

## **NEW POSSIBILITY FOR ANALYSIS OF FIBRE PROPERTIES AND OTHER OBJECTS LIKE SHIVES AND VESSEL CELLS IN RECYCLED FIBRE MIXES**

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### **RESUMEN**

Nuevos analizadores de fibra basados en microscopios computarizados combinados con análisis de imágenes abren las posibilidades de medir también otros objetos que no son fibra en la pulpa/pasta como shives, células vessel y tinta. El L&W Fiber Tester ha sido usado para detectar y clasificar objetos más anchos que las fibras en una planta de papel periódico con 50% de material reciclado y 50% TMP. El método de referencia fue almacenar imágenes capturadas del analizador y clasificar en forma manual todos los objetos y entonces compararlos con análisis automático basado en criterios seleccionados. Fue difícil lograr conformidad total entre inspección manual y clasificación automática pero los resultados dieron la impresión de ser relevantes. Una segunda prueba se basó en preparar mezclas de pulpa con proporciones conocidas de pulpa reciclada y pulpa virgen de maderas duras y compararla con la mezcla del análisis automático. Se encontró buena conformidad entre las células vessels automáticamente detectadas y la proporción de pulpa de madera dura en la mezcla. El propósito de la investigación fue principalmente ver si las células vessels de maderas duras como Eucalipto y Acacia con células vessels con ancho conocido y con frecuencia más críticas podían ser detectadas. La conclusión fue que las células vessels anchas mayores de 100 µm pueden ser detectadas. Estas probablemente son las más críticas también.

Fibra, fibra secundaria, vaso célula, imagen, análisis

### **ABSTRACT**

New fibre analysers based on computerized microscopes combined with image analysis open up possibilities also to measure other objects than fibres in the pulp/stock like shives, vessel cells and ink. A L&W Fiber Tester has been used to detect and classify objects wider than the fibres in a newsprint mill based on 50% recycled matter and 50% TMP. The reference method was to store collected images from the analyser and manually classify all objects and then to compare with automatic analysis based on selected criteria. It was difficult to get a complete conformity between manual inspection and automatic classification but the results seemed to be relevant. A second test was based on that pulp mixes with known proportions of recycled pulp and virgin hardwood pulp were prepared and compared with automatic analysis of the mix. Good conformity was found between automatically detected vessel cells and proportion of hardwood pulp mixed in. The purpose of the investigation was mainly to see if vessel cells from hardwoods like Eucalyptus and Acacia with known wide and often more critical vessel cells could be detected. The conclusion was that wide vessel cells above 100 µm can be detected. These are probably the most critical ones as well.

Recycled, fibres, vessel cells, image, analysers

### **INTRODUCTION**

An increasing potential problem for many paper producers is vessel cells with poor bonding properties from certain hardwoods. The hardwood portion of recycled fibres will increase in Europe because of new pulp capacity from other parts of the world. To be able to evaluate the impact of the vessel cells in an optimal way there is a need to be able to measure them. New fibre analysers based on computerized microscopes combined with image analysis open up possibilities also to measure

other objects than fibres in the pulp/stock. The vessel cells are optical thin and sometimes difficult to detect. It is often a problem to distinguish them from some other objects in the pulp. It is also a big variation in the dimensions and properties of the vessel cells themselves. The standard fibre analyser **L&W Fiber Tester** is well suited for detection of this type of elements. With new image analysis based functions it is also possible to measure vessel cells from hardwoods in mixes with other pulps and to distinguish between different types of hardwoods.

In hardwoods water is transported in separate vessels. Characteristic vessel cells for different species are found in the pulp. 7-29 % of the *wood volume in hardwoods is reported to be* vessel cells. 1-4 % of the *weight* is estimated to be vessel cells. Certain types of vessel cells can cause trouble because of poor bonding to the sheet. Some types of vessel cells are more problematic than others. Wide and short vessel cells are considered more dangerous. If so these vessel cells will be both easier to measure and to remove from or treated in the process. Such vessel cells are found in acasia, eucalyptus and oak. Vessel cells from birch and aspen are more narrow and long in comparison. These are not known as problematic, probably because they are entangled in the fibre network. Concentrated and dried vessel cells looks like a powder. The strength potential is very low.

