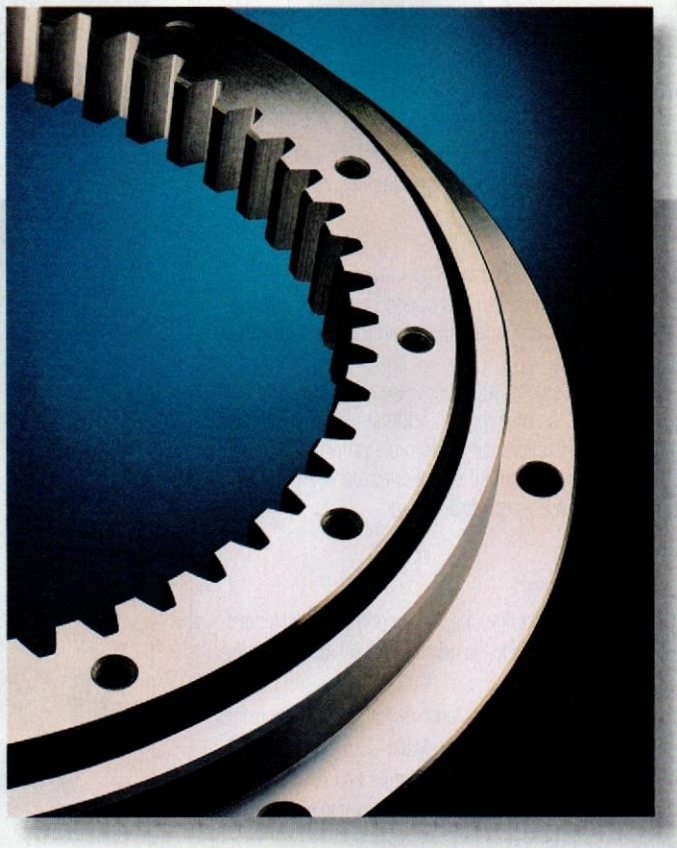
Gearing up your bearings



Slewing ring bearings — the bearings that find use on cranes, wind turbines, and other smaller designs — are sometimes cut with teeth to double as gears. Let's review the benefits and challenges of applying these units.

Scott Hansen
V.P. of engineering
and advanced technology
Kaydon Corp.
Muskegon, Mich.

Drive systems can be simplified by incorporating a gear on either the inner or outer bearing race of a slewing ring. These gear details can take on many styles and features: Fellows stubs, full-depth involutes, straight, helical, hardened or unhardened, and ground or unground, but what factors make for a good slewing-ring gear? Gear static strength, resistance to pitting, gear fatigue, and gear/pinion interfaces, or mesh.

ABB CEO resigns

ABB CEO Fred Kindle is leaving the Zurich-based company due to "irreconcilable differences" on how to lead the power and automation giant in the future. In his absence, the board of directors has named chief financial officer Michel Demaré as interim CEO.

Kindle joined ABB in September 2004, taking over as president and CEO in January 2005. He lead the company through a period of growth and a return to profitability.

"The Board is very thankful to Fred Kindle for driving the company to an extraordinary level of performance over the last three years," chairman Hubertus von Grünberg said. "Under his leadership, ABB is a leading company in respect of growth, profitability, and business ethics."

Online registration open for BSA conference

The Bearing Specialists Association (BSA), Glen Ellyn, Ill., has opened online registration for its Conference Table Session at the association's 2008 annual convention, April 26-29 at Loews Ventana Canyon Resort, Tucson, Az.

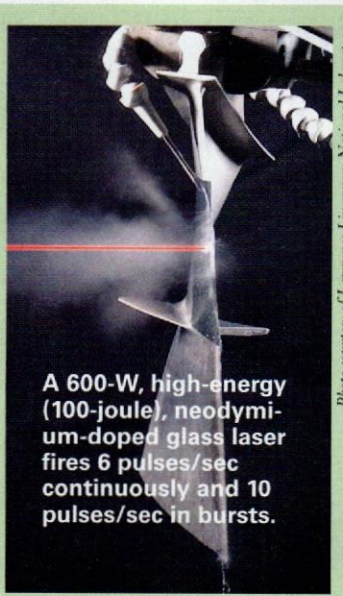
BSA's manufacturer-hosted Conference Table Session offers conference participants an opportunity to pre-schedule and plan for face-to-face meetings to address bearing industry concerns and resolve business problems. Online Conference Table registration is available through April 1; afterwards, registration may be done on-site if space is available.

