RESEARCH ARTICLE

THE DATA REDUCTION USING MATLAB FOR DIFFERENT SPECKLE IMAGES FORM SMALL SURFACES ROUGHNESS

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Abstract
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The so-called laser speckles are bright spots and dark spots formed when a coherent ray is incident on a rough surface which scattered randomly in all directions, the interference of these scattered rays form these bright and dark spots (Laser Speckles).In this paper we are concerned with the formation of Objective speckles calculations. Using MATLAB the image can be converted into binary object (0 and 1) as the speckle spots intensities are dark and bright, respectively.To simplify the calculations, two processes (transform and predictive) may be used, and according to the loss of many data for the using of predictive process, the transform process is considered.The calculations are based on the evaluation on small roughness of surfaces in range 0.1 – 1 μm, on the same footing the contrast was considered in the range from zero to one.Fraunhofer diffraction Unfortunately, no calculations in this field had been done from other researchers.

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Introduction:-
When a laser beam can be incident on rough object with roughness in the order of 5-100 micron, a scattered light will be obtained. This scattered light will interfere to form a bright and dark spot called speckle pattern. Experimental set-up for producing laser speckle pattern is shown in Fig. (1). In Fig. (2) A photograph of such speckle pattern is shown. Speckle image recorded using a high-resolution CCD camera has been transformed into a digital or numeric image using special software. These images can be considered as a fingerprint of the rough object under investigation. [2]

To examine the applied technique, a periodic transparent object has been used as a rough surface to obtain a regularly distributed diffraction pattern or speckle spot. Also, it has been used to compare the same methods of image compression with the case of randomly distributed speckle spots. Also, the retrieving of the periodic object has been presented after masking some orders of the regularly distributed diffraction pattern or speckle spots. Dividing the numeric image into large number of matrices, and then converting all the matrices into its corresponding decimal value, hence retrieving the speckle image once more and comparing its details with the original image. [1]

It has been shown that this compression does not change the details of the surface finish of the rough object. The experimental verifications of the presented techniques in the thesis were discussed and the conclusion was presented. About twenty speckle images are examined with their numeric and compressed images using different techniques of

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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. [1]
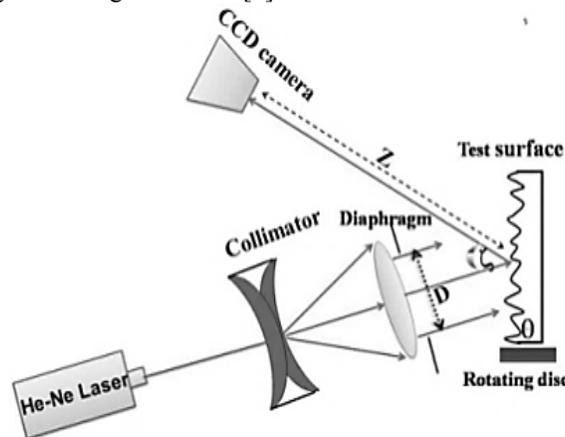

Fig.1:- Experimental Set-up used in Speckle Photography.

The speckle pattern formed using the set-up of Fig. (1), then it can be feed to the PC using a high-resolution CCD Camera to process the image of speckle pattern to obtain its binary representation. [2]
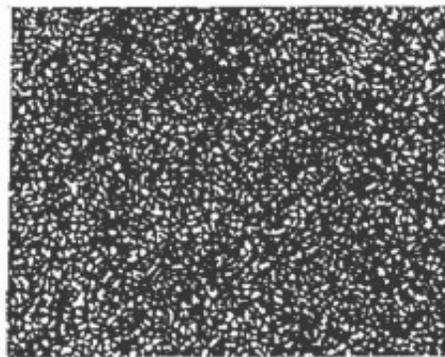

Fig.2:- A laser speckle pattern.

