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Answer these 12 questions to chase away your gage-selection blues.

by George Schuetz

Once you've decided that you need a gage to measure the parts your company is producing, a well-defined selection process will help you narrow down the many possibilities to the one that is right for your application. But to avoid unnecessary expenditure, first determine whether a gage meets your needs better than a less expensive hand tool.

Hand tools, such as micrometers or calipers, are usually better suited for general-purpose applications. They typically have a broader measurement range but coarser resolution. Measurement tasks also take longer to perform with hand tools, which are designed for individual measurements of many different parts rather than high-volume measurements of a narrow range of parts. And because they can be used in so many ways, hand tools generally also require more skill on the part of the user.

Conversely, gages are the best choice for measuring a unique part with close tolerances that will be manufactured and checked in high volumes. The gage allows the operator to simply snap the part in place, collect the relevant data with high accuracy and quickly move on to the next task, fulfilling the need for accuracy and productivity.

Deciding whether you need a gage is the easy part. Once you have decided in favor of a gage, though, it's easier still to find yourself caught in a bewildering quagmire of choices. For example, a simple outside diameter might be measured by any one of the following gage setups, ranging in price from $150 to $150,000:

- A go/no-go snap gage
- A dial indicator on a simple stand
- A benchtop inside diameter/outside diameter comparator
- An air-ring gage
- A custom-built fixture gage with electronic probes
- An engineered gage with fully automated parts handling and sorting by size categories that provide compensation feedback to the machine tool

This type of thinking can make you crazy, so don't even let it begin. Instead, walk through the gage selection process by answering the following 12 questions.

12 engaging questions

1. How specialized does the gage need to be?

Consider what actually needs to be measured. Is it an inside or outside diameter? Height or depth? Length or width? Is the feature being measured for its dimension or for its location in relation to other features (e.g., distance between centers)?

The more specific a gage's task, the more competently it will perform. Indicating snap gages, for example, which only measure outside diameters, offer higher repeatability and faster throughput than do indicator/height stands. Gages may be even narrower in focus, intended to measure not simply a general type of feature (such as a generic outside diameter), but a specific feature on a specific part: for example, a journal on a particular shaft. Such a gage, which would obviously be custom-built, could provide very high levels of performance in terms of repeatability, ease and speed of use. But there are also a surprising number of off-the-shelf gages with very specific applications. To give just one example, there's a stock gage to measure the inside diameter of a crimp groove on aerosol cans.

Specialization in gage design is not always preferable, however. More flexible gages often prove to be more economical if only a few features of any given dimension must be gaged, or if throughput speed is not a crucial consideration.

2. How important is gaging throughput?

Generally, the shorter the production run, the less important gage throughput becomes. But in a larger production run where a single machine setup suffices to produce thousands of identical parts, a few extra seconds spent gaging each part can add considerable time and cost.

Fixed-dimension and purpose-built gaging allow faster throughput than adjustable and general-purpose gaging. For production runs extending several years, in which thousands of parts must be measured every day, fully automated gaging might be appropriate. As a rule of thumb, if a part must be measured every 45 seconds or less, you should automate.

3. What level of accuracy is needed?

Evaluating the accuracy requirement is tricky, because it involves several performance characteristics, including discrimination, repeatability (precision), sensitivity and stability. Discrimination is the smallest graduation on an analog scale (i.e., the dimension represented by one "tick" on the dial) or the last digit on a digital display. Repeatability is the gage's ability to generate the same reading every time the same part is measured. Sensitivity is the smallest input the gage can detect--for example, the smallest movement of an indicator's sensitive contact. Stability is essentially repeatability over the long term.

Each characteristic of accuracy must be assessed. A gage display may discriminate to 20 µin., yet the gage may only repeat to one ten-thousandth of an inch due to environmental instability, operator influences or other factors. If the application really requires 20 µin. precision, it may be necessary to install the gage in a semicontrolled environment, provide training or even re-evaluate the throughput requirement.

Another guideline calls for approximately a 10:1 ratio between the tolerance range being measured and the gage's ability to repeat and discriminate. So if a part tolerance is ±0.0005 in. (total tolerance range = 0.001 in.), the gage should repeat and discriminate to 0.0001 in. A gage that can repeat to microinches in a controlled environment will probably have insufficient range of measurement and poor repeatability if it's used in a production environment to inspect parts that have been produced to tolerances of ±0.001 in.

4. What level of operator skill can be expected?

The more flexible a gage, the more skill required to use it. Adjustable-capacity, rocking-type bore gages, for example, require care to adjust, master and read. It's more difficult to make a mistake using a fixed-size plug gage.

Closely related to skill and training is motivation. The user of a rocking bore gage may do fine on the first 10 parts measured, but will the operator maintain that performance after measuring 1,000 parts? If operator-related factors are likely to cause errors, consider what they will cost in terms of inconvenience, rework or increased warranty costs.

5. Which is portable: the gage or the part?

Portable, hand-held gages are desirable when the part being measured is large, heavy, difficult to move or manipulate, or needs to be measured while it's still fixtured on the machine tool. Smaller parts are normally brought to stationary benchtop gages.

Many gages for measuring IDs and ODs, depths, heights and most other dimensions may be either portable or stationary. On the other hand, some high-discrimination gages (e.g., gage block calibrators and geometry gages) require the inherent stability of stationary installation.

6. What will the inspection environment be like?

When inspection occurs on the shop floor, gages may be subjected to dirt, dust and moisture; changes in temperature and humidity; and vibration from nearby machine tools, forklifts and other equipment. In harsh environments, some gages will provide more stability and require less maintenance than others. In general, it's necessary to increase control over the environment to achieve repeatability at higher levels of discrimination.

Some manufacturers offer harsh-environment modifications of conventional gage types. Dial indicators, for example, can be furnished in "wet proof" versions, with protective dust boots and cases sealed against moisture by O-rings. Gages with marble bases or cast iron frames tend to be more resistant to thermal fluctuations than less robustly engineered ones.

Gaging practice can also be modified to reduce the influence of temperature changes. By staging masters and work pieces on a heat sink prior to gaging, and mastering the gage frequently, one can ensure that all the components of the gaging process are in thermal equilibrium, at least momentarily.

7. Will the work piece be clean and thermally stable?

Parts measured directly off a machine tool may still be warm. Because steel, for example, expands by 60 µin. per inch for every 10ºF rise in temperature, this is no trivial matter.

A larger problem is that of contaminants, such as dirt, chips, oil or cutting fluid, on the work piece. Most gages require parts to be cleaned before measuring. Air gaging, on the other hand, tends to be self-cleaning: The jet of air blows fluids and debris from the part surface. This may save time for the gage operator on a per-part basis, while reducing gage maintenance.

8. Of what material is the work piece made?

Parts made from soft materials like aluminum can be scratched by gages, especially if the gage is moved around to "explore" a surface for flatness. Even steel parts can be damaged if they have finely honed or polished surfaces. In addition, most materials compress to some degree: At standard gaging force, a diamond-tipped indicator contact point with a radius of 0.125 in. will penetrate a steel work piece 10 µin. Whether that small change in dimension constitutes a measurement problem depends entirely upon the tolerance specification.

Penetration may be addressed by applying a compensation factor (if the compressibility of the materials is well-known) or by using a master that is the same material as the work piece. Alternately, lower gage force or a wider contact point will reduce penetration. Lever-type gage contacts (such as those on test indicators) typically operate with less force than plunger-type contacts (found on dial indicators) and are less prone to scratch surfaces. Air gaging, as a noncontact means of measurement, can eliminate these concerns entirely.

9. What process is used to produce the part feature?

Every machining process leaves certain telltale irregularities on the part that must be taken into account. For example, a nominally round OD part produced by centerless grinding may have a form irregularity consisting of three lobes oriented at 120º from each other. Most dimensional gages will measure the diameter directly across 180º. One contact may fall on a high spot and the opposite contact on a low spot to generate an average part diameter. The appropriate gage for this application must measure the maximum OD.

The same holds true for surface finish. If a part has a rough surface, should the dimension be measured at the tops of the "peaks," at the bottom of the "valleys" or halfway in between?

To properly account for these factors in dimensional gaging, it may be necessary to first gage representative parts for surface finish and geometry parameters. Another useful step in these cases is to evaluate the machine to measure the type and size of anomalies it is likely to produce.

10. How are gaging results used?

Gaging serves many different purposes. If the resultant data is used simply to separate good parts from bad ones, then fixed-size go/no-go gages may provide all the information necessary. "Variable" gages (i.e., those with indicators or other numerical readouts), on the other hand, can help a machinist creep up on a dimension in efficient stages. If gage results are to be used in SPC, then numerical results are required. Gages with digital output greatly ease the process of collecting data.

Gages may be used to sort parts by size categories. If a mechanical indicator gage is used, the dial face might be specially designed to designate the proper categories with pie-shaped sections of different colors to improve ergonomics. If an electronic gage is used for the same purpose, relays might be used to illuminate lights over the proper part bin or chute.

"Match gaging" is useful where tight clearance tolerances apply to mating parts (particularly IDs and ODs) but where it's difficult to control the production process within a tight tolerance band. The production process is allowed to vary a certain amount, then potentially mating parts are gaged simultaneously to determine clearance. Match gaging can be performed with either air or electronic gaging instruments.

11. What is your gage acquisition budget?

Gage costs typically increase with speed and accuracy. A single fixed-size gage may cost less than an adjustable gage, but if multiple fixed-size gages are required, then their costs will obviously multiply as well. The cost of mastering the gage should be included when figuring the acquisition cost.

12. What is in the gage maintenance and operation budgets?

Frequency of use affects the reliability of any gage, as do harsh environments. The greater a gage's capacity for accuracy, the more important--and often, the more expensive--proper maintenance becomes.

Some gages can be maintained and recalibrated indefinitely; others may reach a point where they will no longer hold calibration and must be discarded. Some gages can be repaired and calibrated in-house, while others require the services of outside vendors. When choosing the in-house route, figure in the costs of employing skilled personnel plus the expense of calibration and repair equipment.

When large volumes of parts must be gaged at high throughput rates, inspection personnel can be far more costly than gaging equipment. Any time that an inspector must be dedicated full-time to a dimensional gaging task, more specialized equipment should be considered to increase throughput and reduce labor requirements.

Selection made manageable

Between the tried-and-true indicator, electronic and air gages, and the more recent crop of more advanced, often computer-driven systems, inspectors and quality assurance managers face a dizzying variety of choices. It's not difficult to imagine an inspection requirement that might be satisfied by half a dozen different types of gages, not to mention that each type of gage may be available from several vendors that offer numerous minor variations within each general type. The daunting task of gage selection can be simplified by analyzing inspection requirements in terms of the 12 questions presented here.

Unfortunately, this system doesn't lend itself to a decision-tree approach leading to a single "correct" answer. Those involved in the gage specification process must still subjectively judge the relative importance of each issue. It may well happen that no single gage can fulfill all of a user's requirements. For example, a limited acquisition budget may work against the need to obtain certain levels of accuracy, so users must make their own determinations about which characteristics of gage performance are absolute necessities and what compromises are acceptable. The 12 questions do, however, provide a sound methodology that ensures that all of the important considerations will be addressed during the gage selection process.

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This Menu LeveL	[Aero Union] [ISO 9000:2000] [Simulation] [Gages] [ISO Consult] [ISO 14000]
Menu Level Below	[TL 9000]