Gaging & Inspection Tool Design

Training Objective

After watching the program and reviewing this printed material, the viewer will understand the basic aspects of gaging and inspection tool device design.

- The various gaging tools are shown
- Gage application is demonstrated
- Both contact and noncontact inspection methods are discussed
- Gage tool materials are examined

Tolerances and Allowances

Because of the limits of manufacturing, all part dimensions are made within a specified working tolerance, which is the total permissible amount by which a dimension may vary from a specified size. When providing tolerances, designers recognize that no two workpieces, distances, or quantities can be exactly alike. For this reason, an ideal, unattainable condition, referred to as a nominal value, or dimension, is specified and the degree of error or tolerance acceptable from that dimension is stated. Allowance refers to the minimum clearance space intended between mating parts and represents the tightest permissible fit. Shaft diameters and mating hole diameters are a typical example.

Gage Tolerances

Gage tolerance is expressed as a percentage of workpiece tolerance. For fixed, limit-type working gages, gage tolerance is generally set at 10% of workpiece tolerance. The tolerance of inspection gages is usually 5% of work tolerance. Master gages, those used to check the accuracy of other gages, are usually 10% of gage tolerance.

Thus, there are four classes of gagemaker tolerances developed by the American Gage Design Committee.

- Class ‘XX’ - Such gages are precision lapped to the closest tolerances feasible and used as master gages and for very tight tolerance inspection.
- Class ‘X’ - Also precision lapped, but used in limited master gage inspection and for close tolerance inspection and working gages.
- Class ‘Y’ – Lapped to slightly larger tolerances and used as inspection and working gages.
- Class ‘Z’ – These gages are used primarily as working gages where tolerances are large and the number of pieces to be gaged is small.

Once the gage tolerance is determined, the tolerance direction from nominal, either plus or minus, must be decided. Two basic systems used in this determination are the unilateral and the bilateral systems.

In the unilateral system, the work tolerance zone includes the gage tolerance zone. This makes the work tolerance smaller by the sum of the gage tolerances but guarantees that every part passed by such a gage, regardless of the amount of the gage size variation, will be within the work tolerance zone.

In the bilateral system, go and no-go gage tolerance zones are divided into two parts, half minus and half plus, relative to the high and low limits of the work tolerance zone.

Gages can wear beyond usefulness unless some allowance for wear is built in. One method uses a percentage of the working tolerance as the wear tolerance. Another is to create a standard beyond which the gage is not used. Gage wear surfaces are made of hardened alloy steel for medium production quantities, and chromium-plated steel for greater volume. Tungsten carbide is often used for high production quantities and superior wear resistance. Worn contact surfaces are commonly ground, plated, reground, and lapped to size.

Gaging & Inspection Tool Design

To ensure accuracy, gaging and measurement tools are calibrated to known primary standards, such as gage blocks, which provide a common reference for measurement standardization. Gage blocks are machined and precision lapped to very flat, highly accurate surfaces, and are produced from hard, stable material, such as chromium-carbide steel.

In addition to gage blocks, measurement areas typically utilize surface plates, which are flat planes produced from hard, homogeneous granite or cast iron. Surface plates hold extremely tight tolerances and are used as a reference surface from which dimensions or other measurements are taken.

Gage Types

A wide variety of gages are available to visually inspect and gage parts. A few of the basic types include:

- Screw-pitch gages
- Plug gages
- Ring gages
- Snap gages

Screw-pitch gages are used to determine the pitch of a screw by placement on the threaded portion. Such gages are available for the most common thread-pitch forms. However, screw-pitch gages do not check thread size and are not adequate for checking thread form for precision parts.

Plug gages usually consist of two members: the go end and the no-go end, and can be of three types: single end, double end, and progressive.

Ring gages are fixed gages usually used in pairs of go and no-go members. They are available in many sizes and lapped to close tolerance on the inside diameter. Ring gages are often used to gage external threads and splines. These gages are designed in accordance to certain American Society of Mechanical Engineers or 'ASME' standards.

Snap gages are fixed gages with internal measuring surfaces for callipering diameters, lengths, thicknesses and widths. One type of snap gage is the thread-roll snap gage, which is a complete external caliper gage used to inspect the size of a thread-pitch diameter, thread lead, and thread form.

Magnifying/Amplifying Dimensions

As dimension changes become too small for easy measurement, it is necessary to amplify or magnify them prior to measurement. This can be performed mechanically, electronically, pneumatically, or optically using a variety of tools.

Dial indicators have a contact point that is attached to a spindle or rack. When this spindle or rack is moved, it transmits that movement to a pinion and then through a train of gears. These gears magnify the movement, which is then read off the hand on the dial face of the indicator. Because the principle of direct reading from a graduated dial face provides both accuracy and speed of reading, the dial indicator has been incorporated into many types of gaging equipment.

Electronic digital readout tools reduce interpretation errors that may occur when a graduated scale or a dial indicator is read. Electronic digital readout tools provide instantaneous readings; they can be zeroed out at any point; provide out-of-tolerance alerts; and can be used for data collection and analysis for statistical process control (SPC).

Air gages measure, compare, or check dimensions by sensing air flow through the space between a gage head and workpiece surfaces. The gage head is applied to each workpiece in the same way, and the clearance between the two varies with the size of the workpiece. The amount of airflow restricted depends upon the clearance.

Optical projection is a noncontact method of graphically displaying and measuring parts that have dimensions and shapes difficult to measure with conventional contact-gaging tools. A typical optical-measuring projector has a stage where a part is mounted, and an optical path made up of a light source, condensing lens, magnifying lens, and reflecting mirror to bounce a precisely magnified silhouette profile of the part onto a viewing screen. A second illumination source is used to view the part and its surface.

The coordinate-measuring machine, or CMM, is an extremely accurate measuring instrument that provides detailed data and documentation of manufactured parts. CMMs use probes, motor-controlled motion for X, Y, and Z directional movement, along with a computer system and analyzing software.

Several noncontact sensor systems have been developed either individually or in combination with the coordinate measurement process. These systems all involve optical-measuring techniques and incorporate devices such as lasers, video cameras, and microscopes.

A vision system is a noncontact method of obtaining part information using visual sensors. This information enables machines to make intelligent decisions regarding parts. The three main industrial applications of vision systems are:

- Inspection - for gaging, verification, and flaw detection
- Identification - for symbol or object recognition
- Machine guidance - for object location and tracking

Gaging & Inspection Tool Design

Review Questions

1. An ideal, unattainable value with respect to a part dimension is called an:
   a. allowance value
   b. nominal value
   c. tolerance value
   d. fixed value

2. The tolerance of fixed limit-type working gages is:
   a. 5% of workpiece tolerance
   b. related to print specifications
   c. 15% of workpiece tolerance
   d. 10% of workpiece tolerance

3. The most precise and close tolerance gages are classified as:
   a. Z
   b. Y
   c. XX
   d. X

4. Ring gages are often used to gage:
   a. internal threads
   b. hole concentricity
   c. external threads and splines
   d. thread pitch

5. Electronic digital readouts are useful for:
   a. avoiding eye strain
   b. SPC data collection
   c. direct reading
   d. part surface gaging

6. Gage wear surfaces in high-production gaging are often made out of:
   a. hardened alloy steel
   b. tungsten carbide
   c. chromium carbide
   d. chromium-plated steel

7. Parts inspected using a optical projection system can be viewed:
   a. using a touch probe
   b. as multiple images
   c. only in silhouette profiles
   d. as direct images or silhouette profiles

8. A CMM is a:
   a. noncontact measuring device
   b. surface condition measuring device
   c. coordinate measuring device
   d. multiple gaging device

9. X, Y, Z refers to:
   a. gage accuracy designations
   b. base line origins
   c. machine directional movements
   d. inspection sequences

Gaging & Inspection Tool Design

Answers

1. b
2. d
3. c
4. c
5. b
6. b
7. d
8. c
9. c