USING AND MEASURING PRECISION BALLS
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Balls are an integral part of every machine shop. They are found in bearings for both rotary and linear motion applications in machine tools; they act as contacts and pivot points in gaging equipment and tooling; and they serve as masters for both size and roundness gaging.

Balls are especially useful to check the parallelism of surfaces on gages with flat anvils and sensitive contacts, including many thickness gages and snap gages. The procedure is simple enough: Pairs of measurements are taken with the ball at the anvil’s 3:00 and 9:00, and 6:00 and 12:00 positions, and the anvil is adjusted accordingly.

But in order to perform this function, it is first necessary to confirm the dimensional accuracy of the ball. As with most dimensional standards, the accuracy of a precision ball should be roughly ten times greater than the resolution of the gage which it is used to master, and the instrument used to measure the balls should be ten times accurate as they are. Consequently, balls are commonly measured to microinches, or even fractions of microinches.

Comparator gages used to measure balls must not only measure in millionths -- they must also measure to millionths. They must be designed to the highest standards of stability and precision. As shown in Figure 1, the lower anvil of a ball gage is adjustable for parallelism with the sensitive contact. A frictionless mechanism may be used to ensure constant gaging pressure, and a V-notched saddle may be installed on the anvil to locate balls, with the help of a few degrees of backward tilt. The gage must be in a controlled environment appropriate for microinch measurements, with measures taken to guard against contamination and thermal influences.

Some users like to force the ball between the contacts, reasoning that the pressure tends to "wipe" away any dust or oil that could skew the measurement. Others prefer to retract the upper contact with a lifting lever before placing the ball on the stage, believing that this ensures consistent gaging pressure between trials and reduces stress to the mechanism. The jury is out on this one, so take your pick.

Now, what are we measuring for? When we specify a ball, we are usually concerned with its nominal diameter (D): the value by which it is identified, e.g., 1/2", 12 mm, etc. Within the range of its manufactured tolerance, this should coincide with the ball's single diameter (Ds), the distance between two parallel planes tangent to the ball's surface -- in other words, the results of a single gaging trial.

No ball, however, is perfectly round, and no two balls are perfectly identical. When using balls as gage masters, it is important to establish the level of uncertainty. To accomplish this, individual balls are measured several times, at random locations, to find minimum and maximum diameters. The difference between these, known as ball diameter variation, is simply calculated as follows: VDs = Ds max - Ds min.
Manufacturers of balls, and OEMs who purchase balls as components, utilize several additional parameters for quality control, and to sort balls into quality groups. Another basic parameter is ball mean diameter (Dm). This is the arithmetic mean of the largest and smallest single diameters of a ball, calculated thus: \( Dm = (Ds_{max} + Ds_{min})/2 \).

To account for production variation between units, manufacturers typically measure balls in lots of ten. Calculations of lot mean diameter (DmL) and lot diameter variation (VDL) are based on the mean diameters of the largest and smallest balls in the lot, as follows:

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DmL = (Dm_{max} + Dm_{min})/2 \\
VDL = Dm_{max} - Dm_{min}
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See Figure 2 for the relationship between individual balls and lot measurements.

All of the above are static measurements that can be performed using straightforward comparator gaging equipment. Bearing manufacturers, who require orders-of-magnitude more data in order to predict performance under dynamic conditions, perform additional measurements using circular geometry (roundness) gages. These can generate least-squares circles, analyze waviness geometry in a velocity-proportional fashion, and perform harmonic analysis to predict the "noise" effects of part geometry at various speeds and under various loads. These methods are beyond the scope of what we can cover here. But for most machine shops, which use balls mainly as measuring standards, highly precise comparator gages can provide all the data necessary to ensure accuracy.
Ball Measurements
Agree at Both Locations

Sensitive Contact

Lower Anvil

Adjusting Knob

Adjusting Knob