# MORPHOLOGICAL ANALYSIS AND CLASSIFICATION OF TYPES OF SURFACE CORROSION DAMAGE BY DIGITAL IMAGE PROCESSING

J. Garzón R.[1,♦], C. Barrero[2], K. E. García[2], F. Pérez[1], J. Galeano[1], A. Salazar[1] and H. Lorduy[1]
[1]*Grupo de Óptica y Espectroscopía. Centro de Ciencia Básica.*
*Univ. Pontificia Bolivariana. AA 56006. Medellín, Colombia. jgarzonr10@epm.net.co*
[2]*Grupo de Estado Sólido. Instituto de Física. Univ. de Antioquia. Medellín , Colombia.*
(Recibido 14 de Oct. 2005; Aceptado 11 de May. 2006; Publicado 16 de Jun. 2006)

## RESUMEN

En este trabajo se examina un concepto de análisis del daño de superficies de corrosión usando procesamiento digital de imágenes. El fenómeno de corrosión es analizado usando un valor digital para el daño de la superficie morfológica, en lugar de característica electromecánicas. Una imagen es categorizadas por color y textura. Para calcular el color de la superficie se usó la interpretación del modelo RGB. Para los atributos de textura, se usó el método de la matriz de co-ocurrencia. Éste análisis desarrolla un método para la identificación automatizada de los daños de corrosión.

**Palabras claves:** Daño de superficies, corrosion, procesamiento digital de imágenes

## ABSTRACT

This work examines a concept of corrosion surface damage analysis by using the digital image processing. Corrosion phenomena are analyzed using a digital value for morphological surface damage instead of electrochemical features. An initial image is characterized by categories as color and texture. To calculate corrosion surface damage color we use the interpretation of RGB model. For the texture attributes, the method of co-occurrence matrix is used. This analysis develops a method for automated identification system of corrosion damage.

**Keywords**: Surface damage, Corrosion, Digital image processing.

## INTRODUCTION

Corrosion may be defined as the destruction of a material by action of the surrounding environment. For the environment, corrosion may be classified in chemical corrosion, if an electrolyte is not present, and in electrochemical corrosion, if an electrolyte is present. For the form, corrosion may be classified in general or uniform corrosion and local corrosion. In the general corrosion the mean attack deep is uniform on the entire surface. To the first class belong atmospheric corrosion, sea water corrosion and soil corrosion. The second class is usually divided in plate corrosion, pitting corrosion, crevice corrosion and stress corrosion. Different effects of various factors on corrosion process cause different damage types and finally result in different morphological damage. Expert visual examination is the most common and simple method of assessing corrosion damages morphology. Among the drawbacks of the method are the necessities to employ qualified staff and to use of subjective criteria for decisionmaking. The methods

♦ Email: `jgarzonr10@epm.net.co`

of digital images processing, classification and analysis are currently in considerable use in various fields of science but few used to analyze corrosion processes. The aim of this paper is to develop a corrosion damages automated classification method by their optical images. It allows detecting a representative set of morphological attributes.

## SAMPLE PREPARATION OF CORROSION

Total immersion trials of carbon steel coupon (A36) of dimensions 100 x 30 x 3 $mm^3$, were carried out. The processing applied to each coupon consisted in hit it with a spurt of sand to reach the white metal degree, later these were degreased with detergent, hot water and ethyl alcohol. The coupons were submerged in vertical position during 42 days in a 0.6 M chloride of sodium solution (analytical grade) prepared in environmental temperature distilled water and in a continuum low air flow (1.5 cc/min). The final adherent rust (products of corrosion) can be classified in two types: (i) which falls for simple drumming of the coupon, or rust weakly adhered to the steel, and (ii) which is separated by brush metallic scraped, or hardly adhered rust to the steel. .

