

ABSTRACT

Instruments will someday have wide use for inspection of contraries in pulp—especially pulps containing many contraries. Results obtained by visual inspection may not be equivalent to those from instrumental dirt counting. This paper gives results of automatic dirt counting using transmitted light and wet samples. The measurements used the new ISO standards that allow use of instrumental devices in dirt counting. The experiments show correlation between visual and automatic dirt counting of 75%—90% when inspecting wet samples in transmitted light. Repeatability and detection limits of instrumental inspection depend greatly on the equipment used. In our experiments, the coefficient of variation was usually smaller than 15%. The small number of instruments able to use transmitted light made measurement of the reproducibility between different image analyzers difficult. The paper includes results obtained with two different automatic dirt counters.

Application:

Automatic dirt counting with transmitted light and wet samples can provide easier, faster, and more reproducible analysis.

DIRT COUNTING TRADITIONALLY uses visual inspection. Since large variations in results can exist among different people, visual dirt counting is very subjective. Repeatability of counting is often not good, especially if the number of dirt specks is high. Substantial variation in visual inspection results, poor repeatability of visual counting, and speed of automatic measurement are therefore important factors for development of analytical systems for automatic

Results of automatic dirt counting using transmitted light

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dirt counting. The systems are finding increasing use for measurement of pulp and paper contaminants.

The International Organization for Standardization (ISO) has three dirt counting standards for pulp samples today. Two old ISO standards used visual inspection with transmitted light for bleached pulp and reflected light for unbleached pulp (1, 2). Revisions of the old standards were published in 1998. A newer standard, part 3, uses only visual inspection with reflected light (3). The revision of ISO 5350/1 specifies a method for laboratory sheets, and the revision of ISO 5350/2 specifies a method for mill sheeted pulp. Both methods allow use of instrumental devices and prescribe inspection by transmitted light. They differ in that respect from corresponding TAPPI methods. To make them more transparent, the test pieces will also be evenly wet before inspection. Transmitted light is justifiable because the dirt and shive particles in the paper-making process inside the sheet are as harmful as those on the sheet surface. The new standards also document a calibration procedure for the dirt counting instrument.

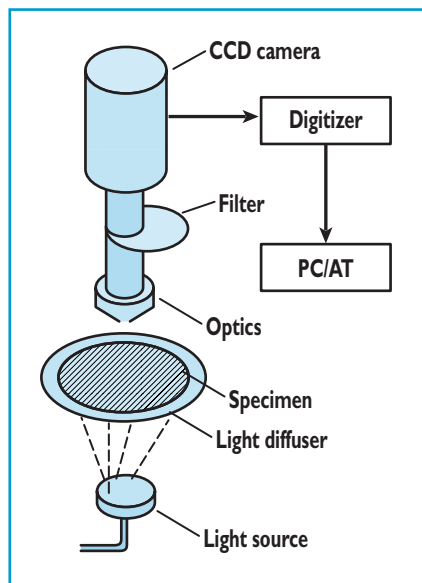
Most automatic image analysis systems today are scanning devices. Only a few instruments on the market can use transmitted light and fulfill the requirements of the new ISO standards. Recent experimental work at KCL has involved an automatic image analysis device using transmitted light. The research reported here uses the new ISO standards.

APPARATUS

Figure 1 shows the automatic dirt counting device used in our experimental work schematically (4). The system has a charged coupling device (CCD) camera with highly effective resolution connected to a computer. The image size is 512 pixels x 512 pixels. The camera views an area of 63 mm x 50 mm. The minimum area of one dirt point is about 0.01 mm². Transmitted or reflected light is suitable. The test sheet is wet before measurement and then placed on an opaline glass. The analyzer scans the entire sample sheet in segments using successive sweeps of the camera. Dirt points in the camera images are noted using image analysis. The ISO standard specifies reporting of contraries larger than 0.04 mm² if they have sufficient contrast. The contraries counted are classified by size and shape. Shives are long, thin dirt points, and dirt particles are round. Units are n/kg, n/mm², mm²/kg, and mm²/m² where n is the number of dirt points.