Speckle Effect.
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".
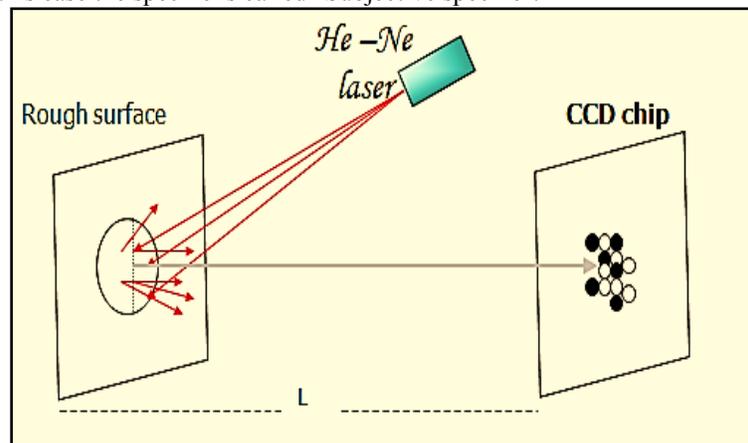

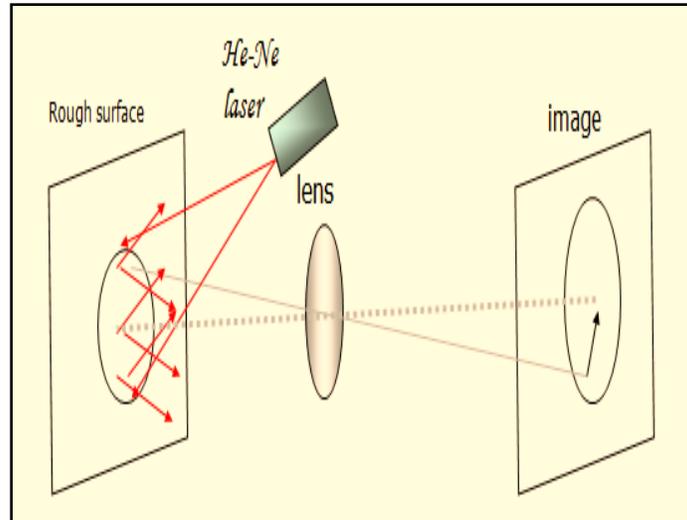**Fig.3a:-** Formation of objective speckle.

Fig.3b:- Formation of subjective speckle.

The average size of a subjective speckle can be taken as a value of Δx (or Δy) such that:

$$(\Delta x)s = {}^{\lambda z}/_L \qquad\qquad \text{Equation (1).}$$

Where λ 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 **Δ** is given by the equation. [3]

$$\Delta = {}^{1.22\lambda}/_{NA} \qquad\qquad \text{Equation (2)}$$

Transformation of speckle image to Binary representation.
The image of speckle after photographing and storing it in the PC using MATLAB. can be represented by the 2-D function f (x, y). This function represents the light intensity at the point (x, y). This function will take the values one or zero, as the speckle spots intensities are bright or dark, respectively. This means that the speckle image is transformed from analog to digital image. [4]

We can say that the digital image obtained make the processing of surface roughness information easier and accurate. This is achieved without any direct change in such information about the surface roughness. [4]
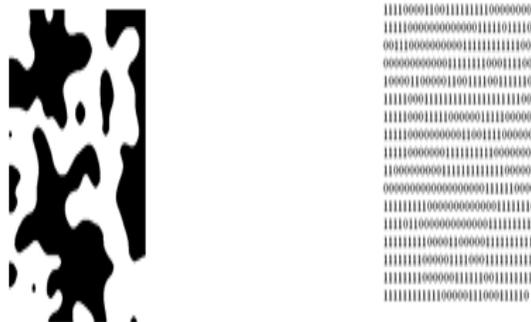

Fig.4:- Speckle Image conversion from contrast to binary digits.

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.

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 10×100, 10×80, 10×60 and 10×40 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]

After the second and third compression of the digital speckle image the image is improved because, we have several specklets is reduced, Also, we have increased the maximum speckles brightness and minimum speckles brightness, which leads to improve the visibility and improve the date between the roughness of the surface that light reflected with the contrast. [5]

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.

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. [7]
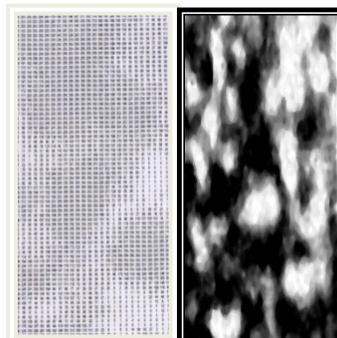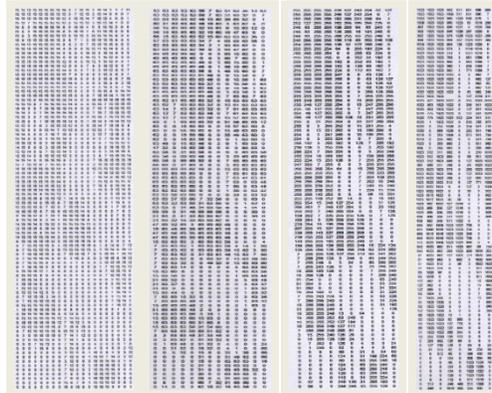

Fig.5:- The gray level representation of speckle pattern intensity distribution.

