Method of measure of roughness of paper based in the analysis of the texture of speckle pattern

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Introduction

At the moment, air leak methods are standardized and employed in paper industry as roughness rating methods. Air leak rate between measured paper surface and a specified flat land is recorded by using specialized pneumatic devices under laboratory conditions. Such a measurement closely corresponds to the roughness of a surface, the greater the air leak the rougher the surface. Air leak methods are rather easy to apply to paper and give stable results, although they measure roughness indirectly, need laboratory conditions, and thus unsuitable for on-line use. To measure real topography of paper surface, it is scanned with mechanical or optical profilometers. These methods provide accurate information on surface topography, but also demand laboratory conditions.

In our work, present a method of measure based in the analysis of the texture of speckle pattern on the surface. The image formed by speckle in the paper surface is considered as a texture, and therefore texture analysis methods are suitable for the characterization of paper surface. The results are contrasted to air leak methods, optical profilometers (confocal microscopy), and fringe projection.

Measurement principle

The information extraction from texture images can be obtained by different texture analysis methods, which are classified into four categories: statistical methods, geometrical methods, model-based methods, and signal processing methods. We used the gray-level co-occurrence matrix is based on second-order statistics, which deal with the spatial relationships of pairs of gray values of pixels in texture images [1], [2]. The definition, compute and calculate of the gray-level co-occurrence matrix have presented it our previous works [1], [2], [6], [7].

The rugosity of the surface is determined, as it has been said, utilizing gray level co-occurrence matrix (GLCM) obtained as from the image of speckle's pattern. We have calculated different texture descriptors, any one their as from GLCM you have to do with Ra. The software's utilized for the capture and analysis of the images of speckle's pattern are: Matrox Imaging (Intellicam), MATLAB (Digital Image Toolbox) and Microcal Origin.

We studied a total of 14 samples of paper provided for Miquel and Costas Company, with different grades of rugosity. These have been characterized previously, utilizing the air leak methods Bendtsen and Bekk [3], [4], [5] (realized measures at the Textile and Paper Engineering Department), respectively. We have also characterized by means of the optics techniques of microscopy confocal and fringes projection (realized measures in the CD6).

We decided to take the rugosity obtained by microscopy confocal as reference for our research. The images of speckle's patterns have been processed by means of algorithms developed in MATLAB and taken to Origin where accomplished the fittings of the curves given by the four descriptors of texture, the one that better you correlate with rugosity is the energy descriptor.

For to relate the rugosity of the surface of each sample with the energy descriptor, we make out an average of the energy's descriptor curves in the four directions. The result can come near to the function given by the equation:

$$y = y_0 + ke^{-\frac{x}{\sqrt{\sigma}}}$$

Where x indicates the offset distance d and y is the energy descriptor value. The parameters of the function,, are utilized to establishment the correlation with the correspondent values of the samples obtained by means of the of optical (confocal microscopy, fringe projection) [6], [7] and air leak methods (Bendtsen and Bekk) [6], [7].

Bibliography

[1] R. M. Haralick, K. Shanmugam, and I. Dinstein, "Texture features for image classification", IEEE Trans. Syst. Man Cybern. 3, 610–621, 1973.

[2] M. Presutti, La matriz de co-ocurrencia en la clasificación multiespectral: tutorial para la enseñanza de medidas texturales en cursos de grado universitario, 4ª jornada de educação em sensoriamento remoto no âmbito do mercosul, São Leopoldo, Brasil 2004.

[3] ISO (8791-1:1986). Paper and board: Determination of roughness/smoothness (air leak methods) Part 1: General method.

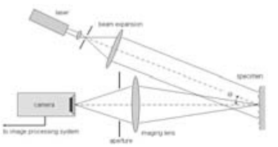
[4] ISO (8791-2:1990). Paper and board: Determination of roughness/smoothness (air leak methods) Part 2: Bendtsen method.

[5] ISO (5627:1995). Paper and board: Determination of smoothness Bekk method.

[6] A. Pino and J. Pladellorens, "Measure of roughness of paper using speckle". Proc. SPIE, Vol. 7432, 74320E (2009).

[7] A. Pino, J. Pladellorens and J. Antó, "Determination of surface properties of the paper using the analysis of the texture of speckle's pattern". Opt. Pura Apl. 43 (1) 43-48 (2010).