## SEGMENTATION IN THE RGB MODEL

This method[3] consists of several steps. A first procedure is to separate as a new image the region of interest **I** (subspace of original image **A**). The images **A** and **I** are divided in their three planes RGB, which we will denote $A^k$ and $I^k$ respectively, with $k$ = 1, 2, 3. In the second step, a mask $M^k$ ($k$ = 1, 2, 3) of the same dimensionalidad of $A^k$ is created, under the following condition:

$$M^k(i,j) = \begin{cases} 1 & sí \quad A^k(i,j) \in I^k \\ 0 & sí \quad A^k(i,j) \notin I^k \end{cases}, \qquad k = 1, 2, 3 \tag{1}$$

In the third step, a new mask $M$ is obtained as a result of the multiplication of the three arrays $M^k$:

$$M(i,j) = \prod_{k=1}^{3} M^k(i,j) \tag{2}$$

Then, the mask $M$ is multiplied with every color component $A^k$, producing three segmented color planes:

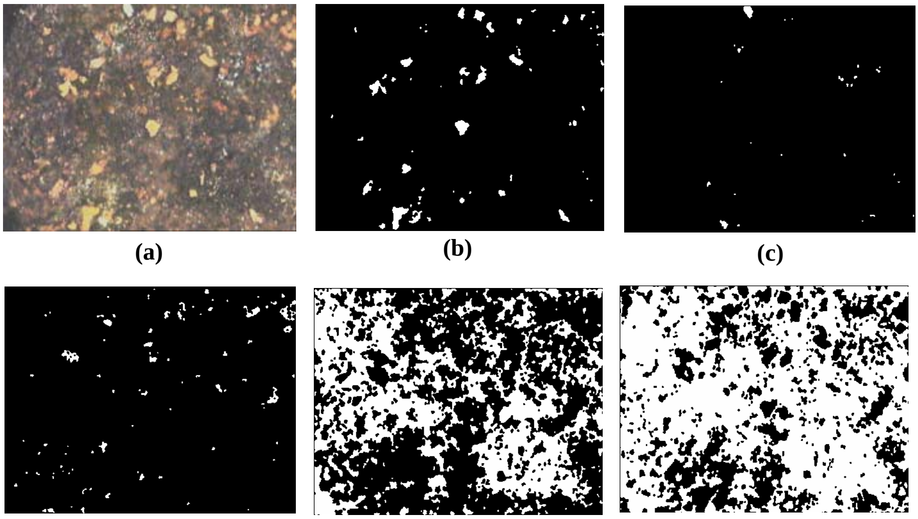
$$P^k(i,j) = A^k(i,j)M(i,j), \quad k = 1, 2, 3 \tag{3}$$

The combination of them return an image **P** in segmented true color.

## EXPERIMENT AND RESULTS

Analysis by X-rays diffraction and by Mössbauer spectroscopy, were presented in another paper (see reference [1]). They show that the hardly adhered rust to the steel is composed of lepidocrocita (18 wt. %), Akaganeita (22 wt. %), Goethita (15 wt. %), and a spinel phase which may be magnetite oxidized (45 wt. %). Above the rust layer, a weakly adhered rust layer is found, which is composed of the same phases of iron but with different relative abundance, that is: spinel phase (54 wt. %), Lepidocrocita (26 wt. %), Goethita (8 wt. %) And akaganeita (12 wt.

%). Qualitatively, to simple view the colours of the layers of rust show the formation of these same composed. In fact, according to Schwertmann and Cornell [2], the magnetite exhibits black colour, the goethita yellow color space, the lepidocrocita yellow-reddish, and the akaganeita yellow-brownish.



**(a)** **(b)** **(c)** **(d)** **(e)** **(f)**

**Fig. 1**. **(a)** Carbon steel sample. Acquired image by mean of metallographic microscopy Leica: Microscope objective of 10×, NA = 0.25, WD = 5mm. Observation field: $8.5 \times 10^5$ μ$m^2$ **(b)** Goethita **(c)** Sodium Chloride .(**d)** Lepidocrocita **(e)** Magnetite. **(f)** Akaganeita.

