Literature review of the latest development of wood debarking

Rodolphe Baroth

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Abstract: The purpose of this report is to present the latest (since 2000) research done in the field of the wood debarking. Since wood is a complex material and debarking results depend on many parameters, various topics are presented.

Therefore, the bark wood bond strength has been studied by several authors. Consequently, it has generally been found out that it increases when logs are dry and can be affected by the temperature regarding on the moisture content of the logs.

The choices of the parameters that have to be control to improve the efficiency of the process in a debarking drum are discussed. Some authors propose calculations to determine wood losses while others focus on the way to compute actual filling degree by means of measurement devices. On the other hand, image analysis tool are developed.

Afterwards, on the basis of these theories, some automatic logics of control the process have been proposed. They all are taking into consideration different factors of wood debarking.

Finally, the research also contributes to the development of debarking machines. As a result, there are presented equipments that, according to their author, can vary the rate of debarking, or help the logs to flow out in a more fluent way.

Keywords: debarking, wood loss, bark, bark wood bond, log cleanliness, debarking drum, control, machine.
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1 INTRODUCTION

The main function of the debarking is to remove bark to the extend necessary for the quality of the final product. The measure of the bark removal efficiency is called the debarking degree. Depending on the different types of pulp manufacture, the cleanliness requirement for the logs can change. The debarking degree can be reached as high as 99%. On the other hand, another important aim in debarking is to keep the wood losses as low as possible in order to save raw material.

This report intends to go over the main articles and research documents dealing with the wood debarking since 2000. Therefore, it includes many kinds of subjects which are sometimes far from the initial purpose of the research. However, this variety of topics gives some aspects that could have an influence on the debarking process. In addition, since this work has been done by a timber engineer student, it was a very interesting point to widen the area of the study and thus take into consideration several non-known aspects. That’s why, for instance, one chapter is talking about the exposure to the biological agents in the debarking process.

On the other hand, since the main purpose of the research is referring to the improvement of the process by means of reducing the wood losses and an enhancement of the log cleanliness and the chip quality, most of the documents have results that could contribute to it. Indeed, there are some studies which deal with the influence of the raw material and its conditioning on the process. Moreover, methods for automatic control of the debarking are discussed like the choice of the parameters to handle. Then, some patents which have developed debarking apparatus are presented.
2 EFFECT OF THE CONDITIONING OF WOOD ON DEBARKING

It is known that the logs are easy to debark when the bark wood bond strength (BWBS) is low. It consequently increases the facility of removing bark, and thus decreases the level of bark remaining on logs. Thereby the BWBS will be the main determining criterion.

2.1 Species of wood and dimensions

It is first known that all species of wood have their own characteristics. Each of these can affect the debarking process. For example, the mechanical properties of deciduous logs are different than those coniferous ones. That’s why there occur more log breakages for deciduous species in the drum. Then hardwood and softwood tend to respond differently to the moisture content and temperature, which are considered to be other important factors.

There is a study relating some experiments on debarking mixed spruce and pine /1/. Thus most of the spruce logs (93%) were poorly debarked.

Then, the author found out that at constant bark thickness, small-diameter logs were often poorly debarked. Consequently, he proposed that large and small diameter logs should be sorted out and debarked separately.

2.2 Moisture content (MC)

In the document /2/, the author shows the moisture content distribution from the outer bark through sapwood of a fresh subalpine fir log. This species of timber is known for having higher wood moisture content than other species, but the following graph (Figure 1) well illustrates the general form of moisture distribution.

![Figure 1: The moisture content distribution from the outer bark through sapwood of a fresh subalpine fir log. /2/](image-url)
Furthermore, figure 2 proves that moisture content is the most important factor in wood/bark adhesion strength.

**Figure 2**: Wood/bark adhesion strength with moisture content over the storage period of 90 days. /2/

Magnus Öman /1/, in his study, also mentions that he has observed the lowest bark/wood shear strengths in May when the wood was still fresh. The highest values were measured on wood that had been exposed to air-drying. Then, his results show that an MC of sapwood around 30% was critical for drum debarking.

Finally, it is shown that the wood/bark adhesion strength decreases exponentially above the fibre saturation point of wood (about 28%).

### 2.3 Storage conditions

In agreement with the precedent paragraph, it can be said that the log blocks have to be stored in high moisture conditions. Indeed Suezone Chow and Alice Obermajer /2/ reveal that the dry stored specimens had mainly inner bark failure. That means that dry logs result in high bark content in pulp chips.

