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

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ABSTRACT

Roughness of paper surface is an important parameter in paper manufacturing. Surface roughness measurement is one of the central measurement problems in paper industry. Surfaces are often coated and the amount of coating and method of application used depends on the roughness of the base paper [1], [2]. 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.

Keywords: Paper roughness, speckle, texture analysis.

INTRODUCTION

At the moment paper roughness measurements require laboratory conditions. There is a need for faster implementations of roughness measurements. An automatic, on-line roughness measurement during the production process could cause significant economical savings. Immediate detection of change in paper quality could decrease the amount of low quality paper that is produced every time quality problems occur. On the way to this goal, optical measuring devices must be improved, and fast algorithms for processing measurement data must be developed. In roughness measurement, the total roughness of the sample can be expressed by one roughness parameter. However, it may occur that the sample is mostly smooth, containing only relatively small rough areas. Those features may be lost, if the sample is considered as a whole. To find those features as well, there is a need to divide the sample into meaningful regions according to their qualities. Paper surface can be considered as a texture. A selection of methods exists to extract different texture features from the image. In paper roughness measurement, these methods can be used to categorize the paper surface.

A rough base paper needs more coating to cover the surface variation and in consequence is so important to know the surface roughness [3]. Average roughness Ra is average height between the roughness profile and its mean line (Figure 1), or the integral of the absolute value of the roughness profile height over the evaluation length, where L is the length of profile and y(x) is the height absolute value from the reference profile in point x (equation 1) [4], [5], [6].

The paper surface is characterized with three different roughness classes [5]:
• Optical roughness at length scales < 1 μm
• Micro roughness at 1 μm - 100 μm
• Macro roughness at 0.1 mm- 1 mm.
Optical roughness is connected to the surface properties of individual pigment particles and pulp fibbers. Micro roughness consists of the shapes and positions of fibbers in the paper surface. Macro roughness derives from the paper formation. In our work, we specified ourselves in microroughness scale.

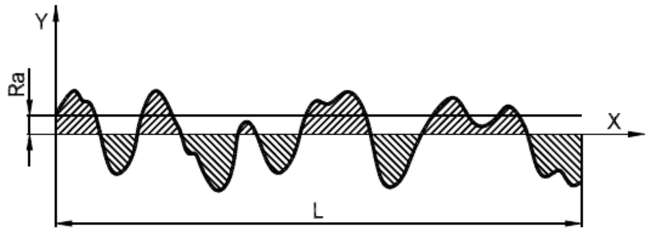


Figure 1. Determination of average roughness (Ra).

$$Ra = \frac{1}{L}\int_0^L y(x)\,dx \tag{1}$$

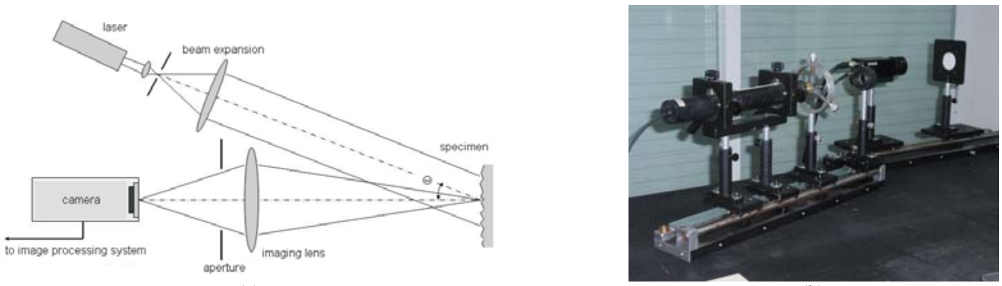
Of the methods used for the measure of rugosity, we will make emphasis in the optical. In optical methods the surface roughness measurement is based on the interaction between light and paper surface. Another approach in optical methods is to measure light scattering, a rougher surface scatters more light than a smoother one. Laser speckle measurement is based on light scattering. A surface speckle pattern, which is a grainy structure in the space produced by scattered light from a rough surface when illuminated by coherent light, contains rich information about the surface fine geometrical properties, such as the surface roughness [7]. Since the invention of lasers, researchers have discussed the relationships between surface roughness and speckle pattern statistical properties as a new method for off-line as well as on-line surface measurements. Using different properties of speckle fields and the different setup of optical systems have also developed a variety of speckle methods for surface roughness measurements [8], [9], [10], [11], [12], [13], [14], [15], [16].
A speckle image will be formed to detector from the different intensities of points. The speckle pattern images taken by an image sensor present texture form. The surface roughness information immersed in the speckle pattern images may be extracted by texture analysis. Surface roughness extraction by means of texture analysis has been explored by some researchers [17], [18]. The surface roughness characterization method using the gray level co-occurrence matrix of surface texture images, which are captured by a vision system, has been investigated [19], [20]. However, very little literature about surface roughness characterization, directly from speckle pattern texture images using texture analysis, can be found.

