in Valbo on April 3 and 4 2013. The demonstration was hosted by Valbo Entreprenad AB, a mid-sized contractor, who provided the site, the material and the machines, and Skogforsk and VTT that jointly studied the machines and presented results from previous studies of two stage grinding techniques.

During the demonstration stumps, coarse ground spruce stumps, fresh and stored tree sections, and recycled wood were ground. For the study the original intention was to study coarse grinding of stumps and final grinding of the produced material. Due to a high local demand for grinding capacity and thus limited availability of machines, we were not able to
demonstrate the originally planned two stage grinding operation with a coarse grinder producing a coarse material and a high speed grinder turning the coarse material into a standard size P45-fuel. Instead we demonstrated a set up consisting of a coarse grinder, a sieve and a return conveyor, which through sieving and regrinding oversized material produced a customer specified hog fuel that should be smaller than 200 mm with low amount of fines.

The contractor was using a Doppstadt DW 3060 low speed grinder that was feeding the ground material directly into a Doppstadt Thrichter separator disc screen. The disc screen was set to accept material of 50 mm diameter and approximately 200 mm length. From the disc screen all oversized materials were returned on a conveyour to the grinder and the accept fuel was stacked on the side of the screen (Figure 1). A Volvo L65 loader was used to load the material into the grinder from stacks on the terminal area and to load the produced hog fuel into containers.

A detailed time study of the grinding operation was done during the demo. The time study was made as a correlation time study with snap back timing (Bergstrand 1987). Time recording was made in centiminutes (1/100 of a minute) using Allegro hand-held computers equipped with Skogforsk SDI software. However as the amount of material produced in the study was small and the produced output was only estimated, no analyses of the data was made.

Figure 1. Oversized chunks are returned to the grinder via the conveyor.

A detailed time study of the grinding operation was done during the demo. The time study was made as a correlation time study with snap back timing (Bergstrand 1987). Time recording was made in centiminutes (1/100 of a minute) using Allegro hand-held computers equipped with Skogforsk SDI software. However as the amount of material produced in the study was small and the produced output was only estimated, no analyses of the data was made.
Due to the limited time available and problems during the set-up we realised that we could not measure fuel consumption of the machine with reasonable accuracy so the fuel measurements were cancelled.

Large, 15 l +, chip samples were taken from all ground materials and taken to VTTs lab in Jyväskylä. There the moisture content, ash content, and particle size distribution of hog fuels produced were analysed according to the EN-standards.

3. Results & Discussion

In hindsight it was unfortunate that we made the demo early in April, as the spring in the area was late and it still was fairly cold. This meant that Valbo Entreprenad needed the machinery at one of their major clients wood yard rather than on their own terminal, where the demo was made. This meant that only two days could be set aside to move the machines between sites, set them up for production and doing both the demo and some studies. However if the spring had been as in 2012, Valbo entreprenad would have been busy emptying their terminal of wood fuels and probably would have had multiple grinders working on the terminal. The short time allocated for the demo and studies limited the usefulness of the time studies and made accurate fuel consumption studies impossible. Good chip samples were obtained of the hog fuels produced from the different feedstocks. It was therefore decided to complement the study data with some data from a previous study of a Doppstadt 3060 Büffel grinding stumps (Fogdestam et.al. 2012).

Fogdestam et.al. (2012) study was made in order to assess hog fuel quality and the productivity and fuel consumption for a grinder and sieve when producing coarse ground stumps. A Doppstadt DW 3060 low speed grinder fed by a truck mounted grapple loader was studied at Jämtkraft AB’s forest fuel terminal close to Fyrås in northern Sweden. The ground material was sieved using a Doppstadt SM 620 drum sieve, which had a drum with 20 mm mesh size. Grinding and sieving operations were studied in three replicates. In each replicate at least 20 metric ton of Stumps were processed. The fine material was considered as a reject material as it, to a large extent, consisted of soil and humus particles, and was left at the terminal while the coarser material (the accept material) was transported to the heating plant in Östersund for combustion. Due to lack of space and the inconvenience of having to move both machines when the grinder was moved along the stump piles, an articulated wheel loader was used to feed the sieve. The wheel loader was also used to load the accept material into containers or to stack it on the terminal.

