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DIAGNOSIS OF MATERIALS COMPOSITION USING NUMERICAL METHODS

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ABSTRACT

In today's world of computer vision, different methods for image processing are heavily used. In this paper, we have processed with MATLAB images of an aluminum alloy after TIG welding and other images of TiO_2 nanoparticles obtained by SEM that we synthesized by the green synthesis process. Also, we processed two other samples of Bubble dissolution during the in-situ growth of copper dendrites experiment and Liquid phase growth of FFA hexagonal crystals after radiolysis obtained by a TEM. Finally, we used the Newton and Chebyshev numerical methods in order to detect the present elements in these samples.

Keywords: *Image processing, FFA, aluminum alloy, MATLAB, Newton, Chebyshev, TiO_2.*

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1. INTRODUCTION

A period of more than three hundred years has passed since a procedure for solving an algebraic equation was proposed by Newton in 1669 and later by Raphson in 1690. The method is now called Newton's method or the Newton–Raphson method and is still a central technique for solving nonlinear equations.

Many topics related to Newton's method still attract attention from researchers. For example, the construction of globally convergent effective iterative methods for solving nondifferentiable equations in R^n or C^n is an important research area in the fields of numerical analysis and optimization (Yamamoto, 2000).

Chebyshev was probably the first mathematician to recognize the general concept of orthogonal polynomials. A few particular orthogonal polynomials were known before his work. Legendre and Laplace had encountered the Legendre polynomials in their work on celestial mechanics in the late eighteenth century. Laplace had found and studied the Hermite polynomials in the course of his discoveries in probability theory during the early nineteenth century. Other isolated instances of orthogonal polynomials occurring in the work of various mathematicians is mentioned later (Chebyshev, 1996).

Mathematics has played a crucial role in various Image Processing tasks. Despite the innovation and rapid advances in the various Imaging Technology, one thing that has remained important throughout, is the use of Mathematics. It has been observed that image processing has got strong connection with Mathematics. Many of the image processing methods rely on the basic Mathematical Techniques of Histogram Equalization including the Chebyshev methods. MATLAB is one of the most commonly used tools by the researchers in the area of Image Processing (Vashisht & Bhatia, 2019).

In this paper we have used numerical methods to process images of different types of samples and it is organized as follows: Section II, presents the principle of the applied numerical methods. Experimental part and results discussion is shown in section III. Section IV represents a comparison between the obtained Results**.** Finally, section V concludes the paper.

2. REVIEW OF LITERATURE

The next subtitle We are going to present the theory of Newton numerical method.

2.1 Newton method

Newton's method or Newton-Raphson method is an iterative numerical method used to solve f(x)=0 type equations. It relies on the fixed-point method and on a particular function, ***g***, related to the derivative of ***f*** (Neumann, 2015).

Newton's method is a fixed-point method using the (eq. 1)

(**g**):
$$g(x) = x - \frac{f(x)}{f'(x)} \quad (1)$$

It can be easily inferred that looking for a fixed point for g comes down to looking for a solution to the (eq. 2):

$$f(x)=0 \quad (2)$$

The numerical scheme for Newton's method is seen in the (eq3):

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \quad (3)$$

i. Geometrical interpretation

The tangent to the curve f at the point (x_n, f(x_n)) has the following (eq.4):

$$y = f(x_n) + f'(x_n)(x - x_n) \qquad (4)$$

Newton's method for solving equations is another numerical method for solving an equation f(x)=0. It is based on the *geometry* of a curve, using the *tangent lines* to a curve. As such, it requires *calculus*, in particular differentiation (Neumann, 2015).

x_{n+1} is nothing less than the abscissa of the point of intersection of this tangent with the

x-axis; indeed :(eq.2.6)

$$y = 0$$
$$x = x_n - \frac{f(x_n)}{f'(x_n)} \qquad (5)$$

We then set x_{n+1} (eq.2.7)

$$x_{n+1} = x_n - \frac{f(x_n)}{f'(x_n)} \qquad (6)$$

2.2 Chebyshev polynomials

Chebyshev polynomials are a useful and important tool in the field of interpolation; the roots of Chebyshev polynomials are definitely the best suited points of interpolation (Soualem, 2021). Chebyshev polynomials of degree n ≥= 0 is defined as:

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$$T_n(x) = \cos(n \arccos x),\ x \in [-1, 1] \qquad (1)$$

Recurrence relation between Chebyshev polynomials: $T_0(x)=1$, $T_1(x)=x$ and for any number $n \in \mathbb{N}$:

$$T_{n+2}(x) = 2xT_{n+1}(x) - T_n(x) \qquad (2)$$

The following table gives the first Chebyshev polynomials:

Table 1. First Chebyshev polynomials

N	Tn
0	1
1	x
2	$2x^2 - 1$
3	$4x^3 - 3x$
4	$8x^4 - 8x^2 + 1$
5	$16x^5 - 20x^3 + 5x$

Source: The authors' own work.

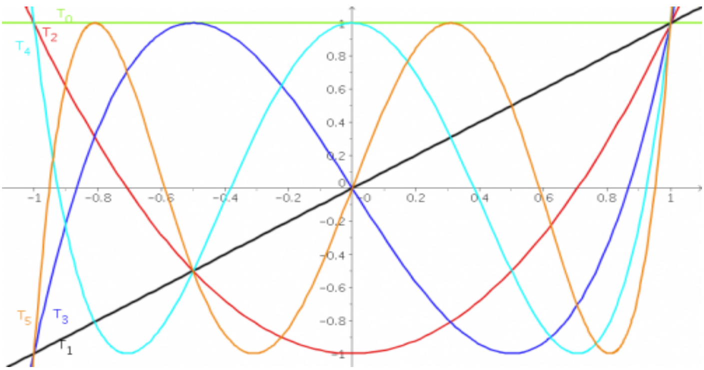

Figure 1. Plot of Chebyshev polynomials Tn(x) for n = 0, 1, 2, . . . ,5
Source : Soualem, N. (2021).

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3. EXPERIMENTAL PART

3.1 Algorithm

-Data insertion.

- Selection of the sample image.

- Conversion of the images into matrixes.

- Application of the Newton numerical method algorithm.

- Show results.

3.2 Examples

In the following part, for a much clearer examples we propose to study four samples from different types of microscopes (sample 1&2 are from a SEM and sample 3&4 are from a TEM):

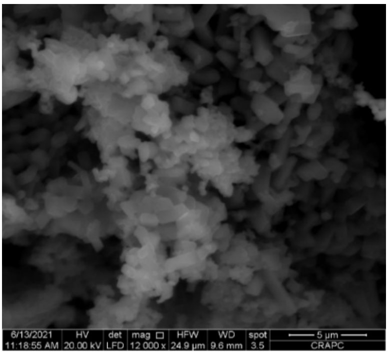

Figure 2. Sample1: TiO2 calcined at 900°C

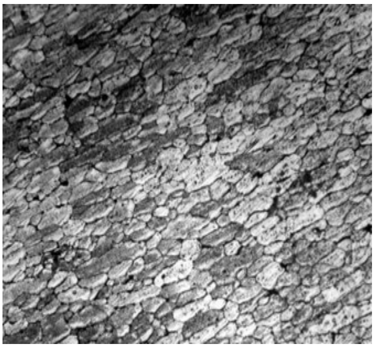

Figure 3. Sample2: Aluminum alloy 7075 T6 (ZAT after TIG welding)

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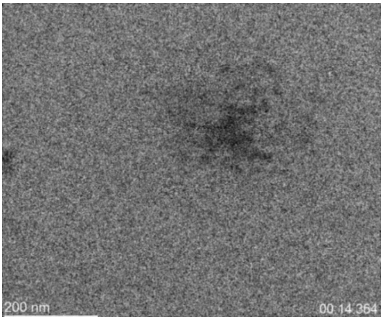

