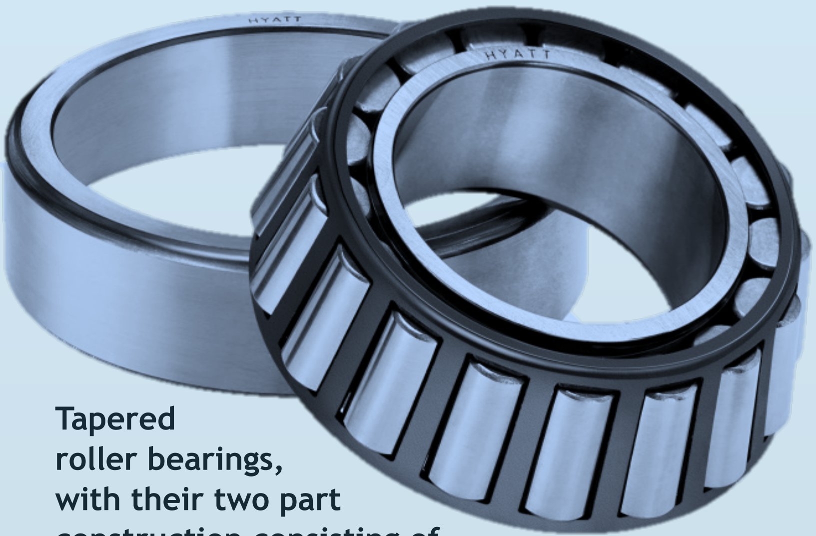
# Measurement Accuracy Considerations for Tapered Roller Bearings




**Tapered roller bearings, with their two part construction consisting of an outer race called a cup and inner race and rollers known as a cone assembly, lend themselves towards solving difficult assembly problems where high load carrying bearings are required.**

Cups and cone assemblies are separable and can be installed in the end assembly at different independent operations. The tapered roller bearing's ability to support both axial and radial loads is also a key feature to its selection in critical assemblies that support the unique loads generated by helical gearing such as used in transmissions and other power transfer products.

Two tapered roller bearings are often used and mounted in a cup back-to-back arrangement, sometimes referred to as an indirect mounting arrangement. (Figure 1)

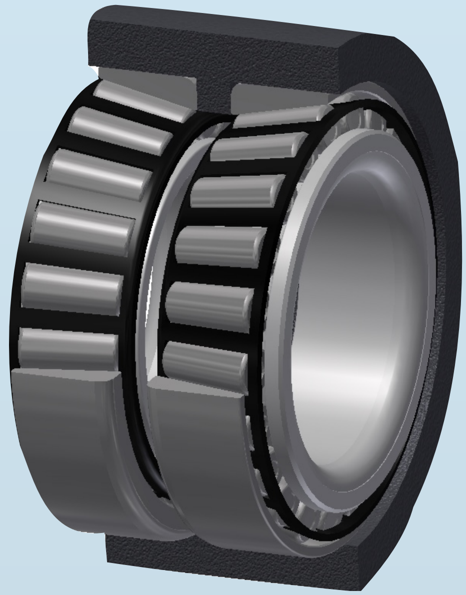


*Fig. 1 Indirect Mounting*

Designers of gearing systems often will seek arrangements that can offer little to no movement or "play" of the components mounted on the shaft attached to the gear. Tapered roller bearings, if assembly is properly controlled, are ideally suited to these applications.

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The ideal range of settings for preload/ endplay can be determined by interpreting a curve similar to Figure 2.

