USING ADJUSTABLE SNAP GAGES

Let's continue last month's discussion about adjustable, indicating snap gages. The principles of care and usage for these simple O.D. measuring tools are straightforward. Because the body of the gage—the C-frame—is a rigid piece of metal, most of the "care and feeding" tips are concerned with the gage's anvils. That's where most of the precision lies.

Make sure the gage is suited to the application. The anvils should be narrower than the part being measured to avoid uneven wear on the measuring surfaces. If you repeatedly gage narrow parts on a broad anvil, you can wear grooves that may not be picked up by mastering. You can get away with a small number of too-narrow parts, but if you're doing a production run, buy different anvils or modify the existing ones.

Anvils can be straddle-milled or side-relieved to fit into grooves or recesses, or to ensure they're narrower than the workpiece. The edges can also be chamfered. This is important when measuring a diameter immediately adjacent to a perpendicular feature—for example, a crank throw on a shaft. There's usually a fillet where two surfaces come together, and if you put crisp, sharp-edged anvils right up against the perpendicular, you'll measure the fillet instead of the critical dimension. Another way to phrase it is: Don't check diameters next to perpendicular surfaces—unless you've got the right anvils.

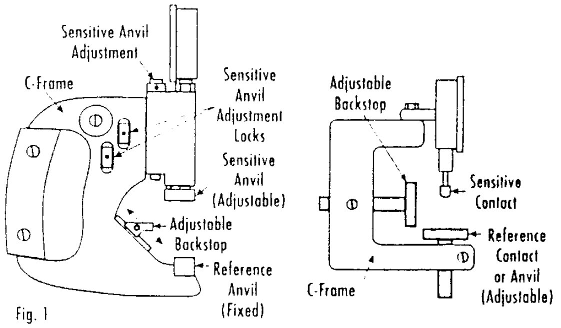


Fig. 1

Regularly check the anvils for wear. Look for scratches, gouges, unevenness, pitting, rust, etc. If problems are detected, the anvils can be removed and their surfaces ground and lapped. Check periodically that the anvils are parallel. This is essential if you've removed the anvils for maintenance or replacement. To check for parallelism, place a precision wire or a steel ball in sequence at the front, back, left and right edges of the anvils. Compare the indicator reading for each of the edges.

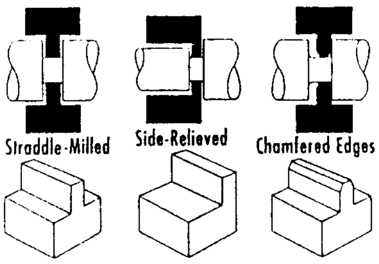
If you detect an out-of-parallel condition and you haven't just replaced the anvils, you've probably dropped the gage. While it's recommended to have the manufacturer tweak it back into shape, many shops can handle this in-house. Remove the fixed, lower anvil, and carefully file the seat in the indicated direction. Go slowly—just a few gentle licks—then re-mount the anvil securely and test again for parallelism. Leave the seating of the upper, moving anvil alone.

Observe the basics of good gaging practice: check regularly for looseness of components, keep the gage clean, protect against rapid changes in temperature, and master regularly. For large production runs, it makes sense to purchase a master disc the size of your part. For small runs, use stacked gage blocks. Make sure you've wrung them properly and observed the other basics of block care and usage.

Adjustments on indicating snap gages are few and simple. Set the backstop so the diameter of the workpiece is roughly centered on the anvils: it's not a critical adjustment. To adjust the gage's capacity, turn the knurled nut that moves the upper anvil/indicator assembly up or down. Move the upper anvil until the indicator zeroes itself against the master. Then, before you tighten the locking nut(s), turn the adjusting nut very slightly in the opposite direction to release the torque on the lead screw. This may seem insignificant, but any amount of tension will relax itself over time. Then lock it down, master the gage, and check for repeatability several times before you start measuring.

Wide anvils normally ensure that the gage seats itself squarely on the part. But if you're using narrow blade-type anvils to check narrow grooves, you have to hold the gage as steady as you can, squaring it up by eye. Offset blade anvils also impose side-loading, which can further reduce repeatability. To accommodate these shortcomings, lower-resolution dial indicators are usually used with blade anvils: .005" resolution is typical, compared to .0001" on most snap gages.