For more information, visit the convention website, www.bsaconventions.org.

Balluff adds metal forming market expert

Balluff, Florence, Ky., has named Drew Stevens as business development support specialist for metalforming. Stevens brings a great deal of metalforming expertise to his new role and will be responsible for directing Balluff's metalforming support programs.

Stevens has been a journeyman diemaker since 1998 and has most recently been responsible for designing, implementing, and troubleshooting die-protection at Die-Matic Corp., Cleveland. As Die-Matic's sensor "guru," Stevens successfully maintained an in-house die-protection program while simultaneously reducing unplanned downtime and improving processes. He also aided in the design of advanced board-level interface devices to improve Die-Matic's existing technology.



A 600-W, high-energy (100-joule), neodymium-doped glass laser fires 6 pulses/sec continuously and 10 pulses/sec in bursts.

Photo courtesy of Lawrence Livermore National Laboratory.

Students explore construction

Visiting ConExpo-Con/AGG this month? For a fun diversion, check out what hundreds of high school students will be learning about the construction industry as they compete in the AEM Construction Challenge. In addition to the "Infrastructure Dialogue" and "Equipment and Careers Product Development," the students had to create and build construction machines that must accomplish moving and lifting tasks in "Road Warrior." Be sure to stop by the AEM booth in the Grand Lobby between North Hall and Central Hall from March 11-15 to see what these students have built with motion control and fluid power components.

A slewing ring bearing has rolling elements designed to create a reactive moment within the bearing's dimensions envelope, to oppose applied (overturning) moment load. The use of one bearing instead of two reduces the height required for an application and can improve performance.

A pressure angle of 20° is most common because 20° cutters are standard, but 14.5°, 25°, and special pressure angles are also used. Machine designers select slewing ring bearings based on load capacities. (See attached load charts.) The tooth size and form is then selected using the following Lewis equation:

$L = SFY P$

Where L = Tangential tooth load

S = Allowable bending stress

Y = Tooth form factor (from tables — *see page 22*)

P = Diametral pitch

F = Face width

The *stub* tooth form is often used in large gears; economics is the main reason. The form requires less material in the ring forging and less gear cutting time. *Full depth* tooth forms, on the other hand, provide greater contact ratio for smoother operation, but have lower bending strength.

With core hardness of 23 to 30 Rc, allowable bending stress is 34,000 psi. With 262 to 302 BHN (27 to 32 Rc) this is 37,000 psi, and 29 to 34 Rc allows 40,000 psi. These stress approximations are for maximum or stall torque conditions — so when shock is included in the loading, higher stresses may occur.

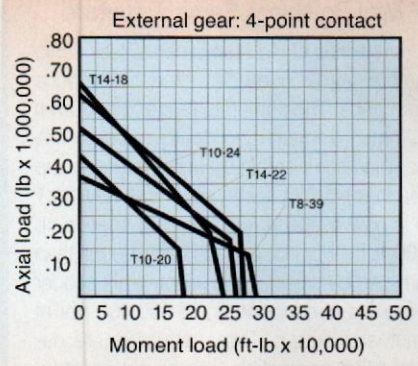
Induction-hardened gear teeth with a minimum surface hardness of 55 Rc should be considered when high tooth surface pressures are constant. One example is an excavator or logger that undergoes high acceleration rates and rapid deceleration during a swing cycle.

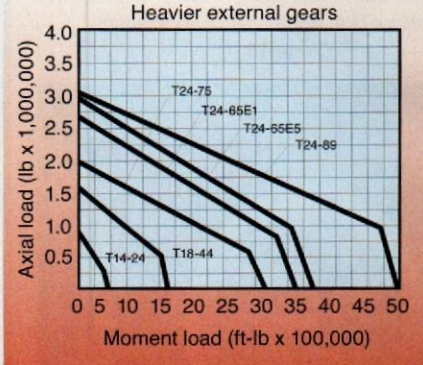
A full root radius with root hardening is also recommended; the tooth pattern and depth of hardness are critical here.

