3 Steps to Understanding Surface Texture

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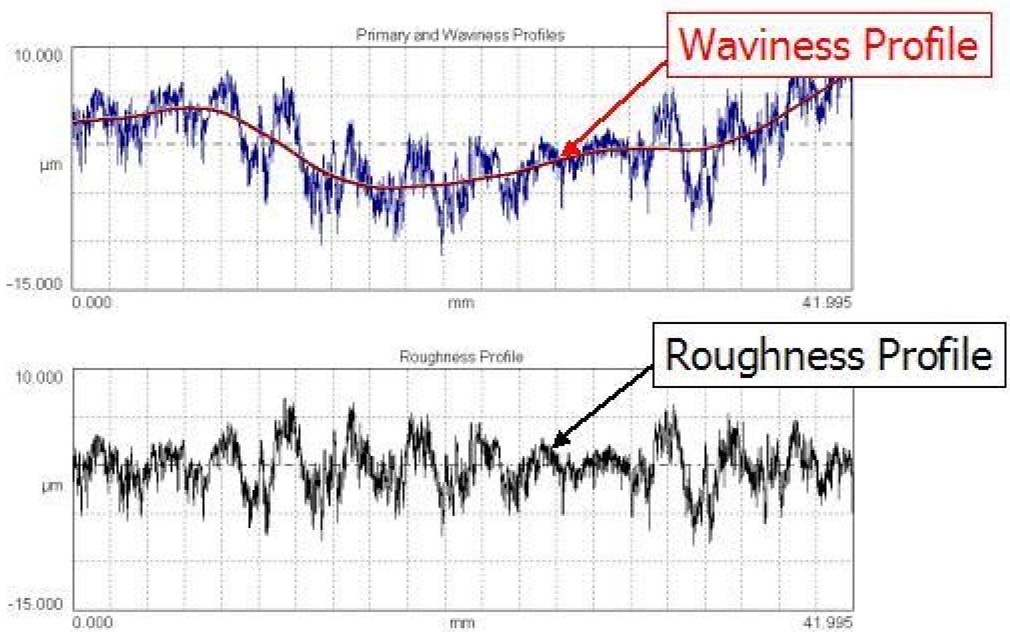
A common question in surface measurement is "I have a surface finish specification. Where do I begin?" or "I'm new to the field of surface measurement. What do I need to know?" With that in mind, this tutorial is provided to help you "hit the high points" of surface measurement (no pun intended).

Measuring Surfaces

Surfaces are comprised of many "shapes". We call the long wavelength shapes: "waviness" and the short wavelength features: "roughness". The measurement of surfaces involves producing numbers to describe these shapes.



By the way, the blue profile in the top graph is referred to as the "primary" profile.

In general, the term "surface texture" refers to the primary profile, roughness, waviness and other surface attributes such as the direction of the surface features (also referred to as the "lay" of the surface). The term "surface finish" typically refers to the "roughness" aspects of the surface – ignoring the shape and underlying waviness. Be careful when dealing with only the "surface finish" as many functional problems are related to waviness as well.

