ISSN (Online) : 2319 - 8753
ISSN (Print) : 2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

An ISO 3297: 2007 Certified Organization, Volume 2, Special Issue 1, December 2013

Proceedings of International Conference on Energy and Environment-2013 (ICEE 2013)

On 12th to 14th December Organized by

Department of Civil Engineering and Mechanical Engineering of Rajiv Gandhi Institute of Technology, Kottayam, Kerala, India

# SURFACE ROUGHNESS CHARECTERIZATION USING INTERFERENCE FRINGE ANALYSIS

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**ABSTRACT**

In this work, a non-contact approach using interference fringes is used for characterizing the surface roughness of diamond polished stainless steel specimens. The interference fringes formed over the surfaces due to the interference of coherent beams can give important details about the surface topography of the material. A fringe intensity curve based parameter developed by plotting the fringe intensity curves at different heights was observed to have a linear relationship with stylus roughness. The value of coefficient of correlation obtained was is 0.71. The average standard deviation of the interference fringe intensity curves were observed to bear a linear relation with the measured stylus roughness with a correlation coefficient of 0.84.The non-contact optical methods used in this work for charactering the surface roughness are cost effective and has an advantage of non contact roughness characterization.

**KEYWORDS**: Surface roughness, Intensity fringe curve, image processing, machine vision, standard deviation, roughness parameter

## 1.INTRODUCTION

The accurate measurement of surface roughness is important for producing standard products. The accurately finished products can reduce the energy losses, mainly due to the frictional resistance between the moving parts and can improve the life of engines and machines. Roughness parameters are, therefore, important in fields like automobiles, manufacturing .The methods based on interferrometric techniques which enable the measurement in terms of the wavelength of light source. When light is made to interfere, it produces a pattern of dark bands, which corresponds to accurate division.

The interferometer consists of a monochromatic light source whose light is focused onto a beam splitter. Part of the beam is reflected to a stationary mirror and part is transmitted to a second, movable mirror. The two beams return to the beam splitter where they recombine. Part of the recombined beam is sent back to the light source and the remainder is directed to an eyepiece or observing screen for analysis. Interference fringes are formed in the eyepiece or on the observing screen and the fringes move by one fringe-spacing every time the movable mirror is displaced one-half wavelength. In interference microscope an additional arrangement is provided to get an enlarged view of interference fringes. The

Lieca interference microscope used for experiment is shown in figure1.2.

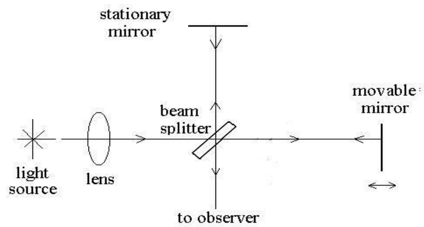



FIGURE 1.1 SCHEMATIC DIAGRAM OFAN INTERFEROMETER

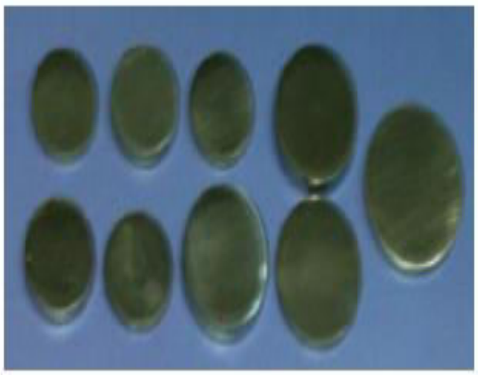
2. LITERATURE REVIEW

In the field of classification and evaluation of surface properties of materials using non contact methods, so many researcherch papers are available . Among them a few have used non contact approches for measuring surface texture of engineering surfaces. The statistical methods like mean, variance, skewness of the data collected were used for correlating surface properties ( Cohen and Fan 1988). The texture characteristics of a surface after manufacturing were studied using images obtained using image processing techniques.The images can give the details of surface nature and from these details the process parameters can be studied and used for control (Ramamoorthy and Radhakrishnan, 1993). For defining periodicity of texture of a surface Parkkinen *et al*, (1990) defined a parameter. Luk *et al*, (1989) measured the surface roughness of steel, copper, and brass samples using the statistical methods of intensity histogram and image analysis. The effect of surface roughness on mean value of intensity distribution is explained in this paper. A new optical parameter is defined for measuring surface roughness by using intensity histogram image processing in Kiran et al, (1998).Ulf Person et al (1993) studied the properties of the speckle pattern formed by the interference of coherent beams and used spectral speckle correlation for measurement of roughness. The advantage of this method is that it enables relative measurement of roughness on surface with range Ra = 0.5m-5m using visible light. Analysis and estimation of surface finish of milled and ground has been done by B. Dhanasekhar et al (2008) with the help of image processing. Various correlation functions are used for developing the relation with the roughness of surfaces. Interferometry, Phase shifting and unwrapping techniques are used for surface roughness analysis by B Dhansekhar et al (2008). Five frame phase shift algorithm has been used for assessing the surface roughness of ground surfaces. Halioua.M and HC Liu et al (1989) presented an interferometric phase measuring algorithm for 3D measurement of roughness. G.Lai and T.Yaagai et al (1991) presented a generalized phase shifting algorithm using Fast Fourier Transform EXPERIMENTAL PROCEDURE:

The experiment was carried out in Lieca interference microscope available in opto physics lab (IIT Madras).


FIGURE 1.2 LIECA INTERFERENCE MICROSCOPE

Nine staineless steel specimens were prepeared and polished using various grades of emery sheets and finally mirror like surface finish was obtained in each specimen by diamond polishing method. Each specimens were placed on the space provided on microscope and illuminated. A white light beam of wavelenghth 532 nm is used for lighting the object. Surface having around 1mm x 1mm at exact middle of specimen is selected for experiment .The fringes developed over the surface can be viewed through the eyepiece provided. A CCD camera provided over the microscope grabs the images and sents to the computer connected to it.The digitized images of interference fringes obtained from all nine specimens were grabbed and used for analysis. the fringe images obtained are shown in figure 1.3.



Nine SS specimens used for experiment

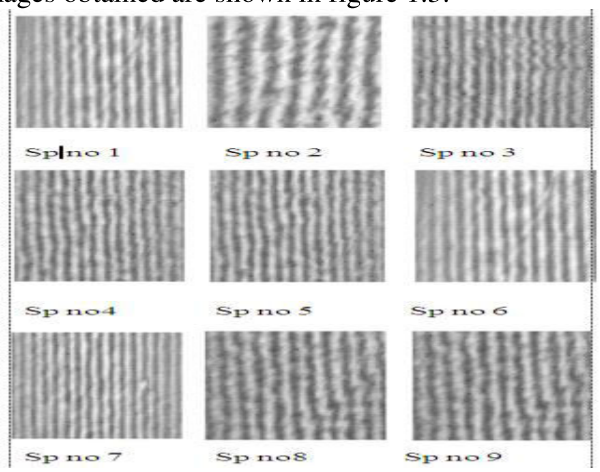
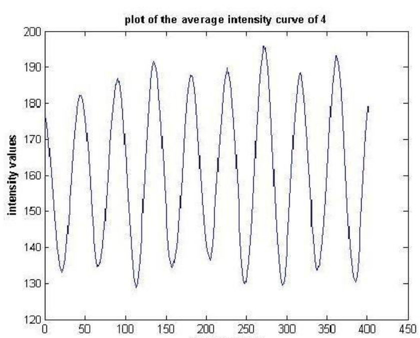



FIGURE 1.3.SPECIMENS AND INTERFERENCE FRINGES OBTAINED FROM SPECIMENS

The average fringe intensity curves were drawn for all images and the graphs are shown in figure1.4 (a) and 1.4(b).



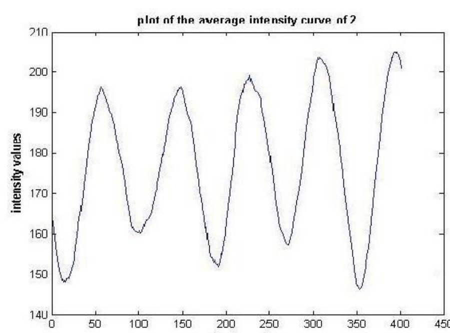
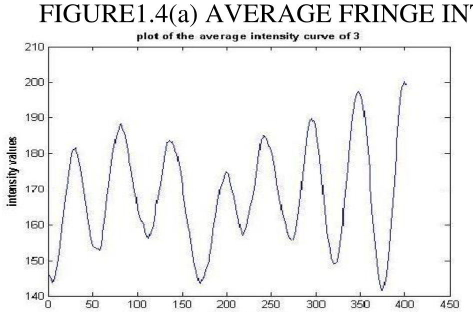
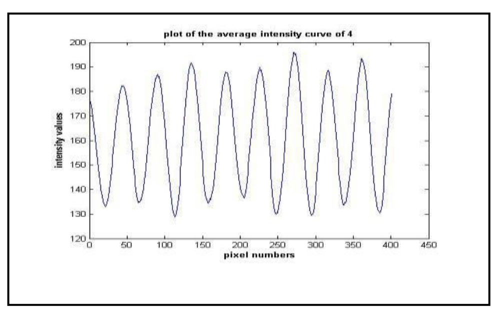




