



PRODUCTIVITY QUALITY INC

Plug gaging of holes by the GO-NOGO method By Van Keuren

Introduction

Introduction The American National Standards Institute defines a gage as "a device for determining whether or not one or more dimensions of a manufactured part are within specified limits." A plug gage is a cylinder designed to check the component tolerance of a hole in a product. The plug gage has been found to be highly accurate, economical and convenient for small hole inspection where a determination is made of compliance with designed limits.

GO and NOGO gaging with plug gages provides a complete check of the dimensions of a hole. If GO-NOGO gaging is used, there is no need to measure the size of a hole to be certain that it is within the design limits. The proper use of plug gages therefore eliminates the need for complex and expensive measuring equipment.

If a GO gage is used to verify the lower limit and a NOGO gage to verify the upper limit of a hole, inspection is precise, clean cut and extremely simple. Inspection with plug gages requires no training or experience in the interpretation of numerical readouts or results which are necessary if measuring instruments are used. By using plug gages an "inspector" has only to determine whether a gage is entering or not entering a hole.

With plug gages, accuracies are possible in the order of .0000005" under proper conditions of hole and gage quality, cleanliness, and temperature control, similar to conditions normally required for any precise inspection.

In addition to eliminating any complicated measuring instruments, no set-up time is required in using plug gages; thus a plug gage can be brought into use more quickly and economically with no loss of accuracy.

Finally a plug gage, having a fixed dimension, requires no set-up, cannot get out of calibration nor is it affected by cumulative error.

Plug gages should be used in a GO-NOGO combination. The purpose of the GO gage is to determine whether the hole has met the low limit of the specifications. If a hole is too small the GO gage will not enter. The larger NOGO gage checks the upper limit of the hole. If the hole is too large the NOGO gage will enter. When the GO gage enters and the NOGO gage is unable to enter the design specifications of the hole have been met.

Gage Wear

The best general purpose material for gage use is a high quality tool steel such as 52100. This steel has several attributes which make it particularly useful for plug gages.

The high chrome content of the steel results in a corrosion resistant gage and also helps to reduce friction between the gage and the product, thus decreasing wear and providing a longer gage life. Such steel, when through hardened and properly treated, becomes highly stable. 52100 steel should be hardened to an optimum of 60-62 Rockwell C scale. Hardness in excess of this range will produce an overly brittle and less easily stabilized steel. A softer steel will of course not have good wear resistant qualities.

Gages made without the proper temperature conditioning may not be fully stable and may change in size without the user's knowledge. Such changes could lead to errors. Since a majority of the parts being gaged are of steel, the matching thermal expansion of rate of 52100 steel contributes to accurate gaging. 52100's rate of 6.3 millionths of an inch per inch per degree Fahrenheit is closely matched by that of all steels and well within tolerance applications. The method of manufacture also affects gage life. Gages produced by grinding will have a surface consisting of peaks and valleys. When such gages are inserted they will be subject to rapid wear due to the ease with which the peaks are abraded.

This wear may immediately eliminate the entire tolerance of the gage and make it undersize. A very smooth surface not subject to rapid wear is obtained by lapping the gage. Lapping removes the peaks and produces a smooth wear resistant surface and a long gaging life. For some applications chrome plating of the gage will produce a harder and more resistant surface and may be more useful in gaging highly abrasive materials such as magnesium or aluminum. Under proper conditions a chrome plated gage may last up to five times longer than a tool steel gage. Under humid or corrosive atmospheric conditions, chrome plating will provide an advantage over tool steel while retaining the thermal characteristics of steel. The extra cost of chrome plating may be justified in particular applications by this more wear resistant surface.

Tungsten carbide is recommended for extreme wear resistance in plug gages. Tungsten carbide gages have a wear life of fifty times that of tool steel and can be extremely useful especially where the component tolerance is very small and a steel gage might quickly wear beyond limits. Tungsten carbide will take a better finish than tool steel. In addition it is somewhat corrosion resistant, nearly non-magnetic, and will not burr. It should be noted, however, that carbide has a coefficient of expansion of only three millionths of an inch per inch per degree Fahrenheit and that therefore when gaging steel products more stringent temperature control in fine tolerance gaging will be necessary. In GO and NOGO gaging it is not uncommon to specify chrome plated or carbide GO members to be used in conjunction with a steel NOGO. The GO member must be resistant to wear. The NOGO member will not usually enter the hole and is therefore not so subject to wear.

Roundness and Out-Of-Roundness

In the manufacture or selection of plug gages, roundness is most frequently the least considered characteristic. If roundness in manufacture is ignored, a gage of one-inch nominal diameter may be unable to enter a one-inch hole. The most common way of measuring diameter is with a two point instrument such as scales, calipers and micrometers. Any two point method, however, is

blind to the most common type of our-of-roundness, the three lobed condition.

As shown in Figure 1, an odd lobed gage will have a greater effective diameter than any two point measurement could indicate. There are several other methods of assessing roundness which may yield different readings under different conditions. No matter how measure, however, it is good practice to restrict out-of-roundness to a maximum of 50 per cent of the gage tolerance.

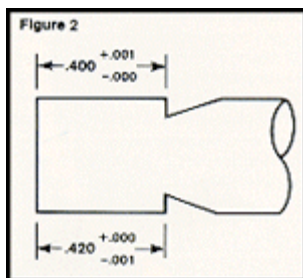
The consequences of an increase in effective diameter due to out-of roundness will differ with the GO and NOGO gages. An effectively over-sized GO gage might fail to enter an acceptable hole and thus cause a part to be rejected. Such a gage can, in this case, rob the manufacturer of part of his design tolerance.

