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Sand Grains Analysis For Abrasive Wear Tests Through Image Processing Techniques

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Abstract

This research focuses on the implementation of morphological image processing in order to compare common sand regarding the mesh standardization for Ottawa sand, used in abrasive wear tests; this technique is used to identify wear, hardness and resistance for various materials in the field of tribology. The aim of this paper is to develop a software tool that, through image processing techniques, allows an automatic comparison of the grains size in the sand sample, resulting in the establishment of comparative and selection patterns with any level of the established standard for the Ottawa sand, thus providing the possibility to evaluate and homologate the sand sample analyzed for the development of this type of wear tests.

Keywords: Morphological image processing, abrasive wear tests, segmentation.

INTRODUCTION

The abrasive wear in machine components is a phenomenon that is constantly present at industrial level, generating efficiency loss and increasing the energy consumption, the established budget, the process dead times, among many other drawbacks. For this reason, the scientific and technological tribology knowledge has become very important in order to find alternatives that increase the life of the machines, increase their efficiency and reduce production and maintenance costs. [1]

One of the techniques used to fight and measure abrasive wear for several industrial materials is the wear tests, performed by specialized machines and governed by standards such as ASTM G-65 [2]. This standardization establishes values to classify the different diameters that the meshes used for the test can have, classifying them in: thick, medium, fine, very fine and thick slime, being the third classification (fine) the standardization used for abrasive wear tests. [3,8]

The main objective of this work is to provide a software tool that allows the image comparison and analysis for specific samples of common sand, being able to determine according to their morphological characteristics, if this sand can be used for abrasive wear tests in the same way as Ottawa sand. The proposed development is based on the sample acquisition to be analyzed, followed by a step of filtering and adaptation of the image to be treated; after this stage, a contour recognition is performed, which delivers a validation percentage regarding the number of sand grains identified at the analyzed image and the quantity of grains accepted for the test.

METHODOLOGY

The proposed development begins with the image acquisition that comes from an electron microscope that captures the sand grains with a resolution of 960 x 1280 pixels at a scale of 1000 microns, after this stage a filtering process is performed eliminating the brightness and noise that affects the analysis of the respective image; once the sample has been conditioned, the binarization of the sample is carried out in order to perform the contour detection to identify and validate each sand grain; this process allows to quickly and efficiently characterize all components of the sample analyzed. (See Fig. 2)

Abrasive Wear Testing

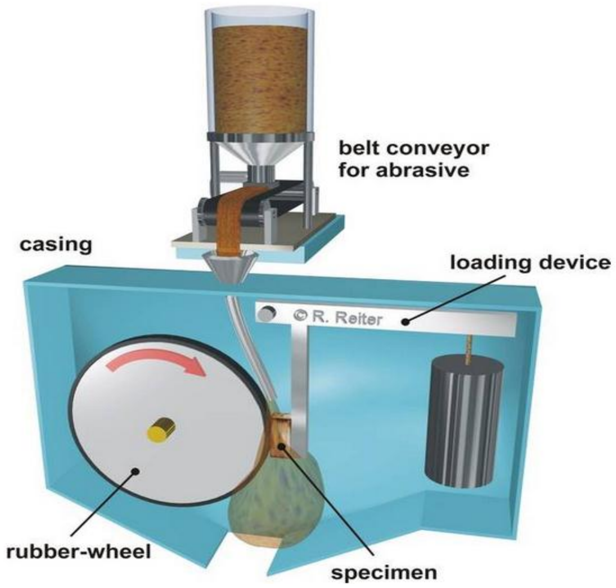


Figure 1: Abrasive Wear Testing Machine according to ASTM G65 [7].

The tribology is responsible for studying the lubrication, friction and wear of moving or stationary parts, factors that become fundamental in the life of the machines [4,5].The analysis of this type of factors is determinant, since the lack of attention and monitoring generates failures that cause significant damages in the machinery, engines and components of the industry in general, increasing the losses associated to the processes of any industrial or production environment.[12]

The basic design of an abrasive wear test machine under ASTM G-65 is shown in Fig. 1; this is one of the tests that are performed on materials to know their properties against wear. The prediction of wear is complex because it is not an intrinsic property of the material, but depends on the whole system with which the body that wears it interacts. [6,8]

In the process, the sand is introduced into the friction contact of a rotating disc and the sample where the test material is pressed against the rubberized wheel by a lever arm with a defined normal force and speed. After certain time intervals, the volume of the material must be carefully measured, in this way, the measured material characteristics of wear, hardness or resistance can be established.

Morphological image processing

The morphological image processing is a technique that is usually used when the appliance of the segmentation processes doesn't obtain the desired results, meaning, when delimiting objects or areas of interest there are inaccuracies in the edge detection or regions overlap. This processing technique is used to extract image components enhancing its geometry and form; its mathematical foundation is supported on operations of set theory. In the case of binary images, the treated sets are subsets of Z^2 and in the case of grayscale images, the element of the set is formed by the coordinates of the pixel and its gray level in Z^3 [9]. In general terms, when applying morphological processing the following results can be obtained: Noise suppression, forms simplification, objects detection, enlargement or reduction, extraction of boundaries or edges, extraction of skeletons, obtaining of areas and perimeters, among many others applications.