(a)   (b)   (c)   (d)

Fig.6:- The numeric representation of the speckle images after converting to natural numbers using matrices of dimensions a-10 x 100, b-10 x 80, c-10 x 60, d-10 x 40.

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 μm, 50 μm, 75 μm, 100 μm of aluminum. The roughness R is defined as. [9]

Arithmetic mean of the surface roughness defined as the arithmetical mean of the sums of all profile values.

$$R_a = \frac{1}{N}\Sigma_{i=1}^{N}|yi| \quad \text{Equation (3)}$$

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

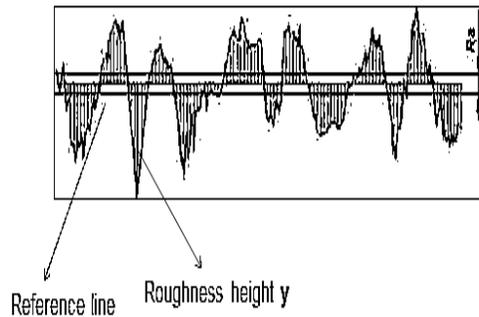$$R_q = \sqrt{\frac{1}{N}\Sigma_{i=1}^{N}|yi|^2} \qquad \text{Equation (4)}$$

Fig.7:- photograph of rough object.

Where n is the sample size, n = M x 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,

$$C = \frac{\sigma}{<I>} \qquad\qquad \text{Equation (5)}$$

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. [8]

The samples have the values of roughness 0.1 μm, 0.34 μm, 0.4μm, 0.5 μm, 1 μm, and We have the interfered reflected beams formed a speckle images as shown,
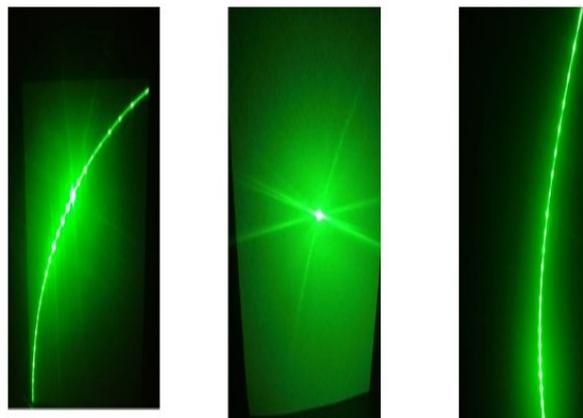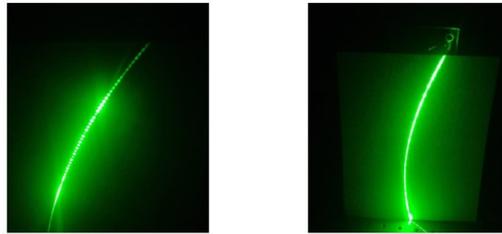
Fig.8:- The laser Speckle formed due to reflected rays with the diffraction diffuse.

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
0.1	0.4148	0.4132	0.4131	0.4130	0.4132
0.34	0.4928	0.4727	0.4727	0.4727	0.4730
0.4	0.5726	0.5709	0.5709	0.5709	0.5713
0.5	0.5836	0.5820	0.5820	0.5821	0.5824
1	0.6789	0.6723	0.6724	0.6723	0.6726
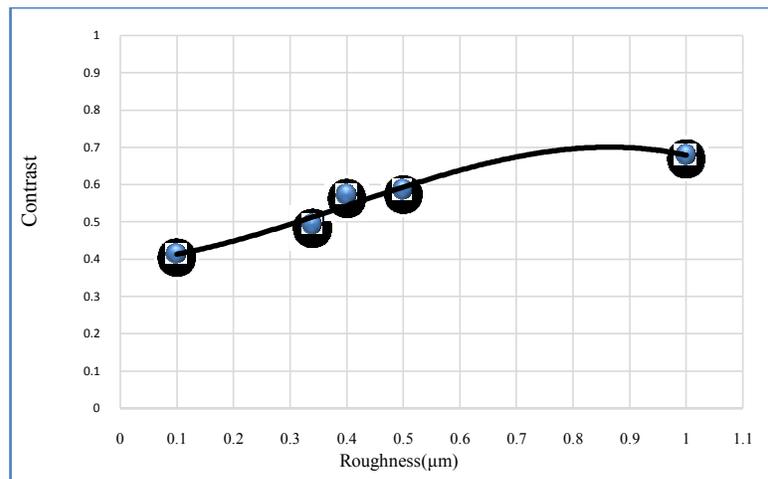
Fig.9:- the graph between the original contrast and Roughness.

