DETERMINATION OF RESIDUAL BARK IN DEBARKED PULPWOOD USING IMAGE ANALYSIS

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ABSTRACT

A new method for the determination of the bark content of wood used in chemical pulping is proposed. The method is based on the analysis of images taken from crushed wood chips. The chip flow is continuously sampled in a wood handling plant for the crushing. The crushed chips form a flat, homogenous target with the exception of bark bits which can be distinguished from the sound wood on the ground of tonal or spectral information using simple image processing operations. The area of bark bits in the images can be used as an estimate for the bark content of the chips. Experiments show strong correlation between the actual bark content of the samples and the values derived from the image data.

Application:

The proposed method has potential use in the control of debarking and pulping processes in chemical pulp mills.

Debarking of logs or stems is one of the key operations in wood handling in the mechanical and chemical wood processing industry. In the manufacturing of chemical pulp logs are debarked and chipped before the pulping process (**Figure 1**). The amount of bark left in chips decreases the pulp quality and causes the need for additional control of the pulping. On the other hand, excessive debarking removes sound pulpwood from the logs and generates waste of material. In addition, the energy consumption is increased. The permitted bark content [grams of bark/grams of wood] of wood chips in a typical Finnish pulp mill is around 1% of the total mass of the chips.

The bark content of chips can be optimized by adjusting the debarking process. This requires measured data on the degree of the debarking. The time period of the debarking adjustment is 5 - 10 minutes which requires the speed of the bark content measurement to be of the same order. Several measurement methods have been proposed for the determination of the bark content. One part of the proposed methods measures bark on logs e.g. (1 - 3). Another approach is based on the analysis of the bark on chips e.g. (4, 5). In most cases the methods utilize some optical means and subsequent signal processing. A typical solution is to image logs (3) or chips (4) with a CCD camera and to calculate the bark content from the image data. However, problems arise, for example, due to specular reflections from curved surfaces. These are strengthened by some environmental factors like moisture or ice on the wood. Images taken from debarked logs and wood chips indicating some problems involved in direct measurement of residual bark are shown in **Figure 2**.

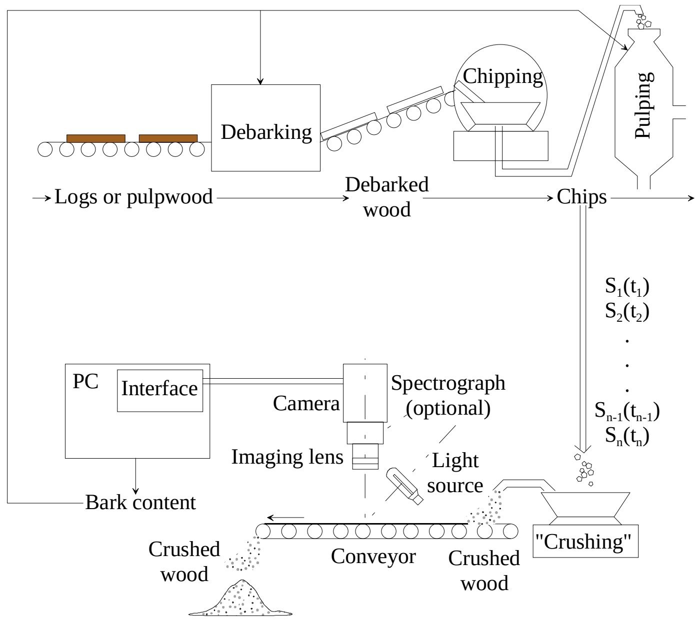
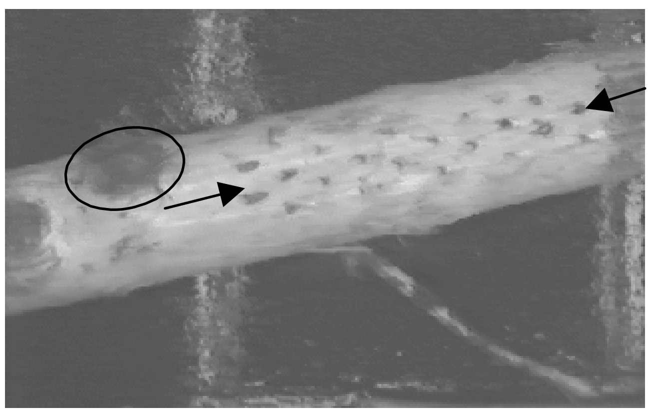


Figure 1. Wood handling in a chemical pulp plant and connection of the proposed bark content measurement to the wood handling and pulping process.

a)



b)

Figure 2. Images of debarked wood. a) A log on a conveyer belt. The dark areas on the log may be caused in addition to residual bark, for example, by knots (indicated by the oval) and decay or other internal defects. The dark spots between the arrows are due to the logging machine. b) A flow of wood chips. The overlapping of the individual chips causes strong shadows in the image.

OVERVIEW

The basic idea of the method proposed in this paper is to smooth the signal variations due to curved surfaces and spatial variations of moisture in chips by crushing the wood into homogenous dust (6, 7). Images taken from the crushed wood can be segmented on the ground of tonal or spectral information to areas corresponding to sound wood and to bark. The bark content can be estimated as a ratio of the bark area to the total image area containing crushed wood. The kind of homogenization procedure proposed here has been previously used in the measurement of the moisture of wood chips (8).

The connection of the bark content measurement to the wood handling and pulping process is shown in Figure 1. The measurement requires an appropriate sampling of the chip flow and mechanical crushing of the sampled chips. The crushed wood is spread evenly on a conveyer belt or on a corresponding flat bed. The imaging of the crushed wood can be done, for example, with a CCD line scan or area scan camera. Due to the slow response time of the debarking process all the image processing can be implemented in a PC.

Throughout the rest of this paper basic theory concerning image processing and sampling in the proposed method is discussed and an analysis of the bark content measurement of crushed dried Scots pine (*Pinus sylvestris*) and green spruce (*Picea abies*) is presented. It is obvious that the method is applicable with other wood species as long as the bark and sound wood have different reflective or transmissive properties. This difference can be manifested either in tonal or in spectral information.

Marszalec and Pietikäinen (9) measured the spectral reflectance curves of sound wood, bark and different defective areas for pine with a spectrophotometer. The most important result of the spectrophotometer measurements is that the reflectance values depend strongly on the natural variations of pine. For example, reflectance values varied at 550 nm wavelength approximately from 32% of non-homogenous light yellow - dark brown sound wood to 61% of homogenous light yellow sound wood. However, in each case this was considerably more than the reflectance values of bark which varied at 550 nm approximately from 8% of dark bark to 18% of light bark. According to the reflectance curves bark segmentation based on global thresholding of tonal information is an appropriate method for the bark content measurement.

Image analysis

Crushed particles containing bark can be segmented from the image data using a threshold operation. An estimate for the bark content in one image is obtained simply by dividing the bark area by the total image area. In a transmissive illumination mode the volume of the crushed wood particles could be incorporated in the analysis by relating the transmission of the light to the thickness of the particles. However, in this paper only reflective illumination is considered.

The proposed method is very sensitive to the bark content because it is possible to detect tiny objects from the image data. The theoretical limit comes from the sampling theory, which states that the sampling frequency must be twice the highest frequency to be resolved. This means that the smallest object that can be reliably detected from the spatially sampled image data corresponds to a size of 2 x 2 pixels.

In principle, the resolution of the measurement is determined by the size range of the crushed wood particles and the pixel resolution of the imaging system. For example, if the image area is 500 x 500 pixels and the system is able to resolve bark areas of 2 x 2 pixels, 4/250000 = 0.00016% bark content can be theoretically resolved from one image. This would demand an extremely uniform spatial distribution of crushed wood particles without any significant overlapping. Another factor affecting the resolution, is the distribution of the size of the crushed wood particles. The system has to be tuned to detect the small particles as well, which means that for an average-sized particle more than four pixels have to be used. The resolution of the measurement decreases correspondingly. A narrow distribution of the particle size would be a benefit for the measurement.