The relationship between mean moisture content and storage time was also demonstrated. On figure 3, there is a slight reduction of wood/bark adhesion strength along storage time in all storage conditions except the dry. /2/
In addition, Magnus Öman indicates that after fast drying conditions, it can be used climate-adapted sprinkling of fresh wood in order to retain the MC at an acceptable level. In case of it cannot be arranged, the author recommends to debark dry wood separately /1/.

2.4 Temperature

At high temperature (30 to 70°C), the failure occurred mainly in the bark for a moisture content of 20-30%, but as the MC exceeded 40%, failure occurred gradually more in the cambial zone (Figure 4). /2/

At lower temperature (-78 to 25°C), the authors explain that regardless of moisture content, the more the temperature decreased, the more failure in the bark it occurred.

One explanation of this phenomenon is the fact that the cambium zone was affected by the low temperature and became frozen. That’s the reason why the shearing occurs in the inner bark and the BWBS become higher.

In addition, this justification has also pointed out by other authors./3/

Finally, they demonstrate (figure 4) that the temperature only has an effect on wood/bark adhesion strength when the MC is greater than the fibre saturation point.

Figure 3: Relationship between mean wood/bark adhesion strength and storage time. /2/
Figure 4: Wood/bark adhesion for samples dried to various moisture contents at 70°C and conditioned and tested at low temperatures. /2/

Otherwise, Gullichsen presented the following table (Figure 5) which shows the debarking degree in relation to the bark to wood adhesion and the wood species. /4/

<table>
<thead>
<tr>
<th>Bark to wood adhesion</th>
<th>Debarking degree</th>
<th>Examples of wood species</th>
</tr>
</thead>
<tbody>
<tr>
<td>kp/cm³</td>
<td>lb./sq.in</td>
<td></td>
</tr>
<tr>
<td>...3-4</td>
<td>...40...55</td>
<td>easy to debark</td>
</tr>
<tr>
<td>5...6</td>
<td>70...110</td>
<td>normal to debark</td>
</tr>
<tr>
<td>8-10.</td>
<td>...140...</td>
<td>difficult to debark</td>
</tr>
<tr>
<td>12…14</td>
<td>170…200</td>
<td>very difficult to debark</td>
</tr>
<tr>
<td>&gt;20</td>
<td>approx. 300</td>
<td>almost unable to debark</td>
</tr>
</tbody>
</table>

Figure 5: Effect of bark to wood adhesion on debarking degree. /4/
3 EXPOSURE TO BIOLOGICAL AGENTS

Many people work on the debarking sites. Consequently manual workers are exposed to an area contaminated by the production wastes.

Some studies were undertaken to characterize and quantify the risks related to working in these areas. The results about the debarking site are presented.

In the study, the raw material debarked was spruce and birch, and they operated with a wet-drum debarking technique. /5/

Some samplers were positioned on several places:
- debarking hall,
- debarking control room,
- sludge treatment,
- sludge control room,
- basins,
- basin exteriors,
- outdoor.

On the other hand, the study /6/ performed air sampling at 17 sawmills at different site:
- debarking,
- sawing,
- planning,
- sorting.

The debarking was carried out mechanically on dry or wet logs.

3.1 Occurrence of endotoxin

The highest endotoxin concentration (375 ng/m$^3$) was found on the servicing bridge of the dry debarking unit /5/. In general, there were lower concentrations on the floor. The total microbe concentration apparently followed the model of endotoxin exposure /5/. The author indicates that the greatest microbe concentration occurred in summer.

Concerning the results /6/, the endotoxin concentration was also the highest at the debarking sites with $1,7 \times 10^4$ EU/m$^3$ (1,700 ng/m$^3$) for spruce and fire species.

