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Cut-offs and the Measurement of Surface Roughness

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Introduction

The mathematical definition of Surface Roughness parameters is very strictly defined by international standards. However, getting the “correct” result depends critically on the selection of a number of parameters that can be set by the metrologist.

In this article Dr Mike Mills – Chief Metrologist at Taylor Hobson – gives some practical advice on how to choose these important parameters.

Definitions

In any discussion of this type, weneed to start with a few definitions.
The important ones here are:

- **Roughness** A quantitative measure of the process marks produced by the creation of the surface and other factors such as the structure of the material. Not to be confused with **Waviness** or **Form,** which have longer wavelengths.

- **Filter** A process to exclude wavelengths above or below a particular frequency. The measurement system is a mechanical filter. Software can perform mathematical filtering.

- **Cut-off** The wavelength at which a filter becomes effective. For surface parameters we normally analyse wavelengths between an upper and lower cut-off: these are referred to as Ls or λs (shortest) and Lc or λc (longest). “Cut off” is also used synonymously with **Sample Length** as the sample length is always set to Lc.
  Bandwidth is the ratio of Ls to Lc

- For a fuller description of these and other parameters look at the FAQ section of our website at: www.taylor-hobson.com/faq

So, where's the problem?

Look at figure 1. This hypothetical profile shows a roughness wavelength of 0.25mm with an Ra of about 20µm. If it were analysed with a cutoff (Lc) of 0.08mm the calculated Ra would be virtually zero. At Lc =0.25mm Ra would be about 10µm and at Lc = 0.8mm or 2.5mm you would get the "correct" result of Ra=20µm. If Lc were set to 8mm or more, the calculated Ra would increase, as the large waviness would then be included as well.

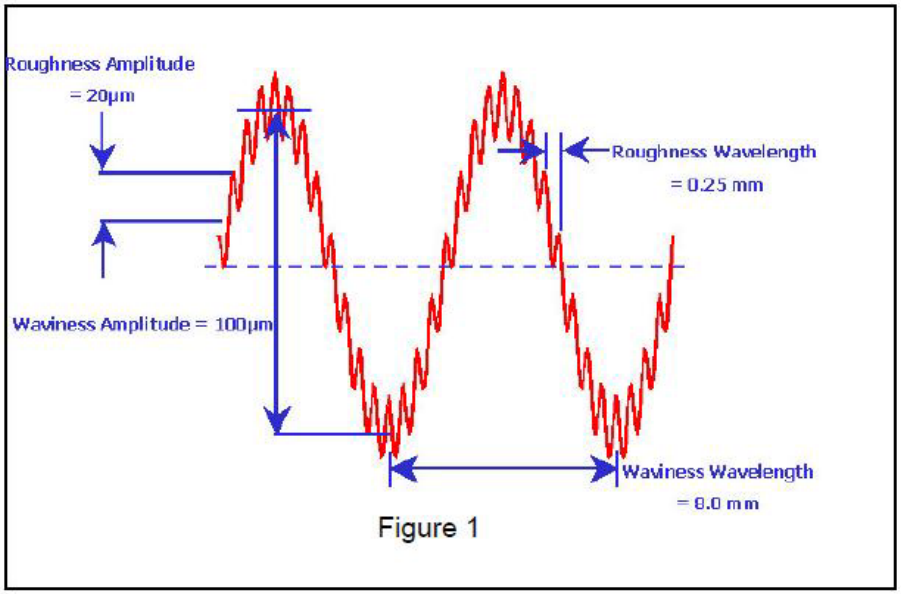

Figure 1

profile showing a roughness wavelength of 0.25mm with an Ra of about 20µm

The effect of choice of filter is subtler, causing changes of "only" a few percent in roughness parameters. However, these can be significant when establishing consistency across sites or between instruments.

Basics

What are the key concepts in filtering a surface roughness profile? The most important concept is to know what you are dealing with – this will enable you to choose the appropriate stylus tip and filters. In most circumstances a single measurement will be made on the surface in order to assess the texture. This measurement must be representative of the surface and appropriate to the purpose of the measurement (e.g. measured normal to the lay of the surface, or in the indicated direction).

Recommended Cut-off (ISO 4288-1996)				
Periodic Profiles	Non-Periodic Profiles		Cut-off	Sampling Length/ Evaluation Length
Spacing Distance RSm (mm)	Rz (µm)	Ra (µm)	λc (mm)	λc (mm)/L
>0.013-0.04	To 0.1	To 0.02	0.08	0.08/0.4
>0.04-0.13	>0.1-0.5	>0.02-0.1	0.25	0.25/1.25
>0.13-0.4	>0.5-10	>0.1-2	0.8	0.8/4
>0.4-1.3	>10-50	>2-10	2.5	2.5/12.5
>1.3-4.0	>50	>10	8	8/40

Recommended cut-offs for different surface finishes

Selection of Lc/ λc

The choice of λc filter will depend on the process being assessed. There are a number of guidelines available, for example ISO 4288-1996 (see table below). However the choice of cut-off should be made after consideration of the spacing of the profile features (peaks and valleys) caused by the machining process, denoted RSm. As a rule of thumb λc should be set to about five times this spacing.

Selection of Ls/λs/Bandwidth

ISO introduced the concept of “bandwidth” in the late 1990’s. Under this regime the shorter wavelengths used in surface roughness analysis are constrained by a short wave filter (know as the λs filter – see ISO 3274:1996).

The bandwidth is then limited in a controlled way that *relates directly to surface features*, rather than being limited by the bandwidth of the measuring system. The ISO recommendation is to use a bandwidth of 300:1 wherever possible.

The smallest λs available will be dependent on the data spacing available in the raw profile: for an instrument with 0.25um data spacing, the smallest λs that can be represented is 1.25um. The λs filter should be chosen so that it does not attenuate wavelengths that are likely to be introduced by the machining process. The recommended combinations of λc, λs and stylus tip radius are shown in ISO 3274:1996.

- **Filter selection**

  In general the Gaussian filter is preferred as it is phase correct and has a fast roll-off without “ripple”. Taylor Hobson Ultra software also offers 2CR and 2CR-PC (phase corrected) filtering. These should only be used when you need backward compatibility with results from older instruments.

- **Other Important Factors**

  The mechanical measurement system is also a filter that will affect the results. For the most accurate possible reproduction of the actual surface I recommend the use of a Taylor Hobson Form

  Talysurf instrument! A fuller version of this article can be found on the Taylor Hobson website in the FAQ section under “Surface Measurement Tips and Tutorials”.

Contact us

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