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Bored Straight

Fundamentals of bore gages and choosing the best one for the job.

A properly functioning bore gage is key to producing bores within tolerance, especially as parts become more complex and tolerances become tighter. Although bore gages come in an almost endless array of styles, there are two basic types: hard, or limit, gages and variable-reading gages.

Dorsey

A variety of tipping bore gages.

Hard and Variable

Hard bore gages are GO/NO-GO plugs—a machined cylinder of a known size, usually made out of hardened steel, that fits into a bore of a specific size. The GO plug end is ground to the low-tolerance limit of the bore to be checked. The NO-GO plug end is ground to the high-tolerance limit. A hole that accepts the GO end, but does not accept the NO-GO end is good.

These basic tools don't have any moving parts. They can tell the operator if a hole is good or bad, but provide no other information.

Variable-reading bore gages incorporate some kind of display, such as a dial or digital indicator, and some physical means to detect variation in bore size. This is most commonly accomplished with mechanical contacts, but other methods, such as air pressure or lasers, are also used. A transducer that feeds a reading to a digital amplifier can also be used.

"You can expand on the accuracy and resolution by substituting an analog-style indicator with a transducer and an amplifier," said David DiBiasio, national sales manager for Brown & Sharpe Inc., North Kingstown, R.I. "That can bring your resolutions down to a millionth of an inch."

One of the advantages of variable-reading gaging over hard gaging is the ability to send data to a data-collection

system. A variable-reading gage can help an operator reach a certain size hole in efficient stages.

Dedicated and Adjustable

Variable-reading bore gages can be further divided into dedicated and adjustable types. Dedicated bore gages measure variation of one specific bore diameter.

Indicating plug gages are a good example. These are similar to the GO/NO-GO gages in that they have a center sleeve that either fits or doesn't fit into the hole. But they also have two or three movable contacts that provide a reading. These are the most accurate and repeatable type, but they have a limited range. Because they remain centralized at all times, plug gages can be rotated in the bore, or slid lengthwise, which is good for finding irregularities such as out-of-roundness.

Adjustable bore gages can be used in a range of hole sizes. They incorporate measuring contacts that are assembled to the approximate size of the bore. A tipping bore gage is an example of an adjustable bore gage. Like the plug gage, it also finds irregularities.

A basic tipping bore gage has two measuring contacts—one sensitive, movable contact that takes the reading and transmits it to the indicator, and an opposing reference contact that is always stationary. The reference contact can be adjusted to any position within the range of the gage. Once adjusted, it is locked in place. The reference contact often has different lengths available for different size holes.

"Say an adjustable gage can measure a 1" range, say 1" to 2"," said Michael Scott, CEO of Dyer Precision Measuring Instruments, Lancaster, Pa. "In that one set, you may have 12 or 14 stationary contacts, or rods. You take one off and put a new one on and measure your next step bore. The sensitive contact has enough travel to compensate for everything in between 1" and 2".

Most tipping gages have some way to centralize the measuring tool when it is in the bore. This feature ensures that the gage is checking the diameter and not a smaller chord (a straight line joining two points on a curve).

When the gage is inserted into the part, the movable contact is depressed. Keeping the stationary contact hard against one side of the hole, the operator "rocks" the gage back and forth, causing the sensitive contact to actuate the indicator as it extends or retracts. When the contacts are oriented exactly perpendicular to the bore's axis, the sensitive contact is depressed further, indicating the true diameter.

Another type of adjustable bore gage is the 3-point contact gage. This is used for many of the same applications as a 2-point gage. The 3-point gage is the only type of gage that can find trilobing irregularities. However, it is not possible to find out-of-round conditions with it. A 3-point gage only gives an average reading; it cannot capture the absolute maximum and minimum of the diameter.

"There is a misconception that 3-point gages are better or more accurate than 2-point gages because when operators rotate a part with a 3-point gage, the reading stays the same," said Scott. "They think they have perfectly round parts, when, in fact, the gage is displaying an average diameter reading, and not the true diameter of the part at a specific location."

Adjustable bore gages are usually set

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An example of a GO/NO-GO gage.

Dyer

Indicating plug gages are similar to GO/NO-GO gages but they have contacts that provide a reading.

Clean and clear

No matter which type of gage is used, a clean bore is a must.

"One of the big problems with adjustable or dedicated gaging is people don't tend to clean the hole out during the machining process," said Stephen Forschler, product manager for Dorsey Metrology International. "You have to have a fairly clean part to get an accurate reading. Dirty parts also tend to increase the amount of maintenance that has to be performed on the bore gages to keep them working."

Caution also needs to be used to ensure the bore gage doesn't scratch or deform the part. One thing to do is use different styles of contacts.

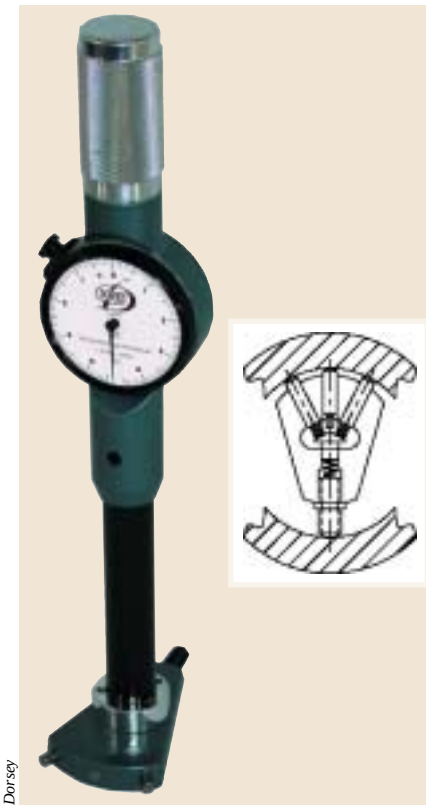
"If you use a bore gage, you can put ruby ball contacts on it," said Michael Scott, CEO of Dyer Precision Measuring Instruments. "Ruby balls and aluminum—they get along." For a GO/NO-GO gage, a coating, such as titanium nitride, can be put on. This helps the gage slide easily into the bore.

For a thin-walled part, like a bushing, a noncontact method, such as air gaging, won't deform the part. Air gaging also doesn't mar the surface. And, always, the gage should be the same temperature as the part being measured to ensure accuracy.

—S. Woods

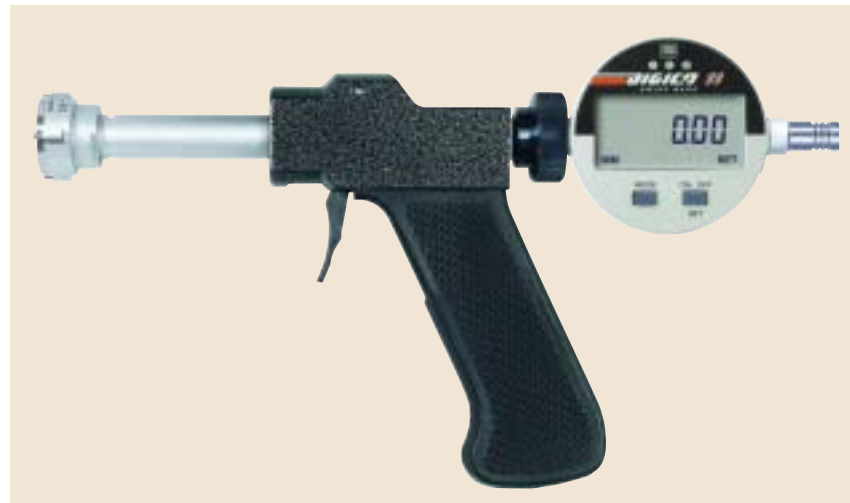
Dyer

The centering base for a tipping bore gage.



Dorsey

A tipping bore gage with two measuring contacts and two centralizing plungers. Inset: Diagram of the tipping bore head.



Brown & Sharpe

A 3-point gage can detect lobing in bores.

to a master ring. A master ring, or ring gage, is basically a bore of known size. It is typically made out of steel and might be chrome-plated.

Accurate Bores

Several factors should be considered when choosing a bore gage. The first is the accuracy, or tolerance, range. For open tolerances, operators typically use hard gaging.

Generally, the tighter the tolerance, the more apt a person is to go with a dedicated bore gage.

"I would tend to use dedicated gaging for tolerances of less than 0.001"," said Stephen Forschler, product manager for Dorsey Metrology International, Poughkeepsie, N.Y.

Adjustable bore gages can typically measure tolerances from 0.005" on up.

The size of the bore also affects gage choice. The larger the bore, the less practical hard gaging becomes. "If you get up to an 8" or 10" hole with a hard gage, it is like swinging a dumbbell around all day," said Forschler. "It is big and heavy and pretty expensive to make. It is probably easier to do the big holes with adjustable gages."

The range for indicating plug gages is anywhere from ⅛" to 9". The standard range for adjustable bore gages is 2" to 12". Specials tend to be used for bores with diameters larger than 12".

Small bores are a consideration as well. "The smallest hole we measure is 0.0018" in diameter," said Scott. "We use a split probe that is a tipping plug gage. We can't get an indicating plug gage in there because you can't get the sleeve, contacts, etc. in a hole that small."

Other Factors

When production runs are short or inspection speed is not an issue, adjustable gaging may be the best choice because the gage can accommodate a greater number of bore sizes. It rarely makes economic sense to purchase a fixed-size gage if only a few bores of a given size are to be inspected.

However, for high-volume production runs, where thousands of identical parts must be inspected rapidly, or for runs that are likely to last for months or years, indicating plug gages are the way to go. The plug gage promotes much higher throughput.

The more flexible a bore gage is, the more skill required to use it. GO/NO-GO and indicating plug gages take a lot less operator skill than adjustable gages. Only the gage itself needs to be inserted in the bore—no rocking is required, and reading is simple.

Tipping bore gages, on the other hand, require a fair amount of skill to obtain an accurate reading. "Adjustable gaging is probably not as easy to use and set up and, therefore, people tend to draw the assumption that it is not as accurate," said Forschler. "With the decrease in skills out there, especially in machining industries, there is probably a bit of truth to that. With a really tight tolerance on a bore and an operator of limited skill, the dedicated gage is probably the quickest, easiest and most accurate way to go."

Pricing for both types of gages depends on the style, size and accuracy. For a small a bore with an open tolerance, a GO/NO-GO gage can be had for under $100. For a large or complicated bore, it can be in the thousands. High-end bore gages with accuracy in the millionths can cost up to $5,000.

Common Mistakes

The biggest mistake operators make is using a bore gage that isn't accurate enough. They have a tendency to look at only the resolution of the gage to de-

termine if the gage is OK, but they also need to look at the overall accuracy of the gage.

The way to qualify the gage, and make sure that it is good for a particular part, is to do a gage R&R study, where in the reproducibility and repeatability are rated.

Scott explained how it works: "You take the gage and you have 10 sample parts and three sample operators. Each operator measures each part two times so you get 60 different measurements. You do the math and come out with a percentage of error with respect to the tolerance of the part. Say your tolerance is 0.001", and your gage R&R number comes out to be 10 percent. This means that the gage has a 10 percent uncertainty, or 10 percent error (0.0001"), no matter who uses it."

A second common mistake is only taking one measurement. "In some instances, people take a single measurement as opposed to multiple measurements," said DiBiasio. "They don't bother to move the gage, say 40°, just to check for ovality."

Another mistake people make is thinking of bore gages as a commodity item. "You can use standard bore gages if your tolerance allows it," said Scott. "But, most bore gages should be tailored for the application to make sure that the operator can get the most reliable reading possible."