Fig. 2



For large gages that weigh several pounds, the spring pressure on the upper anvil may be insufficient to achieve repeatability in a hand-held situation. There's a simple solution to this one: turn the gage upside down and allow the weight of the gage to rest on the fixed anvil instead. Then just rotate the bezel on the dial indicator, so it reads right-side up.

O.D. GAGING CAN BE A SNAP

Insert a workpiece into a snap gage and you'll understand how these extremely effective, fairly simple tools for checking precision O.D.s got their name. You have to push deliberately to get the part past the leading edges of the anvils. But once you've overcome the 4 1/2 lbs. of spring force, the part slips suddenly back against the backstop, contacting it with a good, healthy "snap."

Snap gages can be hand-held to measure workpiece O.D.s still on the machine, or can be mounted on stands for use with small parts. The heart of the tool is a simple C-frame casting, and measurements rely upon a direct, in-line, 1:1 transfer of motion. These factors make snap gages simple, reliable, and fairly inexpensive.

The earliest snap gages, of the fixed, or Go/No-Go variety, did the job well enough so that thousands are still in use. But fixed gages have some distinct liabilities. For one thing, you need a different gage for every dimension you wish to check.

But the biggest shortcoming of the Go/No-Go snap gage is that it tells you nothing about your process. You know if you're within tolerance, but you can't see if you're gradually getting larger or smaller, and so adjust the process accordingly—until you're out of tolerance.

Then some clever engineer (not I) replaced the upper anvil of a fixed snap gage with a dial indicator, and the whole scenery changed. *Indicating* snap gages are able to measure to the limits of resolution of the indicator, and as they are comparative gages (i.e., they read to zero), they give the machinist a window on his O.D. machining process.

But the high cost associated with a different gage for every dimension was not solved until the introduction of the *adjustable* indicating snap gage. With a typical range of adjustment of one inch, the adjustable snap can eliminate dozens of tools from the shop. Adjustable snaps are still comparative gages: the adjustable jaw is set to a master or a stack of gage blocks, and the indicator is "zeroed" before gaging begins.

With a standard dial indicator installed, the measuring range of an adjustable snap gage is typically .020", with a resolution of .0001". But there's no rule that says an adjustable indicating gage has to have a mechanical dial indicator. One can specify digital indicators, air probes, or electronic probes—they all use the same standard 3/8" diameter mounting. With an electronic probe and amplifier, you can achieve resolution of 10 microinches, for tolerance measurements tighter than .0005".

Usually no modifications are necessary to retrofit an indicating snap gage with the probe or indicator of your choice. It's a simple, in-house job, and it's very possible to take an entire shop's worth of old mechanical indicating gages and refit them with digital indicators or electronic probes. And these can be tied into SPC or other computer-based quality systems.

Adjustable indicating snap gages can be modified to accommodate special applications. Extra-large C-frames can be built to measure O.D.s up to 48". Anvils can be side-relieved, chamfered, or straddle-milled to provide access in difficult part profiles. Blade-type contacts can be used to measure diameters or grooves right up against perpendicular surfaces.

Usage is particularly simple and straightforward, but, as with any gage, there are a number of principles of operation and maintenance one must observe to obtain accurate measurements and long life. These will be the subject of next month's column.

INSPECTING MULTIPLE DIAMETERS

During the past few months, this column discussed circular geometry gages at some length, and pointed out the rapidly growing popularity of these extremely useful instruments. It is important to bear in mind, however, that most inspection gaging of round features is still performed with traditional indicator gages.

When measuring multiple diameters on shafts and similar parts with two or more cylindrical features, fixture gages incorporating multiple indicators offer convenience, speed, and economy. By building multiple gaging stations into a single fixture, it is possible to eliminate the expense of duplicate work-holding devices. The gage user need only fixture the part once, and can quickly scan across the indicators or readouts, thus saving time and effort over the use of multiple gages that each measure just one feature.

Gaging a single outside diameter is among the simplest of inspection tasks, but gaging multiple ODs simultaneously in a fixture gage can be deceptively tricky. Even when using a gage designed specifically for the part in question, it is possible to get diameters, roundness, and concentricity mixed up. Different gages or setups are required to properly measure each of these parameters.

In gaging fixtures, workpieces may be held in V-blocks or between centers, or may be stood on end. Some workpiece feature or features must rest securely against reference points on the fixture, to establish the proper position relationship between the gage's sensitive contact and the workpiece. In the case of V-blocks as references, end-journals on the workpiece are commonly used.

