



Productivity Quality

Where do we go wrong in surface finish gaging?

by Alex Tabenkin,
Marketing Manager--Instrumentation
Federal Products Co.
Providence, RI

Twelve common mistakes to know and avoid

Surface finish determines more than just how parts look and feel. It also influences how they wear, conduct heat, distribute lubrication, accept and hold coatings, resist corrosion--even how they sound. In spite of the capabilities of the new gages, surface finish remains a complex field that is subject to misunderstanding. It is important that gage users and specifying engineers understand what can go wrong to make sure that it doesn't. Here are a dozen common errors to avoid.

1. Not understanding parameters Parameters--the quantitative methods used to describe and compare surface characteristics--are defined by the algorithms used to calculate a numerical value from the raw measurement data. A surface finish requirement without a defined parameter is not specified. For example, a requirement that states "roughness = 50 μ " is not acceptable today, because there are dozens of parameters used to measure roughness. On the other hand, "Ra = 50 μ " or a symbol are acceptable, because the Ra roughness parameter is specified.



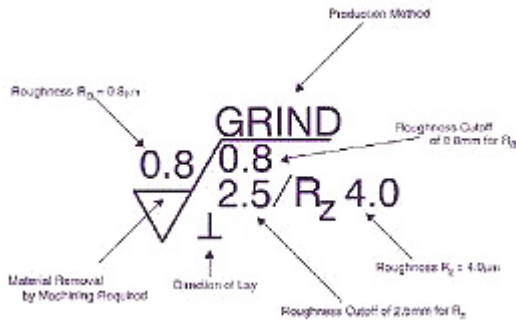
Some skidless surface finish gages are capable of measuring more than 100 parameters, generating both charts and numerical results, and performing special analytical tasks.

The main body of the new ASME B46.1-1995 standard describes more than a dozen parameters, and includes many more in appendices, while new ISO standards describe even more. Even more problematic is the fact that past discrepancies between standards have made some parameters ambiguous. Three different "Rz" parameters may be found on part prints: an old international version (ISO); an old Japanese version (JIS); and a German (DIN) version that is now accepted by ISO and JIS. Since ISO and JIS dropped their old Rz definitions and adopted the DIN version, there is now only one current version. But there is still opportunity for confusion, if the specification is taken off an older part print, if the specifying engineer relies upon an old standard, or if the inspector uses an old gage. Confusion between two roughness parameters, Ra and Rq (formerly called AA and RMS, respectively), is another source of error. When measuring a pure sine-wave profile, Rq results are 11 percent higher than Ra results. For this reason, some gage manufacturers used to incorporate a switch on their instruments, which simply applied a multiplication factor to convert AA to RMS (using the old terminology). Some end-users who now own gages that measure only Ra have learned to apply that multiplication factor manually if Rq is required. But whether this conversion is done automatically or manually, it will generate inaccurate results when measuring any profile other than a pure sine wave because there is no simple mathematical relationship between the two parameters. Real-world results on manufactured parts can vary by more than 50 percent between the two parameters.

2. Selecting the wrong gage There are two basic categories of surface finish gages: "skidded" and "skidless" types. In skidded gages, the stylus moves up and down relative to a pad attached to the bottom of the probe that traverses along the surface of the part. Because the skid follows the general profile of the part, the stylus registers only higher-frequency roughness characteristics--in other words, tool marks. Thus, skidded gages are for roughness parameters only. In a skidless gage, the probe moves relative to a reference surface inside the drive mechanism, so that the stylus is free to follow the full profile of the part, including low-frequency geometry characteristics, such as out-of-straightness and waviness, as well as tool marks. Skidded gages may use either a velocity-sensitive or a position-sensitive transducer, while skidless gages use only position-sensitive devices. Mistakes can be made in purchasing, where a gage with inadequate capabilities might be selected in an unwise attempt at economy. ASME B46.1 includes a useful chart that classifies surface finish gages according to their measurement capabilities. A gray area exists in the measurement of profile straightness, which can be measured by skidless profiling surface finish gages, and by geometry gages with precision slides (i.e., "cylindricity" gages). The larger tip radius of a geometry gage mechanically "filters" out most roughness and some waviness features, while a profiling surface finish gage, with its smaller tip radius, responds to all features (roughness, waviness, and straightness), and can filter out roughness

electronically. A straightness callout that does not specify the use of a particular electronic filter could be measured with either type of gage, but results would be different, depending on whether waviness is included.

