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# Low intensity refining of hardwood and deinked pulps with a new type of filling in a double disc refiner

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## Abstract

Refining plays an important role in stock preparation as well as throughout the compolete paper making process. Next to raw material selection, it has the greatest influence on produce quality. This high ranking in the process means it is all the more important to operate with the optimum machine, equipped with the optimum type of filling.

The paper presents the refining of several hardwood pulps (eucalyptus, birch and mixed tropical hardwood) as well as recovered fibres using a new generation of filling. The new type has a finer bar width and narrower grooves, resulting in increased cutting edge length.

The plate design secures a reduction in specific edge load and no-load power as well as operation under low intensity conditions. The benefit for the papermaker is increased refining effeciency and reduced total specific refining energy.

Trials with different cutting angles, bar widths and specific edge loads were undertaken. It was found that for low intensity, low energy refining the optimum plate design for reaching high strength properties on eucalyptus and birch is a cutting angle of 40º rather than 60º as well as the finest possible bar width. A specific edge load below l.0 J/m proved to be the best.

To obtain optimum strength properties with low intensity refining for mixed tropical hardwood, a higher cutting angle than for other hardwood pulps is required as well as very low specific edge loads.

Trials were also carried out with deinked pulp, showing optimum results with a smaller bar width, a high cutting angle and very low specific edge loads.

## 1. Introduction

Refining plays an important role in stock preparation as well as throughout the complete paper making process. Next to raw material selection, it has the greatest influence on final product quality.

This high ranking in the process makes it all the more important to operate with the optimum refiner, equipped with the optimum type of fillings and under optimum refining parameters. To meet growing demands for low intensity refining, a new plate design secures a reduction in specific edge load (= low intensity refining) and no-load power. Resultant benefits for the papermaker are higher refiner efficiency and lower total specific refining energy, as well as better paper quality.

This paper describes the refining of several hardwood pulps (eucalyptus, birch and mixed tropical hardwood) as well as recovered fibres such as deinked pulp, using the new generation of fillings. For this purpose optimization trials were carried out with different cutting angles, bar widths and specific edge loads.

## 2. Basics

### 2.1. Why low intensity refining?

Pulp market surveys show that in the future the demand for paper and board will increase (1) . The biggest increase will be in recovered fibre stock, while virgin pulp will increasingly originate from hardwoods, particularly fast-growing species from plantation areas in Asia (2) . Industrial requirements are responsible for this development. It is a fact that more and more short-fibre hardwood pulps are being used, not only due to their excellent optical properties (good opacity) and improved surface characteristics (good printability) but also due to their low costs. With this increasing use of hardwood pulps, the importance of refining similarly increases. Today, these pulps can secure high strength properties, but the papermaker needs to reach the best possible overall result with the furnish. Due to the high strength properties of hard-wood pulps, the proportion of softwood pulps in paper products can be reduced. For optimum results with this type of furnish, refining conditions have to be modified.

Hardwood pulps have shorter and thinner fibres than softwood pulps, and their resistance against refining load is much lower. Likewise, secondary furnishes have a relatively low refining resistance, since most of the fibres have been refined previously. Furthermore, each recycling process generally has a weakening effect on most fibres. For this reason, refining of hardwood and secondary furnishes should be very gentle, requiring low intensity refining with a low specific edge load (SEL). Energy input should be very low. This optimally exploits the papermaking potential of the fibres, primarily by minimizing, or even avoiding any further shortening of fibres. This is a very important requirement for high tear strength, which rapidly diminishes with a high SEL when refining secondary fibres.

On the other hand, higher demands on printability mean higher surface quality requirements (3) . This particularly applies to secondary fibre stock preparation for improved newsprint, SC and LWC grades. To improve surface quality, the R14 content in deinked pulp from recovered household paper must be reduced, in other words any remaining coarse TMP fibre bundles have to be broken down (Fig. 1).

Another purpose of refining in recovered paper stock preparation is to improve the main technological properties of recycled fibres. A good many of these have a high potential which can be exploited by refining, thus correcting the negative effects (such as on swelling, flexibility, and bonding potential) of fibre treatment in previous recycle stages. Since the objectives of refining recycled fibres depend on the end product and the kind of recovered paper used, refining applications vary widely.

