

# The data reduction for different Speckle images using MATLAB and IMAGE pro-plus.

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## Abstract

*When coherent light rays can be incident on an optically rough object it will scatter randomly through all directions. Interference of these scattered rays leads to the formation of a bright spots (constructive interference), and dark spots (destructive interference), these are called Laser Speckles.*

*In this paper, we are concerned with the formation of Objective speckles calculations to read the speckle image using two different software application that they are MATLAB and IMAGE pro-plus. That to make a comparison for different calculations. That for speckles formed from reflected rays of rough objects.*

*Digital Speckle image is under studying for different thresholds to show optical density variations. Also block processing showed a noticeable change to the value original contrast.*

*Unfortunately, no calculations in this field had been done from other researchers.*

## Keywords

*Speckle images, Optical density, Brightness, Darkness, Image processing.*

## 1.Introduction

The laser light scattering technique for surface roughness measurement has received wide attention in the past few decades, where the roughness information is obtained from the intensity scattered through certain directions. [2]

Also, the autocorrelation function of the surface height variation is determined from the scattered intensity. When coherent light waves meet, they interfere to form constructive and destructive patterns. The most familiar example is young's double slits experiments in which fringes are formed by the waves from two coherent point sources. [1]

A speckle pattern is an intensity pattern produced by the mutual interference of a set of wave fronts. This phenomenon has been investigated by scientists since the time of Newton, but speckles have come into prominence since the invention of the laser and have now found a variety of applications that in figure 1. [3]

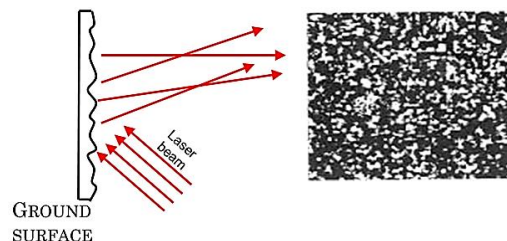


Fig.1 Experimental setup for speckle formation.

The speckle effect occurs only when the surface is optically rough i.e., its height variation is of order of, or greater than wavelength of the illuminating light is found to vary randomly with position, this known as "Objective speckle."

When a laser light illuminates a rough surface and an imaging of the surface is formed, the image shows similar random intensity variations, but this case the speckle is called "Subjective speckle". [3]

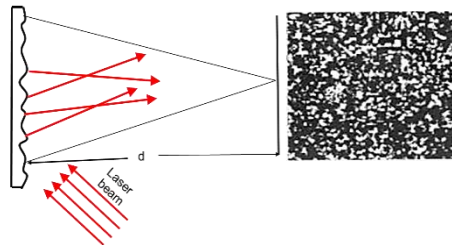


Fig.2a Formation of objective speckle.

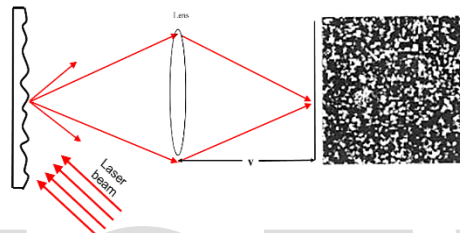


Fig.2b Formation of subjective speckle.

The average size of a subjective speckle can be taken as a value of  $\Delta x$  (or  $\Delta y$ ) such that:

$$(\Delta x)_s = \lambda z / L \quad \text{Equation (1)}$$

Where  $\lambda$  is the wavelength of using laser,  $z$  is the distance between viewing and object planes and  $L$  is the distance between the screen and the camera.

The subjective speckle also called Image-plane. It occurs when an image is formed of an object, which is illuminated by laser light, the intensity of image varies randomly i.e. It is 'speckled'. Speckle pattern is observed in the image plane of a circular imaging lens with radius  $r$  as shown in fig.3b. It called subjective because its size depends on the numerical aperture (NA) of the imaging system, the speckle grain size  $\Delta$  is given by the equation. [3]

$$\Delta = 1.22\lambda / \text{NA} \quad \text{Equation (2)}$$

## 2.Data Compression for random speckle Pattern.

The use of data compression techniques makes the operation of storing, transforming and analysis of data simpler. There are two techniques of data compression, namely, predictive coding and transform coding. In this paper the technique of transform coding was used. In such technique the compression takes place using new ranking without losing most of the information. This was achieved by packing large number (amount) of information into a smaller number. This of course, leads to some distortion of the final image. [7]