On the other hand an out-of-round condition on the NOGO gage may prevent the gage from entering an oversized hole causing the acceptance of a faulty part. While an out-of-round condition should be avoided when checking the size of a hole it is only with a deliberately manufactured out-of-round NOGO gage that the roundness of the hole can be checked.

An out-of-round hole with only one diameter in tolerance will prevent a round NOGO gage from entering even if the hole is over-sized in all other directions. Therefore, in order to check the other diameter of the hole the gage must be deliberately "flattened" on both sides and rotated to check the NOGO dimension for all diameters. When such a "paddle type" gage is used approximately twenty five per cent of the gage diameter should be removed from each side. If a "paddle type" NOGO gage enters the hole being checked in any orientation the hole is out of tolerance in at least one dimension. It is also possible to use the "diamond shaped" gage illustrated below.

Other Gage Modifications

Other dimensions of a hole can be checked simultaneously with the gaging of the hole diameter. Among these are depth, and - when concentricity is involved - alignment.



Checking depth of holes To determine whether a hole is sufficient depth, a plug gage may be designed with minimum and maximum notches on the cylinder. Most common is the so-called "Whistle Notch" type as shown above. It is a visual check, in this case insuring that depth is between .400" and .420".

Plug Gage Tolerance

Standard practice in American industry is to allow 5% of the product hole tolerance for the GO gage tolerance and 5% for the NOGO gage tolerance. The GO gage, whose nominal size is at the low limit of the hole to be checked is generally given a plus tolerance in order to insure that all parts accepted fall within the product tolerance (See figure 3).

For the same reason the NOGO gage, whose nominal is at the high limit of the product tolerance, is given a minus tolerance. In this age of strict product liability perhaps it is better to reject a few acceptable parts than to pass any out-of-tolerance parts. The GO gage plus tolerance and the NOGO minus tolerance have become universal in American Industry and 10% of the hole tolerance - 5% at each end - is sacrificed to insure that all pieces accepted are within tolerance.

There can be several reasons for using finer or coarser tolerances that the 10% rule would dictate. In a case where the production process is such that a significant number of acceptable parts are expected to fall in either of the 5% areas of product tolerance which may be rejected due to gage tolerance, a tighter tolerance should be considered. The value of these parts or the effort necessary to re-inspect them weighed against the cost of a finer gage such as Class XX, Class XXX or Class XXXX, can more than justify the cost of the finer tolerance.

On the other hand there may be cases where the production process is known to produce holes whose diameters will be distributed well within the design tolerance and where only a rare part will even approach the limits of that tolerance. In such a case it might not be profitable to use anything but a coarse tolerance plug gage to insure only that the stray reject part would be caught. Providing for a wear allowance on the GO gage will in addition to increasing gage life, serve to reject an additional number of acceptable parts.

The value of those parts likely to be rejected should be carefully evaluated when gage specifications are determined. In general since the cost of inspecting and, if necessary, replacing a gage is not great, such a sacrifice in product tolerance is not warranted. Rather than sacrifice tolerance when gage wear is a concern, the use of chrome plate, tungsten carbide, or other slower wearing materials is recommended. In fact, when such materials are used, a finer tolerance can be chosen, thereby further reducing the likelihood of rejecting an acceptable part. Another way of minimizing the number of acceptable parts that are rejected is to employ a two stage process where those parts rejected by a relatively coarse tolerance gage during the production process are later re-inspected with fine tolerance gages in conditions where temperature, cleanliness, and gage wear have been more closely controlled. In this way only those parts which are truly unacceptable will be ultimately rejected.

Additional Tips on Plug Gage

Use Certain practical considerations are advisable to insure that plug gages are used correctly.

1. Holes to be gaged should be as clean as possible and free from burrs which would interfere with insertion.
2. The gage should of course be aligned with the hole for insertion; however, there are some gage features which can aid in this. A chamfer or radius on the gage end will help guide the gage into the hole. In addition, the GO gage may be vented for gaging blind holes so the air pressure within the hole will not interfere with the insertion of the gage.
3. The gage should be turned into the work slowly and carefully. A good fit will be snug. A plug gage should never be forced into a part.
4. In using a NOGO gage you should be certain that the gage is truly unable to enter the hole before the part is accepted. The procedure which is normally made to insert the GO gage should be followed to insure that the NOGO gage is being properly used.
5. When gaging steel the temperature of a steel gage and the part should be the same. Where the materials differ, however, such as tungsten carbide gage or a non-steel part, consideration should be given to actual temperature since the coefficients of expansion of the materials will differ. Standard temperature is 20 C (68 F). Gages are always calibrated at this temperature, and when the product is also at this temperature accurate gaging is insured.
6. Gages should be carefully protected against prolonged exposure to heat and moisture. After cleaning gages should be oiled carefully with a rust inhibitor and stored in containers or cases protected with rust inhibitor.
7. Any program of gage use should include periodic inspection of the gages to insure that they are not worn below tolerance or have otherwise become scratched or marred. GO gages are, of course, subject to more wear and should, therefore, be inspected more frequently. If a GO gage has worn below its tolerance it will begin to accept undersized holes. Excess wear on the NOGO gage, while not as common, will still interfere with the intended use of the gage. The more the NOGO gage wears the more acceptable parts may be rejected. Unlike the GO gage, unacceptable parts will never be accepted; however, the rejection of good parts may still be a costly price to pay for not having properly checked the NOGO gage.