It is difficult but not impossible to separate the vessel cells from the pulp or to eliminate them by refining.



*Figure 1. Eucalyptus vessel cells in pulp (hydrocyclone inject, Noss)*



*Figure 2. Eucalyptus vessel cells in hydrocyclone reject (Noss)*

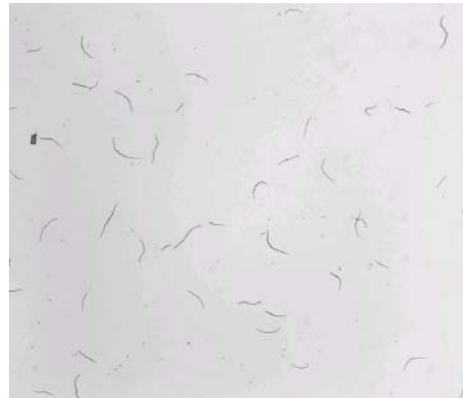
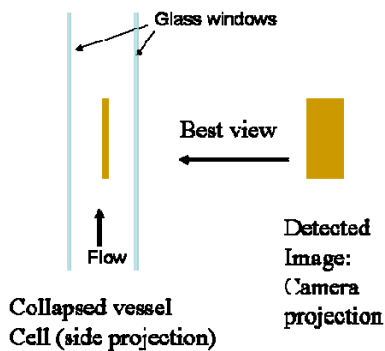
Vessel cells in eucalyptus pulp are shown in figure 1. Note that they are significantly wider than the fibres. They are also much fewer.

In figure 2 is shown eucalyptus vessel elements concentrated with hydro-cyclones (Noss) in the laboratory. Similar results have been reached also in mill scale with acasia. But still with low reject rates. The idea can be to concentrate the vessel cells and then treat them and feed the pulp back to the process. In our studies we have also analysed samples fractionated by Bauer Mc Nett screens. The result shows that it is possible to concentrate the vessel cells with this equipment before measurement.

## METHODOLOGY

Earlier work by Granlöf et al based on the STFI Fibermaster technology and new algorithms showed the possibilities to analyse vessel cells more in detail with image analysis. The new software developed for L&W Fiber Tester is designed to utilize the ideas from STFI. It is also possible to save images and make them available for further mathematical image processing for example for the researchers at STFI.

STFI Fibermaster was developed to be able to accurately measure fibre deformations. A small measurement gap between two glass-plates and a flow profile forced the fibres to the centre between the glass plates. The same principle is used in L&W Fiber Tester. This is also an advantage for measurements of vessel cells. Since they are often collapsed it is an advantage if they can be viewed from the side with the biggest area. The flow pattern will allow the best projection of the vessel cells. (figure 3).



*Figure3. A collapsed vessel cell is shown in two projections. The vessel cells are oriented in the flow cell for optimal projection angle for the camera.*

*Figure 4. This is a typical image from L&W Fiber Tester. 100 images may include a couple of vessel elements. One can be seen in this image.*

In figure 4 a typical image from measurement of hardwood is seen. One vessel cell can be seen in this image. The images of such objects are cut out and are collected and can be analysed and monitored separately.

The most common calculation procedure of length and width in L&W Fiber Tester is very suitable for long and slender objects like fibres. For objects with length close to the width other methods are better suited. An alternative method is applied in the latest release of the vessel cell detection software. The principle is based on that length is measured in the mass direction of the fibre and the width is measured in the middle of the objects transverse to this main direction of the mass. Both alternatives are reported.

All objects with a width of less than a specified value (for example 75 µm) are regarded as fibres. All wider objects can be saved as grey scale images. A number of parameters are calculated from these images and are used for selection of vessel cells. A third step can be to manually identify/verify vessel cells from the automatically selected objects. If 10 000 objects have passed the first test (from maybe 1000 000 objects analysed) maybe these are reduced to 500 after the second test, which is a significant reduction of data and a number possible to review. In table 1 are some of the parameters listed. Totally 20 parameters are available. Maximum and minimum limits can be set to each parameter.