Figure 1(a) shows the acquired image of the carbon steel coupon. Like any other problem of image analysis, the goal is obtaining the identification and characterization of the sub-regions of the corrosion image. In relation to visually interpretable objects, the morphology comprises the notions of color and texture of the objects under analysis. Algorithmically its solution is derived from the determination of relations between the identified color and texture characteristics of the surface portions, In our case, is to do a segmentation of the compounds in the corrosion image.

Applying the model of segmentation in the RGB space and using operations of mathematical morphology was possible to obtain the regions with goethita, sodium chloride, lepidocrocita, magnetite and akaganeita. The results are shown in the figure 1 (b)-(f). On the other hand, the texture characteristics were obtained from construction of the co-occurrence matriz (**C**) based on the relation of the values hue (HSV model) in the segmented color regions and a position operator defined as “one píxel to the right and one píxel below”. More generally, the problem is to analyze a given **C** matrix in order to categorize the texture of the region over which the matrix **C** was computed[4]. A set of descriptors useful for this propose includes the shown ones in the table 1.

**Table 1.** Characteristics of texture

| Region | Area $\mu m^2$ | Hue Mean | Hue Stan. Desv. | P. Max. | EDMp $p = 2$ | IEDMp $p = 2$ | U | E |
|---|---|---|---|---|---|---|---|---|
| Goethita | 18248.0 | 35.6 | 24.8 | 0.0362 | 15295 | 25.0 | 0.0099 | 7.0 |
| Sodium Chlo-ride | 2633.9 | 74.7 | 64.2 | 0.1635 | 8233 | 12.5 | 0.0446 | 5.4 |
| Lepidocrocita | 11972.0 | 21.6 | 31.0 | 0.0313 | 1947 | 13.8 | 0.0186 | 5.8 |
| Akaganeita. | 514650.0 | 70.2 | 85.8 | 0.0158 | 784494 | 26.5 | 0.0032 | 8.5 |
| Magnetite | 303210.0 | 80.3 | 88.8 | 0.0651 | 461290 | 18.3 | 0.0134 | 7.4 |

Where the Maximum probability (P. Max) is defined as $\max_{i,j}\left(C_{i,j}\right)$; the element difference moment of order p (EDMp) as $\sum_i \sum_j (i-j)^p C_{i,j}$ ; the inverse element difference moment of order p (IEDMp) as $\sum_i \sum_j C_{i,j} / (i-j)^p$ ; the uniformity (U) as $\sum_i \sum_j C_{i,j}^2$ and the entropy (E): $-\sum_i \sum_j C_{i,j} \log_2 C_{i,j}$ .

## CONCLUSIONS

Morphological attributes will allow us to perform the probabilistic identification of the compounds in the corrosion image. Our results have shown, that apart from someone meted [1], corrosion can be evaluated by digital image processing in morphology, color, and texture.The analysis of corrosion damage by digital image processing is an important step in the promising direction in corrosion diagnostics.

## REFERENCES

[1] K. E. García, A. L. Morales, C. A. Barrero, and J. M. Greneche, “New contributions to the understanding of rust layer formation in steels exposed to a total immersion test”, Aceptado en Corrosion Science (2006).

[2] Schwertmann and Cornell, *Iron oxides in the laboratory, preparation and characterization*, Second edition, Wiley-VCH Verlag GmbH, Weinheim, Germany, 2000.

[3] Garzón J. Plata A., Meneses J. Suárez M. and Vesga W. “*Método policromático para la caracterización de imágenes metalográficas*”. Memorias del VII ENO. Editado por la Academia de Ciencias Exactas y Naturales. 2004.

[4] Gonzalez R. and Woods R.“*Digital image processing”*. Prentice Hall, Second edition, New Jersey, USA,2002.