In the image compression techniques, the image under processing is divided into smaller pixels each should be coded by the binary system. The coded image of speckle pattern is converted from a dark and bright spot into a numeric map. This was achieved by divided the speckle image into an equal sub images of equal dimensions. Applying two techniques, in the first one the Image Matrix-numerical matrix is to be converted into a sub matrix of decimal number. The matrix is of dimension  $10 \times 100$ ,  $10 \times 80$ ,  $10 \times 60$  and  $10 \times 40$  respectively, each matrix value represents the brightness of the laser speckle corresponding to such matrix, representing certain roughness on the surface. The contrast of the original speckle image and its corresponding compressed images and its corresponding compressed images is the same. [6]

If you are reducing the size of a speckle image and you choose bilinear or bicubic interpolation, compression automatically applies a low-pass filter to the image before interpolation. This filtering reduces the effect of *Moiré patterns*, ripple patterns that result from aliasing during resampling. Note, however, that even with low-pass filtering, the resizing operation can introduce artifacts, because information is always lost when you reduce the size of an image. [4]

### 3.Experimental procedure.

In this work the technique of speckle image compression has been used by segmentation the digital image into segments of equal dimensions. This can be done by dividing the main matrix into secondary sub matrices having the same dimensions. Hence each sub matrix has been coded by transforming it into decimal number representing its dimensioned.



Fig.3a the gray level representation of speckle pattern intensity distribution

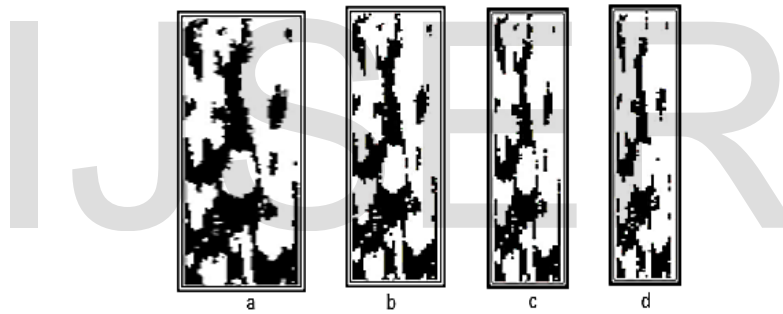


Fig.3b compressed the numeric representation of the speckle images after converting to natural numbers using matrices of dimensions a-10x100, b-10x80, c-10x60 and d-10x40.

In this paper a method for measuring surface roughness of flat lapped, ground, and polished metallic surfaces, by the far-field speckle contrast method is presented. The laser speckle contrast technique depends on the existence of an approximately linear relationship between the speckle contrast and the roughness of the illuminated surface the roughness  $R$  of different metallic surfaces of aluminum has been measured using the relation between speckle contrast and surface roughness. Investigation on the contrast variation of image speckle patterns is conducted systematically for various surface rough nesses of the objects. The speckle pattern obtained with four different roughness's namely: 25  $\mu\text{m}$ , 50  $\mu\text{m}$ , 75  $\mu\text{m}$ , 100  $\mu\text{m}$  of aluminum. The roughness  $R$  is defined as.

$$R_a = \frac{1}{N} \sum_{i=1}^N |y_i| \quad \text{equation (3)}$$

$R_a$  is the most widely used one-dimensional roughness parameter. It is also called the roughness average, and The root mean square surface roughness is calculated by equation,

$$R_q = \sqrt{\frac{1}{N} \sum_{i=1}^N |y_i|^2} \quad \text{Equation (4)}$$

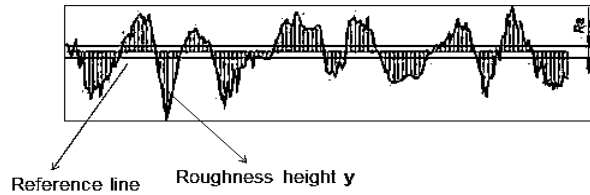


Fig.4 A photograph of rough plate

Where  $n$  is the sample size,  $n = M \times N$  pixel of an image. The speckle contrast is defined as, to enhance the difference between healthy and eroded regions, a common technique of dynamic speckle was adapted to spatial speckle. The method is known as Laser Speckle Contrast Analysis (LASCA), consists of calculating the contrast of the image given by the following equation:

$$C = \frac{\sigma}{\langle I \rangle} \quad \text{Equation (5)}$$

The speckle contrast is always having values between 0 and 1, a high coherence in the incoming light increases the contrast, and the contrast of a speckle pattern is also proportional to the surface roughness. A completely smooth surface would produce no speckles at all.

