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Machine Vision Based Surface Roughness Detection System

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Abstract- Now a day for surface roughness detection machine vision has become important aspect as it is online, real time and noncontact type of method. In this work we obtained the optical roughness parameter Ga from digital images of machined surface and compared with the stylus calculated roughness values Ra and ANN predicted values. The proposed system uses DSLR camera, White light sources for capturing the images. The images are stored and analyzed on laptop using MATLAB software to get roughness features through FFT. The results obtained shows good correlation in optical roughness Ga and ANN predicted values as well as stylus obtained values.

Keywords: Surface Roughness Measurement, Machine Vision System, Artificial Neural Network(ANN), Image Processing, Fast Fourier Transform(FFT).

I. INTRODUCTION

Surface roughness is most important factor in specifying surface integrity. It is important that the roughness of surface must be in certain limits in every manufacturing industry. Therefore, Surface roughness measurement is important in quality control. Surface roughness measurement can be done by either contact or noncontact methods. The typical contact type of method used is stylus instrument, which performs the vertical movement of a diamond-tipped stylus on the surface under investigation (as shown in Fig 1).

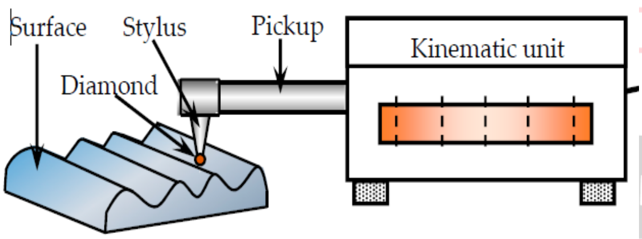

Fig. 1 Profilometer Sketch[1]

The stylus method consumes much more time in roughness detection as the ongoing manufacturing process needs to be stopped. Also depending on the the tip of the probe of the stylus device the accuracy of the instrument may create problem [2]. As a solution to this the different noncontact methods are atomic force microscopy, phase shifting interferometry, stereo scanning electron microscopy, and laser scanning microscopy. But again they are offline based methods. Machine Vision is one of the easiest online and real-time surface roughness measurement technique. "Machine vision systems is having vital role in the monitoring and control of automated machining systems". [3] The main factor that affects the image pattern in machine vision system is lightening ie the source of light, the angle at which light incident on the workpiece. Thus the image must be captured in such conditions where we can get good correlation of the optical parameters with actual roughness. [11]

Hoy and Yu developed a technique in which they stated "the magnitude and frequency information obtained from 2-D fast Fourier transform (FFT) of the digitized surface image are used as measurement parameters of the surface finish" [4]. The effect of component inclination on the surface roughness was studied by Priya, B. Ramamoorthy using digital image processing [1,5,13]. Kiran, B. Ramamoorthy, B. Radhakrishnan has studied how machine vision system can be applied for assessing surface roughness [6]. In most of the cases Optical Roughness value(Ga) is estimated and compared with traditional stylus obtained value(Ra). Fadare and Oni proposed that the machine vision system can be used along with ANN model for on-line monitoring of surface roughness of machined components and it results into acceptable accuracy. In Artificial Neural Network input data is linked with output data using a set of non- linear basic functions. [3]. In various fields of engineering for complex relationships Artificial Neural Networks (ANNs) is mostly used wherever it is difficult to describe with physical models [12].

II. EXPERIMENTAL PROCEDURE

Initially some standard specimens of mild steel having size 5cm * 5cm were prepared on horizontal grinding machine by changing the parameters of machining such as wheel speed, feed and depth of cut. Then the average

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surface roughness i.e. Ra of all specimens was measured by traditional stylus instrument i.e. SURFACE ROUGHNESS MASTER C-083 at NABL approved calibration centre.

As a next step the images of specimens were obtained in machine vision setup(Fig.2).

Initially different trials were taken to select appropriate light source to get the proper workable clear image of the surface and thus the two white LED light source (3V each) were finalized which gives proper illumination. Then to get proper reflection free image from defined light source, the light source was adjusted at different angles and trials were taken. From observations it was finalized to fix the light position at angle of 45 with respect to vertical from both sides (i.e. LHS and RHS) of sample.

The **Nikon D5300** Digital Single Lens Reflex (DSLR) **Camera** with a 24.2-megapixel resolution was positioned perpendicular to the plane of sample. The camera was connected to computer.

All this technical arrangement was enclosed in a black corrugated box of size 37cm * 20cm * 45cmto avoid the interference of external light.

Thus the finalized machine vision setup consists of Nikon D5300 Digital Single Lens Reflex (DSLR) Camera with a 24.2-megapixel resolution connected to computer, two angular white light sources for illuminating the specimen surface and enclosed in box to avoid the effect of any other light source. The captured images were preprocessed using MATLAB software to remove the noise. Then the noise free grey images of specimens were analyzed for feature extraction using 2-D Fast Fourier Transform using MATLAB.