*Table 1. Classification parameters for automatic classification of vessel cells are:*

Mean length (fibre model)	Mean Area
Mean width (fibre model)	Mean grey
Mean length (mass orientation model)	Mean grey border

Mean width (mass orientation model)

Mean grey interior

For fibre analysis enough of fibres are normally counted to assure repeatability in the order of 1%. The vessel cells are much fewer. A significantly extended measurement still normally includes more than 10 times fewer vessel cell objects compared to fibre counting. This gives a lower repeatability but still on an acceptable level.

In an example of repeatability test the coefficient of variation was close to 3 %.

### Detection of vessel cells in hardwoods

For pure virgin hardwoods the measurement of vessel cells was mainly based on detection of wide objects. If the selection criteria based on fibre width is set high enough the selection of vessel elements is quite good. Then we talk about objects with a width above 100  $\mu\text{m}$ . But some species have a significant amount below this limit. That was one reason why we started to improve the vessel cell detection software. More sophisticated selection criteria were implemented.

We could see that these cells were sorted out efficiently by checking the saved images. Measurements on acasia gave images similar to figure 5.

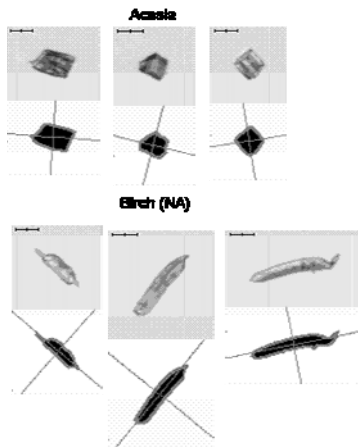


Figure 5. Example of vessel cells.

For comparison see typical birch vessel cells in the same figure (5). The main difference is that these are longer than acasia vessel cells. They are also narrower. An overview of the length and width for each object of acasia vessel cells are seen in figure 6. A lower limit for fibre length is often set to 0,2 mm (standard). Shorter objects are regarded as fines. This limit is not used for detection of vessel cells. For acasia most vessel cells are below 0,5 mm in length. The main part is wider than 100  $\mu\text{m}$ .

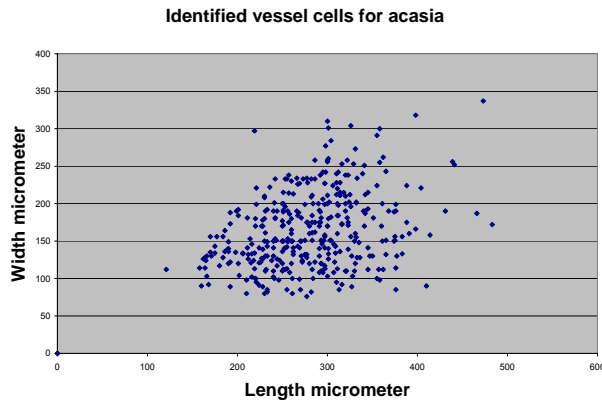


Figure 6. Length and width of individual identified vessel cells for acasia.

New selection criteria have successfully been set up as a default for detection of vessel cells in virgin hardwood pulp. The result was verified by the inspection possibility by viewing the stored selected objects (both vessel cells and non-vessel cells).

### Detection of vessel cells in DIP

To measure vessel cells in newsprint DIP is something completely different from measuring on virgin hardwood pulps. Newsprint is made of TMP with mechanically treated pulp at high energy levels and with all lignin left. Shives or very wide fibres can be found in these pulps. You will also find fibre bundles, ink, fines and debris. These objects are as frequent as vessel cells in the recycled paper. TMP for newsprint is mainly produced from softwood. But different grades of fine paper and other printing grades including hardwood fibres are mixed into the recycle fibre circulations. The amount of hardwoods fed into the recycling streams increases from year to year.

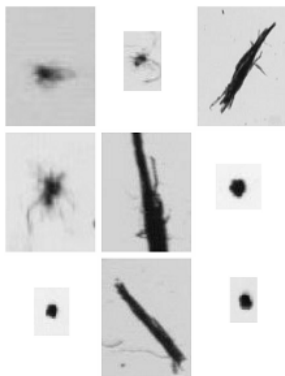


Figure 7. Typical objects detected in DIP. Fibre bundles, ink and shives or very course fibres.