In the Fyrås study, the stumps were highly contaminated with soil and humus particles. Although on average 31 per cent of the dry weight was rejected in the sieving process the accepted material had an ash content of 7.6 per cent, while the rejected material had a significantly higher ash content of 53.9 per cent. Thus the total ash content on the ground material was 22 per cent prior to sieving. When grinding these stumps the grinder produced 25.8 ton dry matter per effective hour of which 18.7 were acceptable hog fuel after sieving. The drum sieve could receive 30.6 dry ton of ground stumps per effective hour which resulted in 20.4 ton dry matter of acceptable hog fuel per effective hour. The average diesel fuel consumption per acceptable ton dry matter was 1.75 l for the grinder and 0.45 l for the drum sieve.
6.9.2013

On average a truck transporting uncomminuted stump parts can load 20 – 21 metric tonnes due to the bulky material. The coarse grinding increases the gross load weights to approximately 30 metric tonnes due to the better packing properties of the more homogenous material (von Hofsten & Granlund 2010). As the Fyrås study shows, sieving the coarse ground stump parts increases the share of burnable material per ton of material. For the 63 km transport from Fyrås to the CHP plant in Östersund, coarse grinding and sieving the material prior to transport increased the net load of burnable material from 10.6 to 17.9 oven dry ton per load and decreased the amount of material in need of transport by 31 per cent.

In the present study, the grinder and sieve combination produced a hog fuel with a small amount of fines < 8 mm (Figure 2) and low ash content (Figure 3), which is what the heating plant in Sandviken prefers.

**Figure 2. Particle size distribution for the produced hog fuel depending on feedstock**

**Figure 3. Ash content for the produced hog fuel depending on feedstock.**
4. General evaluation

The studied grinder set up performed reasonably well but the produced hog fuel would not have been accepted at the majority of Swedish heating plants due to the size of the chips. However this is not an issue as it fitted the specifications of the client that had ordered the fuel.

For longer production runs it is necessary to have sieves installed in the grinder reducing the production of oversized pieces so that less material is returned to the grinder via the conveyor. In normal operations the contractor uses bottom sieves in his own Doppstadt 3060. The machine used in the demo was a trial machine sent up for the demo from OP Maskiner, the Swedish agent for Doppstadt, and had not been fitted with sieves after service. Furthermore a more careful placement of the machines and conveyor would facilitate a more rational feeding of the grinder and improve the loading and transport of the produced hog fuel.

5. Demo results

In total twenty persons showed up at the demo. Among these were representatives for the biomass business of three of the major forest companies (Sveaskog, Stora Enso bioenergy & SCA), the Mellanskog forest owner association, OP Maskiner (the Swedish agent for Doppstadt) and three other comminution contractors. Furthermore the demo resulted in a large newspaper article in ATL (Figure 4), one of the major business papers for agriculture and forestry.

6. Acknowledgements

The authors wish to thank the following people for their support with the study and demo: Ulf Ytterbom, Valbo entreprenad AB; Inger Petré and Fredrik Staland Skogforsk.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015] under grant agreement n°311881. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that maybe made of the information contained therein.
7. References


Fogdestam, N., Granlund, P. & Eliasson, L. 2012. Grovkrossning och sållning av stubbar på terminal. (Coarse grinding of stumps and sieving of the produced hog fuel.). Skogforsk, Arbetsrapport Nr. 768, 9 pp. ISSN 1404-305X.

Ny teknik gör stubbfilisen intressant
Bättre betalt när halten av aska kan sänkas

...kan den här metodikna leda till att vi få bättre betalt för stubbfilis i alla led...

Figure 4. The ATL news article presenting the demo.
INFRES – Innovative and effective technology and logistics for forest residual biomass supply in the EU (311881)
Demo Report 2 – Smart chipper demo in Germany

Dissemination Level

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Sesto Fiorentino, June 25th, 2013
1. Introduction

The wood chip energy market continues to evolve throughout Europe and future growth largely depends upon the trade-off associated with investment in alternative heating/electrical systems and the cost (economic, environmental, and ecological) of alternative energy supply systems relative to existing fossil fuel based systems. A significant environmental and economic cost component for this forest residue supply chain is associated with the efficient operations of wood chippers in the forest.