Also, for each speckle image for the samples that is observed a principal maximum pattern which has its owner thickness.

By comparing the relation between the roughness and the thickness of the principal maximum pattern that is recorded in the next table 2,

Roughness(µm)	Thickness (pixels)
0.1	**32.27**
0.34	**26.57**
0.4	**17.1**
0.5	10.5
1	17

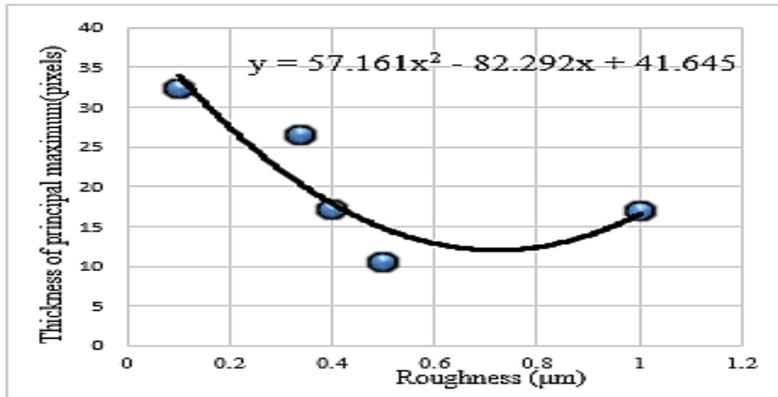The graph related to the last data can be described as shown,

Fig.10:- The graph of relation between the roughness of glass samples and thickness of principal maximum pattern.

From the curve we obtain that, the thickness decreased until a certain value of roughness then it increases after that, this value is near to the wavelength of the incident light on the sample.

We use a laser with output green beam with wavelength (0.532 ± 0.018) microns.
for the speckle images in the samples, we observe a diffraction pattern in some of them.

The diffraction is defined as the slight bending of light as it passes around the edge of an object. The amount of bending depends on the relative size of the wavelength of light to the size of the opening. If the opening is much larger than the light's wavelength, the bending will be almost unnoticeable. However, if the two are closer in size or equal, the amount of bending is considerable, and easily seen with the naked eye.
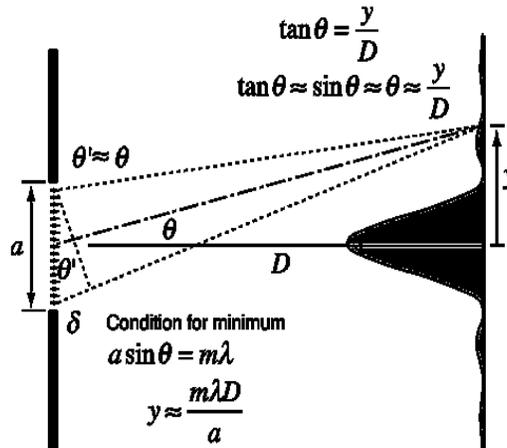

Fig.10:- The formation of Fraunhofer diffraction pattern.

Where y is the distance from the center of maximum pattern, m order of pattern, λ is the wavelength of the incident laser, D is the distance between slight bending and film and a is the width of the bending.

The width of the bending must be near to the incident wavelength.
For the speckle images, we have samples has roughness that near to the wavelength of the incident light, they obtain a diffraction patterns with the next data in table 3.

