# EVALUATION OF VESSEL PICKING TENDENCY IN PRINTING

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## ABSTRACT

Bleached eucalyptus kraft mill pulps, *Eucalyptus globulus* and *Eucalyptus grandis*, were fractionated using hydrocyclone (Bauer 3”) in order to enrich the vessel elements in one of the fractions. Chemical analyses: lignin, carbohydrate composition, acetone extract and uronic acids, were conducted to the various samples. Calculation of the cell type composition (fibers, vessels and ray cells) was performed for the pulps. The content and dimensions of the vessel cells in the pulp samples were determined by light microscopy.

The vessel picking tendency was analyzed with a new method developed at KCL. In this method the handsheets are printed with a full scale printing machine, 4-colour sheet-fed offset printing press, and using a commercial printing ink.

The vessel picking printing was performed for the unfractionated eucalyptus kraft pulps, the vessel-rich and vessel-poor fractions. Picked particles were analyzed and counted using an image analyzer. The vessel-rich fractions were also analyzed after PFI-beating 2000 revolutions.

Enrichment of the vessel elements succeeded. Hydrocyclone separated the vessels according to their size, and the vessel-rich fraction had more square-like vessels than the other pulps. The refining of the vessel-rich fraction decreased the vessel picking tendency to the same or even lower level than that of the unfractionated pulp.

## INTRODUCTION

The vessel picking trouble is a phenomenon that some of the hardwood vessel elements in the paper surface tend to be picked off by an ink-tackiness of the printing press (1). Hardwood vessel picking in the offset printing of uncoated fine papers is characterized by the appearance of small, white spots in solid and halftone areas in the print. These defects will repeat exactly in the same area of the print for several hundred impressions, but they will eventually become smaller and less intense until they fade away. The shapes of these white spots are either elongated or they may appear more as squares of the order of 1mm or less in dimension. Vessels on the blanket of a conventional offset press are intrinsically oleophobic because of preferential wetting by the fountain solution. These vessels become oleophilic and accept ink only after printing few hundred impressions. Thus, if a vessel-picking problem is going to occur, it usually becomes evident after printing a few hundred sheets (2).

It is generally known that vessel picking tendency is mainly caused by the presence of large vessel elements in hardwood pulps and the trouble will be worsened when the bonding strength between vessel elements and fibers is too weak (1). The number of vessel elements, which will be picked off during printing, is considered to be caused by the following factors, such as, (1, 3)

- Number, size and shape of the vessel elements in the paper surface,
- Bonding strength between vessel elements and paper sheet,
- Number and bonding strength of fibers, which are covering vessel elements.

Reduction of vessel picking tendency of hardwood pulps can be achieved by (1, 4, 5, 6, 7)

- Reducing vessel content in a stock.
  - The selection of suitable hardwood raw material, which has small and slender vessel elements and conformable fibers.
  - The removal of large and square-shaped vessel elements by using hydrocyclones.
- Reducing the size of the vessel elements.
  - Hydrocyclone separation – HC refining.
- Increasing vessel-to-fiber bonding strength
  - Increasing fiber conformability.
  - Using pulp with high hemicellulose content.
  - Surface sizing.
  - HC-refining.
  - Hydrocyclone separation of vessel elements– enzyme treatment.
- Forming a suitable sheet structure, i.e. covering vessel elements with fibers.

A laboratory printability tester is not reliable to analyze commercially made fine papers, or not even different pulps, because the area of paper printed is too small to capture the statistically rare vessel pick defect. In this study, the vessel picking tendency was analyzed by printing handsheets of different fractions with a full scale printing machine, 4-colour sheet-fed offset printing press, and using a commercial printing ink. This is a new method developed at KCL.

## OBJECTIVES

The objectives of this study were to evaluate the effects of vessel content, vessel shape and pulp refining on the vessel picking tendency. The evaluation of the vessel picking tendency was performed using a new method developed at KCL.

## EXPERIMENTAL

### Raw material

The bleached eucalyptus kraft mill pulps used in the trials were *Eucalyptus globulus* from South Europe and *Eucalyptus grandis* from South America. Both pulps were mill-dried.

