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Research paper

Loader performance during woodchip loading

Marco Manzone

University of Turin, L.go Braccini, 2, 10095 Grugliasco, Torino, Italy

A R T I C L E I N F O

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A B S T R A C T

Woodchip is preferred to other biomass forms because it offers benefits in terms of load density and uniform sizes. Until now, many studies have been focused on woodchip: comminution wood productivity, the environmental impact of chipping operations, woodchip transportation, woodchip storage techniques, but few have been done on woodchip loading. The goal of this work was to evaluate the working time, productivity and work quality for four types pf loader used in woodchip loading. Front loaders and knuckle-boom loader were tested. The highest productivity was observed for a mechanical shovel equipped with a high dump bucket (303 m^3 h-1) when handling woodchips to be stored in piles near a wall, while the lowest working rate was achieved by a wheeled loader with a clamshell bucket (176 m^3 h-1) in the same work conditions. Frontal loaders storing woodchip in a pile near a wall showed a 12% increase in productivity. Independently of the pile position, the agricultural telescopic loader showed good performance (about 240 m^3 h-1). All loaders achieved a good work quality, with the amount of ground losses always lower than 2 m^3 (2% of load). From this study it is found that agricultural telescopic loaders equipped with a hinged bucket are the right machine for woodchip loading.

1. Introduction

Biomass is the main renewable source used for thermal and electrical energy production [1]. Among all biomass types, wood biomass seems to offer the greatest prospect as a substitute for fossil fuels because it has many advantages in terms of supply and use [2]. In particular, woodchip is preferred to other forms of biomass because it offers benefits in terms of load density and uniform size [3].

Woodchip can be produced by the comminution of biomass harvested in dedicated plantations [4] or in forests [5]. While the woodchip produced by forestry residues may be discouraged because it can cause the loss of several nutrients in the soil [6,7], woodchip obtained from dedicated plantations is encouraged in many countries [8]. Moreover, the comminution of forest wood is not always easy due to soil and weather conditions, [9].

Wood comminution can be performed simultaneously with the biomass harvesting [10] or some months after tree cutting [11]. The machines used in chipping operations can be divided into two different groups on the basis of their comminution devices, i.e., discs and drums. Drum chippers are more productive in comparison to disc chippers, but are less energy-efficient [12]. Chippers are mobile or stationary as a function of their frame type. Mobile chippers are mainly used in fields or forests, while stationary chippers are assembled directly at the power station [13].

Until now, many studies have focused on woodchip: comminution wood productivity [14], the environmental impact of chipping operation [15], woodchip transportation [16], or woodchip storage techniques [17], but few have investigated woodchip loading [18]. The woodchip loading operation is very important because a less than optimal performance of this operation can cause unproductive time during vehicle loading and transport [16].

On the basis of this latter consideration, the goal of this work was to compare the working time, productivity and work quality of four types of loader used in woodchip loading.

2. Materials and methods

Woodchip loading trials were performed in Piemonte region in the northwest of Italy. Front loaders and knuckle-boom loader were tested. Specifically, four different loaders used in woodchip loading were analysed: 1) a mechanical shovel with a standard bucket, 2) a mechanical shovel equipped with a high dump bucket (Fig. 1a), 3) a wheeled loader with a clamshell bucket, and 4) an agricultural telescopic loader equipped with a hinged bucket (Fig. 1b) (Table 1).

Trials were carried out using semi-dried poplar woodchip (moisture content of 42%) produced by a drum chipper (Pezzolato

E-mail address: marco.manzone@unito.it.

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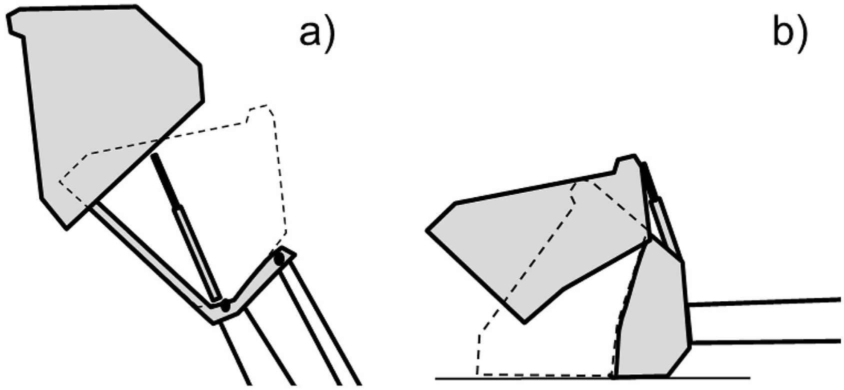

Fig. 1. Scheme of buckets used in the trials: a) high dump bucket, and b) hinged bucket.

