# DIVINATION FROM CHIPS: MONITORING OF THE SAWING PROCESS WITH CHIP GEOMETRY ANALYZES

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## Abstract

*Chips produced during machining process are usually unwanted effect of the cutting. However analyses of the chips could provide many information regarding machine, tool and processed material. A simple method of fractioning chips with vibrating meshes is very simple and popular, but it has some important limitations. The goal of this work was to develop an alternative system for more precise measurement of the chips geometry. It bases on the video camera and image processing software. Some results showing advantages of the vision system usage are presented in the example of the chips produced during sawing of frozen and unfrozen wood samples. The amount of information produced by such system is superior to the mechanical separation method. It provides inputs for the diagnosing of the sawing process.*

**Key words:** *sawing chips, mechanical separation, camera vision, frozen wood cutting*

## INTRODUCTION

The processing of wood is an ages-long activity of the human. During cutting of timber various types of chips are produced. These could be a target of manufacturing or just redundant waste of the raw material. In all cases however the structure and geometry of chips depends on the raw material properties, kinematics of the cutting, machine and tool conditions. Therefore analyses of chips could provide a lot of information regarded the manufacturing process, its inaccuracies and troubles [1, 2, 3]. Exploiting of such analyzes will be then a way to monitor and diagnose the cutting process [6].

Numbers of techniques for evaluation of chips are known and used practically. An expert person toughing chips can judge the process or define its weaknesses. However such skills are very rear and rather subjective. In the same time developments of the new information techniques provide new and alternative tools for the evaluation of the chips. In this project we aimed to develop such technique for measuring sawing chips. The analyses of relations between chip size, elongation, dimensions and cutting conditions for varied cutting conditions and workpieces are presented.

## MATERIALS AND METHODS

Blocks (Scots pine wood, *Pinus sylvestris* L.) of dimensions 88×88×800 mm and moisture content ~30% were the workpiece in the experiment. Samples were conditioned to reach two temperatures: a room temperature (+18ºC) and frozen (–20ºC). The frozen sample has been selected intentionally as the problem of the processing of the frozen wood (typical for sawmills during winter) is one of the low researched problems is wood machining. Moreover due to different cutting physics of both samples some differences in the sawing chips geometries are expected. In general the frozen wood behaves as more brittle material, the cutting resistance rises when the wood becomes frozen and cutting conditions become harsher. Some defects easily observed after cutting frozen wood is chip welding to the lower (base) side of the sawn block [5].

Experimental samples have been processed out on the frame sawing machine PRW15M with the hybrid dynamically balanced driving system and elliptical teeth trajectory movement [4, 7]. Tool used were mini gang saw blades with stellite tipped teeth, having overall set $S_t$ = 1.25mm, saw blade thickness $s$ = 0.8mm and pitch $P$ = 13mm. Cutting conditions were set to three levels of the feed speed: 0.55m/min, 0.9m/min and 1.35m/min, what corresponds to feed per tooth of 0.067mm, 0.109mm and 0.162mm respectively.

Chips produced during cutting wood on the saw have been collected for the further analyzes isolated from the air to keep the moisture content.

Half of the chips have been separated in to fractions by using traditional mechanical separation method [1, 2]. The machine used was Retsch with a set of calibrated meshes of the size 4.7, 8.4, 65.7, 117, 548, 1050 mm$^2$ (Figure 1a). All smaller chips (dust) where collected in the last container. The time of vibration has been selected in to 5 minuts to assure a proper separation in to fractions and minimize an effect of the further milling of particles in to smaller dusts. The vibration frequency of the mechanical separator was 50 Hz. The weight of each fraction has been measured with an accuracy of 0.001 g.