2. METHODOLOGY

2.1. Theory and System Setup Configuration.

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.

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. 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 [18], [21]. The definition, compute and calculate of the gray-level co-occurrence matrix have presented it our previous works [18], [21], [25], [26].



(a) (b)

Figure. 2. The basic configuration of the setup for surface roughness measurements.

The rugosity of the surface is determined, as it has been said, utilizing gray level co-ocurrence 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.

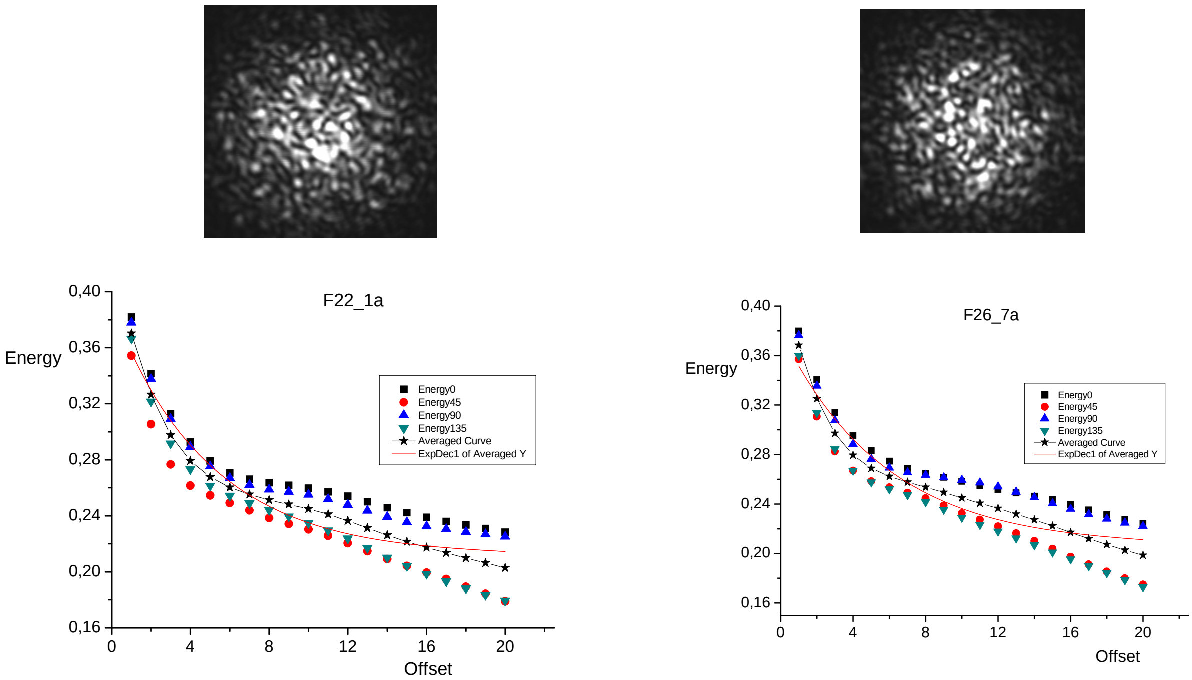
3. RESULTS

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 [22], [23], [24] (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). These results are shown in the Table 1.