3.2 Occurrence of fungi

The debarking site /5/ housed fungi as Penicillium spp., Aspergillus fumigatus and Rhodotorula glutinis. The highest Penicillium spore counts (97,000 cfu/m$^3$) were found on the servicing bridge of the debarking units, whereas the Aspergillus fumigatus spores amounted to 25,000 m$^3$.(Figure 6)
According to a study, this last kind of fungi may be responsible for allergic alveolitis. /6/

In addition, it was also found the greatest amount of fungi at the debarking sites. Then the highest concentration of fungi measured was about \(1.7 \times 10^4\) cfu/m\(^3\). Those were mostly *Penicillium* species. /6/

<table>
<thead>
<tr>
<th>Site</th>
<th>Species</th>
<th>Summer</th>
<th>Fall</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Debarking hall</td>
<td><em>Penicillium</em> sp.</td>
<td>++++</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td><em>A. fumigatus</em></td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Rhodotorula glutinis</em></td>
<td>++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td><em>Cladosporium</em> sp.</td>
<td>-</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td>Debarking control room</td>
<td><em>Penicillium</em> sp.</td>
<td>++</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>A. fumigatus</em></td>
<td>++</td>
<td>++</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Rhodotorula glutinis</em></td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td><em>Cladosporium</em> sp.</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

+ indicates the presence of >1,000 cfu/m\(^3\) in 25% of the samples, ++ >1,000 cfu/m\(^3\) in 26-50% of the samples, +++ >1,000 cfu/m\(^3\) in 51-70% of samples and ++++ >1,000 cfu/m\(^3\) in more than 71% of the samples.

**Figure 6:** Seasonal variation in the occurrence of major fungi on the debarking sites. /5/

The authors pointed out that this occurrence results from the abundance of molds in bark. Thus they added that this presence of bark should support the growth of microorganisms and can also explain the high endotoxin levels found.

Finally, all these exposures are a major problem for the industry and greatly increase the risks of disease of the workers. Moreover, further studies could be carried out in order to precisely know what could be provided or done to improve the security of these people.

### 3.3 Biochemical oxygen demand (BOD)

The biochemical oxygen demand (BOD) is the amount of oxygen used in the metabolism of biodegradable organics. In practical, BOD is a common indicator of the degree of contamination of water by organic pollutants.

According to the St. Marys Paper company /7/, which eliminated their wet debarkers to their process, the BOD of the effluent sent to the treatment plant decreases with the use of dry debarking.
4 THE WAYS TO CONTROL WOOD LOSSES

Wood losses are defined as the wood part going to waste in the debarking process. According to the most of the researches, it is the key factor affecting the technical and economical performance.

4.1 The main parameters to control

There are different theories concerning the parameters which affect this issue. In accordance with most of the studies, log cleanliness and wood losses depend on following variables:

- position of closing gate of the drum,
- rotating speed of the drum,
- capacity (flow through the drum),
- de-icing in the winter and water treatment in the summer,
- filling degree of the drum,
- debarking time,
- power consumption in debarking per the amount of wood,
- structure of the drum,
- wood properties.

However, as the author /8/ finds out, only the first four variables are independent in the practice.

One parameter present in many variables is the debarking time. The longer the logs are staying in the drum, the cleaner the logs are while wood losses increase.

In addition, the bark removal degree is calculated like in equation (1). /4/

\[
Y_{rem} = e^{-2.5} \times \frac{(S \times B)}{T^{1.5}}
\]

(1)

where \( Y_{rem} \) is bark removal degree,
- \( S \) bark to wood bonding strength, Lb/in.\(^2\),
- \( B \) bark thickness, in. and
- \( T \) barking time, min. .

The equation 1 means that the BWBS has to be known beforehand as well as the bark thickness of the logs entering the drum.

On the other hand, another author /4/ also proposes to quantify debarking losses with equation (2):
\[ Q_L = 100 \times \left( \frac{b_w b_b}{w_w Q_b} \right) \% \]  \hspace{1cm} (2)

where \( Q_L \) is wood loss, \( Q_b \) amount of wood coming to debarking, \( m^3/s/h \), \( w_w \) bound dry wood, \( kg/m^3 \), \( b_b \) bound dry bark, \( t/h \) and \( b_w \) bound dry amount of wood in the bark to the boiler, \( kg/t \).

In this case is as well needed clear information about the process. That means that devices of measurements have to be provided on the debarking drum.

In further studies, \( /9/ \) is using a pilot scale drum in order to analyse the debarking time in handling log flows. According to the authors, the debarking time correlates with wood loss and log cleanliness in the real process. Hence experiments were carried out in a pilot scale drum, with barking staves inside.