### Project to find a reference by manual judgement of potential vessel cells detected from a deinked pulp

An investigation was made on samples from Holmen, Braviken, a Nordic paper mill with 50 % re-circulated fibre included in the production of newsprint. The plan was to manually analyse a considerable number of potential vessel cell objects from

different positions in the process and then use the result as a reference for development and comparison with automatic classification procedures.

*Table 3. Sample positions in the DIP production line*

After pulper	R200 fraction from pulper	Final DIP pulp
R200 fraction final DIP	Pure TMP	Flotation reject
Fine screen reject from process		

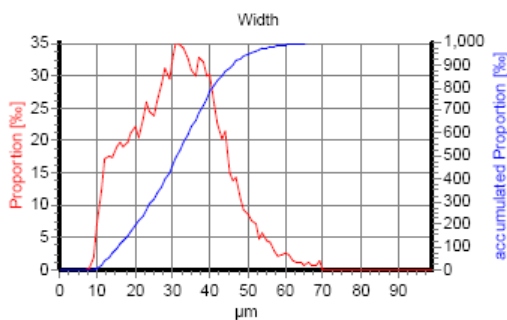
One sample from each position according to table 3 was investigated. The classification of the material was divided by judgement into 10 classes. The limits between the classes are not at all sharp. To start with the analyst visited two different pulp test laboratories and discussed the classification of the images with the microscope specialist from these laboratories respectively. The manual classification was based on this experience. This was a classification based on human experience and not bound to specific rules other than objects wider than 70 µm were selected automatically for classification. This report concerns mainly vessel cells but also other objects can be detected with the same technique.

*Table 4. Classification*

Vessel cells	Fibres	Fibre bundles	Ink
Vessel parts	Crossed fibres	Debris	Fines
Shives	Fibrillated fibres		

Images of about 11000 objects wider than 70 µm were collected. The 500 first of these objects were analysed manually by classifying of each object into one of 10 classes.

As can be seen in figure 8 the amount of fibre length with fibres broader than 70 µm has gone down to a very low level. There can still be a few very stiff fibres or not separated fibres (shives) here. This area was investigated more in detail in this project.



*Figure8. Length weighted width distribution for newsprint.*

For manual classification 500 objects were considered to be a reasonable amount for classification for a limited number of samples. An automatic analysis could work with all 11000 objects in order to achieve a statistically acceptable representation. We compared the statistical distributions in different properties of the 500 selected objects with the statistical distribution of the about 11000 totally detected objects and these distributions were similar which indicate that the selection made was representative.

## RESULTS

36 vessel-like cells out of 500 objects were found in the DIP pulp from the reference study. None was found in the sample from TMP, as expected. The corresponding number for shives in DIP was 30 and in the TMP 28 shives were found. 34 shives were detected in the fine screen reject.

Ink objects were mainly found in the flotation reject. 120 objects were detected.

70 fibre bundles were detected in the DIP pulp and 38 in the TMP pulp.

23 objects were classified as fibres wider than 70  $\mu\text{m}$ . Very few were classified as crossed fibres. And very few were also classified as fibrillated fibres. Fines regarded as short fibres were significant. In general 40 - 50 % of the 500 objects fell into the first 9 classes. The rest was unclassified debris.

For the automatic classification we used the same material. Main selection parameters used in this specific study were length, area, mean greyness of the interior area of the object and the ratio between the mean greyness of the border of the objects divided by the mean greyness of the inner area.

If we sorted out shive objects in the DIP sample with a width greater than 70  $\mu\text{m}$ , length above 0,5 mm, an area greater than 20 000  $\mu\text{m}^2$  and a minimum greyness value then 24 objects remained as shives. 10 of the manually selected 30 objects were identical. In this case 42 % of the automatically detected shives were also regarded as shives from the manual classification.