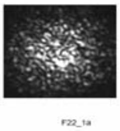
Experimental Setup

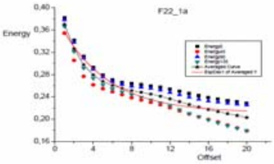


The basic configuration of the setup for surface roughness measurements by means of speckle pattern images are shown in Figure.2. The setup is built with a CCD camera UNIQ UM-301 with effective pixels 756 x 576 with 8 bits per pixel, a 5mW He-Ne laser with a wavelength of 632.8 nm and beam expander, the power of which can be adjusted to avoid the digital camera signal saturation.

The camera is located in the sample normal direction. The format of the images was 200 x 200 with 256 gray levels and the diameter of the pattern of speckle formed was made of 10mm. The angle between the incident laser light beam and the normal direction is fixed to be as small as practically possible to reduce the effect of the direction of surface microstructure in the surface roughness evaluation. In the setup, the angle is 25°. By means of the simple setup, different speckle pattern images from paper surface roughness samples are obtained.

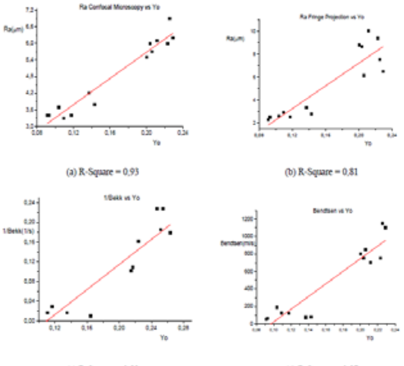
Results





No.	Sample	Ra (Confocal) µm	Ra (Fringe Pro.) µm	Bendtsen (ml/s)	Bekk(s)	Yo
1	F24HP100_7a	6,9 ± 0,5	7,51 ± 0,47	1150	4,4	0,22522
2	F24HP100_2a	6,2 ± 0,5	6,45 ± 0,47	1100	4,4	0,22881
3	F22HP35_1a	6,1 ± 0,5	10,00 ± 0,15	700	5,4	0,21148
4	F22HP35_3b	6 ± 0,5	8,66 ± 0,80	750	6,2	0,20363
5	F22HP35_6a	6 ± 0,5	9,37 ± 0,78	750	5,6	0,22299
6	F26LC50TCF_7a	5,7 ± 0,5	6,13 ± 0,40	850	9,8	0,20588
7	F26LC50TCF_1a	5,5 ± 0,5	8,78 ± 0,15	800	9,2	0,20018
8	T47_7a	4,2 ± 0,5	3,39 ± 0,62	75	95	0,13699
9	T47_9a	3,8 ± 0,5	2,80 ± 0,25	80	97	0,14317
10	velin_7a	3,7 ± 0,5	2,61 ± 0,52	190	35	0,1037
11	verge_8a	3,4 ± 0,5	2,55 ± 0,52	120	60	0,11762
12	BB36NT_10a	3,4 ± 0,5	2,52 ± 0,56	60	106	0,09309
13	BB36NT_9a	3,4 ± 0,5	2,30 ± 0,65	55	106	0,09112
14	verge_7a	3,3 ± 0,5	2,92 ± 0,62	125	61	0,10913

Speckle's patterns against the paper surface roughness and fitting curves for energy descriptor and parameters of rugosity measured by means of the optical and air leak methods.



(a) R-Square = 0,93

(b) R-Square = 0,81

(c) R-Square = 0,82

(d) R-Square = 0,87

The parameter is that maintains a very good correlation with the measures of rugosity obtained with the applied methods. In the figure 4, we presented a series of graphs where the results of the correlation between the measures can be observed.

Conclusions

We have put forward a surface roughness measurement technique through investigating the relationship between the surface speckle pattern texture and the features of the texture image GLCM. In our research, the four commonly used features contrast, correlation, energy, and homogeneity are studied with respect to surface roughness. As discussed, the parameter of the exponential curve of the energy feature has a good relationship with the surface roughness and is the best feature parameter to characterize the surface roughness.

From the experimental results with the paper surface roughness samples, the surface roughness measurement technique is effective to characterize the paper surface roughness from to . For different samples surfaces by specific methods, the range of the surface roughness, which can be characterized by the method, may be different. This means the surface roughness measurement technique we have developed needs calibration beforehand. The parameter of the exponential trend of the energy feature for a specific paper surface is computed from only a single speckle pattern texture image of the surface. This means, after the measurement system is calibrated by standard samples surfaces, that the surface roughness of the paper surface composed of the same material in the same way as the standard samples surfaces can be evaluated from a single speckle pattern texture image.