FIGURE1.4(a) AVERAGE FRINGE INTENSITY CURVE OF IMGES OF SPECIMEN1, SPE2, SPE3 AND SPE4



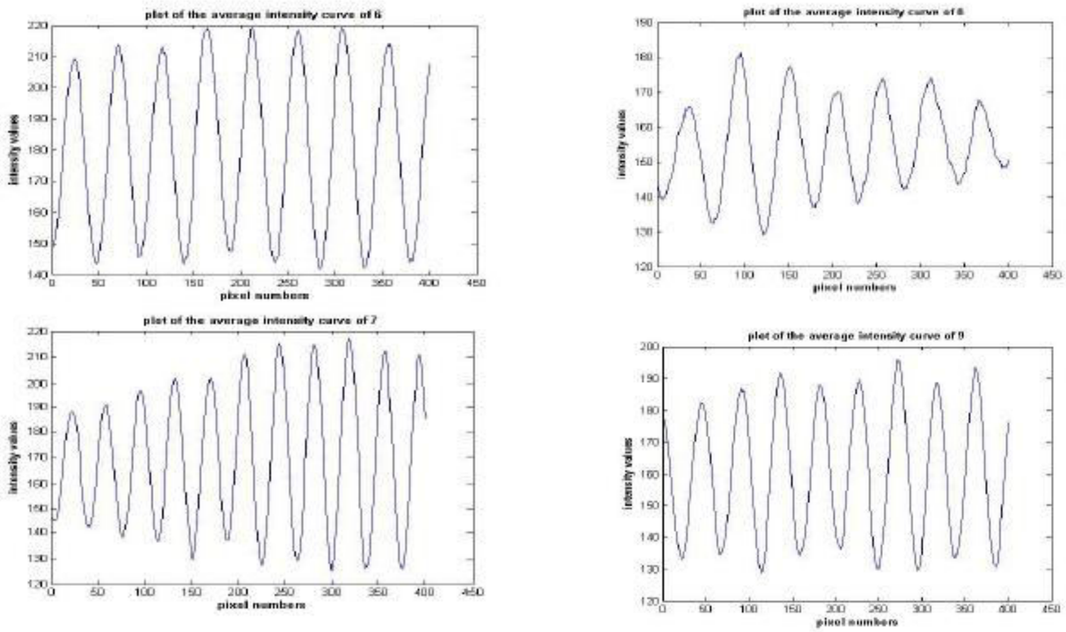



FIGURE 1.4 (b) AVERAGE FRINGE INTENSITY CURVES OF IMAGES OF SPECIMEN 5, SPE6,SPE7,SPE8 AND SPE9

## 3. IMAGE ANALYSIS

Fringe intensity curve of each pixel row represents the gray scale intensity variation along horizontal direction .Y axis of the graph represents grey scale value which varies from 0 (dark) to 255(white) and X axis of the graph represents pixel numbers.At each pixel of image the grey value depends on the amplitude of the interfered light beam falling ,and the amplitude of the light beam is determined by the nature of surface from which it is reflected. Using image analysis techniques the fringe intensity curve of images can be generated and its properties can be correlated with surface roughness of the work specimens.In the reference paper(Sabazalipour et al., 2011 ) the authors have used a pixel shift method for finding out the thickness of a step made on a thin film. The average of x-directional shift (pixel shift) of peaks between average intensity curves of upper and lower parts is taken as $\Delta x$. If $\lambda$ is the wavelength of monochromatic light used and X is the average of x-directional distances between peaks or valleys of intensity curve then thickness of the step is given by the equation:

$$\text{Thickness of step} = \frac{\Delta x}{X} \cdot \frac{\lambda}{2}$$

sample's roughness is explained below. First, fringes picture is divided to some equivalent stripes, here, 38 horizontal (576×10 pixel × pixel) ones as shown in figure1.5. Then the average intensity curve in vertical direction of each stripe is extracted (plot 'a' in Figure 1.6). This average intensity in each stripe is the interference of reflection of light from average unevenness surface with respect to the lower surface of the Test Plate. Then, each main stripe is divided to some horizontal sub stripes, here , three sub-stripes (576×3,576×3,576×4 pixel × pixel) and the average intensity in vertical direction of each sub-stripe is extracted(plot 'b' in Fig.1.6). The shift of peaks of (b) with respect to the peaks of (a) will give the surface roughness parameter with respect to the average unevenness surface. This should be performed for all stripes and sub-stripes and averaged.