Pezzolato is a leading Italian equipment manufacturing company, specializing in machines for the forest and wood products industry, including disc and drum wood chippers, splitting machines, pallet packing machines and a variety of saws for sawmills operations. They have developed a new wood chipper with improved operational aspects that may significantly increase operational cost efficiencies, especially in central European forest conditions with steep terrain and limited landing/loading space availability. In particular, this machine is designed to bring industrial chipping as close as possible to the forest, preventing costly hauling of loose residues to a terminal or a large landing. At the same time, the machine is capable of independent relocation between work sites, which is a valuable quality where tract size is small, like in Central and Southern Europe. Otherwise, a forwarder-mounted chipper would be a suitable piece of equipment for taking chipping close to the forest.

The new chipper truck demonstrated within INFRES is capable of working on narrow landings or directly at the roadside, when space is too limited for semitrailer access. At the same time, this machine can easily relocate between worksites, being mounted on a truck and qualified for road travel.

The main characteristics of the machine are:

- Reduced vehicle width, especially important for narrow forest roads with limited operating and loading space.
- Traction on all 6 wheels, for climbing on steep road and trafficking difficult terrain
- Capacity to discharge chips to front, side and rear of vehicle, likewise increasing operational flexibility for loading chip trucks
- Chip moisture content meter for measuring/recording moisture content in field operations.
- On-board GPS tracking and CAN-BUS data collection in order to monitor and track detailed movements and operations from base office.
The goal of the demonstration was to test the machine for productivity, technical efficiency and fuel consumption, and show its capacity to interested stakeholders. Furthermore, the data collected in this demonstration were used to conduct a desk comparison between chipping on the forest road and chipping to the landing after intermediate transportation of loose slash, in order to determine the eventual savings obtained with the introduction of the new chipper.

2. Materials and Methods

The demonstration was organized in Germany, near Offenburg. Demonstration was hosted by the University of Freiburg (FELIS) and Fallert Holzenergie. The former organized the sites and the logistics, while the latter provided the wood and the receiving chip trucks. Pezzolato SpA was the guest manufacturer, and IVALSA accompanied Pezzolato in order to act as a liaison and assist with data collection.

The demonstration was planned for conduction right after the FORSTLive fair in Offenburg, so that the project, the machine and the live demo could be advertised at the fair, through suitable posters and leaflets.

The demonstration and trials were conducted on the 16, 17 and 18 of April at three different sites, all characterized by difficult accessibility. Since the demonstration site changed every day, the rendez-vous place for the public was set at a nearby train station, in order to avoid confusion. Every day at the appointed hours (morning and afternoon) the FELIS van would show up at the station for leading visitors to the demo sites.

The machine on trial was the Pezzolato Hacker-Truck PTH1200/820. This machine was installed on a MAN TGA 540 truck, and it was powered by the truck engine, delivering a maximum output of 397 kW (Figure 1). The drum was the close type, with a diameter of 820 mm and a width of 1200 mm. This drum was specifically designed for processing logging residues (tops and branches). The machine was equipped with a wood splitter in order to treat heavy defective logs, too large for the chipper infeed opening. During the trial, the chipper was equipped with a 170 x 60 mm mesh screen (sites 1, 2 and part of site 3) or with a 60 x 60 mm screen (part of site 3). Cut length was set to 25 mm.
Product output was determined by taking all loads to the certified weighbridge available at Fallert. Loose volume output was obtained by measuring the internal volume of the containers and by visually estimating the volume of any mounds or voids on the trailer top. One 500-g sample was collected from each replication in order to determine moisture content and particle size distribution. Each 500-g sample was obtained after reduction of a larger sample assembled by mixing subsamples collected at different points from the container top. Moisture content was determined with the gravimetric method, according to European standard EN 14774-2. Fresh weight was determined on-site with a portable scale, immediately after sample collection. Particle size distribution was determined with the oscillating screen method, using four sieves to separate the five following chip length classes: > 63 mm (oversized particles), 63-45 mm (large-size chips), 45-16 mm (medium-size chips), 16-3 mm (small-size chips), < 3 mm (fines). Each fraction was then weighed with a precision scale. The average chip size was obtained as the weighed average of the central value in each size class by the percent incidence of the class itself.