Then, some parameters were adjustable like the position of the closing gates, the angle declination of the drum and the rotating speed of the drum. The others factors were calculated, according to Piggot & Thompson (1987) like the residence time 3:

\[ \text{residence time} = \frac{\text{volume of wood in a drum}}{\text{flow rate of log through drum}} \]  \hspace{1cm} (3)

The filling degree was calculated by multiplying single sticks volume by their amount.

Because of the nonlinearities between variables, linguistic equation modelling method was selected. The parameter estimation is achieved using an equation (Juuso, 2004) based on the non-linear scaling of variables.

Then, models were analysed. Its manipulation clearly proves that the residence time of logs in the drum can be modelled only using the filling degree and the capacity. The inclusion of the other inputs does not improve results.

Finally, it was found out that a short residence time requires low filling degree and high capacity. However, the study didn’t take into consideration the fact that the real process used neither homogenous wood species nor homogenous diameters. \( /9/ \)

The wood losses are also identified on logs which are rounded at the ends, and on logs which broke in the drum. Furthermore, the study \( /10/ \) tried to investigate the relation between wood breakage and wood losses.

By doing measurements in three Finnish pulp mills, the authors \( /10/ \) observed that the increase in filling degree like the increase in rotation speed increase the amount of cut logs.
They explain that log breakage can generally be avoided by making so that impacts between logs were maximised. So they propose to use low filling degree and high rotation speed or to use high filling degree and low rotation speed. However, these hypotheses are not true for debarking of wood mixes of thinner and thicker logs. According to them, these mixes should be avoided to keep wood losses low.

In addition, they propose a calculation of the rate of wood losses regarding to dimensions of the logs:

\[ W_{L_{\text{max}}} = 1 - \frac{l \cdot \pi r^2 + \frac{4}{3} \cdot \pi r^3}{(l + 2r) \cdot \pi r^2} \]  

(4)

where \( r \) and \( l \) refer respectively to log radius and undamaged length of log.

### 4.2 Measuring of these parameters

#### 4.2.1 The filling degree

In a common mill practice, the calculation of the filling degree is based on a strain-gauge, which measures log weight and then convert it on volume content in the drum.

This strain-gauge typically measures the forces acting on the support structure. Nevertheless, reliable weight information is quite difficult to obtain in this way. Thus the measurements are disturbed by temperature. /11/

Consequently the author recommends using a transducer which directly measures the distance of the wood bed level through bark slots of the drum, as explained by the drawing on figure 7:

![Diagram](image)

**Figure 7:** Measurement of the filling degree using transducer 11. /11/
Transducer continuously obtains a signal reflecting the distance $E$ to logs rotating in the drum. Since the level in the drum is non-homogeneous, an average value is calculated. As the diameter of the drum is known beforehand, the height $H$ and so the filling degree can be calculated.

On the other hand, wood is a hygroscopic raw material. It means that its density varies according to its moisture content. Therefore for a fixed filling degree calculated, the weight would not be the same if wood is fresh or dry. This phenomenon is explained on figure 8.

![Figure 8: Influence of the moisture content on the filling degree.](image)

Accordingly, one author /13/ explains that the calculation of the filling degree can’t be only based on the top level of the log bunch or on the weight of logs rotating in the drum. Consequently, he proposes a method, illustrated by figure 9, based on both the information of weight and log level, in addition with intermediate calculations. These calculations would afterwards take into consideration other parameters like moisture content, length and diameter of logs.

This method consist in the followings steps:

- Computing of the torque ($M$) required for rotating the drum from the currents of the electric drive motor. (It can also be measured from the reduction gear support of the drive machine thanks to the manner shown on the patent /12/),
- The weight ($Q$) is measured conventionally as exposed herein,
- The length ($X$) of the torsional moment arm of the segment center of gravitation can be computed as in equation 5:

$$ M = QX $$ (5)
- For a known tumbling inclination angle ($\beta$) of the log bunch, the angle $\alpha$ spanned by the tumbling segment can be found on the basis of the equation 6:

$$\frac{X}{\sin \beta} = \frac{4R \sin^3 (\alpha/2)}{3(\alpha - \sin \alpha)}$$

\[ (6) \]

\textbf{Figure 9:} Measurement of the filling degree using trigonometry properties. /13/

- Finally, the filling degree could be computed from the value of angle $\alpha$.