### Fractionation

Mill-dried pulps were allowed to swell over night, and in the next morning they were disintegrated using KCL's 50-litre disintegrator. Time in disintegration was 15 minutes and consistency 5%.

The pulps were fractionated using KCL's Bauer 3" hydrocyclone. With the Bauer 3" hydrocyclone it is possible to control only the accept and the feed flows. Trials were performed in the feed pulp consistency of 0.1%, and the pressure difference was 1.6 bar.

The trial configuration for *Eucalyptus globulus* is shown in Figure 1. The eucalyptus pulp that was fed to the hydrocyclone is called feed pulp, the accept pulp is called vessel-poor fraction, and the reject pulp is called vessel-rich pulp in this presentation.

*Eucalyptus globulus* was fractionated in a two-stage system. The reject of the first stage was the feed of the second stage. The accept pulp from the second stage was not recovered.

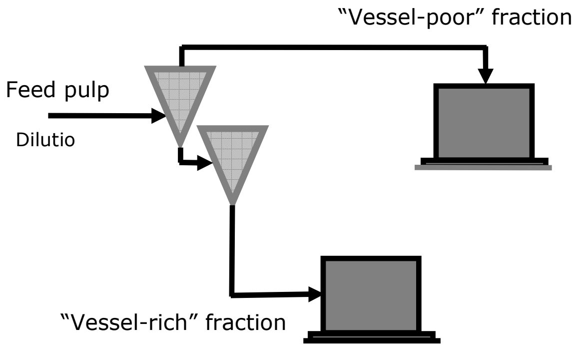


Figure 1. Trial configuration for *Eucalyptus globulus*.

The trial configuration for *Eucalyptus grandis* is shown in Figure 2. *Eucalyptus grandis* was fractionated in a four-stage system. The reject of the first stage was the feed of the second stage, and the reject of the second stage was the feed of the third stage etc. Also in this the case the accept pulp from the second, third and fourth stages were not recovered.

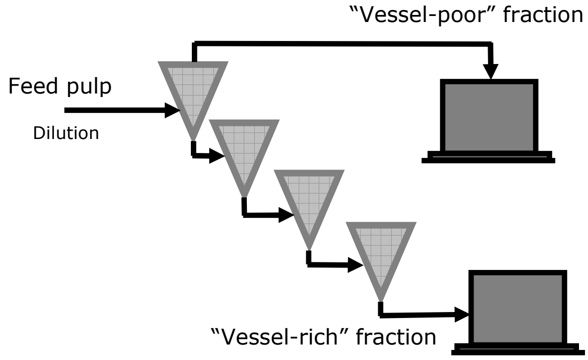


Figure 2. Trial configuration for *Eucalyptus grandis*.

After each fractionation stage the pulp samples were conducted to fiber analysis. Number of vessel elements, length and width was determined using Kajaani FS-300.

### Analyses

Calculation of cell type composition (fibers, vessels and ray cells), SCAN-G3:90, was performed for the feed pulps, vessel-rich and vessel-poor fractions. The vessel length and width was also determined using light microscope, 300 vessels were measured.

The following chemical analyses were conducted on the feed, vessel-rich and vessel poor fractions:

- Total residual lignin, Klason and acid soluble lignin (KCL internal method TAPPI T222 modif.)
- Uronic acids (KCL internal method, SCAN Forsk 737)
- Acetone extracts (SCAN-CM 49)
- Carbohydrate composition (TAPPI T249, modif.)

Before these analyses the fines were removed from the pulps.

### Vessel picking test

The feed pulps, vessel-poor and vessel-rich pulps were used as unrefined. In addition, the vessel-rich fractions were refined using PFI-mill for 2000 revolutions in order to see the effect of the refining on the vessels.

Handsheets were formed according to standard EN ISO 5269-1 from the unrefined feed pulps, vessel-poor and vessel-rich fractions and also from the refined vessel-rich fractions. Target grammage of the sheets was 60 g/m$^2$.