Time input was determined with a Husky Hunter handheld computer, running the Siwork3 dedicated time study software. Both productive and delay time were measured, but the analysis was conducted on productive time only, in order to avoid the confounding effect of delay time, which is typically erratic.

Fuel input was measured at the end of the day, by refilling the diesel tank with a fuel pump accurate to 0.1 litres, after parking the truck on the same level spot. Fuel consumption was the gross fuel consumption for the chipper and the loader, since both were powered by the same engine.
3. Study result

The test lasted 23 hours, including transfers, delays and preparation. During this period the chipper processed 619 loose m³ of chips, or 215 green tonnes with a mean moisture content of 49%. There were no significant differences between the three sites for what concerned moisture content. The wood was mostly spruce and fir on the first two sites (with some minor amounts of hardwoods), and pure poplar on the third site. On this last site, the pile contained a certain amount of large cull logs, which needed splitting.

Actual work represented 11 hours, or slightly less than 50% of the total scheduled time. Based on actual work, average productivity was 55 loose m³ or 19.5 green tonnes of chips per hour. Actual work included chipping proper, chipper manoeuvres, container truck manoeuvres, log splitting.

Table 1 – General statistics

<table>
<thead>
<tr>
<th>Work step</th>
<th>hours</th>
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<tr>
<td>Transfer</td>
<td>2.49</td>
</tr>
<tr>
<td>Chip</td>
<td>8.71</td>
</tr>
<tr>
<td>Other work</td>
<td>2.28</td>
</tr>
<tr>
<td>Delays</td>
<td>5.78</td>
</tr>
<tr>
<td>Preparation</td>
<td>3.34</td>
</tr>
<tr>
<td>Total</td>
<td>22.59</td>
</tr>
<tr>
<td>m³ loose</td>
<td>619</td>
</tr>
<tr>
<td>Green tons</td>
<td>215</td>
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Figure 2 shows the breakdown of worksite time among different process steps. Delays represented 26% of total worksite time. The delay factor (ratio of delays to actual work time) was 52%. Preparation accounted for 15% of worksite time, or about 1 hour per work day.
Table 2 shows the results for fuel consumption. Overall, 494 L of diesel were used for the trial. Specific fuel consumption was 0.80 litre m⁻³, or 2.3 litre t⁻¹. Hourly consumption was 46 litres of diesel per hour of actual work.

Table 2 – Fuel consumption

<table>
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<tr>
<th>Day</th>
<th>m³</th>
<th>green tons</th>
<th>litres diesel</th>
<th>litres m⁻³</th>
<th>litres green tons⁻¹</th>
<th>litre work h⁻¹</th>
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</thead>
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<tr>
<td>16-apr</td>
<td>238</td>
<td>90</td>
<td>196</td>
<td>0.82</td>
<td>2.19</td>
<td>44</td>
</tr>
<tr>
<td>17-apr</td>
<td>188</td>
<td>65</td>
<td>160</td>
<td>0.85</td>
<td>2.47</td>
<td>50</td>
</tr>
<tr>
<td>18-apr</td>
<td>193</td>
<td>60</td>
<td>138</td>
<td>0.72</td>
<td>2.29</td>
<td>43</td>
</tr>
<tr>
<td>Overall</td>
<td>619</td>
<td>215</td>
<td>494</td>
<td>0.80</td>
<td>2.30</td>
<td>46</td>
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4. Chain level comparison with conventional chains