Figure 4. Sample3: Liquid phase growth of FFA

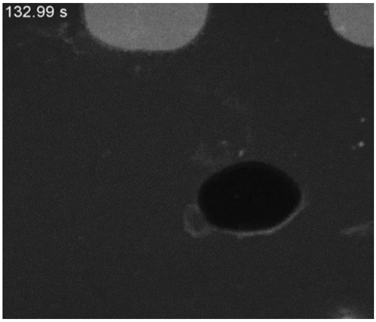

Figure 5. Sample4: Bubble dissolution during the in-situ growth of copper dendrites experiment

The first sample (Figure 2) represents TiO_2 tetragonal nanoparticles that we have successfully synthesized at the C.R.A.P.C center by a green process using the natural extract of orange peels skin. The materials used for the synthesis TiO_2 are: Titanium (IV) isopropoxide 97% purchased from sigma Aldrich, isopropanol solution and fresh peel of orange.

The second sample was welded after treatments using the TIG (Figure 3) process in the welding center (CSC) of Cheraga by Mohamed Sellam. The semi-automatic welding machine is of the type: square wave TIG - 355 brand (Lincoln Electric) equipped with a mixture of Argon / Helium shielding gas and we have its composition table (Temmar et al., 2011).

The experiment of the FFA crystals (Figure 4) was conducted in order to visualize the nucleation and growth of organic molecules as they develop into solid crystals. It was done by the radiolysis process, where a stock solution of 50mM FFA (Sigma-

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Aldrich, 97%) was produced by dissolving in absolute ethanol (Fisher scientific HPLC grade) (Cookman et al., 2020).

The bubbles in the Figure 5, were formed during this experiment which was realized in order to show the benefits of the award-winning Stream system during the in-situ growth of copper dendrites experiment (Beker et al., 2020).

3.3 Results and discussions

3.3.1 Sample1

```
Elapsed time is 0.682468 seconds.

precision =

  100.0000
```

Figure 7. Execution Time and Precision of Newton Method (TiO2 Sample)

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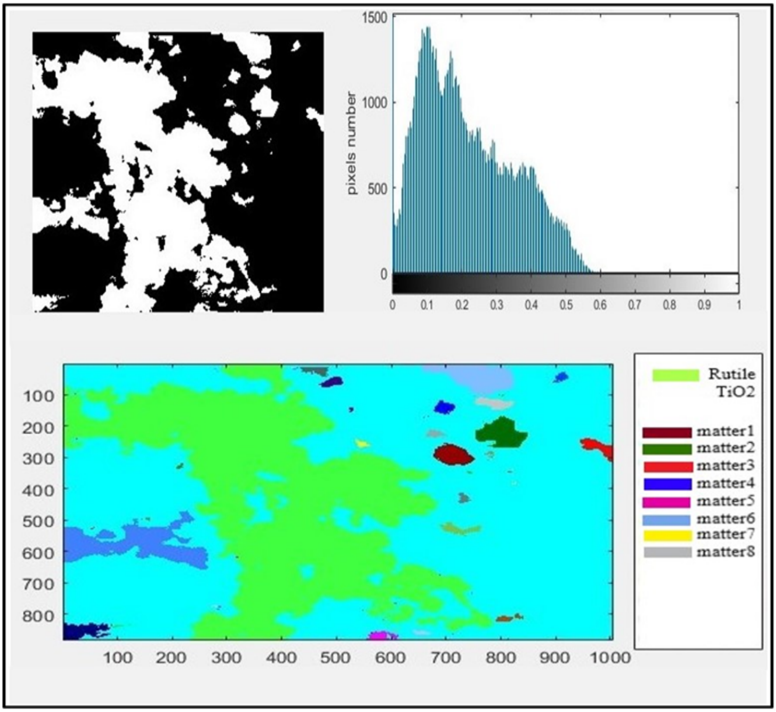

Figure 8. Results of Newton Method (TiO2 Sample)

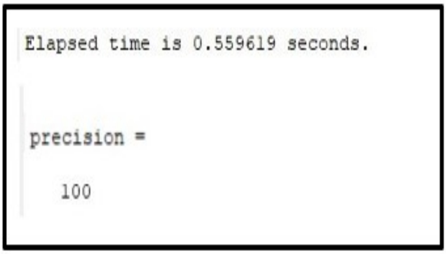

Figure 9. Execution Time and Precision of Chebyshev Method (TiO2 Sample)