Further important requirements of the industry are savings in refining energy and longer lifetime of fillings, thus reducing operating costs.

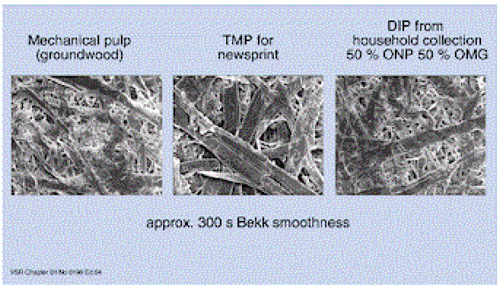


Fig. 1: Scanning electron microscope photos of calendered Rapid-Köthen test sheets, showing different furnishes

**2.2. What does low intensity refining mean?**

The technological results and cost of refining depend on the intensity and frequency of the fibre treatment. Fibre treatment conditions are best described by the key figure "specific refining energy" expressed in kWh/t or HPD/T. Specific refining energy is the quotient of net/total power and mass flow of stock. It can be understood as the product of intensity and frequency of fibre treatment. However, specific refining energy is not adequate for exact description of the refining process or prediction of refining results. For this reason, several other key figures have been worked out to describe intensity and frequency of refining. Meltzer and Sepke (4, 5) give a good overview of these key figures.

A globally acknowledged measure of refining intensity is specific edge load (SEL) as defined by Brecht and Siewert (6) . As indicated by the name, the work done by the bar edges plays a dominant role in the process of fibre treatment. This key figure for predicting refining results is calculated from the net refining power (P e ) and the cutting edge length (CEL).

$$\mathrm{SEL\ (J/m)} = \frac{\mathrm{P\ e\ (kW)}}{\mathrm{CEL\ (km/s)}}$$

Net refining power is the difference between total refining power and pumping power (no-load or idling power in water) of the fillings.

The CEL is derived from the number of rotor and stator bars, the average bar length, and the rotational speed of the refiner.

$$\mathrm{CEL\ [km/s]} = zR\ .\ zS\ .\ l\ .\ n/60$$

where: z R = number of rotor bars
z S = number of stator bars
l = length of bars [m]
n = rotational speed [rpm]

The higher the specific edge load, the more fibres are shortened, while a lower value has a more pronounced fibrillation effect.

For refining under low intensity conditions, there are two possibilities:

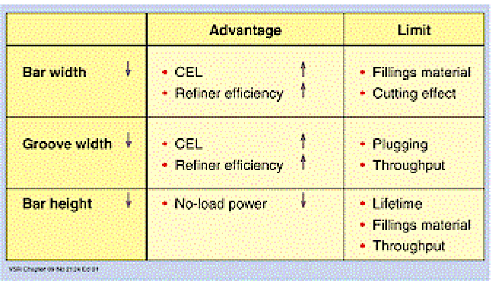
1. Reduce refining power
2. Increase cutting edge length

Reducing refining power results in poor efficiency, with the result that more machines are required for attaining a given refining result. To increase CEL, more bar length is required, and therefore finer bar widths and/or narrower grooves are necessary.

Another geometrical parameter influencing refining results directly is the cutting angle. The results presented in this paper therefore also refer to the cutting angle.

**3. Requirements of a new generation of fillings**

What are the requirements for fillings suitable for low intensity refining of short-fibre pulps?



| | Advantage | Limit |
|---|---|---|
| Bar width ↓ | • CEL ↑<br>• Refiner efficiency ↑ | • Fillings material<br>• Cutting effect |
| Groove width ↓ | • CEL ↑<br>• Refiner efficiency ↑ | • Plugging<br>• Throughput |
| Bar height ↓ | • No-load power ↓ | • Lifetime<br>• Fillings material<br>• Throughput |

Tab. 1: Fillings for low intensity refining

As shown in Table 1, bar width should be as fine as possible and groove width as narrow as possible. This results in a high cutting edge length. Due to material strength considerations, the bar width can only be reduced to a limited extent. Material strength is also affected by bar height, since the lower the height, the finer the bars can be. Another advantage of a low bar height is a low no-load power. On the other hand, bar height must be sufficient to secure the required high throughput and an adequate service life. The latter factor is particularly important since secondary raw materials are generally more abrasive than primary fibre stocks due to their high filler content.

