Laboratory method: Image analysis of wood chip cracks

B. Petržela[1]

[1]Faculty of Forestry and Wood Sciences, Czech University of Life Sciences in Prague, Czech Republic

1 Introduction

Introduced method is a direct laboratory characterization of a wood chip cracks of an individual chip. Method is developed for sorted chip fractions from screen 2 (over-thick chips) and screen 3 (accept chips) as these fractions represents a majority of chips for pulp and paper industry and has ideal parameters for using this method. Laboratory chalking method with image analysis follows steps described in methodology.

2 Materials

- wood chips, fraction accepts (>13mm holes) or over-thick (>8mm slots) chips according to standard ISO 17225-1:2021, air-dried
- chalk powder of Calcium Carbonate ($CaCO_3$), multiple particle sizes 10 – 149 μm

3 Equipment

- optical microscope
- distilled water
- linear microtome
- climatization chamber
- black permanent marker
- rubber gloves, fine brush
- sliding caliper
- camera compatible with optical microscope
- image merging software (e.g. Microsoft Image Composite Editor)
- image analysis software (e.g. NIS elements, ImageJ)
- data processing software (e.g. MS Excell, Statistica)

4 Methodology

4.1 Chip selection and preparation

Soak chips in distilled water for 24 hours for reaching fibre saturation point. The soaking precedes microtone cutting for reaching smooth surface while cutting which has 2 effects. Ad 1 it does not create additional cracks which would depreciate gained results, ad 2 when having smooth cut image analysis is to have more precise results when evaluating individual elements.

4.2 Microtone cutting

After soaking, chip is cut on linear microtome for creating flat surface as a prerequisite for image taking of chip surface. Chip is cut approximately in the middle and perpendicularly to the wood elements (fibres, tracheids…). The height – distance from the bottom to the cut surface - of a cut chip is not exceed limitations of microscope used (having a bigger height may disable to focus microscope properly).

CRITICLAL STEP: Clean and smooth cut is critical for further analysis, deformation of surface by cutting may invalidate results obtained.

4.3 Drying

Condition chips in climatization chamber at a temperature of 20°C and relative humidity of 65 % for 24 hours.

CRITICAL STEP: Do not dry samples in higher temperatures for it may cause emergence of new drying cracks invalidating the results.

4.4 Base colour application

Apply base colour on the flat surface of the chip using black permanent marker to ensure adequate contrast between the base colour and chalk layer for optimal image analysis. Cover surface fully and evenly. Let the base colour dry out before next step.

4.5 Chalk application

Apply a chalk powder layer on dried out base colour using rubber gloves and a fine brush. If having more chalk fractions, apply the biggest fraction at the first, then continue in application from the biggest to the smallest fraction. Use the brush to smoothly brush off the surface so the chalk would remain only in surface´s recesses. Chalk is filling gaps and pores of transverse cut and thus creating contrast between base colour and chalk layer applied. Surface of prepared sample should look like figure 1.

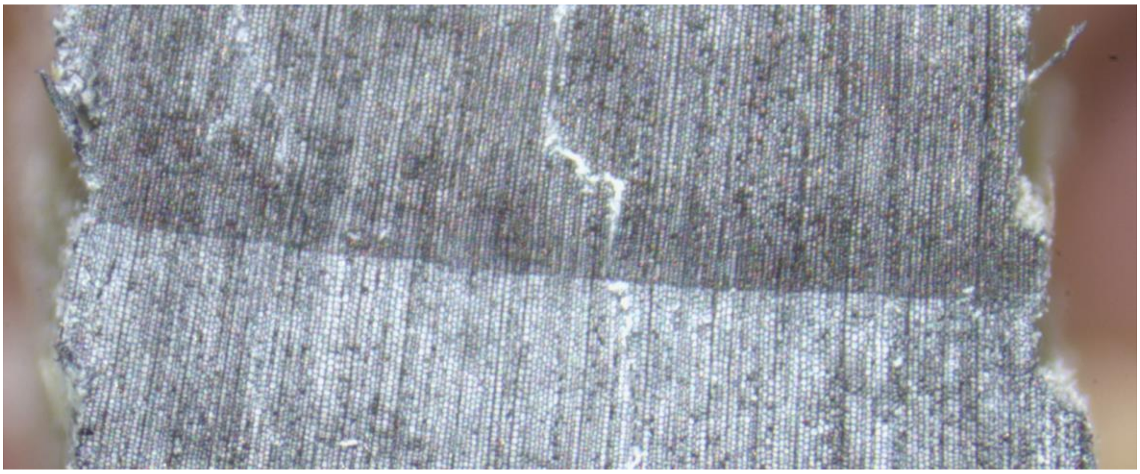

Figure 1: Chip surface preparation

Source: Petržela, 2024

4.6 Microscope photography

Use optical microscope with camera to make images of prepared surface of chip. It is important to know resolution of images to enable recalculation from pixels to micrometres during analysis. To ensure that measure length of each chip with digital sliding caliper or photograph each surface with etalon. As wood chip is usually longer then wider, it is possible to make several images of chip surface to ensure higher resolution and optimal focus of microscope lens.