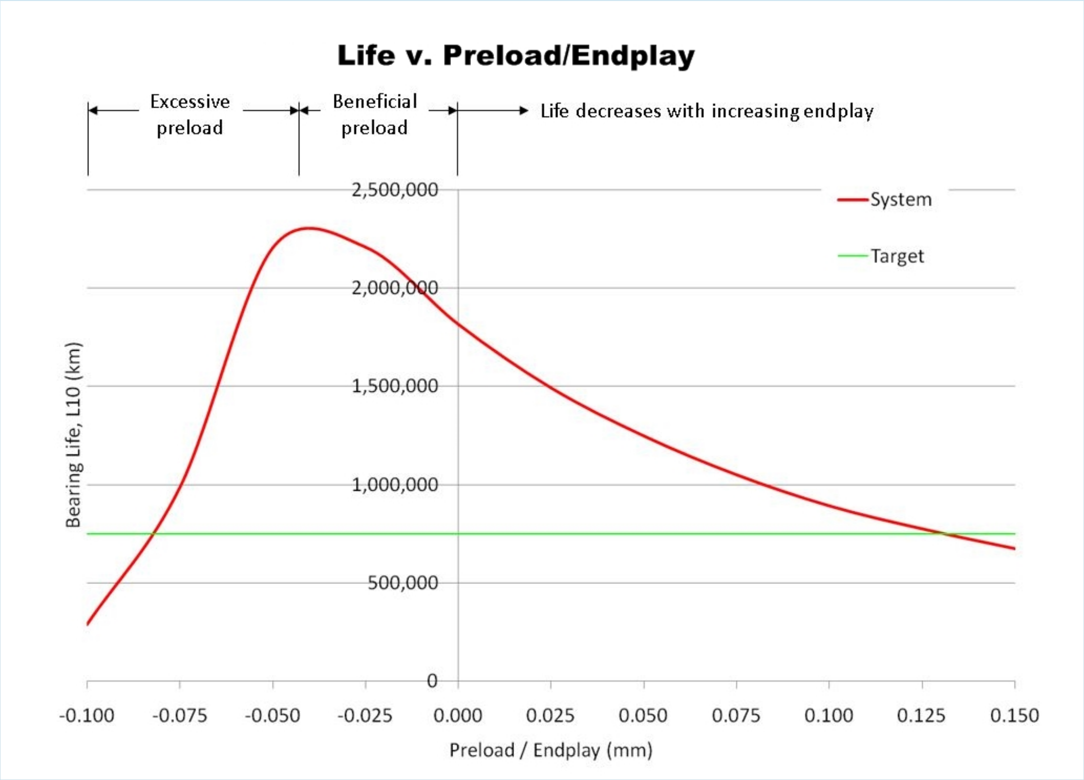


*Fig. 2 Life v. Preload/Endplay*

Tapered roller bearing preload, properly controlled, can actually enhance the life of the bearing system as shown on the curve. Too much preload and the life will drastically diminish and parasitic energy losses will increase. Determining the exact setting needed is the key to a high performance system where both long life for reliability, low system parasitic energy loss, and no play are required.

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## Case Study

Figure 3 shows an application of indirect mounting of tapered roller bearings.

