

**International Journal of Innovative Research in Science,
Engineering and Technology**

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 4, April 2017

A Survey on Design and Manufacturing of Comparator Type Center Depth Internal Taper Gauge

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ABSTRACT: Today many industries are facing the challenge of maintaining quality with mass productions. However, due to this problem rejection of product/ job will occur. To reduce the rejection of job, quality control is necessary. This paper deals with the quality control of a tapered job by using taper gauge. Taper gauge is a mechanical device which is used for comparing taper depth with the master having a constant specific angle which is machined on CNC or VMC. This paper deals with the design and working principle of taper gauge used for comparing taper depth having taper angle 60 degrees.

KEYWORDS: Comparator, Taper, Internal Taper Gauge, CMM, EN19

I. INTRODUCTION

A comparator works on relative measurements, i.e. to say, it gives only dimensional differences in relation to a basic dimension. So a comparator compares the unknown dimensions of a part with some standard or master setting which represents the basic size, and dimensional variations from the master setting are amplified and measured.

Taper gauge is a Mechanical device used for comparing purpose. It is a device in the shape of the frustum of a cone. It is used to compare a job having internal tapers with a standard job having specific dimensions, to maintain the quality of a job. This device has a wide application in a metrology. A gauge can be described as "a device for measuring physical quantity according to some standard dimensions." this taper gauge measure internal taper as well as it can do the comparison between two jobs which contain a section like an internal taper. The important parameter which we have to compare as well as measure of an internal taper is a diameter at bigger end.

II. LITERATURE REVIEW

a) TWO PRECISION BALL METHOD

This method typically deals with checking an angle of an internal tapered hole, this method require two balls of different sizes, depth gauge, height gauge etc.

In this a small ball of radius R1 is first inserted in the hole in lower position and then depth H1 from upper surface of tapered hole to the top of the ball is measured. The size of small ball must be such that as to be seated somewhere in the hole. Then bigger ball having radius R2 is placed in the hole and distance H2 i.e. between the top of ball and tapered hole is measured with height gauge. In fig.1 O1 and O2 represent the centres of two balls. Now Draw O1S parallel to the XY of tapered hole in section and O2S perpendicular to O1S. Then $O2O1S = A/2$; (where A is the angle of tapered hole).

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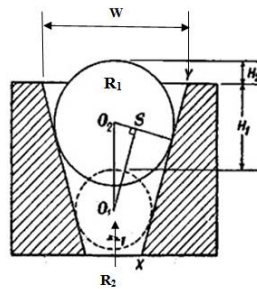


Fig.1 Two precision ball method [Ref.12]

Following formulas can be used to get taper angle (θ) & diameter at large end (w),
Where H_1 & H_2 Below surface are taken positive while above surface are taken as negative

$$\theta = \sin^{-1} \frac{(R_1 - R_2)}{(H_2 + R_2 - H_1 - R_1)} \dots\dots\dots (2.1.1)[\text{Ref.12}]$$

$$W = 2[R \cos\theta + (R + R \sin\theta - H) \tan\theta] \dots\dots\dots (2.1.2)[\text{Ref.12}]$$

b) SINE BAR

Sine Bar is an indirect measuring instrument which is used for measuring small angles. It consists of a bar to which two cylinders of equal diameter are attached at a precise distance apart. As this method is only used for measuring angle diameters at both ends cannot be determined by this method accurately

Some holes are often drilled in the body of the sine bar to reduce its weight and to facilitate handling. In using the sine bar for measuring an angle the job is placed on the bar and one end of the bar raised slowly till the top surface of the job becomes horizontal as shown by a dial gauge, the height H to which the end of the sine bar has to be raised to make its top horizontal is measured by precision gauge blocks. Then as shown in fig.2 a the angle θ to be measured is given by

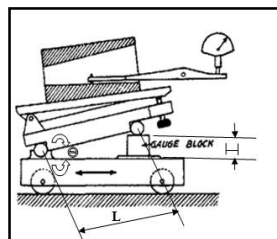


Fig. 2 Sine bar method for measuring taper angle [Ref.12]

From above figure we can get,

$$\sin\theta = H/L$$

c) PLUG & RING GAUGES

Plug gauge are one type of GO-NOGO gauge of a specific degree produced on a gauge.

In this method the gauge is put into the taper (in case of internal tapered hole) or over the taper (in case of external taper), and if the taper is correctly machined the large diameter of the taper will be between the gauge lines or step or sometimes engineers blue is applied over the plug gauge.

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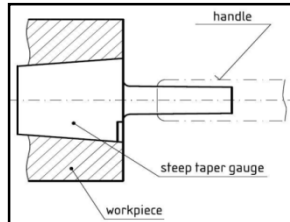


Fig. 3 Plug and ring gauges [Ref.9]

d) VERNIER CALLIPER:

This is a simple method to measure small tapers. To start measurement place the taper between 1-2-3 blocks and measure diameter across the 1 inch surfaces with the calipers, but make sure that the calipers are flat against the blocks and repeat measurement across 2 inch surfaces. Now subtract the smallest diameter from the largest and divide the result by two. The angle of ONE side of the taper will be the arc-tangent of this number.



Fig.4 Measuring taper with the help of vernier calliper [Ref.12]

III. OBJECTIVES

The main objectives of this Comparator Type Internal Taper Gauge are:

- To get optimal quality in minimum cost.
- To increase Probability of acceptance of lot.
- To reduce online inspection time.
- To feed machine Necessary action instantly in case of deviation found in job machined earlier to that one.

IV. SELECTION OF MATERIAL

When we talk about material selection, various factors should be considered while selection, they are as follows:

1. Material Properties.
2. Material Cost and Availability.
3. Environmental Effects.
4. Manufacturing Process.

All these factors are inter-linked to each other. By considering all this factor a material En19 is selected, by applying following procedure taken from Material Selection in Mechanical Design by Michael Ashby [Ref.11].

Four Basic Steps

- 1) Translation: expressing design requirements as constraints and objectives.
- 2) Screening: eliminating materials that cannot do the job.
- 3) Ranking: finding materials that best do the job.
- 4) Supporting Info: handbooks, expert systems, web, etc.

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EN19T – Mechanical properties in “T” condition	
Max Stress	850-1000 N/mm ²
Yield Stress	700 N/mm ² Min
0.2% Proof Stress	680 N/mm ² Min
Elongation	9% Min
Impact KCV	55 Joules Min
Hardness	248-302 HB

EN19 Specification Chemical composition	
Carbon	0.36-0.44%
Silicon	0.10-0.40%
Manganese	0.70-1.00%
Sulphur	0.040 Max
Phosphorus	0.035 Max
Chromium	0.90-1.20%
Molybdenum	0.25-0.35%

V. COMPONENTS OF INTERNAL TAPER GAUGE

The entire taper gauge is made up of EN19 steel [Ref.1] and machined on CNC machine and then it is through hardened. Hardening increases the carbon percentage in the material which further increases its hardness.

Hardening process is as follows:

- **Pre-heating :**

In preheating heat treatment Components are preheated to relieve internal stresses which are produced in them due to the machining process. This process includes heating the material from temperature of 550 to 560°C for at least 1 hour.

- **Loading in furnace:**

After preheating process the material is loaded in the furnace which is maintained at high temperature approximately of about 810°C and then this temperature is further increased up to 860°C to 880°C, and material is allowed a soaking time of 1 hour.

- **Oil quenching :**

Oil quenching (rapid cooling) is the process of cooling down the hot material treated in the furnace. This involves quenching of material in oil for 35-45 minutes.

- **As quench Hardening:**

In this process the material restore its hardness in order to resist indentation.

- **Tempering :**

In tempering heat treatment the material is heated from 360°C to 380°C in order to restore toughness and to adjust hardness.

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A. GAUGE BODY

The role of gauge body is to guide the center rod.