In practical measurements the average size of the crushed wood particles can be in the millimeter scale (for example 5 - 10 mm). This would demand around 0.5 - 1 mm/pixel resolution for the image formation. Thus, an image of 500 x 500 pixels would cover an area of at least 250 x 250 mm in the object plane. The theoretical resolution of the measurement would be roughly 0.04% if the spatial resolution is 0.5 mm/pixel and an average particle size is 5 mm^2, corresponding approximately to 10 x 10 pixels. This is an appropriate performance for practical measurements in which the typical need is to measure bark contents down to 1%. The resolution can be even increased by increasing the image size in pixels or by incorporating the information from several images in the analysis.

EXPERIMENTAL

Sample material

The performance of the bark content measurement was evaluated in the laboratory by analyzing images taken from crushed pine and spruce samples of known bark content. The samples were prepared by mixing crushed sound wood and bark material in selected proportions. Each of the seven samples contained 100 g of wood and the bark contents of the samples were 0.1%, 0.5%, 1.0%, 2.0%, 3.0%, 4.0% and 5.0%. The pine samples were prepared from dry planedust and spruce samples from green sawdust which lead to a different average particle size in the two cases. Typical dimensions of the crushed wood particle are shown in **Figure 3**. Although planedust or sawdust of beneficial particle size was used in this study, modified power tools like garden shredders could be used in the in-line sample preparation in a woodyard.

Set-up

The samples were spread uniformly over a bed for the imaging. The pine samples were imaged using a Sony XC-003P 3CCD analog color camera with a 25mm f1.3 Computar TV lens. The signal was digitized with a Mikrotron INSPECTA-2 frame grabber board. The lens aperture was f2.8 and the imaging distance was around 1500 mm, which gives approximately 0.38 mm (H) x 0.38 mm (V) for the pixel resolution. The spruce samples were imaged using a Pulnix TM-560 analog black and white camera with a 16mm f1.4 VT TV lens. The lens aperture was f2.8 and the imaging distance around 280 mm, which gives approximately 0.19 mm (H) x 0.19 mm (V) for the pixel resolution. The signal was digitized with a Matrox Pulsar frame grabber board. Fluorescent aperture tubes were used in both cases as diffuse light sources.

Several images were taken from each of the samples in order to allow averaging of the results. The samples were shaken between the images to randomize the spatial distribution of the particles. All the image processing was done with Matrox Inspector 2.2 software. An example image of a pine sample is shown in Figure 4a.

a)

b)

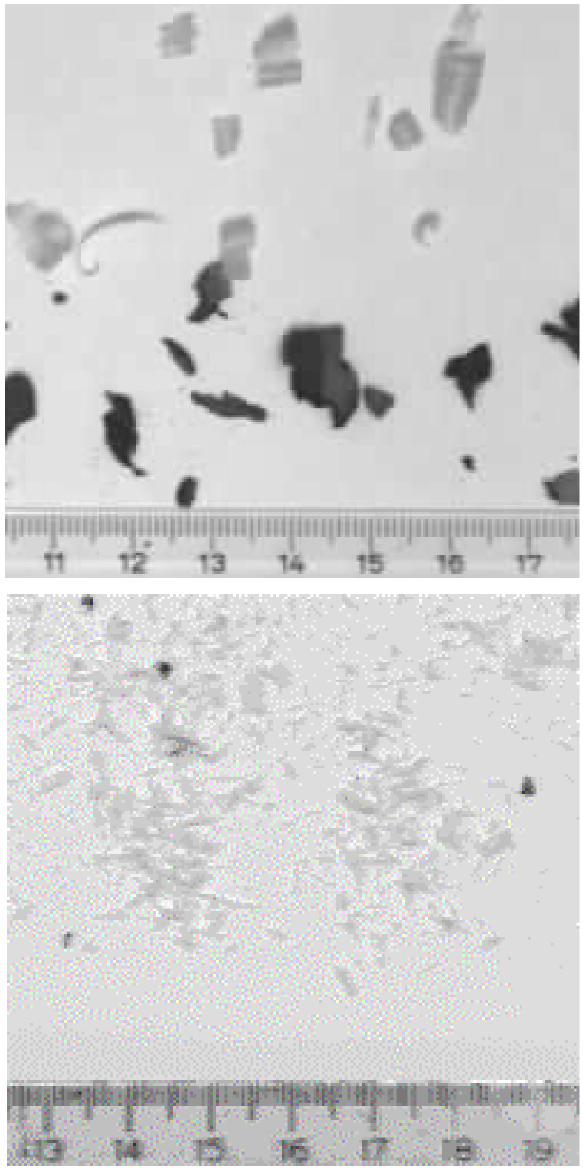


Figure 3. Dimensions of crushed Scots pine (Pinus sylvestris) (a) and spruce (Picea abies) (b) particles. Sound wood particles are lighter than bark particles. The width of the original image area corresponds in both cases approximately to 70 mm.

Results

The analysis of both RGB- and HSI-components of the color images showed that the tonal information essentially separates the sound pine wood and bark. Thus, the original RGB images were transformed to 8-bit unsigned gray tone images before the remaining processing. So the analysis of both the pine and spruce samples were done based on the gray tone information.

Due to the uniform target and illumination no special background correction operations were performed. The gray tone images were segmented globally (threshold = 85) based on the statistical analysis of the tonal properties of sound wood and bark (**Figure 4**). The area corresponding to bark particles was determined and related to the image area. The resulting ratio was used as an estimate for the bark content. Due to the variation of the estimates calculated from different images, an average value calculated from 10 images was used as a final estimate. The number of averages was determined by observing the change of the average value as the number of images increased (**Figure 5**).

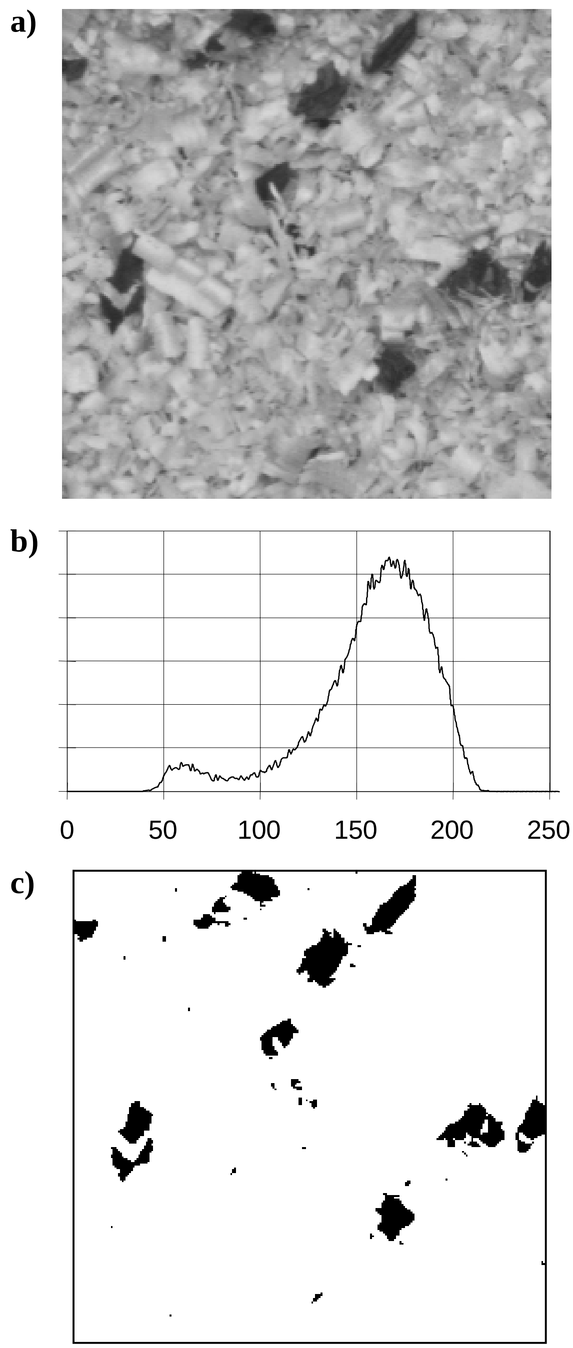


Figure 4. Segmentation of the crushed pine images. a) Original image, b) its histogram, and c) result of segmentation with threshold T = 85.

