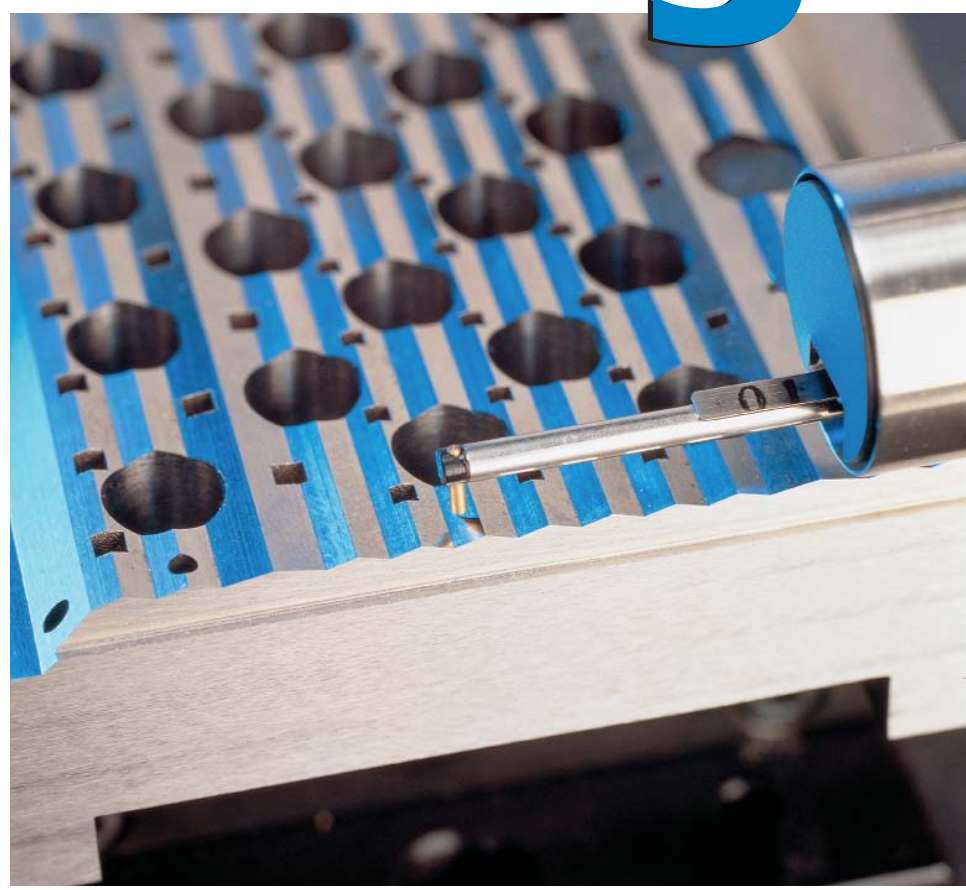
➤BY SUSAN WOODS, FEATURES EDITOR

ROUGH Going

Low-cost, portable, surface-roughness measurement gages help users perform quick inspections on the shop floor.



Carl Zeiss

Even though grinding yields a better surface finish than milling and milling produces a better surface finish than sawing, all machining processes leave some surface irregularities on a part. Factors such as the cutting tool, machine tool condition, machining parameters, vibration and environmental factors influence these irregularities.

High-precision parts usually require a high-quality finish. "Measuring surface finish is critical, especially for the aerospace industry," said Ed Arruda, service manager at Fred V. Fowler Co. Inc., Newton, Mass. "Anybody making airplane parts has to measure the finish of the parts to make sure they are smooth enough to travel through the air at high speeds."

He added that for mating parts, such as those found in pumps, the surfaces have to match exactly. "You want to take a surface measurement from both parts to make sure they have the same roughness finish."

To verify the surface finish is within spec, it must be measured. For surfaces specified only by a roughness parameter, portable, battery-powered skidded gages—typically measuring about 5"×3"×1" and weighing about 14 oz.—are available for $2,000 or less. These devices, which can measure in microinches or micrometers, have a metal or ruby skid—a rest attached to a probe—that rides across the surface of the part and a diamond-tipped stylus that moves up and down relative to that skid.

For more sophisticated surface-finish measurements, skidless gages, which start around $6,000, are available. In skidless gages, 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.