The performance of the new system was compared with that of a conventional system, using bibliography data. In particular, we assumed that with the conventional system a tractor and trailer unit was used for extracting uncomminuted residues to a landing, before chipping could occur. The productivity and cost of secondary extraction with truck and trailer units was obtained from previous studies conducted in the Italian Alps. These studies also offered the main data for chip transportation to the end user.
Based on these studies, we made the following assumptions: productivity of secondary hauling: 4 green tons h\(^{-1}\); fuel consumption for secondary hauling: 10 litres h\(^{-1}\), or 2.5 litres green t\(^{-1}\). Productivity of transportation on a 70 km distance (one way): 7 green t h\(^{-1}\); fuel consumption for secondary hauling: 12 litres h\(^{-1}\), or 1.7 litres green t\(^{-1}\)(for a 70 km distance). It was also assumed that once the biomass was taken to a landing, delay time was halved. Furthermore, access to a landing allowed using a simpler chipper, 20% less expensive (Spinelli 2007, Spinelli 2012)

Results for this comparison are reported in Table 3. On a chain basis, the innovative system allowed a 13% saving on financial cost and a 35% saving on fuel cost.

**Table 3 – Chain level comparison of the new system and a conventional one**

<table>
<thead>
<tr>
<th>Process</th>
<th>Conventional system – loose residue extraction + chipping</th>
<th>Innovative system – chipping + chip extraction</th>
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<tr>
<td></td>
<td>green tons h(^{-1})</td>
<td>€ h(^{-1})</td>
</tr>
<tr>
<td>Secondary extraction</td>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>Chipping</td>
<td>16</td>
<td>200</td>
</tr>
<tr>
<td>Transportation</td>
<td>7</td>
<td>70</td>
</tr>
<tr>
<td>Total cost and consumption</td>
<td>34</td>
<td>6.2</td>
</tr>
<tr>
<td>Savings with the new system</td>
<td>0.13</td>
<td>0.35</td>
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5. General evaluation

In technical terms, the new chipper performed well. It showed excellent mobility and a high productivity. Chip quality was also good, and especially suitable for demanding users. Overall, particles longer than 63 mm represented less than 0.5% of the total chip weight. Fines represented slightly more than 5%. Accepts (chips in the 3 to 63 mm class) represented 93% of the total. Medium-size chips (8 to 16 mm) represented for the largest single fraction, accounting for 47% of the total weight.
The front blower performed well, but it was slower than the main blower and the operator had to dose feeding in order to avoid chip backups that could jam the discharge system. The front blower represents a last resort, to be used only when there are no other viable solutions (Figure 3).

The machine represents an ideal solution for small, scattered tracts in mountain forests. Under these circumstances, road standards are poor and relocation is frequent, calling for a machine capable of associating agility with good road mobility.

In case, the performance of this machine could be improved by equipping it with a central tire inflation system, so as to maximize its cross-country mobility, while minimizing forest road wear (Ranta & Rinne 2004, Ross 2005, Sturos et al. 1995).

In general, it was demonstrated that the new machine offers significant financial and energy savings at a chain level, as postulated by the original project application.

6. Demo results

Despite all the efforts to advertise the event, the turnout was much lower than expected. Overall, we counted about a dozen of visitors. They were all very interested and they liked the machine. It is possible that organizing a demo just after a fair may not represent the best strategy for attracting a large audience. While we thought that clustering the events would create synergy, it is not unlikely that people who had already attended the fair decided not to spend the extra day to see just another machine, for as innovative as this could be.
7. Acknowledgements

The authors wish to thank the following people for their support with the study and demo: Mr. Fallert & son (Fallert Holzenergie), Dr. Natascia Magagnotti (IVALSA), Mr. Jurgen Mergelsberger (Fallert Holzenergie), Mr. Giacomo Puppo (Pezzolato SpA) and Ms. Juliana Walkiewicz (FELIS).

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2012-2015) under grant agreement n°311881. The sole responsibility for the content of this report lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible for any use that maybe made of the information contained therein.
8. References


Ross I. 2005. Tired of re-paving roads, forestry giant looks to technology: CTI systems can reduce wear on roads and tires, potentially slashing maintenance costs and even extending the harvesting season. Northern Ontario Business, Sept. 1.