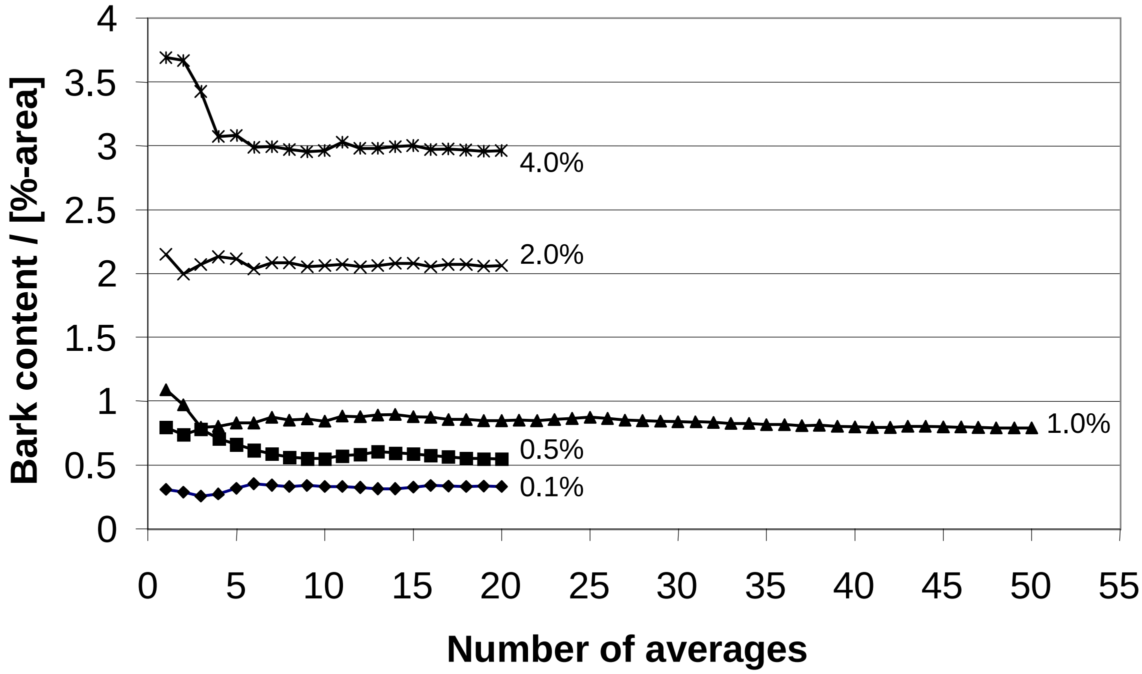
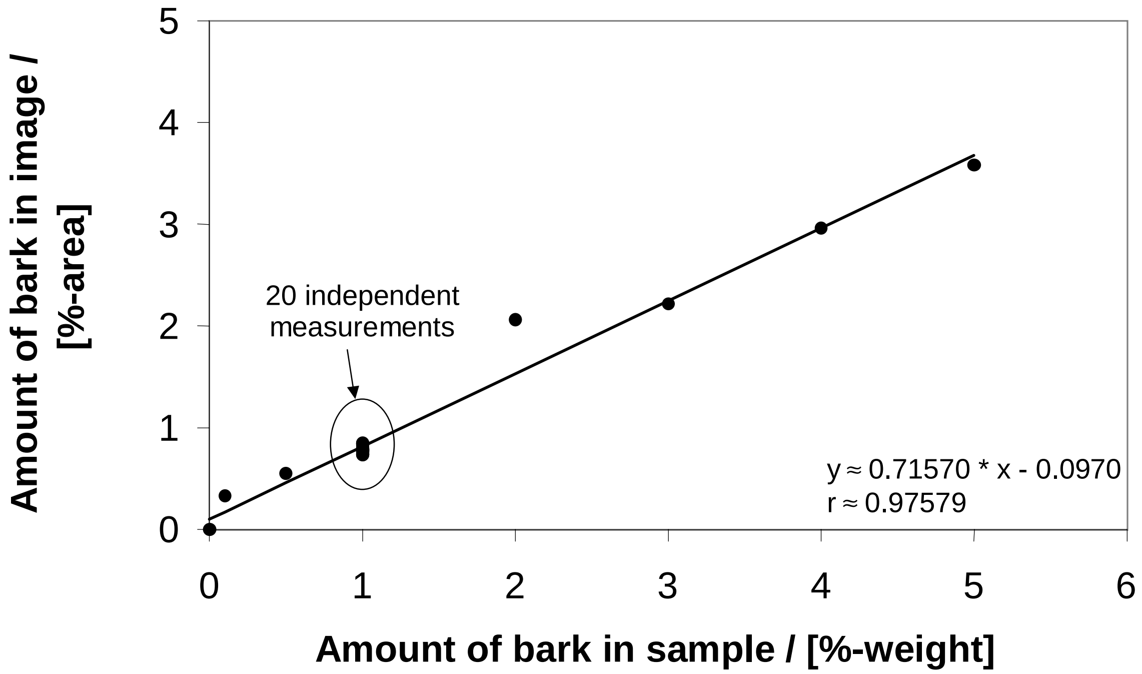