Problems arise when cylindrical features are assumed to be concentric with the end journals but are not in fact. Diameter A establishes the relationship between the part and the gage. Because Diameter B is not concentric with Diameter A, its position relative to the gage contact is unknown, and it changes as the part is rotated. Diameter B therefore cannot be measured for diameter or roundness. On the other hand, this setup can be used to assess the concentricity of Diameter B relative to Diameter A. Furthermore, because Diameter A is properly referenced, we could measure it for size and roundness simply by building a second indicator into the gage. (For simplicity, we've shown only two features on the part, but some gages may measure many more.)

Fig. 1

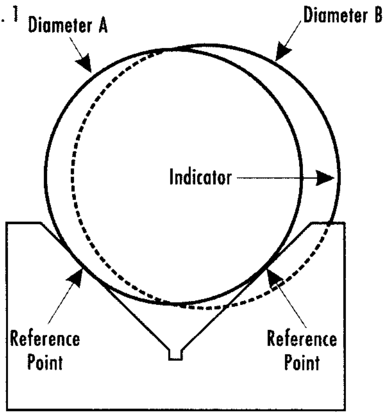
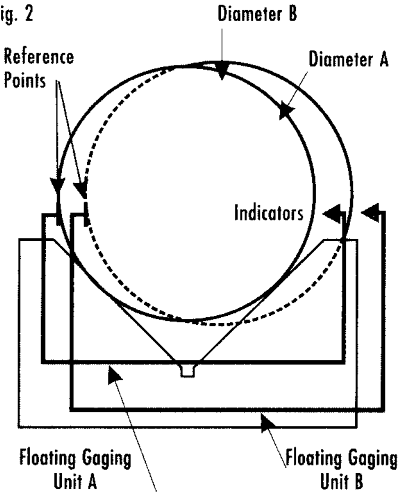


Fig. 2



If one wishes to measure Diameter B for size or roundness, the gaging unit must incorporate a pantograph-style gage or similar mechanism that is free to "float" around the non-concentric feature, while maintaining a fixed relationship between the reference and the indicator. (Air gaging with opposing jets on a single circuit may also be used, if out-of-concentricity will fall within a limited range. As the eccentric feature moves closer to one jet, it moves away from the opposite one, so that total pressure in the system remains constant and the gage reading remains unchanged.)

We stated above that measuring a part with a single diameter is among the simplest of tasks. There are conditions, however, where single-diameter work that is significantly out-of-round will appear perfectly round when using a micrometer, snap gage, or any other two-point method (such as that shown in Figure 2). This is especially so with centerless-ground parts, in which three or five lobes may appear evenly spaced around the part's diameter, so that high and low points are all diametrically opposed. In this situation, the diameter remains nearly constant, even though the radius may vary significantly.

A circular geometry gage is required to detect and understand this condition. Thereafter, it is possible to perform approximate out-of-roundness inspection on a production basis using indicator gaging. The part is staged on a V-block, and a simple indicator is positioned over the V-block's centerline using a height stand or similar comparator device. As the part is rotated in the V-block, the Total Indicator Reading (TIR) is noted, then multiplied by a constant. For three-lobed parts, use a V-block with a 60° included angle, and multiply TIR by 3.00; for five lobes, use a 108° angle, and multiply TIR by 2.24; for seven lobes, use a 128°34' angle and use a 2.11 multiplication factor. This method provides sufficient accuracy for roundness measurements within a few thoudanths. For greater accuracy, a true circular geometry gage may be required.

CALIPERS: IDEAL FOR MEASUREMENT ON THE GO

Although it has been around for a long time, the caliper is still an extremely versatile and useful tool for making a wide range of distance measurements (both ODs and IDs). While micrometers are more accurate, they have a limited measurement range (typically several inches). The caliper, on the other hand, can span from two inches to four feet, depending on the length of the scale. External measurements are made by closing the jaws over the piece to be measured, while internal measurements are made by opening up the inside diameter contacts.

Three Types

There are three different types of caliper which may be found today in a machinist's tool chest.

Vernier. The vernier caliper was the original design and is still the most rugged. Graduated much like a micrometer, it requires the alignment of an etched scale on the vernier plate with an equally spaced scale running the length of the tool's handle. Skillful alignment of the tool and interpretation of the reading is necessary to achieve the measurement tool's stated accuracy.

Dial. A dial caliper is the second generation caliper. Similar to the construction of the vernier caliper, this style replaces the vernier scale with a dial indicator. The indicator is fixed to the moveable jaw, and engaged with toothed rack on the body of the unit. The dial, which is typically balanced (i.e., can move in either plus or minus directions from zero), may be graduated in either inch or metric units.

The dial caliper is a dual purpose tool for making either direct or comparative measurements. To make a comparison, first measure the reference dimension and set the dial indicator to zero. Then measure the compared dimension. The indicator will show how much the compared dimension varies from the original (plus or minus).

Another useful feature of the dial caliper are jaws which slide past each other to allow contact points or depth rod extensions to fit into narrow openings for small ID measurements.

Digital. In the last 20 years the digital caliper has made its way onto the shop floor. The latest designs provide many numerous electronic features which make the device easier to use, but add little in the way of cost. These include: easy switching between inch and metric units on the readout, tolerance indications, digital output to electronic data collection systems, zero setting anywhere along the caliper's range, and retention of the zero setting even when the caliper is turned off. With no moving parts in the readout, the digital caliper is exceptionally durable, standing up to some of the toughest manufacturing environments.

Concerns

Care and Respect. Like any measurement tool, the caliper must be treated with care and respect. Don't use it for purposes for which it was never intended (such as prying things apart). Wipe it clean after using, and don't throw it on the workbench. For dial calipers, be particularly wary of dirt which can accumulate on the rack, throwing measurements off and ultimately damaging the indicator. Store a caliper in its case. If it's going to be there for a while, apply a thin coat of oil to the jaws to inhibit corrosion.

Wear and Calibration. Check the caliper often for wear, as well as burrs and scratches on the jaws and contacting surfaces. A simple way to do this is to pass a master disc along the jaws while inspecting for wear or taper. Like any measurement tool, a caliper should be calibrated at least once a year ù more often when use is heavy or there are multiple users of the same instrument.

Proper "Feel". While the caliper is a versatile tool, it is not one of the most precise. Skill is required for positioning the tool and interpreting the measurement result. As the user develops his "feel" for the tool, his measurement results become more consistent.

While the digital caliper may take some of the guess work out of reading the measured value, it still requires skill on the part of the user to apply the tool properly to the dimension being measured. The jaws of the caliper must be square or perpendicular to the part. They are held firmly against the part, but not to the point of deflecting them. The part should be kept as close as possible to the frame of the measurement tool.

Knowing Its Limits. The rule of ten says that a measurement tool should have ten times more resolution than the tolerance of the dimension. Calipers typically read in 0.001" units. So if the tolerance is tighter than ±0.005", a micrometer (or some other higher accuracy tool) is the way to go.

The humble caliper is a surprisingly versatile tool for a wide range of general purpose distance measurements. With a little skill, you can make a fast direct measurement or comparison in seconds and move on quickly to your next important task.

MICROMETERS: MEASURING UNDER THE INFLUENCE

The basic micrometer is one of the most popular and versatile precision hand-held measuring tools on the shop floor. While the most common type is the outside diameter style, the principle can be used for inside diameters, depths and grooves. With so many options for holding the spindle and alternate contact points available, it's a tool to satisfy an endless number of measurement applications.

The biggest problem with micrometers is that measurements are subject to variations from one operator to another. There are two types of influences that contribute to this variation: "feel" or inconsistent gaging force, and subjective factors.

The micrometer is a contact instrument. Sufficient torque must be applied to the micrometer to make good positive contact between the part and the instrument. The only torque calibration in the human hand is the operator's "feel." What feels like solid contact to one operator may not feel correct to another, so the readings will be different. In order to eliminate the "feel" part of the measurement, the designers of micrometers incorporated a ratchet or friction thimble mechanism. This is an attempt to assure more consistent contact pressure and eliminate the human influence.

A psychologist might say that the other type of measuring influences, the subjective ones, are all in the operators' heads. Tell an inspector that the best machinist in the plant made this part and influence enters the picture. Or suppose your boss walks over and asks you to measure a part and he adds, "I just made it myself." In these cases, measurements will tend to be better than the part deserves.

There are also more subtle types of influences. For example, if you know what size the parts ought to be before you measure them, readings will tend to be closer to that ideal than if the target dimension were unknown.

Don't take my word on this, conduct your own experiment.

Step 1: Take a number of workpieces and have several people measure them using micrometers without a clutch or ratchet or friction type thimble. Don't reveal the actual dimension of the workpiece or what anyone else got for readings. These are uninfluenced measurements.

Step 2: Give the same operators a known test piece to practice on to get a feel for obtaining a repeatable reading. Then ask them to measure an unknown part. Next give another group a sample known part to practice on to get a feel for obtaining a repeatable reading; then have them measure parts where the size is known. These are influenced measurements and I'm willing to bet good money that there will be significantly less variation in these results. It's just human nature.

Step 3: Replace the micrometer with one with a ratchet or friction thimble. The measurements are likely to improve even more.

Now that you have a better understanding of measuring under the influence you can do something about it. The simplest thing to do is use a hand tool that has ratchet or friction drives to achieve more consistent gaging pressure. Or, in the case of the micrometer, the best way to obtain the most consistent reading is with an indicating micrometer. This type of micrometer combines the flexibility of range with the high resolution and consistent gaging force of a dial indicator.

The lower anvil of an indicating micrometer is actually the sensitive contact of a built-in indicator which provides readings (it's typically in 1µm/50µ" gradations) clearly and quickly with no vernier to read. Like the standard micrometer, you can adjust the spindle to the size needed and obtain a consistent gaging force when the master is set to zero on the dial indicator. Once established, the spindle is locked into position. Now the measuring tool begins to act like a gage by making measurements in a comparative mode. A retraction lever is also incorporated in the gage, making it easy to position the part for measurement quickly and to reduce wear on the contacts.

An indicating micrometer is a perfect gage for medium run, high tolerance parts. With this one gage an experienced operator can quickly set up the measurement process. Once the gage is locked in place, the indicating micrometer applies identical gaging pressure for each measurement, regardless of who is using it. The novice quickly obtains the same uniform high accuracy results as the experienced inspector regardless of differences in feel or what is known or not known about the part.

"STYLIN" WITH YOUR MICROMETER

Convenience is one of the reasons the micrometer is often the tool of choice for length/diameter measurements. The basic micrometer provides direct size information quickly, has high resolution, and is easily adaptable to many different measurement applications. Beyond the basics, there are all sorts of micrometer styles which extend these advantages to many special measurement applications.

A micrometer consists of two opposing surfaces, a stationary anvil and a moveable spindle. On most micrometers, these hardened steel or carbide-tipped contact surfaces are flat.

However, micrometers can also be equipped with built-in or contact tips with unique forms for measuring special part characteristics.

Have A Ball. Ball contacts are used to measure wall thickness of tubes and other cylindrical components. Micrometers are available with one or two ball/radiused contacts. The one ball/radius style may be used for inspection of wall thickness on tubing. Two ball/radius contacts can inspect thickness between holes. In some cases the ball contacts can be supplied as attachments for use with a standard flat tipped micrometer. The attachments may be quickly and easily applied to either the anvil, the spindle or both. When using this type of attachment, the ball diameters must be taken into account by subtracting them from the micrometer reading.

Time for Recess. Reduced spindle style micrometers have a turned down diameter on both the anvil and spindle. These contacts are used to measure inside recesses where the normal diameter may be too wide to penetrate. Because the contact areas of the anvil and spindle are very small, these micrometers may take a little getting used to. To get the proper "feel," take care to make sure the face of each contact is square with the axis of the diameter being measured.

In the Groove. Measuring the outside diameter of a cylindrical part from inside a turned groove on its surface calls for still another type of micrometer contact blades. Often these grooves can be so narrow that neither a standard nor reduced face micrometer will fit completely into the groove. Blade contacts, as the name implies, are very slender and flat. They nest readily into narrow-bottomed grooves. The blade solution created an interesting problem for the blade micrometer's designer. The spindle surface of most micrometers rotates as the micrometer barrel is turned, but a blade inside a groove would eventually be constrained from rotating. So blade micrometers have a spindle that slides along the axis of movement instead of rotating. Using this style micrometer calls for greater care. As always, check to make sure the micrometer is on the true diameter. Also, check frequently for wear on the measuring surfaces. Because the ends of the blades are so narrow, there is very little measuring surface. Excessive pressure on these narrow blades, as the tool is being rocked to find the true diameter, can result in premature wear.