Spinelli R. 2012. Powerpoint presentation with the final results of the CARITRO Biomasfor Project, Trento, November 28, 2012

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Demo Report 3 – Pezzolato chipper truck demo in Sweden – D4.3.3

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Uppsala, July 9, 2013
1. Introduction

The wood chip energy market continues to evolve throughout Europe and future growth largely depends upon the trade-off associated with investment in alternative heating/electrical systems and the cost (economic, environmental, and ecological) of alternative energy supply systems relative to existing fossil fuel based systems. Chipping is a crucial operation in any forest fuel supply system. It transforms the forest fuel to a product usable in CHP and heating plants and, if done on the landing, in many cases it also improves transport economy. Chipping at the landing is costlier than comminution with a large machine at a terminal or heating plant, but it increases load density and payloads for low density materials, such as logging residues. It thereby reduces transport costs and this gives a lower total cost when transport distance exceeds 50 to 70 km.

Pezzolato is a leading Italian equipment manufacturing company, specializing in machines for the forest and wood products industry, including disc and drum wood chippers, splitting machines, pallet packing machines and a variety of saws for sawmills operations. They have developed a new wood chipper with improved operational aspects that may significantly increase operational cost efficiencies, especially in central European forest conditions with steep terrain and limited landing/loading space availability. The machine is a high capacity chipper intended for use on small landing. Thus, it enables contractors to replace costly hauling of loose residues to a terminal or a large landing with transport of chips directly to customers. At the same time, the machine is capable of independent relocation between work sites, which is a valuable quality where tract size is small, like in Central and Southern Europe.

The new chipper truck demonstrated within INFRES is capable of working on narrow landings or directly at the roadside, when space is too limited for semitrailer access. At the same time, this machine can easily relocate between worksites, being mounted on a truck and qualified for road travel.

The main characteristics of the machine are:

- Reduced vehicle width, especially important for narrow forest roads with limited operating and loading space.
- Traction on all 6 wheels, for climbing on steep road and trafficking difficult terrain
- Capacity to discharge chips to front, side and rear of vehicle, likewise increasing operational flexibility for loading chip trucks
- Chip moisture content meter for measuring/recording moisture content in field operations.
- On-board GPS tracking and CAN-BUS data collection in order to monitor and track detailed movements and operations from base office.
The goal of the demonstration was to study the performance and fuel consumption for the chipper as well as the quality of the chips produced, and show its capacity to interested stakeholders.

2. Materials and Methods

The demonstration and study of the Pezzolato chipper truck was organized in in Hestra, Sweden on June 10 and 11, and the machine was also showed at the nearby Elmia Wood fair on June 5 to 9. The INFRES project, the machine and later demo was advertised at the fair through posters and leaflets. The demonstration in Hestra was hosted by Sveaskog, who provided the sites and material as well as the container trucks that transported the chips, and Skogforsk, who had selected the sites and managed the logistics during the study. Pezzolato SpA provided the machine with operator and the studies of the machine were made jointly by Skogforsk and IVALSA.

The studied machine was a Pezzolato Hacker-Truck PTH1200/820. This machine is built on a MAN TGA 540 truck, and is powered by the truck engine. The truck delivers a maximum output of 397 kW. The chipper has a closed drum with a diameter or 820 mm and a width of 1200 mm. This drum is specifically designed for processing logging residues (tops and branches). The machine is equipped with a wood splitter in order to treat heavy defective logs, too large for the chipper infeed opening. During the trial, the chipper was equipped with a 170 x 60 mm mesh size screen and chip cut length was set to 25 mm. Sharp blades were used throughout the study.

The material to be chipped consisted of tops and branches (logging residues) from final felling of mixed coniferous stands where seed trees of pine had been retained. The chipped material consisted of approximately the same amount of pine and spruce material in a fairly even mix. In addition to the tops and branches, Sveaskog had made a pile of mixed pulpwood sized logs available for the demonstration (figure 1). During the studies the chipper truck produced 11 containers of logging residue chips and 1 container of chips from the logs.
Figure 1. Chipping of logs on the road in the seed tree stand.

A detailed time study of the chipping operation was done as a comparative time study with snap back timing (Bergstrand 1987). Time recording was made in centiminutes (1/100 of a minute) using Allegro hand-held computers equipped with Skogforsk SDI software. Chipping work was split into 10 elements (table 1), of which the element other was not used. All measured times for each load has been summarized per work element and divided by the oven dry mass of the load to get times in centiminutes per oven dry ton (odt). Only effective times have been included in the analysis of the time study data, thus no delays are reported.