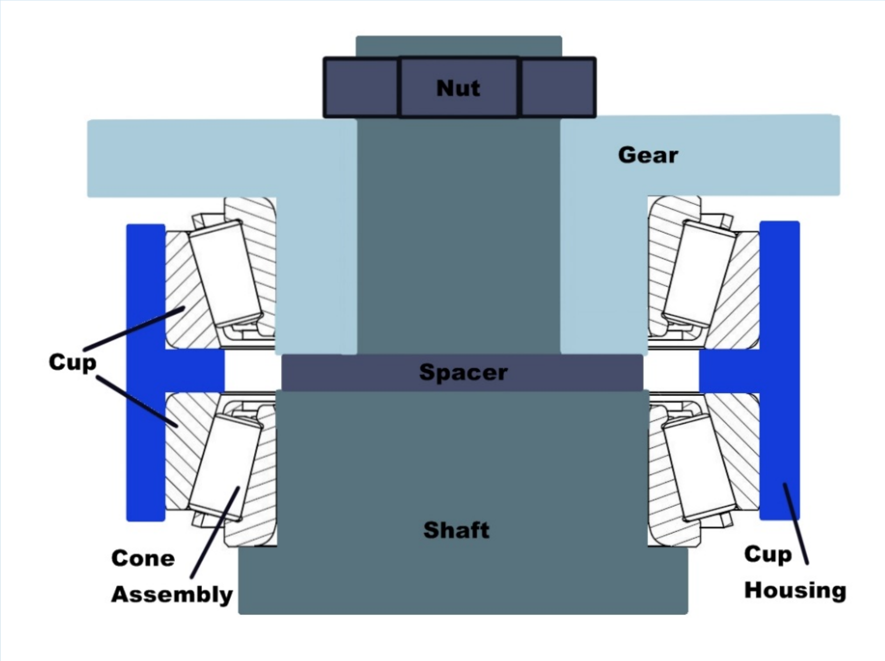


*Fig. 3 Case Study application*

The drawing shows two tapered roller bearings. The lower bearing has its cone assembly mounted to a vertical shaft. The lower cup and upper cup are mounted to a fixed housing. The upper cone is press fitted to a hub on the bottom of a gear. A selected spacer is installed between the face of the shaft and the face of the gear hub. The spacer is selected to impart a slight preload to both upper and lower Tapered Roller bearings. A nut installed at the end of the shaft is torqued to a constant value for all assemblies.

Of utmost importance for both efficient assembly of the shaft and gear arrangement and long bearing life of the tapered roller bearings is the accurate sizing of the spacer used between the two contact faces. If the spacer is too small the axial preload on the two tapered roller bearings will be excessive and the torque to turn the two bearing will be very high. If the spacer is too large, the shaft will have too much play which may lead to noise issues in the assembly and as our life v. endplay curve illustrates, shorter life for the bearings if the endplay is excessive.

The issue then reduces down to the best way to accurately gauge the space between the two faces of the shaft and gear hub in the shaft-gear assembly so that the spacer is selected correctly every time.

Since the cup and cone assembly of the upper bearing are separable they are installed on their respective components at different times and assembly stations. As the two assemblies are separate prior to the spacer being installed there is an opportunity to measure the distance from the shaft face to a reference point on the upper cup. Similarly, the distance from the gear hub face to a reference point on the cone assembly can also be obtained.

## Measurement of the cone assembly reference point to gear hub face

The gear and its installed cone assembly can be presented for measurement with the cone assembly small end facing up. This provides the advantage of allowing gravity to assist in seating the large end of the rollers against the flange rib of the cone ring, which is its intended running position under load.

A good method to then obtain the distance from the hub face to the cone assembly reference point is to use a cup which has its inside contact portion in the geometric shape of a conical section. By using known masters the gear hub face to cone assembly reference point distance can be obtained reliably and accurately. Spinning of the cone assembly in the gauge cup will further increase accuracy ensuring the rollers are properly seated after only a few turns.

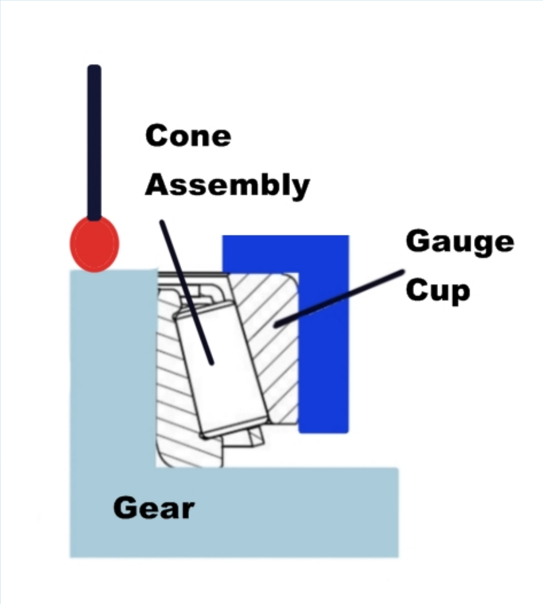


*Fig. 4 Cone assembly- gear face gauging*

## Measurement of the shaft face to cup reference point

Intuitively, it might be concluded that the best way to measure the shaft face to cup reference point would be to use a cone assembly. Unfortunately this would not work in practice as the rollers and cage are free to move vertically, restricted only by the rib located at the small end of the cone. Upon contact with a cup, some of the rollers would move up, but seating would not be guaranteed.