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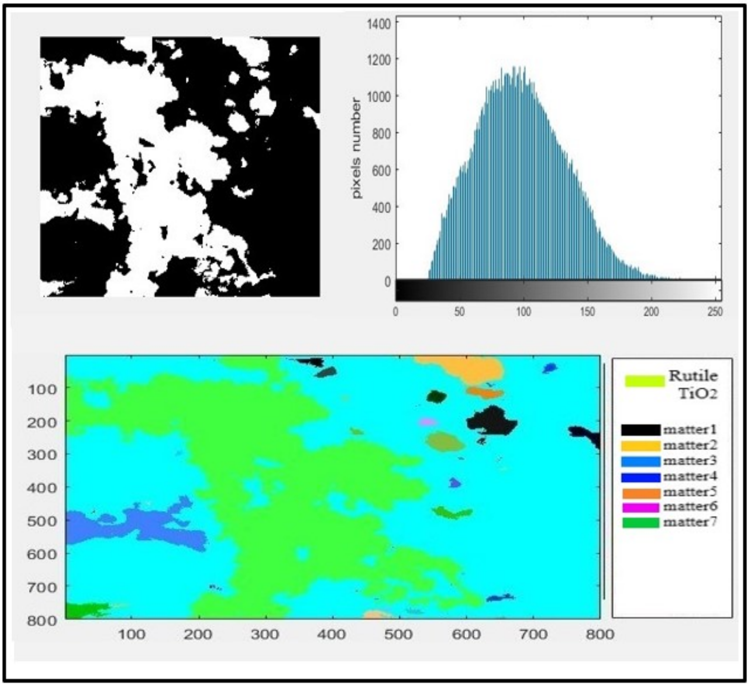

Figure 10. Results of Chebyshev method (TiO2 sample)

3.3.2 Sample 2

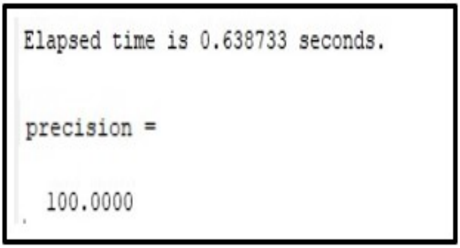

Figure 11. Execution time and precision of Newton method (Aluminum alloy sample)

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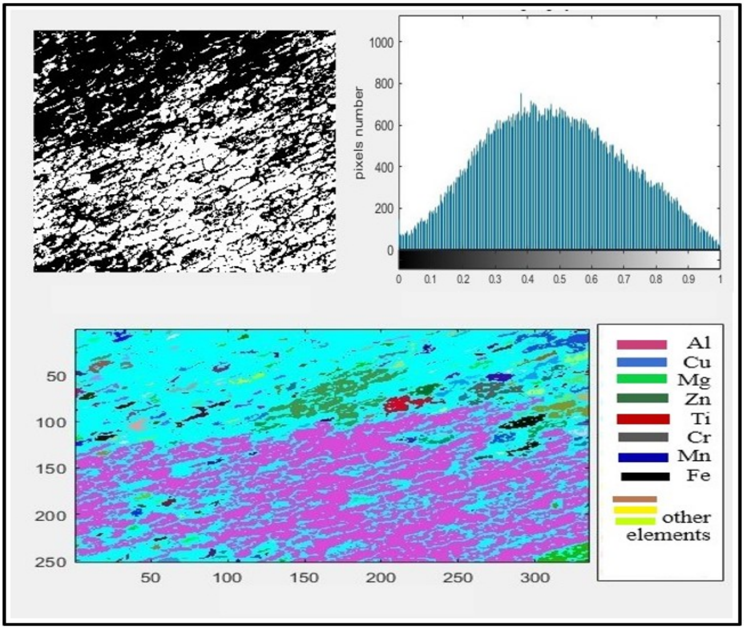

Figure 12. Results of Newton Method (Aluminum Alloy 7075 T6 Sample)

Table 2. Composition of the Aluminum Alloy after Welding

Element	Ti	Mn	Cu	Fe	Cr	Mg	Zn	Al	Others
Mass %	0.04	0.03	1.53	0.22	0.19	2.50	5.63	89.72	0.14

Source: The authors' own work.