Therefore, according to the author, all these parameters computed can be used in order to estimate the average density of the log bunch and further obtain information on the lengths and moisture content of the logs. In that case, Arvo Jonkka /13/ proposes to find the other information in accordance with the following equation:

$$\rho_1 = \left( \frac{L}{l} \right)^{\frac{1}{2}} \left( \frac{D}{d} \right)^{\frac{1}{3}} (1 + M) \rho_2$$

where $L$ is length of the longest log, $l$ is length of the shortest log, $D$ is the largest diameter of log, $d$ is the smallest diameter of log and $M$ is the moisture content of log (%).

In contrast, other author /14/ radically considers that there are so many variables to take into consideration that it’s not possible to do a correct measurement of the filling degree.
4.2.2 The weight

Herein, it is notified that the weight measurement was carried out by strain-gauge. It is also warned that this could be affected by temperature. Moreover, it seemed that the direction and magnitude of the drive torque rotating the drum affects the sensed weight. This hypothesis is discussed in patent application FI 942515.

According to practical tests, shaft transducers measuring shear stress would produce very accurate measurement results. In this way, Arvo Jonkka /13/ suggests to adapt these sensors two by two in parallel at opposite ends of the drum. Then, the measurements could be combined, and weight or changes in values will be computed.

He also advised that the torque support of the reduction gear may be equipped with this kind of shear-stress transducer.

4.2.3 The presence of material

In many applications, debarking processes needs to know the presence of material in a given location. For instance, one automatic system described further /15/ preferably places ultrasonic sensors at four locations: The drum feed conveyor, the debarking drum, the discharge conveyor, and the chipper feed conveyor. To his mind, these ultrasonic sensors are able to detect the presence and quantity of material.

On the other hand, other authors /11/ suggest measuring the wood content on the bark conveyor as wood loss and the bark content on the logs after debarking as the measure of residual bark. To carry out the measurements, a CCD or linear camera would be used. Then image analysis would be done in order to obtain the needed information. This measurement is based on the difference in colour between the bark and the wood. This type of technology is already used in several companies /16, 17/. Its device carries out over 700 measurements per hour.

Furthermore, Jyrki Laitinen /18/ proposes to crush the chip samples and then scan the crushed wood with a CCD line scan or area scan camera. This system, illustrated by figure 10, could avoid confusing between real bark and for example dark area, knots, dark spots caused by the logging machine or strong shadows in the image due to the overlapping of the individual chips.
Then, the images are segmented on the ground of tonal or spectral information to areas corresponding to sound wood and to bark. According to the author, thanks to a sufficient frequency of measurement, a good correlation could occur between the measured and real values of the bark content.

/14/ also proposes to control the debarking drum by measuring the amount of damaged logs in the log flow discharged from the drum. The damages that can occur on logs are the roundness at their ends, and their breakage. In this case, the measurement done by means of the image formed of each logs, refers the damaged logs as logs narrower than the expected value, and deviated from their expected cylindrical geometry.

The St. Marys Paper company /7/ is using one of this automated logs scanning in order to determine log size and also the amount of bark remaining on the logs. Their system apparently takes 50 images of each log in few microseconds. Thus, they can achieve trend analysis.
4.3 Suggestions for automatically control the debarking process

4.3.1 Arvo Jonkka’s method

This method claimed by Arvo Jonkka /13/, is the continuation of that previously explained in chapter 4.2.1 relative to the measurement of the filling degree.

On the first hand, a control computer obtains weight information from the support structure, and drive torque information from the support structure of the reduction gears. Then, according to the following chart (figure 11), and based on this information, the computer logic follows the next steps:

- Determining of the filling degree (as performed on chapter 4.2.1),
- Determining the average density of a log bunch tumbling in the drum (as performed on chapter 4.2.1),
- Calculating a target value for the log retention time,
- Controlling at least one of the following variables: drum rotation speed, the position of the discharge gate, the discharge rate of the logs, the infeed rate.

Figure 11: Chart of the control system logic. /13/

In addition, the author pointed out that depending of the application, the control computer could also use the feed and the discharge information from their respective sensor. The outfeed one could give information about the debarking result.

However, the author doesn’t precise the way of calculating or determining the suitable values.
4.3.2 Jouko Niinimäki’s method

The second method illustrated on figure 12 based on Jouko Niinimäki’s theory, deals with the fact that the amount of broken logs can be used to control the debarking drum /14/. Moreover, the control would occur thanks to several measurements carried out by one measurement unit according to the method explained in chapter 4.2.3.