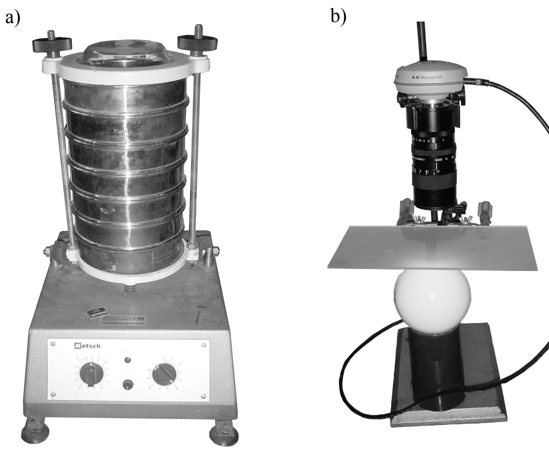


Fig. 1. Equipment used for sawing chips measurement: a) mechanical separator, b) camera vision system

Another alternative method of the chip measurement developed for this project was a camera based vision system (Figure 1b). Chips were randomly spread on the milk-glass plate by hand. A special care has been taken to assure that chips lay on the glass separately not making groups. It was very important as it affected the results of measurements. The glass was backlight-illuminated by a lamp installed under the plate. A high resolution CMOS video camera (Pixelink PL-A682) equipped with a low distortion macro lenses captured an image of the chips and stored the image in a computer memory for further processing. An example of the image to be processed is presented in Figure 2a. A preset size of the image was 1584x1200 pixels, what corresponded to ~41x31 mm field of view. Therefore the system has a resolution of 38.6 pixels/mm.

After the acquisition, all images have been processed to extract information regarding the geometry of chips: length ❶, width ❷, elongation of the chip ❸ (counted as a ratio between long and short axis of the ellipse representing the chip) and also an area of the chip ❹, as is presented on the Figure 2b. Dedicated software has been created in LabView. In the first step the algorithm corrected uneven illumination, extracted green plane and eliminated background by applying a threshold to the image. As an effect all particles corresponding to chips where identified. The program removed all particles which were close to the border. A special algorithm has been used to analyze geometry of all particles providing numerical indictors for each chip. At least 5000 chips were measured for each set of investigated cuttings. The last step was to perform statistical analyzes and histograms of the values measured. The limitation of the system presented was a measurement only in two dimensions; however a simple modification (stereovision) could improve the hardware to measure also a thickness/depth (a missing dimension in this experiment).

a) b)

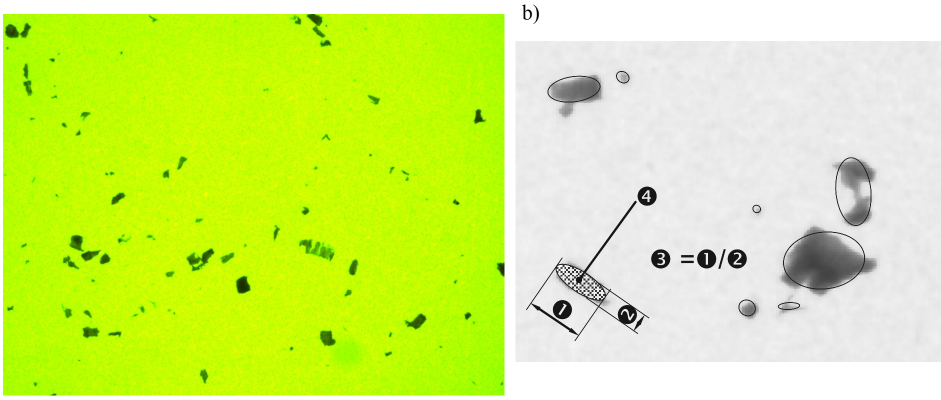


Fig. 2. Image of the chips taken by the camera (a) and indicators of the chip geometry calculated from the image (b)

## RESULTS AND DISCUSSION

In the first stage of the experiment all chips were measured by using mechanical separator. An example of the histogram obtained with this method is presented in Figure 3. It is clear that variations of the histograms are almost unvarying, suggesting constant cutting processes. However all the histograms were created from chips obtained with varying feed speed of the frame sawing machine!

