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NOISE CORRECTION FOR SURFACE MEASUREMENTS

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In roughness measurements often noise plays a role. Noise may give an offset in measurement parameter as noise makes the parameter deviate away from zero. In this paper we propose a method to correct for noise bias for the surface parameter Sq. By considering the decrease in Sq once an average over multiple measurements is made, an unbiased value for Sq is estimated by extrapolating the value to an infinite amount of measurements. It is shown that using this method for two measurements only, the true measurand is approached better than with averaging tens of measurements. This principle is extended to obtain a complete 'noise-corrected' surface by considering the power spectrum and the change of each Fourier component with averaging. Combining the two methods and considering the statistical significance of each Fourier component enables a further reduction. Examples and simulations are shown for the calibration of roughness drive axis and surface measurements.

1. Method

1.1. *Parameter extrapolation*

The parameter Sq in surface metrology is a measure of power as it is the rms value of the surface. It is possible to use the mean square, Sq^2 to extrapolate the Sq to a power level with reduced noise bias. As the noise is independent of the measurement, the power of a measurement consist of the power of the object and the power of noise [1]:

$$Sq^2_{measurement} = Sq^2_{object} + Sq^2_{noise} \tag{1}$$

If multiple measurements are taken, noise is reduced by the number of measurements n, but the power of the object remains:

$$Sq^2_{mean(n)} = Sq^2_{object} + Sq^2_{noise}/n \tag{2}$$

Rearranging 2 and 3 gives the power of the object:

$$Sq^2_{object} = \frac{n \cdot Sq^2_{mean} - \left\langle Sq^2_{measurement} \right\rangle}{n-1} \tag{3}$$

In figure 1, the results are given of the extrapolation for a simulated block surface with an Sq of 1.381 µm. Measurement surface is 0.01 mm², period 10 µm and amplitude 1 µm. A normal distributed noise with a standard deviation of

1 μm is added. As the standard uncertainty in the extrapolated sets does not decrease, e.g. averaging two profiles gives $Sq =1.547$ μm ± 12 nm and the reduced pairs give $Sq =1.376$ μm ± 10 nm, it is possible the calculated parameter is lower as the 'clean' surface, but within the uncertainty limits. The bias effect is observed in surface plates [2] and noted for rms values of wavefronts by Davies [3]. Davies uses a combinatorial method to remove the bias.
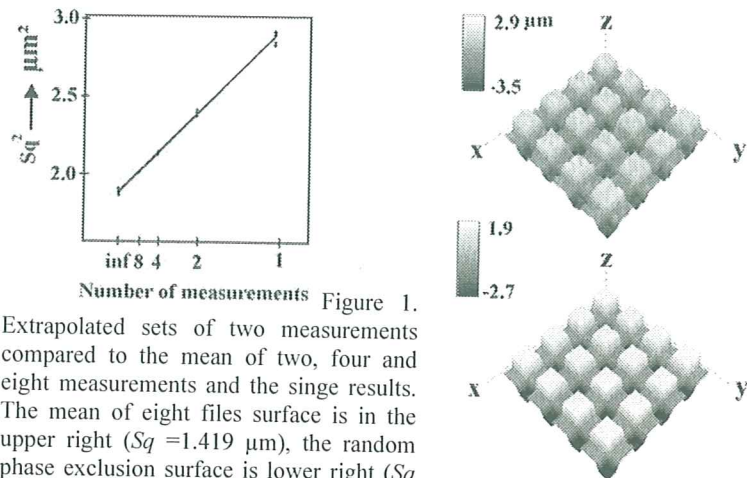

Figure 1. Extrapolated sets of two measurements compared to the mean of two, four and eight measurements and the singe results. The mean of eight files surface is in the upper right ($Sq =1.419$ μm), the random phase exclusion surface is lower right ($Sq = 1.374$ μm).

1.2. Fourier reduction

The next step is to obtain a complete reduced surface. First a Fourier transformation is performed. The power, the squared amplitude, of a single frequency also consists of an object and a noise part. Following formulas 1 to 3, the amplitude spectrum of a noise reduced surface can be calculated. Inverse transformation is done with the phase of the mean of measurements. If a noisy frequency is encountered it is possible the power is reduced to a negative number. In that case the power of the frequency is set to zero.

1.3. Random phase exclusion

Even further reduction is possible. The Fourier terms are sorted by statistical importance. The more random a frequency, the larger the standard deviation in the mean of phases of that frequency will be and the less significant it is. Starting with the most significant frequency, Sq is calculated and compared to the extrapolated Sq_{object} calculated with equation 3. If the limit is not met the next frequency is added to the spectrum until $Sq_{surface}$ meets Sq_{object} .

2. Calibration

A drive axis of a roughness tester is calibrated with a randomizing method [4]. A reference plain is measured at 6 different positions. The reference and its phase is thus randomized while the axis remains constant. Using the noise correction and random phase exclusion methods, a plot of the axis is derived.
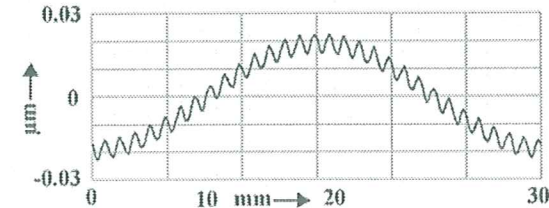

Figure 2. Calibration of drive axis of roughness tester with random phase exclusion.

Acknowledgement

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