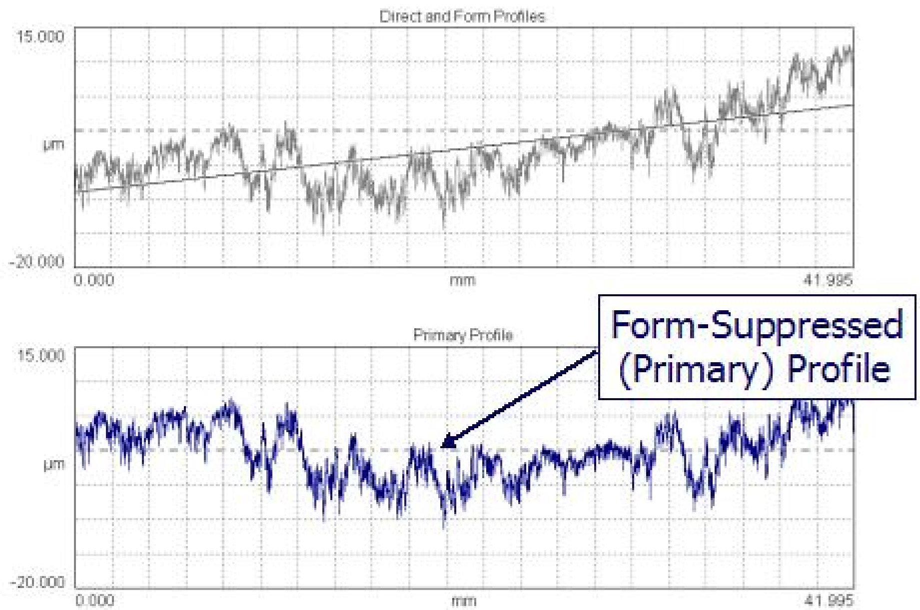
The picture is pretty, but how do we do it?

Surface measurement can be understood through the use of 3 fundamental topics:

- Fitting
- Filtering
- Analysis

1. Fitting

The first step in dealing with surface finish or surface “texture” is removing the underlying “shape”. In many cases the surface to be measured is tilted relative to the measuring device. In other cases, the surface may be nominally curved. In either case, the underlying geometry must be removed. This involves the “fitting” of a geometric reference such as a line or an arc and then looking at the wiggles (residuals) above and below the reference geometry.



The raw data from the probe is shown in the top (gray) profile. Superimposed on the raw data is a least squares line. In this case the least squares line is used to remove the tilt from the profile. The residuals (above and below the line) make up the blue (primary) profile.

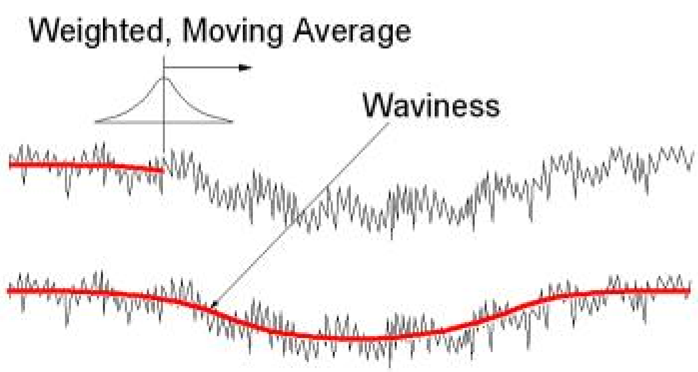
Note: a small filter is sometimes used to remove noise from the primary profile. This filter is called the “short wavelength filter” but that’s another topic for another day.

2. Filtering

Once the geometry has been removed we need to separate the waviness and the roughness. This is the most critical aspect of surface measurement and yet it is probably the least understood.

