

“MEMORY” EFFECT ANALYSIS TO ELECTROCOATED SURFACE FROM DISPERSE SYSTEM

D. L. Rujan*, G. Draganescu^a, Z. Gropsian

Faculty of Chemistry and Environmental Engineering, University “Politehnica” of Timisoara, Romania.

^aFaculty of Mechanics, University “Politehnica” of Timisoara, Romania.

The calculation of fractal dimension for surface microgeometry offers a great opportunity for characterization of microscopic images transformed in pixels matrix, as gray level on a scale of 1 to 255. A study based on Hurst coefficient gives sharp information about microdispersion process that produce different rough surfaces from disperse system. It represents a strong method to identify and quantify a “memory” field effect across, which can be persistent or antipersistent, with deep influence in nanostructured coatings.

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1. Introduction about “memory” field effect

Within the randomness of electrocoated rough surface may be an order called "memory" effect, where a data point is dependent on a long spatial term series of those data elements preceding it.

The Hurst exponent [2] measures the fractal dimension (D_F) of data series. Based on Hurst exponent D_F may be calculated in two ways:

$$D_F = 2 - H \quad (1)$$

$$D_F = 1/H \quad (2)$$

The cumulative of white noise (Gaussian) is known as regular Brownian motion (Bm). Calculation of Hurst exponent (H) is useful for determining if a data series extracted from experimental work is distinguishable from white noise (Gaussian). A Hurst exponent of 0.5 indicates no long-term “memory” effect across the surface and the cumulative of the data series is a pure Brownian motion. That means that in this situation each observation is independent of all prior observations.

Higher values indicate the presence of “memory” effect. It may be visible or not depending on its spatial duration. Also, the H values above 0.5 indicates that the “memory” effect belongs to persistent series. In this case, each data value has a positive correlation with preceding values.

For the other case where H is less than 0.5, the data series is called anti-persistent. Now, each data value has a negative correlation with preceding values.

2. Experimental

Electroplating procedure that produces surfaces with different roughness has been described in our previous work [1]. Then, the microgeometry of surface was visualised through computer video microscopy (CVM). The resulted samples [1] presented in figure 1a and 1b have associated a fractal dimension calculated through Box-Counting method.

*Corresponding author: danlucian2003@hotmail.com

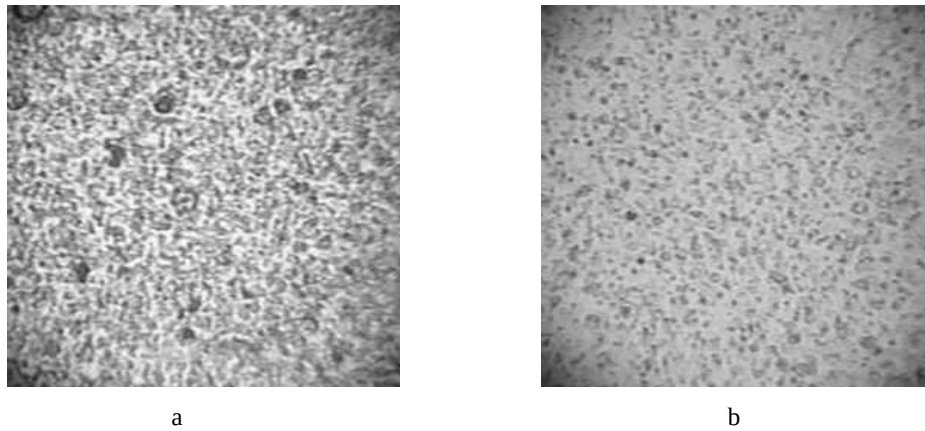


Fig. 1. a) Sample 1, with rough surface $D_F = 1.522$, b) Sample 2, with rough surface $D_F = 1.355$.

For data series of samples presented in figs. 2a, 2b, present work starts performing a fractal dimension calculation based on Sevcik's algorithm [3].

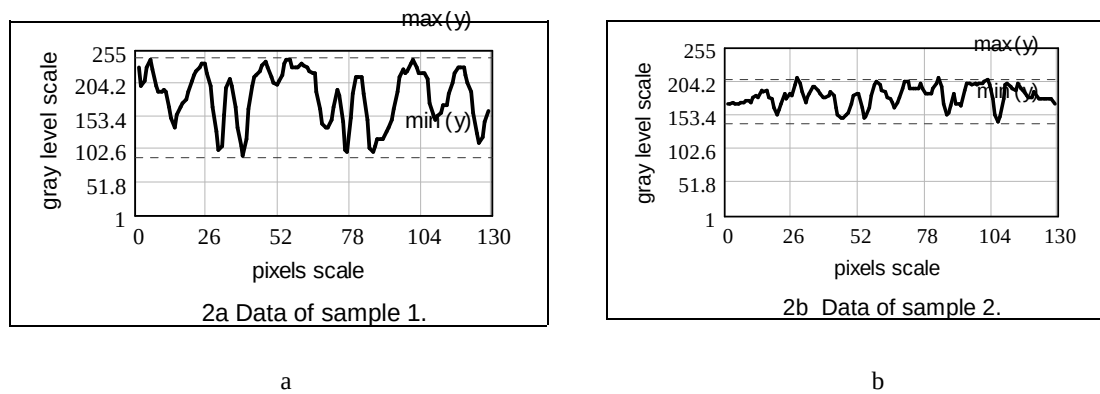


Fig. 2. a) Data of sample 1, b) Data of sample 2.

In comparison with original work [3] this paper calculates the normalization for data increments as follows:

$$y_i = \frac{y_i - 1}{255 - 1} \quad (3)$$

Then, in order to verify whether the data set is distinguishable from white noise, is inspected the autocorrelation series [4, 5].