Figure 5. ***Effect of averaging on the estimated amount of bark in pine samples. The horizontal scale indicates the number of images that was used in each case to derive the bark content estimate (nominal bark content of the samples is attached to the curves.)***

The results of the bark content measurements, as well as the linear fit for the measured data are shown in **Figure 6**. The correlation between the actual and measured values is obvious for both wood species, which suggests that the linear regerssion curve can be used to convert the bark content values derived from the image information [%-area] to the actual values [%-weight]. The regression coefficient of the linear lest mean square fit is around 0.9758 for pine and 0.9888 for spruce. The measured value for the 0% bark content is 0% in both cases. The difference in the slope of the response in the measurements of pine and spruce obviously originates from the different average particle size in the samples.

In order to percieve the repeatability of the proposed method the measurement was repeated for 20 different pine samples with 1.0% bark content (Figure 6a). This is the most interesting bark content region in the context of the pulping process. The calculation of the individual estimates was based on the averaging the information of 10 images and utilized the linear fit depicted in Figure 6a. The mean value of the 20 bark content estimates was 0.9621% and the standard deviation 0.05236%. The minimum value was 0.8880% and the maximum 1.0517%. Obviously, the repeatability of the measurement is reasonable near 1.0% bark content.

a)



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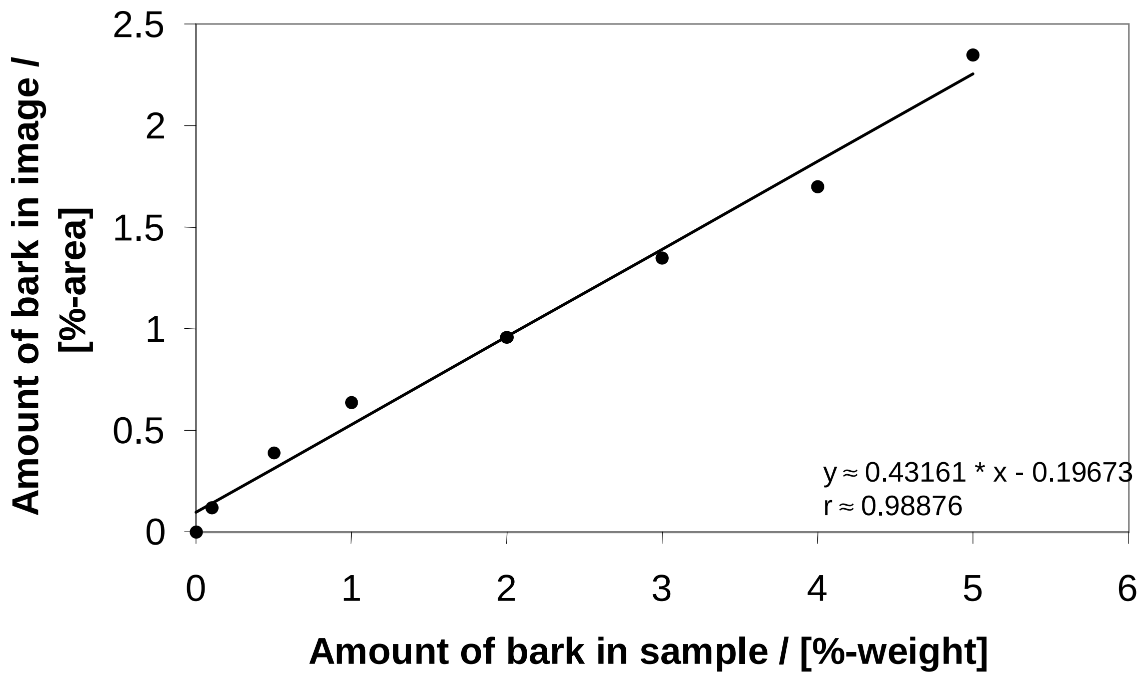

