machine design

Setting techniques for tapered roller bearings

Motion System Design

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Here is what manufacturing and plant engineers should know before setting and installing tapered roller bearings in new or repaired products

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Tapered roller bearings can be set to any desired axial or radial clearance when installed in equipment being manufactured on the production line. This feature lets a designer control bearing clearance to meet operating conditions, and thereby optimize bearing and machine performance. Tapered bearings can be set by a variety of methods, either manual or automatic. You can also get them as preset assemblies. Here, we describe each method to help you select the most practical approach for your equipment. Table 1 summarizes the capabilities and limitations of each method as well as the skill level and tools required.

Bearing setting

The term "setting" indicates a specific amount of end play (axial clearance) or preload in a bearing. Unlike other rollingelement bearings, tapered bearings don't require close control of shaft or housing fits to obtain an accurate setting. Because they are mounted in pairs, Figure 1, their setting depends mostly on the location of one bearing row relative to the other on the shaft.

Bearings can be set to achieve one of two conditions:

• End play — Axial clearance between bearing rollers and races, which allows axial shaft movement when axial (thrust) force is applied.
• Preload — Axial interference between rollers and races so there is no axial shaft movement.

Generally, a setting ranging from near zero to slight preload maximizes bearing life. Some applications use moderate preload to increase rigidity of highly stressed parts that would otherwise be adversely affected by excessive deflection and misalignment. Excessive preload, though, can drastically reduce bearing fatigue life or cause high temperatures that can quickly lead to bearing damage.

Manual setting

Production-line assembly workers often set bearings manually for equipment that is manufactured in low-tomoderate volume, and where a non-exact and wider-than - normal range of end play is acceptable. No special tools, gages, charts, or fixtures are typically required. In a truck nondriven wheel, for example, manual setting consists of tightening an adjusting nut on the end of the shaft while rotating the wheel until a slight bind is felt. Then the assembler backs off the nut 1/6 to 1/4 turn to the nearest locking hole or enough to let the wheel rotate freely. The adjusting nut is then locked in position.

Setting accuracy depends on the assembler's skill in determining when the wheel binds slightly. For large, complex machines, or high-production applications, manual setting may be too troublesome, time-consuming, or inappropriate. In such cases, preset bearing assemblies and automated setting techniques offer better alternatives.

Preset bearing assemblies

Many machines require closely positioned bearing arrangements. To facilitate bearing setting in such cases, machine manufacturers often use preset, or spacer, bearings. Though various types are available, most of them use customfitted spacer rings between bearing rows to control internal clearances, Figure 2. These matched spacers can't be interchanged with other bearing assemblies.

Manufacturers supply each preset bearing with an *unmounted* internal clearance or bench end play (BEP) that is chosen to provide the desired mounted setting for the application. The *mounted* bearing setting depends on this BEP plus the shaft and housing fits. Typically, assemblers tight-fit either the shaft or housing on the rotating bearing member, producing a mounted setting range of less than 0.008 in. To apply a preset assembly to a machine, simply mount and ensure proper clamping of the bearing components through the spacers.

Preset bearings are typically applied in planet pinions, transmission idler gears, sheaves, conveyer idlers, and large gearboxes, plus fan hub, water pump, and idler pulley shafts.

Automated setting techniques

Bearing manufacturers have developed various automated bearing setting methods. For example, our company offers five methods: Set-Right, Acro-Set, Projecta-Set, Torque-Set, and Clamp-Set. These methods offer reduced set-up time and assembly cost, plus consistent and reliable settings. In most cases, they can be used in both production and field service environments.

Set-Right. This method evaluates the effect of accumulated tolerances on bearing setting. The laws of probability indicate that the combination of all low and high tolerances in an assembly will rarely occur. Therefore, for a normal distribution of parts, the dimensional stack-up of parts tends to be near the middle of the total possible tolerance range.

Generally, this method requires close control of some mounting tolerances, as well as bearing tolerances. The objective is to control only the most critical tolerances affecting bearing setting, whether in the bearing or mounting components, Figure 1, so the setting is within the desired probability range for 99.73% (6 3 sigma) of all assemblies. No adjustment steps are required. The worker simply assembles and clamps the machine components.

This method requires that the tolerances and probable distribution of bearing mounting dimensions be consistently maintained on all units. Also, the correct bearing tolerances (specified by ABMA class and Timken code) must be applied for both production and field replacement.

If the setting range is too large for the application, consider the following variation.

Spin-Right variation of Set-Right. Assemblers apply this method to further reduce the bearing setting range. First, divide the normal bearing setting range by a factor of 2 or 3, depending on which is necessary to obtain an acceptable setting range for the application. For example, assume the normal bearing setting range is 0.018 in. and the application requires 0.000 to 0.009-in. end play. The assembler divides the normal range by a factor of 2, obtaining a 0.009 in. shim size for use between end plate and shaft, Figure 1. The following steps are applied:

1. Assemble the unit without a shim or seals and spin the shaft to determine if the bearings have end play or preload, Figure 3. If the shaft spins freely, end play is present, and the bearings are properly set.

2. If the shaft doesn't spin freely, the bearings are preloaded and a 0.009-in. shim must be installed. A second spin check should produce free rotation.

If preload is desired, apply the procedure in reverse. If the shaft rotates freely, the bearings are not properly set and a 0.009-in. shim needs to be removed.

Typical applications include tractor power take-off assemblies, farm equipment wheels, geared speed reducers, planet pinions, and construction vehicle sprockets and torque hub units.

Acro-Set. This widely applied technique assumes that with reasonably uniform parts, the total deflection of any assembly will be consistent for a given applied load.

Technicians first establish the deflection characteristics for test units by measuring the gap between end plate and shaft end for different set-up loads, Figure 4. This establishes a constant amount of deflection for a given load. Adding this deflection constant to the desired bearing setting gives a total constant. On the production line, adding the measured gap to the total constant gives the required shim thickness for each unit. Assemblers generally select the shim thickness from a chart that is based on gap measurements taken at two positions 180 deg apart, Table 2.

To apply this method:

1. Apply the set-up load, P (based on the tests) through two cap screws, 180 deg apart, Figure 4.

2. Rotate the bearings while applying the load, and measure the gap.

3. Select the shim thickness from the chart (Table 2).

4. Install the shim between end plate and shaft end, then tighten all cap screws.

This method is commonly used for large, heavy assemblies. Applications include transmissions, axle assemblies, planetary pinions, differential shafts, geared speed reducers, and off-highway truck wheels.

Projecta-Set. Though similar to Acro-Set, this method adds a gaging fixture that lets the assembler project an inaccessible gap (or reference surface) to a position where it can be measured. Built-in dial indicators or LVDTs usually display the gap readings, Figure 5. Here, the assembler sets the pinion bearings by inserting a spacer between the two cone front faces.

The required steps are:

1. Place the assembly, except for upper cone (with cage and rollers) and gage, on a press table. (The press clamps the upper cone in place, though some gages accomplish this with a threaded nut arrangement.) Position the gage on the upper bearing cup taper and add the upper bearing cone.

2. Apply a press load to clamp the gage through the two bearing cones. A Belleville spring in the gage applies an axial load to the bearings. 3

. Oscillate the gage to seat the bearing rollers. The LVDTs measure axial displacement between the two gaging members and a digital readout displays the required cone spacer size.

4. Apply the required spacer between the two cones.

This method is capable of closely controlled setting ranges (0.002 to 0.004 in.) and is especially suited to high volume applications. Separate gages or interchangeable components are required for different bearing series. Also, an alternate method (typically Acro-Set) must be used for field servicing.

Torque-Set. This method is based on the principle that rolling torque required to rotate a bearing is proportional to its preload. A technician establishes this relationship by testing several units under load, then prepares a chart showing what size shim to use for a given torque. In production, the assembler measures initial bearing rolling torque (preferably with a torque wrench) and selects the shim size from the chart to obtain the desired bearing setting.

The steps required are:

1. Assemble the unit with a standard thickness shim, which ensures a bearing preload, Figure 6. The preload differs for each assembly depending on accumulated tolerance variations.

2. Measure the bearing rolling torque.

3. Select the shim thickness for this torque value from the chart (based on testing).

4. Install the shim and tighten the cap screws.

This method is not recommended for use with an unbalanced load (due to clutch plates or caliper brakes) that would cause the torque to vary, or for field servicing with used (run-in) bearings.

It has been used for many years on industrial and automotive applications including pinion and differential shafts and gearboxes.

Clamp-Set. Limited to lightly loaded applications with minimal vibration and shock, this method uses a spacer ring that deforms under load to accommodate axial tolerances in a machine assembly. The bearing component (cup or cone) adjacent to this compensating ring must be loose fitted. Assembling the bearing, Figure 7, compresses the ring and closes the gap between cup carrier and housing. Removing the load lets the system (ring, bearing, and housing) recover by a known amount. Technicians determine the amount of recovery in a few test units by measuring the gap after load is removed. Adding this gap to the required bearing setting gives a shim thickness that will be applied to all assemblies.

Setting procedure:

1. Assemble the unit with compensating ring.

2. Apply a clamp load to the cup carrier (while rotating the shaft).

3. Release the load, producing a gap between carrier and housing.

4. Install a shim of predetermined thickness (based on testing previously described) between carrier and housing to obtain the desired bearing setting.

Typical applications are geared speed reducers, conveyers, pumps, air compressors, and small farm tractor transmissions.