![Diagram of debarking process]

**Figure 12:** Principle and position of measurement. /14/

Furthermore, this measuring device should measure the amount of bark, the amount of broken logs and possibly even the roundness of the logs and finally control the rotating speed of the drum. Therefore, the filling degree would also be measured.

The automatic system has to be carried out by maintaining the amount of bark on the logs at a fixed level. As a consequence the less bark there is in the discharge conveyer, the more efficient the debarking is.

Afterwards, the speed of rotation and the filling degree of the debarking drum are controlled by means of a known device.

Here is shown some examples of the logic:

- If the amount of damaged logs increases, lower the filling degree and compensate the debarking power with increasing the speed of rotation,
- If there are rugged logs, maximize the filling degree with minimizing the speed of rotation to prevent the wearing of the log ends,
- If there are long thin logs, keep the drumming power constant with increasing the speed of rotation and simultaneously lowering the filling degree, to maximize the wood contacts.

The author pointed out that this method has to be used for a control of debarking different sizes and species separately.
4.3.3 John P. Price and Robert Stone JR’s method

Herein, the authors /15/ commented the Jonkka’s method, and said that it requires an installation which involve re-working of existing debarking drum equipment and would also increase the cost of producing a new debarking drum. They therefore proposed a method that would overcome these re-working.

The method is based on three components:

- **programmable logic controllers (PLCs),**
  They would control the conveyers and the drum operations. They would furthermore control the times at which they may start, stop, accelerate, or slow down.

- **Look-up tables (figure 13),**
  These look-up tables are the main particularity of the invention. So, there are multiple sets of those which may each reflect factors that influence the operations. In this way, the variety of wood and the season of mill are for instance taken into consideration.

- **Implantation of sensors.**
  These sensors give information about the wood material presence and quantity at various places of the system. It is proposed to place it at the drum feed conveyer, the debarking drum, the discharge conveyer, and at the chipper feed conveyer.

<table>
<thead>
<tr>
<th>Table Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFC Infeed Delay (seconds)</td>
<td>60</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>PFC Delay to Stop (seconds)</td>
<td>60</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>PFC Infeed Sensor Depth (inches)</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>PFC Sensor Depth (inches)</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>Drum Slow Speed (rpm)</td>
<td>6</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Drum Fast Speed (rpm)</td>
<td>12</td>
<td>16</td>
<td>20</td>
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<tr>
<td>Drum Delay to Slow (seconds)</td>
<td>60</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>Drum Delay to Stop (seconds)</td>
<td>60</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>DDC Slow Speed (feet/minute)</td>
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<td>80</td>
<td>150</td>
</tr>
<tr>
<td>DDC Fast Speed (feet/minute)</td>
<td>150</td>
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</tr>
<tr>
<td>DDC Delay to Slow (seconds)</td>
<td>60</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>DDC Delay to Stop (seconds)</td>
<td>60</td>
<td>75</td>
<td>45</td>
</tr>
<tr>
<td>DDC Sensor Depth (inches)</td>
<td>12</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>CFC Slow Speed (feet/minute)</td>
<td>100</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td>CFC Fast Speed (feet/minute)</td>
<td>150</td>
<td>125</td>
<td>175</td>
</tr>
<tr>
<td>CFC Delay to Slow (seconds)</td>
<td>60</td>
<td>60</td>
<td>45</td>
</tr>
<tr>
<td>CFC Delay to Stop (seconds)</td>
<td>60</td>
<td>75</td>
<td>45</td>
</tr>
</tbody>
</table>

*Figure 13: Example of look-up tables. /15/*
Along with information given by the sensors, the PLC accesses data at specific rows within the look-up tables, and consequently controls the operations. In other words, the PLC has the different sensors as input, and generates output signals fed to feed conveyer motor, debarker drum motor, discharge conveyer motor, and chip feed conveyer motor.

The values included in look-up table (figure 13) are limit or reference value to respect for the different criterion it contains. They are determined empirically from the debarking apparatus capacity and from the programmer’s experience.

One table is proper to a particular operating session and is chosen by the operator through computer.

For instance, one table could correspond to one wood species or one season.

The values are continually compared with sensor information according to the computational logic illustrated by flow charts. Moreover, the author provided one flow chart for each measurement point.

Figure 14 illustrates an example of the drum sensor flow chart.