Table 1. Description of work elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom out</td>
<td>Boom movement from the chipper to the piled material</td>
</tr>
<tr>
<td>Grip</td>
<td>Gripping of material</td>
</tr>
<tr>
<td>Feed</td>
<td>Boom movement from the pile to the machine, releasing the grapple load and assisting in feeding the chipper</td>
</tr>
<tr>
<td>Chip</td>
<td>Chipping while the loader is idle</td>
</tr>
<tr>
<td>Adjust</td>
<td>Adjustments of material already left on the feeding table</td>
</tr>
<tr>
<td>Move</td>
<td>Moving the chipper alongside the pile of material or between piles</td>
</tr>
<tr>
<td>Other</td>
<td>Other work time – works not covered above that is needed to complete the work task</td>
</tr>
<tr>
<td>Delay – Con</td>
<td>Delay due to lack of containers to fill</td>
</tr>
<tr>
<td>Delay – Mech</td>
<td>Mechanical delays, e.g. blade changes</td>
</tr>
<tr>
<td>Delay - Other</td>
<td>All delays that not is mechanical or container related</td>
</tr>
</tbody>
</table>
Fuel consumption of the machine was measured for each load during the first day by top filling the tank in field using a high precision fuel pump. The measured fuel consumption is the gross fuel consumption for the chipper truck, as the same engine powers the truck, the loader and the chipper. By refilling the tank in field the fuel consumption due to truck movements is minimized.

The amount of produced chips in each truckload, i.e. in 3 containers, was measured at the heating plant in Värnamo by the Timber Measurement Association of South Sweden. There the weight, loose volume and moisture content (MC) were measured by certified staff. During the study, three additional 500 g samples were taken from each container for a more accurate determination of MC and 2 10 liter samples per load was taken for determination of the particle size distribution. Each 500-g sample was consisted of chips collected at different points from the container top. Moisture content was determined with the gravimetric method, according to European standard EN 14774-2. Fresh weight was determined on-site with a portable scale, immediately after sample collection and dry weight after 24 hours of drying at 105 centigrades using the same scale. Particle size distribution was determined with the oscillating screen method, using six sieves to separate the seven following chip size classes: > 63 mm, 63-45 mm, 45-31.5 mm, 31.5-16 mm, 16-8 mm, 8-3 mm, < 3 mm (fines). Each fraction was then weighed with a precision scale.

### 3. Results

During the study 64.3 odt (97.3 raw tonnes) of logging residues and 7.7 odt (12.0 raw tonnes) of logs were chipped. On average the effective chipping time per odt of chips were more than twice as high when chipping logging residues (3.2 minutes) as when chipping logs (1.5 minutes). This time difference is mainly explained by that the time to handle residues with the loader is longer, i.e. the time for *boom out, grip and feed* (Table 2). During the study the machine produced 18.5 and 39.3 odt per hour of efficient chipping time when chipping logging residues and logs, respectively. Fuel consumption was on average 2.5 liter of diesel per odt of residue chips produced.

The chipper truck produced fine cut chips, with most chips being smaller than 31.5 mm. The amount of fines (<3 mm) and chips < 8 mm was especially high when chipping residues (figure 2). The amount of fine chips in general is not surprising given the 25 mm cut length of the blades.

Although the moisture content gauge gave instant readings (Figure 3) while the machine chipped the data interface between the gauge and the machine computer failed to give averages per container produced and thus we did not get values that could be compared to the estimates provided by the chip samples.
Table 2. Time consumption per oven dry ton (cmin/odt) separated on work element and chipped material.