Backlash

All gears need backlash room. This is especially true of bearing gears, in which large diameters and large center distances require greater manufacturing

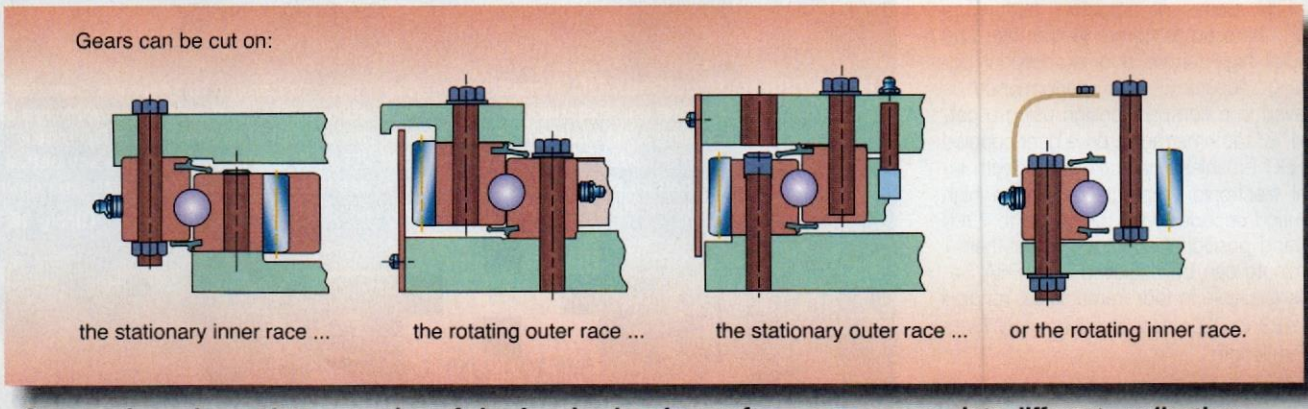
Load ratings





Gear-related slewing ring bearing ratings are determined by tooth geometry.

Gear where?



Gear teeth can be cut into a number of slewing ring bearing surfaces, to accommodate different application requirements.

Compact, High Torque, Zero-backlash Actuators

RSF-3 Ultra-miniature Actuator

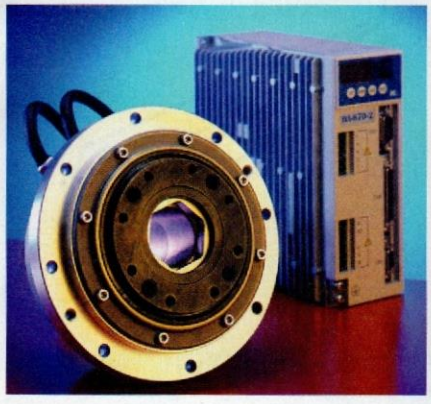
A new ultra-miniature servo actuator is now available from Harmonic Drive! Measuring just 12mm square x 47 mm in length, the RSF-3 brushless actuator delivers maximum torque up to 1.8 in-lb and maximum speeds up to 333 rpm, depending on gear ratio. Zero-backlash harmonic drive gearing provides positional accuracy better than 10 arc minutes and a 200 line, 2 channel incremental encoder (w/ index) gives a minimum resolution of 24,000 ppr at the output shaft. Ideally suited for precision servo applications where available space is at a premium.

Circle 15

RSF Mini Brushless Servo Actuators

This new series of high torque brushless servo actuators is designed for exceptional price performance. The actuators range from 30mm to 50mm in diameter and deliver torques 50% higher than comparable brushed actuators (up to 240 in-lb) at 20% faster speeds. A new 30:1 ratio is now available for maximum speeds up to 200 rpm. Positioning accuracy better than 90 arc-sec is achieved and an integral encoder can provide a resolution up to 400,000 ppr at the actuator output. These actuators are designed to be compatible with brushless servo drivers from most manufactures and are well suited for high volume OEM applications.

Circle 16



Hollow Shaft Actuators

The FHA Series of actuators features a through-bore up to 45mm in diameter and provides high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a patented "S" tooth harmonic drive gear coupled to a DC brushless pancake motor with integral electronic commutation and a high resolution encoder. Max torque up to 7300 in-lb and positional accuracy better than 1 arc-minute can be achieved. The FHA Series is available in four frame sizes, ranging from 128 to 230mm in diameter, and 78 to 127mm length.

Harmonic Drive LLC
800-921-3332
www.HarmonicDrive.net
Circle 17

Hollow Shaft Brushless DC Actuators feature a through-bore up to 14 mm in diameter and provide high torque and exceptional positioning accuracy. This performance is achieved in a compact design using a high performance harmonic drive coupled to a brushless DC motor and a high resolution encoder. Maximum torque up to 250 in-lb and positional accuracy better than 1.5 arc-minute can be achieved. The FHA Mini Series is available in 3 frame sizes, ranging from 50 to 75 mm square, and 48 to 66 mm in length.

Circle 18

HARMONIC DRIVE
TOTAL MOTION CONTROL
800.921.3332 www.HarmonicDrive.net

Surface hardness

Case depth-induction hardened gears

Diametral pitch	Flank depth	Root depth
4.00	0.040	0.030
3.50	0.050	0.035
3.00	0.060	0.040
2.50	0.075	0.050
2.00	0.100	0.070
1.75	0.125	0.080
1.50	0.150	0.100

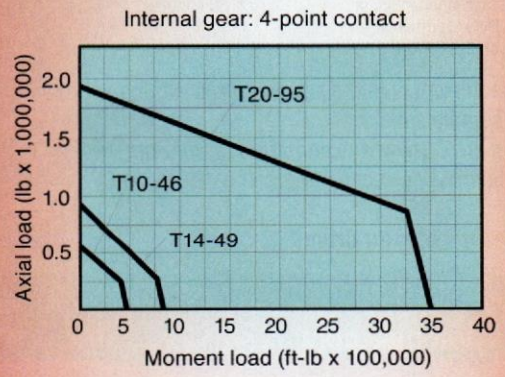
Gear teeth are hardened through to their full root radius resist high surface pressures.

Backlash allowances

Gear pitch diameter	Minimum backlash (in.)	Maximum backlash (in.) Diametral pitch 1.5	1.75	2	2.5	3,4,5
20	0.014	0.029	0.027	0.025	0.023	0.022
30	0.015	0.030	0.028	0.026	0.024	0.023
40	0.016	0.031	0.029	0.027	0.025	0.024
60	0.018	0.033	0.031	0.029	0.027	0.026
80	0.020	0.035	0.033	0.031	0.029	0.028
100	0.022	0.037	0.035	0.033	0.031	0.030
120	0.024	0.039	0.037	0.035	0.033	0.032

The large center distances and (often) big diameters of slewing ring bearings require tighter tolerances, so gear teeth must be designed to allow for backlash.

Axial and moment load



Slewing ring bearings withstand loading from multiple directions.

tolerances. Other factors can determine whether adjusting the center distance between gear and pinion is appropriate to make room for backlash. The cost advantages of adjustment should be kept in mind: Gear size tolerance can be greater (and life extended) with take-up for wear.

Installation

Installation of bearing/gear assemblies should be done in a clean, dry, well-lit area. Housing mounting surfaces and pilots should be unpainted and wiped clean of chips, dirt, and lint, because even soft materials make high spots when entrapped. Any

Arrangements

Slewing ring bearing options abound. Unfortunately, there is no one best design for all applications. Selecting the right one depends on requirements for load, stiffness, speed, size, and smoothness of rotation. Traditional king-post bearing mounting arrangements (used to support radial, thrust, and moment loads) consist of two ball or roller bearings spaced along a common axis. Their moment capacity is boosted by spacing the bearings further apart and by using heavier sections. But their significant space and mounting complications means they do not lend themselves to many new applications.

A better solution nowadays is a single four-point contact ball bearing. This bearing utilizes gothic arch race construction for the inner and outer race ball paths to generate four points of contact for each ball. This in turn generates intersecting contact angles that create a large effective pitch diameter to offset any overturning moment load. The use of a single larger diameter bearing allows for wiring and plumbing through the bore of the bearing. This can simplify overall design, improve appearance, and help to protect components.

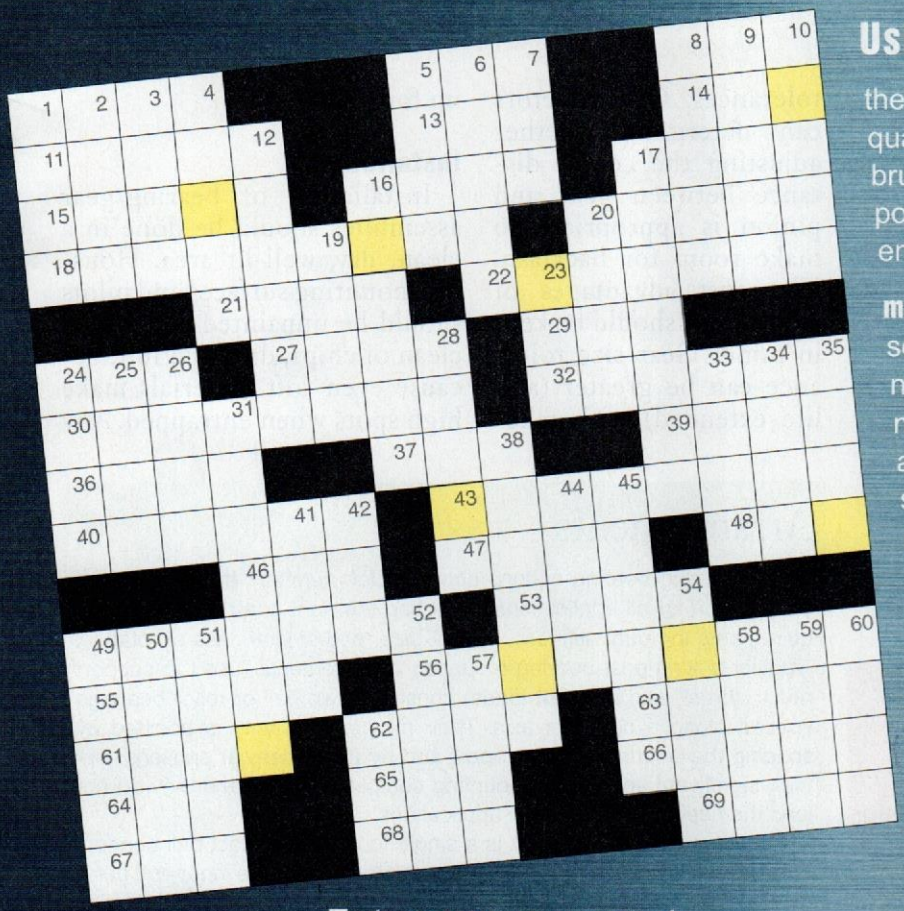
Four-point contact bearings have been used for many years in the construction equipment industry for cranes, backhoes, and excavators, and now these bearings are also used in specialty equipment: Robotics, lift-and-rotate tables, machine tools, aerial baskets, aerial platforms, and radar pedestals.

Though load vs. capacity considerations dominate bearing cross section and diameter selection, other parameters also influence which design is best. Torque considerations may indicate the use of a two-row ball bearing in place of a four-point contact bearing. Increased moment stiffness may require a two-row roller or a cross-roller bearing. Deflections, or use of an aluminum mounting structure, may dictate the need for an aluminum wire race version of a steel ball or roller bearing. The use of aluminum bearing rings with hardened steel wires not only matches the coefficient of expansion of aluminum mounting structures, but can also provide the flexibility needed to compensate for mounting distortions.

Smaller-bore bearings may be necessary in weight-sensitive applications such as robotics and manipulators; these enable smaller mounting structures, and overall weight reductions that reduce moments of inertia — to allow for faster movements with fewer structural deflections.

Standard turntable bearings are available in bore sizes to more than 800 mm. Some manufacturers also offer standard slewing ring bearings in bore sizes as small as 50 mm. The relatively high capacity of these bearings make them suitable in the joint positions of articulated systems.

Enter the maxon motor Crossword Challenge!



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ACROSS

1. Leather and ____
5. Former Giant great Mel
8. Draft org.
11. Small land masses
13. Contend
14. Cheerleaders have it
15. Former Pontiac model
16. Provide for a bit
17. Ice cream holder
18. Much mechanical output for little electrical input
20. Eek causer
21. Canyon feedback
22. Fragrant
24. Former NBA competitor
27. Years and years and years
29. Industrious insect
30. Security no. for your beeper?
32. Wall paintings
36. Pivot
37. Brylcreem serving size
39. S-shaped molding
40. Wisdom
43. No Fe here
46. Anger
47. Put cargo on a ship
48. Web feed format
49. High-torque-density footprint
53. Move fast
55. Fencing blades
56. Torque
61. Campus bigwig
62. False god
63. Land of La Scala
64. Carney or Linkletter
65. Make a mistake
66. This device's movement is measured in degrees
67. Actor Liotta
68. D-Day craft
69. Fad

DOWN

1. Cereal Mikey liked
2. Clueless response
3. Musical symbol
4. Weird
5. Bakery need
6. Shades
7. Red Sox great Williams
8. You'll find one on a tea kettle
9. Common or horse
10. how far/how long
12. European football, to Americans
16. Meteor shower
17. Digital or analog, closing the loop provides it
19. Pancake chain, for short
20. Bistro reading material
23. Mechanical motion-transfer device
24. Renters' abodes, for short
25. L. Frank who wrote *The Wizard of Oz*
26. Taj Mahal locale
28. Slimy slow mover
31. Allow to age?
33. Teen or golden follower
34. Opposite of more
35. Conf. component
38. Rio's country
41. La-la preceders
42. Shorter than a min.
44. Take in too much of
45. New evergreen?
49. Moth-repellant wood
50. Where the fat lady sings
51. Fleshy
52. Former Russian rulers
54. Faraday and Tesla invented one
57. Portion
58. Tat preceder
59. A moneymaker for the plumber
60. Novelist Brontë's Jane
62. EU country

Use the letters in the shaded boxes within the puzzle to complete the sentence.
Log on to ***www.maxonmotorusa.com/puzzle*** and type in the correct word for a chance to win.

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maxon motor

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PRECISION MOTORS

Circle 19

Tooth form factor

The tooth form factor is used in the Lewis equation to determine the right gear size.

Tooth form factor (Y)						
Number of teeth	20° full depth involute system	20° stub tooth system	Fellows stub tooth system			Internal gears 20° full depth system
12	0.245	0.311	0.301	0.349	0.320	
13	0.261	0.324	0.317	0.361	0.336	
14	0.276	0.339	0.330	0.374	0.352	
15	0.289	0.348	0.339	0.386	0.361	
16	0.295	0.361	0.349	0.396	0.374	
17	0.302	0.367	0.358	0.405	0.383	
18	0.308	0.377	0.367	0.411	0.389	
19	0.314	0.386	0.374	0.412	0.399	
20	0.320	0.393	0.380	0.424	0.405	
21	0.327	0.399	0.386	0.430	0.411	
22	0.330	0.405	0.393	0.437	0.412	
24	0.336	0.415	0.402	0.446	0.427	
26	0.346	0.424	0.408	0.455	0.437	
28	0.352	0.430	0.418	0.462	0.443	0.691
30	0.358	0.437	0.424	0.468	0.449	0.678
34	0.371	0.446	0.437	0.480	0.461	0.660
38	0.383	0.456	0.440	0.484	0.468	0.644
43	0.396	0.462	0.452	0.446	0.480	0.628
50	0.408	0.474	0.462	0.506	0.490	0.613
60	0.421	0.484	0.471	0.515	0.499	0.597
75	0.434	0.496	0.484	0.525	0.509	0.581
100	0.446	0.506	0.496	0.537	0.521	0.565
150	0.459	0.518	0.509	0.547	0.534	0.550
300	0.471	0.534	0.525	0.563	0.550	0.534
Use in Lewis Formula for P			4	5	6	

weld spatter, nicks, and burrs should be removed.

The bearing can be lifted or hoisted into position using eye bolts in mounting holes (or nonmetallic slings) which can prevent damage to bearing surfaces and gear teeth.

Inherent to the hardening process of most turntable bearings is a small gap at one point in the raceway; loading holes are drilled through this gap. These gaps (and load hole plugs, in races with through holes) should be positioned at minimum load points if possible. Load hole plugs in races with tapped holes or weld rings must be so positioned. With the rotating race, this is done by placing the loading hole 90° off the maximum load zone from moment loading. With the stationary race, this position depends upon the location of the lightest load relative to the lower structure of the machine.

For good internal load distribution and smooth, low-torque operation, the bearing should be as round as possible when the bolts are tightened. If one race is doweled or piloted, it should be mounted first when possible.

On unpiloted gear bearings the gear/pinion backlash should be checked and adjusted. The minimum backlash point of the gear is often identified by yellow paint in the tooth space.

When installing:

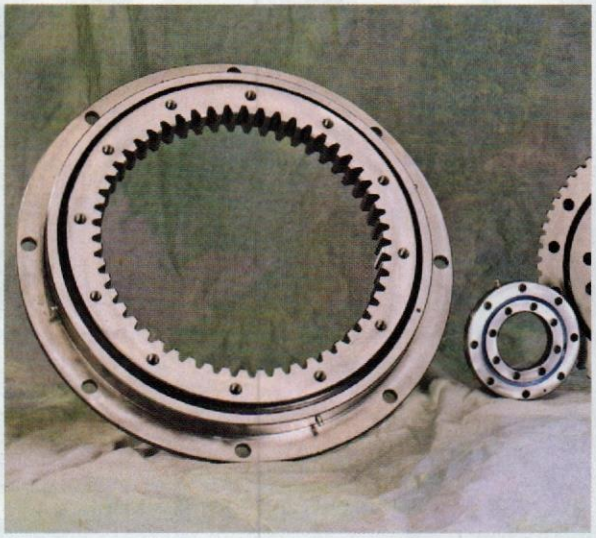
- Leave all mounting bolts loose until both mating parts are attached to the bearing.
- While applying a moderate centered thrust load to the bearing, measure the torque to rotate the bearing. Then tighten all bolts to the level prescribed by the bolt manufacturer. This is very important; improperly tightened bolts can fail due to fatigue and can harm equipment and workers.
- Again measure the torque required to rotate the bearing. If greater than the first measurement, the bearing is being distorted. Determine

and correct the cause.

After these steps, gears on fixed centers can be checked for backlash, and pinions on adjustable centers set for proper backlash.

When all backlash checks are completed, the gear should be coated with grease suitable for the operating conditions, and rotated to ensure coverage of all contacting surfaces with the pinions.

Complete installation of all rotating components of significant weight, and check bearing for freedom of rotation. Again, excessive torque or variations are indicative of an unsatisfactory installation condition.



Team player
The teeth of slewing ring bearings can be tailored to designs just as regular gears.

Beyond backhoes: Small designs

Significant changes are taking place in the use of slewing ring bearings. The traditional perception of slewing ring bearings as large-diameter, heavy-section, low-precision bearings with bolt holes and gears for construction equipment applications is no longer valid; these bearings are increasingly used in smaller, precise applications.

Improved manufacturing methods and design concepts are behind this trend. Smaller, off-the-shelf slewing ring bearings (preloaded to eliminate clearance and improve stiffness) have become standard in the machine tool industry; runout and diameter tolerances for these bearings can be specified in ten-thousandths of an inch, vs. thousandths.

Big and small
Slewing ring bearings are no longer limited to large, heavy applications. Their versatility is boosting performance in smaller designs as well.

The design is useful in even small designs because it's simple to bolt a rotating structure to a stationary base.

For more information, visit kaydonbearings.com or motionsystemdesign.com and click on the Component Zone links for bearings and gears.