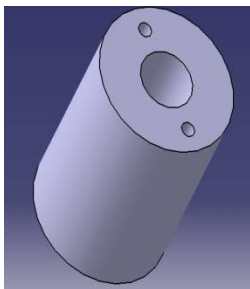


Fig.5 CATIA model of the gauge body



Fig.6 Front view of the gauge body



Fig.7 Top view of the gauge body

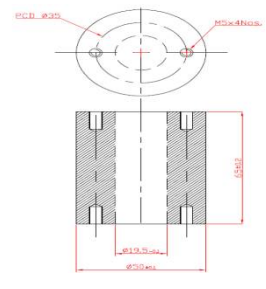


Fig.8 CAD model of the gauge body

B. MASTER

This component plays a vital role towards the gauging as it is used as the standard for comparing with the object which has to be gauged. It is also made of the same material EN19 and then Hardened. It is very important that this part should be accurate as this is the reference part.



Fig.9 Top view of master

C. CENTER ROD

The name of this component itself justifies that this is the component which is placed at center inside the gauge body. The center rod consists of a taper at its bottom end which helps us to gauge the work piece to be gauged. It is also made of the same material EN19 and then Hardened.

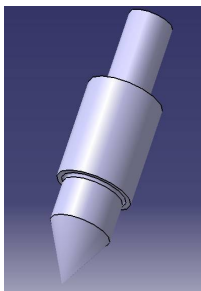


Fig.10 CATIA model of the center rod



Fig.11 Front view of center rod

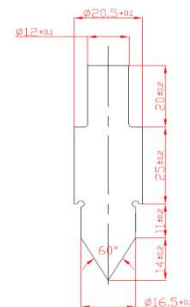


Fig.12 CAD model of the center rod

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D. TOP AND BOTTOM PLATE

This is the covering plates used to cover the body. Top plate is used to support the dial indicator which is used to compare the error of the work piece with the master. The bottom plate is used to support the center rod.

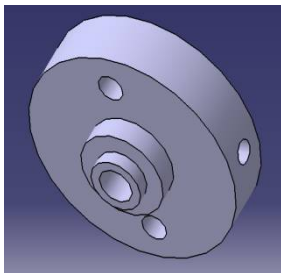


Fig.13 CATIA model of the top plate



Fig.14 Front view of the top plate

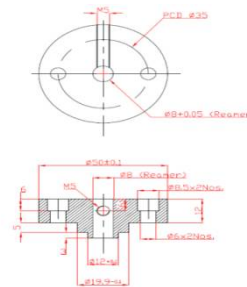


Fig.15 CAD model of the top plate

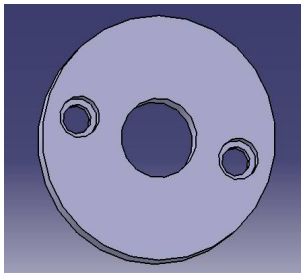


Fig.16 CATIA model of the Bottom plate



Fig.17 Front view of the Bottom plate

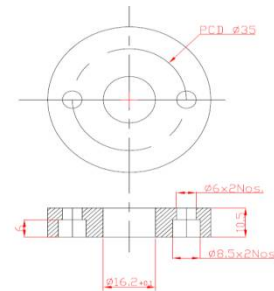


Fig.18 CAD model of the Bottom plate

E. DIAL INDICATOR

Dial indicator of 1 micron (depends on tolerances prescribed) is placed at the top of the body and supported by the top plate. There is a spring fixed at its bottom end which will give us the deflection in linear direction. The dial indicator will convert this linear deflection into the angular deflection and we can find out error.



Fig.19 Dial indicator

F. SPRING

One end of the spring is supported at the bottom end of Top plate while it's other end is placed on the center rod.

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Spring Calculation:

1. The weight of the gauge is around 1.4kg i.e. approx. 14N.
2. We assume that the initial compression of the spring is due to the self weight of the gauge and bolted joints.
3. We have chosen the spring of initial free length 51mm.
4. Due to geometrical constraints we have to compress the spring to its compressed length of 35mm which is achieved by tightening the bolts for fixing top plate.
5. Material for spring is mild steel whose modulus of rigidity is taken as 75GPa.
6. An amount of force to carry out the measurement for comfort of worker is being taken as 5N.
7. Mean coil diameter is being selected such that the spring does not come in contact with I.D. of gauge body which is of 20.065mm. So we choose mean coil diameter of 19.80mm.
8. Total no. of active coils being considered as '6' (total no. of active coil is 6 & inactive coil is 2 one at bottom and one at top).

