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A comparative study of methods for treating the end effects in surface finish measurement

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Abstract

Surfaces in engineering can be considered as a weighted overlapping of various sinusoidal components which can be separated by their wavelength. The study of the influence of surface micro-geometry on the functional behavior of the pieces requires the separation of these components. This separation is carried out by applying filtering techniques to the digitized values representing the considered profile or surface. Most widespread filtering techniques, such as the Gaussian filtering, are based on a convolution between the points of the surface with a weighting function. While convolution is being performed, those points near to the ends of the sample length have not enough information to rightly perform the convolution and the phenomenon known as end effect appears consequently. The present work makes a comparative analysis between different criteria proposed by the ISO standards to reduce the impact caused by the appearance of the end effects.

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Keywords: Surface finish;Roughness; Filtering; End effects; ISO 16610

1. Introduction

From the first analog filters [1] implemented by surface finish measurement devices to the digital filters used nowadays [2, 3], the need to isolate wavelength intervals out of the measured signal has been a matter inherent to the

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characterization of surface finish due to the varying influence of these intervals in the functional behavior of the components. Although there is an increasing trend towards the use of robust and splines filters [4] [5], the majority of the instruments aimed at roughness measurement include Gaussian filters [6]. These kinds of filters are based on the assignment of a value to each discrete point of a set, being the value derived as a Gaussian-weighted average of the values of the adjacent points. This feature involves that the points near to the extremes of the profile or surface have a lack of measurement information to be filtered. This fact generates a distortion in filtered results commonly known as end effect [7] as Fig. 1 shows. To avoid this effect, the common practice is to consider measured data in a length longer than the one that will effectively undergo the filtering operation. In this way it is guaranteed enough measured data to neutralize the effect caused by the lack of data at both sides of each point under consideration. Several criteria exist in order to relieve this undesirable effect, some of which are contained in the ISO standards [8]. The first and simplest is the so-called Zero Padding criterion (ZPA). As its name already indicates, the algorithm associated to this criterion consists in adding zero-valued points to the left and right sides of the profile, that is, as a continuation of the equivalent lengths that would be subject to featuring end effects. In such a manner it can be that the filtered profile, once the end regions have been discarded, has the same length as the original one. Using the elements shown in Fig. 1, the zero-padded profile can be represented mathematically by the following function:

$$\tilde{z}(x) = \begin{cases} 0 & -l_2 \leq x < 0 \\ z(x) & 0 \leq x \leq l_t \\ 0 & l_t < x \leq l_t + l_1 \end{cases} \tag{1}$$

In the above expression, $\tilde{z}(x)$ replaces the original function of the profile during the filtering computation, which is now able to be performed over the whole measured length. This method is not suitable for steep profiles (although the slope can be removed prior to filtering) or if the extreme values of the profile differ significantly from zero (in this case it could be alternatively applied a padding with a non-zero value).

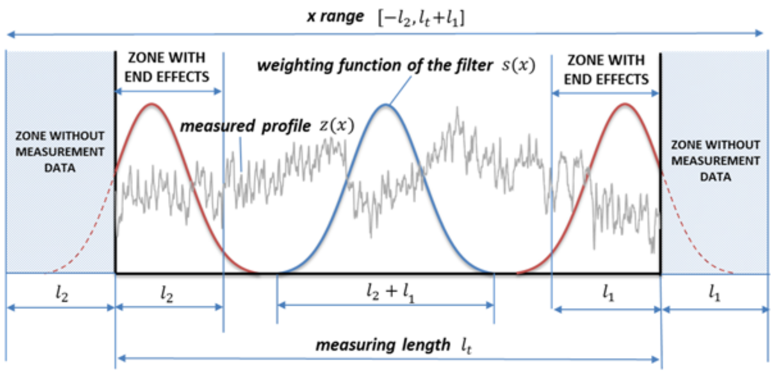

Fig. 1. Graphical illustration of end effect zones.

The second method is based on the linear extrapolation of the profile and is called Linear Extrapolation (LEX). According to this criterion, the profile is complemented at both sides with a least squares regression line of the points at the end regions. The regression applied can be expressed as

$$\int_{l_i^-}^{l_i^+} [z(x) - m_i x - n_i]^2 dx \to Min_{m_i,n_i} \tag{2}$$

where $l_i^{\pm}$ are the limits of each end effect region and coefficients m_i, n_i represent, respectively, the slope and the intercept of the line of fit that results from the least squares operation. In general, these coefficients are different for the right and left sides of the profile. Once the results of the regression have been obtained, the function of the original profile can be accordingly modified: