Non Contact Surface Finish Monitoring of Machined Surface using Vision System

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Abstract - With ever increasing demand for the accurate engineering products, the control of surface texture has become more important. The measurement of surface roughness during machining process is critical for the automatic control of surface quality in computer-integrated manufacturing (CIM). Many methods of online measurement of surface roughness range from simple touch comparator to sophisticated optical techniques. The latest technology of measuring surface roughness during machining is the combination of optical techniques and computer vision systems. Unlike stylus instruments, the optical techniques and computer vision system have the advantage of being non contact type and are capable of measuring over an area from the surface of machined part rather than a single line. In this paper an attempt has been made to develop an experimental technique for in process surface roughness measurement based on the intensity distributions of scattered light from the machined surface. For this purpose a low cost vision system is proposed. By impinging a laser beam at an angle on the machined surface, a random pattern of bright and dark regions known as speckle is observed. These speckle images are captured using charge coupled device (CCD) camera and are stored in digital format. A source code in C++ is developed to compute the reference values from the stored image for online monitoring of the surface roughness. The method developed may be used effectively for calculating the roughness of ground, turned and milled components. Owing to the simple method of measurement, the image grabbing technique seems to be more promising for online monitoring of surface roughness

Keywords – surface finish, non contact, vision system, CCD camera

I. INTRODUCTION

On-line inspection of surface roughness during a machining process can provide a quality control check on the process, indicating if the surface finish of the machined part is within predefined tolerance, without disrupting the production process. Non-contact methods of inspection represent the key to successfully control product surface quality in a sensor based manufacturing environment. It is essential that any tendency for a machine parameter to move out of tolerance be instantly identified and the offending component can be readjusted or replaced. Variations in the basic surface roughness property required detection and classification.

Optical techniques seem to be more promising than contact methods since an effective combination can be achieved between the optical systems and the advanced image processing techniques.

The latest technology for measuring surface roughness is the computer vision systems. Unlike the stylus instruments, the optical techniques and computer vision systems have the advantage of being non-contact type and are capable of measuring an area from the surface rather than single line. Extensive research has been performed on optical surface roughness measurement techniques.

Robert A. Sprague [1] made an experimental investigation for measuring the surface roughness. By impinging coherent white light on to the surface of the part to be inspected, the speckle patterns were obtained. Then the author found a relation between contrasts of the speckle to the surface roughness.

H.Fuzi and T.Asakura [2] applied a speckle pattern technique to measure fine scale roughness of various metal surfaces produced with different finishing processes. The researchers measured the average contrast of speckle patterns produced in the far field region of the illuminated metal surfaces as a function of illuminated spot width of the laser light. Subsequently Fuzzi et al found a relation between this function and the centerline average roughness. This made the authors possible for measuring the surface roughness of metal objects having various profiles by investigating the average contrast variation of speckle intensity distributions as a function of illuminated spot width of laser light.

H.Fuzzi and T.Asakura [3] investigated another method for studying the granularity of the speckle pattern produced on the surface under illumination of laser light. The investigators measured average contrast of intensity variations in near field speckle patterns and found that the variation of speckle contrast against the receiving distance was closely related to surface waviness of objects. Basing on this relation the authors proposed a simple method to inspect surface quality of objects.

K.E.Pieponen and T.Tsuboi [4] used light scattering method to estimate the root mean square surface roughness by measuring the mean intensity of scattered light. Since the underlying theory assumes a Gaussian surface profile, it may not be useful for machined surface.

E.S.Gadelmawala and M.M.Kaura [5,6] introduced a new technique to capture an image for a surface and then extract the roughness heights from the captured image.

II.EXPERIMENTAL INVESTIGATION

An experimental setup as shown in Fig.1 has been arranged for assessing the surface roughness of ground, milled and turned work pieces. The vision system consists of a CCD camera interfaced to a PC. The experimental setup mainly consists of 3 major components.