IMPLEMENTATION

The analysis begins once the image at the electron microscope is acquired, the selected image has a RGB color format, corresponding to three superimposed matrices; for this reason, it is necessary to convert it to a grayscale image to identify the luminosity of the objects to be analyzed, this conversion performed in order to facilitate the manipulation of the data so it can be processed [10,11,13]. Once the most luminous objects are identified, a filtering step is performed, making the data of the matrix less relevant to zero and allowing only the passage of a luminosity greater than 31.3%, meaning that the positions of the matrix corresponding to a value greater than this percentage of brightness are converted to a value of 255, in order to perform a binarization of the image with greater precision. (See Fig. 3)

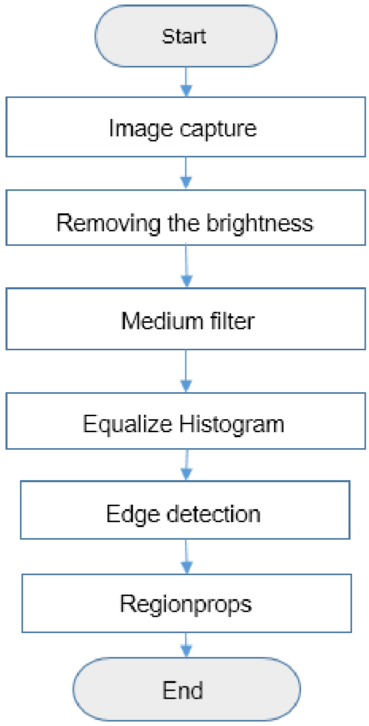


Figure 2: Flow diagram

After the image has been binarized, the contour detection proceeds; this process is carried out by the implementation of the "Regionprops" function of MATLAB. When executing this function by using the "BoundingBox" command, the coordinates in the image matrix are known, corresponding to the upper, lower and lateral edges of the recognized object.

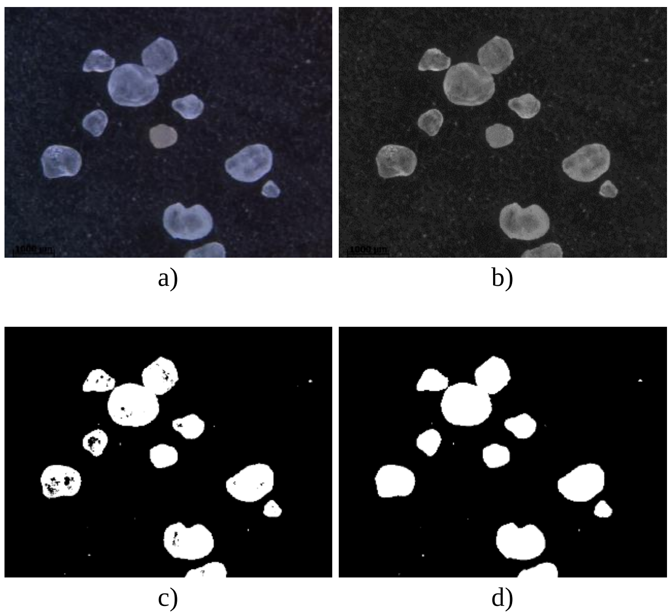


Figure 3: Sand grains image at a scale of 1000 microns. a) Color b) Grayscale c) Binarized d) Filtered

In order to perform a specific analysis associated with the size of the sand grains, a mathematical equation must be established that allows the converting of the image number of pixels to a scale of 1000 microns, taking into account the reference given by the microscope and the image resolution, the following equation is obtained:

$$x\ microns\left(\frac{156\ pixels}{1000\ microns}\right) = x * 0.156\ pixels$$

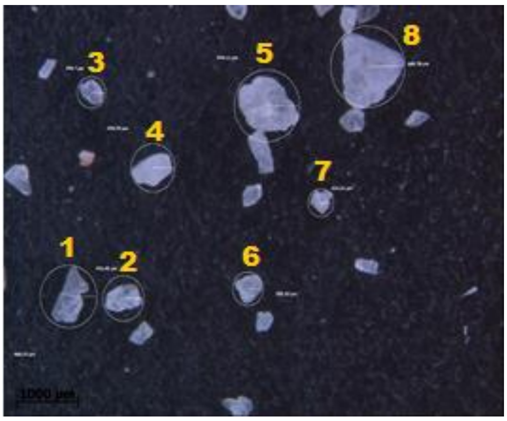
As the analyzed sand grains have an irregular outline, it is necessary to make a comparison of the number of pixels that exist between the upper and lower edges and the difference between the lateral edges, in this way it is possible to know if the object has more length in its width or height; also known the circle radius that allows to completely enclose the figure or contour detected.

The software tool designed, in addition to drawing a circle on the figure found, allows filtering by size the radius of the sand grains according to the standardization of meshes for the classification in the tests of materials wear. The accepted diameters for the test must be between 200 microns and 400 microns.