The corresponding procedure was applied on vessel cells. Objects shorter than 0,5 mm, an area above 20 000  $\mu\text{m}^2$  and also limitations on greyness gave that 88 objects out of 500 were automatically classified as vessel cells. 25 of these were also selected by the manual classification which sorted out 36 objects. In this case 28 % of the automatically detected vessel cells were also regarded as vessel cells.

By tightening the selection parameters it is possible to sharpen the precision in the selection. The price we have to pay is a reduced number of detected objects.

*Table 5. Summary of manual investigation and comparison with automatic test.*

Width > 70 $\mu\text{m}$	TMP, Shives	DIP, Shives	DIP, Vessel cells
Manually identified objects of 500	28	30	36
Automatic (length, area, mean grey interior)	31	24	88
Objects detected By both methods	19	10	25
Objects detected By both methods (%)	61	42	28

The calculations here are made by number (arithmetic values). When we tighten the selection criteria it will preferably mean that bigger objects will get priority. This means that relative to area, volume or weight the selection will be more representative than the numbers mentioned here. Shives are easier to detect and judge, which explains higher percentage of same objects detected by both methods.

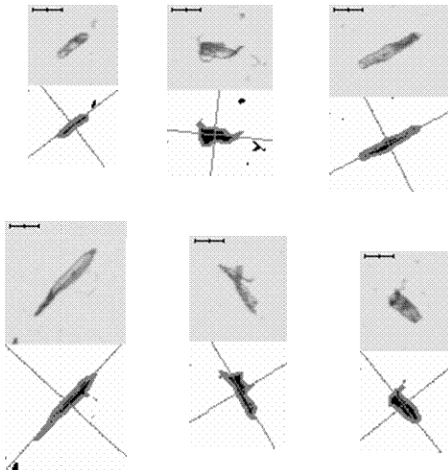


Figure 9. Example of detected cells manually classified as vessels.

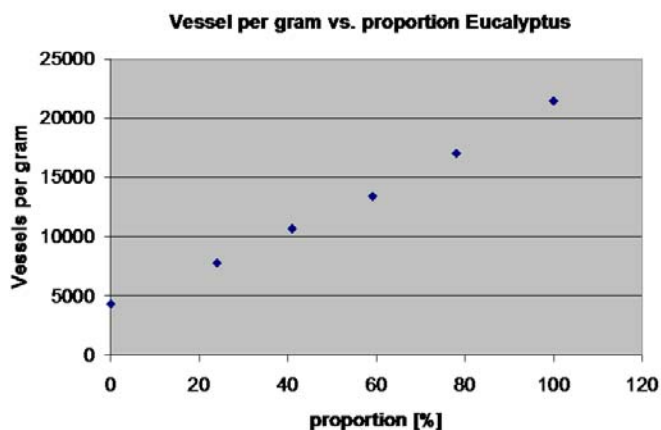
In the TMP line the corresponding values for tighter limits were 31 automatically detected shives and 19 of them were identical with manually detected shives, which was 61 %. No vessel cells were detected.

For some objects it is difficult to say if it is a vessel cell or not. This uncertainty can be one explanation of why the percentage of identical objects look low. Figure 9 shows some example of objects which was manually classified as vessel cells. Most of the detected objects were relatively long and slender indicating that they might come from birch. We were not completely satisfied with this result. Was it good or bad? With the experience from this project we decided to analyse known mixes of recycled pulp and virgin hardwood. We wanted to see how well we could predict mixes and if we could tune the parameters tighter.

### Test of mixes between recycled newsprint and eucalyptus pulp

A DIP sample, a virgin eucalyptus sample and mixes of the two were measured in L&W Fiber Tester. The parameters were set so that the vessel cells in eucalyptus could be detected and at the same time the effect of disturbing objects (debris etc) in DIP minimized. 20, 40, 60, 80 and 100 % of eucalyptus in mixed with the recycled newsprint were analysed.