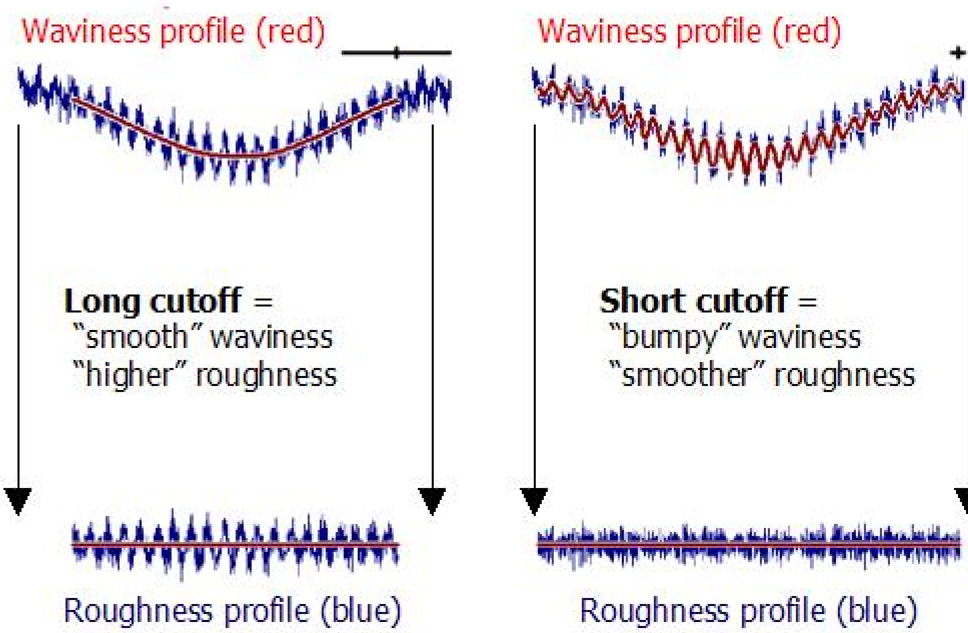
Filtering surface profiles involves running a "smoothing" filter through the primary data. The amount of smoothing is based on a "filter cutoff wavelength". The "cutoff wavelength" is the wavelength that separates roughness from waviness. Shorter wavelengths fall into the roughness profile and longer wavelengths appear in the waviness profile.

A "Gaussian" filter is recommended in ASME and ISO standards. Gaussian filters are based on passing a Gaussian, weighted average through the primary profile – resulting in the waviness profile. The roughness profile is made up of all of the peaks and valleys (residuals) above and below the waviness profile.



Changing the filter cutoff value (which changes the amount of "averaging" and "smoothing") can have a huge impact on the measurement of roughness and waviness. Choosing a smaller cutoff value will result in smaller roughness values… even though the real surface could be very rough. The filter cutoff provides the means for defining "what I am calling roughness".

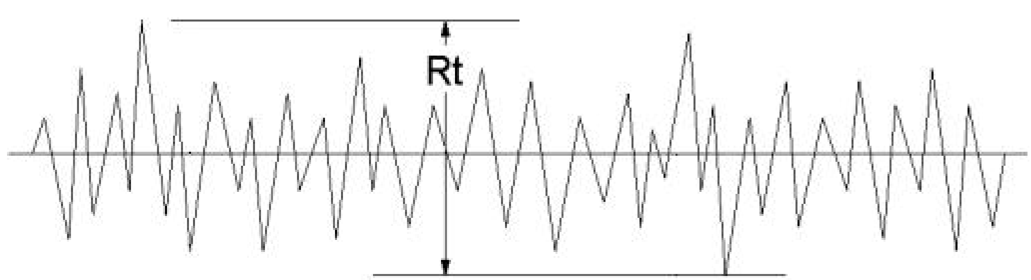
The following graphic presents the same surface with two different filter cutoffs. The roughness profile on the bottom left gives twice the "average roughness" (Ra) value of the profile on the bottom right.



There is a table of "standard" cutoff values (along with selection recommendations) in ASME B46.1-2002 as well as ISO 4288-1996. This information is also provided in OmniSurf's help system.

3. Analysis

Once we've separated things into roughness and waviness profiles we need to come up with numbers to describe them. After all, pictures are great, but engineers love numbers. The simplest of parameters is the "total" height of a given profile. This is the "peak-to-valley" height of the profile. For the primary profile the total, peak-to-valley height is designated: "Pt". For the waviness profile it is "Wt" and for the roughness profile it is "Rt". (The first letter always designates the profile.)