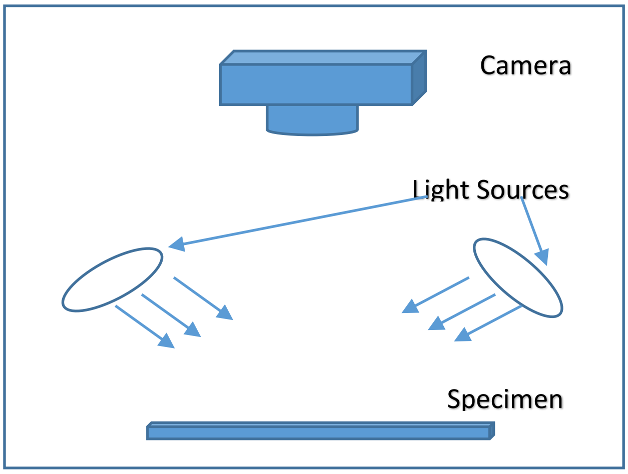

Fig. 2 Machine Vison Setup

III. Extraction of Surface Roughness Parameters

In the current work different five frequency features extracted using 2-D Fast Fourier Transform, as proposed by Priya and Ramamoorthy [5][1] were used to characterize the surface roughness of the machined workpiece. The surface roughness parameter used here is the average surface roughness Ra as it is mostly used in the industries and research field. [8,9,10]

Suppose f (*m*, *n*) be the grey level of a pixel at a point (*m*,*n*) in the original image of size N by N pixels centered on the origin. The discrete 2D Fourier transform of *f* (*m*, *n*) is given as [1,5]

$$F\ (u,v\ ) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} f\ (m,n) e - j\omega 1 m\ e - j\omega 2 n\ (1)$$

Where ω1 and ω 2 are frequency variables and F (*u*, *v)* is the frequency domains representation of *f* (*m*, *n*)

i. Peak Frequency-Major (F1)

The major peak frequency is defined as [1,5,13]

$$F1 = (u2 + v2)^{1/2} \qquad (2)$$

Where *u* and *v* are the frequency coordinates of the maximum peak of the power spectrum, i.e.

$$p(u,v) = max[\,p(u,v)\forall(u,v) \neq (0,0)]\ (3)$$

Feature F1 is the distance of the major peak (u_1, v_1) from the origin (0, 0) in the frequency plane.

ii. Principal component magnitude squared (F2)

The principal component magnitude squared is defined as [1,5,13]

$$F2 = \lambda 1\ (4)$$

Where λ_1 is the maximum eigenvalue of the covariance matrix of *p* (*u*, *v*). The covariance matrix M is given by

$$M = \begin{matrix} var(u2) & var(uv) \\ var(vu) & var(v2) \end{matrix} \qquad (5)$$

Feature F 2 indicates the variance of components along the principal axis in the frequency plane.

iii. Average power spectrum (F3)

The average value of power spectrum is defined as [5][1]

$$F3 = \Sigma P(u,v)\ /\ S\ (6)$$

and (*u*, *v*) ≠ (0,0)

Where $S = N^2 - 1$ for a surface image of size N×N.

iv. Central power spectrum percentage (F4)

The central power spectrum percentage is defined as [5][1]

$$F_4 = \frac{p(0,0)}{\sum_u \sum_v p(u,v)} x100\% \qquad (7)$$

The frequency component at the origin of the frequency plane has the maximum power spectrum.

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v. Ratio of major axis to minor axis (F5)

The ratio of major axis to minor axis is defined as [5][1]

$$F5 = (\lambda 1 / \lambda 2)^{1/2} \quad (8)$$

Where λ_1 and λ_2 are the maximum and minimum eigenvalues of the covariance matrix of *P* (*u*, *v*).

vi. Optical roughness

The optical roughness value (Ga) defined as the arithmetic average of grey level intensity values [1,5,13]. It was estimated as

$$Ga = \frac{1}{n}\sum_{i=1}^{n} |g_i| \quad (9)$$

Where the difference between the grey level intensity of individual pixels and the mean grey value of all the pixels is given by g_i. The input parameters for the training and testing of the neural network are five frequency features (F1, F2, F3, F4, and F5), while the output parameter is optical roughness. For training and testing purpose a Feed-forward multilayer perceptron (MLP) neural network with 3 layers was designed. The number of neurons in the input layer was five, the hidden layer contained four, while there was one neuron in the output layer.

IV. RESULT, DISCUSSION

The result obtained were as given in Table1.