Speckle patterns after compression with the different techniques mentioned before, the roughness  $R$  were calculated using the measured values of calculated contrast. The obtained results were presented in the following table1:

Roughness in microns	Speckle Contrast	Speckle Contrast after first compression	Speckle Contrast after second compression	Speckle Contrast after third compression	Speckle Contrast after fourth compression
25	0.4526	0.3082	0.3042	0.3015	0.2972
50	0.4473	0.3158	0.3134	0.3119	0.3099
75	0.5425	0.4612	0.4585	0.4571	0.4556
100	0.6083	0.5475	0.5460	0.5452	0.5441

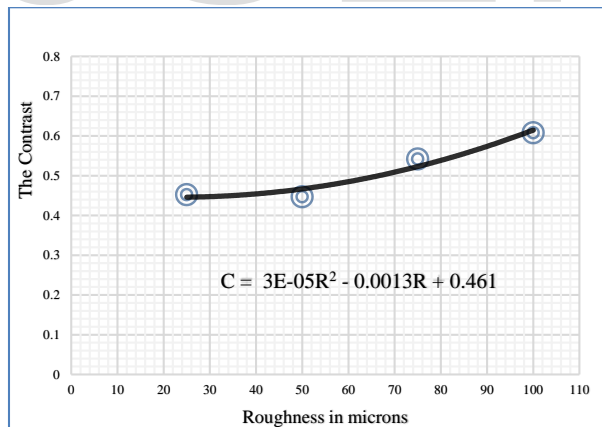


Fig.5 the graph between the original contrast and Roughness.

By using another application, that image pro-plus program the procedure used that make more one step to evaluate the contrast of the speckle image.

Also, the equation of contrast takes another way that the contrast of speckle image is calculated from equation (6).

$$C = \frac{I_{max} - I_{min}}{I_{max}}$$

Where  $I_{max}$  is the maximum value of intensity of the speckle image, and  $I_{min}$  is the minimum value of intensity.

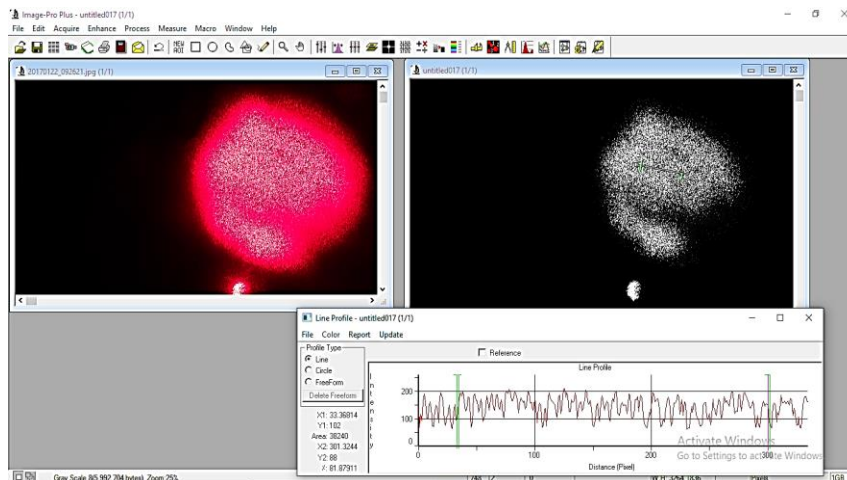


Fig.6 the image pro-plus application with input speckle image.

By analysing the data of the previous speckle images formed by the four samples 25µm, 50µm, 75µm, and 100µm. We obtain the data in table 2.

Roughness(µm)	I <sub>max</sub>	I <sub>min</sub>	Contrast
25	244	134	0.4508
50	252	134	0.4683
75	239	78	0.6736
100	237	73	0.6919

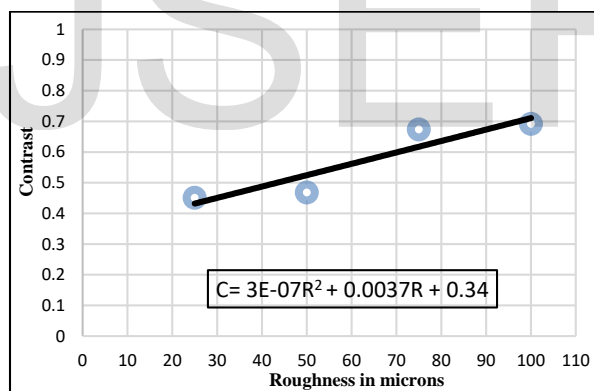


Fig.7 the graph between contrast and Roughness using image pro-plus.

