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ROUGHNESS MEASUREMENT BY MEANS OF OPTICAL METHODS

MĚŘENÍ DRSNOSTI POVRCHU POMOCÍ OPTICKÝCH METOD

Abstract

The article treats of roughness measurement by means of optical methods. We own two unique optical devices enabling roughness measurement (CASI ans µSCAN). Both were produced by Schmitt Industries. Measuring range is from 1 Å to 2000 Å.

Abstrakt

Drsnost lze definovat jako souhrn nerovností povrchu s relativně malou vzdáleností. V praxi se užívají nejčastěji kontaktní metody měření drsnosti. Naše pracoviště vlastní dva unikátní optické přístroje umožňující měřit drsnost povrchů. Jedná se o výrobky firmy Schmitt Industries Micro-Scan a CASI.

1 INTRODUCTION

The quality of machined surface is characterized by the accuracy of its manufacture with respect to the dimensions specified by the designer [1]. Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely spaced micro irregularities left by the cutting tool. Each type of cutting tool leaves its own individual pattern which therefore can be identified. This pattern is known as surface finish or surface roughness. Usually there are 2 possibility to measure the roughness. Contact or non contact methods. The first method is based upon contact scanning of surface. Second one is based upon optical methods.

2 ROUGHNESS

Roughness consists of surface irregularities which result from the various machining process. These irregularities combine to form surface texture. We usually use two roughness parameters Ra and Rq [2].

Roughness height is the height of the irregularities with respect to a reference line. It is measured in micrometers or Å. It is also known as the height of unevenness. Roughness width is the distance parallel to the nominal surface between successive peaks or ridges which constitute the predominate pattern of the roughness. It is measured in millimetres.

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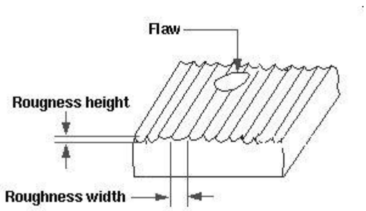

Fig. 1 Surface roughness

Ra is the most commonly used parameter to describe the average surface roughness and is defined as an integral of the absolute value of the roughness profile measured over an basic length:

$$Ra = (\frac{1}{L})\int_0^L |Z(x)|dx \, , \qquad (1)$$

and simply:

$$Ra = (|Z_1| + |Z_2| + ... + |Z_N|)/N \, , \qquad (2)$$

where :

L - basic length ,

Z(x) - the profile height function.

The average roughness Ra is the total area of the peaks and valleys divided by the basic length, it is expressed in µm. The total area of the peaks above the mean line should be equal to the total area of the valleys below the mean line.

Rq is the root mean square of the profile height deviations from the mean line, recorded within the basic length L :

$$Rq = \left[\left(\frac{1}{L}\right)\int_0^L Z(x)^2 dx\right]^{\frac{1}{2}} , \qquad (3)$$

$$Rq = [(Z_1^2 + Z_2^2 + ... + Z_N^2)/N]^{1/2} . \qquad (4)$$

Ra and Rq are both representations of surface roughness, but each is calculated differently. Ra is calculated as the roughness average of a surfaces measured microscopic peaks and valleys. Rq is calculated as the root mean square of a surfaces measured microscopic peaks and valleys. Each value uses the same individual height measurements of the surfaces peaks and valleys, but uses the measurements in a different formula.

3 OPTICAL METHODS

We mention two optical non contact systems for roughness measurement. These systems use scatter light from measured surface.

3.1 µSCAN

The SMS µScan System consists of a hand held Control Unit (CU), an interchangeable measurement head, and a separate charging unit. The CU controls all aspects of the system operation. From a single measurement, a user can determine Rq surface roughness, reflectance and scattered light level (BRDF) on flat or curved surfaces under any lighting conditions. System consists of laser beam reflectivity measuring sensor and two scatter light sensors. BSDF is calculated from scatter light and Rq from PSD. PSD is Fourier transformation of BSDF. Fig 2. shows scheme of µSCAN head. The Rq range of the system is 1Å – 1100 Å, spatial bandwidth is from 1µm - 1000 µm and accuracy of the measurement is less then 3 % [4].