3. Results and discussions

Figs. 3a and 3b present the D_F calculation results using Sevcik's algorithm.

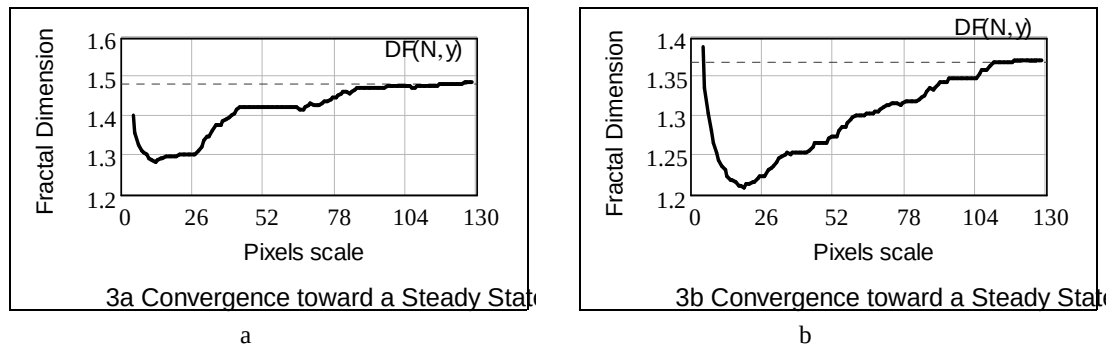


Fig. 3. a) Convergence toward a Steady State for sample's 1 data set. b) Convergence toward a Steady State for sample's 2 data set.

In order to obtain valid results for D_F , the normalization of data increments is realized according to equation 3. This adjustment is necessary to have the same scale for all data sets; otherwise the normalization range affects the result. For the case when the increments of data set are included in a 1 to 255 scale and particularly when are analyzed for comparison more data sets, is useful to use formula 3.

Also, when D_F is calculated using different algorithms is necessary to use the same scale for all methods. For experimental data obtained in the way described in our previous work [1] the best option is a 1 to 255 scale.

Then, a Hurst exponent is calculated from D_F using both equation 1 and equation 2, for both Box-Counting and Sevcik methods. The results are presented in Table 1:

Table 1. D_F and H calculated for both Box-Counting and Sevcik algorithms.

Sample	D_F		Hurst Coefficient			
	(Box-Counting)	(Sevcik)	(Box-Counting)		(Sevcik)	
			2 - D_F	1/ D_F	2 - D_F	1/ D_F
Sample 1	1.522	1.490	0.478	0.657	0.510	0.671
Sample 2	1.355	1.371	0.645	0.738	0.629	0.729

From table I results different Hurst exponents obtained using relations 1 and 2. According to interpretations presented in chapter 1, for the first sample appear a contradiction concerning a “memory” field effect.

A qualitative verification of presence of a “memory” effect is obtained inspecting the autocorrelation series. The autocorrelation function expresses the dependency between a signal and itself delayed with a factor r .

As can be seen from figures 4a and 4b, from autocorrelation inspection a “memory” effect is present in both data series. So the adequate relation for H calculation is equation 2.

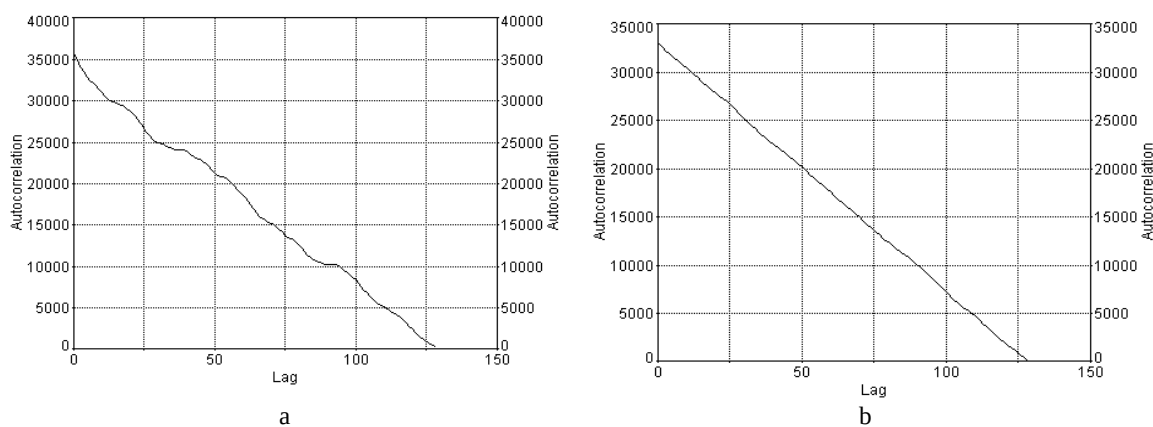


Fig. 4. a) Autocorrelation inspection for sample's 1 data set, b) Autocorrelation inspection for sample's 2 data set.

4. Conclusions

As resulted from table I, both Box-Counting and Sevcik methods are adequate for calculating fractal dimension of a rough electrocoated surface. More, the use of Hurst exponent for identification of a “memory” field effect is a good option. While the autocorrelation calculation make only a qualitatively analysis, the Hurst exponent offers a quantitative one.

Both surfaces analysed exhibit a “memory” effect; both data sets are persistent series. A comparison between them shows that for sample 2 this effect is higher. This is a measure of microdispersion or secondary dispersion process that produces a levelling effect. Microdispersion as one of the most involved processes in nanotechnology is able to define some properties of nanostructured coatings, such as corrosion resistance.

References

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