Between The Grooves. On the same part, measuring the distance between the grooves is accomplished with a disk micrometer designed for thickness measurements on features that have narrow clearances. The measurement contacts are relatively large disk-like flats which extend beyond the diameter spindle and anvil. Because these contacts have such a broad measuring surface, parallelism errors can creep into the measurement. So it is important to check parallelism of the contacts using a precision ball on many locations between the contact faces. A discrepancy of more then a grad of the vernier is a sign that the parallelism of the anvil and spindle needs to be corrected.

Even the best and most basic hand measuring tool can be made better by adapting it to special application requirements. By choosing the most appropriate style of the application, you will achieve a faster and more accurate measurement. Each style, however, has its own unique requirements for care and use. If you're going to measure with style, make sure you know how to do it properly.

STACKING UP FOR BIG ID'S

For those medium and large parts with inside diameters greater than four inches, an inside micrometer is often used as the inspection tool of choice. This is especially true if the volume of parts is low and there is a large range of diameters to account for. Versatility of measurement range is one of the inside micrometer's most important characteristics.

This is actually one of the most straightforward of gages, since the gage itself duplicates the distance being measured. The axis of the inside micrometer *becomes* the diameter of the part. We mentioned Mr. Abbé a couple columns ago—you can't comply any better with his law than with an inside micrometer.

Usually in the world of dimensional measurement, it is frowned upon to add extension rods to a gage, since this can become a source of error. However, with the inside micrometer, this is exactly how the gage is used. In fact, the extension rods are all made to known reference lengths, as is the micrometer head. This way, the whole gage is put together with the extensions to become the size being measured. Though there is apt to be some error based on the accumulation of errors in the extensions, the large diameters themselves usually allow a larger tolerance, and typical gage tolerance rules can still be met. However, if a reference standard is available, it can also be used to convert the gage to a transfer-comparative gage for better performance.

The inside micrometer is similar to a standard micrometer, but without the frame. It is often sold in sets to allow for a wide range of diameters. Other characteristics include:

- A shortened spindle to allow access to smaller holes
- Spherical contacts which have radii smaller than the smallest radius they will contact
- Extensions that are manufactured to known lengths
- A collar to hold the extensions, which can be combined to reach diameters greater than 30"

However, while the inside micrometer does comply nicely with Abbé's Law, it is not without issues. The fact that it can be extremely long often makes it difficult to handle: sometimes it may even require two people. Plus, there is the fact that it's a two-point measurement without a third reference point. This means that it has to be rocked inside the diameter in two directions—axially and radially—searching for the maximum diameter. The best way to do this is to hold the reference contact against one side of the part and adjust it for fit, while moving the measuring end and simultaneously adjusting the micrometer for the best "fit."

Temperature is the other issue to be concerned with. Since the gage has to be handled in order to be used, and the only way to handle it is to hold it, the gage is subject to the worst enemy of measurement: body heat transfer. This can be minimized though by using the gage for the shortest time possible, holding the gage only at the very extreme ends, and wearing insulating gloves. Some gages also employ insulated sleeves or holding areas to minimize body heat transfer.

While the mechanical inside micrometer version is still the most common set provided, technology has also stepped in to help the operator achieve better performance. By replacing the micrometer with a high precision, digital indicator with dynamic memory functions, operator influence can be minimized. With the gage in minimum memory mode, all the operator needs to do is sweep the ID, and the gage will search out the correct ID reading—lessening the need for rocking and the potential errors of trying to achieve the right feel. Though it is not without faults, the versatility and low cost of the inside micrometer gage makes it ideally suited for low volume part measurement applications.

MICROMETER ACCURACY:
Drunken Threads and Slip-sticks

With the number of micrometers on the shop floor and in inspection areas these days, it’s important to understand the degree of confidence that one can expect from this instrument. Whether it's a screw thread or digital micrometer, the level of precision depends on two factors: the inherent accuracy of the reference (the screw thread or the digital scale) and process errors.

With a screw micrometer, accuracy relies on the lead of the screw built into the micrometer barrel. As with any screw based movement, error in this type of micrometer tends to be cumulative and increases with the length of the spindle travel. This is one reason micrometers come in 1 in. (25 mm) measuring ranges. Apart from the difficulty of making long, fine threads, the error generated over the longer lengths may not be acceptable enough to meet performance requirements.