![Drum sensor logic flow chart](image)

**Figure 14:** Drum sensor logic flow chart. /15/

Finally, the authors indicated that the invention is providing components that have the advantage to save energy since they slow down or stop equipment that are not in use.
5 MACHINE DEVELOPMENT

This next chapter is describing in detail some apparatus achieved to reduce wood losses. Otherwise, some other machinery of several companies are briefly presented in articles /16, 19, 20, 7, 21/ (Metso Paper), /22, 23/ (Andritz), /17 and 24/ (Teknosavo).

5.1 Debarking drum with covered bark slots

This machinery /25/ has been more particularly developed in order to debark logs which have a thick stringy bark.

In this apparatus (figure 15), drum has a multiplicity of slots with different sizes. Some of them, larger than normal, have a minimum width of 3.5 inches (88.9 mm), and the other preferably 6 inches (152.4 mm), with a length of about one or two feet (609.6 mm).

22 – Debarking drum  44 – Bark slots
22 – Cylindrical shell  46 – Covers
24 – Cylindrical surface  47 – Sticks
26 – Exterior surface  48 – Covers central section
32 – Logs  50 – Short legs
34 – Lifters  52 – Inside surface of the slot cover
36 – Wall  57 – Lateral slots

Figure 15: Drum with covered bark slots. /25/

The largest slot has a cover located on the exterior surface of the drum. Each cover has a shallow U-shaped member which extends about one to one-half inches on either side of the slot.
The quantity and location of the bark slots are determined by the drum size.

This function combined with the tumbling action of the logs and the slab of bark moving through the slot will tend to be broken into smaller pieces which can then pass through the slots.

In this way, thick fibrous or stringy bark could be separated from the logs. Furthermore, sticks and long log pieces are prevented from passing through the large slots.

## 5.2 Drum discharge spool

The wood losses are primarily due to logs breakages in the drum. This phenomenon is the result of entanglement of logs with each other which takes place at the end of the drum.

This present invention provided according to his author /26/ an efficient manner to exit the logs from the drum. The apparatus (figure 16), called “Drum Debarker Discharge Spool”, helps to pull the wood out of the debarking drum and put it into the discharge chain conveyer located level with the lower lip of the drum. This last conveyer remains the wood parallel through and out of the drum.

Thanks to plates with irregular surface rising above the conveyer surface, the short and long logs are grabbed and moved onto the discharge conveyer.

This system was carried out to decrease the amount of wood breakage and to more efficiently control the flow of wood into the chipper.

**Figure 16:** Drum Debarking Discharge Spool. /26/
5.3 Drum using ridge-like protrusions

This invention /27/ provides a drum and drum equipment which permit an efficient debarking of logs. The apparatus (figure 18) is composed of a number of blades on the inner surface of the drum which can be replaced. Each blade is comprised of a blade disc (figure 17) provided with teeth and rotates around its central axis.

![Figure 17: Blade disc of the debarking drum. /27/](image)

These blades tear the bark and make transverse cuts in the bark at suitable intervals.

Furthermore, ridge-like protrusions winding in a spiral manner are arranged on the surface of the inner sleeve. Therefore, the blades are arranged in such a way that when the drum rotates and the logs rest on the ridge-like protrusions, the blades will tear the surface of the log and so cut the bark.

![Figure 18: Debarking drum with ridge-like protrusions. /27/](image)

On the other hand, the speed of rotation of the drum has to be so high that the centrifugal force will cause an ejection movement of each logs and then bring out an increase of the forces directed at the bark. Consequently, the debarking is further intensified.
5.4 Drum with different spaces of treatments

This kind of apparatus (figure 19) /28/ is performed for debarking logs which break easily. It is characterised by an inner member inside the drum. This member is arranged to divide the space of the drum into a treatment space and the space remaining outside it.

Since the logs are fed to travel through the drum via treatment space, they will pass through in a substantially more parallel manner.

![Debarking drum with different spaces of treatments](image)

2 – Central axis  
3 – Drum  
4 – Inner sleeve  
5 – Inner member  
6 – Treatment space  
7 – Space  
8 – Slot  
9 – Bark space  
10 – Blade  
11 – Wheels  
12 – Supporting bearing  
13 – Actuator  
14 – Beams  
15 – Actuator  
16 – Supporting bearing  
17 – Wall  
18 – Wedge-like beak

**Figure 19:** Debarking drum with different spaces of treatments. /28/

This inner member is held at both ends by means of suitable beams and supported bearing on the framework of the apparatus. An actuator, attached to the framework, locks it in its normal position. The inner member design forms a wall shaped as a wedge-like beak. In this way, the rotary movement of the drum will force the logs to move in the same manner. However, the drum is equipped with ridge-like protrusions as seen herein.