To avoid excessive fibre shortening, bar width should not be reduced beyond a certain minimum limit. Overlooking this fact could counteract the positive effects of increased cutting edge length or lower specific edge load.

Another important aspect to be considered in connection with groove width is the risk of plugging, which depends on the type of fibres and their condition. The highest risk is with long and unrefined fibres.

In all cases, the cutting edge length must be extremely high in order to keep the ratio of no-load power to total refining power as low as possible at relatively low specific edge loads. Fig. 2 shows the key factor of no-load power as a function of refiner efficiency. Assuming constant no-load power, fillings with a higher cutting edge length are much more efficient. For the same efficiency using 3 mm bar width fillings as with 2 mm bar width fillings at 0.8 J/m, SEL increases to 1.5 J/m. In other words, for a given SEL the amount of refining power transferable with a finer fillings design therefore has to be increased.

**4. Trial conditions**

Trials were carried out in the Research and Technology Centre of Voith Sulzer Stock Preparation in Ravensburg / Germany. Fig. 3 shows the refining plant and test conditions.

The refining plant consists of a 7 m$^3$ pulper, two chests with 9 m$^3$ each and an industrial size double disk refiner (fillings diameter: 20 "). Refining trials were carried out at stock consistencies between 4 and 5 %, and flow rates between 360 and 2100 l/min, depending on the desired specific energy input per pass. All trials were made in changeover chest mode. For each trial, 250 kg o.d. pulp were slushed with fresh water for 10 minutes at a stock consistency of about 6 % and a temperature of approx. 30 - 35 °C. The net refining power set-point is calculated from the desired SEL and the CEL of the fillings. By adding the no-load power measured in water, the total refining power is arrived at as refiner control parameter.

Refining power is controlled by varying the refining gap between rotor and stator plates. Throughput is calculated from the desired specific refining energy per pass.

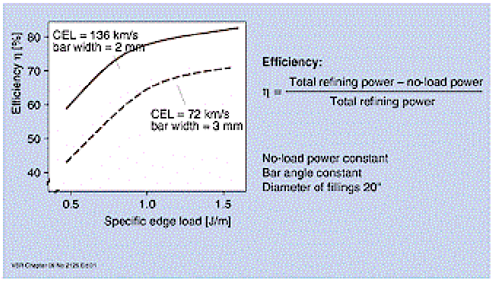


Fig. 2: Influence of cutting edge length (CEL) on refiner efficiency

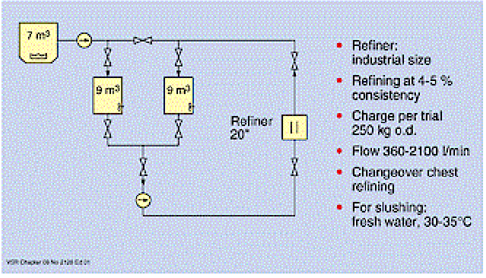


Fig. 3: The refining plant and specific trial conditions in the Voith Sulzer Research and Technology Centre, Ravensburg / Germany

**The double disk refiner**

Fig. 4 and Fig. 5 show the new Voith Sulzer TwinFlo E double disk refiner. Five different sizes are available, each with four different fillings diameters. The installed motor power range is up to 3000 kW. An integrated plate changing device ensures quick and easy exchange of fillings.

The stock flowing into the machine is distributed evenly between the two refining gaps between stator and rotor. As the suspension moves through these gaps towards the periphery, the fibres are refined between the fillings of the rotor and the two stators before leaving the machine. The rotor is hydraulically self-centering thanks to free axial movement on the spline shaft.

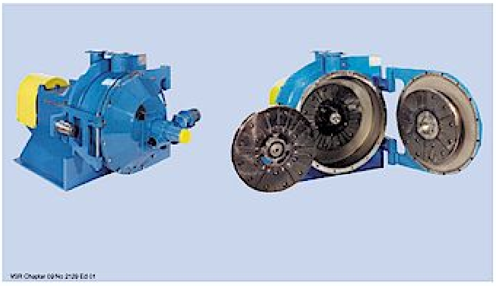


Fig. 4: The Voith Sulzer TwinFlo E refiner

This arrangement secures precision parallelism of the refiner fillings and provides a highly efficient and uniform fibre treatment. To adjust the refining gap, an electromechanical device moves the stator in the axial direction, which also adjusts motor power. If there is no stock flow, the electromechanical adjusting device provides a high speed release system.