Calculation of stiffness:

I.
$$K = \frac{F}{\delta}$$

Where, F = force required by hand to compress the gauge against master =5N
 δ =1.520mm (from drawing of Auto-Cad)

$$\therefore K = \frac{5}{1.520} = 3.289 \text{ N/mm}$$

II. We know,

$$K = \frac{Gd^4}{8D^3 N}$$

Where, d = wire diameter

D = mean Coil diameter

N= no. of active coil

$$\therefore 3.289 = \frac{(75 \times 10^3) \cdot d^4}{8 \cdot (19.80)^3 \cdot 6}$$

$$\therefore d^4 = 16.3418$$

$$\therefore d = 2.010 \text{ mm}$$

Standard available diameter close to 2.010mm is of 2mm. So we select wire diameter as 2mm.



Fig.20 Front view of the spring

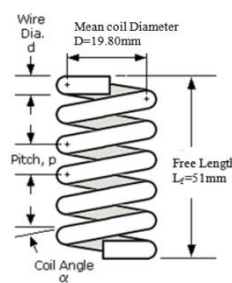


Fig.21 Spring

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VI. PROPOSED DESIGN OF GAUGE

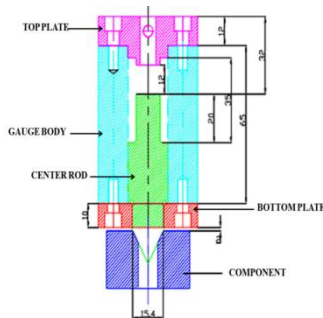


Fig.22 CAD model of the assembled gauge



Fig.23 Assembled Gauge

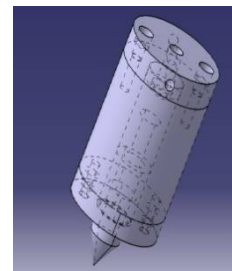


Fig.24 CATIA model of the assembled gauge

VII. WORKING PRINCIPLE

First we will adjust the dial gauge to zero by placing it on the master. The master is of the required dimension which work piece should have. So, place gauge as shown in fig.15 on the master piece and, set dial to “zero” in compressed state. Place gauge on the work piece that we have to inspect as shown in fig.16 and you can get error from dial indicator. When checking a taper hole, the taper gauge is inserted into the hole and a slight pressure is exerted against it. Then the dial indicator is observed for the errors. The error may be either positive or negative. With reference to the observed error the necessary action is fed to the machine.

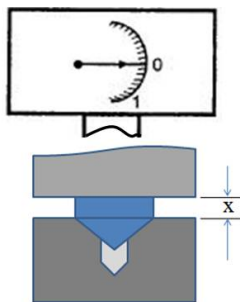


Fig.22 Comparing on master and Setting dial to zero

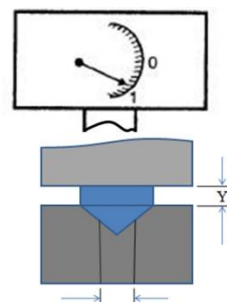


Fig.23 Gauging on work piece (X≠Y)

VIII. ADVANTAGES

- Capital cost of gauge is less.
- Gauging time is very low as compared to the CMM's.
- Online Inspection can be done.
- It is portable and robust compared to CMM's which are less portable.
- No Power requirement for operation.
- It is very useful for Mass Production.

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IX. CONCLUSION

This paper concludes that measurement of accuracy of taper plays an important role in manufacturing & inspection industries. Various measurement systems such as sine bar, two ball methods were used earlier but had some limitations. Naval types of designed gauge has capabilities to check taper of component .Various components were designed, manufactured & discussed in detail with their working .This paper also provides us the advantages of Internal Taper Gauge over the conventional methods used.

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