STANDARDS

Our work used the new ISO standards that impose certain requirements on the automatic device. The light source must be suitable for inspection by transmission. Construction must allow counting and reporting of contraries with areas and contrasts corresponding to the tables of the standards as Table I and Fig. 2 show. The instrument should have a minimum pixel size of 0.01 mm² and a minimum grey scale resolution of 0.5% transmittance. The



1. Principle of the automatic image analyzer (4)

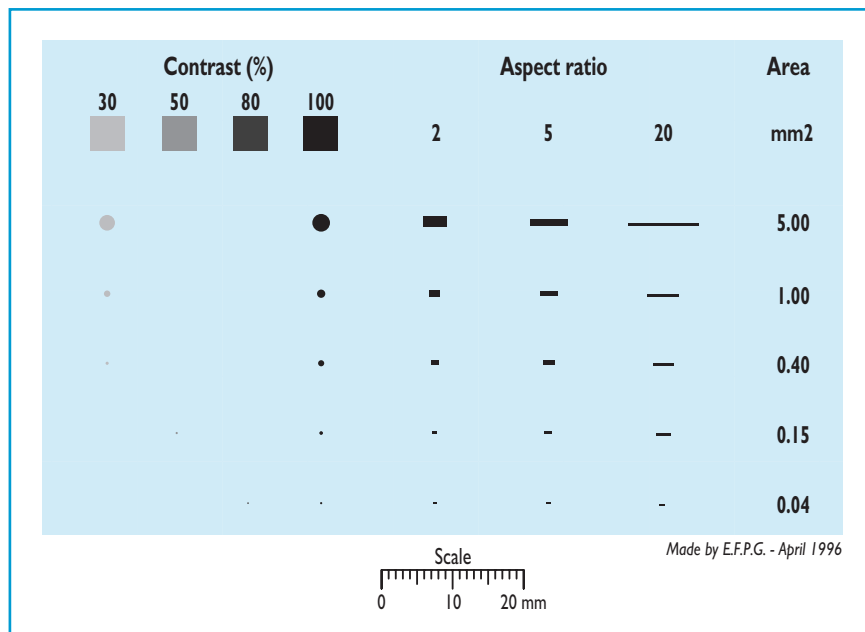
Size class, mm ²	Minimum contrast, %
>5.0	25
1.00–4.99	25
0.40–0.99	25
0.15–0.39	50
0.04–0.14	80

1. Minimum contrast values for different size classes (1, 2)

device must also be able to identify contraries with an aspect ratio exceeding 3:1 for reporting shives separately. Repeatability of the device must be such that coefficient of variation does not exceed 15% when inspecting a test area five times. The contrast necessary to make a contrary visible depends on the size of the contrary. Small spots are visible only if they have a high contrast with the surrounding pulp, but large spots are visible at low contrast. A single contrast is therefore not suitable as a limit. Table I gives the minimum contrast values for different sized classes.

CALIBRATION

Calibrating the automatic instrument used the comparison chart of the



2. Comparison chart (1, 2) (The left part of the chart is for contrast calibration of an instrumental device. The spots on the right indicate contraries of different aspect ratios. Size calibration uses this part of the chart.)

new ISO standards. The chart has a series of spots of different areas and contrasts. The chart is placed on a sheet of white paper. The instrument then records all contraries in the actual class indicated on the comparison chart. If this did not occur, the instrument was adjusted. Figure 2 is a copy of the comparison chart.

RESULTS

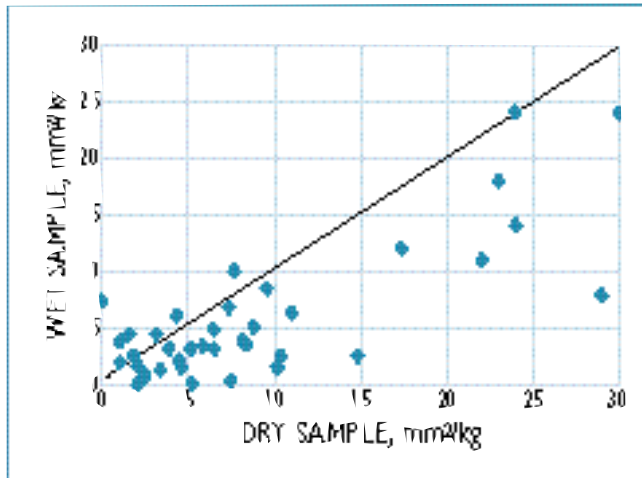
Our work measured dirt points on dry and wet samples in transmitted light. The same samples were measured visually and with an automatic dirt analyzer. We examined correlation between wet and dry samples and between visual and automatic measurements. Results from some precision investigations are also presented.