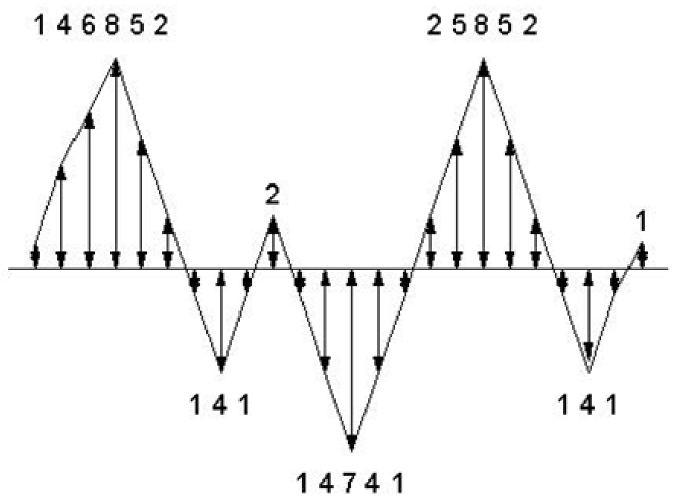
Unfortunately, the old adage "you get what you pay for" holds true here. The parameters, Pt and Rt are often quite unstable since they can be influenced by dirt, vibration and other things that are "outside the normal statistics" of the surface. On the other hand, the peak-to-valley waviness, Wt, is considerably more stable as it is based on only the long wavelengths and effects such as dirt are “smoothed out”.

Regarding roughness parameters, hundreds of parameters have been proposed. We won’t go into all of them here because, after all, we have gone well past our 60 seconds.

The most common roughness parameter is the average roughness, Ra. Many years ago this parameter was referred to as the “arithmetic average” (AA) or the “centerline average” (CLA). Today we designate it “Ra” to be consistent with all of the rest of the parameters.

The average roughness (Ra) reports the “average distance between the surface and the meanline” looking at all of the points along the profile.

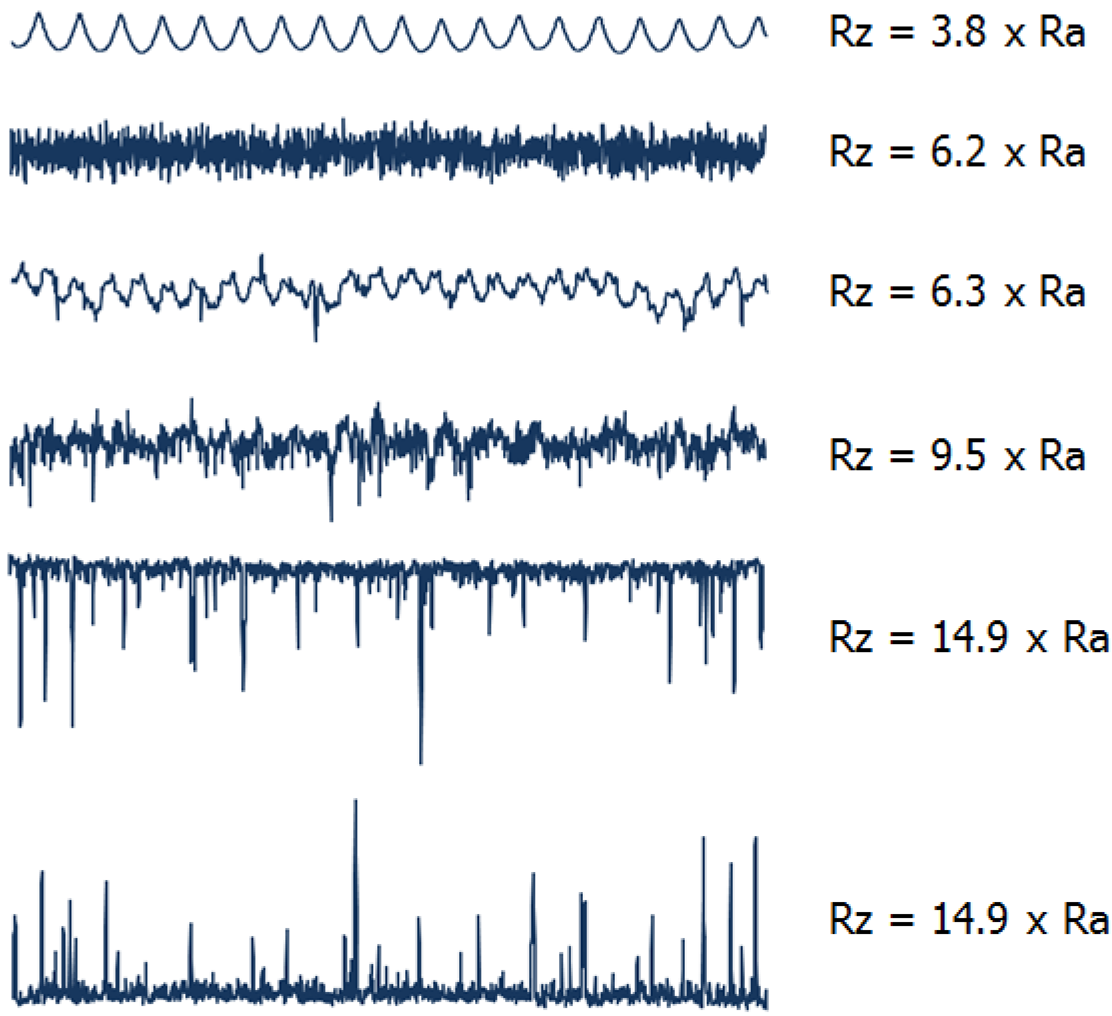
For example, if a surface has heights and depths as follows, it will give an Ra value of 3.33 (in units of height such as microinches or micrometers):