3. Reliance on default cutoff value The cutoff is the sampling length within which roughness data is collected. The cutoff length must be long enough to provide sufficient data for the measurement, but not so long that part geometry could impose extraneous data. A properly-specified cutoff usually includes 10 to 15 tool marks. For most machined surfaces, this means cutoffs of .010", .030", or .100" (0.25 mm, 0.8 mm, 2.5 mm). Don't confuse cutoff with stroke or traverse length, which is the total distance the probe travels, and may be 2", 12" or even 18" long (50 mm, 300 mm, 450 mm), in order to evaluate waviness and straightness. Detailed information about the choice of cutoffs is found in Chapters 3 and 4 of ASME B46.1.



A typical surface finish callout consists of many elements, all of which may be required because of the complexity of surface finish metrology. Under the old ANSI B46.1-1985 standard, a default value of .030" (0.8 mm) applied to any surface finish callout that did not specify a cutoff. This is an effective cutoff value for many, but not all, roughness measurements. To avoid confusion and lax specifying, the new ASME B46.1-1995 standard abolishes the default and insists that all cutoffs be specified. It is standard procedure to measure five cutoffs within a single stroke and average the results, although fewer may be used if the surface is too short to include five. Where a manufacturing process is known to be consistent, less than five cutoffs may be sufficient to generate reliable results. When reporting results, the number of cutoffs should be indicated if it is not five. To report the use of four cutoffs, the form shown in the following example would be followed: Ra4 = 25µ".

4. Choosing the wrong signal-processing filter The signal generated by the gage head must be filtered electronically before the data can be converted to a numerical result. The new 50 percent Gaussian filter, which is the default according to ISO, is a better, more accurate filter in metrological terms than the older 2RC filter. Many part prints, however, still specify (or assume) the use of a 2RC filter, because it is more familiar, and because it is available on most gages, including those with old analog technology. Because the two filters will generate different results, design engineers should be sure to specify which filter is intended, and the inspector should follow the specification, or seek clarification if it is absent. For evaluation of some specific surfaces, such as plateau-honed cylinder liners and porous materials, another filter, known as the "Valley Suppression" filter, is used.

5. Using the wrong size stylus Gage styluses are available in three standard tip radii: 80 µ", .0002", and .0004" (2 µm, 5 µm, and 10 µm). A stylus that is too large will be unable to penetrate to the bottom of some very fine surface irregularities, so gage accuracy may suffer, or at least, uncertainty will increase. (Figure 5) On the other hand, a stylus that is too small will exert excessive pressure that may result in scratching delicate surfaces.



Modern skidded roughness gages can be compact, economical, and well-suited to shop-floor inspection tasks. In addition to the possibility that the part might be ruined by scratching it, the measurement could be inaccurate, because the scratch represents a modification of the surface. Plastics, rubber, graphite, copper, aluminum, and many alloys are also subject to deformation at fairly low levels of force, which could also influence profile measurement results. These materials therefore require the use of a probe with the lowest force possible.

6. Using a damaged stylus As with a stylus that is too large, a stylus that is worn or chipped will not penetrate as deeply into

fine surface irregularities as one that is in good condition. (Figure 1) The first indication of a worn or broken stylus may be a change in gage readings, or may be found during the calibration process (see Common Error #11). If a problem is suspected, the stylus may be examined with a special test patch or a low-power microscope.

7. Ignoring the lay (measuring in the wrong direction) Most machining processes create tool marks that run in a particular direction across the part surface. When measuring roughness parameters, it is essential that the gage traverse at right angles to the "lay," or pattern of toolmarks, to capture worst-case conditions.

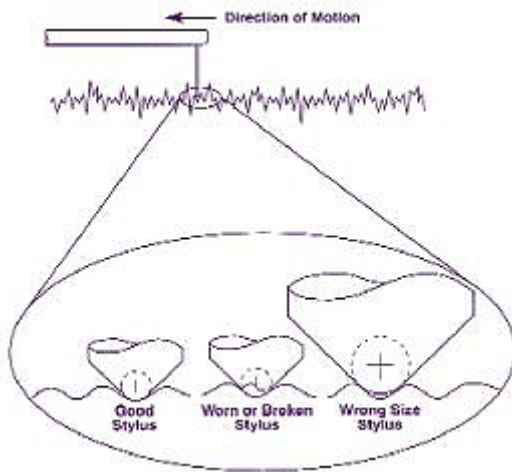


Fig. 1 -Styluses that are worn or broken, or too large for the surface, may generate inaccurate results because they can't reach the bottom of the surface valleys. Some processes, however, such as electrical-discharge machining (EDM) and plastics molding, do not create unidirectional tool marks. When this is the case, it is advisable to take two measurements at 90 deg. to each other, to check whether there is a distinct lay to the surface. If there is, then the rougher of the two measurements must be used.

