

# Tutorial - Cut-offs and the Measurement of Surface Roughness

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, we need 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  $\lambda_s$  or  $\lambda_s$  (shortest) and  $\lambda_c$  or  $\lambda_c$  (longest). “Cut off” is also used synonymously with **Sample Length** as the sample length is always set to  $\lambda_c$ . **Bandwidth** is the ratio of  $\lambda_s$  to  $\lambda_c$

For a fuller description of these and other parameters look at the FAQ section of our website at: [www.taylor-hobson.com/faq](http://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  $R_a$  of about  $20\mu\text{m}$ . If it were analysed with a cut-off ( $\lambda_c$ ) of 0.08mm the calculated  $R_a$  would be virtually zero. At  $\lambda_c = 0.25\text{mm}$   $R_a$  would be about  $10\mu\text{m}$  and at  $\lambda_c = 0.8\text{mm}$  or  $2.5\text{mm}$  you would get the “correct” result of  $R_a=20\mu\text{m}$ . If  $\lambda_c$  were set to  $8\text{mm}$  or more, the calculated  $R_a$  would increase, as the large waviness would then be included as well.

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).

## Selection of $\lambda_c$ / $\lambda_c$

The choice of  $\lambda_c$  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  $R_{Sm}$ . As a rule of thumb  $\lambda_c$  should be set to about five times this spacing.

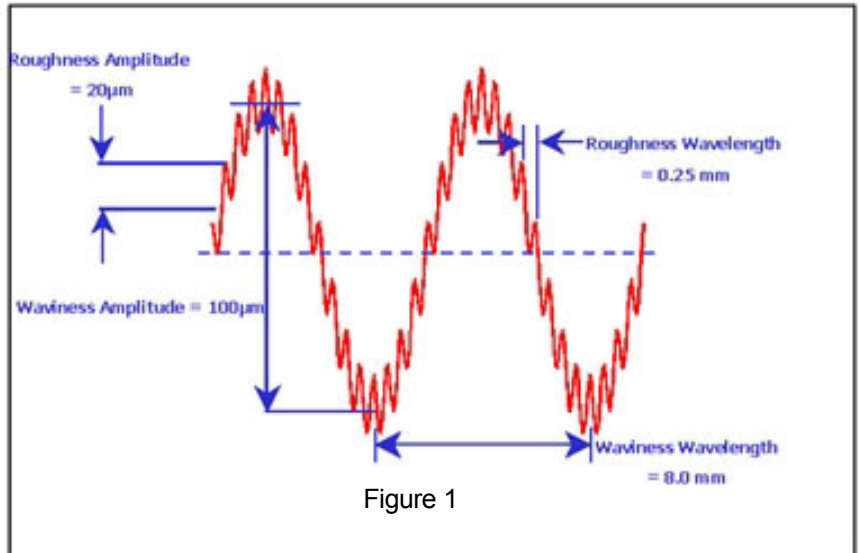


Figure 1

profile showing a roughness wavelength of 0.25mm with an  $R_a$  of about  $20\mu\text{m}$

Recommended Cut-off (ISO 4288-1996)				
Periodic Profiles	Non-Periodic Profiles		Cut-off	Sampling Length/ Evaluation Length
	$R_z$ ( $\mu\text{m}$ )	$R_a$ ( $\mu\text{m}$ )		
Spacing Distance $R_{Sm}$ (mm)				
>0.013-0.04	$T_0 0.1$	$T_0 0.02$	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

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## Selection of $\lambda_s/\lambda_c$ /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 (known as the  $\lambda_s$  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  $\lambda_s$  available will be dependent on the data spacing available in the raw profile: for an instrument with 0.25 $\mu$ m data spacing, the smallest  $\lambda_s$  that can be represented is 1.25 $\mu$ m. The  $\lambda_s$  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  $\lambda_c$ ,  $\lambda_s$  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”.



From Talysurf Series