Correlation between dry and wet samples

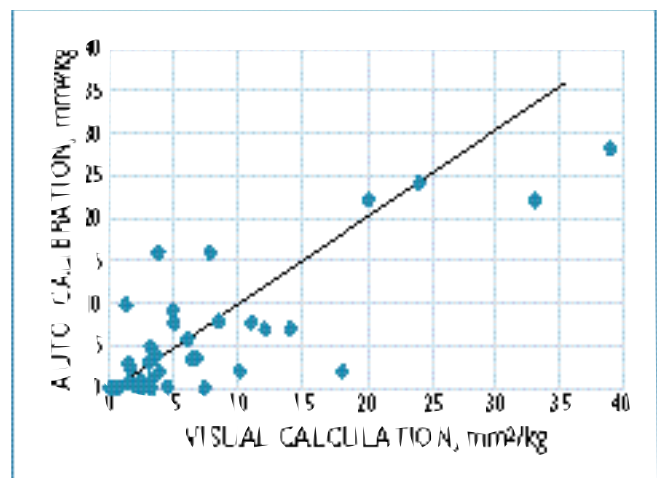
Most current standards use visual inspection of dry samples in transmitted or reflected light. The new ISO standards use inspection of wet samples visually or automatically. Correlation after visually inspecting

37 wet and dry samples was 0.63. Total area of contraries varied from less than 1–30 mm²/kg. Figure 3 shows the results. The corresponding correlation between wet and dry samples in the instrumental measurement was 0.77.

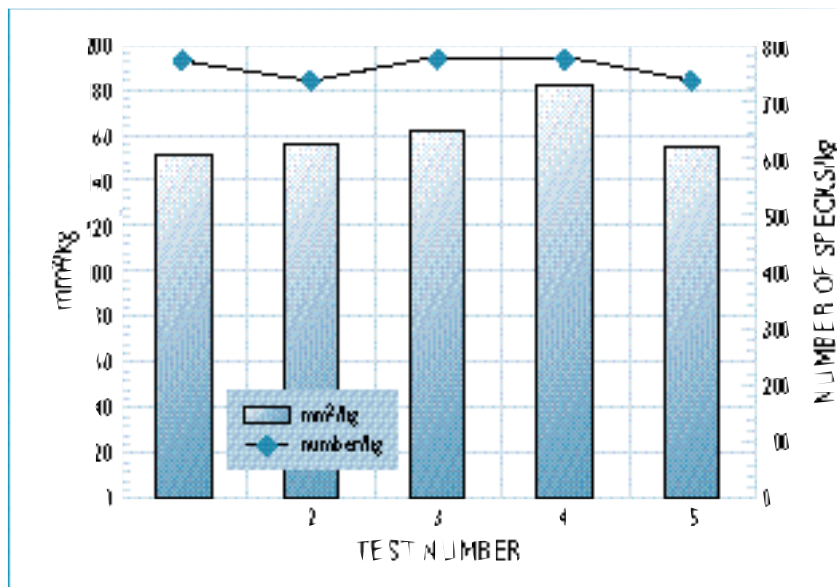
The results show that the number and total area of contraries usually decrease when the samples are wet. We examined some dirt spots that became invisible when the sample sheets were wet and found that these contraries can be real or unreal dirt points. Those dirt points that disappeared included fiber bundles, talc, and some kinds of resin spots. Although some dirt points disappeared, wetting has many advantages. For example, some unclear dirt points become more clear or disappear completely. This influences the calibration of the automatic instrument. With a wet sample, calibration is much easier, and many different pulp qualities can use the same calibration since sheet formation does not affect calibration.