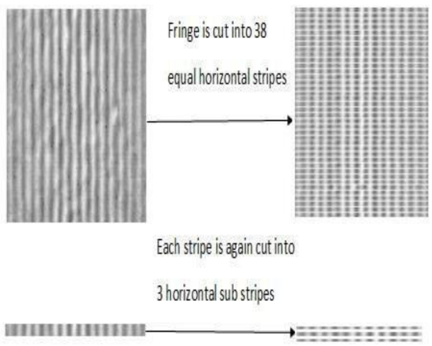



FIGURE 1.5. STEPS FOR CUTTING THE FRINGES

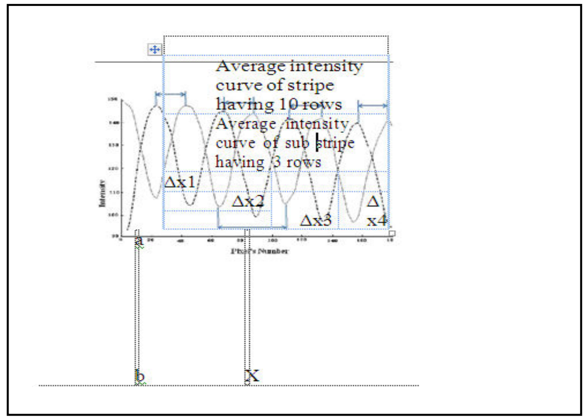



FIGURE 1.6. TYPICAL FRINGE INTENSITY CURVES FOR MAINSTRIPE AND SUB STRIPE

For each specimen, the average of x-directional shift (pixel shift) of peaks between average intensity curves of horizontal stripes and its sub stripes (Δx) and average of x directional distance between the crest points (X) are calculated and substitutes in the equation .This value is taken as the roughness parameter based on intensity curve.

$$\text{roughness parameter}(r) = \frac{\Delta x}{X} \cdot \frac{l}{2}$$

The values of intensity curve based roughness parameter and corresponding stylus roughness are given in Table 1.1 and the relationship is shown in figure 1.7.

TABLE 1.1 ROUGHNESS PARAMETER OBTAINED FROM INTENSITY CURVES AND STYLUS ROUGHNESS (Ra)

| Specimen number | Ra value obtained from stylus instrument(μm) | Intensity curve based roughness parameter |
|---|---|---|
| 1 | 0.045 | 11.649 |
| 2 | 0.028 | 09.643 |
| 3 | 0.031 | 09.315 |
| 4 | 0.056 | 11.674 |
| 5 | 0.050 | 11.959 |
| 6 | 0.035 | 08.817 |
| 7 | 0.053 | 09.555 |
| 8 | 0.034 | 08.226 |
| 9 | 0.028 | 11.665 |

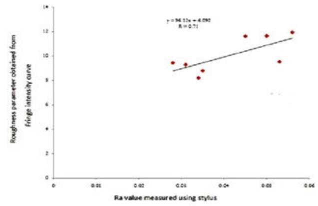


FIGURE 1.7. RELATIONSHIP BETWEEN STYLUS ROUGHNESS VALUES AND COMPUTED VALUES

A straight line relationship with coefficient of correlation R=0.71 has been obtained.

## 4. ANALYSIS USING STANDARD DEVIATION

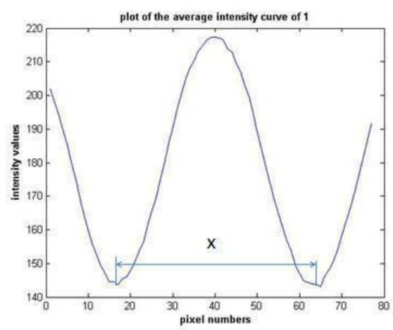



FIGURE1.8. PART OF FRINGE INTENSITY CURVE SHOWING REGION SELECTED TO FIND STANDARD DEVIATION

Standard deviation of fringe intensity curve is calculated by selecting the curve region within X as shown in figure1.8. In each specimen there are 8 to 12 regions depending on the fringe width in the image. Standard deviation of each region is calculated and averaged for getting the roughness parameter based on the intensity fringe curve. Same is repeated for all nine specimens and values obtained are compared with stylus roughness which is shown in Table1.2.

TABLE 1.2 Ra VALUES AND STANDARD DEVIATION OF VALLEY POINTS BASED ROUGHNESS PARAMETER

| Specimen number | Ra value obtained from Stylus instrument(µm) | Roughness parameter based on standard deviation of valley points |
|---|---|---|
| 1 | 0.045 | 26.05 |
| 2 | 0.028 | 20.82 |
| 3 | 0.031 | 18.79 |
| 4 | 0.056 | 29.80 |
| 5 | 0.050 | 24.77 |
| 6 | 0.035 | 23.32 |
| 7 | 0.053 | 32.28 |
| 8 | 0.034 | 15.57 |
| 9 | 0.028 | 22.43 |

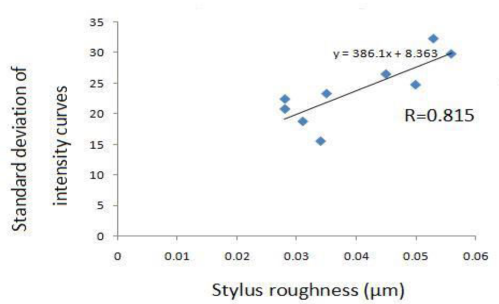



FIGURE 1.9 RELATIONSHIPS BETWEEN STYLUS ROUGHNESS AND STANDARD DEVIATIONS VALLEY POINTS

It shows a straight line relationship having coefficient correlation 0.815 between stylus roughness and standard deviations.

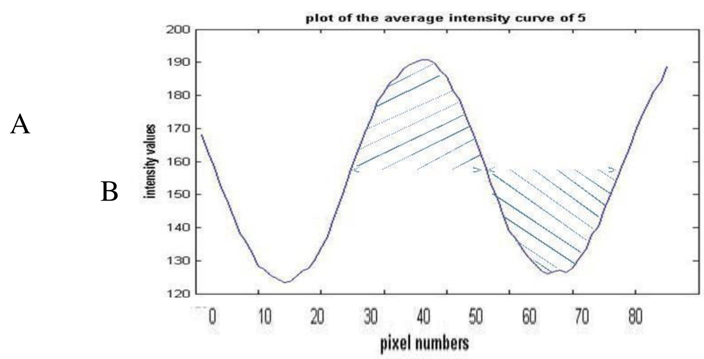



FIGURE 1.10. PART OF FRINGE INTENSITY CURVE SHOWING REGION SELECTED TO FIND STANDARD DEVIATION

Standard deviations of the hatched regions A and B of intensity fringe curve are calculated. After finding out these values for 8 to 12 regions included in fringe intensity curve of each specimen and added .The average of this value is taken as roughness parameter. The values are given in table1.3. The relationship between standard deviation and roughness which is having R=0.702 is shown in figure 1.11.

TABLE 1.3 Ra VALUES AND STANDARD DEVIATION BASED ROUGHNESS PARAMETER

| Specimen number | Ra value obtained from stylus instrument(µm) | Roughness parameter based on standard deviation |
|---|---|---|
| 1 | 0.045 | 25.24 |
| 2 | 0.028 | 22.28 |
| 3 | 0.031 | 12.64 |
| 4 | 0.056 | 23.82 |
| 5 | 0.050 | 24.64 |
| 6 | 0.035 | 20.33 |
| 7 | 0.053 | 32.40 |
| 8 | 0.034 | 15.64 |
| 9 | 0.028 | 20.12 |

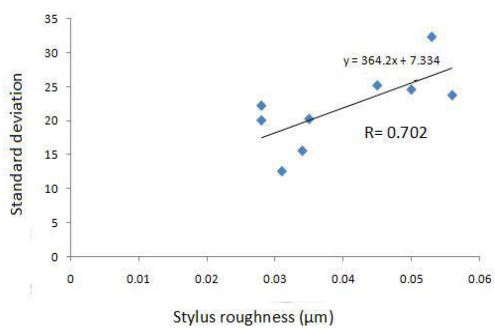



FIGURE1.11. RELATIONSHIPS BETWEEN STYLUS ROUGHNESS AND STANDARD DEVIATIONS

## 5. CONCLUSION

In this work, a non- contact approach using interference fringes is used for characterizing the surface roughness of diamond polished stainless steel specimens. Fringe intensity curve generated from interference fringes have been used for characterizing the surface roughness. The following conclusions were drawn from the studies. A fringe intensity curve based parameter Roughness developed by plotting fringe intensity curves was observed to have a linear relationship with stylus roughness. The value of coefficient of correlation obtained was 0.71. The average standard deviation of the interference roughness parameters fringe intensity curves were having a linear relation with the measured stylus roughness .Surface roughness characterization using intensity fringe curve can be used for specimens which are prepared by other process such as lapping, grinding with different materials. The study of surface roughness obtained by profilometry, speckle image analysis and fringe intensity curve analysis can be done in order to predict the accuracy of methods. Analysis using fringe intensity curve can be used to find out the roughness at nano level which may give a better result.

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