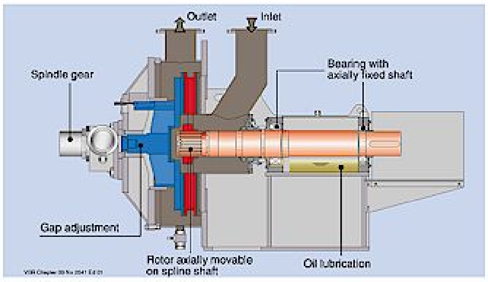


Fig. 5: Cross section through the TwinFlo E refiner

**Trial procedure**

Extensive trials with different types of fillings were undertaken.

Trials with different bar and groove widths and various cutting angles were carried out at different specific edge loads. The aim of the trials was to find the optimum parameters for obtaining best technological results with various furnishes.

Energy input during the trials was deliberately higher than in a typical mill application. Results presented here summarize the main findings of numerous trials and concentrate on the following:

- Comparison of two cutting angles (40 ° and 60 °)
- Comparison of two bar widths (2 mm and 3 mm)
- Comparison at different specific edge loads.

Fig. 6 shows the types of fillings used for these trials.

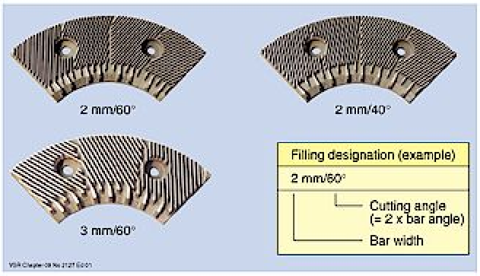


Fig. 6: Refiner fillings used for the trials

To avoid misunderstandings, Fig. 7 shows the Voith Sulzer definition of mean bar angle a, where the bar angle is measured on the centreline of a sector relative to the radius. The sum of rotor and stator bar angles aR and aS represents the fillings cutting angle c. To be absolutely correct, it should be taken into account that both these angles are a function of fillings sector angle b and change accordingly during rotation. The practicability of this key figure (mean bar angle) would then be seriously reduced, however. The sector angle b should therefore be as small as possible. This theme is treated in detail by Joris (7, 8).

The hardwood furnish used comprised Scandinavian ECF bleached birch, Portuguese eucalyptus and mixed tropical hardwood from Indonesia. The deinked pulp (DIP) was a mixture of 50 % recovered newsprint (ONP) and 50 % magazines (OMG). There are many different types of DIP, containing different furnishes from different sources. In the trials a typical DIP mixture was used. Before refining, the deinked pulp was cleaned at high consistency, then holescreened and flotated.

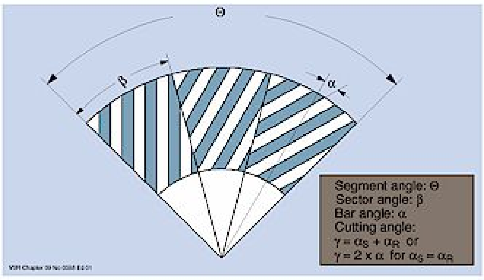


Fig. 7: Definition of bar angle

## 5. Results

### 5.1. Cutting angle

*Eucalyptus / birch*

Fig. 8 shows the influence of cutting angle on tensile strength for the two hardwood pulps birch and eucalyptus.

The trials were carried out under low intensity conditions, with 0.6 J/m SEL and 2 mm bar width. As shown by this comparison, better results are attained for both pulps with a cutting angle of 40 ° rather than 60 °. With birch, for example, a given tensile strength of 70 Nm/g is reached at a lower Schopper-Riegler value (28 SR with 40 ° and 33 SR with 60 °), and less refining energy is required (180 kWh/t instead of 210 kWh/t total specific energy).

As shown in Fig. 9, a cutting angle of 40 ° results in higher bulk and opacity for a given tensile strength. At high tensile strength values, there is no further increase in strength, but bulk and opacity rapidly decrease.