The handsheets were calendered with a sheet calender. The calendering conditions were as follows: line pressure of 94 kN/m (15 bar), 1 nip. The calendered laboratory sheets were taped to a carrier sheet. The sheets were printed with a 4-colour sheet-fed offset printing press using a commercial printing ink and one back-trap nip. Pick marks were collected from the blanket with adhesive tapes. The tapes were analyzed with an image analyzer to count picking tendency.

## RESULTS AND DISCUSSION

### Cell type composition

Enrichment of the vessel elements succeeded to the reject fraction. Ohsawa et al. (4) had also found that it is possible to separate vessel elements by hydrocycloning, and that the vessel elements are accumulated to the reject fraction. Table 1 and Table 2 show the cell type composition of *Eucalyptus globulus and Eucalyptus grandis*, respectively.

Table 1. Cell type composition of *Eucalyptus globulus*.

| m/m, % | Feed | Vessel-poor | Vessel-rich |
|---|---|---|---|
| Fibers | 96.5 | 97.4 | 98.4 |
| Vessels | 0.4 | 0.2 | 1.2 |
| Ray cells | 3.1 | 2.4 | 0.4 |

Table 2. Cell type composition of *Eucalyptus grandis*.

| m/m, % | Feed | Vessel-poor | Vessel-rich |
|---|---|---|---|
| Fibers | 96.7 | 95.5 | 96 |
| Vessels | 0.5 | 0.4 | 4.0 |
| Ray cells | 2.8 | 4.1 | traces |

When the hydrocycloning was performed in a two-stage system, Table 1, it was possible to increase the vessel content of the pulp from 0.4 % (m/m) to 1.2 % (m/m). In the four-stage system the vessel content of the pulp increased from 0.5 % (m/m) to 4.0 % (m/m), Table 2.

It can also be seen from Table 1 and Table 2 that the ray cells content of the vessel-poor fractions were higher than that of the vessel-rich fractions. In the case of *Eucalyptus grandis* the ray cell content of the vessel-poor fraction was even higher than that of the feed pulp. The enrichment of ray cells to the accept fraction has also been seen earlier (8).

The calculation of the vessel elements showed higher values after the refining (Table 3). This is because in the refining the vessels were broken and split as shown in Figure 3.

Table 3. Vessel content of the unrefined and refined pulp, *Eucalyptus grandis*.

| m/m, % | Unrefined vessel-rich | Refined vessel-rich |
|---|---|---|
| Fibers | 96 | 95.1 |
| Vessels | 4.0 | 4.9 |
| Ray cells | traces | - |

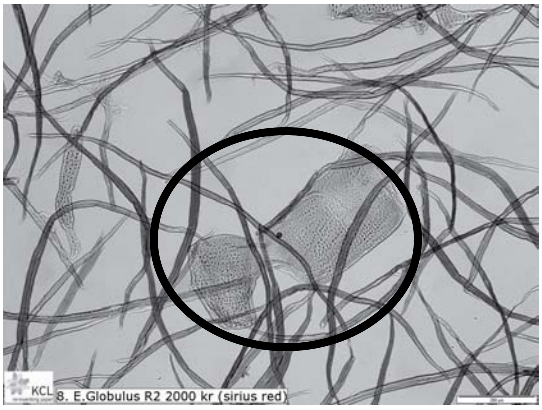


Figure 3. Refined *Eucalyptus globulus* vessel-rich fraction.

### Dimension of vessels

Table 4 and Table 5 show that hydroyclone separated the vessels according to their size. In addition, the vessels of the vessel-rich fractions were more square-like (width/length) than those of the feed pulp and those of the vessel-poor pulp.

Table 4 and Table 5 also show that the dimensions and the shape of the vessel elements were different after the refining. Width/length ratio was lower, which means that the vessels were not so much square-like than before the refining.