Almost half of chips are in the 548mm$^2$ fraction. Relatively undersized amount of small chips and more large chips in the bigger fractions could be also interpreted from the graph. Obviously the amount of facts is very limited. It makes a usefulness of the mechanical separation method for process evaluation rather problematic. Other limitations are proofs that the method does not provide much information (low number of fractions, only weight ratios, no differentiation of the chip geometry (shape, length, etc.). Moreover it is very probable that during the vibration some chips are furthermore damaged (secondary fragmentation). Realizing such limitations we decided to develop an alternative camera vision method.

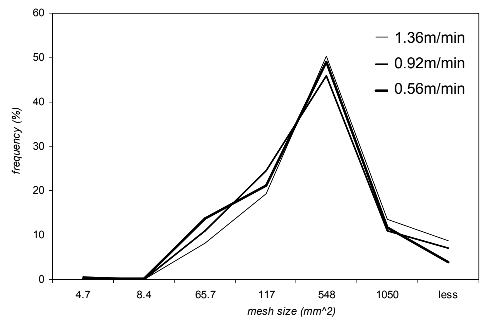


Fig. 3. Fractions of chips separated mechanically as a function of feed speed (un-frozen wood)

Results obtained after image analysis of sawing chips are presented in Figures 4 and 5. It can be clearly seen that amount of information available is superior to the mechanical separation method. It seems that, at the first impression, all histograms appear to be very similar (main peaks located in the similar locations), though after careful examination some interesting details can be excavated:

Analysis of the chip length (Figure 4a and 5a) shows that most of the chips are short. Nevertheless, in case of slow feed speed a relatively high amount of long chips are produced. Very few chips are longer than 2 mm.

Clear frequency peak's accumulation is observed in the region of ~1.3 mm length of chip (gray arrow on the Figure 5a). It corresponds to the width of kerf ($S_t$ = 1.25 mm). Peaks are also correlated to the feed per tooth, what was discovered by analysing of the chips width (Figure 5b). It has been observed that the scatter of the chip width was much lower than the scatter of the chip length distribution; sawing chips possessed uniform chip's width. Basically no chips were wider than 1 mm.

For all cutting conditions, chip area (chip size) histograms present comparable distribution (Figure 4c and 5c); however when the wood temperature decreases the major frequency reduces (decrement of the peak's value); in particular for a slow feed speeds. It can be explained by the changes of the wood's toughness. Generally, larger chips are produced during processing of the tough materials.

The elongations of the chip histograms show two main peaks (Figure 4d and 5d). First related to the almost rounded chips (ellipse axis ratio ≈1), second peak for slightly elongated chips (ellipse axis ratio ≈2). Similarly to the previous findings, the cutting of the frozen wood effect in a producing non-uniform chips, as the histogram presents much more scattered distribution for frozen wood chips.