Table 1. Parameters of rugosity measured by means of the optical and air leak methods.

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

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, view the figure 3.



F22HP35_1a F26LC50TCF_7a

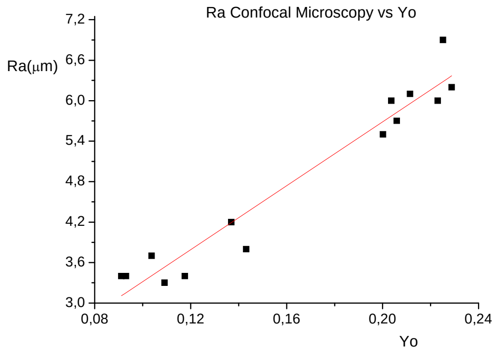
Figure 3. Speckle’s patterns against the paper surface roughness and fitting curves for energy descriptor.

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 2.

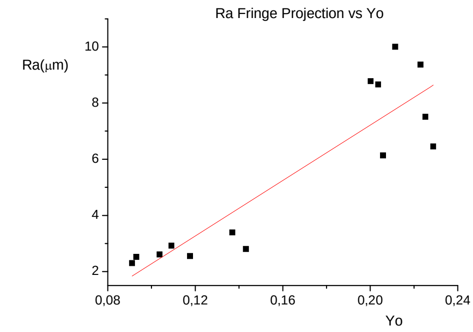
$$y = y_0 + ke^{-\frac{x}{\sqrt{\sigma}}} \qquad (2)$$

Where x indicates the offset distance d and y is the energy descriptor value. The parameters of the function y_0, k, σ are utilized to establishment the correlation with the correspondent values of the samples obtained by means of the of optical (confocal microscopy, fringe projection) [25], [26] and air leak methods (Bendtsen and Bekk) [25], [26].

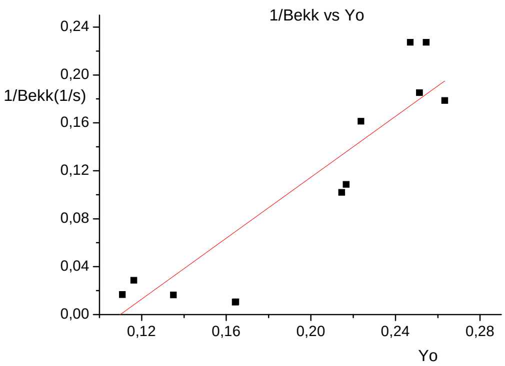
The parameter y_0 is that maintains a very good correlation with the measures of rugosity obtained with the applied methods. In the figure 4, we presented a series of graphs where the results of the correlation between the measures can be observed.



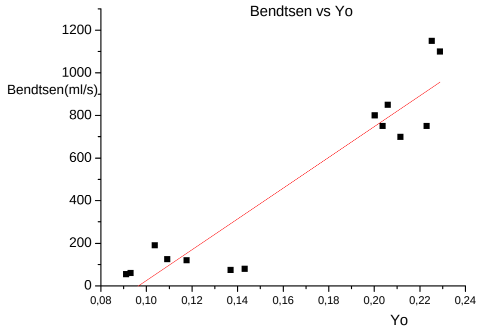
(a) R-Square = 0,93



(b) R-Square = 0,81



(c) R-Square = 0,82



(d) R-Square = 0,87

Figure 4. The graphics shows the correlation between the parameter "Yo" and the methods applied.

4. 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. There are many texture features that can be extracted from the 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 "y_0" 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 R_a=3,00μm to R_a=8,00μm. 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. In the surface roughness measurement technique, the speckle pattern texture images are taken by a very simple setup configuration consisting of a laser and a CCD camera. The parameter "y_0" 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.

ACKNOWLEDGMENTS

We would like to thank to J. Colom and A. Torres of the Textile and Paper Department of the Polytechnical University of Catalonia, F. Laguarta, S. Royo and Miguel Ares of the CD6 of the Optics and Optometry Department of the Polytechnic University of Catalonia for the help provided and also to Miquel y Costas & Miquel S.A. for his financial support.

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