Table 1
Technical characteristics of loaders used in the trials.

Loader	Manufacturer	Power (kW)	Max. dumper height (m)	Mass (kg)	Bucket cap. (m^3)	Price (€)
1	Newholland W170b	146	3.8	14527	2.7	175000
2	Newholland W170b	146	4.5	14650	5.0	175000
3	Euromec EH200	125	6.5	13950	1.6	120000
4	Merlo P 32.6 Plus	75	6.5	6820	4.0	72000

PTH 1000). The moisture content of the woodchip was determined using a gravimetric method [19]. All loaders were tested during the loading of a truck equipped with a "large volume" container (100 m^3) [16]. Each test was performed with an amount of 100 m^3 (the same volume as the truck body) of wood chips piled on a concrete surface. In order to evaluate the loaders' performance in different working conditions, trials were carried out by placing the pile in the middle of the yard and near a wall. All the machinery tested was driven by the same driver with working experience of more than 100 h for each machine type. Also if one operator is not representative of the general pool of operators, that choice was performed in order to reduce eventual driving difference of more operators. In all tests the truck was parked near the pile, always in the same position, and the woodchip was placed in a conical pile with a basal diameter of about 9 m.

In this study, working times were recorded at the cycle level [20], where a full truck load was considered as a cycle. Working times were split into different time elements, following the classification proposed by Biojerdan et al. (1995) [21] for the forestry sector. A centesimal digital stopwatch (Hanhart® PROFIL 5) was used to record the different working time elements.

Productivity was calculated with an analytic method considering the amount of woodchip handled in the unit time. The working rate of loading operations was expressed in terms of density (m^3 h^{-1}).

In the present study, the work quality of all the loaders tested was determined by evaluating the amount of the woodchip left on the ground (ground losses) after concluding the loading operation. That amount was estimated by hand-sweeping the square and successively introducing wood chips in a box of a cubic meter capacity.

Each treatment was replicated three times, for a total of 24 tests (Table 2).

Data were processed using Microsoft Excel Software and SSPS 22 (2015) advanced statistics software. The statistical significance of the eventual differences between tests was checked by performing the Tukey post-hoc test [22] and adopting a significance level of $\alpha = 0.05$. The Tukey test was chosen because with this data distribution it showed a high power [23].

Table 2
Experimental design adopted in the study (total of 39 replications).

Pile position	Loader	Test (n°)
In the middle of the yard	1	3
	2	3
	3	3
	4	3
Near a wall	1	3
	2	3
	3	3
	4	3

3. Results

In the trials, the time necessary for the truck (100 m^3 capacity) to move the woodchip ranged between 19.8 and 34.1 min with respect to the loader considered. A data variation from 6.2 to 8.2 was observed between the replications. No significant difference was observed between the two pile positions (Table 3).

During the test, all the machines achieved a good utilization level: the resulting productive working time (net loading time and complementary work time) was ≥95%. Consequently, unproductive

Table 3
Time consumption recorded during the truck loading (100 m^3 capacity).

	Loader	Mean	Min	Max	SD	CV
In the middle of the yard	1	35.4a	33.2	37.6	2.20	6.2
	2	22.8c	21.2	24.6	1.72	7.5
	3	33.3a	30.6	35.6	2.52	7.6
	4	26.7b	24.6	28.9	2.15	8.1
Near to wall	1	31.6a	29.8	33.8	2.03	6.4
	2	19.8c	18.4	21.2	1.40	7.1
	3	34.1a	31.6	36.6	2.50	7.3
	4	23.8b	21.6	25.3	1.95	8.2

Note: SD = standard deviation; CV = Coefficient of variation (%). Different letters indicate significant differences between treatments for $\alpha = 0.05$.