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Research paper

Effect of anvil position on cutting force and energy measurements of a disc chipper

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ABSTRACT

Using renewable energy as wood chip or improving wood chip heating process are different usual ways to reduce carbon dioxide emission. The more uncharted path to reduce it is to limit energy consumed to produce wood-based fuel as wood chips or pellets. Wood chipping is the first step of each wood fuel production process. Chipping wood knowledge is also important for improving wood chipper efficiency. This paper compares two methods for determining cutting energy of a disc chipper and evaluates influence of anvil position on chipper efficiency.

Cutting force is measured by the anvil bending during chipping and disc chipper energy supply is calculated by multiply the torque applied by the Power Take Off (PTO) to the shaft of the chipper by the shaft speed. In our study, a large set of chipping conditions are tested on a disc chipper with different species, log diameters, infeed volume rates and anvil vertical position.

Cutting force measured from anvil's strain represents one impact for each half disc turn because the disc has two knives, whereas chipper energy supply is similar to a sinus curve. Cutting force depends of wood specie, diameter, infeed volume rates and anvil vertical position. Higher the wood infeed volume rate and diameter are, higher the cutting forces are. A disc chipper efficiency is estimated as the ratio of the cutting energy and the chipper energy supply.

1. Introduction

The use of wood biomass becomes an important renewable energy to achieve the environmental European Union target of the year 2020. In France, wood biomass is almost the whole of the renewable energies which are burn in wood boiler [1]. Wood chipping is also crucial in the wood biomass supply because automatic boilers request homogeneous and sieving chips [2,3]. Moreover, comminution allows a better loading and handling of wood residues [4]. Disc and drum forestry chippers are either powered by an independent engine near to the chipper (electric or gasoline) or by tractor's PTO. Choosing an independent engine depends of the needs [5].

Even if disc and drum chippers have been known for a long time, chipper performance is still difficult to evaluate during chipping. Few researches are focused on cutting power measurement due to the dynamic behavior of the system.

In 1987, Stockes et al. [6] evaluated chipping efficiency with a gasoline engine. The study focused on the power of disc chippers by measuring the fuel pressure and engine speed used for chipping different species of wood. The chipper energy consumption is a function of the number of logs and their diameters fed simultaneously into the chipper. More recently, Abdallah et al. [7] shows that electrical power consumed by the chipper engine varies as a linear function of the cutting power. Even if engine power consumption helps to evaluate power requirement for chipper, this method depends of chipper efficiency.

In order to measure cutting forces, Abdallah et al. [7] built up an indirect measurement system. It is constituted by the anvil of the chipper and two surface strain sensors, screwed on the middle of the under face of the anvil. However, the cutting force measured is only the vertical force Fz (Fig. 1) and only disc chipper is investigated.

Hellström et al. [8] has instrumented the chipper knife holder by four dynamometers. It could be faired that introduction of the dynamometers modifies the dynamic behaviour of disk-knife holder - knife system, having a big effect on chipping process.

The last way to evaluate chipper performance is to multiply

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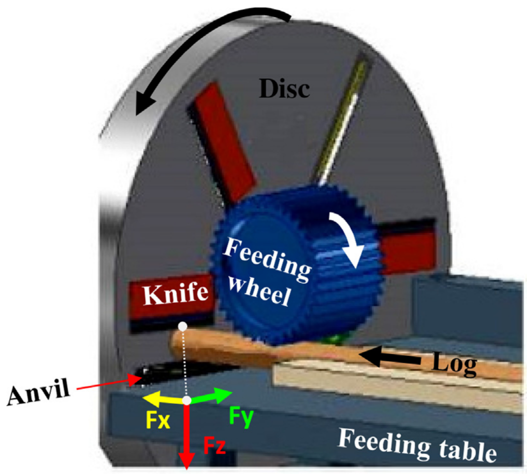

Fig. 1. Chipper cutting elements and cutting force components Fx, Fy and Fz.

PTO's torque by rotational speed of the chipper shaft. Spinelli et al. [9] measure the energy supply of disc and drum chipper and shows that drum chipper requires more power than disc chipper. More recently, Spinelli et al. [10] concludes that a drum chipper as a worst energy efficiency than grinder. Assirelli et al. [11] note that stem requires more power than top by measuring energy consumption to chip them. Kovac et al. [12] measure that chipping energy consumption is near proportional to wood section regardless of wood species.

