BIOMASS AND BIOENERGY 64 (2014) 269–275

Available online at www.sciencedirect.com

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A dynamic measurement of a disc chipper cutting forces

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ARTICLE INFO

Article history:
Received 12 April 2013
Received in revised form
26 February 2014
Accepted 28 February 2014
Available online 21 March 2014

Keywords:
Cutting forces
Wood
Chipping
Disc
Energy efficiency

ABSTRACT

Nowadays wood chips produced from raw material of inferior quality are mainly used to feed domestic and industrial boilers. For this use, a good chip size distribution and low manufacturing energy consumption are required. Cutting forces are still inaccurately measured during the wood chipping process, which implies the use of oversized chippers' motors. A test bench for chipping wood under reasonably realistic conditions of industrial production is improved by adding an indirect force measurement system with high bandwidth of 3 KHz. The dynamic experimentations give the data needed to compute the curve presenting the vertical component of the cutting force, which is composed of three sections; the first one presents the values of the impact force; the second one is relatively straight and it refers to shear stress in wood; the third section corresponds to the period between two crosscuts.

1. Introduction

The measurement of cutting forces has important and extensive applications in the wood machining operations such as supervising of the tool wear evolution, optimizing the cutting parameters, helping to study chip formation and estimating the chipping cost. Even though the disc chipper was invented in 1889 under the Wigger brand, there is still lack of studies on the cutting forces during the chipping process. As no accurate prediction laws of cutting forces for wood chipping exist, wood chipper motors are oversized, increasing the wood chips production cost.

Abdallah et al. [1] studied the effects of four chipping parameters: feed per tooth, rake angle, sharpness angle and cutting speed, on the distribution of the wood chip size.

In Fig. 1, the traditional cutting angles are represented: the cutting angle which is also called the rake angle (γ), the sharpness angle (β), the clearance angle (α). The sum of these three angles is always 90. Using these angles make it possible to know the angles between the knife faces and the disc. We have added a fourth angle (Fig. 1(2)), which Abdallah et al. [1] have called the real cutting angle (γ_r). It is the angle between the cutting face and the grain direction. This angle has an important effect on both chip formation and cutting forces [2].

Hartler [3] studied the chipping process at high cutting speed (5, 10, 15 and 20 m/s) and proposed an idealized diagram for the vertical reaction force (Fig. 2), which is recorded from the anvil during the chipping process. In this study, the force rises rapidly and reaches a maximum value called "impulsive force" when the knife hits the wooden rod. Then, the force

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http://dx.doi.org/10.1016/j.biombioe.2014.02.033
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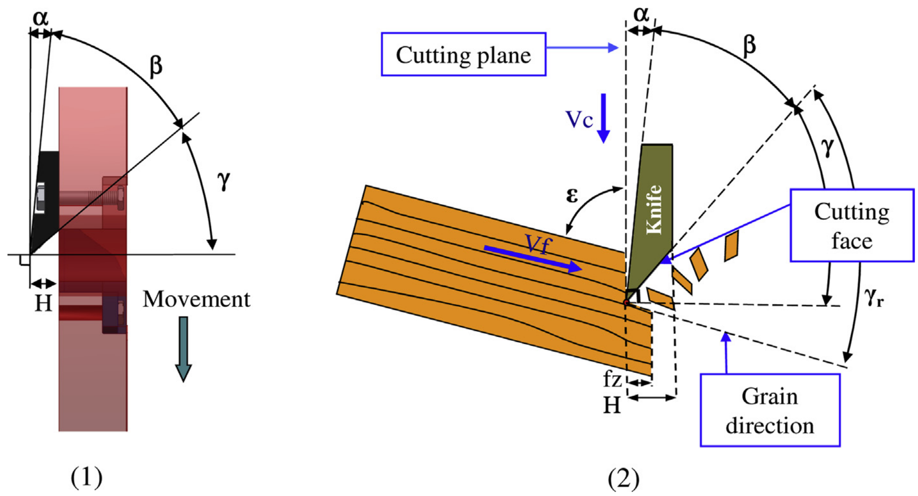

Fig. 1 – Cutting angles.

drops down to a constant value called "chipping force" before becoming zero when the knife leaves the wood.

Hartler concludes that the sharpness angle (β) only affects the impulsive force when the knife hits the sample, and that the impulsive and cutting forces increase when increasing the cutting speed and the dry content of the wood. He also underlines the difficulty of making reliable measurement of cutting forces during high-speed chipping.

The results of Uhmeier [4], who studied the wood chipping at low cutting speed (up to 0.08 m/s), show that the bigger the clearance angle (α) and the chip length, the greater the cutting force's components. Whereas Hellström [5] disagrees with Uhmeier about the influence of the chip length, she didn't find any influence of it on the cutting force for similar cutting speed. But Uhmeier and Hellström [6,7] agree that an increase of the friction between the knife and the wood leads to rise the cutting force. At these cutting speeds, there is only the "chipping force" part and not the impulsive one, which in it the energy consumption is the most important.

Recently, Hellström [8] built up a laboratory wood chipper able to operate under conditions similar to the real ones, the cutting speed can reach 50 m/s. The chipper uses one knife mounted on a holder instrumented by four 3-components dynamometers. Even if a simple two degrees of freedom model is used to take into account inertial effects, the measured cutting force diagram is very different from that obtained in Hartler's study. The dynamic behavior of the system composed of the disc, the knife and its holder could be modified by the use of the dynamometers, which cause a big effect on the chipping process.

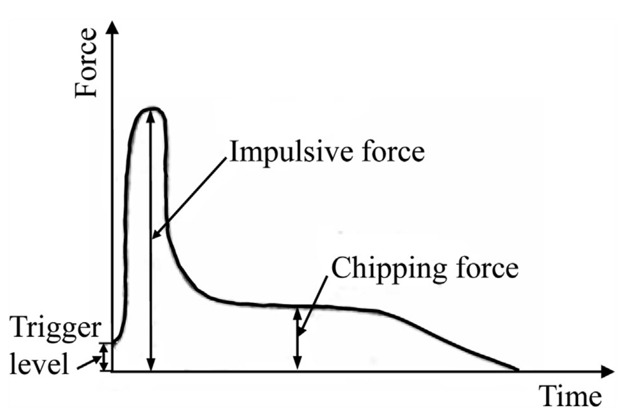

Fig. 2 – Idealized diagram for the vertical chipping force component, proposed by Hartler [3].

To summarize, in spite of the importance of measuring the cutting forces during the wood chipping process, there wasn't yet any reliable measurements of the chipping force. Most of the existing measurements attempts were done under unrealistic chipping conditions with low cutting speed or specific chippers.

2. Materials and methods

2.1. Test bench

Using the chipping test bench of Abdallah et al. [1], the effects of many parameters can be tested under real conditions. This test bench is constituted of two independent units (Fig. 3): a disc chipper and a feeding mechanism.

The disc weighs 182 kg and has a diameter of 950 mm. A variable speed driver allows to modulate the disc's rotation speed from 1 to 1000 rpm corresponding to a variable cutting speed from 0 to 32 m/s at the middle of the knives. It is possible to use either two or four knives. The chipper is powered by 21 kW asynchronous motor. The feeding speed which is controlled by a second variable speed driver and a gearbox can be varied from 0 to 25 m/min.

On this test bench, the vertical component of the cutting force (F_y) is considerably more important than the two others (Fig. 4). Therefore, we decided to measure this component in order to test our cutting force measurement method.

2.2. Measurement of anvil longitudinal strain during chipping

In order to be able to measure the cutting force, we built up an indirect measurement system which consisted of the anvil of