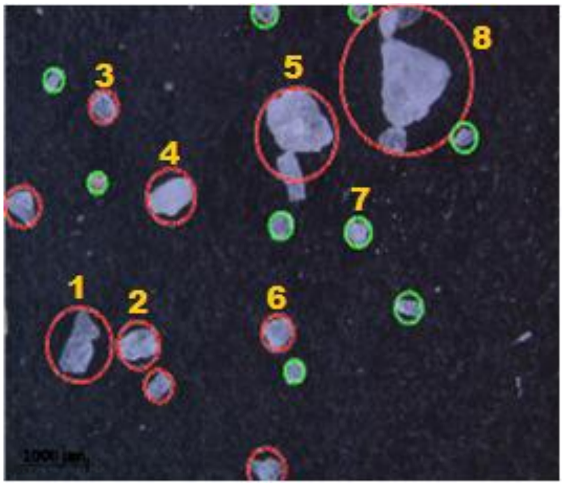
RESULTS

In general terms, the development of this tool arises from the need to create an automatic process that will be in charge of measuring, classifying and analyzing the sand grains for wear tests, since this process of measurement and classification was executed by the laboratory manager manually grain by grain, generating a considerable increase in the analysis times and the generation of errors when delimiting the contour of the samples analyzed.

The developed tool not only allows to perform the measurement and characterization of the grains automatically, but also allows to make a specific selection and classification of the sand grains in function of their size, that is to say, a size filter can be configured to indicate which and how many grains correspond to diameters between 200 and 400 microns, see Fig. 4.



a)



b)

Figure 4: a) Manual measurement b) Automatic measurement using proposed solution

In Fig. 4-b, it can be seen that the sand grains enclosed into green circles correspond to the grains which are within the range of 200-400 microns, while the grains which are outside the range are the enclosed into red circles ones.

The algorithm developed associated to image processing, reflects an efficiency percentage greater than 87.8% for the automatic detection of samples. It was observed that when there is a junction between the sand grains, the measurement is significantly altered, producing a margin of error for the measure, see Fig. 4-b, however, as shown in Fig. 5, when there is no overlap or junction between the grains, the detection efficiency is 100%.

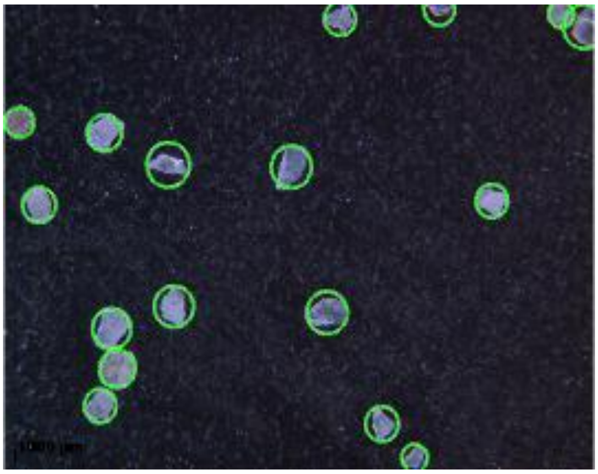


Figure 5: Automatic detection without joints or overlaps in the grains

In order to know the difference between the measurements made manually by an operator and the ones by the software, the tool allows to calculate a correlation coefficient determined by:

$$\mu x = \frac{\sum x}{n}$$

$$\delta x = \sqrt{\left(\frac{1}{n-1}\right)\left(\sum (x-\mu x)^2\right)}$$

$$\mu y = \frac{\sum y}{n}$$

$$\delta y = \sqrt{\left(\frac{1}{n-1}\right)\left(\sum (y-\mu y)^2\right)}$$

Where:

μ - mean value for the data represented

x - data measured manually

y - data measured by software

n - amount of data

δ - standard deviation

Finally, the correlation coefficient " ρ " can be determined, obtaining:

$$\rho = \left(\frac{1}{n-1}\right)\left(\sum\left(\left(\frac{x-\mu x}{\delta x}\right) * \left(\frac{y-\mu y}{\delta y}\right)\right)\right)$$

It is important to emphasize the execution times achieved, because a substantial improvement is obtained in this process, since the algorithm hardly takes an average of 593 milliseconds to obtain all the analysis parameters of the samples (diameters, classification, averages and generation of reports). The software validation tests were performed in a MATLAB 2015a development interface, this platform runs on a 64-bit Windows 10 operating system, with an Intel Core I7-4702MQ CPU 2.2 GHz processor and 8 Gb in RAM.

CONCLUSIONS

An effective software tool was developed based on image processing and the detection of contours of geometric figures, capable of significantly reducing the analysis times associated to the study, classification and homologation of samples of sand grains used in abrasive wear tests. The generation of this type of tool based on general concepts of image processing, facilitates the development of the tasks elaborated by the technical personnel responsible of evaluating and standardizing the sand samples, demonstrating once again that the mathematical concepts related to the processes of automation solutions provide practical and effective solutions for real problems in the productive sector.

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