Accurate shive classification using image analysis

K W CORSADDEN1, S JACK2, C JOSS3, R J TREPANIER4

SUMMARY
Classification of shives by image analysis requires the measurement of at least 3 morphological attributes of a shive. This paper describes how this was achieved, with an instrument using a cytometric flow cell and compares the results to traditional laboratory screening methods.

Keywords
Wood pulp fibres, shive classification, morphological properties, image analysis, Somerville screen.

INTRODUCTION
The presence of shives in pulp is undesirable as they promote local stress variations that adversely affect paper machine operations. They are also a major source of problems in the pressroom, causing degradation in print quality and reducing sheet runnability. Screening methods such as the Somerville or Pulmac are used to quantify the presence of reject material and assess screen and cleaner performance. These methods measure the weight of all rejects retained on a screen. The Somerville screen, though originally designed to measure the shive %-weight content in groundwood pulps (1,2) has subsequently been used to estimate the content of shives, and other contaminants, in both mechanical and chemical pulps (3).

The size distribution of shives is subject to the same Poisson counting statistics as dirt (4,5) specks. The frequency of shives decreases exponentially as they get larger. Consequently, large shives have relatively low frequency, but contribute significantly to %-weight of the material retained after screening. Leask (6) reported that particles less than 1.5mm in length can account for up to 80% of the total screened rejects but less than 30% of the total weight in publication grade SGW and TMP pulps (Fig 1.)

This creates a problem when comparing shive measurement using screening methods with imaging analysis techniques as the latter report the shive content by %-count.

This paper presents a comparison of the results obtained by image analysis using an OpTest Fibre Quality Analyzer (7,8,9) with those obtained using a Somerville laboratory screen and demonstrates that three morphological attributes are necessary to accurately characterize shives using image analysis.

SHIVE MEASUREMENT USING IMAGE ANALYSIS

Shives can range from small “solid” fibre bundles to large highly branched structures up to 1cm long (Fig 2.) Attempting to measure with image analysis even simple parameters such as shive length requires algorithms that can differentiate between complex features and irregular shapes. Working with researchers at Paprican, it was found that three properties described as “effective length”, “shive area” and “branch index” are necessary to fully describe a shive.

Shive detection and analysis
Throughout this paper, a shive is defined as having an effective length greater or equal to 0.350mm and effective width greater or equal to 0.175mm.

Effective length
The inability or difficulty in measuring the “actual” length of a shive using image analysis is overcome using the effective length “L_{eff}” as shown in Fig 3A and Fig 3B. L_{eff} is defined as the measurement of the diagonal of a software-generated box whose boundaries encompass the extreme edges of the shive.

Area of the shive
The area of the shive is a strong indicator of the degree of impact that the shive will have on the papermaking or printing process and on its compactness, when combined with effective length. The area is determined by measuring the active pixels within the software-generated box. The effective shive width can then be calculated by dividing the area by the corresponding effective length.

Shive branch index
Two shives can have the same effective length and area, but have very different structures or shapes. The following technique, which produces a Shive Branch Index “SBI”, was found to be the most effective way to quantify the shape of a shive.

The SBI is based on the ratio of an ideal moment of inertia to the actual moment of inertia of the shive.

Firstly, an estimate of the actual moment of inertia, I_{actual}, is produced based on the shive area, as determined by image analysis. Secondly, a model of the ideal moment of inertia, I_{ideal}, is produced using a stick of fixed width, with the length of the stick based on the shive perimeter (Fig 4.)
The SBI is produced using the ratio:

$$\text{SBI} = \frac{I_{\text{ideal}}}{I_{\text{actual}}}$$

When a shive is more branched its perimeter increases, the modelled stick used to represent $I_{\text{ideal}}$ become longer and the SBI increases.

**EXPERIMENT**

The apparatus used in this experiment includes:

1. Somerville Laboratory Screen as described in PAPTAC (2) standard method and TAPPI (3) standard practice.
2. An OpTest Fibre Quality Analyzer (FQA). The FQA incorporates a cytometric flow cell having a cross section area of 33 mm², with circular polarizing optics. The field of view is 10mm x 10mm.

**Sample preparation**

Four pulps were tested, consisting of two unbleached Kraft Eucalyptus and two unbleached Kraft Pine dry lap sheets, identified as E1, E2, and P1 and P2 respectively. Approximately 120g of dry pulp sample was soaked in water for over 24 hours and then manually pulled apart into 4cm² size pieces. These were disintegrated, in accordance with TAPPI T205 (8), at 3000 rpm, in 10L of de-ionized water. Following 10 minutes disintegration, the degree of dispersion was checked by diluting a small amount of the sample in a glass vial. The E2 and P2 pulps did not show sufficient dispersion and it was found necessary to disintegrate them for an additional 5 minutes. Disintegration was minimized to avoid fibre damage and shape changes. Following disintegration, each sample was further diluted, with de-ionized water, to obtain a consistency of less than 1%. At this point, duplicate consistencies for each sample were determined and specimens from the whole pulp samples were set aside for routine FQA measurements.

**Tests Using Somerville Laboratory Screen**

A 50g OD sample of whole pulp was screened according to TAPPI method T275 (3). For each Eucalyptus and Pine sample two specimens were screened. The material retained on the screen from the first specimen was collected, oven dried, and weighed to give the percent weight of shives.

For the second specimen the un-dried material, retained on the screen, was collected and stored in sealed containers for subsequent analysis on the FQA.

**Tests Using The FQA**

Two tests were performed using the FQA as described below:

**Test A.** The whole pulp samples were diluted (10) to obtain concentrations of 1mg/L for the Eucalyptus pulps, and 4mg/L for the Pine pulps. These concentrations correspond to a fibre measurement frequency of 5 - 50 fibres per second (5). Each diluted sample was well mixed. At least seven FQA measurements were made per pulp sample.

