Available online at www.sciencedirect.com

SciVerse ScienceDirect

http://www.elsevier.com/locate/biombioe

Wood chipping performance of a modified forager

Marco Manzone [a,1], Raffaele Spinelli [b,*]

[a] Università degli Studi di Torino, DEIAFA sez. Meccanica, Via Leonardo da Vinci 44, Grugliasco (TO), Italy
[b] CNR IVALSA, Via Madonna del Piano 10, Sesto Fiorentino (FI), Italy

ARTICLE INFO

Article history:
Received 19 April 2012
Received in revised form
23 December 2012
Accepted 11 January 2013
Available online 25 April 2013

Keywords:
Agroforestry
Biomass
Harvesting
Forestry
Energy

ABSTRACT

The authors tested a 409 kW forager turned into an industrial chipper through a special conversion kit. Conversion was temporary, and the forager could be returned to its original occupation with one day of work. The converted forager proved as effective as a dedicated chipper of the same power. Net chipping productivity varied between 25 and 33 green t h^{-1}. Productivity was highest with poplar tops and lowest with pine tops. Fuel consumption ranged from 1.6 to 1.8 l green t^{-1}. Fuel consumption did not change with tree species, but increased significantly with knife wear. Temporary conversion allowed a better depreciation of the invested capital and resulted in a 25% reduction of unit chipping cost. The converted forager proved an ideal solution wherever the production of wood chips was a complementary business within the scope of a larger agricultural economy. In technical terms, this machine offered the combined advantages of road-capability and good off-road mobility, allowing low-cost independent relocation and effective in-field chipping.

1. Introduction

The global drive to renewable energy has generated a strong interest for the increased use of wood biomass, which many governments support through subsidies, tax-exemptions and other incentives [1]. Chipping is an essential element of all modern energy wood chains, because automated boilers only accept homogeneous fuel particles within specified size limits. Besides, chipping offers additional benefits in terms of increased load density and improved handling quality [2]. For this reason, bulky raw materials should be chipped as early as possible, in order to accrue such important benefits all along the supply chain [3]. That explains the widespread popularity of mobile chippers, which allow size reduction directly in the forest or at the roadside landing, before transportation [4]. Like many other industrial activities, chipping benefits from economies of scale, with larger chippers being more efficient than smaller chippers [5]. On the other hand, large mobile chippers are very expensive to buy and must be depreciated on a proportionally large work volume, which is difficult to achieve where tract size is small [6]. Part-time chipping operators can resort to smaller chipper models designed for application to a farm tractor, thus maintaining a certain degree of operational flexibility. These machines may partly match the performance of large industrial chippers only if applied to the most powerful tractors on the market. However, these tractors are specialized machines themselves, characterized by high investment costs and limited operational flexibility. An alternative solution consists of fitting the chipper to a forage harvester. This machine is powerful, largely available and generally underutilized, being designed for a seasonal job. Temporary use as a wood chipper may allow extending the annual usage of the forager, thus solving two problems at once. This is one of the reasons for the

* *Corresponding author*. Tel.: +39 (0)55 5225641; fax: +39 (0)55 5225643.
E-mail addresses: marco.manzone@unito.it (M. Manzone), spinelli@ivalsa.cnr.it (R. Spinelli).
[1] Tel.: +39 (0)11 6708608; fax: +39 (0)11 2368608.
0961-9534/$ – see front matter
http://dx.doi.org/10.1016/j.biombioe.2013.01.006

widespread success of modified foragers for harvesting short rotation wood crops [7]. In this instance, the main modifications concern the pick-up header, while the original chopper is retained and used for wood chipping [8]. That limits the maximum size of the trees that can be chipped with a modified forager [9]. Increasing the wood chipping capacity of a modified forager requires the replacement of the chopper with a dedicated wood chipping device. Such modification must be temporary and allow the extended use of the forager as a prime mover. Forager-base wood chippers may represent an ideal solution to the wood processing needs of afforested farmland, whose total surface is rapidly growing worldwide [10]. Both disc and drum chippers have been fitted to foragers, and with good results [11]. However, no studies offer reliable information on the performance of these machines. The goal of this study was to determine the productivity, fuel consumption, processing cost and product quality obtained with a forager-base wood chipper, under the typical conditions of farm forestry. The study also tested the effect of tree species and blade wear on machine performance, providing useful information for work planning and chipper maintenance.

2. Materials

The machine chosen for the test was a 409 kW John Deere 7700 forage harvester (Fig. 1). This machine was modified for heavy duty wood chipping by replacing the original header and chopper with a dedicated wood chipping conversion kit. This was a commercial product, designed by Pezzolato SpA (www.pezzolato.it) for installation to any John Deere forager. Conversion was temporary and was performed by two mechanics in about 8 h. The kit consisted of a robust frame, supporting a drum chipper, an infeed table and a knuckle-boom loader (Table 1). The frame was fitted with two folding outriggers, to increase stability when working with a fully extended loader. The live infeed table could tilt downwards to reduce the strain on the upper infeed roller when engaging long stems. Chips were moved to the original blower of the forager, and discharged through its outlet pipe. A sizing screen could be placed between the drum and the chip evacuation device, so that chips longer than the target length were retained within the drum chamber until they were re-cut to target size. Different mesh sizes were available. The screen used during the test was an 80 mm vertical bar type, designed for producing coarse chips.

Fig. 1 – The modified forager used for the test.

Table 1 – Technical characteristics of forager, chipper and loader.

Forager		
Make		John Deere
Model		7700
Power	kW	409
Mass	kg	12560
Chipper		
Make		Pezzolato SpA
Model		Conversion
Type		Drum
Mass	kg	1450
Diameter	mm	820
Width	mm	900
Knives	n°	2
Infeed		Live table
Knuckle-boom loader		
Make		Kronos
Model		6020
Outreach	mm	8000
Lift	kgm	1100

Note: the total weight of the chipper conversion kit is 7800 kg, all included.

The machine was tested with three feedstock types, and namely: logging residues from conventional poplar (*Populus* × *euroamericana*) plantations, logging residues from Weymouth pine (*Pinus strobus* L.) plantations and whole stems from black locust (*Robinia pseudoacacia* L.) short-rotation coppice plantations. The average butt diameter of the individual pieces was 220, 250 and 140 mm, respectively. Maximum diameters were in turn 270, 310 and 160 mm. All wood was freshly felled, with a moisture content of 55% for the poplar, 50% for the pine and 48% for the locust. Hybrid poplar, Weymouth pine and black locust are the main species used for the afforestation of North Italian farmland, and can be considered representative of the feedstock handled by forager-base wood chippers. All this material was made available in large piles built at the field edge. The chipper stationed by the piles and used its loader to move the wood into the infeed device. Chips were blown into three-axle silage trailers with a capacity of 40 m^3. Trailers were towed by farm tractors, so that the whole operation was based exclusively on farming equipment.

3. Methods

The sampling unit consisted of a full silage trailer. The experimental design aimed at testing the effect of species (three levels) and knife wear (two levels, i.e. new and worn). Blades were considered worn after they had processed about 100 tonnes of wood. Each treatment combination was replicated 3 times, for a total of 18 repetitions. The machine was studied while carrying out its scheduled commercial activity, and therefore it was impossible to randomize the experimental design. In contrast, observations were blocked for species and blade wear status: hence, the first three repetitions were conducted on the poplar field with new blades, and the following three on the same field after the blades had