*Mixed tropical hardwood*

The tensile strength characteristic for mixed tropical hardwood indicates that contrary to experience with eucalyptus and birch, best results are achieved with a cutting angle of 60°, also under low intensity conditions, this time with an SEL of 0.8J/m (Fig. 10).

As far as total specific energy is concerned, refining with a cutting angle of 60 ° is much more efficient with this stock.

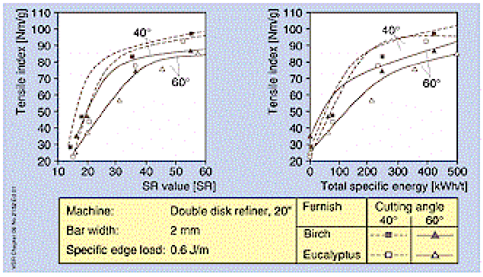


Fig. 8: Influence of cutting angle on tensile strength for hardwood pulps

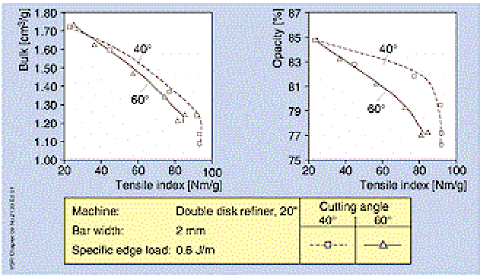


Fig. 9: Influence of cutting angle on bulk and opacity versus tensile strength for eucalyptus

Very often another factor with hardwood pulps is their vessel cells. These cells are the cause of offset printing defects, often known as vessel picking 9 . Vessel cells are very flat, flexible and about 0.5 -1.0 mm long. Fig. 11 shows an unrefined vessel cell present in mixed tropical hardwoods.

Their flexibility makes the vessel cells impossible to fractionate and difficult to reduce in size. In the forming section of the paper machine, these cells collect on top of the sheet and can cause problems during the coating process or later. During the printing process, the vessel cells are picked out and adhere to the surface of the rolls in the printing machine, thus causing missing dots. There is, however, a possibility of reducing vessel picking (Fig. 12).

With suitable fillings the z-strength of the paper can be increased in such a way that the vessel cells are kept in the paper plane. Refining with a cutting angle of 60° gives the best results. Two examples of vessel picking - small white defect areas where ink has failed to transfer in offset printing - are shown in Fig. 13.

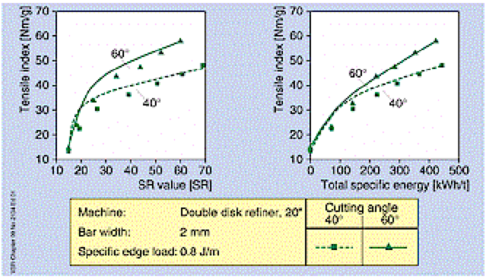


Fig. 10: Influence of cutting angle on tensile strength for mixed tropical hardwood

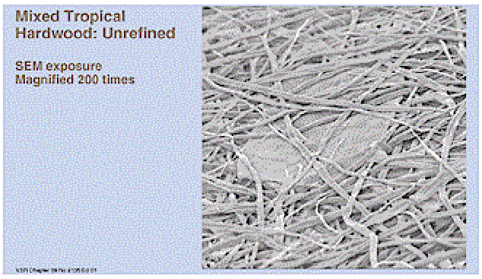


Fig. 11: A vessel cell in mixed tropical hardwood

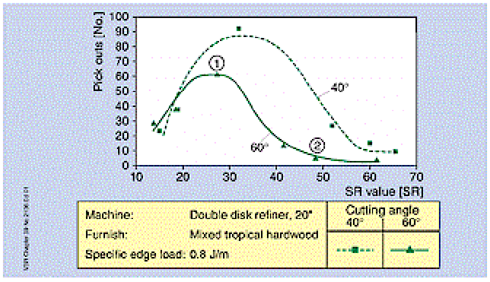


Fig. 12: Influence of cutting angle on development of vessel picking for mixed tropical hardwood

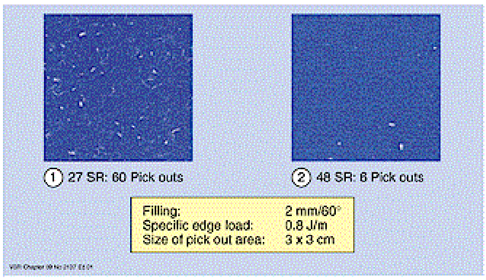


Fig. 13: Results with vessel picking test on mixed tropical hardwood

**Deinked pulp**

As shown in Fig. 14 the optimum cutting angle for obtaining good strength properties is 60 °. Refining with 40 ° requires a higher Schopper-Riegler value and more energy for a given tensile strength than with a cutting angle of 60 °.

