Analysis of the chain-flail debarking using a high speed motion analysis system

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Chain-flail delimbing-debarking technology is suitable for multi-tree processing of small-diameter trees. In the chain-flail debarking process, the rotation speed of the chain drum ranges 300–500 rpm. Therefore, a high-speed motion analysis is the only method to show what really happens in the debarking process. In this study, it was noticed that debarking occurs in a very short time (about 0.5 ms) when the chain hits the timber. If the chain hits the side of the tree, the chain just slides on the surface of the tree and is not able to debark the tree efficiently. In the determination of the impact force there is a clear correlation between the results obtained by a load cell mounted at the hitting point of the chain and those calculated using the impact time determined with a high-speed motion analysis system. This information makes it possible to determine the maximum impact force of the chain without measuring it.

1 Introduction
Chain-flail delimbing-debarking technology is suitable for multi-tree processing of small-diameter trees. The trees are delimbed and debarked at the road-side storages or terminals by whipping the trees with steel chains. Debarked pulpwod, can be chipped directly into a lorry, and the wood residues, e.g. the branches and needles, formed in the process, can be used as fuels. The chain-flail delimbing-debarking technology has been developed in the United States, where it is in commercial use (Edman 1989). At present the wood raw material for the Finnish pulping industry is mainly harvested by a log-length method and debarked in debarking drums at the factory. The use of the chain-flail delimbing-debarking method has been estimated to become more common in integrated production of industrial raw material and energy wood in Finland.

In chain-flail debarking the trees are whipped with steel-chains to remove the bark from the wood material. The impact force of the chains is not allowed to be too high to prevent the wood material losses from becoming too high. The target in the development of the chain-flail delimbing-debarking technology is to minimise the portion of the bark content of remaining wood (<1%) with as small a wood loss as possible. According to our results, the portion of bark in the pulp chips after processing pine with chain-flail delimbing-debarking unit ranged 0.5–2.5% in summer (Aho et al. 1997). In winter, the bark content and wood losses were higher. The main reason for this is that during the winter, the bond between the bark and the wood is 2–3 times stronger than during the growing season. In addition, the debarking result is also unsatisfactory if the trees are too small or have dried too much.

Raw material properties (e.g. tree species and growing season), weather conditions (moisture content of the bark), and process-technical factors, e.g. the chain used (material, size), the rotation speed of the chain bundle and the feeding speed affect the result of debarking. Because the debarking process is affected by so many factors, the effect of an individual factor on debarking is not easy to predict. The objective of this research was to analyse phenomena in the chain-flail debarking process. In the debarking process, the rotation speed of the chain drum varies from 300 rpm to 500 rpm. Therefore, the high-speed motion analysis is the only method to show what really happens in the chain-flail debarking process.
2 Equipment

2.1 Full scale laboratory simulator

In our research, we are using a full scale laboratory simulator, its length being 23.4 m, height 5.2 m and width is 3.3 m. The full-scale laboratory equipment comprises different kinds of module: 1) feeding unit, 2) chain flail delimber, 3) chain flail debarker, 4) brush debarker, 5) branch and bark conveyor and 6) a control center. The rotation speed of the debarking drums can be adjusted within the range of 0–1400 r/min, the debarking angle within ±45 degrees and the feeding speed of timber from 0 to 40 m/s (Fig. 1.). The sides of the full scale chain-flail deliming-debarking unit are covered with a thick glass sheet, so that it is possible to acquire images during debarking (Fig. 2).

2.2 High speed motion analysis system

The Kodak Ektapro system of VTT Energy consists of an imager unit and a processor unit (Fig. 2). The size of the CCD sensor in the imager unit is 256 × 256 pixels and the number of gray levels is also 256. The available recording rates are: 30, 60, 125, 250, 500, 750, 1125, 2250, 4500 full frames (256 × 256) per second and 9000, 13500, 18000, 27000 and 40500 segment frames per second. The exposure time is 222 μs for all full frame recording rates. The exposure time for frame segment recording is the reciprocal of the recording time. For example the exposure time at 40500 pps is 24.7 μs and the size of the image is 64 × 64 pixels (Kodak 1995). The processor unit has a circular frame buffer. The result is that the memory always holds the most recent images. Using a circular frame buffer with built-in trigger allows capture of almost any event (Sittig et al. 1992). These triggers can come from virtually any kind of sensor, including optical, acoustical and acceleration sensors. In this research we are using an inductive sensor. The size of the frame storage is 3072 full frames (192 MB). In other words system is capable to record 256 × 256 pixel images about 3 s, when the recording rate is 1125 images/s. Once captured by the analyzer, the stored images can be downloaded to SVHS tape or computer harddisk for future analysis.

In high speed videography, there is a trade-off between frame rate (images/s) and resolution (number of pixels in the image). As a common rule, it can be said that high resolution is not an essential requirement for high speed videography. The primary requirement is a high frame rate. Various formulae for the recording rate have been presented. The developers of Kodak Ektapro system have estimated the lower limit of frame rate to be the inverse of the time necessary for an object to move one tenth of the viewing area (Etoh et al. 1992). In our research the frame rate (N) is determined from equation (1)

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N = \frac{v \cdot ne}{FOV},
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where \(v\) is the motion speed (m/s), \(ne\) is the number of elements in one row of the sensor and FOV is the field of view. For example, when the motion speed is 20 m/s, \(ne\) is 256 pixels and FOV is 0.5 m, the frame rate is about 10000 frames per second. In this case the effect of blurring is negligible.

In high speed videography short exposure time (<1 ms) is needed to eliminate blur in recorded images. Therefore, high intensive, flicker free lighting systems are needed (Burkhard 1990). In practice the minimum illuminance required is about 10–20 klux and the quality of images improves as the illuminance level increases. There are several possible light sources for high speed videography: fluorescent light, tungsten halogen bulbs and metal halide lamps. The fluorescent and metal halide lamps require electronic power supplies to eliminate light

![Fig. 1. Schematic diagram of delimming and debarking modules of a full scale laboratory simulator](image1)

![Fig. 2. High-speed motion analysis system of VTT Energy. System consists of a camera unit and a processor unit inserted in an electronics cabinet which also contains SVHS tape recorder and a monitor](image2)

Bild 1. Schematische Darstellung eines Entastungs- und Entbindungsmoduls in einem wirklichkeitsgetreuem Laborversuch

Bild 2. Hochgeschwindigkeitsanalyse-System der VTT Energie. Das System umfasst eine Kamera- und eine Rechenhardware, zusammengefasst in einem elektronischen Gehäuse, das auch einen SVHS-Tape-Recorder und einen Monitor enthält