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Roller Bearing Application: *A Case Study*

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Credit: 2 PDH

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Introduction

Anti-friction bearings are composed of ball bearings and roller bearings. Ball bearings, as the name suggests, have rolling elements that are spherical. Rolling contact bearings are composed of cylindrical roller bearings and tapered roller bearings also named after the shape of their rolling elements. This course deals with cylindrical roller bearings. Cylindrical roller bearings are very versatile engineer tools that come in a number of different configurations. They are designed to support primarily radial loads and, to a lesser extent, thrust loads. Radial loads act perpendicular to the bearing axis of rotation while thrust loads act parallel to the axis of rotation. This course begins with a step-by-step analysis in the application of cylindrical roller bearings supporting a spur gear. It follows with drawings of a number of different applications for cylindrical roller bearings including expert analysis of each.

A Case Study

The following pages contain a step-by-step detailed review of the procedure used to determine the cylindrical roller bearings needed for an application. Bearing selection, operating life calculations, and the completed design are discussed to demonstrate the unique design flexibility offered by cylindrical roller bearings.

Figure 1 has a drawing of a spur gear supported by two blanked- in spaces where the bearings are to be located. Along with the diameter restrictions shown, the design requires that the gear and the coupling flange on the left side of the shaft be assembled and removed from the right without interference.

The design employs a spur gear which imposes radial loads only. There are no other loads that the bearings must support. The coupling on the left delivers torque without imposing any thrust loads on the gearshaft. Radial loads with little or no thrust loads, make cylindrical roller the bearing of choice for this application.

The radial load from the pinion gear teeth reaction is 2,800 pounds; the speed is 1,020 revolutions per minute; and the desired life is 7,500 B10 hours. B10 hours is the life that 90 percent of the bearings will operate without failure under the load and speed given, and is the standard used for all anti-friction bearings.

An application of this type requires that the shaft be supported axially to ensure the correct positioning of the gear. Figure 2 shows that the bearing outer rings have opposing ribs to ensure proper axial positioning of the gear. Each inner ring has two ribs to contain the shaft. The bearing on the left must have an outer ring rib inner diameter larger than the shaft coupling diameter of 2.750 inches. The bearing on the right is mounted in the cover. Assembly is accomplished as follows:

- The outer ring of the left bearing is installed in the housing.
- The complete shaft assembly with both, bearing inner ring assemblies and the pinion gear in place, is inserted from the right side.
- The outer ring of the right bearing is installed in the end cap which is then assembled to the housing and bolted in place.

Now that the bearing types and assembly procedure have been developed, it is time to determine the bearing capacities that are needed to give the desired life of 7,500 B10 hours. The equation for bearing B10 life is as follows:

$$L_{10}=3000(C/P)^{10/3}(500/S)$$

- L_{10} is the expected operating life under the load and speed specified.
- C is the capacity of the bearing in pounds and is found in industry catalogs.
- P is the radial load which equals $2,800/2=1,400$ pounds for each bearing.
- S is the application speed of 1,020 rpm.

Inserting the values into the equation and solving for C reveals that a bearing with a capacity of at least 2,280 pounds is required for the application. Also, the left bearing outer ring rib inner diameter must be greater than 2.750 inches so that the shaft assembly coupling flange can be removed to the right from the gear case. In addition, the roller assembly outside diameter must be less than the 3.250 inch pinion root diameter in order to clear the lower gear (shown on Figure 2) when inserting the shaft assembly from the right.

There are standard industry bearings that meet all the requirements for this application. The left bearing has a 2.1654" bore, 3.5433" OD, .7087" width, outer ring rib inner diameter of 3.045", roller assembly outer diameter of 3.170", and capacity of 2,350 lbs, all of which meet application requirements for the left bearing.

For the right bearing, a standard size bearing with a bore of 1.5748", an outer diameter of 3.1496", a width of .7087", and a capacity of 2,500 lbs is selected. The shaft is stepped under the gear and under the right bearing so that the gear press fit mounting surface does not become damaged when pressing on the left bearing and the right bearing mounting surface does not become damaged when press fitting the gear. Shaft and housing bearing mounting surfaces are held to extremely close tolerances and have very restrictive surface finish requirements. Normally with a rotating bearing inner ring and a stationary outer ring such as the case in this application, the rotating inner ring is a press fit and the stationary ring is predominately a loose fit. A table of bearing shaft and housing fits is as follows:

Position	Shaft Size	Bearing Bore	Resultant Fit
Left	2.1666-2.1659	2.1654-2.1648	.0005T-.0018T
Right	1.5756-1.5752	1.5748-1.5743	.0004T-.0013T

Position	Housing Bore	Bearing OD	Resultant Fit
Left	3.5438-3.5428	3.5433-3.5427	.0011L-.0005T
Right	2.6778-2.6768	2.6772-2.6767	.0011L-.0004T

As it can be seen from the chart above, rotating inner rings require a press fit on the shaft so that there is no relative movement between the two when the shaft is rotating. The fits for outer rings which do not rotate in this application are predominately loose for installation reasons, and also, so that bearing internal clearance from an excessive press fit is not reduced an excessive amount causing bearing internal radial preloading and failure. Also, outer rings with excessive looseness may rotate in the housing (journaling) when the bearing is rotating causing excessive housing wear and premature failure. The Annular Bearing Engineers Committee (ABEC) establishes tables of bearing fits for various applications ranging from standard to super precision.

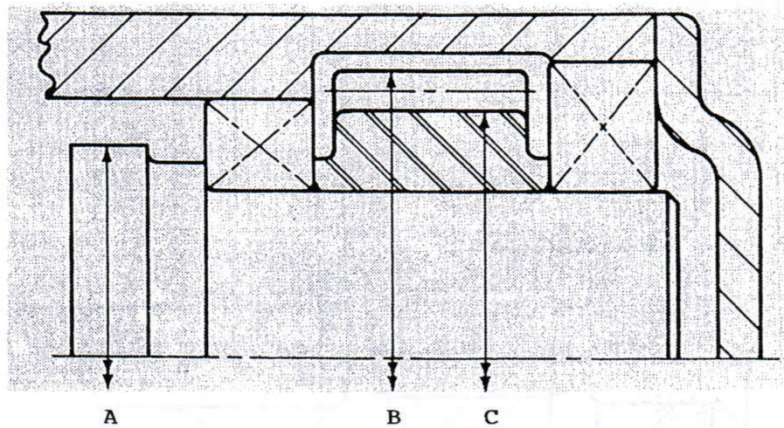
The lubricant for such a design will be gearbox oil. The level of oil in the gearbox is set at just above the lowest active member which, when rotating, splashes lubricant throughout the gearbox. Sometimes channels are provided in the housing and cover to direct oil to both bearings.

The design was made possible by using cylindrical roller bearings with u-shaped inner rings and single-ribbed outer rings. U-shaped outer rings and single-ribbed inner rings could have also been used. Figure 3 lists other configurations that are available with cylindrical roller bearings. Following that are cylindrical roller bearing application drawings with expert analysis.

Figure 1

Roller Bearing Application

Bearing Proposal Drawing



- Dia. A = 2.750" - Coupling Flange OD
- Dia. B = 3.750" - Pinion Spur Gear OD
- Dia. C = 3.250" - Pinion Gear Robot Dia.