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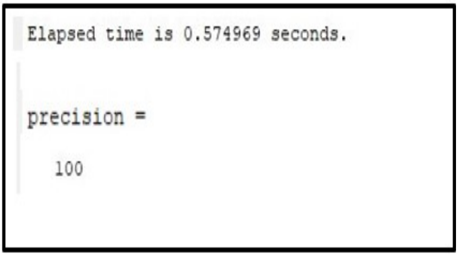

Figure 13. Execution Time and Precision of Chebyshev Method (Aluminum Alloy Sample)

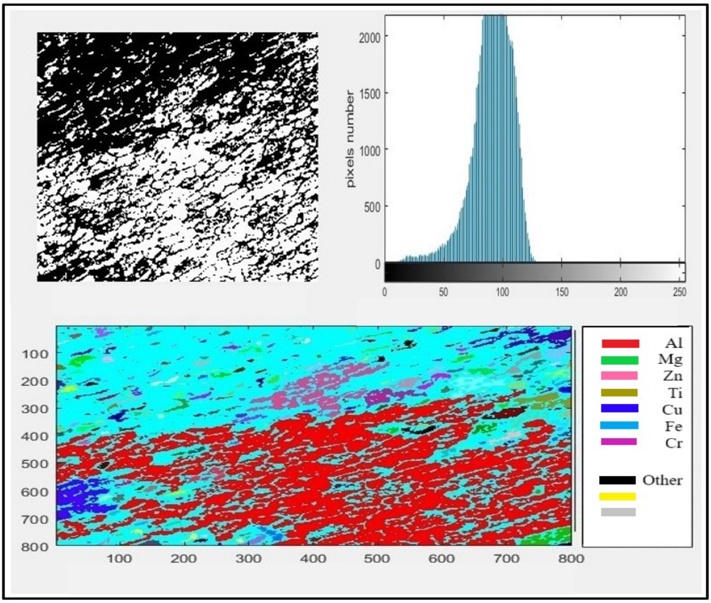

Figure 14. Results of Chebyshev method Aluminum alloy 7075 T6 Sample Results

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3.3.3 Sample 3

```
Elapsed time is 0.609136 seconds.

precision =

  100.0000
```

Figure 15. Execution Time and Precision of Newton Method (Liquid Phase FFA Sample)

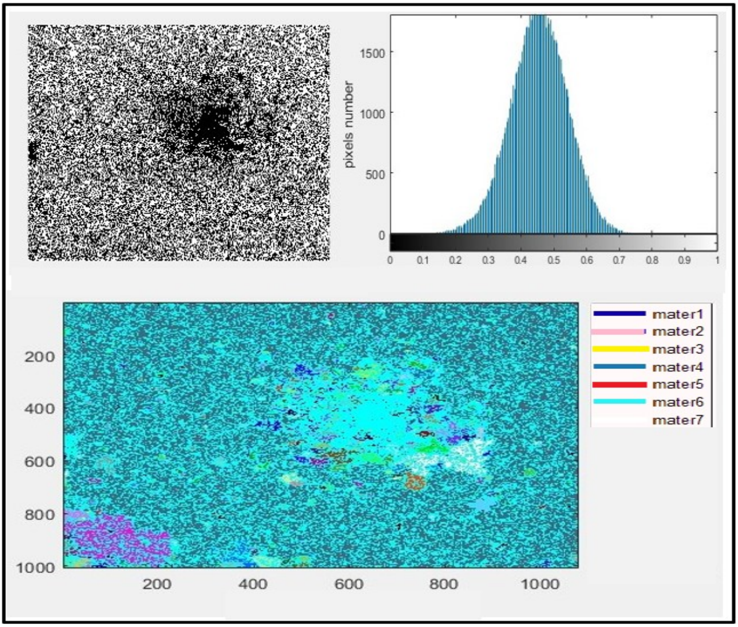

Figure 16. Results of Newton Method (Liquid Phase FFA Sample)

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```
Elapsed time is 0.600241 seconds.

precision =

   100
```

Figure 17. Execution Time and Precision of Chebyshev Method (Liquid Phase FFA Sample)

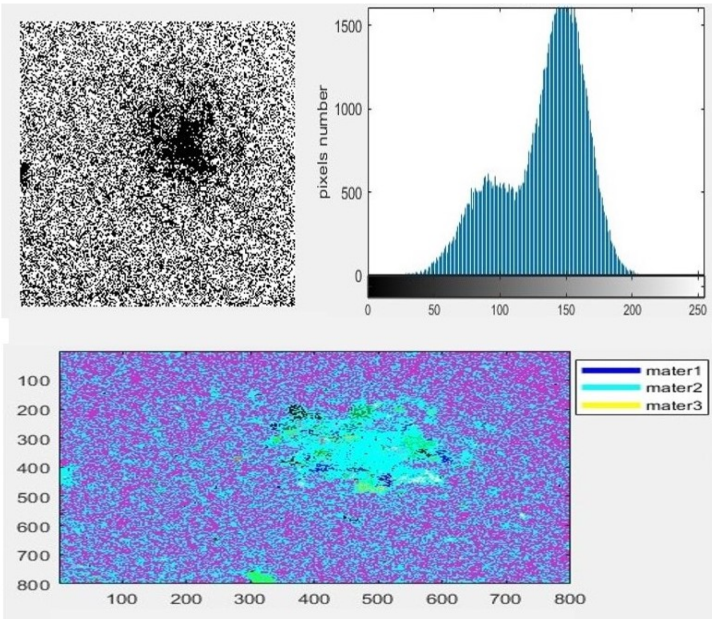

Figure 18. Results of Chebyshev Method (Liquid Phase FFA Sample)

3.3.4 Sample 4

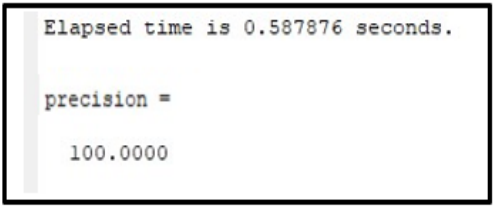

Figure 19. Execution Time and Precision of Newton Method (Copper Dendrites Sample)

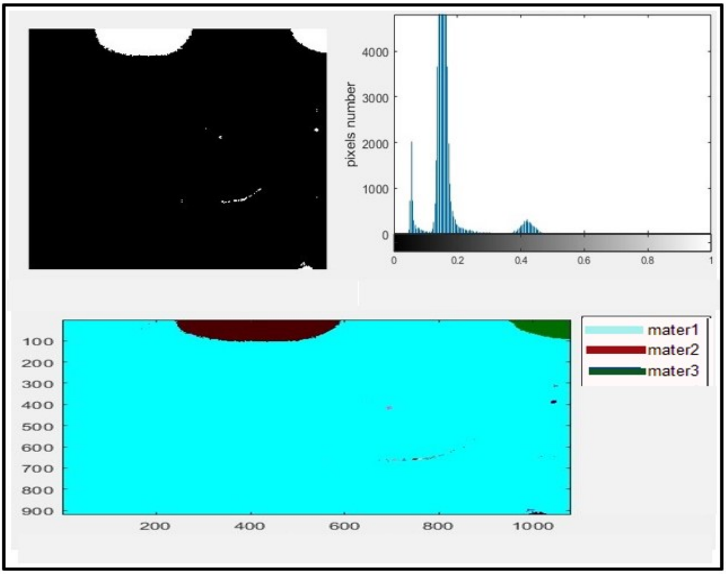

Figure 20. Results of Newton Method (Copper Dendrites Sample)

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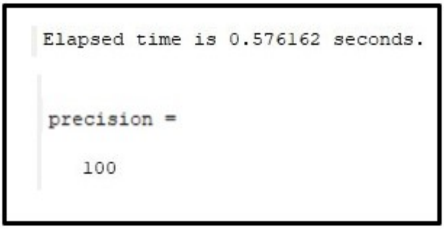

Figure 21. Execution Time and Precision of Chebyshev Method (Copper Dendrites Sample)

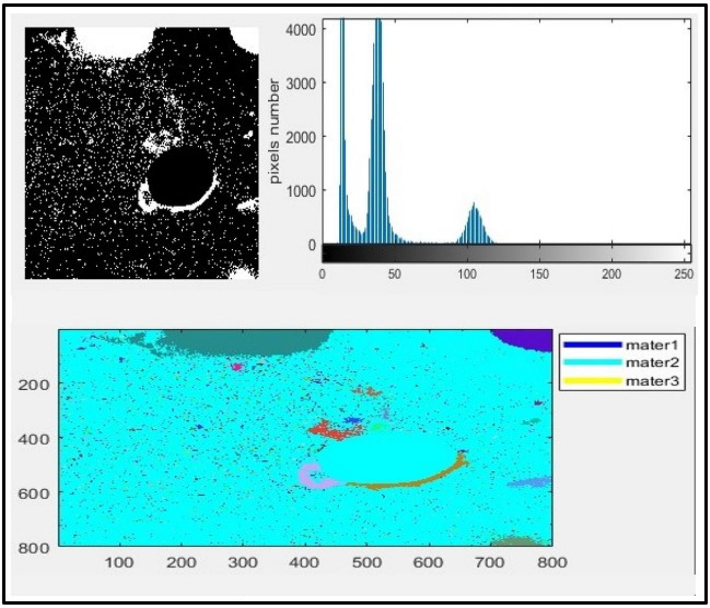

Figure 22. Results of Chebyshev Method (Copper Dendrites Sample)

The binary images result from the application of the Newton and Chebyshev methods, they contain only two-pixel elements: (0 & 1), where 0 refers to black and 1 refers to white. The background is black and the white parts represents the detected elements. The histograms which represent a graph showing the number of pixels at each different intensity value found in the original images, can help us explain why some images look grey or black by observing the position of the most intense peaks on the grayscale axis. Finally, colored images are obtained by coloring the bright surfaces of the details present in the binary images according to the variation in light intensity. The displayed result by these images is a cyan background and the other colors represent the elements present in the sample.

3.4 Results Comparison

Table 3. Comparison Between Results from Both Methods

		Execution time(s)		Precision of the detection (%)	
	Samples	Newton	Chebyshev	Chebyshev	Chebyshev
SEM images	TiO_2	0.68	0.56	100	
	Aluminum alloy	0.64	0.57	100	
TEM images	Liquid phase FFA	0.61	0.60	100	
	Copper dendrites	0.59	0.58	100	

Source: The authors' own work.

4. CONCLUSION

In this paper we have processed two samples of materials obtained by SEM (TiO_2 (Titanium dioxide) and Aluminium alloy), and two other samples of TEM (Liquid phase FFA and Copper dendrites growth) using two methods: Newton and Chebyshev techniques for the first time on the samples above. After comparing results, we found that these techniques are almost equally effective on the two types of microscopes images and allowed us to get many information and especially the detection in a short time (an average of 0.6s) with high precision up to100%. Our study helped us to extract the details of an image (SEM and TEM) using the two methods above. with the help of the binary images and the colored images which allowed us to detect the elements that compose the samples.

At the end, we can conclude that in some cases where the result of an experiment is expected and needs confirmation the use of numerical analysis methods in image processing can help researchers and scientists to examine any sample of matter in a short period of time with great accuracy and lower cost than other techniques. In our case, it only took 0.6s while in the laboratory it needs the use of multiples techniques such as: SEM, XRD, EDX…. and the use of previous results from a database for confirmation.   So, we ask to combine image processing programs with the experience of laboratory to obtain precise results in short time.

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