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Research paper

An agile chipper truck for space-constrained operations

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A B S T R A C T

A new chipper-truck was developed for extending the benefits of industrial chipping to space-constrained landings, normally inaccessible to industrial operations. The new machine was taken for a European test tour, so that it could be tested under conditions considered typical of Mediterranean, Alpine, Central and Nordic Europe. The same machine and operator were used for all tests, which lasted 65 h and produced over 100 chip containers. Productivity varied between 13 and 19 tonnes of green chips per scheduled hour, inclusive of all delays. Fuel consumption ranged from 1.8 to 2.8 dm^3 of diesel per tonne of green chips. Machine utilization ranged from 68 to 89%, and it was highest in the Nordic trials, due to the use of pre-parked containers, which dramatically reduced the occurrence of interaction delays. Regional differences were only related to operational layout and organization, which set the Nordic trial apart from all others. Knife wear and screen size had a major impact on chipper performance. The same accounted for cut length. Production of small chips is only justified when the market offers premium prices for this assortment.

1. Introduction

The increased global competition for finite fossil fuels and the need to mitigate climate change have generated a strong universal interest and demand for renewable fuels [1]. In Europe, forests are still the main source of wood fibre and are largely underutilized [2]. In general, forest biomass operations are hampered by the limited access and availability of forest road infrastructure, which is reduced to the essential, given the wide dilution of the forest resource [3]. Insufficient landing space poses specific constraints to biomass recovery operations, which are based on roadside chipping. That requires enough space to accommodate a chipper and the chip vans necessary to collect the product and move it to the end user. Both chipping and transportation efficiency are maximized when using large industrial units, but these equipment are difficult to maneuver in narrow landings, commonly available at most forest sites. Transitioning to small-scale machinery may solve the limited space problem, but may result in a high production cost, limiting the financial sustainability of biomass recovery. One solution is to upgrade the forest road network and build suitable landing sites. However, this is a long-term investment that requires a large capital outlay. Besides, road-building is a complex and delicate business that must be carefully planned and executed, in order to contain cost and prevent hydrological problems. The alternative is developing advanced industrial equipment that is both maneuverable enough to negotiate narrow roads, and powerful enough to operate at high levels of productivity.

The goal of this study was to determine the performance of a new industrial chipper, specifically designed for negotiating poorly accessible sites. In particular, the study aimed at determining chipper productivity, fuel efficiency, utilization, mechanical availability and product quality under a wide range of conditions. For this reason, the geographic scope of the study was fully European, and the machine was tested in some of the main forest regions of Europe, including: Mediterranean, Alpine, Central and Nordic.

2. Materials

The new chipper analysed in this study was a Pezzolato Hacker-

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truck PTH 1200/820 (www.pezzolato.it). This machine is a new generation chipper-truck, where the two-bladed drum chipper is powered by the truck's engine through a dedicated power take-off. Total engine power is 400 kW, which fully qualifies this machine for industrial use [4]. At the same time, the truck base is a three-axle compact unit with a turning radius of 7 m, specifically designed for negotiating narrow, steep roads (Fig. 1). To this purpose, the truck width has been reduced from 2.5 to 2.3 m, and traction power is delivered by all three axles (6 × 6). Total machine length, height and weight are 7.9 m, 3.9 m and 26 t, respectively. Purchase price is 480,000 €. This machine can bring industrial chipping as close as possible to the forest, preventing costly hauling of loose residues to a terminal or a large landing [5]. At the same time, the machine is capable of independent relocation between work sites, which is a valuable quality where tract size is small. Maneuverability in narrow landings is maximized by the capacity for discharging chips on all three available sides. These are the rear, front and left side, while the right side is unavailable for truck approach, because it is occupied by the in-feed opening and must face the wood stack. Therefore, the new chipper offers several possibilities for the docking of receiving chip vans, which allows adapting to the small available space.

The study consisted of field trials conducted at four geographic locations, considered as representative of the main forest conditions of Europe. From south to north, these were located in Central Italy, Northern Italy, Germany and Sweden (Fig. 2). The attributes of terrain, landing characteristics and feedstock types were considered representative of these different regions (Table 1). Similarly, supply chain logistics and product specifications varied between regions, which may have impacted the results of individual trials. Each field trial lasted from two days to one week, and resulted in the production of at least 12 chip containers, with a volume between 30 and 40 m^3 per container. In order to satisfy local quality specifications, the chipper was used with different cut length and screen size settings at different sites, so that each test represents the unique combination of site conditions, feedstock type and machine setting, considered representative of that specific region.

All tests were conducted between late September 2012 and early June 2103. The study time amounted to 65 h, including delays and local transfers, but excluding the transfers from one region to the other. During this time, the chipper produced 105 containers, amounting to 3100 m^3 loose chips or 880 tonnes of fresh chips (mean bulk density 284 kg m^{-3}). The machine was operated by the same driver, a well-trained, experienced and efficient professional who was very proficient with his job and equipment. He had about 2 years of experience with a similar chipper-truck built by the same manufacturer, and had operated the test machine since this was commissioned in August 2012.

3. Methods

The authors carried out a typical time-motion study, designed to evaluate machine productivity and to identify those variables that are most likely to affect it [6]. Each work cycle was timed individually, using hand-held field computers, running dedicated time study software. Productive time was separated from delay time [7], and the filling of a chip container was considered as a cycle. All delays were included in the study, and not just the delays below a set duration threshold, because such practice may misrepresent the incidence of downtime, especially on comparatively long observation periods [8]. However, delays generated by the study itself were separated and removed from the data set.

Total volume output was estimated by measuring the internal volume of all containers and visually assessing the volume of any mounds or voids on the container top. Total mass output was determined by taking all loads to a certified weighbridge, or to portable truck scales when a weighbridge was not available. Two 500 g samples were collected from each replication (container load) in order to determine moisture mass fraction 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 mass fraction was determined with the gravimetric method, according to European standard CEN/TS 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 sample into five chip length classes: > 63 mm (oversize particles), 63–46 mm (large-size

Fig. 1. The chipper-truck at work in a roadside operation (Central Europe).