3. Correlation between wet and dry samples on visual measurement with CV = 0.63



4. Correlation between visual and automatic dirt counting with CV = 0.81



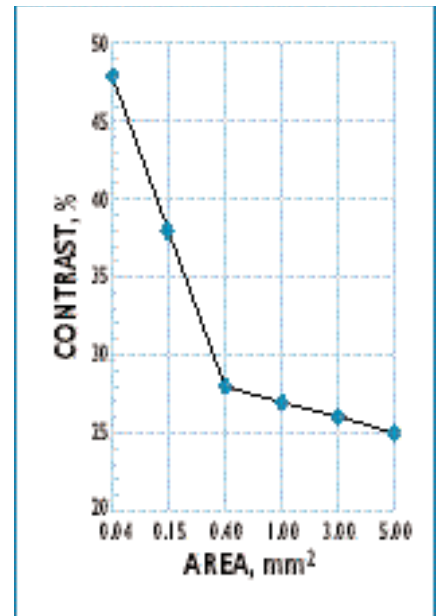
5. Repeatability of instrumental inspection

Correlation between visual and automatic dirt counting

We inspected 37 wet samples visually and with an automatic dirt counter in transmitted light. The total area of contraries varied from less than 1–39 mm²/kg. Resulting correlation was 0.81 as Fig. 4 shows. According to our experiments, the correlation between visual and automatic dirt counting is 75%–90%.

Repeatability of instrumental inspection

When measuring one sample of 0.5 m² total area five times using transmitted light, the mean value of the total area of dirt points was 161 mm²/kg with 12.0 mm²/kg standard deviation (STD) and 7.5% coefficient of variation (CV). Expressed as number of specks/kg, the corresponding mean value was 758 and STD was 20.3. CV was 2.7%. Figure 5 shows the results.

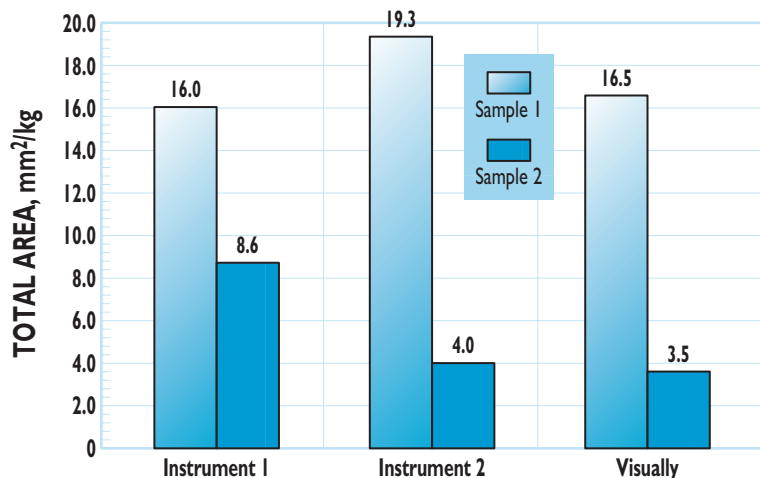


6. Detection limit of automatic dirt counting

As the number of specks decreases, repeatability becomes poorer. For example, the STD was 1.3 mm²/kg and the CV was 10.0% for a sample in which the mean value of the total area of dirt points was 13 mm²/kg. Repeatability does depend strongly on the equipment used.

Detection limits of automatic dirt counting

A single contrast cannot be specified



7. Reproducibility of instrumental inspection

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LITERATURE CITED

1. ISO 5350/1, "Pulp—Estimation of dirt and shives—Part 1: Inspection of laboratory sheets."
2. ISO 5350/2, "Pulp—Estimation of dirt and shives—Part 2: Inspection of mill sheeted pulps."
3. ISO 5350/3, "Pulps—Estimation of dirt and shives."
4. Backstrom, C. and Lehtikoski, O., *Paper and Timber* 71(5):477(1989).

as a limit because small spots are visible only if they have high contrast with the surrounding pulp. **Figure 6** shows that the contrast can be 25% if the spot is larger than 0.4mm^2 . If the spot is smaller than 0.4mm^2 , the contrast must also be higher as Table I shows.

Correlation of automatic imaging devices

Measuring reproducibility was difficult because only a few instruments can use transmitted light. **Figure 7** presents results for samples measured with different instruments and shows the results of visual inspections. Both instruments were calibrated independently. The correlation between different automatic image analyzers depends greatly on calibration procedure.

CONCLUSIONS

Automatic dirt counting analysis systems are finding increasing use for measurement of pulp and paper contaminants. With more experience using instrumental devices, correlation between visual and automatic dirt counting will reach an acceptable level, and instrumental methods will be the main parts of international standards such as ISO. Before this can happen, more instruments equipped to use transmitted light and more experimental work are necessary. **TJ**

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