If the results from table are analyzed using graph, then we get following observations. As shown in Fig.3 optical roughness obtained from machine vision system is having good correlation with values obtained from artificial neural network. Here we got R^2 =0.941

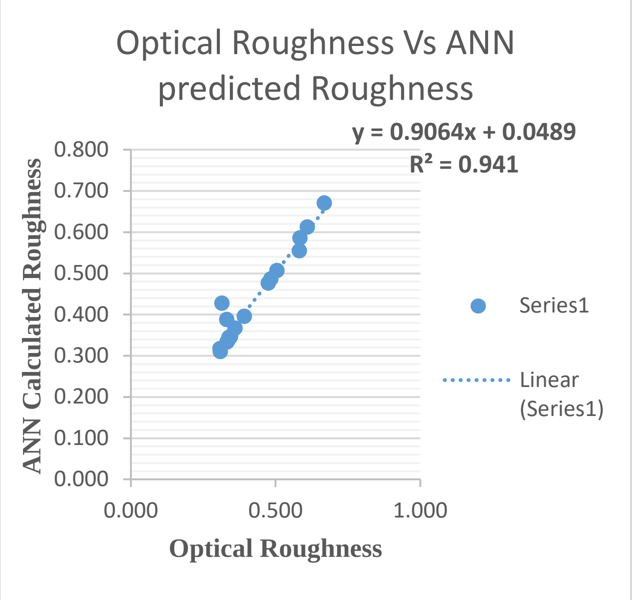

Fig. 3 Optical Vs ANN predicted Roughness

Fig.4 shows the correlation between the optical roughness value(Ga) and the roughness value obtained from traditional stylus instrument(Ra). Here we got R^2=0.7991.

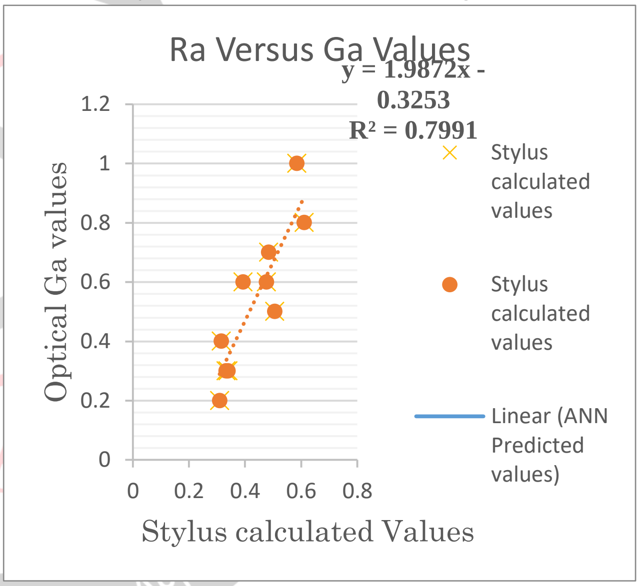

Fig. 4 Stylus calculated Vs Optical Roughness

Table 1 Comparative Values of Roughness parameters, optical roughness, ANN predicted roughness and Stylus obtained values

Specimen	F1	F2	F3	F4	F5	Ga	ANN Predicted values	Stylus calculated values
M1.1.JPG	1893	166	5.66E+10	94.964	67277734	0.345	0.347	0.200
M2.1.JPG	1823	131	2.66E+10	93.731	68941163	0.310	0.310	0.200
M3.1.JPG	1870	131	2.12E+10	90.369	43448972	0.340	0.344	0.300
M4.1.JPG	1819	120	3.56E+10	93.868	50619238	0.333	0.333	0.700
M5.1.JPG	1811	113	2.75E+10	91.818	42486511	0.360	0.366	0.600

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M6.1.JPG	1873	167	2.41E+10	89.126	49853881	0.393	0.395	0.600
M7.1.JPG	2113	156	4.49E+10	81.341	79082312	0.670	0.670	0.300
M8.1.JPG	2035	77	5.13E+10	86.470	130634036	0.583	0.554	0.200
M9.1.JPG	1454	125	1.50E+10	92.365	27520697	0.332	0.388	0.300
M10.1.JPG	1495	121	2.28E+10	89.559	32501944	0.506	0.506	0.500
M11.1.JPG	1760	132	2.20E+10	93.133	62922636	0.309	0.317	0.600
M12.1.JPG	1873	134	3.06E+10	94.744	225323265	0.316	0.427	0.400
M13.1.JPG	1822	154	3.00E+10	94.200	80000000	0.341	0.342	1.100
M14.1.JPG	1870	143	4.50E+10	95.150	37828744	0.335	0.335	0.800
M15.1.JPG	1805	131	3.68E+10	90.055	17366605	0.485	0.486	0.700
M16.1.JPG	1847	146	3.61E+10	88.968	180000000	0.476	0.476	0.600
M17.1.JPG	2052	155	1.25E+11	94.298	52260232	0.585	0.586	1.000
M18.1.JPG	2005	139	1.44E+11	94.708	104229491	0.611	0.612	0.800

V. Conclusion

The proposed system shows that Optical roughness is having good correlation with ANN predicted values and hence is acceptable. The correlation coefficient obtained in case of Ga Vs ANN is 0.941. As well as optical roughness is also compared with stylus calculated values. In case of Ra Vs Ga correlation coefficient obtained is 0.7991. Further work will be continued for more accuracy of the system.

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