Improvement of wood chips quality by means of a Fontana mechanical sieve

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Abstract: *The study analyzed the performance of a mobile screening device for upgrading coarse wood chips to residential user standards, by removing oversize particles and fines. The machine was mounted on an agricultural trailer-chassis and equipped with a diesel electricity generator for operating in delocalized yards. Average productivity was 1.9 oven-dry tons (odt) hour^{-1}, corresponding to a screening cost of 28.5 € odt^{-1}. This figure was lower than the price increase obtained by upgrading industrial chips to residential user standards. Hence, screening offered a profit of 4.7 € odt^{-1}, or 16% of the original screening cost. The screening process reduced the incidence of oversize particles below the 1% critical threshold and substantially reduced the content of fin, upgrading chips from industrial to residential specifications.*

Keywords: wood chips, screening, quality, cost, class size distribution

1 Introduction

The quality of wood chips used for energy generation is defined by such parameters as moisture content, ash content, and particle-size distribution (Asikainen and Pulkkinen 1998). Particularly, particle size distribution is crucial to fuel handling efficiency (Jensen et al. 2004). This is especially critical with small-size plants, whose conveying ducts are relatively small and can be blocked by oversize particles (Strehler 2000). For this reason, small-size plants represent a specific market sector: compared to industrial plants, they impose tighter specifications on fuel quality and offer a better price (Spinelli and Magagnotti 2010). The incidence of both fine and oversize particles depends on a number of different factors, and especially tree part and species (Spinelli et al. 2011), chipper type (Spinelli et al. 2005), comminution device (Matsson and Kofman 2003), chipping tool wear (Nati et al. 2010) and setting (Abdallah et al. 2011). Hence, obtaining a given particle size distribution requires the concurrent manipulation of a number of different parameters, which is often impossible or impractical to achieve. The goal of this paper is to analyse the performance of a mechanical screening device specifically designed for removing oversize particles from fuel chips. In particular, our experiment aimed to determine: a) the productivity and the cost of the mechanical screening device and b) its actual capacity to remove oversize particles and obtain a high-quality chip, suitable for the feeding of small-size domestic and residential boilers.

2 Materials and methods

The authors tested a mobile chip screening device, designed for transportation to forest landings, logistic terminals and plant chip yards. Screening is obtained by pouring the chips on a vibrating bench, consisting of four corrugated steel panes, tiled upon each other. Oversize particles make it all the way to the end of the bench, whereas commercial chips fall in the space between the tiled panes. The distance between the panes can be adjusted between 2 and 7 cm, and in the specific study was set to 3, 2.5, 4 and 2.5 cm. Three belt conveyors respectively feed unsorted chips to the bench, take commercial chips to their pile and move oversize particles to the reject bin. Motion is obtained with five electric motors, powered by a 5 kW diesel generator installed in the chassis of a two-axle trailer which allows transportation to delocalized work sites. The machine is produced in Italy by Fontana Srl. (www.fontanasrl.com) and comes in two models – 100 and 170 – which refer to the width of the vibrating panes, in cm. The machine used for the test was a 170 C model, weighing 4400 kg, including the trailer. This unit was coupled to a 70 kW farm tractor, equipped with a front-end loader. The tractor was used for relocating and feeding the screening machine, so that the trailer-mounted screening device, the tractor and its driver represented a fully independent small scale chip screening operation.

Productivity was estimated with a time-motion study, conducted during commercial operations. The study consisted of three replications, each consisting of a full farm trailer load, weighing about 4 metric tonnes. All loads were weighed before and after screening, by taking the loaded trucks to a certified weighbridge. Chips came from the harvesting of short-rotation forestry (SRF) poplar, comminuted with a truck-mounted drum chipper. Each screening cycle was stop watched individually, using Husky Hunter hand-held field computers running the dedicated Siwork3 time study software. Productive time and delay time were recorded separately (Björheden et al. 1995). Moisture content was determined according to the European standard CEN/TS 14774-2, on three 500-g samples per load. Machine hourly costs were estimated with the method described by Miyata (1980), on the assumptions shown in table 1. Labour cost was set to 16 € h^{-1}, inclusive of indirect salary costs. The costs of fuel, insurance repair and service were obtained directly from the operators. The calculated operational cost was increased by 20% in order to include administration costs (Hartsough 2003).