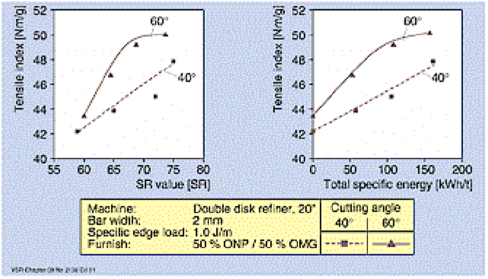


Fig. 14: Influence of cutting angle on tensile strength for deinked pulp

Results of the influence of cutting angle in the low intensity refining of hardwood pulps such as eucalyptus and birch show that the optimum cutting angle for high strength properties and low specific energies is 40°. This is not, however, valid for all furnishes. For refining mixed tropical hardwood and deinked pulp a higher cutting angle around 60° is required.

One reason for this may be that mixed tropical hardwood and deinked pulp both give a less resistant furnish. The cutting angle has almost no impact on fibre shortening for eucalyptus and birch pulp, but with mixed tropical hardwood and deinked pulp, the cutting angle of 40° has a much higher shortening effect than the 60° angle.

### 5.2. Bar width

To operate successfully with a finer bar width, it is important to know the influence of bar width on refining results.

*Eucalyptus*

As shown in Fig. 15, the reduction in bar width from 3 mm to 2mm leads to slightly higher tensile strengths with eucalyptus. The cutting effect with finer bars is somewhat higher, but as far as total refining energy is concerned, efficiency is much lower with a fillings bar width of 3 mm. Bar width influences tensile strength development less than cutting angle. Fillings with 2 mm bar width and 40° cutting angle result in higher strength properties than 3 mm/60°fillings. Refining of birch shows the same trends.

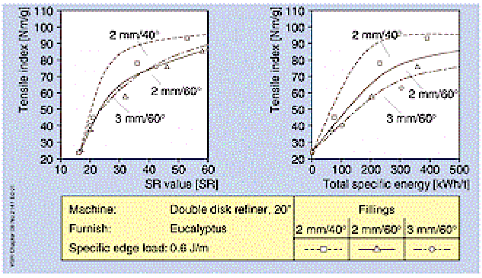


Fig. 15: Influence of bar width and cutting angle on tensile strength for eucalyptus

*Mixed tropical hardwood*
Fig. 16 shows that with a cutting angle of 60 °, the influence of bar width on mixed tropical hardwood refining results is not very high in terms of tensile strength. With wider bars, the increase in tensile is rather more, but much more energy is required to reach a given tensile level. This is due to the low CEL of the fillings, where the ratio of no - load power to total refining power is higher.

It can be concluded from this trial series that bar widths have little or no influence on strength properties, but refiner efficiency is greatly improved by finer bars (high CEL).

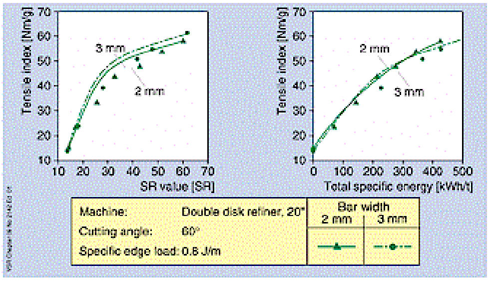


Fig. 16: Influence of bar width on tensile strength for mixed tropical hardwood

### 5.3. Specific edge load

*Eucalyptus/birch*
Trials on eucalyptus and birch with different specific edge loads were conducted with fine bars (2 mm bar width) and a cutting angle of 40°. With lower refining intensity, the increase in tensile strength is greater (Fig. 17).