Figure 2

Roller Bearing Application

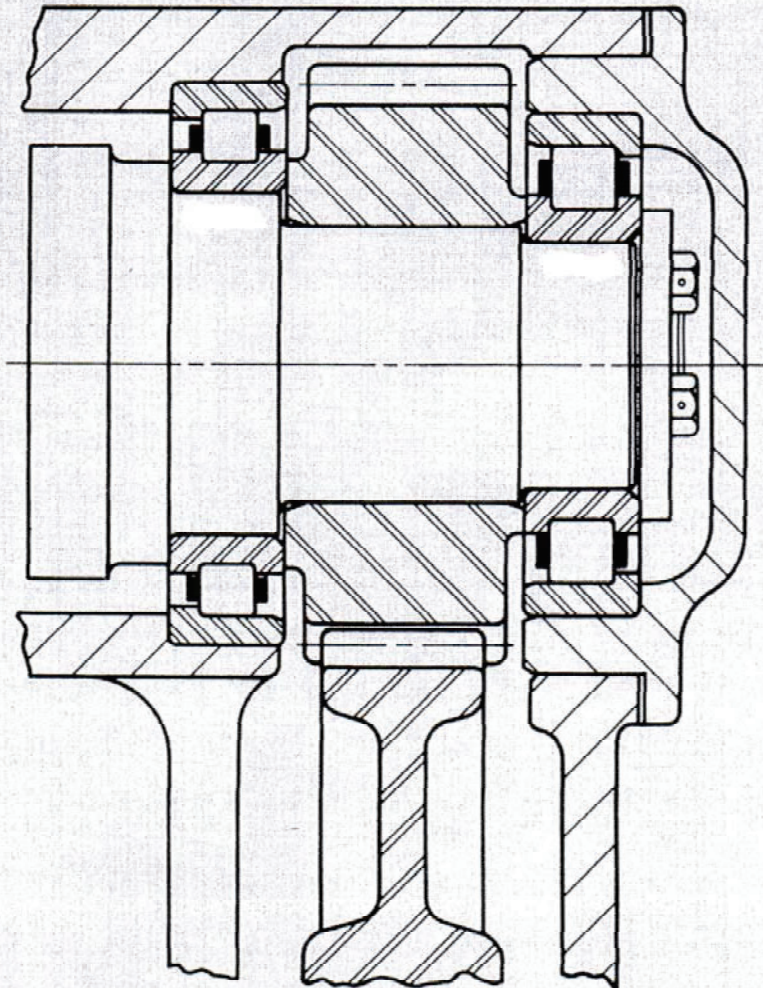
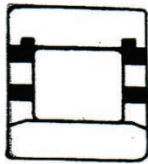
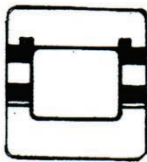


Figure 3

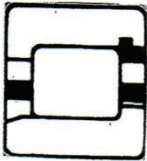
Cylindrical Roller Bearing
Design Configurations



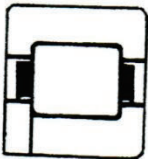
Low cost two-part bearing. Inner ring can be removed and bearing run directly on shaft.



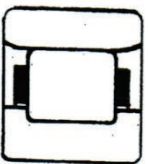
Non-separable bearing design for ease of shipping, handling, and assembly.



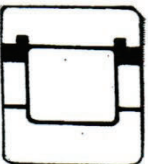
Ribs on opposite sides of bearing allow for supporting one-directional thrust.



Inner ring plate allows two-direction thrust. Has formed bar and side ring high speed separator.



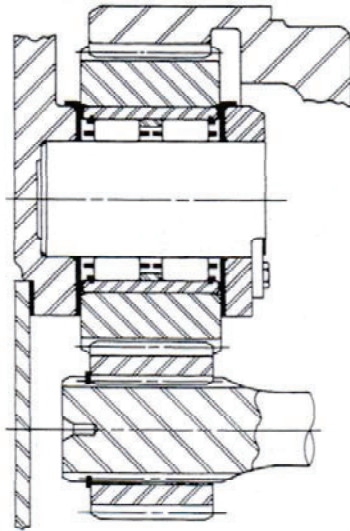
Outer ring can be removed and bearing run directly in housing. Has high speed separator.



No separator allows full complement of rollers and maximum load capacity. Speed limited.

Figure 4

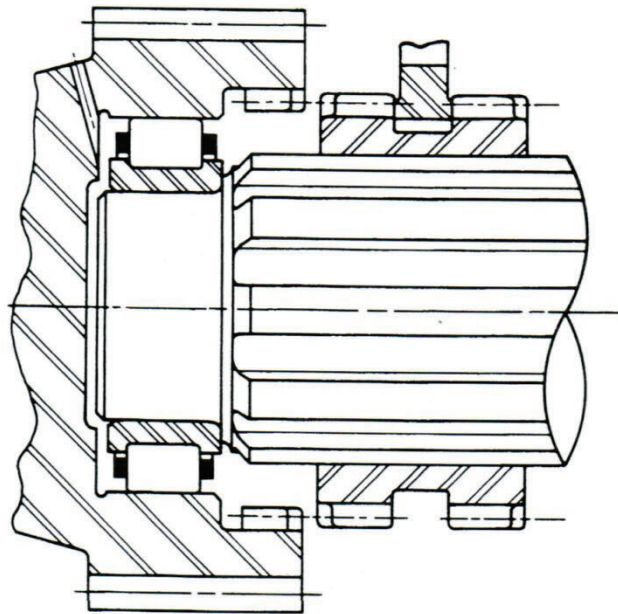
Roller Bearing Application



A double row cylindrical roller bearing supports a planet gear. Elimination of the inner ring and the low profile dual set of rollers serve to support heavy loads and afford ample radial space for the shaft and gear rim. Axial support is provided for the gear by the use of thrust washers.

