

Technology

## Start To Finish: The Basics of Surface Measurement

Brought To You by Mahr | Feb 13, 2019

When an engineer includes a surface finish spec on a print, the intent is usually not just to make the part look good. Surface finish affects how a part will fit, wear, reflect light, transmit heat, distribute lubrication and accept coatings. The finish should be determined by the part's function: you want a surface that fulfills the engineering requirements of the application, without wasting time and effort on a higher quality finish than is necessary. (In fact, many applications do better with a certain amount of "texture," and too fine a finish can be as bad as too coarse.)

Thirty years ago, when most dimensional tolerances were measured in thousandths of an inch, the difference of a few millionths in surface finish was often irrelevant. Now that tolerances of "tenths" or even tens of millionths are commonplace, variations in surface finish represent a sizable percentage of the total error budget.

Note the following example:

The maximum peak-to-valley height on a surface is usually four or five times greater than the average surface finish, as measured by the Ra method. A part with an Ra value of  $16 \mu\text{in}$ , therefore, probably has a peak-to-valley height of  $64 \mu\text{in}$  or greater. If you're trying to meet a dimensional spec of  $.0001\text{in}$ , the  $16 \mu\text{in}$  finish represents over half the allowable tolerance.

Surface finish – also known as profile – is composed of two components: waviness and roughness. Waviness, or longer-wavelength variation, is caused by macro-type influences, like worn spindle bearings, or vibration from other equipment on the shop floor. Roughness – the short-wavelength pattern of tool marks from grinding, milling or other machining processes – is influenced by the condition and quality of the tooling. Both can be influenced by the operator's choice of feed rate and depth of cut.

Although fingernail scratch-pads may provide a usable guide to finish, they can't meet the modern requirements of documentation and traceability. Hence, the increasing importance of surface finish gages. There are two basic varieties: skid-type, or averaging systems; and skidless, or profiling systems. Skid gages have a hinged probe assembly, with the probe riding next to a relatively broad skid that also contacts the workpiece. The skid tends to filter out waviness, so the probe measures only short-wavelength variations. A skidded gage has a dial or LCD readout to display the measurement as a single numerical value.

Skidless gages incorporate a smooth, flat internal surface as a reference, so the probe can respond to waviness as well as roughness. In order to allow separate analysis of long- and short-wavelength variations, profiling gages usually generate a chart (on paper or on a computer screen) rather than a single numerical result.

Every application reacts differently to different combinations of roughness and waviness, and the industry has responded by creating more than 100 different formulae with which to calculate surface finish parameters from the same measurement data. Many of these are very application-specific, and most shops are able to confine their measurements to a half-dozen or so parameters. In almost all cases, measurements are presented in microinch or micron units. Ra is the most widely used parameter, because it provides an arithmetic average of surface irregularities measured from a mean line that lies somewhere between the highest and lowest points on a given cutoff length. A slightly more sophisticated variant, Rq, uses a root mean square calculation to find geometric average

roughness – an averaged average, if you will.

Both of these, however, tend to minimize the influence of surface anomalies like burrs or scratches. If such factors are critical to the application,  $R_{max}$ ,  $R_y$ ,  $R_t$ , and  $R_{tm}$  all calculate roughness as a function of maximum peak-to-valley height. Also useful is  $R_z$  – the “ten-point height” parameter – which calculates the average of ten maximum peak-to-valley differences within the sampling range.

If surface finish is called out on a drawing but not otherwise specified, it is standard practice to assume  $R_a$ . But no single parameter is best for all types of parts, and many applications are best served by using two or more parameters: for example,  $R_a$  (average roughness) in combination with  $R_{max}$  (maximum roughness) may provide a good general idea of the part’s performance, and alert QA to the presence of potentially damaging surface anomalies.

Surface finish is not simply a challenge to meet: it represents an opportunity as well. In some cases, if you can maintain good control over surface finish, you may be able to safely reduce precision in other areas.

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