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Surface roughness classification using image processing

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ABSTRACT

Surface roughness is an important factor in determining the satisfactory functioning of the machined components. Conventionally the surface roughness measurement is done with a stylus instrument. Since this measurement process is intrusive and is of contact type, it is not suitable for online measurements. There is a growing need for a reliable, online and non-contact method for surface measurements. Over the last few years, advances in image processing techniques have provided a basis for developing image-based surface roughness measuring techniques. Based upon the vision system, novel methods used for human identification in biometrics are used in the present work for characterization of machined surfaces. The Euclidean and Hamming distances of the surface images are used for surface recognition. Using a CCD camera and polychromatic light source, low-incident-angle images of machined surfaces with different surface roughness values were captured. A signal vector was generated from image pixel intensity and was processed using MATLAB software. A database of reference images with known surface roughness values was established. The Euclidean and Hamming distances between any new test surface and the reference images in the database were used to predict the surface roughness of the test surface.

1. Introduction

Machining of metal surfaces through processes such as planning, milling, EDM or grinding produces a specific lay pattern. For example, a milled surface has a typical regular and periodic lay pattern. Surface topography has two fundamental features: the amplitude of peak or valley on the surface, and the wavelength between the peaks or valleys. Surface measurements are generally expressed in terms of profile of a surface $y(x)$ in two dimensions and are assumed as equivalent to three-dimensional expressions. The average surface roughness parameter (R_a) represents the average deviation of a surface profile about a mean line. R_a is generally used for surface roughness measurement and characterization [1].

For many years, the stylus instrument has been widely used for measuring surface roughness parameters with high reliability. The vertical movement of tip of the stylus is measured for a predetermined length horizontally. The stylus tip, however, could not reach into all the valleys of the surface, and thus acts as a low-pass filter of surface data. Therefore, the stylus tip radius has a limitation in the measurements of fine surfaces. Also, the high frequency components of surface roughness are filtered by the stylus tip, as well as any non-linear deformation in the surface cannot be adequately measured. In addition, the stylus tip may cause damage to and/or may get damaged on contact with the surface being measured. Requiring considerable time for setting up the stylus instrument before surface measurement is another limitation.

The need for a high-speed, non-contact and highly reliable surface measurement system is on the rise. Although many techniques are available for surface roughness measurements, including the optical techniques, no technique has been established reliable and robust enough for shop floor applications. The methods adopted and used in this

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paper were followed successfully in biometric recognition. An attempt is made in the present work to use a similar technique for surface characterization of machined parts. The biometric recognition techniques are proven to be robust and reliable and are also found good for surface characterization. This is one among the non-contact methods using the surface images to measure the values of the Euclidean distance and Hamming distance of the reference images and a test surface image for comparison. The surface roughness measurements of reference surfaces were done using stylus and the corresponding images were stored in the database. The test surface image was characterized based on value of Euclidean and Hamming distance. The smaller this value, the greater is the matching of the reference surface image with test surface image.Thus, the average surface roughness, R_a, of that reference image can be attributed to the test image.

2. Literature

Optical methods [2] have more potential and numerous possibilities for surface characterization. Some of the commonly used optical methods for surface measurements are optical microscopy, light scattering technique and use of vision systems. In optical methods, a coherent or incoherent light is used and the scattering of light from the surface can be used for surface measurement and characterization.

2.1. Light scattering

Light scattering has been used in many studies of surface characterization of machined surfaces. Tian et al. [3] used plane-polarized light and a scatter light detector for surface characterization. The angular-resolved scatter (ARS) and total integrated scatter (TIS) are the two methods based on light scattering to measure surface roughness. In ARS method, the theoretical expression of ARS against surface roughness involves the state of polarization of the incident light. In TIS method, the light that scatters into a hemisphere from the surface being investigated is collected and measured using a scatter light detector for surface roughness measurement.

2.2. Laser speckle image

When a coherent beam of light (laser) is projected onto a rough surface, a speckle image is obtained from the mutual interference of scattered light because of the spatial fluctuations of the rough surface. A typical laser speckle image [2] is shown in Fig. 1.

Several laser speckle techniques have been developed for surface roughness evaluation. Light scattering is caused by roughness of the surface and so the speckle images obtained can be used to measure surface roughness [2].

Persson [4] used a speckle contrast technique to characterize surface roughness. The speckle pattern is produced by illuminating the rough surface with a He–Ne laser. Based on the contrast parameters of the speckle pattern, surface roughness measurements and characterization are evaluated. The contrast parameters are obtained from the variation in the intensities of speckle image.

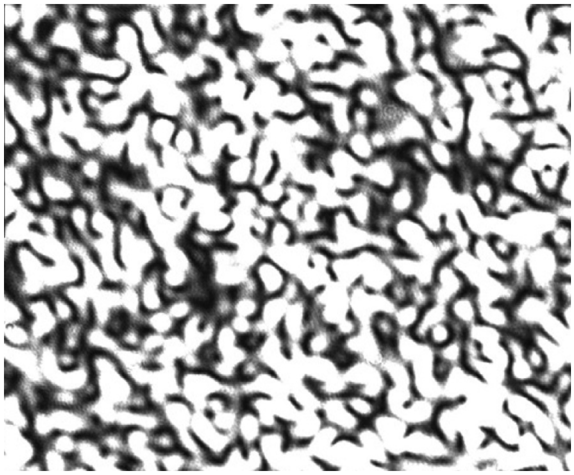

Fig. 1. A typical laser speckle image.

Fujii and Asakura [5] investigated surface roughness from the statistical properties and distribution of speckle image intensity. In the study, the standard deviations of the intensity fluctuations in the speckle patterns were observed to be having a linear relationship with surface roughness values.

2.3. Machine vision system

Machine vision-based techniques are suitable for online inspection of surfaces of machined parts and are safe on surfaces being measured and the measuring system.

Kumar et al. [6] used a vision system to obtain surface images and quantified the surface roughness using a regression analysis. The average gray value (G_a) of the surface image was calculated and calibrated with the respective average surface roughness (R_a) of the surface measured by the stylus.

Gadelmawla [7] and Tian and Lu [8] used the Gray Level Co-occurrence Matrix (GLCM) method. This statistical method considers the spatial relationship of pixels on the surface image. Surface roughness is extracted by exploring the relationships of average surface roughness (R_a) with the features of GLCM of the surface image.

2.4. Advances in image processing techniques

Several techniques for the recognition of fingerprints and iris for human identification are commercially available.

Ma et al. [9] used the local sharp variation points, representing the appearance or vanishing of an important image structure, to characterize the iris. In their study, the procedure for feature extraction of iris consisted of two steps. A set of 1D intensity signals were generated for characterizing the most important information of the original 2D image. Then a matching scheme based on exclusive OR operation was used to compute similarity between the