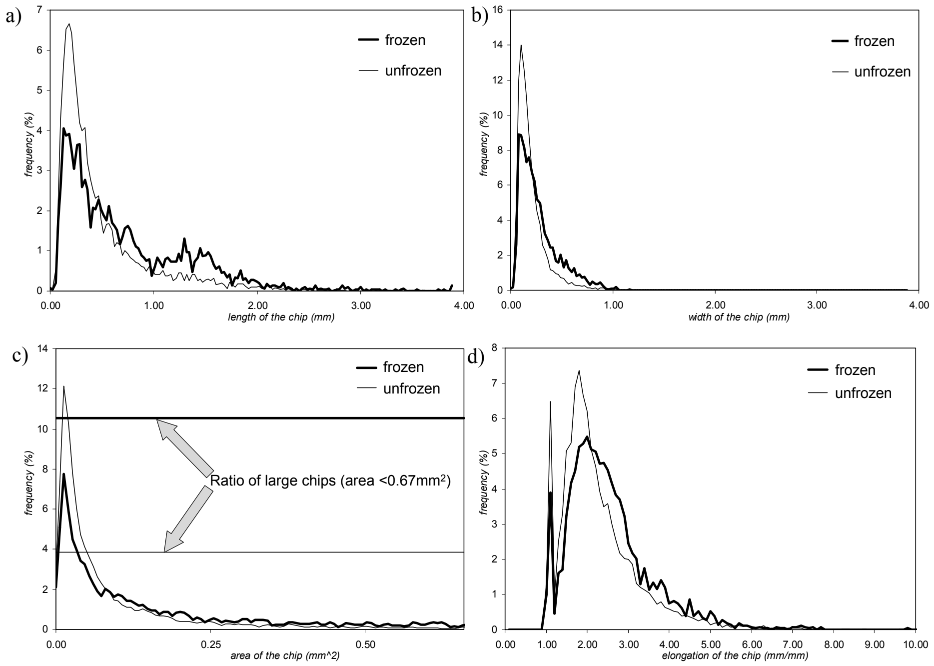


Fig. 4. Effect of wood temperature on the chip geometry (feed speed 0.56m/min); a) chip length, b) chip width, c) area of the chip, d) chip elongation

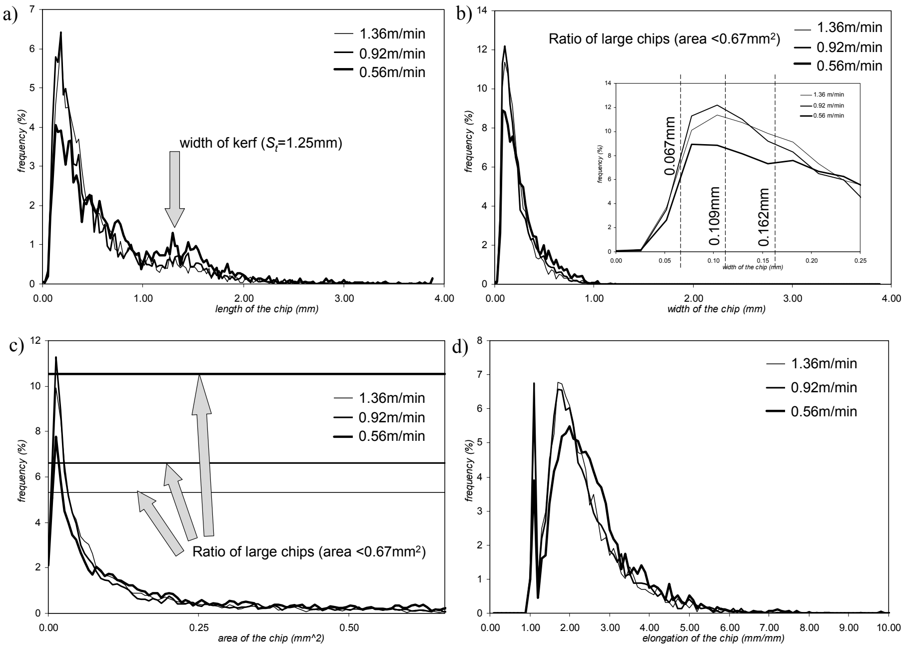


Fig. 5. Effect of the feed speed on the chip geometry (frozen wood); a) chip length, b) chip width, c) area of the chip, d) chip elongation

It was observed that, in a case of unfrozen wood, increment of the feed follows to the reduction of the chip separation and slight rise of the large particles quantity. Conversely, for the frozen wood this trend changes. Relatively fewer large chips are created - in addition to more intensive chips refining - when the feed per tooth increases. It is due to the degeneration of the cutting conditions as the workpiece become more brittle. It has been confirmed during another experiment; the increment of the cutting resistance during the cutting process of the frozen wood has been noticed [5]. Moreover, an uncontrolled material pulls out occurred simultaneously to the cutting process when sawing frozen wood.

## CONCLUSIONS

Experimental results shows advantages of the usage the vision system compare to the combustion method. Simple statistical analyzes of the data obtained by image processing provide a lot of guidelines to be used for understanding of the cutting process. An example described is a problem of the sawing frozen wood. Numerous differences between room temperature and frozen wood cutting physics have been exploited. The statistical data provided by image analysis classify the frozen wood as more brittle compare to “normal” wood, and the sawing process much more harsh.

An improvement of the camera vision method could be stereovision, providing as an effect three dimensional characterization of each chip measured.

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