Afterwards, a slot is provided between the wedge-like beak and the inner sleeve in order to discharge bark from the treatment space to the space on the opposite side of the wall. Then, bark in the bark space is arranged to discharge automatically by means of some device.
5.5  **Apparatus for varying the rate of debarking**

5.5.1  **Apparatus with activation plates**

Here, the author /29/ pointed out that a drum equipped on its inner surface with a traditional sequence of longitudinal flights suffers from its weak ability to control and vary the rate of debarking.

Consequently, the present apparatus is provided for debarking drum (figure 20) with variable debarking action by carrying out an abrasive debarking surface into the drum to increase the rate of debarking. On the other hand, the apparatus can be moved into a retracted position to minimize contact with logs so to decrease the rate of debarking.

![Diagram](image)

**Figure 20:** Debarking drum with activation plates. /29/

Furthermore, the device includes on the inner surface a plurality of fixed flights with an L-shape cross-section. These flights act to lift logs into the drum interior.

It also includes additional debarking projections comprising at least one movable debarking surface and positioned below the level of the top edge of the fixed flights. One plate is formed with three projections.

2  – Drum  
10  – Inner surface  
12  – Flights

20  – Debarking apparatus  
40  – Activation plate  
56  – Rollers
There are then two ways of debarking. First, the plates are positioned such as their retracted position, and so the logs tumbling will tend to contact the top edges of flights which will debark the logs at a lower rate.

Secondly, the movable debarking plate can be displaced away from the inner surface, in such a way that they are located above the level of top edge of flights by a fixed distance. Therefore, log tumbling will tend to contact the abrasive edges of debarking plates which will increase the rate of debarking.

The activation of the system is carried out by an activation plate at the outer surface of the drum connected to the movable debarking plate. The activation is effected via a plurality of connecting rods.

The various operating positions are established by moving rollers which are rotary element engaging the activation plate.

According to the author, the operating position could be performed automatically. Nevertheless, this subject is not discussed in the present patent.

### 5.5.2 Apparatus for reversible rotation drum

This apparatus aims at overcome the drawback already explained herein concerning the traditional debarking drum. It however only concerns the drum that can rotate in different directions.

Moreover according to this patent /30/, the choice of the feel rotation makes the desired aggressiveness of debarking. In addition, it means that when logs are easy to debark, the drum rotates in a direction such that log to log contact and simple contact with the drum walls and flights are achieved. Alternatively, when bark is difficult to remove, the drum (figure 21) rotates in such a direction that the logs are exposed to an additional debarking element.

The carrying out of this system is provided by swivable plates with an abrasive surface that is exposed or concealed depending on the direction of rotation.
Besides, the apparatus alternatively includes a movable cover that covers or exposes a fixed abrasive surface depending on the direction of rotation. In this case, the movable plates take account of a counter-weight involving their sliding to the exposed or covered position due to gravity on rotation of the drum.
6 CONCLUSION

The recent studies concerning the debarking have been presented.

First, it has been established that the conditioning of the logs is very important and can have a dramatic influence on the debarking results. Indeed, the bark wood bond strength is different depending on the wood species and is higher when the logs are dried, and is affected by the temperature when the moisture in logs is high.

Moreover, the control of the process was discussed and many researchers’ opinions are diverging. However, some of them agree with the fact that a minimum of parameters have to be handled. Consequently, few studies focused on the filling degree measurement and others developed concepts of detecting logs decays or bark in chips by means of image analysis.

On the other hand, many authors agree that the best way to minimize wood losses is to debark the different sizes or species of logs separately. In accordance with this choice, some automatic logics to control the process have been proposed.

Conversely, in order to overcome the costs and re-workings that this kind of installation could involve, it was proposed a method based on the use of look-up table which could take into consideration several parameters like species.

In addition, various apparatus have been proposed like drums varying the rate of debarking as well as discharge tools aiming at help the logs moving through the drum in a substantially more parallel manner.

Otherwise, it has been noticed that the debarking process plant, because of exposure to endotoxin and fungi, can be a risky place for workers health.
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