<table>
<thead>
<tr>
<th></th>
<th>Residues</th>
<th>Logs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boom out</td>
<td>75.0</td>
<td>27.2</td>
</tr>
<tr>
<td>Grip</td>
<td>46.1</td>
<td>14.2</td>
</tr>
<tr>
<td>Feed</td>
<td>162.4</td>
<td>70.6</td>
</tr>
<tr>
<td>Chip</td>
<td>30.6</td>
<td>31.1</td>
</tr>
<tr>
<td>Adjust</td>
<td>10.2</td>
<td>9.6</td>
</tr>
<tr>
<td><strong>Effective chipping time</strong></td>
<td>324.3</td>
<td>152.8</td>
</tr>
<tr>
<td>Move</td>
<td>38.6</td>
<td>35.9</td>
</tr>
<tr>
<td><strong>Effective work time</strong></td>
<td>362.9</td>
<td>188.7</td>
</tr>
</tbody>
</table>
Figure 2. The display showing the instant readings from the moisture gauge.

Figure 3. Particle size distribution of the produced chips for the two materials chipped.

4. Comparison with conventional chippers used in Swedish biomass supply chains

The studied chipper truck has better off-road capabilities than the ordinary 8×4 chipper trucks used for chipping material forwarded to roadside landings. If the ditch on the side of the road is small or absent, this enables it to park close to the pile of material so that there is enough room for transport trucks to set out containers on the road parallel to the chipper.
truck (figure 4). However, its off-road capabilities are limited compared to the forwarder mounted chippers that also are used to chip forwarded forest fuels.

Figure 4. Chipping while standing beside the road with the chipper truck

The observed performance of 18.5 odt per hour of efficient chipping work is in the same magnitude as performances noted for similar sized chippers. In previous studies of chipping of logging residues using Bruks 805 series chippers, a Scania R560 chipper truck produced 19.9 odt per hour of efficient chipping work with a fuel consumption of 2.0 liter per odt (Bergstrand, K.-G. 1987. Planning and analysis of time studies on forest technology. Bullentin 17. The Forest Operations Institute of Sweden).

(Eliasson & Picchi 2010), and a forwarder mounted 805STC produced 19.5 odt with a fuel consumption of 2.6 liter per odt (Eliasson et al. 2011). However, for the latter machine performance and fuel consumption was heavily dependent on knife wear, and the performance sank from 22.8 odt to 13.7 odt per efficient chipping hour when the knives went from new to worn out. A similarly sized Jenz HEM561 produced 17.8 odt per hour of efficient chipping work with a fuel consumption of 2.4 liter per odt (Eliasson et al. 2011). It is important to note that the Bruks machines and to a lesser degree the Jenz produced coarser chips then the Pezzolato chipper in the present study as Swedish CHP-plants wants a P45 fuel. If the studied machine had had a somewhat longer cut length both chip characteristics, chipper performance and fuel consumption likely should have been even closer to the previously studied machines.
5. General evaluation

The studied chipper performed well. Productivity was high, despite the relatively small chip size, which is known to detract from productive potential. In fact, the chipper was designed for the production of small-size chips to be used in residential small-scale boilers. In Central and Southern Europe, these boilers represent a major market, offering premium prices. However, these chips are considered too fine for the Swedish market, and therefore any machine of this type eventually purchased in Scandinavia should be equipped with the separate large-chip drum, offered by Pezzolato as an option (Spinelli & Magagnotti 2013).

The moisture content gauge is an interesting addition to the machine which will be valuable when the machine computer can present average moisture content for the volume of chips produced. An interesting option would be if it also could present average moisture content for the last minute or for a few minutes. This will enable the contractor to add value to the product by delivering chips within the right moisture content range to the customer or end the chipping if the material needs to dry more. The moisture content meter will work well for contractors in southern and central Europe and will be accurate as long as it is used with a correct calibration curve (cf. Volpe 2011, Fridh 2012). In northern Europe where a lot of chipping is done in the cold winter months the use will be limited as the drawback with the capacitance technology chosen for the gauge is that it will not work on frozen material (Volpe 2011, Fridh 2012). In fact the manufacturer of the gauge states that material below 0°C cause faulty measurements (Schaller 2011).

6. Demo results

In total two (2!) people showed up at the demo despite all the efforts to advertise the event. However, as the machine was demonstrated at the Elmia Wood exhibition the week before, where it was 54 215 visitors, many of the persons interested in a chipper technology probably already had seen those demonstrations.

There is a possibility that the demo will result in an article in one of the larger agriculture/forestry business magazines.

7. Acknowledgements

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8. References


6.9.2013

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