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AN IMAGE ANALYSIS METHOD FOR CALCULATING THE SURFACE AREA OF SCREWS AND OTHER SIMILAR FASTENERS

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Abstract: A simple method has been developed to calculate the body surface area of screws combining descriptive geometry concepts with digital image analysis. This one can also be applied to the other threaded fasteners. One of purpose of this work is to assist researchers in corrosion tests in which the exposed area of a screw is a very important parameter.

Keywords: screws; fasteners; image analysis; surface area; corrosion.

2010 Mathematics Subject Classification: 62H35.

1. INTRODUCTION

Corrosion tests are considered to be the most important aspect of corrosion engineering. The main objectives of the corrosion tests are: evaluation and selection of materials for a specific environment; evaluation of new materials to determine the environments in which they are suitable; control corrosion resistance of the material or the corrosivity of the environment; study of corrosion mechanisms. Many tests are made to select metals and alloys for construction of tools, equipments, machines, engines, etc. Laboratory tests, including electrochemical [1] and non-electrochemical [2] methods, are characterized by small samples immersed into small volumes of solutions and conditions are simulated insofar as conveniently possible. Then, changes in the sample and/or solution are monitored directly or indirectly during a relatively short period of time.

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Corrosion reactions are typical examples of heterogeneous kinetic and so corrosion rates depend on the surface area of samples. In this sense, it is expected that major surface areas should result in higher corrosion rates. Size and shape of samples vary, and selection is a matter of discernment. Disks, cylinders and flat samples are often used, but small metallic components and fasteners such as pins, rivets, studs, screws, bolts and nuts are also tested. When particular shapes are involved, the area determination can become a serious problem. Since the area enters in the formula for calculating the corrosion rate (e.g. mg/dm^2/day or mdd), the results can be no more accurate than the accuracy of the measurement of the area [3].

Screws are widely used in various industrial sectors and the most common applications of screws are to hold objects together or to position objects. In medicine, the field of screws for internal fixation within the body is huge and diverse. Titanium screws are used to fix dental prosthesis in the jaw, as an alternative for the replacement of the tooth loss. Plates and screws of titanium alloys or stainless steels are used as orthopedic implants to treat all kinds of bone fractures [4].

A screw can be essentially described by having a head on one end followed by a helical ridge (triangular, trapezoidal or rectangular) extending along its length (male thread) [5]. Before a screw is submitted to corrosion test, the calculation of exposed area becomes the main problem to solve. In practice, it is often assumed that screws have a simple geometry and they are modeled as cylindrical or conical bodies. This assumption may cause big errors whose magnitude will depend on the thread types.

In this context, it is proposed a simple method to calculate the body surface area of a screw combining concepts of descriptive geometry with digital image analysis. The screw head surface area will not be calculated since the head and body are almost always exposed at different environments and so they are usually submitted to distinct corrosion tests.

2. PROCEDURE

The method can be described in five main steps as shown below:

1. Measure the major diameter (D_{maj}) of body-screw using a caliper. This parameter will be used to determine of the screw image scale.
2. Capture the image of the screw in vertical position with a digital camera or stereomicroscope;

3. Analyze the obtained image to generate a scaling factor by relating the pixels number with the diameter measured by a caliper (e. g. pixels number: mm). For this purpose, free software like GNU Image Manipulation Program (GIMP 2.8.16) can be used.
4. Determine through the obtained image the minor diameter (D_{min}) and the length of the body-screw profile (L). In cylindrical screws without shank (unthreaded portion), L_{cyl} (the sum of edges of a pitch multiplied by the pitches number) will be equal to the length of a hypothetical cylinder of diameter $D_{min\text{-}cyl}$.
5. Calculate the exposed area of body-screw as being the area of the hypothetical cylinder (A_{cyl}) according to equation 1.

$$A_{cyl} = \pi \, D_{min-cyl} \, L_{cyl} + \pi \left(\frac{D_{min\text{-}cyl}}{2} \right)^2 \tag{1}$$

In cylindrical screws with a truncated conical end (chamfer), the exposed area (A_{ctc}) can be calculated from equation 2. In this case, L_{cone} is the sum of all edges at the end.

