Image processing applied to measurement of particle size

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Abstract. Five different types of aggregates have been analyzed, and the size of particles on samples immersed in distilled water as silicon dioxide, titanium dioxide, styrenes and crushed silica particles is made; an attempt at applying the digital image processing (DIP) technique to analyze the particle size, we developed a system of measures microparticles using a microscope, a CCD camera and acquisition software and video processing developed in MATLAB. These studies are combined with laser light using measurements by diffractometry and obtain calibration in the system implemented, in this work we achievement measurement particle size on the order of 4 to 6 micrometers. The study demonstrates that DIP is a fast, convenient, versatile, and accurate technique for particle size analysis; the limitations of implemented setup too will be discussed.

1. Introduction

This paper contains the principal fundaments of a digital measurement model for size particles in order of the micrometers. In this investigation the issue over the measurement of micrometric particles using digital image processing and whose main purpose is to demonstrate that it is possible to measure very small particles optimally, efficiently and easily.

The basic ideas and principles of digital image processing are established for many years, but were not carried out due to lack of computers. With the advent of computers and high-capacity memory, it was natural to begin to develop this field. One of the first places they started making digital processing was at the Jet Propulsion Laboratory in 1959, with the aim of improving the images sent by the rockets. The results obtained in a relatively short time were so impressive that very soon the application of the method is extended to other fields [1].

Finally we can say that the image processing is studied through optical microscope and a simple purchasing system and computer image processing, the main feature of this type of measurement is the ability to obtain results in real time.

2. Procedure

The layout of the paper is as follows: In Section 2, we present the detailed underlying theory of the diffraction method as applied to measurement calibration. This is followed by a brief description of the simulation technique in Section 3. Details of simulation algorithm and simulation results are described respectively, in Sections 4 and 5. Finally some concluding remarks are made in Section 6.

2.1.Diffraction grating

A diffraction grating is a binary repeating set of equally spaced diffracting elements (apertures or obstacles), which produce periodic alterations in the phase and / or amplitude of the light wave studied. The grating can separate a beam of light incident on it in their colors or constituent wavelengths, this phenomenom can also will be measured and obtain the differents wavelengths. We distinguish two types of diffraction gratings: grating reflection and grating transmission . The gratings are constructed by reflection stripes equispaced parallel recording on the polished surface of a metal. The light is reflected in the projections between the marked lines. In gratings for transmission, the parallel lines are written on a glass plate, and the light passes through the transparent spaces between said stripes [2]. In many of college texts the constant (d) is mistakenly referred as the distance of separation between slits, when this constant in reality correspond to the spatial period of the diffraction grating, which is the distance of the slit separation distance over which a new slot (zone begins black grid), so that it can fulfill the equation that relates to the lattice constant, which is the number of lines per millimeter which can be observed in equation (1), a diffraction grating can be seen in Figure 1.

$$C_{gra} = \frac{10^{-3}}{p}. \tag{1}$$

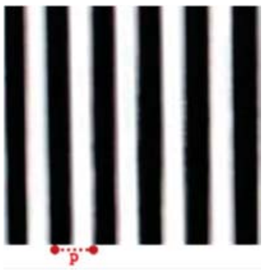

Figure 1. Spatial period of diffraction grating

3. Scheme for experimental measurement of period the grating

The spatial period of the diffraction grating has been experimentally calculated using the setup implemented at the optical bench and is shown in Figure 2.

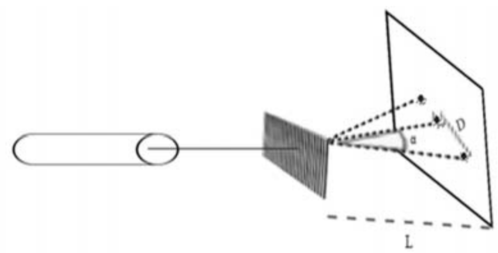

Figure 2. Experimental setup for measurement of spatial period in the grating

The experimental setup consists of a conventional He-Ne laser with a wavelength (λ = 633nm) , a diffraction grating to calculate the spatial period, the theory used for this purpose is the Bragg's Law, this relationship is showed in equation (2) , and consist in an observation plane at a distance L of diffraction grating; in this plane an interference pattern is formed, at correspondence with the

