Hardwood Cutting Forces at Different Speeds up to 80 m/s for an Evaluated Real Chip Thickness

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Introduction

Within widespread types of industry connected to the bio-based material's utilization, the mechanical disintegration processes are one of the most important [1]. Nowadays, the European timber and furniture industry are facing higher demands on the efficiency and surface quality of the machining method. In contrast, global environmental changes caused a higher ratio of hardwood species in the forest of middle Europe whereas the corresponding processing technologies are not optimized yet [2].
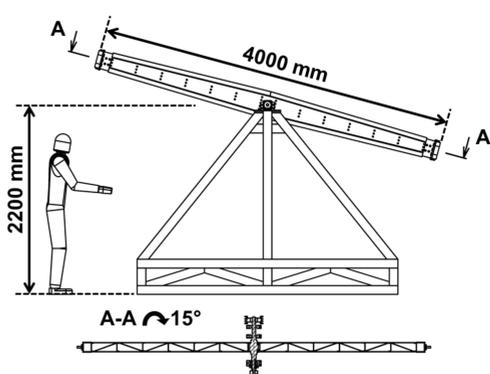

Figure 1. The test device sketch

Novel Experimental Device

To be able to investigate wood disintegration behavior a **novel test device** was developed. The device works on the principle of a rotor arm rotation (figure 1). The self-designed machine enables the simultaneous examination of cutting forces and deformations of **linear cutting** processes at cutting speeds of **up to 100 m/s**.
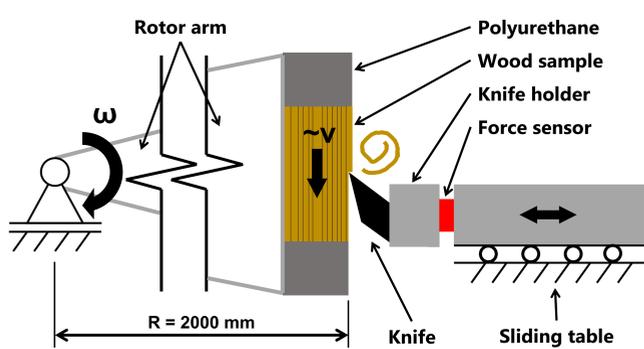

Figure 2. Measurement principle

Materials and Methods

Wood samples made of beech (Fagus sylvatica) stored in standard climate (20 °C / 65% RH) were tested. The specimen, which is mounted on a rotating arm, passes the **stationary knife** parallely to the grain orientation (figure 2). The cutting process is recorded by means of a sensitive three-dimensional **quartz force sensor** (9027C, Kistler, Germany) placed beneath the knife. Accuracy of the chip dimension is measured by means of a laser sensor with a **resolution up to 2 μm** (LAM-F-20, WayCon, Germany) recording sample height before and after cutting.

Results

Analysis of the test set-up showed high accuracy and hence reproducibility of different process parameters. Nevertheless, the **evaluated real chip thickness** varied of +/- 15%. For that purpose, the force value was scaled according to the linear progression coefficient to the original value. Within the range from 0.05 to 0.2 mm, data showed a linear correlation between cutting force and chip thickness (e.g. $R^2 = 0.981$ at speed of 50 m/s). Figure 3 shows a mean **peak cutting force** depending on cutting velocity at different cutting depths. The force increase with increasing chip thickness can be seen in the graph. In contrast, increasing **velocity did not impact forces linearly**. The lowest forces were observed at 20 m/s for all cutting depths in contrast to the literature [2, 3]. It supposed to be related to the **speed of pre-splitting** (figure 4) [4] which affects cutting in B direction [5]. For lower cutting thicknesses (0.05 mm) the influence of cutting speed was hardly observable. This could be related to the fact, that **share of friction** (taking place when the knife compresses the sample surface) to forming a chip is higher.
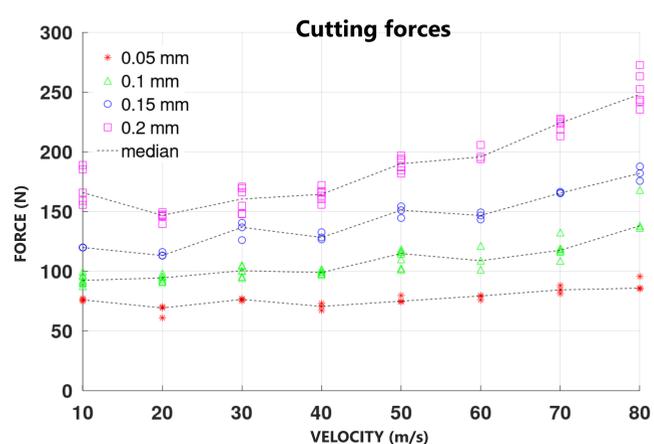

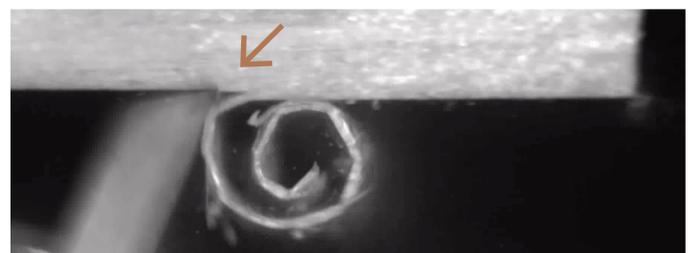**Figure 3.** Cutting forces depended on cutting velocity for different chip thicknesses

Figure 4. Pre-splitting [4]

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