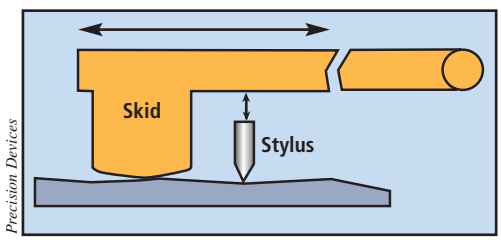
"With the skidless gages, you just have the diamond stylus touching the surface," said Gene Ripa, applications engineer at Mahr Federal Inc., Providence, R.I. "A drive unit moves the diamond across the surface and it makes its measurement with respect to a precision slide that is built into the drive unit. The

purpose of the skidless gage is to 'see' everything of the surface, including the profile, waviness and roughness."

At the highest end are instruments that use optics and other noncontact methods to measure surface finish.

A Skid in the Road

With a skidded gage, the stylus reads the peaks and valleys and determines the roughness of the surface. The skidded gage is only intended to measure the roughness of the surface because the purpose of the skid is to make sure the waviness does not affect the roughness reading.



Precision Devices

In this simple view, the stylus rides on the surface and measures peaks and valleys relative to a skid, which also rides on the surface.

"The skid is like a mechanical shoe that rides on the surface," said Ripa. "The diamond stylus makes its measurement with respect to the skid, rather than making its measurement with respect to the precision slide. So, the only reference is this 'shoe,' or skid. The skid rides on the actual surface being measured. It will rise up and down on the waves but it won't 'see' the waves. Its purpose is to remove the waves from the measurement so that only roughness is measured."

Most skidded gages measure three surface-roughness parameters: average roughness (R_a); maximum roughness depth (R_{max} or R_y); and mean roughness depth (R_z).

R_a is an average of all the peaks and valleys that are symmetrical about the mean line.

R_{max} measures the vertical distance from the highest peak to the lowest valley within five sample lengths and selects the largest.

R_z is based on the evaluation of five sample lengths, but instead of selecting the largest peak-to-valley distance of the five, it averages the five values.

Mahr Federal

Pocket Surf portable surface-roughness gage.

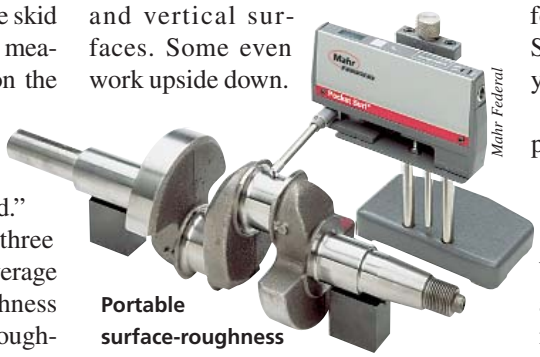
R_y is identical to R_{max}, but is used when measuring less than five sample lengths.

At a minimum, the operator must set the desired parameter to be measured and the desired cutoff. Typically, the parameter is evaluated at five times the cutoff length.

"For instance, a cutoff of 0.030" would be evaluated over 0.150" with a total measured length of 0.180"," said Robert Wasilesky, business manager for SF&G team, Carl Zeiss Inc., Thornwood, N.Y.

Other Features

For measuring holes or curved surfaces, most gage manufacturers offer optional probes that attach to their gages. The gages also take measurements from a variety of positions and several angles and measure horizontal and vertical surfaces. Some even work upside down.



Mahr Federal

Portable surface-roughness gages can be used on automotive parts.

Most of these gages have digital displays and many also have recorders for printing the results. They also have RS-232 outputs for statistical process control applications and can be plugged into a PC for statistical analysis.

Most gages also come with a surface-roughness master. Upon receiving their instrument, and throughout the day or week, operators can check the master and make sure the gage is reading correctly. And if they need to calibrate the gage, they can.

"We actually have people buying these systems to monitor the performance of their central machining processes themselves."

The Bad and the Good

Skidded devices are limited somewhat because they only measure surface roughness—not profiling features or waviness.

Carl Zeiss

Surfcom 130A portable surface-roughness gage.

"There is no doubt that in a lot of applications if you are just measuring surface roughness you are not measuring enough," said Wasilesky. "For example, on flat surfaces where the intention is to seal, like the head deck on an engine block, if there is too much waviness, you might not have seal conformability and the system could leak. So if you are just measuring roughness, you might not be able to find that."

Another example would be "orange peel" on an automobile. "You can measure surface roughness on an automobile's body panel and come up with roughness that is acceptable," said Wasilesky. "But you still might have an orange peel effect because that is more visible as a waviness component than a roughness component."