The removal efficiency over oversize particles from the chips was estimated in a separate experiment, conducted with smaller batches. This way one could alternate individual batches from three different chip types in a random pattern. Each batch was represented by a single bucket-load, collected with a front-end loader. The weight of the individual batch varied between 100 and 200 kg. Two chip types were sampled, and namely: SRF poplar, comminuted with a drum chipper and with a disc chipper, both with a moisture content of 58%. The test was based on 10 replications per treatment. Three 500-g samples were collected after each replication, respectively from the chips before screening, the chips after screening, and the rejects. After air natural drying, each sample was analysed for particle size distribution, according to European Standard CEN/TS 15149-1:2006, using a certified automatic screening device. The following chip length classes were separated: > 100 mm, 100-63 mm, 63-45 mm, 45-16 mm, 16-3 mm, < 3 mm. Each fraction was then weighed with a precision scale

Table 1: Costing assumptions and machine cost

Operation		Screen	Tractor
Purchase price	Euro	32000	50000
Service life	years	8	8
Salvage value	% of new	20	20
Interest rate	%	4	4
Fuel consumption	litres SMH^{-1}	2	4
Crew	n	0	1
Depreciation	Euro $year^{-1}$	3200	5000
Annual usage	SMH	1000	1000
Total fixed cost	Euro SMH^{-1}	4.9	7.6
Repair and maintenance	Euro SMH^{-1}	3.2	2.5
Personnel cost	Euro SMH^{-1}	0.0	16.0
Total variable cost	Euro SMH^{-1}	5.9	26.3
Overhead (20%)	Euro SMH^{-1}	2.2	6.8
Total	Euro SMH^{-1}	**12.9**	**40.7**

Notes: SMH = Scheduled Machine Hours

3 Results

The sieving gross productivity resulted to be 1.9 odt per scheduled machine hour (SMH). This figure includes all delays, amounting to 25% of total scheduled time. Screening cost is 28.5 € odt^{-1}. This figure is calculated on the amount of accepted chips, and excludes chips failing to meet size specifications, which were discharged in the reject bin: these amount to about 2% of the total and are going to be returned to the industrial fuel stream.

Regarding wood chips quality, before screening the chips produced with the drum chipper present the best particle size distribution, with the highest incidence of accepts and the lowest proportion of fines. Both products (drum and disc produced chips) fail to meet the P45 standards for small size boilers (as specified by the European Standard CEN TS 14961), due to their high content of oversize particles, which exceeds 1%. Screening seems to improve particle size distribution by increasing the proportion of accepts and decreasing that of fines and oversize particles (Table 2). However, this effect is statistically significant only for the accept and fine content of the product obtained from the disk chipper and the shredder. After screening, the particle size distribution of chips obtained from the drum chipper is altered, but differences are not significant in statistical terms. The same is true for the proportion of oversize particles in all product groups: this appears to be reduced by half after screening, but such reduction lacks statistical significance.

Table 2 – Particle size distribution in the two fuel types, before and after screening

Chipper	Process	Oversize	Accepts	Fines
Drum	Before	1.3[a]	96.1[a]	2.7[a]
	After	0.6[a]	97.4[a]	2.0[a]
Disk	Before	1.3[a]	92.1[b]	6.4[b]
	After	0.6[a]	96.6[c]	2.8[ac]

4 Discussion

The productivity study shows that the cost of screening is lower than the price increase obtained through it. In fact, screening may offer a profit of 4.7 € odt^{-1}, or 16% of the original screening cost. However, this result is based on a short-term study, and should be taken with caution. Short-term studies may misrepresent the effect of delay time on productivity and cost.

Screening does improve particle size distribution, reducing the incidence of both fines and oversize particles. However, the effect on oversize particles is not statistically significant. The most likely explanation lays in the fact that the proportion of oversize particles is generally a very small one, and is represented by a relatively small number of fragments in each given samples. Hence the very large variability in the proportion of oversize particles, which makes differences difficult to prove statistically with the limited number of samples collected in our study. Further variability is introduced by the relative inaccuracy of the standard method based on the use of horizontal screening devices (Hartmann et al. 2006). Nevertheless, the study does hint at a substantial reduction of oversize particles after screening.

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