Table 4. Vessel dimension of *Eucalyptus globulus*.

| Vessel dimension, µm | Feed | Vessel-poor | Unrefined vessel-rich | Refined vessel-rich |
|---|---|---|---|---|
| Length | 305 | 293 | 307 | 334 |
| Width | 178 | 153 | 190 | 171 |
| Width/length | 0.58 | 0.52 | 0.62 | 0.51 |

Table 5. Vessel dimension of *Eucalyptus grandis*.

| Vessel dimension, µm | Feed | Vessel-poor | Unrefined vessel-rich | Refined vessel-rich |
|---|---|---|---|---|
| Length | 357 | 346 | 368 | 394 |
| Width | 179 | 167 | 208 | 220 |
| Width/length | 0.50 | 0.48 | 0.57 | 0.56 |

### Chemical composition of the pulps

The polysaccharide composition and the lignin content of the various pulps did not show any differences despite the enrichment of the vessels. The content of extractives was below determination limit in all the cases. The only difference was seen in the content of hexenuronic acid. The *Eucalyptus grandis* vessel-rich pulp contained more hexenuronic acid than the *Eucalyptus grandis* feed pulp and the vessel-poor pulp.

**Vessel picking tendency of the pulps**

Figures 4, 5 and 6 show the pictures taken from the printed sheets.

Picked areas are shown as white spots in the sheets. The picture taken from the sheet made from the feed pulp (Fig. 4) and the vessel-poor fraction (Fig. 5) are almost alike. The sheet made from the feed pulp contained somewhat more, and showed a little greater pick marks than the sheet made from the vessel-poor pulp.

The sheet made from the vessel-rich fraction (Fig. 6) had so high a number of vessel elements in the printed sheets that the pick marks are shown as big areas rather than spots. When the pick marks were observed with a loupe, it was noticed that the picked vessels had also released fibers with them from the paper surface.

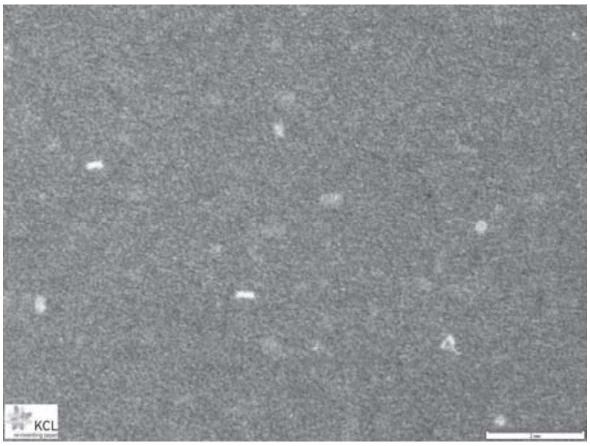

Figure 4. Printed sheet of the feed pulp, *Eucalyptus grandis*.

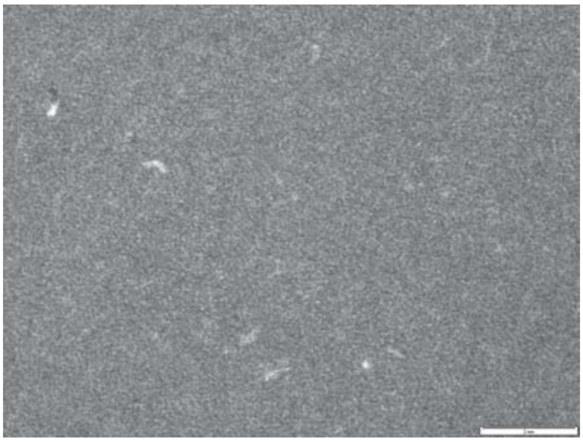

Figure 5. Printed sheet of the vessel-poor fraction, *Eucalyptus grandis*.

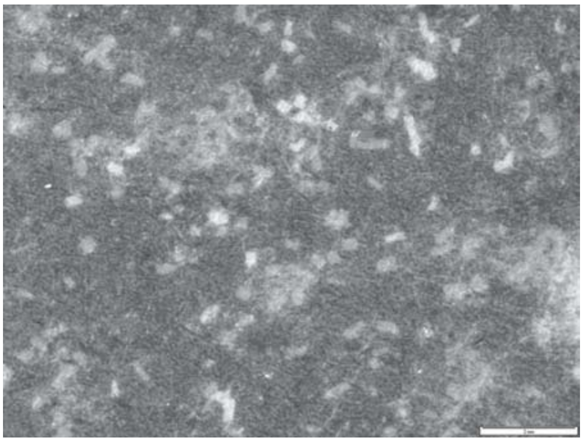

Figure 6. Printed sheet of the vessel-rich fraction, *Eucalyptus grandis*.

The total number of picks/cm$^2$ in the feed, vessel-poor and vessel-rich *Eucalyptus globulus* pulp was 6.4, 4.7 and 27.0, respectively (Table 6).

The picked area of the vessel–rich *Eucalyptus globulus* pulp was 14 times greater than that of the feed pulp. The picked area of the vessel-poor *Eucalyptus globulus* pulp was lower than that of the feed pulp, 0.15 µm$^2$ vs. 0.23 µm$^2$.

Table 6. Vessel picking results for *Eucalyptus globulus*.

| Number of picks/cm$^2$ | Feed | Vessel-poor | Vessel-rich |
|---|---|---|---|
| Ink | 4.1 | 3.0 | 16.2 |
| Back trap | 2.2 | 1.7 | 10.8 |
| Total | 6.4 | 4.7 | 27.0 |
| Picked area, µm$^2$ | | | |
| Ink | 0.19 | 0.12 | 1.09 |
| Back trap | 0.04 | 0.03 | 0.35 |
| Total | 0.23 | 0.15 | 1.44 |

The total number of picks/cm$^2$ in the feed and vessel-poor *Eucalyptus grandis* pulp was 5.3 and 3.6, respectively (Table 7). The vessel-rich *Eucalyptus grandis* pulp contained too many picks to be counted.

The picked area of the vessel-poor *Eucalyptus grandis* pulp was lower than that of the feed pulp, 0.11 µm$^2$ vs. 0.26 µm$^2$.

Table 7. Vessel picking results for *Eucalyptus grandis*.

| Number of picks/cm$^2$ | Feed | Vessel-poor | Vessel-rich |
|---|---|---|---|
| Ink | 3.2 | 2.3 | Too many picks to count |
| Back trap | 2.1 | 1.3 | Too many picks to count |
| Total | 5.3 | 3.6 | Too many picks to count |
| Picked area, µm$^2$ | | | |
| Ink | 0.20 | 0.08 | Too many picks to count |
| Back trap | 0.06 | 0.03 | Too many picks to count |
| Total | 0.26 | 0.11 | Too many picks to count |

**Effect of the refining on the vessel picking**

The vessel-rich pulps were refined in a PFI-mill for 2000 revolutions and after the refining the picking tendency was determined.

Figure 7 and 8 show the picture taken from the printed handsheets made from the unrefined and the refined vessel-rich fraction.

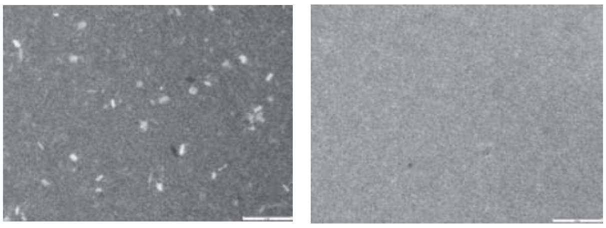

Figure 7. Printed handsheet made from unrefined (on the left) and refined (on the right) *Eucalyptus globulus* vessel-rich fraction.

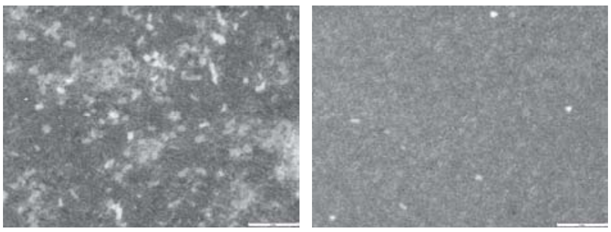

Figure 8. Printed handsheet made from unrefined (on the left) and refined (on the right) *Eucalyptus grandis* vessel-rich fraction.

By refining the *Eucalyptus globulus* vessel-rich fraction the number of picks/cm$^2$ was reduced from 27.0 picks /cm$^2$ to 2.3 picks/cm$^2$ (Table 8). As shown earlier the vessels were broken (Fig. 3) in the refining and due to this also the picking tendency was reduced. After the refining the vessels were not so much square-like than before the refining. In addition, the bonding strength of the fibers is increased in the refining and this decreases the picking tendency of the pulp.