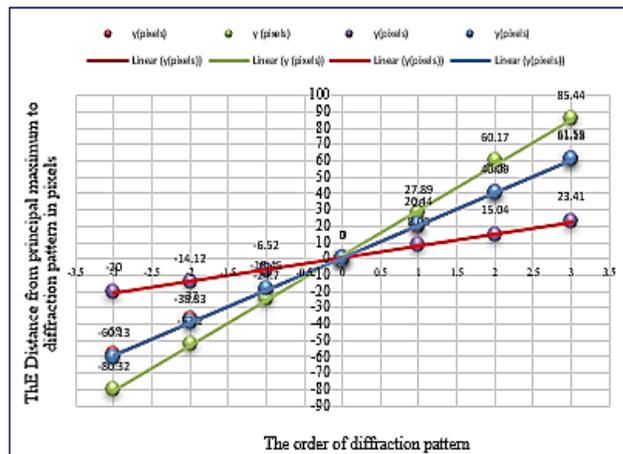| R = 0.1 µm		R = 0.4 µm		R = 0.5 µm		R = 1 µm	
M	y(pixels)	m	y (pixels)	m	y(pixels)	M	y(pixels)
-3	-59	-3	-80.32	-3	-20	-3	-60.13
-2	-37	-2	-52.2	-2	-14.12	-2	-38.83
-1	-19.1	-1	-24.7	-1	-6.52	-1	-18.45
0	0	0	0	0	0	0	0
1	20	1	27.89	1	8.08	1	20.44
2	40.8	2	60.17	2	15.04	2	40.09
3	61.55	3	85.44	3	23.41	3	61.18

Fig.12:- The graph between the odder of diffraction patternwith the distance from the principal maximum to the pattern.

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).

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. [4]

Averaging filter, Find the average value of each 10-by10 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 replaced in the image by,

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

[4]
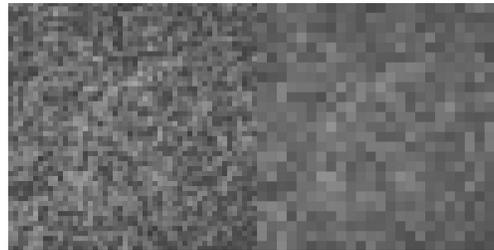
Block's size 2×2   Block's size 4 × 4
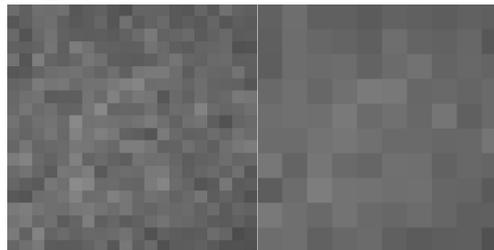
Block's size 5 × 5   Block's size 10 × 10.

Fig.13:- the blocked digital speckle images with different sizes of blocks.

Now, lets study the effective 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 0.1μm, 0.35 μm, 0.4μm, 0.5μm, and 1 μm, of glass. The block processing effectiveness using averaging filter isshown in table(4).

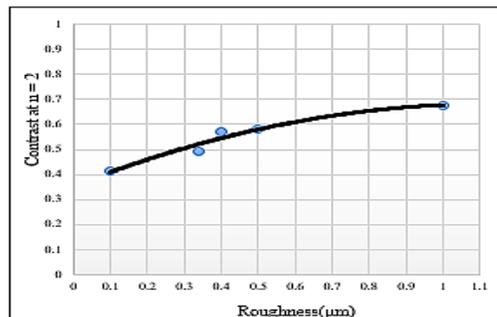| Roughness (μm)	The contrast at n=2	The contrast at n=4
0.1	0.4142	0.4135
0.34	0.4905	0.4855
0.4	0.5710	0.5704
0.5	0.5820	0.5810
1	0.6777	0.6757

Fig.14a:- The relation between Contrast at n = 2 and Roughness after applying block processing filter.
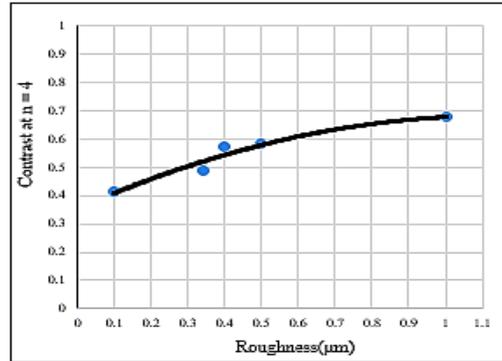
Fig.14b:- The relation between Contrast at n = 4 and Roughness after applying block processing filter.

Conclusion:-

The trial check of the introduced procedures was talked about, and the end was introduced. Around manyspeckle images were inspected with their numeric and compressed images utilizing various techniques of separating and concealing. It has been accomplished for the arbitrarily and consistently circulated dots and the numeric pictures of the harsh article are given. All in all, this work can be considered as a non-contact and non-dangerous fingerprinting, testing, and examination of unpleasant surfaces.

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