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TECHNICAL NOTE

QUESTIONED DOCUMENTS; CRIMINALISTICS

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Evaluation of Two Instrumental Methods of Comparing Writing Paper

ABSTRACT: An organization had approved the sample of writing paper, and accordingly the supplier had to execute the supply. The supply received was suspected to be of different quality from approved one. The organization sent the samples for comparison to the Forensic Science Laboratory. Both the approved and supplied samples were compared using Tensile Testing Method with the Material Testing Machine and Fluorescence and spectral analysis using the Video Spectral Comparator (VSC2000). The difference between the mean loads at peak before rupture in the tensile testing mode for the two samples was about 33%. The two samples differed significantly in terms of UV fluorescence, and there was about 5% average difference in the percentage of maximum reflected intensity in the wavelength region of 400–900 nm. It has been observed in this study that these two methods can adequately distinguish paper samples of different origin.

KEYWORDS: forensic science, paper quality, tensile strength, tensile index, tension length, fluorescence

In the present age, paper is one of the most widely used items and finds its use in many areas. Because of the diverse applications, paper is available in a wide range of sizes, types, and qualities. In the forensic context, paper as a physical evidence can be encountered in cases related to forgery, counterfeiting, and felonious use. However, this article reports a case in which writing paper approved for supply and the paper actually supplied were compared.

In the forensic setup, physical methods of comparison of paper include fiber analysis and microscopic methods (1,2). The physical examination of color, size, weight, opacity, and fluorescence constitutes the first step of such analysis. Further, watermarks examination can be another distinguishing characteristic. In situations where these properties indicate similarity, further examination of fiber type, chemical analysis, and trace element profiles is resorted to (3). However, these methods require considerable time and efforts of the experts.

Some governments and organizations like the Bureau of Indian Standards (BIS [4]), TAPPI, and ASTM provide standard methods for the sampling and testing of paper and allied products. Not all these methods are feasible in the forensic cases. However, one of these methods, the measurement of the tensile strength of paper, in a way is the most important property of paper. For the finished product, the tensile strength can be modeled on the basis of type of fibers and the manufacturing process (5). Earlier a discrimination method for paper using fourier transform and cross-correlation has been reported by Miyata et al. (6).

In this report, two instrumental techniques, viz. tensile strength measurement and spectral and fluorescence observations, have been used to discriminate the approved and supplied sample of paper.

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Materials and Methods

Four sheets of approved sample of paper (P/1) and 10 sheets of the supplied sample (P/2) were received for comparison. Table 1 shows the different test results of the approved samples claimed to have been performed by the supplier and compared with the Standards' specifications. Here, the term MD refers to the Machine Direction and CD denotes Cross Direction.

Both the samples were conditioned in the same ambient conditions (22°C, 55% RH). The observed physical dimensions and surface texture of P/1 and P/2 appeared to be different. Additionally, instrumental methods were applied to provide more objective data about the nonmatch.

Video Spectral Comparator (VSC 2000; Foster and Freeman, Evesham, Worcestershire, U.K.) was used for finding the reflectance spectra and fluorescence of the two samples, when illuminated with lights of different wavelengths. The Material Testing Machine (Model Micro 500; Testometric, Rochdale, Lancashire, U.K.) was used for tensile testing of the paper samples. Thin strips of paper of width 25 mm and length 180 mm cut from the samples were clamped in the jaws of the machine for tensile testing. A constant rate of traverse mode was adopted at a rate of 7 mm/min. The sample could only be used in the Machine Direction because of limitation on the sheets available.

Results and Discussion

Size, Texture, and Thickness

Average size and thickness of the two samples are shown in Table 2.

UV Fluorescence

Two representative sheets from each sample were compared side by side on the VSC 2000 for UV fluorescence. As shown in

TABLE 1—*Test results submitted by the supplier in respect of the approved sample P/1.*

Test Result	IS Specifications	Results Obtained
Grammage	48 (±2.5%)	48.9
Brightness (%)	Min 70	71.8
Tensile index (N.m/g)	CD 17.00	CD 19.10
	MD 25.00	MD 27.20
One minute Cobb	22 (max)	20.3
Tear index (mN.m^2/g)	CD 4.0	CD 4.5
	MD 3.5	MD 3.7

TABLE 2—*Comparison of the physical properties of the two samples.*

Property	P/1 (Approved)	P/2 (Supplied)
Size (in cm)	33 × 20	29.7 × 21.1
Texture	Both sides equally smooth on touching	One side smoother than the other on touching
Thickness (in mm)	0.055	0.064