The number of picks/cm$^2$ was lower than that in the unrefined feed pulp and also even lower than that in the vessel-poor pulp. The number of picks/cm$^2$ of the feed pulp, vessel-poor pulp and refined vessel-rich fraction was 6.4, 4,7 and 2.3, respectively.

Also, the picked area decreased remarkably in the refining from 1.44 µm$^2$ to 0.05 µm$^2$, and it was lower than that of the feed pulp ( 0.23 µm$^2$) and that of the vessel-poor pulp (0.15 µm$^2$).

Table 8. Vessel picking results for *Eucalyptus globulus* feed pulp, vessel-poor, unrefined and refined vessel-rich fraction.

| Number of picks/cm$^2$ | Feed | Vessel-poor | Unrefined vessel-rich | Refined Vessel-rich |
|---|---|---|---|---|
| Ink | 4.1 | 3.0 | 16.2 | 1.2 |
| Back trap | 2.2 | 1.7 | 10.8 | 1.1 |
| Total | 6.4 | 4.7 | 27.0 | 2.3 |
| Picked area, µm$^2$ | | | | |
| Ink | 0.19 | 0.12 | 1.09 | 0.03 |
| Back trap | 0.04 | 0.03 | 0.35 | 0.02 |
| Total | 0.23 | 0.15 | 1.44 | 0.05 |

The number of picks/cm$^2$ and the picked area decreased in the refining of *Eucalyptus grandis* vessel-rich fraction. However, the total number of picks/cm$^2$ of the refined *Eucalyptus grandis* vessel-rich fraction was 7.0 (Table 9). This is about 30% higher than that of the feed pulp.

The picked area in the ink was about the same for the feed pulp and for the refined vessel-rich fraction. In the back trap the picked area was still clearly higher for the refined vessel-rich fraction than that of the feed pulp. The total picked area was about 20% higher for the refined vessel-rich fraction than that of the feed pulp.

Table 9. Vessel picking results for *Eucalyptus grandis* feed pulp and refined vessel-rich fraction.

| Number of picks/cm$^2$ | Feed | Refined vessel-rich |
|---|---|---|
| Ink | 3.2 | 4.2 |
| Back trap | 2.1 | 2.8 |
| Total | 5.3 | 7.0 |
| Picked area, µm$^2$ | | |
| Ink | 0.20 | 0.22 |
| Back trap | 0.06 | 0.10 |
| Total | 0.26 | 0.32 |

## CONCLUSIONS

Bleached Eucalyptus kraft mill pulps, *Eucalyptus globulus* and *Eucalyptus grandis*, were fractionated using hydrocyclone (Bauer 3”) in order to enrich the vessel elements in one of the fractions.

The vessel picking tendency was analyzed with a new method developed at KCL. In this method the handsheets are printed with a full scale printing machine, 4-colour sheet-fed offset printing press, and using a commercial printing ink.

The vessel picking printing was performed for the unfractionated eucalyptus kraft pulps, the vessel-rich and vessel-poor fractions. Picked particles were analyzed and counted using an image analyzer. The vessel-rich fractions were also analyzed after PFI-beating 2000 revolutions.

Enrichment of the vessel elements succeeded. Hydrocyclone separated vessels according to their size and the vessel-rich fraction had more square-like vessels than the other pulps.

The vessel-rich pulps had a higher number of picks/cm$^2$ and also the picked area was larger than that of the feed pulps and the vessel-poor pulps. The vessel-poor pulps had a lower number of picks/cm$^2$ and the pick marks were smaller than those of the feed pulps.

In the refining the vessels were broken and split, and the bonding strength of the fibers was increased. Due to this the refining of the vessel-rich fraction decreased the vessel picking tendency to the same or even lower level than that of the unfractionated pulp. Also the area of the pick marks decreased.

This study proved that the method developed at KCL evaluates properly the vessel picking tendency of the various pulps. It was also shown, that fractionation technique enables the study of pulps with various vessel contents: the chemical composition of those pulps, and the effect of separate treatment of those pulps on the vessel picking tendency.

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