In this study, influence of vertical gap between the anvil and the infeed table is evaluated by measuring chipper energy supply and cutting energy for two species of wood: beech and spruce.

2. Materials and methods

2.1. Wood and chipper characteristics

Wood and chipper characteristics are gathered in Table 1:

Table 1
Wood and chipper characteristics.

Wood characteristics		Chipper characteristics	
Species	Beech and spruce	Chipper type	Disc
Diameter	70 and 100 mm	Number of knives	2
Moisture content	30–50%	Rotated speed	1050 rpm
		Infeed speed	Up to 30 m/min
		Maxi wood diameter	160 mm

The disc chipper is driven in rotation by a 45 kW electric motor. A low and a high infeed volume rate per tooth respectively of 46 and 92 cm^3/tooth are calculated by multiplying feed per tooth by wood section. The infeed volume rate replaces the usual feed per tooth parameter because a combined infeed speed/diameter of log control scheme is tested. Wood logs are harvested in local forests of France. Two logs per test are chipped.

2.2. Vertical gap between the anvil and the infeed table

Effect of vertical gap between the anvil and the log is studied in 90°–90° wood cutting mode. Three different vertical gaps (Fig. 2) are studied in this paper.

An in-feed table is developed to choose and keep the fed direction of the log during chipping. Two wedges are manufactured to reduce the gap between the anvil and the log. The three anvils are instrumented to determine the cutting force during chipping. For each vertical position of the anvil, the influence of infeed volume, species and diameter of wood are tested on chipper energy consumption.

2.3. Chipper energy efficiency

Chipper energy efficiency is evaluated by measuring both cutting force normal to the anvil and chipper energy supply as show sensors location on Fig. 3.

Data acquisition system records simultaneously rotational speed of the disc and torque applied to the Universal Join Shaft (UJS) that rotary drive the disc chipper shaft. The strain of the anvil due to chipping forces is also measured with a sampling frequency of 10 kHz. This sampling frequency is choose in the aim of recording more than 20 values during one cut of the knife through one section of the log.

2.3.1. Measurement of cutting forces applied on the anvil

Cutting force is measured using an indirect force measurement system implemented on the chipping test bench improved by Abdallah [7]. It is constituted by the anvil of the chipper and a surface strain sensor (type Kistler-9232A), screwed on the middle of the under face of the anvil. During the chipping process, sensor measures anvil's longitudinal strains caused by the vertical component of the cutting force. Auchet [13] propose to measure a dynamic sensitivity which links vertical component of the cutting force to resulting anvil's longitudinal strains. This dynamic sensitivity function is a complex correction function taking into account

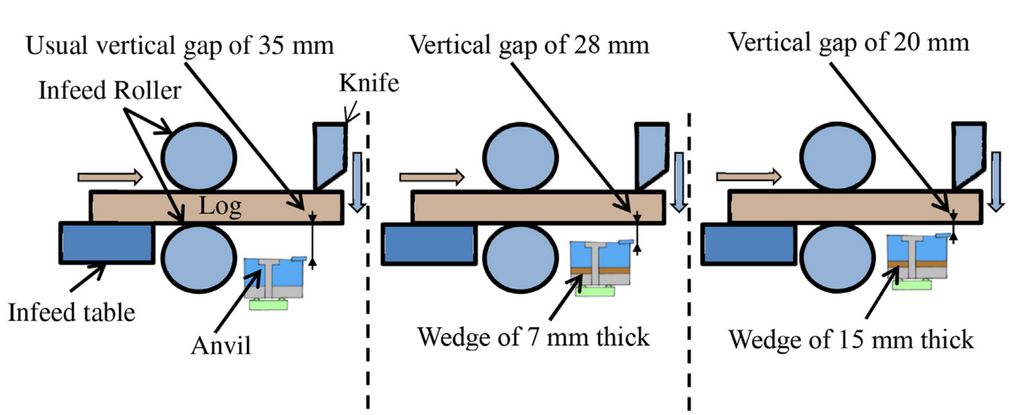

Fig. 2. The three vertical gaps between the anvil and the in-feed table of the chipper studied.