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Fourier Theory. The spatial period was referred in terms of the wavelength in accordance to equation (2.1). Then the spatial period has been calculated in the follow form [6].

$$n\lambda = p\sin\alpha, \tag{2}$$

$$p = \frac{\lambda}{sin\alpha}. \tag{2.1}$$

For obtain the angle α, trigonometric functions has been used in terms of the tangent of the rectangle triangle formed by the distance of the observation plane, to the grating, in other words the distance L and Fourier plane in terms of the separation distance of the maximum intensity of the first-order diffraction (n = 1), taking account the figure 2, and equation (3); then, the angle α is calculated by:

$$\alpha = \tan^{-1}\left(\frac{D}{L}\right). \tag{3}$$

Several measurements obtained, for every cases the distance L was modified and the distance D was experimentally obtained; and then, the angle αwas calculated with the help of equation (3). In Table 1 the data obtained are show.

Table 1. Experimental measuring obtained for spatial grating period.

L (cm)	D (cm)	$\alpha = \tan^{-1}\left(\frac{D}{L}\right)$
108,50	1,45	0,7656583863
130,00	1,65	0,7271766166
150,00	1,85	0,7066121209
175,00	2,25	0,7366194349
200,00	2,55	0,7304816075
220,00	2,80	0,7291796420
230,00	2,90	0,7223867662
Average α		0,7311592249
n=1 λ=633nm α=0,7311592249		$p = 4{,}96051\times10^{-5}$

The standard error of measure has been calculated, using the equation (4) [7], the measurement error obtain was approximately 0.667%. Finally with these data has proceeded to calculate the lattice constant of the reference grating with the aid of Table 1 and Equation 1, which gives a value of 201 lines per millimeter

$$S_{\bar{x}} = \frac{S}{\sqrt{n}}, \tag{4}$$

where $S =$ standard deviation and $n =$ sample size.

4. Software design and graphics interface

A program of acquisition and processing video in real time was been developed using the mathematical tool MATLAB. This software consists of video imported by the card type ENLTV-FM3 [8], and an export of video GeForce 7200 GS-E [9 development]; the captured image using the camera sensor is displayed and digitized [4] in a Independent monitor. Algorithms for different video capture analog sources (CCD cameras, video camera are output RCA Protocol) and USB digital cameras were utilized. The video capture devices (CCD and USB camera) should be placed in the position of the microscope eyepiece, having withdrawn this previously [3], the assembly is as shown in Figure 3.

Figure 3. Experimental setup for acquisition and video processing

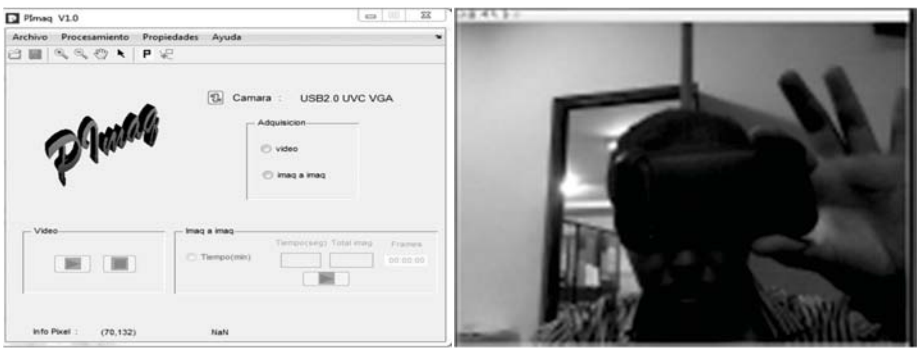

Figure 4. Graphical interface designed

4.1 System calibration

The calibrate of the system and the optimal measures using the developed software we proceeded to observe trough of different microscope objectives [5] the diffraction grating used in Section 3; is the reference pattern of measurement using the assembly shown in Figure 3. Then proceeds to measure in pixels the spatial period of the grating which is observed through the microscope, different measures for different images are shown in Figure 5. a mathematical relationship was used for the calculate of the multiplication factor for converting the image size in pixels to its corresponding real value in microns, table 2 shows conversion factors for different microscope objectives.

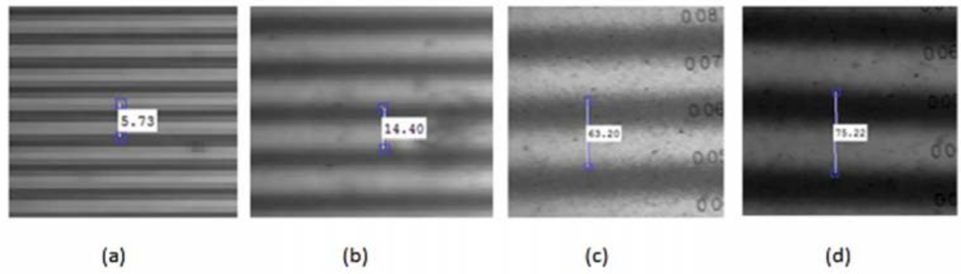

Figure 5. Reference pattern observed with different microscope objetives a. observed 5X, b. Observed at 10X, 40X Observed c, d. Observed at 100X)

Table 2. Process of converting pixels at distance micrometric

	Objetive 5X	Objetive 10X	Objetive 40X	Objetive 100X
Number of pixels in pattern	5.73	14.4	63.2	75.22
Conversión factor	8.657085515 X 10-6	3.444798611 X 10-6	7.848908228 X 10-7	6.594668171 X 10-7

5. Results

The results obtained finally taking account the measuring of the particle size in pixels [10] and then multiplied by the conversion factor according to the objective pattern that is used to observe, the conversion factors experimentally obtained are showed in Table 2. And finally was developed an algorithm on the computer that allows to select the conversion factor on the menu of the interface graphical and then processing distance between pixels where the user selects the microscope objective that is used to view the sample (see Figure 4.).

For particular application we proceeded to measure the core of a standard optical fiber multimode fabricated by the Newport company , in this process; objectives different of conventional microscope has been used to compared our experimental results with the specification sheet of optical fiber given for the Newport company , which in its specification detailing the extent of 100 μ m for core and 140 μ m for the blindaje . Experimental setup for measures in optical fiber using our system can be showed in Figure 6.

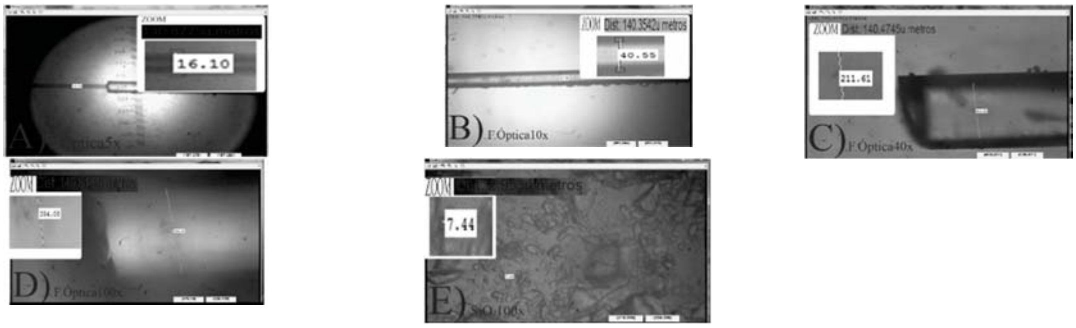

Figure. 6 Images of experimental measurement over geometrical parameters of Optical Fiber multimode of Newport company (a, b, c, d) and Silicon Dioxide in distilled water (e).