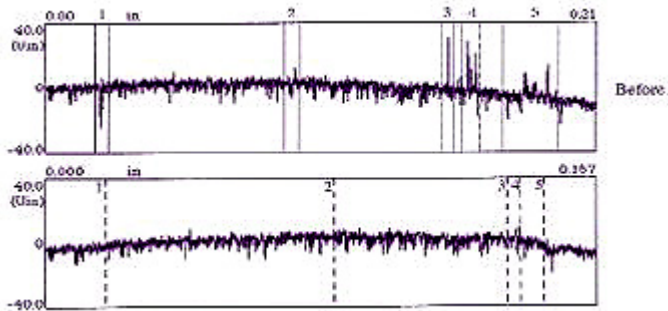
8. Including flaws in the measurement Parts may include flaws that are unrelated to the manufacturing process. Parts may also include other features that interrupt the surface, such as a pore in a porous metal. Though surface finish gaging is intended to monitor and ensure the stability of the manufacturing process, it is essential that these irregularities be excluded from the measurement. This can be easily done post-measurement with some computer-driven gages, where software enables the user to visually identify irregularities on the trace, and exclude them from the calculation. For gages that report roughness only as a numerical result and do not generate a trace, care must be taken to avoid irregularities in the first place. On the other hand, there are some cases where it is desirable to include these irregularities in the measurement: for example, to check if a part meets specifications in spite of a scratch. So irregularities should not be automatically excluded. Each instance must be considered separately.

9. Inattention to leveling This problem applies to skidless gages, where the gage must be level relative to the workpiece. To measure fine surface characteristics at high magnification, the gage must be mechanically pre-leveled, before final electronic leveling can be performed by the computer. To pre-level the gage, a test trace is performed, then software indicates how many turns are required on the leveling knob on the drive mechanism. Once the gage's attitude is within an acceptable range, the computer performs the final leveling, compensating for any remaining out-of-level condition after the measurement is performed.

10. Ignoring vibration in the gaging environment Many surface finish gages are used on production floors, where vibration from manufacturing equipment may interfere with the measurement signal. Some skidless gages have a built-in "static mode" function to assess this condition. With the traverse motor turned off and the stylus in contact with a surface, any signal generated is the result of ambient vibration. Vibration effects can be reduced or eliminated by relocating the gage near a bearing wall, by isolating the gage with vibration-absorbing rubber pads or a high-density table, or by removing it from the area altogether. It may also be possible to identify and eliminate the source of vibration.

11. Misunderstanding calibration Surface finish gages are verified against test patches or specimens whose surface characteristics are known and certified. If gage results do not agree with the characteristics of the specimen, the gage must be adjusted. The nature of the adjustment differs considerably between simple, non-computer-driven gages, and sophisticated computerized ones. Simple gages are generally checked against a roughness patch with either a triangular or sine-wave profile.

If the gage reads other than the patch's calibrated value (usually around Ra 125 μ "), a potentiometer is adjusted to bring results into agreement with the specimen. In this case, it is the "back end" or calculating portion of the gage that is being adjusted. The "front end"--the raw input data--is untouched. The reverse applies to computer-driven gages, where the back-end consists of the software algorithms that turn raw data into numerical results. As the algorithms cannot be modified, the way the gage perceives the raw data at the front end must be adjusted. Skidless gages are usually calibrated against a step-height specimen, then a multiplication factor is entered into the computer to adjust signal gain from the transducer before it reaches the algorithm software. From that point on, all data entering the computer is corrected by the same multiplication factor.



The unmodified chart (top) shows five segments that include anomalies such as scratches, burrs, or bits of dirt. The gage user has applied "segment analysis" to delete these segments, in order to measure the surface generated by the machining process, without interference from the anomalies. Note that the bottom chart has "closed up" around each of the five deleted segments, so that the total length being measured has dropped from 0.21'' to 0.167''. Measurement results follow: