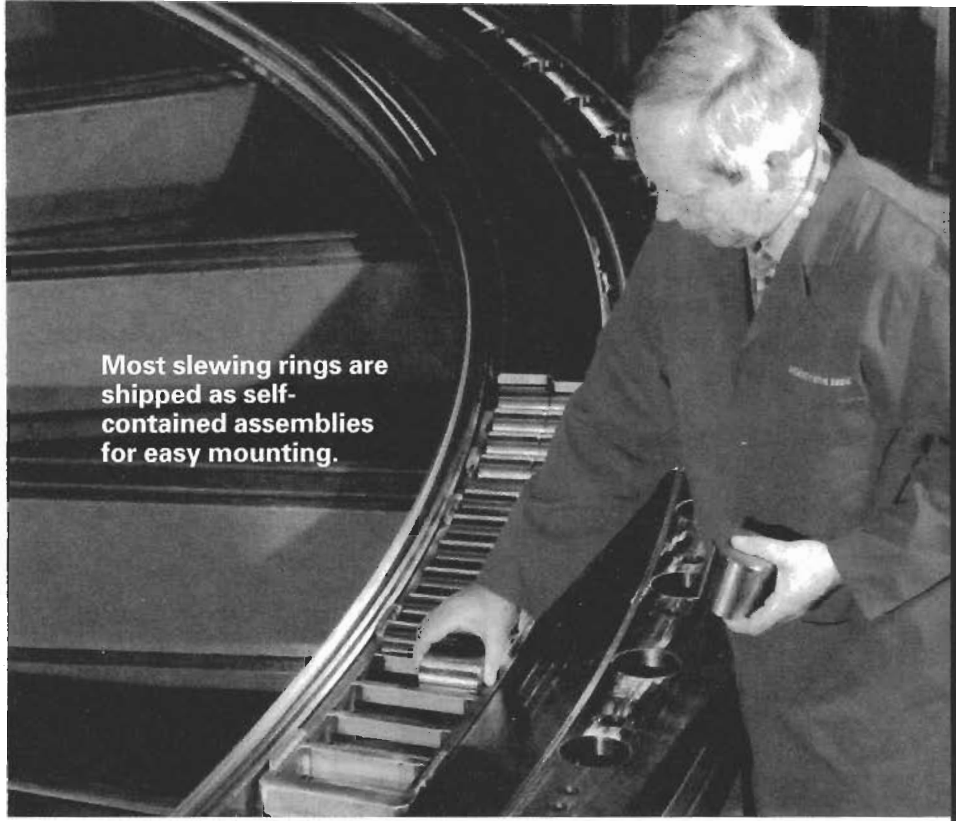


Most slewing rings are shipped as self-contained assemblies for easy mounting.

Ringing true: Slewing basics

Slewing rings, known for their large diameters and open centers, rotate unique machinery. Gear teeth add functionality.

Bolt it in place, and off you go: A slewing ring is a contained system of balls or rollers, caging, raceways, mounting provisions, and often, integral gearing as well. These large units are designed to transmit axial, radial, and tilting moment loads. And because they handle loads (and different combinations of them) in one assembly, these bearings eliminate weight, space, and cost penalties of other rotational designs.

The most suitable slewing ring for a design depends on static and dynamic loads, bolt requirements, and gearing specifications. How are loads on a slewing ring best calculated? By using the classical engineering approach of creating free-body diagrams and then solving for unknown variables using static equilibrium equations. (Such a sketch shows forces, their vectorial direction in terms of X and Y Cartesian coordinate values, and the X and Y perpendicular distances of these forces relative to the bearing center.) The bearing plane becomes a cut line for the free-body diagram dividing forces — left and right or top and bottom relative to the bearing plane. Bearing loads are simply the reaction forces at the cut plane. Equations of static equilibrium return reactionary forces at this plane are:

Σ Axial forces = 0
Σ Radial forces = 0
Σ Moments = 0

The directions of force and moment rotation are very important, indicating whether a value is positive or negative. Moment loads are calculated about the center of the ring — that is, where the center plane and rotation axis of the ring cross.

Types and capacities

After loads have been calculated, product specification sheets can give basic data for choosing one or more

Loads defined

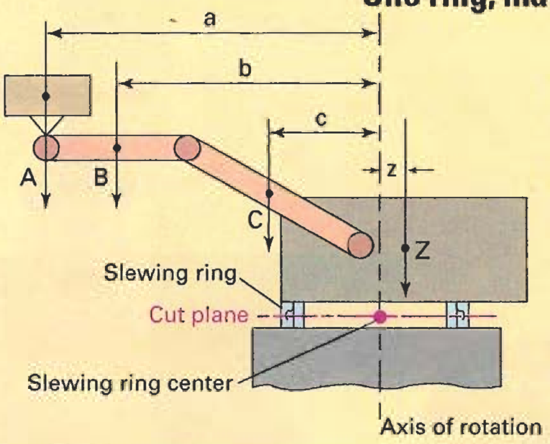
Axial load acts parallel to the axis of rotation. *Compressive* axial loads squeeze mounting surfaces together; it's commonly referred to as thrust load. *Tensile* axial load, on the other hand, acts to pull bearings away from supporting structures. Called a tension or a hanging load, tensile axial loads are not possible without mounting fasteners.

Radial load acts perpendicular to the axis of rotation. Often called side or shear loads, they're resisted by the frictional holding power of clamped interfaces. In certain cases, precision cylindrical pilots or dowels are used to transmit high radial loads.

Moment or *overturning* loads act about a line perpendicular to the axis of rotation. They result from an axial load applied at a distance from the axis of rotation, a radial load applied at a perpendicular distance from the bearing plane, or a combination of both. A moment load induces thrust on one half of the bearing and tension on the other.

That's why it is important that only axial, radial and moment load components acting simultaneously define a single bearing-load case.

One ring, many loads



A = Weight of load, lb
a = Distance from center of gravity of A to center of rotation, ft
B = Weight of boom section, lb
b = Distance from center of gravity of B, ft
... and so on.

Thrust load = $A + B + C + Z$ (lb)
Moment load = $Aa + Bb + Cc - Zz$ (ft-lb)

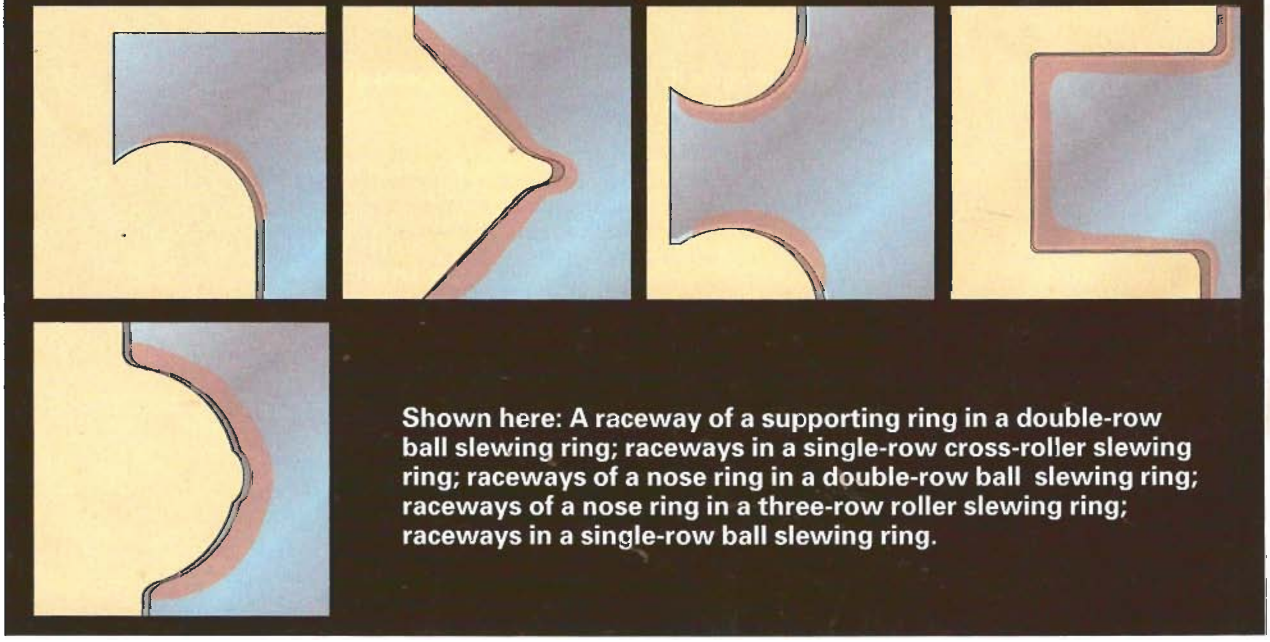
This free-body diagram approximates the load on a lift slewing ring. A plane is cut through the ring's center. All loads above the cut plane must be transmitted by the ring for equations of static equilibrium to be satisfied.

possible bearing style for a particular application. To illustrate: Some rings are developed for use as fifth-wheel bogie steering pivots on trailer applications. Other slewing rings are common on general turntable applications; their moment capacity provides stability to turntables having diameters well in excess of the bearing diameter. Finally, slewing rings with high contact angles and increased internal clearance are suitable for thrust applications where the center of force remains within the raceway diameter.

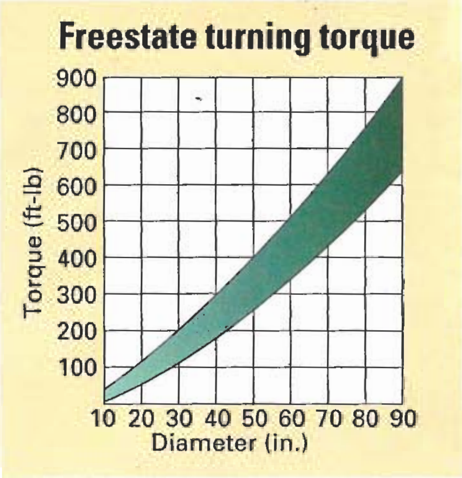
Wire-race slewing rings are known for being very light and reliable. They're used in medical scanning equipment and radar antennas, and are appropriate where lightweight, replaceable raceways or ring material selection is an important consideration. However, self-selection is not recommended; manufacturers should be involved in the design process for slewing rings.

Listed raceway capacities are often *static* ratings. Since most large-diameter ring applications involve intermittent slewing and a broad spectrum of loads, it's prudent to select a

Raceway lineup



Shown here: A raceway of a supporting ring in a double-row ball slewing ring; raceways in a single-row cross-roller slewing ring; raceways of a nose ring in a double-row ball slewing ring; raceways of a nose ring in a three-row roller slewing ring; raceways in a single-row ball slewing ring.



Estimates of freestate turning torque for most rings are charted here, from statistical studies of single-row ball slewing ring lines with diameters from 12 to 90 in., dual seals and internal clearance.

ring based on its static capacity — *and* a recommended application service factor. Capacities listed are non-simultaneous: In other words, a catalog thrust capacity doesn't account for moment or radial loading. Similarly, moment capacity assumes no thrust or radial load, and listed radial capacity accounts for no thrust or moment. When applications involve a load combination, the load components must be combined into an equivalent load. (For static raceway calculations, this equivalent load is taken to be load as seen by the highest loaded rolling element.)

The exact machine duty cycle and the mounting structure design have tremendous influence on the durability of the ring. In high-cycle applications, dynamic capacity, rather than static capacity, may dominate the slewing ring selection.

Turning torque. Turning torque can be substantial on large-diameter slewing rings. Classical theory and empirical data from equations and catalog values helps estimate this value. Factors affecting turning torque include the frictional coefficient, applied loads, and their distribution, mounting orientation, rolling element separators, the flatness and stiffness of the supporting structure, the viscosity and amount of grease in the ring, the seal type and preload, and the presence of lubrication at the sealing interface. The torque required to rotate slewing rings is a function of all these influences.

Free-state torque. Free-state torque T_F is the frictional torque of a bearing as it arrives out of the box, before any other load is applied. It's usually ignored when bearing loads are high. However, under relatively light loads, free-state torque values must be taken into account. (Estimates are charted for most standard slewing rings.)

Slewing rings with seals — and the drag they induce — typically exhibit higher free-state torque. Preloaded rings (manufactured with negative internal clearance) also exhibit greater free-state torque. For special designs, this value must be evaluated on an individual basis.

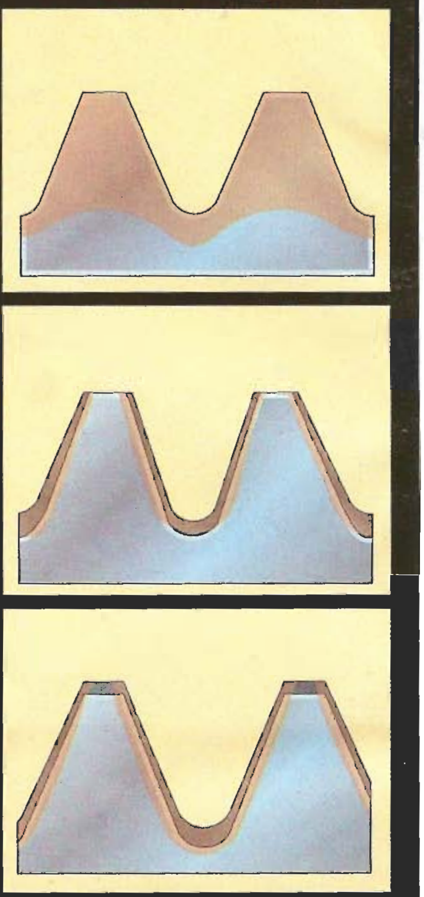
Load friction torque. Load friction torque is a function of ring load magnitude. Average running torque T_R under ideal conditions is:

$$T_R = \frac{\mu}{2}\left(k \cdot M_k + \frac{F_A \cdot D_L}{12} + \frac{k \cdot F_R \cdot D_L}{24}\right)$$

Where µ = Friction coefficient: Typically from 0.003 to 0.008
k = Load distribution factor: 4.37 for balls, 4.1 for rollers
M_K = Moment load, ft-lb
F_A = Axial load, lb
D_L = Bearing race diameter, in.

Starting torque is typically one-third greater than running torque. In contrast, turning torque can vary considerably even between supposedly identical bearings. The suggested design load friction torque is equal to $f_T \cdot T_R$, where f_T is a value from 2 to 5. The highest value of f_T should be used when the supporting surfaces are at the high end of the flatness and stiffness limits and for designs operated until the maximum wear allowable wear limit is reached.