**Test B.** The samples of the un-dried material retained on the laboratory screen, for each pulp, were diluted such that a minimum of 200 shives per pulp were analysed by the FQA.

**RESULTS & DISCUSSION**

The results obtained using the Somerville screen are displayed in Table 1. They show marked differences between the shive contents of all four pulps. Firstly, the softwood, P1 and P2 pulps exhibit an average of 4.5 times more shives than the hardwood, E1 and E2 pulps. Secondly, the E2 and P2 pulps respectively have over 1.5 times more shives than the E1 and P1 pulps.

The results obtained using the FQA are displayed in Table 2. The results are presented as shive count and shive count per metre. The shive count per metre is a measure of the shive content, normalized by the total fibre length tested, Equation 1.

$$\text{Shive/m} = \frac{\text{Total shive count}}{\text{Total fibre length (m)}}$$

Figure 2 Image of shives obtained with the OpTest FQA. These shives have been collected on a laboratory screen and analysed with the FQA. The field of view is 100mm².

Figure 3a Solid shive Figure 3b Branched shive

Figure 4 Shive branch index determination

Stick to generate ideal moment of inertia

Actual shive image

Centroid

Fig. 2 Image of shives obtained with the OpTest FQA. These shives have been collected on a laboratory screen and analysed with the FQA. The field of view is 100mm²
The %Uncertainty value in Table 2 relates to the percentage uncertainty of the shive count and has been calculated using Equation 2 where N is defined as the total number of shives counted.

\[
\%\text{Uncertainty} = 100 \times \frac{1}{\sqrt{N}}
\]  

The average shive count of the E2 pulp measured was approximately 1.4 times greater than the E1 pulp and is reasonably consistent with the shive ratio for the E1 and E2 pulps obtained by %-weight. In contrast, the average shive count for the P1 pulp was 2.3 times greater than the P2 pulp, which is the opposite of the results reported by %-weight. This highlights the caution necessary when comparing shive results reported by weighing and counting methods.

Correlating the results reported as total count against %-weight listed in Tables 1 and 2 lacked significance with an \( r^2 \) of only 0.23. The correlation was improved (to an \( r^2 \) of 0.68) by comparing shive count/m to %-weight. These results are displayed in Figure 5.

The following results demonstrate the improvement in correlation achieved by incorporating the three parameters of \( L_{\text{eff}} \), Area and SBI in the analysis, which take account of the size and degree of branching of individual shives.

The results in Table 3 are obtained by analysing the screened material using the FQA, described as test B. This material is used to provide a representative measure of the area and branch index of shives present in these pulps.

Table 3 presents the values obtained when the average area and SBI listed in Table 3 are applied to the Shive/m data from the whole pulp shown in Table 2. Multiplying the Shive/m results by the average area produces a Shive Count in \( \text{mm}^2/\text{m} \), column 4 in Table 4, and is designed to compensate for the potential bias caused by larger shives. Dividing the Shive Count in \( \text{mm}^2/\text{m} \) by the SBI produces a Count \( \text{mm}^2/\text{m}/\text{SBI} \), column 6 in Table 4. This is consistent with the expectation that shives with more branches are more likely to be retained on a screen.

Figure 6 displays the Shive Count-\( \text{mm}^2/\text{m} \), and the Shive Count-\( \text{mm}^2/\text{m}/\text{SBI} \) for the whole pulps, plotted against the shives reported by %-weight for the whole pulps. Multiplying the Shive/m values by the average area, resulted in an increased correlation with an \( r^2 \) of 0.79. A further increase in correlation was observed by including the SBI, resulting in an \( r^2 \) of 0.82.

The effect of including the shive morphological characteristics with the shive count brings the results for P2 closer in agreement with the results reported by %-weight.
weight technique, but it still remains lower than P1. The Shive/Fibre count results, in Table 3, reveal that the P2 had 50% more fibrous material retained on the screen than the P1 pulp and this may contribute to the discrepancy between the image analysis and %-weight results. The eucalyptus pulps also had over three times more fibre counted, in the material retained on the screen, compared to the Pine pulps. Although there is no measure of mass of retained material, it is suspected that this would impact detrimentally on the precision of the laboratory screening measurement of shives.

The data in Table 3 also shows that the average area of the shives detected in the Pine pulps is approximately 50% greater than that found in the Eucalyptus pulps, whilst the average I_eff is over 80% greater, indicating that shives in the Pine pulps take up more space. The SBI results also show that on average, the Eucalyptus shives are 40% more branched than the Pine shives.

CONCLUSIONS

The agreement of shive image analysis measurement with screening and weighing methods is improved by incorporating the shive area and branch index with the shive count/m. The image analysis results reveal that whilst this approach significantly improves correlation between the two techniques some differences still exist. The results indicate that this may be due to the retention of non-shive fibrous materials that are included in the weighing technique, but not the image analysis measurements.

REFERENCES

(3) Tappi Standard Practice T275. - Screening of Pulp (Somerville-type equipment), TAPPI Test Methods, TAPPI Press, USA, 2002
(12) Tappi Standard Method T563 - Equivalent Black Area (EBA) and Count of Visible Dirt In Pulp, Paper And Paperboard By Image Analysis, TAPPI Test Methods, TAPPI Press, USA, 2002

Original manuscript received 8 August 2006, revision accepted 3 November 2006

Fig. 6 Graph of shive (Count-mm²/m) and count-mm²/m/SBI) compared against shive content %-weight for the whole pulps.