$$A_{ctc} = \pi \, D_{min-cyl} \, L_{cyl} + \pi \left(\frac{D_{min-cyl}}{2} + \frac{D_{min-cone}}{2} \right) L_{cone} + \pi \left(\frac{D_{min\text{-}cone}}{2} \right)^2 \tag{2}$$

When cylindrical screws have a conical end, the exposed area (A_{cc}) can be obtained from equation 2 with $D_{min\text{-}cone} = 0$ (equation 3).

$$A_{cc} = \pi \, D_{min-cyl} \left(L_{cyl} + \frac{L_{cone}}{2} \right) \tag{3}$$

3. RESULTS AND DISCUSSION

Finally, this method will be applied to a machine screw, which has trapezoidal pitches (Figure 1). This screw has D_{maj} = 6.15 mm and 39 pitches. The image scale (6.15 mm : 384 pixels) was obtained from the image processing.

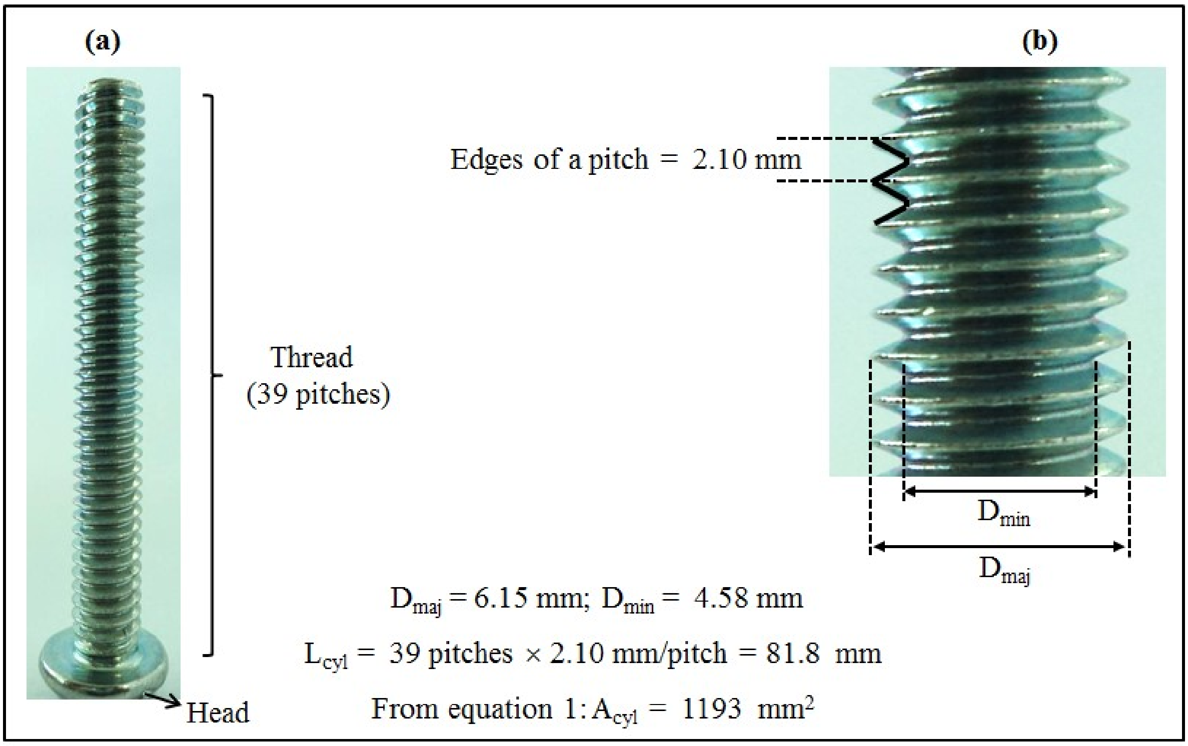

FIGURE 1: (a) Photograph showing different parts of a machine screw: head and thread, and (b) enlarged part of the same photograph showing shape and size of the pitches.

If the screw is modeled as a cylinder with the following basic characteristics: length = 50.10 mm and major diameter = 6.15 mm, the estimated exposed area will be 998 mm^2. This value is 16% less than the one calculated using the method above described. When this method was applied to a sheet metal screw of the same D_{maj} as the machine screw, and length of 49.80 mm (cylindrical portion = 44.65 mm + conical portion = 5.15 mm) (Figure 2), the difference between the calculated and estimated areas was less than 4%. From these results, it is interesting to emphasize that the difference in the area values is mainly related to L_{cyl} and this difference increases as the pitches number increases.

