EVALUATION OF SURFACE ROUGHNESS USING IMAGE PROCESSING TECHNIQUE

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ABSTRACT
This paper aims at the application of image processing technique for the evaluation of surface roughness. The machined surfaces of ductile iron were used for the evaluation surface roughness. From this investigation, it is found that the standard deviation data and back lighting are the best combination to find the surface roughness using a digital camera. The image processing technique is a feasible solution for the in-process evaluation of surface roughness of the materials. As the image processing technique scans the two-dimensional area of the specimens, the data would be the best representative of the surface texture.

Keywords: image processing, surface roughness, machining, ductile iron

1. INTRODUCTION
The surface finish is one of the quality characteristics of any product obtained by a manufacturing process. The surface roughness is a measure of surface finish [1, 2]. The conventional methods of surface roughness measurement have the disadvantage of requiring a physical contact between the stylus probe and the sample surface to be tested. The other difficulties of conventional methods are slow speed of measurement, wear or damage of the stylus probe and the sample surface and the navigation around any discontinuity in the surface. A limited number of single line traces, which may not be the representative of the entire surface, are used for the surface inspection and for the measurement of roughness values in the conventional methods.

The roughness measurement system proposed in the present investigation uses the light scattering theory by which the intensity field of light scattered from a rough surface can be defined as a function of the surface topography [3, 4].

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In this method, the sample is illuminated by a light source, the image is captured by a digital camera and the digital information of the image is analyzed by the computer algorithm. The computer algorithm computes the roughness parameter from the gray level histogram of the image. The Ra value for the roughness is then determined through the use of correlation curve that relates a range of the roughness parameter to a range of Ra values. The resulting Ra value is then displayed on a video monitor.

The proposed method avoids the pitfalls encountered by the conventional methods. The image processing technique has the following characteristics:

- No physical contact with the surface
- No surface damage
- No need for navigation of discontinuous surface
- The speed of the measurement is high

The proposed technique is based on the scanning of two-dimensional area. The machined ductile specimens were used for the evaluation of surface roughness [5].

2. EXPERIMENTAL PROCEDURE
The samples were prepared under different machining parameter settings. Four specimens of ductile iron were prepared under four different machining parameter settings to produce different surface roughnesses as given in Table-1.

TABLE-1: parameter settings for machining

Sample	I	II	III	IV
Speed, rpm	150	150	200	200
Feed, m/min	50	40	40	50

The image of each specimen was captured using a digital camera. Direct lighting was achieved using a 3.6 W white light bulb. Images were also captured under diffuse conditions produced using a 150W light projected from behind the samples (back lighting).

The acquired images were loaded into an image manipulation computer program for processing. Computer programs were written to determine three image parameters: Standard Deviation (SD), Arithmetical Average Deviation (AAD) and Root Mean Squares (RMS). These parameters are defines as:

$$SD = \sqrt{\frac{1}{n-1}\sum_{i=0}^{255} F_i\left(X_i - \overline{X}\right)^2} \qquad ...(1)$$

$$RMS = \sqrt{\frac{1}{n}\sum_{i=0}^{255} F_i^2} \qquad ...(2)$$

$$AAD = \frac{1}{n}\sum_{i=1}^{n}\left|X_i - \overline{X}\right| \qquad ...(3)$$

where n = number of pixels in the image, X_i = gray (brightness) level $(0 \subseteq i \subseteq 255)$ and F_i = frequency count of pixels in the image at brightness level. The surface roughness parameters computed for each sample are presented in Table-2. The average surface index, Ra values were also calculated from the measured readings of conventional stylus-probe type surface roughness testing instrument (SURTRONI-3P) for the comparison purpose.

3. RESULTS AND DISCUSSION

The results are discussed in the context of topographical visualization of surfaces, regression analysis and sensitivity and accuracy.

3.1 Topographical Visualization

Numerical data listed inTable-2 is of stylus measurement and image processed readings. Variations of both Ra and image processed results are due to the nature of the machining process employed to produce the samples. The variation of Ra across each sample can be observed qualitatively in the three-dimensional reconstruction of the sample surfaces, which were created by plotting the brightness level of the image along the Z-axis with the spatial coordinates in the X-Y plane.

On examining the topographic reconstructions, it is evident that the irregularities in the topographic reconstruction from sample-IV, which has the smallest Ra, are larger than those displayed in the topographic reconstructions from samples- I, -II and -III. This observation confirms that the image processing technique has the capability to distinguish between different patterns of the surface roughness.

3.2 Regression Analysis

The correlation curves for each of the three image processed parameters (SD, RMS and AAD) were plotted against the known Ra values determined using the calibrated stylus measurement system for direct, back and side lightings as shown in Fig-1, -2 and –3. A logarithmic curve gives a good fit for the readings obtained from direct lighting. The readings of the image processing with back lighting can fit into a polynomial curve of order three. A polynomial curve of order two is a good fit for the readings obtained from the side lighting.

3.3 Sensitivity and Accuracy

R-squared values for SD, RMS and AAD data obtained from direct, back and lightings are presented in Table-3. The R-squared values are highest for the combination of standard deviation data and back lighting. It is observed that the standard deviation data obtained from the back lighting option estimates

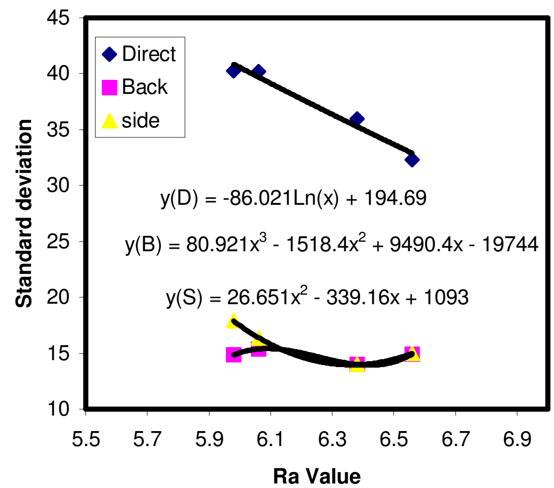

Fig-1 Standard deviation data for various lightings

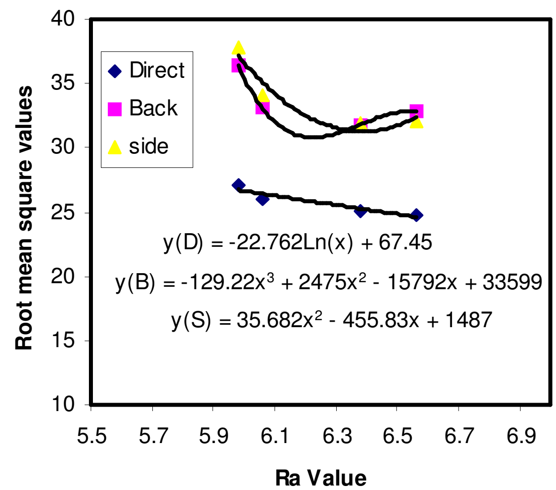

Fig-2 RMS data for various lightings

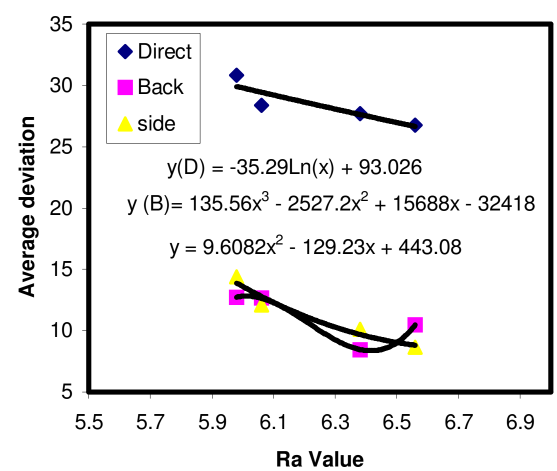

Fig-3 AAD data for various lightings

accurately the surface roughness values of image processing technique for the ductile iron. Since only four data points were observed in this investigation, it is difficult to make a broad claims regarding the accuracy and sensitivity of the image processing technique, but these preliminary findings suggest that the image processing technique presents acceptable values of the surface roughness.

Table-3: R-squared values

	SD	RMS	AAD
Direct lighting	0.9698	0.9040	0.7790
Back lighting	1.0000	1.0000	1.0000
Side lighting	0.9998	0.9265	0.9508

Table-2: Derived parameters values

Sample	Average, Ra	Direct Lighting			Back Lighting			Side Lighting		
		SD	AAD	RMS	SD	AAD	RMS	SD	AAD	RMS
I	6.56	32.330	24.803	26.745	14.931	32.861	10.468	14.986	32.099	8.643
II	6.38	35.986	25.099	27.704	13.992	31.803	8.467	13.987	31.842	10.089
III	6.06	40.172	26.081	26.361	15.378	33.098	12.653	16.376	34.099	12.0986
IV	5.98	40.243	27.097	30.814	14.834	36.456	12.732	17.896	37.895	14.372

4. CONCLUSIONS

The experimental results of the surface roughness obtained by the image processing technique suggest that such a system is feasible. The image processing technique provides a fast and flexible method of performing the surface roughness assessment, which is well suited for use as an in-process inspection system. While this paper is concerned with measuring the surface roughness of machined ductile iron surfaces, the system can be adapted to other materials and manufacturing processes by developing the standard correlation curves and the lighting option.

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