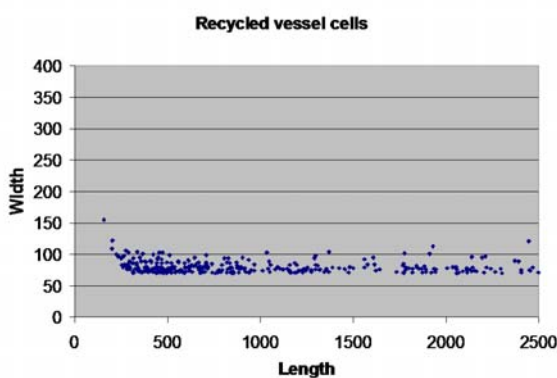
Newsprint paper was put in water and then disintegrated in a standard disintegrator. The different mixes with eucalyptus pulp were prepared by weighing. The amount of vessel cells in the mix was measured and compared with the known mix.



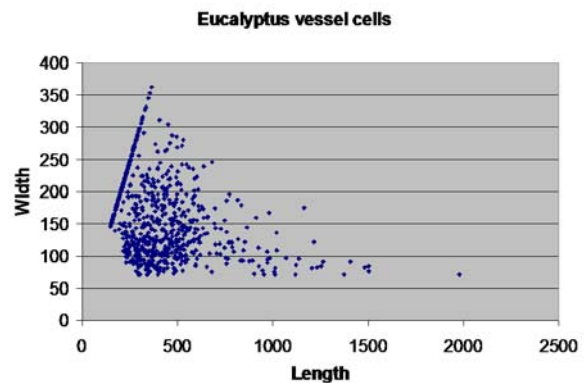
*Figure 10. Counting of vessel cells in prepared known mixes of recycled newsprint and eucalyptus.*

Based on the reference study the classification parameters were further tuned. The results in figure 10 were obtained with these improved settings. The result in figure 10 looks very much like a straight line between detected vessel cells and proportion of eucalyptus in the mix. This indicates that we have a good sensitivity to increased amount of vessel cells relatively to the repeatability of the measurements. Only one measurement was made for each mix. The question was then if the counted vessel cell objects at 0 % eucalyptus really were vessel cells. Also small amounts of eucalyptus vessel cells are required to be measured. The length and width of the detected objects in the 100 % recycled pulp is shown in figure 11.

The length/width distribution of the vessel cells was analysed for the recycled newsprint. It looks like almost all remaining objects are in the region 70-100  $\mu\text{m}$  in width. Earlier study of Nordic recycled newsprint showed a lot of birch like vessel cells. The main part is below 100  $\mu\text{m}$  in width. Since this is a Nordic paper mill it might be so that this is mainly vessel cells from birch. It can also be other objects but observe that it is very few objects above 100  $\mu\text{m}$ .



*Figure 11. Detected vessel cells in the recycled pulp with optimised detection settings.*



*Figure 12. Detected vessel cells in the eucalyptus pulp measured with optimised detection settings.*

In figure 12 is shown length and width values for detected vessel cells in 100 % eucalyptus. The major part of the vessel cells is above 100  $\mu\text{m}$  but there are also objects below this level.

## DISCUSSION

A minor part of vessel cells in eucalyptus (figure 12) is below 100  $\mu\text{m}$ . If these cells are neglected it is possible to remove most of the offset that we saw in figure 10. The corresponding distribution for recycled cells is shown in figure 11. This gives us an opportunity to measure at least wide vessel cells in recycled pulp! The offset in figure 10 will be removed with this width limit.

Wide eucalyptus vessel cells can be detected in this case.

Vessel cells are presented as length/width distribution classes. This means that it is possible to see if object classes less than 100  $\mu\text{m}$  correlate with higher classes (wider objects).

## CONCLUSIONS

The reference study gave us an interesting amount of data. This data is stored and contains more information than we have been able to utilize so far. We have made the following statements in this paper:

- Vessel cells above 100  $\mu\text{m}$  were possible to measure in mixes of eucalyptus pulp and recycled newsprint.
- Objects in the range 70 – 100  $\mu\text{m}$  are more critical. But it is believed that wide and short objects are the dangerous ones.
- The vessel cell software in L&W Fiber Tester is a very powerful tool for development of new applications. A number of selection parameters are available. If the selection parameters are changed, it is easy to check the measured result by viewing the identified vessel cells as well as the non selected objects.

## REFERENCES

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