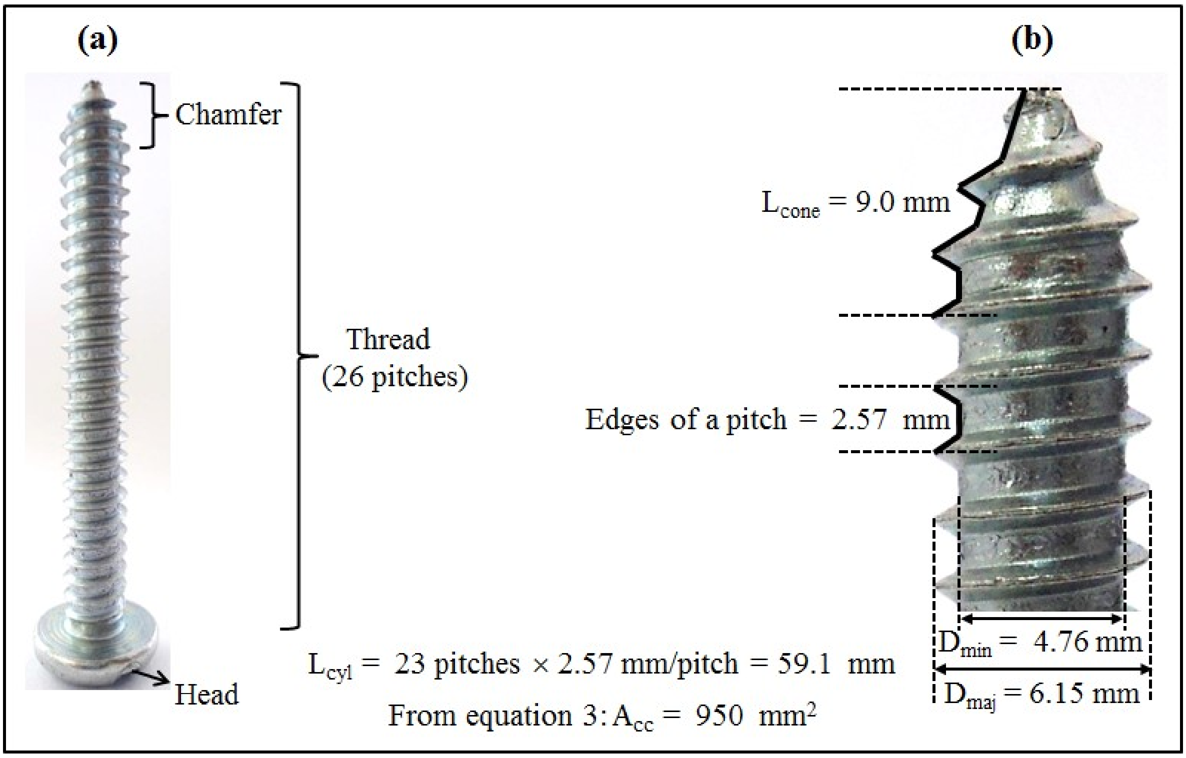

FIGURE 2: (a) Photograph showing different parts of a sheet metal screw, and (b) enlarged part of the same photograph showing shape and size of the pitches (6.15 mm: 305 pixels).

4. FINAL CONSIDERATIONS

The proposed method is a powerful tool to calculate the surface areas of screws and other similar fasteners. It is also effective when chamfers of screws can be modeled as regular geometry bodies. Both the pitch size and shape are not limiting factors of the method if the pitch edges are preserved during the image processing.

Conflict of Interests

The authors declare that there is no conflict of interests.

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Nomenclature

A_{cc}	exposed area of cylindrical screw with a conical end
A_{ctc}	exposed area of cylindrical screw with a truncated conical end
A_{cyl}	exposed area of cylindrical screw
D_{maj}	major diameter of body-screw
D_{min}	minor diameter of body-screw
$D_{min\text{-}cone}$	minor diameter of cone
$D_{min\text{-}cyl}$	minor diameter of cylinder
L	length of the body-screw profile
L_{cone}	sum of edges at the conical end of a screw
L_{cyl}	sum of edges of a cylindrical screw