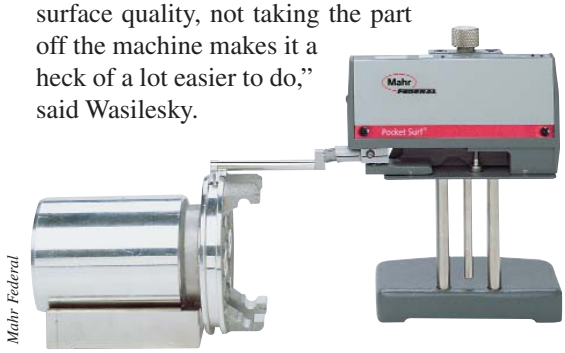
Another drawback is that the skid can put enough pressure on a surface to burnish it.

Also, the range and resolution of skidded gages are not as accurate as more sophisticated devices. Typical skidded gages cannot resolve accurately in fractions of a microinch, nor should they be used when measuring

surface roughness below 10µin.

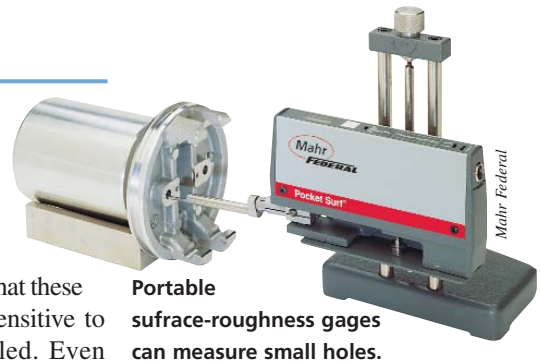
The biggest drawback, according to Scott Robinson, technical support at L.S. Starrett Co., Athol, Mass., is that these skidded devices "are very sensitive to being dropped or mishandled. Even though industry tries to make them as rugged as they can, they can't prevent them from being dropped."

One of the biggest benefits to using a skidded device is a part can be measured on or off the machine. "That is a real benefit because if you are actually machining and you want a particular surface quality, not taking the part off the machine makes it a heck of a lot easier to do," said Wasilesky.



Mahr Federal

Portable surface-roughness gages can measure grooves.



Mahr Federal

Portable sufrace-roughness gages can measure small holes.

Even when more complex surface measurements are needed, skidded devices still have a place on the shop floor. A shop may have one skidless gage for manufacturing engineering and quality-assurance purposes, and make several skidded gages available to machinists. Once the machining process is established and confirmed on the skidless gage, machinists use the skidded gages strictly as a means of ensuring process stability.

"We actually have people buying these systems to monitor the performance of their central machining processes themselves," said Wasilesky. "If you collect enough data, you can see parameters and characteristics that match to different processes for a multiple-operation part. If you are turning and the surface finish worsens, there comes a point where you know exactly when to change the tool if you are monitoring the process 100 percent. And on a grinding wheel, you know exactly when to redress. While most people use them to check part quality, I think their best use is for process control.

"However, when you start changing your measuring process from one or two parts in a batch to measuring a greater number of parts in a batch, it becomes more labor-intensive. So to use it for process control means you need to increase the frequency of measurement and people associate that with more labor. But the reality is you can make your process that much more efficient while increasing overall quality," said Wasilesky.

Look Out

There are certain desirable features in the skidded devices. One is a display that is visible in all lighting conditions.

Another useful feature is the ability to display the stylus' position. In order to troubleshoot the stylus, the operator needs to know its position. So some type of analog or digital real-time feedback for stylus positioning helps.

Still another important feature is a measuring force that is low enough—below 400 mg—that it doesn't scratch the surface.

Also, if the operator wants to measure according to a standard, such as ISO or ASME-B46, it is important to have a device that is traceable back to that standard.

Finally, the operator should be aware of stylus-replacement costs. Depending on use, the stylus will eventually wear out. "If the system is in your price range but the stylus cost is greater than 25 percent of the system cost, buyer beware," said Wasilesky. "You don't want to buy a $2,500 system with a $1,200 stylus." Most replacement stylus costs between $200 and $400. △

Surface roughness glossary

Cutoff—The sample length on the surface of a part that is measured.
Evaluation length—The entire length of a profile over which data has been collected.
Sample length—One evaluation length consists of several, usually five, sample lengths.
Skid—A rest attached to the probe.
Stylus—A cone-shaped spherical point made of diamond.
Waviness—Repeating surface irregularities with spacing greater than the roughness.

The following companies contributed to this report:

Carl Zeiss Inc.
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Fred V. Fowler Co. Inc.
(800) 788-2353
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Mahr Federal Inc.
(401) 784-3100
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L.S. Starrett Co.
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