#### 4 - Optical Density of the Binary Speckle image with different thresholds.

In MATLAB, a binary speckle image is a logical two-dimensional uint8 or double matrix that contains only 0's and 1's. All toolmaker works that give back a double image return them. Concerning illustration uint8 arrays. Working with binary speckle images with the toolbox is very direct. In most cases you will load a 1-bit binary speckle image, and MATLAB will create a logical uint8 image in memory. You will normally not encounter double binary images unless you create them yourself using MATLAB. [7]

At first show how MATLAB useful to counting the number of bright speckles or the dark at different gray threshold (or level) that after converting to the binary system at any method. It help us to make counting the bright (or dark) specklets for more than time.

We can use the threshold and constant number that between 0 and 255 which remains to the chosen intensity level that converting to the binary image, for example we take the threshold at levels 80, 90, 100, 110, 120 we observe the change in the bright and dark spots of the image.

Also we can make the threshold as a factor multiplied by the maximum value of intensity that recorded for the input image for example  $0.5I_{max}$ ,  $0.55I_{max}$ ,  $0.6I_{max}$ ,  $0.65I_{max}$ , and  $0.7I_{max}$  that we have the maximum value of intensity  $I_{max}$  is differ from a digital speckle image to another.

We have the optical density of the digital speckle image is defined as the integrated area of the speckle grains  $A_s$  considered as a signal divided by the total area of the whole image  $A_T$ .

$$O.D = \frac{A_s}{A_T} \quad \text{Equation (7)}$$

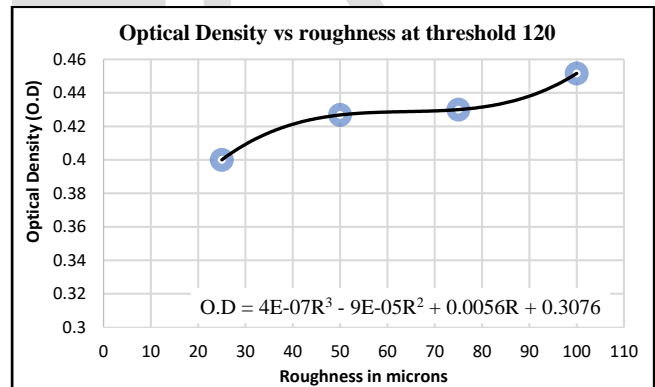
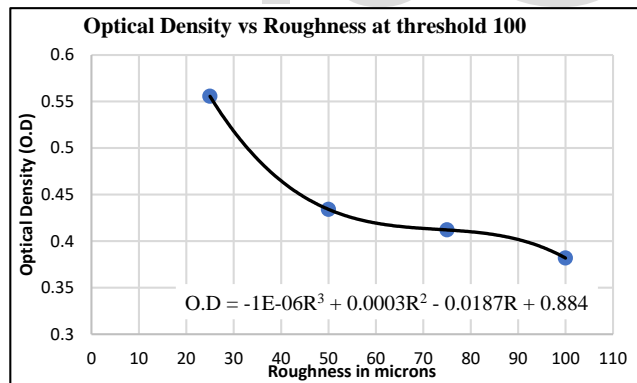
Where ( $A_T = A_s + A_n$ ), and  $A_n$  is considered as a noise background. This optical density is considered as the degree of agglomeration of the binary speckle image.

$$O.D = \frac{A_s}{A_s + A_n} \quad \text{Equation (8)}$$

That we observe that  $A_s$  is related to integrated of the bright objects of the digital speckle image, and  $A_n$  is the total some of the dark objects at a finite threshold.

The data between the optical density (O.D) and Roughness of the surface in microns. And thresholds taken are constants 100, 120, and 130 that shown in table (3). [5]

Roughness of surface in microns	Optical Density at threshold 100	Optical Density at threshold 120	Optical Density at threshold 130
25	0.5556	0.4000	0.4615
50	0.4341	0.4268	0.4368
75	0.412	0.43	0.4213
100	0.3818	0.4516	0.4167



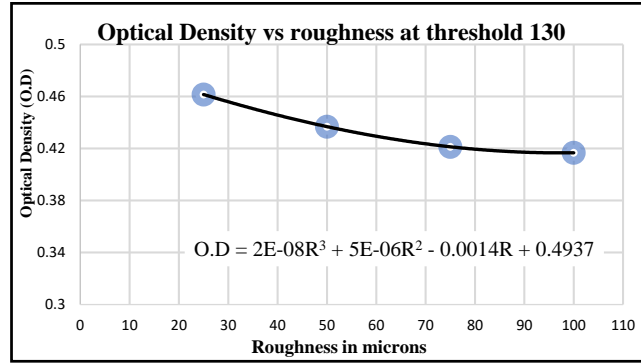


Fig.8 the graphs between optical density and roughness at thresholds 100, 120, and 130  
 The data between the optical density (O.D) and Roughness of the surface in microns. And thresholds taken are constants  $0.55I_{max}$ ,  $0.65I_{max}$ ,  $0.75I_{max}$ , that shown in table (4).

Roughness of surface in microns	Optical Density at threshold $0.55I_{max}$	Optical Density at threshold $0.65I_{max}$	Optical Density at threshold $0.75I_{max}$
25	0.3256	0.2593	0.3951
50	0.2823	0.4146	0.5432
75	0.1960	0.5103	0.6043
100	0.1521	0.6212	0.6867

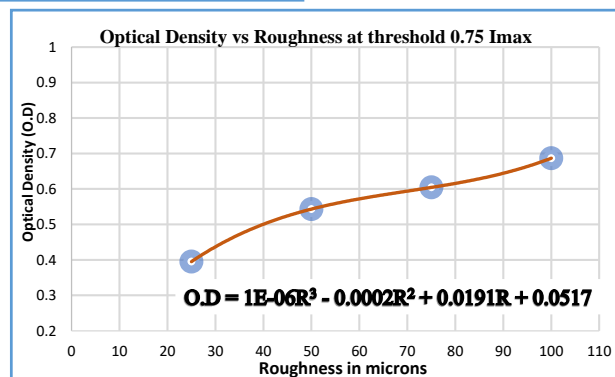
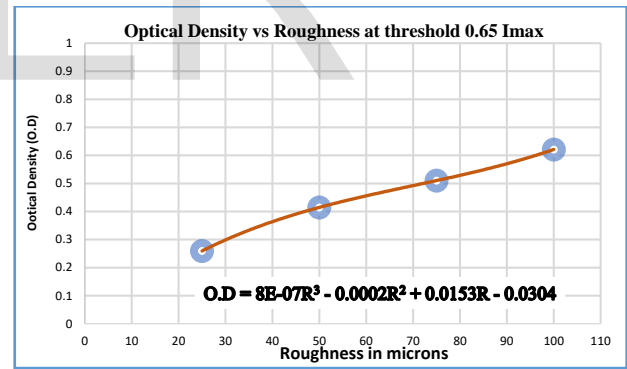
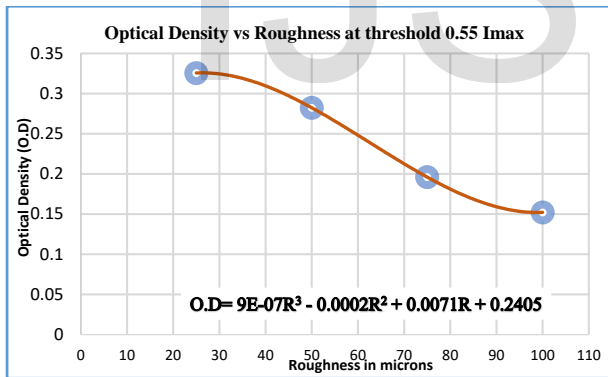


Fig9. the graphs between O.D and roughness at thresholds  $0.55I_{max}$ ,  $0.65I_{max}$ , and  $0.75I_{max}$

By using the image pro-plus program we can determine the optical density for the input image one time only and cannot control the threshold, that is built in the program.

The data between the optical density and roughness using image pro-plus is as shown in table (5)

### 5. Block processing effectiveness to the digital Speckle images.

An operation in which image is processed in blocks rather than all at once, the blocks have the same size across the digital speckle image. An operation is applied to one block at a time, once processed the blocks are reassumed to form the output speckle image, for example, (Distinct block operations). [4]

Distinct blocks are rectangular partitions that divide a digital speckle image into m-by-n sections,

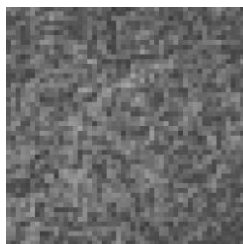
Blocks are overlaid by starting at the upper-left corner, zeros are added onto blocks exceed the size of digital speckle image.

Averaging filter, Find the average value of each 10-by-10 and replace all pixels in the block with the average value, for example, take a block 10-by-10 from an image, as shown,

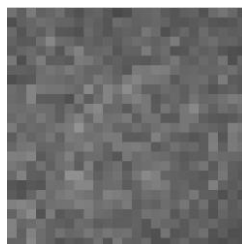
67	75	77	74	81	81	71	70	76	79
74	88	82	82	76	77	82	82	88	68
64	88	103	83	70	75	77	78	89	68
68	70	66	69	76	80	81	86	96	100
77	90	95	95	72	64	98	127	104	89
69	106	109	118	90	71	93	96	66	97
75	73	61	87	91	77	70	70	83	84
75	78	101	111	112	104	94	91	93	103
80	75	102	101	110	115	106	109	118	127
86	70	71	79	83	87	84	87	138	143

It will be transformed into,

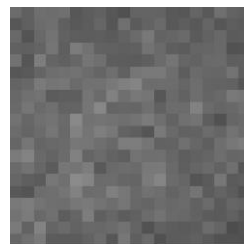
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87
87	87	87	87	87	87	87	87	87	87



Block's size 2\*2



Block's size 4\*4



Block's size 5\*5



Block's size 10\*10

Fig.10 Digital speckle image at different block sizes

Now, let's study the effectiveness of block processing to the digital speckle image for reflected incident ray laser beam to surfaces that are different in the roughness.

We have the digital speckle image for surfaces has the root mean square roughness 25µm, 50 µm, 75 µm and 100 µm.

The block processing effectiveness using averaging filter is shown in table (6),



Roughness in microns	The contrast at n=2	The contrast at n=4	The contrast at n=5	The contrast at n=10	The contrast at n=20
25	0.3769	0.3188	0.3190	0.29	0.2644
50	0.4422	0.4368	0.4369	0.4283	0.4129
75	0.4912	0.4673	0.4673	0.4506	0.4251
100	0.5648	0.5484	0.5486	0.5351	0.5100

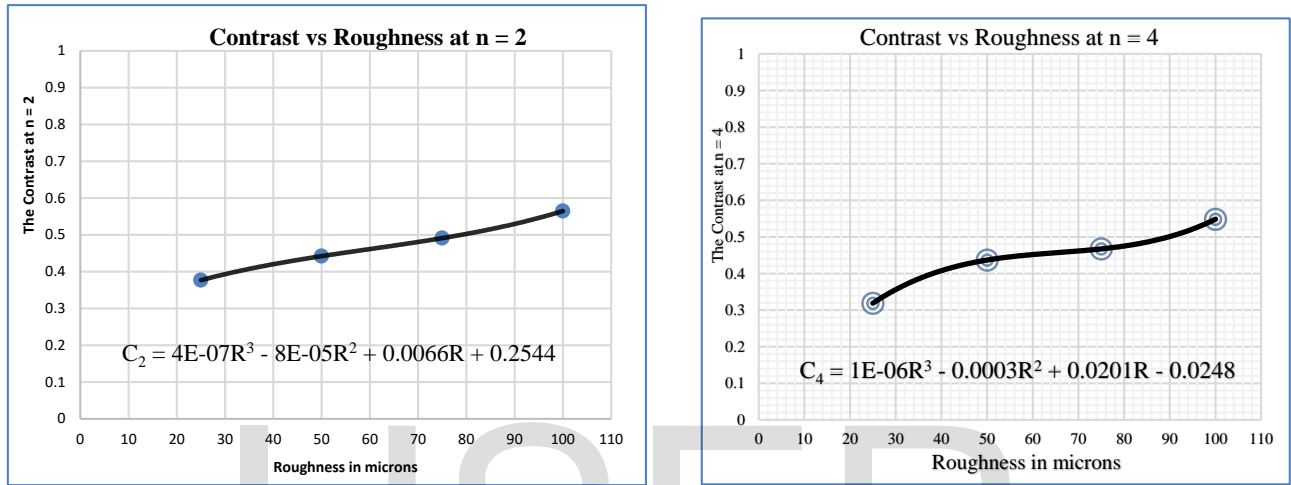


Fig.11 The graphs between the contrast and roughness for n = 2 and 4

### 6. conclusions:

The experimental verification of the presented techniques was discussed, and the conclusion was presented. About many speckle images were examined with their numeric and compressed images using different techniques of filtering and masking. It has been done for the randomly and regularly distributed speckles and the numeric images of the rough object are given. In conclusion this work can be considered as a non-contact and non-destructive fingerprinting, testing, and analysis of rough surfaces.

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