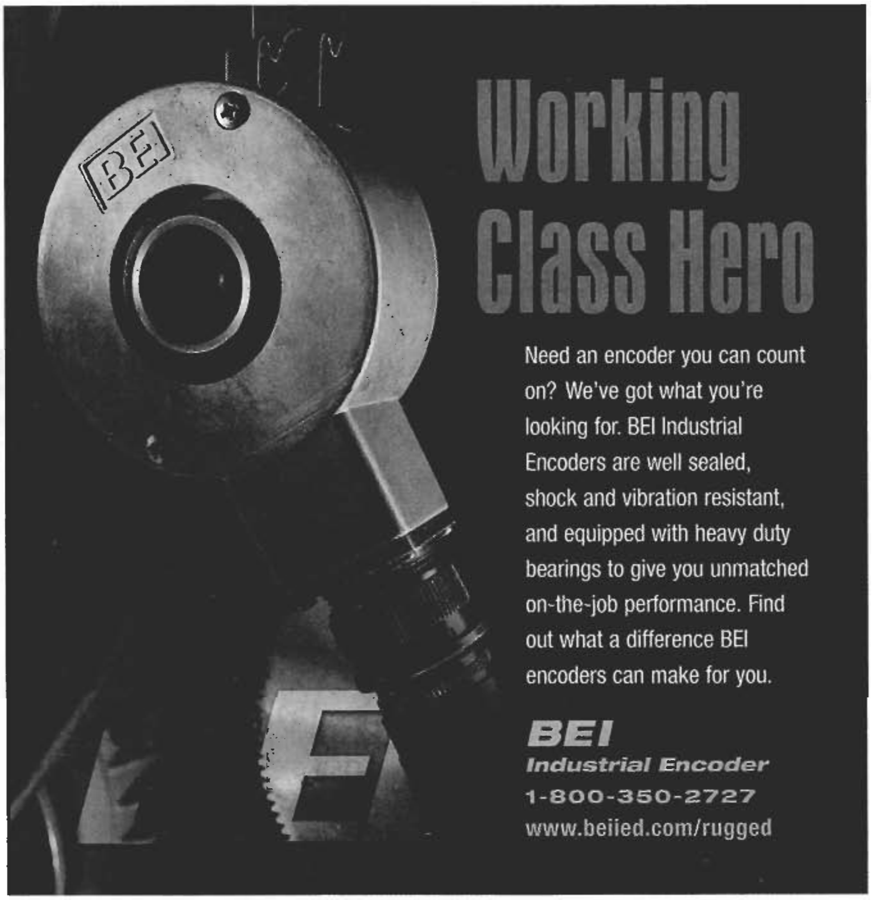
Better biting



Spin hardening, tooth flank hardening, and tooth contour hardening are used to strengthen slewing-ring gears.

Other torque loads. In addition to frictional torque, other sources of torque must be considered when sizing a drive unit. These can include affects from wind loads, gravitational forces, drag loads, acceleration inertia, and so on.

Total bearing torque. Ring torque T is the summation of free-state, load friction, and all other



external torque load components.

When rings are geared

Slewing rings are available without gearing, but many slewing rings are supplied with either internal or external spur gear teeth cut into one race ring. An integrated gear eliminates additional bolt-on gears, which helps to reduce design work and cost.

Just as with any gearing, slewing ring teeth must meet load ratings. In high-use or continually revolving applications, special dynamic calculations may be in order.

Some slewing rings have induction-hardened gear teeth for wear resistance. Induction hardened gearing can substantially improve gear life by preventing surface wear and fatigue.

Various forms of gear induction hardening include spin, tooth flank, and tooth contour hardening. For slewing rings, tooth contour hardening is by far the most common. Tooth contour induction hardening provides hardness through the root of the gear teeth in addition to along the flanks. Hardening through the gear tooth root improves the bending fatigue life of the tooth. Flank hardening does not extend into the gear root region, and is usually limited to gears in abrasive environments with relatively low tooth loads.

Induction hardening can be provided on both internal and external spur gears. It greatly improves the life of the gear teeth in dynamic applications. Still, for most slow-speed slewing applications, standard gear teeth will last the life of the slewing ring. The properties of the high-quality, quench and tempered steel forgings used in the production of slewing rings also makes for high-quality gear teeth.

Information courtesy Rotek Inc. of ThyssenKrupp Technologies, Aurora, Ohio. For more information, call (800) 221-8043 or visit rotek-inc.com.