Figure 5

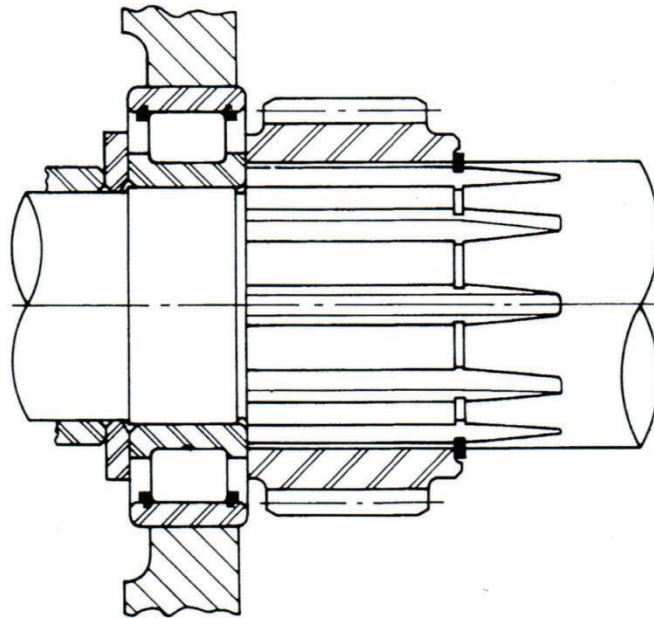
Roller Bearing Application



A cylindrical roller bearing without an outer ring permits a more compact shifter mechanism design without minimizing bearing life.

Figure 6

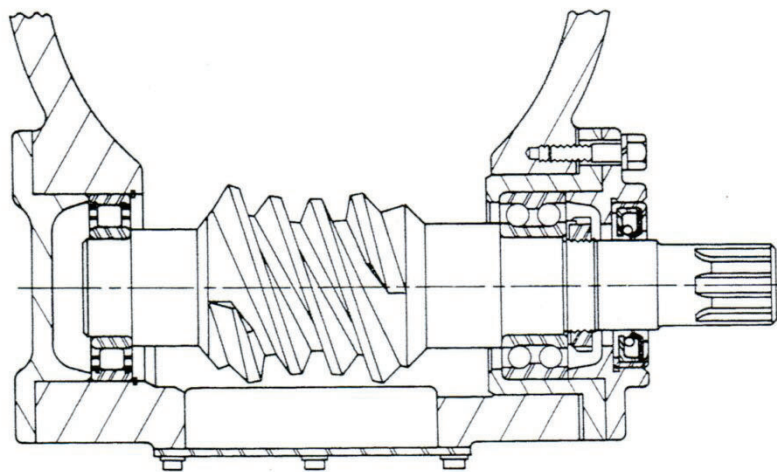
Roller Bearing Application



A cylindrical roller bearing without a separator enabling the assembly of extra rollers offers maximum radial load capacity for this transmission countershaft. The inner ring is axially clamped while there is no need to provide axially clamping for the outer ring.

Figure 7

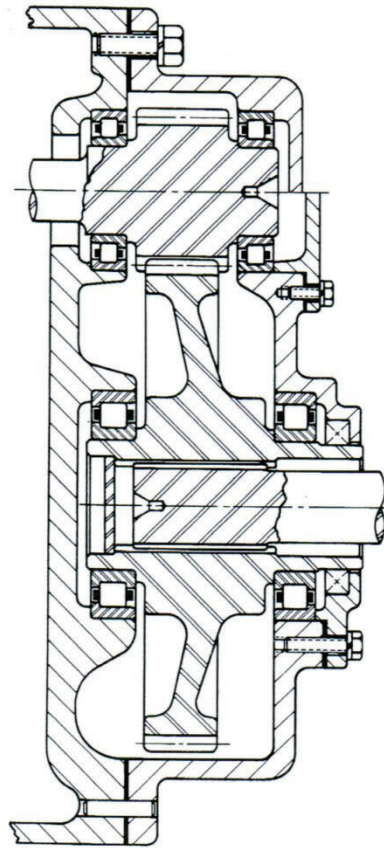
Roller Bearing Application



A separable cylindrical roller bearing supports one end of a worm gear. The outer ring and roller assembly are mounted in the housing and the inner ring is press fitted on the shaft making installation and removal of the worm gear possible. The double row ball bearing on the right provides radial as well as axial load support.