4.7 Image editing

For merging images together to create subsequent “landscape” several software may be used, e.g. Microsoft ICE (Microsoft Image Composite Editor), which merges images into "landscape" automatically. Illustrative photo of merged image is show in figure 2.

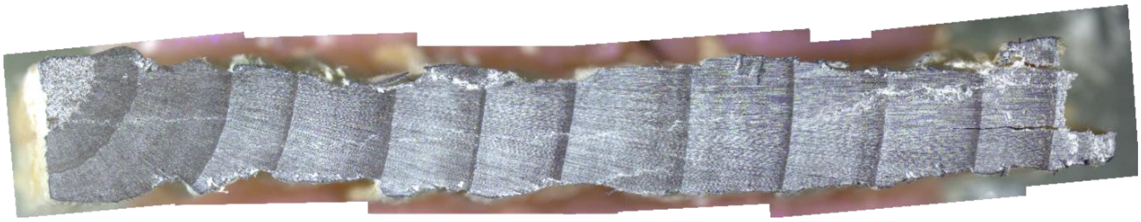

Figure 2: Chip imaging, merged

Source: Petržela, 2024

4.8 Image analysis

For image analysis use appropriate software, e.g. NIS elements, or ImageJ could be used, where the first one is professional but with licence, and second one is less specialized, but available for free. Use software to analyse given parameters:

- chip area,
- maximum and minimum chip projection for length,
- maximum and minimum chip projection for width,
- single crack area,
- single crack maximum and minimum projection for length,
- single crack maximum and minimum projection for width.

For calculation in software both calculation in pixels [px] or setting scale directly to micrometres [μm] may be conducted. Measurement and evaluation of elements can be done either manually or automatically with manual control and correction. Methodology for automatic measurement and evaluation has not been optimized yet and thus is not included in this method. For manual measurement in NIS elements software, area of each element is defined by marking its outline. Maximum and minimum projections are calculated automatically for each element. Finally, process data in any sheet editor (MS Excell, Google Sheets, etc.) or statistical software (Statistica, Gretl, etc.) regarding the requirements of your study.

5 Limitations

Limitations regarding the methodology are expressed below. Following concerns may have influence results and has to be considered regarding the results obtained by this methodology.

5.1 Chip preparation

It is important to be careful during chip preparation given that any additional disruption to the chip's structure may distort the obtained results. This risk can be avoided by taking a responsible approach in the chip preparation process.

5.2 Length of chip

During chip preparation, the length of the chip may be limited by microscope used due to the position of the microscope's focal point, which may limit the maximum length dimension of the chip.

5.3 Image editing

For image analysis with high resolution, images had to be merged into a panorama, which may cause inaccuracy in measurement of individual elements. This risk can be avoided by sticking to precise procedure and correct setting of sample – microscope – camera system.

5.4 Manual image analysis

The primary limitation of this methodology lies in the manual measurement and evaluation of individual elements using image analysis software. This manual process significantly increases the time and effort required for analysis, thereby restricting the number of samples that can be analysed. To enhance the efficiency of the image analysis method for future applications, optimizing the analytical procedures to enable automated chip evaluation is essential.

5.5 2D vs 3D analysis

Given method introduce two-dimensional analysis which only describes single cross-section of chip compared to whole three-dimensional profile of chip. This aspect sets limits complete understanding of wood chip cracks profile and its evaluation.

6 Outlook and optimisation

Regarding the primary limitation of this method which is need of manual analysis it is important to focus on future automation of analytical process. The cornerstone of automation lies in finetuning chip preparation, especially in chalking procedure to effectively fill all surface depressions to create desired contrast enabling automation of image analysis.

Further innovative approaches in development of direct wood chip cracks analysis may focus on ultrasonic testing or X-ray tomography which could enable evaluation of not only two-dimensional cross-section of chip, but rather three-dimensional modelling of whole chip and therefore a progression of cracks. It is important to ensure that used devices have desired resolution as wood chips are rather small inhomogeneous object with dimensions variability. Electron microscopy was found as not favourable method for purpose as wood is an organic material and hence an electron flow could damage an analysed surface of chip.

References

ISO 17225-1:2021. (2021). Solid biofuels — Fuel specifications and classes.

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