Ra = Average(1, 4, 6, 8, 5, 2, 1, 4, 1, 2, 1, 4, 7, 4, 1, 2, 5, 8, 5, 2, 1, 4, 1, 1)

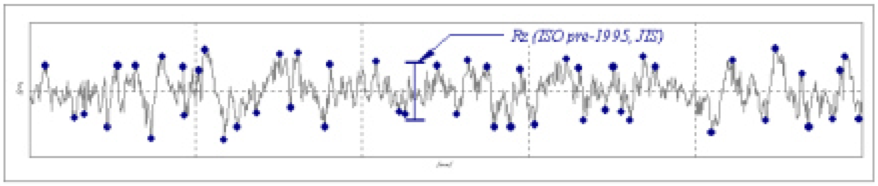
Ra = 3.33

Since the average roughness (Ra) is simply the “average distance” from the meanline, peaks and valleys are treated the same way. So several profiles can all have the same Ra value:

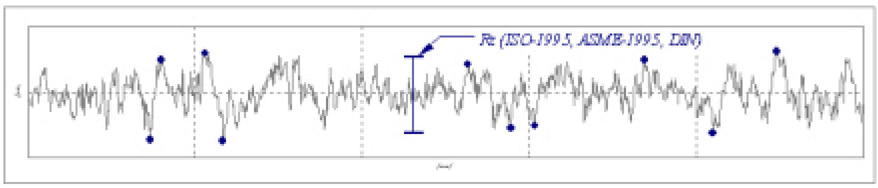


Second to Ra, in terms of popularity is the “average peak-to-valley roughness” or “ten-point roughness”, designated Rz. Rz has different definitions based on the standard that you are working with. However there are two basic definitions: one used in German (DIN) standards (which is in today’s ASME and ISO standards) and one used in Japanese (JIS) standards which was used in older ASME and ISO standards. There is no time left to discuss these in great detail, but it can be said that the DIN approach uses one peak and one valley in each sampling length, whereby the JIS approach uses 5 peaks and 5 valleys in each sampling length. As a result the DIN values are always equal to or higher than the JIS values. Be sure that you know which one you are using!

Rz (JIS, ASME pre-1995, ISO pre-1995)



Rz (DIN, ASME 1995+, ISO 1995+)



There is a lot more to talk about. That's why Digital Metrology offers on-site training for surface texture specification, measurement and analysis.

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