Figure 8

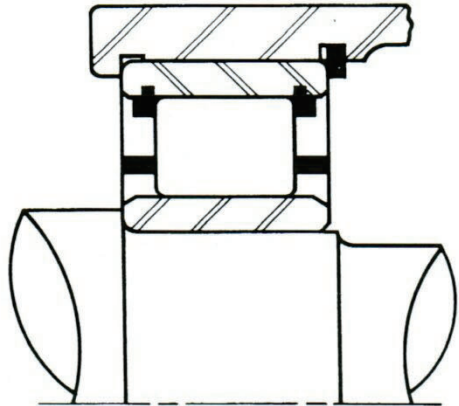
Roller Bearing Application



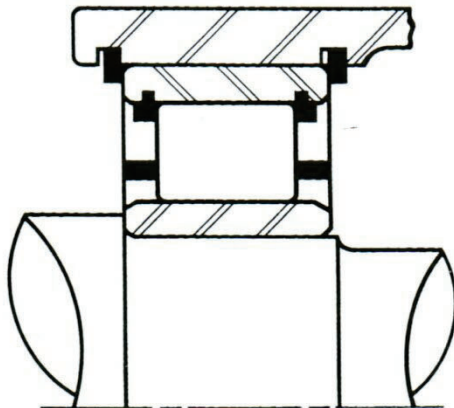
Separable cylindrical roller bearing assemblies support a pair of spur gears providing maximum radial load carrying capacity and simplifying assembly methods and production. Alternate production methods are shown for machining the house bores for both shafts. The configuration above the centerline illustrates separately machined bearing houses bores while the design below the centerline employs the use of separate covers which permits both bores to be machined at once.

Figure 9

Outer Ring Retainment



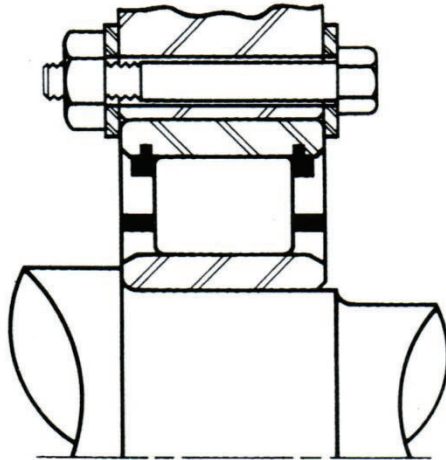
This outer ring is retained by the housing shoulder and a snap ring.



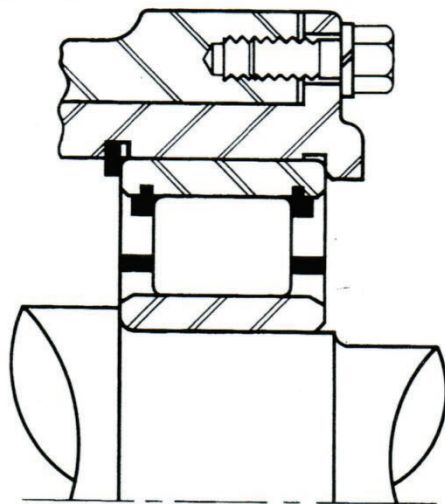
This outer ring is retained by two snap rings.

Figure 10

Outer Ring Retainment



Through-bolt and washers retain outer ring and roller assembly.



Bearing cartridge used to provide space for gear assembly and removal.

Summary

This course provides the steps necessary to specify cylindrical roller bearings in supporting a spur gear. It explains how to specify the correct bearing pair given the operating life, size, and assembly procedures needed in a specific design package. It concludes with presenting drawings of cylindrical roller bearings in mechanical equipment with expert analysis.