1. A stand with the arrangement for camera and light source
2. CCD camera interfaced to a PC
3. He-Ne laser source

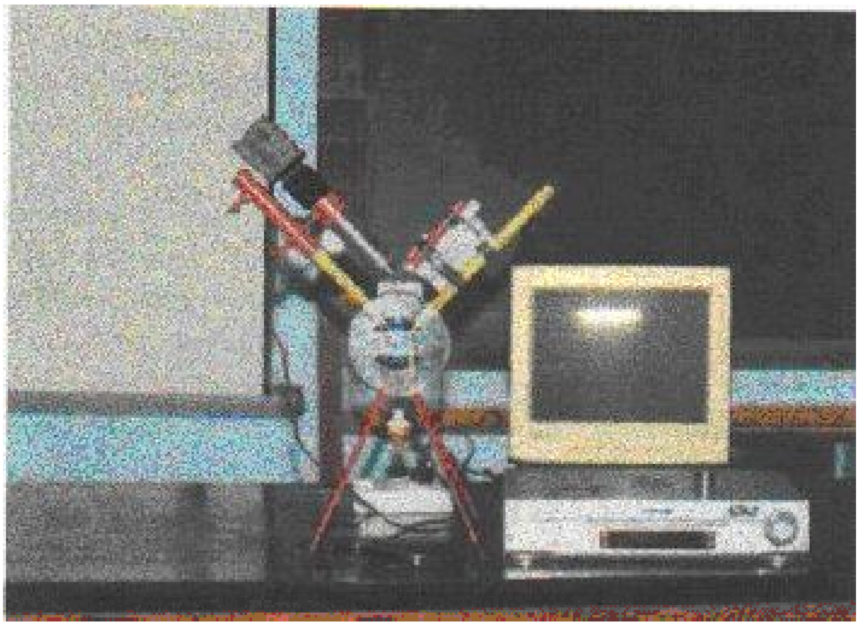

Fig.1. Experimental setup

Experiments are performed on ground and turned surfaces of three different materials, Mild steel, En4 and En6. In order to study the effect of machining operations performed ten responsive variables are considered and computed. For this experiment five mild steel ground pieces of different R_a values are used. While conducting the experiments complete randomization of observation is ensured. The illumination angle and angle of capture are set at 45^o to the specimen surface as shown in Fig.1. It is observed that surface roughness values are same for different angles. Hence further experiments are conducted keeping 45^o angle of incidence only.

Materials and machining conditions and laser specifications for conducting the experiment are given in Table.1. These samples are ground and turned using medium grain size grinding wheel and single point cutting tool respectively.

Table.1. Experimental specifications

Materials	Machining conditions	Light source
En4	Turning	Laser Light Source (He-Ne) with a wave length of 633nm
En6	Turning	
Mild Steel	Grinding	

Speckle pattern formed depends on the roughness of the surface. The size of the illuminated surface is used as an estimate of the surface roughness by defining following parameters.

$$\text{Optical Roughness Indicator (ORI)} = \frac{1}{Isat}\left(\sum_{i=1}^{M}\sum_{J=1}^{N}\frac{I1}{NM}\right)$$

I1 - Function of Intensity of pixels i,j of the speckle image

M - Number of pixel columns

N - Number of pixel rows

I_{sat}- Intensity corresponding to maximum grey level

The relation between I1 (The measured intensity) and I (actual Intensity) of the region corresponding to pixel (i,j)is defined as follows

If $I > I_{sat}$ $\quad$ $I1 = I_{sat}$

If $I <= I_{sat}$ $\quad$ $I1 = (I * (2^n - 1)) / I_{sat}$

where n is the number of bits used for grey level of the captured image

By performing several experiments the ORI readings are computed and are used for calculating R_a. The surface roughness is calculated by following relation.

$$R_a = 10^{(ORI-a)/b}$$

Where a and b are constants which depend on wavelength and angle of incidence of laser beam used , as given in Table.2.

Table.2.Angle of incidence

Constant	Angle of incidence(in degrees)				
	30	35	40	45	50
a	0.49	0.52	0.44	0.46	0.42
b	-0.32	-0.23	-0.35	-0.34	-0.38

III. RESULTS AND DISCUSSIONS

To validate the basic methodology used in developing the machine vision system for calculating surface roughness and thus in-process monitoring, experiments are carried out and results obtained from electronic stylus instrument are compared with the results obtained through program from the present experimental setup. Stylus measured surface roughness values and Optical Roughness Indicator (ORI) values for ground mild steel, and for turned En4 and En6 steels are computed from the speckle images. These results are summarized in the Table.3.

Table.3. Optical surface roughness values from the program

ORI	Optical Roughness in microns	%Error
Grounded Mild Steel		
0.501	0.754	4.57
0.497	0.774	2.30
0.453	1.04	1.96
0.415	1.35	1.50
Turned EN4		
0.477	0.899	3.85
Turned EN6		
0.572	0.459	9.28

IV .CONCLUSIONS

A vision –based measurement of roughness parameters for machined surfaces for online monitoring is described. The feasibility of using this inexpensive vision system for the optical characterization of machined surfaces is concluded as follows.

Parameters derived from the captured speckle images are investigated for differentiating between surfaces of different roughness values. It is also found that roughness of the surface conclusively affects the vision parameters.

It is also investigated that ambient light during image capturing is found to have no pronounced effect on the measurement of vision based roughness parameters. Hence it is concluded that these vision-based parameters can serve effectively in evaluating the roughness of machined surfaces.

If the evaluated surface finish values exceed the permissible values stored in the system, the computer in turn sends a feed back signal to control the influencing parameters such as speed, feed and depth of cut.

Owing to the simple construction of measurement, the image grabbing technique seems to be more promising for on-line monitoring of surface roughness. Future work will exploit the steps in further investigation to tag the offending parameters, which influence the surface finish.

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