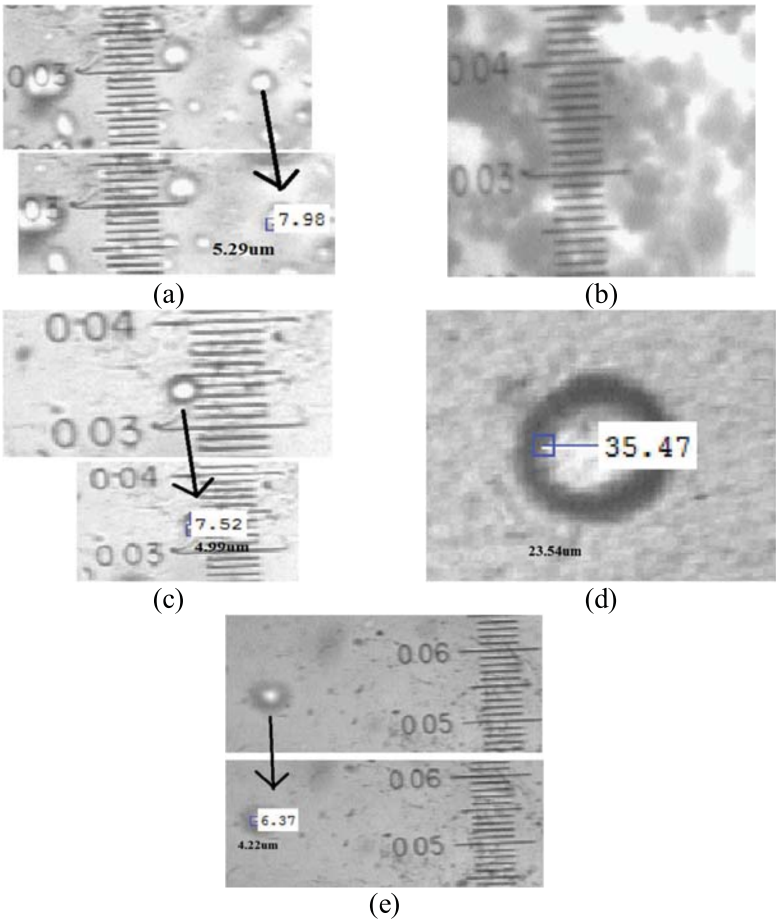

Figure. 7 Observed particles objective 40X: (a).Silicon dioxide more distilled water, measuring 5.29µm in small spherical particle observed. (b) Titanium dioxide more distilled water. (c) Styrene spheres, measuring 4.99µm in small spherical particle observed. (d) Fat globules, measuring 23.54µm in small spherical particle observed. (e) Silica spheres, measuring 6.37µm in small spherical particle observed.

Also, different size particles are measured as fat globules, silicon dioxide, spheres of silica, titanium dioxide, this particles was addition distilled water, these particles has distilled water added to them as a means of immersion. These microparticles are of special interest since it is intended to work in an optical trap using optical fibers and require to know the size of the particles, which partly determines the viability of the trap, the work is under development in the optical e informatics group of popular of Cesar university, Particle measurements can be seen in figure.7.

6. Conclusion

In this paper the design of a hardware and software system that enables the measurement of micrometer particles through digital image processing, based on a optical calibration method (He-Ne laser and diffraction by grating) the physical principle was based experimentally in the concept of the diffraction lattice constant, which is used as yardstick for measurements in microscopic images; in this method the standard error calculated is approximately of 0.667%, and basically is introduced by the manual measurement of researchers. The system captures the image, and then parameterized in pixels and using simple math automated in the software and in accordance with the objective that this under a microscope to observe the sample is multiplied by the conversion factor, and these data finally produced the size of the microparticles observed in the program in real time on the scale of micrometers, the multimode optical fiber of Newport company was used for a particular application, which guarantees through its specifications of design and factory the correct and respective dimensions of the core and blindaje. In this paper using our method is proved that with the use of digital image processing tool of easy form can be obtain micrometric measurements with high precision.

On the basis of experiments with non-biological samples: silicon dioxide, titanium dioxide, styrene and crushed silica spheres, all immersed in distilled water (Figure. 7); It is workable mounting optical traps with silicon dioxide, styrene and crushed silica because the shapes of the particles are approximately spherical and the size is less than or equal (= <5 micron) with respect to those embodied in researches related to the thematic [11].

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