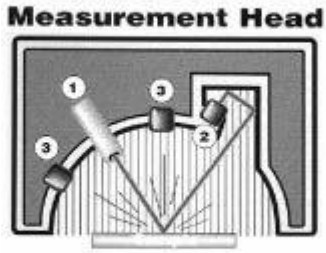

Fig. 2 µSCAN head. Sensor 3 is scatter light detector, sensor 1 is specular beam trap.

3.2 Casi

The SMS Scatterometer measures scatter over all angles (±90 from specular) in the plane of incidence with an instrument called CASI (Complete Angle Scatter Instrument). This instrument essentially throws a well collimated beam on the test surface at a well defined incidence angle, and one or several detectors detect and measure the scattered light. These detectors are mounted on arms so that the scattering angle can be varied. The scattering solid angle is defined by baffles and stops. One of the methods is to determine the angle-resolved scattering known as Bidirectional Scattering Distribution Function (**BSDF**). Relatively smooth surfaces (peak to valley less than 500 Å) will reflect most of the light into the zero order (the specular direction) and diffract small fractions of the light to the +1 and -1 orders. For gratings this smooth, the light diffracted into the second order can be neglected. The **BSDF** function is the relation between the light power received within a solid angle in a certain scattering direction depending on the beam incidence angle and its power, this way determines the position and the magnitude of the diffraction orders [3].

$$BSDF\,(\vartheta) = \frac{\delta P_s(\vartheta)}{P_i \delta\Omega_s \cos(\vartheta)}, \tag{5}$$

where ϑ is the scattering direction (from the normal), P_i is the power in the incident beam, δP_s is the power in the scattered beam inside the solid angle $\delta\Omega_s$ around the direction ϑ.

The magnitude of the first order light is determined by the sinusoidal amplitude and frequency, while the position (angle of diffraction) is determined by the grating frequency and direction. Any arbitrary surface composed of many sinusoidal surfaces should then diffract in many directions where each direction and magnitude define a sinusoidal component present on the surface. Measurements of the magnitude and direction of the scattered light can be used to calculate the amplitude and frequency of the sinusoidal components present once it is known exactly how sinusoidal gratings diffract their light. Measurement of these quantities amounts to measurement of the surface PSD (surface power spectral density). This curve defines the surface statistics, but not the exact surface profile. From PSD we can calculate Rq and Ra of the surface.

CASI Measures : Bi-directional Scatter Distribution Function, Transmittance (BTDF) and Reflectance (BRDF), Calculates Total Integrated Scatter (TIS), Total Hemispherical Reflectance (THR), Power Spectral Density (PSD), and Rq roughness. Total system accuracy is less then 2 % [4]. Fig. 4. represents typical result of CASI measurement. PSD function and roughness for spatial infrequences 0,005 1/µm.

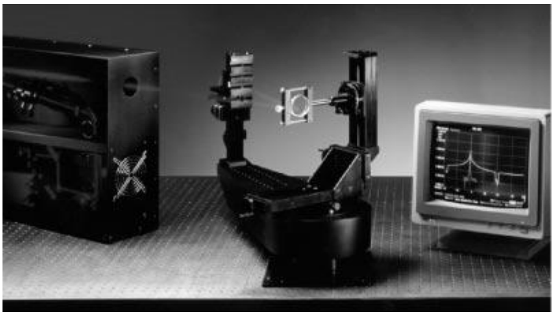

Fig. 3 Complete Angle Scatter Instrument. Laser source (left), detector (middle).

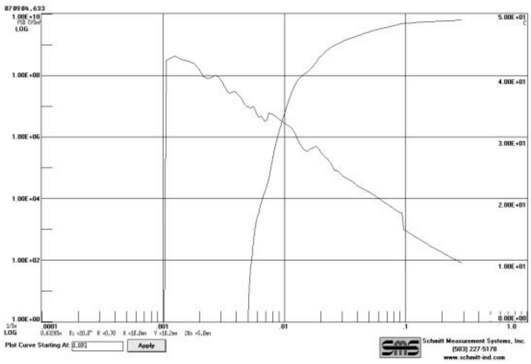

Fig. 4 PSD function and spectral Rq.

4 CONCLUSIONS

Two optical roughness systems were presented. SCAN and CASI enable to measure reflective optical and non optical surfaces (e.q. glass, mirrors, metal plate, el. semiconductors,etc.). Reflectance of the measured surface is condition for good result.

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