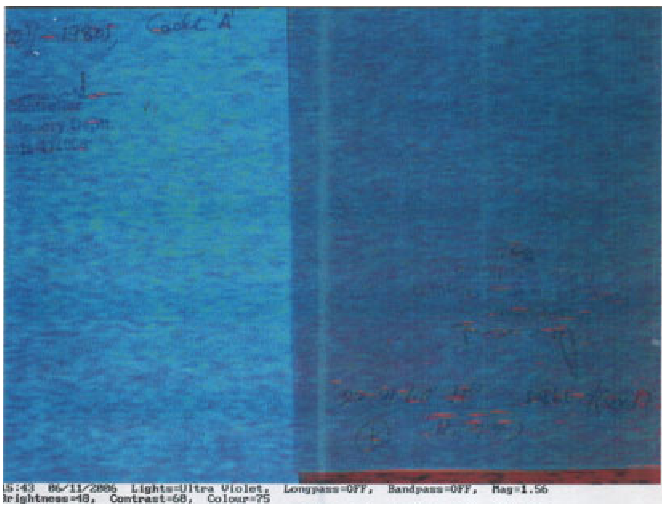

FIG. 1—*Fluorescence of the two samples under ultraviolet radiation (the left part corresponds to P/1).*

Fig. 1, the approved sample P/1 (on the left) has more of the greenish fluorescence with a light blue background.

Reflectance Spectra

Lights of different wavelengths in VSC 2000 illuminated four sheets from each sample. The reflectance spectra of these sheets are distinctly grouped as shown in Fig. 2. However, the percent of maximum intensity is above 80% in both the samples. The average spectra of the two samples can easily be distinguished as shown in Fig. 3.

Tensile Properties

Twelve strips each of appropriate size from both samples were used for the tensile testing. The Grammage (GSM) was taken to be 50 g/m^2 in both cases. Distribution of Load@Peak (*N*) and Strain@Peak (%) is shown in Figs 4 and 5, and the statistical parameters like minimum, maximum, mean, median, standard deviation, and coefficient of variation for the two samples are tabulated in Table 3. It may be noted here that Load@Peak is the load just before rupture while Strain@Peak is the strain withstood by the sample just before rupture. From Figs 4 and 5, one can easily see that the Load@Peak has a greater discrimination than the Strain@Peak (the clustering is closer for both the samples in the later case).

On the basis of the above parameters, the machine generated some additional parameters. These have been shown and compared in Table 4. Note that only the tensile index is available in the Indian Standard (IS), which is stipulated to be minimum 25 J/g (7).

Conclusion

The examination of paper on the basis of reflectance spectra, fluorescence, and tensile testing is quite effective in discriminating paper samples. These methods are simple and less time consuming when the questioned and reference samples are compared in nearly the same conditions. Further studies on known reference samples from different manufactures using other statistical techniques are

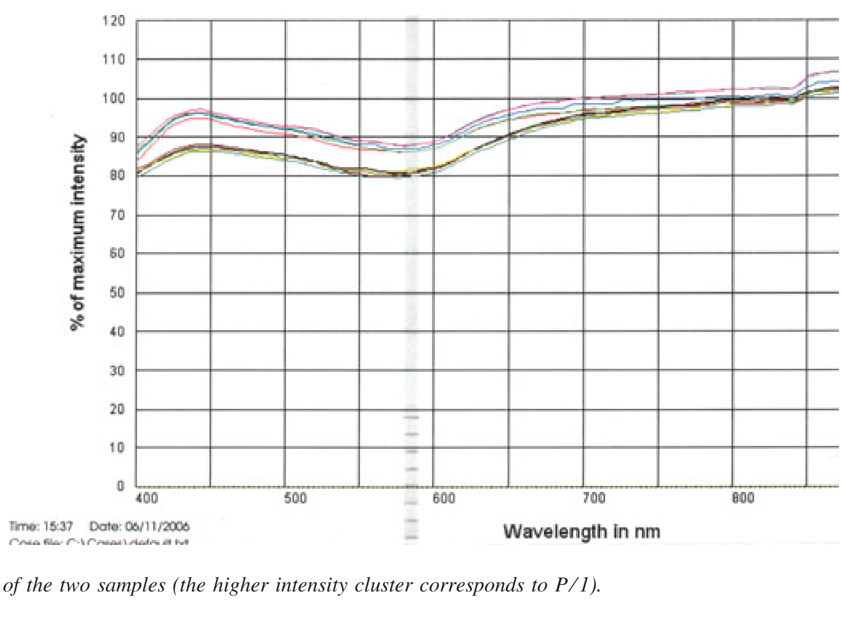

FIG. 2—*Reflectance spectra of the two samples (the higher intensity cluster corresponds to P/1).*