One approach that sometimes improves the overall performance of the measurement is to tune the micrometer to the range where it is most likely to be used. For example, if a 0 - 1 in. (0 - 25 mm) micrometer is to be used on parts towards the largest size, the micrometer could be calibrated and set up so that the optimum accuracy is at some other point in its travel than at its starting point. You could chose the middle to balance any errors at the end points, or elsewhere to maximize performance at any particular point of travel.

Aside from the calibration error of the thread, which reflects the accuracy of its movement per rotation, there are also two other thread related errors you should be aware of. One is error within the rotation, known as drunken thread, because of slight thread waver over the course of a rotation. The other is slip-stick, or backlash, which is caused by unwanted slop between the mesh of the threads. This is a common cause of reversal errors. As a point of reference, the drunken thread is like profile error on a machined surface, while slip-stick is similar to backlash errors seen in gears on dial indicators.

With electronic micrometers the thread usually drives a sensing head over a scale, or uses a rotary encoder as the displacement indicator. Both can induce slight errors, but the thread of the barrel remains the single largest source of error. However, an electronic micrometer can remember and correct for such errors, and in the end, provides better performance than the interpreted mechanical micrometer.

The process for checking the performance of a micrometer is similar to that of other comparative or scale based instruments. Gage blocks of known sizes are measured and the deviations from the expected values are plotted. Usually the gage blocks are chosen so that the spindle travels for a full or half turn of the screw. Taking this one step further, a single rotation of the screw can be analyzed by taking very small increments of measurements around the peaks discovered on the first pass. These small increments—maybe ten steps in one revolution—may reveal even larger errors, or show patterns that were machined into the screw threads.

Besides thread errors, the other significant cause for errors can be found in the parallelism of the anvils. The precision method for inspecting the condition of the anvils is with an optical flat. Using a monolithic light source, it is generally acceptable to allow two visible bands when assessing individual anvil flatness. For inspecting parallelism, a total of six bands may be observed, the combined total of both sides.

The applied measuring force of the sensing anvil on the part and the reference anvil is the other source of process measuring error. The friction of ratchet drive thimbles does reduce the deflection of the micrometer frame, but condition still exists as a source of error. With about two pounds of measuring force, typical frame deflection is roughly 50 microinches, although this is apt to increase on larger micrometers where the rigidity of the frame increases.

As with any hand tool measurement, other sources of errors will also sneak in. Temperature, dirt, and the means by which the operator aligns the gage to the part play a large role in the overall performance of any micrometer.

EVALUATING GAGING FOR THE SHOP FLOOR

Understanding the New IP Standard

Measuring instruments have been used for the inspection of manufactured parts ever since the first vernier caliper was introduced. It didn’t take much to take care of these old tools out on the shop floor: a clean cloth, a little elbow grease and a good storage box was all that was needed to make those gages last a lifetime. In fact, they often became prized possessions, as those old craftsman handed tools down from generation to generation.

In the past thirty years or so, electronic gages have become increasingly common on the shop floor because of their ease of use, speed, and ability to do complex measurements. However, when it came to caring for these new gages, one thing was clear: you didn’t want to get that digital caliper, micrometer, indicator, amplifier or computer anywhere near water or coolant, or there was sure to be trouble. Either the gage wouldn’t work, or even worse, it would produce incorrect readings.

This didn’t make sense, of course, that the tools needed in an environment where there was coolant, grease, dirt and chips flying around did not like those conditions. Recently, there have been improvements in a lot of the electronic gaging that finally gives these tools the characteristics needed to survive out on the shop floor. Improvements in scale technology, microcircuits and sealing have made gages capable of literally making measurements under water.

Now that these types of gages are finally available, a new standard has been set up to help identify what type of tool is best for the environment in which it will be used. This rating is called Ingress Protection – IP for short. Associated with the IP is a two-digit rating number that tells what type of conditions that gage can survive in. The first digit describes the protection for solid foreign objects, while the second digit indicates protection against harmful ingress of water. A potential third digit, which is the defined impact protection, has not yet made its way into the measuring instrument table.

For example, a gage might have a rating of IP-65. As you can see from the accompanying table, this gage is totally protected against dust and protected against low pressure jets of water from all directions, with limited ingress permitted. Today there are calipers and micrometers with ratings as high as IP-67. These can be subjected to the type of dust and dirt found in the shop and are both water and coolant proof.

So, electronic tools that can finally be used on the shop floor – what a good idea! But one cautionary note. Just because these new gages can handle the environment doesn't mean their measurements are impervious to environmental conditions. They are still precision gages and all the basic rules for precision gaging still apply. We'll review the classic SWIPE paradigm next month.

First number (Protection against solid objects)	Definition	Second number (Protection against liquids)	Definition
0	No protection	0	No protection
1	Protected against solid objects over 50 mm (e.g., accidental touch by hands)	1	Protected against vertically falling drops of water
2	Protected against solid objects over 12 mm (e.g., fingers)	2	Protected against direct sprays up to 15° from the vertical
3	Protected against solid objects over 2.5 mm (e.g., tools and wires)	3	Protected against direct sprays up to 60° from the vertical
4	Protected against solid objects over 1 mm (e.g., tools, wires and small wires)	4	Protected against sprays from all directions - limited ingress permitted
5	Protected against dust - limited ingress (no harmful deposit)	5	Protected against low pressure jets of water from all directions - limited ingress permitted
6	Totally protected against dust	6	Protected against strong jets of water, e.g., for use on ship decks - limited ingress permitted
		7	Protected against the effects of temporary immersion between 15 cm and 1 m. Duration of test 30 minutes
		8	Protected against long periods of immersion under pressure

MICROMETER ACCURACY

Drunken Threads and Slip-sticks

With the number of micrometers on the shop floor and in inspection areas these days, it's important to understand the degree of confidence that one can expect from this instrument. Whether it's a screw thread or digital micrometer, the level of precision depends on two factors: the inherent accuracy of the reference (the screw thread or the digital scale) and process errors.

With a screw micrometer, accuracy relies on the lead of the screw built into the micrometer barrel. As with any screw based movement, error in this type of micrometer tends to be cumulative and increases with the length of the spindle travel. This is one reason micrometers come in 1in. (25 mm) measuring ranges. Apart from the difficulty of making long, fine threads, the error generated over the longer lengths may not be acceptable enough to meet performance requirements.

One approach that sometimes improves the overall performance of the measurement is to tune the micrometer to the range where it is most likely to be used. For example, if a 0-1 in. (0-25mm) micrometer is to be used on parts towards the largest size, the micrometer could be calibrated and set up so that the optimum accuracy is at some other point in its travel than at its starting point. You could choose the middle to balance any errors at the end points, or elsewhere to maximize performance at any particular point of travel.

Aside from the calibration error of the thread, which reflects the accuracy of its movement per rotation, there are also two other thread related errors you should be aware of. One is error within the rotation, known as drunken thread, because of slight thread waver over the course of a rotation. The other is a slip-stick, or backlash, which is caused by unwanted slop between the mesh of the threads. This is a common cause of reversal errors, and in the end, provides better performance than the interpreted mechanical micrometer.

The process for checking the performance of a micrometer is similar to that of other comparative or scale based instruments. Gage blocks of known sizes are measured and the deviations from the expected values are plotted. Usually the gage blocks are chosen so that the spindle travels for a full or half turn of the screw. Taking this one step further, a single rotation of the screw can be analyzed by taking very small increments of measurements around the peaks discovered on the first pass. These small increments – maybe ten steps in one revolution – may reveal even larger errors, or show patterns that were machined into the screw threads.

Besides thread errors, the other significant cause for errors can be found in the parallelism of the anvils. The precision method for inspecting the condition of the anvils is with an optical flat. Using a monolithic light source, it is generally acceptable to allow two visible bands when assessing individual anvil flatness. For inspecting parallelism, a total of six bands may be observed, the combined total of both sides.

The applied measuring force of the sensing anvil on the part and the reference anvil is the other source of process measuring error. The friction of ratchet drive thimbles does reduce the deflection of the micrometer frame, but the condition still exists as a source of error. With about two pounds of measuring force, typical frame deflection is roughly 50 microinches, although this is apt to increase on larger micrometers where the rigidity of the frame increases.

As with any hand tool measurement, other sources of errors will also sneak in. Temperature, dirt, and the means by which the operator aligns the gage to the part play a large role in the overall performance of any micrometer.