Rotation of the cone assembly would eventually seat the rollers, however time to do this reliably would hinder assembly efficiency. Adding the rotation feature would also make the gauge unnecessarily complex.

The simplest method would be to use a fixed, solid gauge head that would simulate the interaction of a cone assembly with properly seated rollers.

Again, one would probably assume the best shape to use would be a conical section. The conical section would be able to enter the cup, seat against the inside and allow the proper measurement of the shaft face to cup reference point.

Unfortunately, this also would not work, but not for obvious reasons.

The cup has a more complex geometry than meets the eye. Manufacturers have discovered that the addition of a slight convex crown to the contact face of the cup improves its life under misalignment in application. The height of this crown is controlled within tolerance limits.

The angle of the conical section of the cup is also controlled within tolerance limits and can therefore vary within those limits.

Finally, if the cup is press fit into its housing, as it is in our example, the inner shape of the cup will change to emulate the shape of the bore of the housing which is often manufactured to tolerances several magnitudes looser than that of the cup diameters. The press fit also will distort the angle of the conical inside of the cup. The thicker cross section of the cup will shrink less than the thin cross section at the large end of the cup. This will vary with the press fit size and will alter the angle of the cup conical section.

The combination of all these variables will make gauging a cup with a solid conical section very inaccurate as the contact reference point will be highly variable from part to part assembled in its housing.

Fortunately these variables, if controlled, will not affect the life of the Tapered Roller bearing once properly assembled. The rollers and cone conical section also are crowned to accommodate differences as mentioned above.

So then, what is the best shape to use in these types of gauges to simulate a cone assembly?

We have found that the best shape to use is a section of a torus (see figure 5).

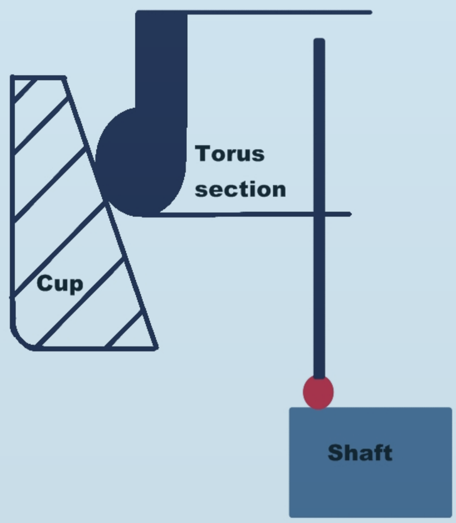


*Fig. 5 Torus interacting with cup conical section*

The torus is ideal for this application as its contact with the cup conical inside forms a locus of points around the diameter. This accurately simulates the contact of the crowned rollers of the cone assembly to the crowned cup conical inside.

Gauge Repeatability and Reproducibility (GR&R) is vastly improved over the section of a cone method as the torus can ignore differences due to reasons above the same way the cone assembly can in operation.

Offsets to accommodate the gauge diameter location can quickly be established to make this a reliable method for a robust assembly process.

## Verification Methods

The spacer now can properly be sized and installed. Verification of a proper installation can be done via dynamic torque measurement of the turning of the shaft. Manufacturing techniques for the cup, cone, and roller surface finishes are robust and repeatable making their variation negligible during torque measurement. All this ensures a reliably produced assembly manufactured efficiently that will limit and control system parasitic energy losses.

***Hyatt is the industry leading supplier of tapered roller bearings for wheel end applications for the truck and trailer industries.***