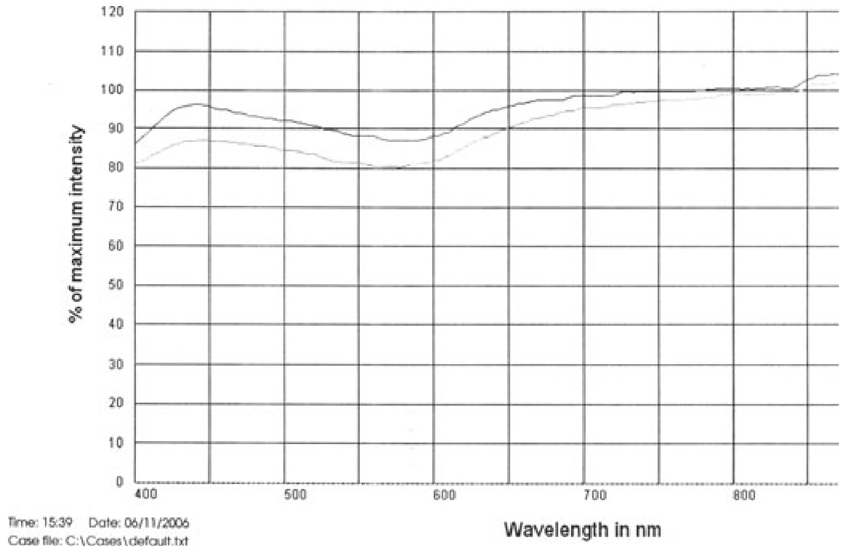

FIG. 3—*Average of the reflectance spectra of the two samples (the higher intensity curve corresponds to P/1).*

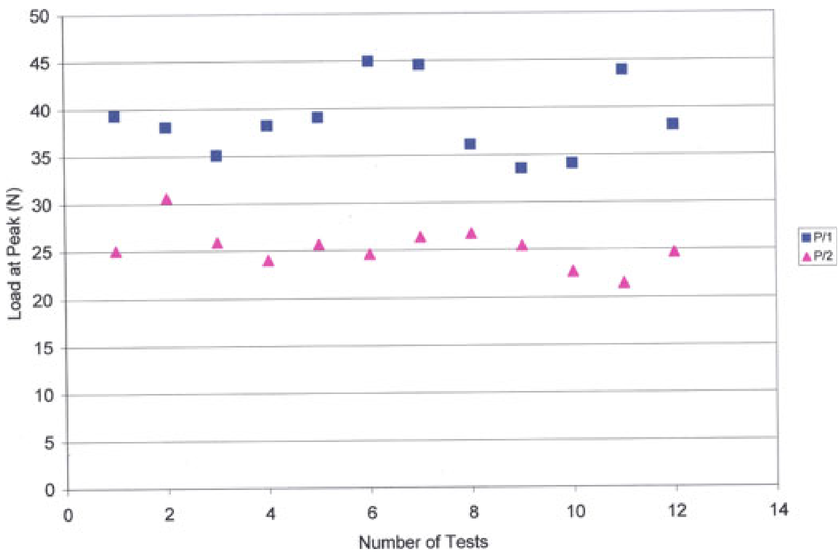

FIG. 4—*Load@Peak distribution for the samples.*

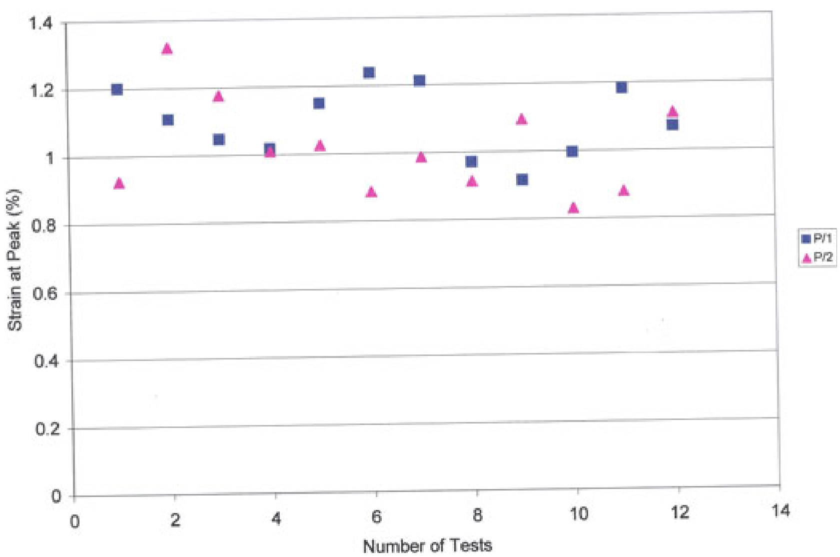

FIG. 5—*Strain@Peak distribution for the samples.*

TABLE 3—*Statistical parameters under tensile testing of the two samples.*

	P/1 (Approved)		P/2 (Supplied)	
Parameter	Load @ Peak (*N*)	Strain@ Peak (%)	Load@ Peak (*N*)	Strain@ Peak (%)
Min	33.450	0.9090	21.470	0.8286
Mean	38.735	1.0897	25.268	1.0115
Median	38.290	1.1030	25.400	1.0034
Max	45.020	1.2379	30.650	1.3195
SD	3.953	0.1076	2.277	0.1417
Coefficient variance	10.21	9.87	9.01	14.01

TABLE 4—*Additional parameters of tensile testing (MD only).*

Property	P/1	P/2	Standard
Tensile strength (N/m)	1549.40	1010.73	–
Breaking strain (%)	1.10	1.03	–
Tensile index (J/g)	30.99	20.21	25 (min)
Tension length (m)	3160	2060	–

needed to effectively assess the discriminating potential of the techniques especially when the samples are perceptibly similar.

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