The higher SEL of 1.2 J/m results in a slightly faster initial increase in tensile for birch, but at a certain point, however, there is virtually no further increase at all. This standstill in tensile development is due to so-called overloading. Other strength properties react similarly. For eucalyptus, an SEL of 1.2 J/m is too high over the entire range and strength development is inferior. A lower SEL is more economical.

*Deinked pulp*
Trials on deinked pulp with different specific edge loads (0.5J/m, 1.0 J/m and 1.5 J/m) were carried out with fine bars (2 mm bar width) and a cutting angle of 60 °. As shown in Fig. 18, the lower the SEL, the higher the tensile strength attained. In terms of specific energy, there is virtually no difference in tensile strength up to an energy consumption of 50 kWh/t. With further refining, however, the higher intensity leads to higher Schopper-Riegler values, which means reduced dewatering on the paper machine and reduced production capacity.

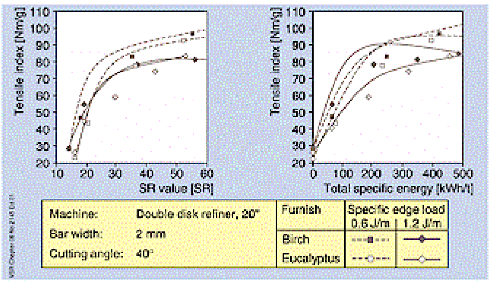


Fig. 17: Influence of specific edge load on tensile strength for hard-wood pulps.

With high intensity refining (1.5 J/m) the development in tensile versus total specific energy shows the same overloading tendency as previously established with birch. Refining with an SEL higher than 1.0 J/m is therefore uneconomical and leads to lower strength properties for this kind of deinked pulp.

Fig. 19 shows that with higher refining intensities, development in tear strength decreases faster. For a minimum reduction in tear strength, the optimum setting is at the lowest refining intensity. The advantage of high tear strength values is better runnability of the paper and printing machines.

### 6. Conclusion

With optimum refining equipment, there is no problem in meeting the paper industry's requirements for refining lowresistance fibres. Refiner operation should be at low specific edge loads below 1.0 J/m (low intensity refining) and fillings should have a high cutting edge length. Optimum cutting angles vary according to furnish, and have to be established by carrying out trials.

Eucalyptus and birch hardwood pulps, for instance, require a cutting angle of 40 °, whereas mixed tropical hardwood and deinked pulp should be refined with a cutting angle of 60 °. The influence of cutting angle on development in strength properties is much higher than the influence of bar width. The final result is optimum strength and optical properties, higher refiner efficiency and low specific refining energies (Fig. 20).

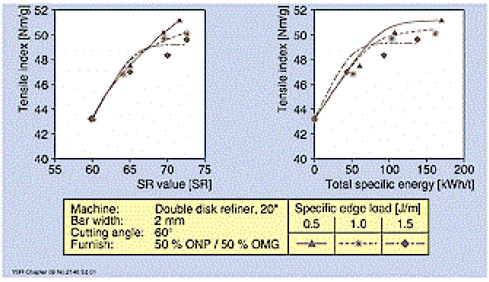


Fig. 18: Influence of specific edge load on tensile strength for deinked pulp

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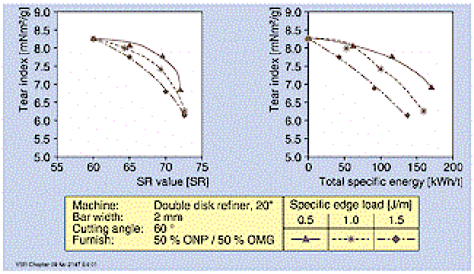

Fig. 19: Influence of specific edge load on tear strength for deinked pulp

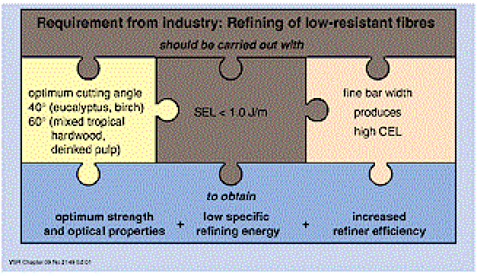

Fig. 20: Summary

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