Figure 6. ***Estimated amount of bark as a function of the bark content. a) Pine samples and b) spruce samples.***

DISCUSSION

Here, a new automated method for the determination of bark on wood chips is proposed. The method is based on the analysis of images taken from homogenous crushed wood. The main idea is to avoid complicated image processing by homogenizing the target material. Another benefit is due to the fact that the target area is small compared to methods where entire logs or a flow of chips are imaged. This decreases the amount of imaging components required and leads to a reduced total cost for the system. The first laboratory experiments indicated good correlation between the measured and actual values of the bark content as well as a reasonable repeatability of the measurement. This suggests that the method can be used to measure the bark content of wood chip flow in a pulping mill.

The chip flow has to be sampled for the measurement and the total number of the samples has to be a representative specimen of the chip flow. A sufficient number for the samples can be estimated based on the statistical analysis and should be determined in future research. Here only reference is made to other chip measurements that are based on some sort of sampling of the chip flow e.g. (4, 8) in order to confirm the practicability of the sampling.

In addition to bark, the method described in this paper could probably be utilized in the measurement of the content of other parts of wood. These include, for example, knots and decay and other internal defects affecting the quality of pulp. The detection of such defects should obviously be based on color or spectral information.

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LITERATURE CITED

1. Pat. US 5544757. Optical sorting for wood processing - measuring surface structure and appearance to monitor back coverage and wood quality. Andritz Patentverwaltungs Gmbh. (Geiger, B., Grabher, R.). 13 Aug 1996.
2. Pat. WO 9107653. Continuous detection of bark on wood - uses beam of light incident on wood, and observations of size and shape of resulting light spot. STFI Svenska traeforskningsins. (Johansson, L., Ringström, L.). 30 May 1991.
3. Pat. WO 9117030. Control process for timber bark removal - uses weight measurement to control fullness of barking drum, and monitors deg. of barking to control rotational speed of drum. Andritz Patentverwaltungs Gmbh. (Silenius, S., Suominen, A.). 14 Nov 1991.
4. Pat. EP 831320. On-line wood to bark ratio determination for moving material - uses CCD camera and computer to calculate ratio from contrast measurements of sodium light illuminated chips. Valtion teknillinen tutkimuskeskus. (Aho, V.J., Ahonen, M., Pietikäinen, K., Silvennoinen, P., Suuronen, J.). 25 Mar 1998.
5. Pat. US 4266675. Optical segregator for wood bark - orientates wood chips between light source and detector and measures light transmitted through each chip. US Sec of Acric. (Barwise, R. D., Brumm, D. B., Sturos, J. A.). 12 May 1981.
6. Laitinen, J., SCIA'99, The 11th Scandinavian Conference on Image Analysis, 1999, DSAGM/IAPR, Lyngby, p. 487.

7. Finnish patent application no. 982341.
8. Pat. JP 63180855. Moisture measuring apparatus for wood chip. Chino Corp. (Imai, K., Shimoyama, H., Harada, S.). 25 Aug 1988. (English abstract.)
9. Marszalec, E., Pietikainen, M., Colour analysis of defects for atomated visual inspection of pine woods, SPIE, Vol. 1907, 1993, p. 80.

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