ASME SRB-1–2018

Design, Installation, Maintenance, and Application of Ball Slewing Ring Bearings

AN AMERICAN NATIONAL STANDARD

The American Society of Mechanical Engineers

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Two Park Avenue • New York, NY • 10016 USA

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The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

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FOREWORD

The uniqueness of large-diameter ball bearings is evidenced by the fact that most of the existing standards available to the public are applicable only to small diameter "standard" or "off-the shelf" bearings and are not meant to be applied to slewing ring bearings (SRB). To date, some conventions but few standards have been established for this product.

In the late 1970s, a letter was circulated to slewing ring bearing (SRB) manufacturers suggesting that a committee of manufacturers' representatives be formed. The idea was generally accepted, but it was agreed that the manufacturers should also gain the sponsorship of a professional or trade organization. Since several of the slewing ring bearing manufacturers were members of the then Anti-Friction Bearing Manufacturers Association (AFBMA), now American Bearing Manufacturers Association (ABMA), that organization was petitioned. The AFBMA agreed to sponsor the committee in 1984.

Over the next several years, interest and membership within the SRB Committee declined, and AFBMA withdrew its sponsorship of the committee. The committee was disbanded by AFBMA in 1987.

In late 1987 a member from the disbanded AFBMA SRB Committee requested that The American Society of Mechanical Engineers (ASME) assume the responsibility of developing a standard to cover large-diameter slewing ring bearings and reconstitute the SRB Committee. On September 29, 1988, the ASME Council on Codes and Standards approved the scope for a standardization project on slewing ring bearings. The recruitment of members for the newly established ASME Committee on Slewing Ring Bearings began in 1989, and the first meeting of the SRB Committee was held on December 6, 1989. The Slewing Ring Bearing Committee was disbanded on April 12, 2002 due to lack of interest from the industry. Work on the draft was discontinued.

In 2010 ASME re-evaluated industry interest for the formation of a new Slewing Ring Bearing Standards Committee. A new Committee was formed to develop and maintain standards relating to the design, manufacture, application, quality assurance, installation, and maintenance of slewing ring bearings. The committee, which consisted of bearing manufacturers, equipment manufacturers, consultants, and equipment end-users, held its first meeting on June 28, 2010. Originally, the standard was envisioned to cover both ball and rolling-element slewing ring bearings. However, subsequent lack of participation from those members with rolling-element SRB design expertise led to a decision to publish the initial standard addressing ball-bearing SRBs only. Recruitment for new members with additional expertise in the design of rolling-element SRBs is ongoing, and the next edition is expected to cover these bearings.

This Standard was approved by the American National Standards Institute on July 27, 2018.

ASME SRB COMMITTEE
Slewing Ring Bearings

(The following is the roster of the Committee at the time of approval of this Standard.)

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CORRESPONDENCE WITH THE SRB COMMITTEE

General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, SRB Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Interpretations. Upon request, the SRB Standards Committee will render an interpretation of any requirement of the Standard. Interpretations can only be rendered in response to a written request sent to the Secretary of the SRB Standards Committee.

Requests for interpretation should preferably be submitted through the online Interpretation Submittal Form. The form is accessible at http://go.asme.org/InterpretationRequest. Upon submittal of the form, the Inquirer will receive an automatic e-mail confirming receipt.

If the Inquirer is unable to use the online form, he/she may mail the request to the Secretary of the SRB Standards Committee at the above address. The request for an interpretation should be clear and unambiguous. It is further recommended that the Inquirer submit his/her request in the following format:

Subject:	Cite the applicable paragraph number(s) and the topic of the inquiry in one or two words.
Edition:	Cite the applicable edition of the Standard for which the interpretation is being requested.
Question:	Phrase the question as a request for an interpretation of a specific requirement suitable for general understanding and use, not as a request for an approval of a proprietary design or situation. Please provide a condensed and precise question, composed in such a way that a "yes" or "no" reply is acceptable.
Proposed Reply(ies):	Provide a proposed reply(ies) in the form of "Yes" or "No," with explanation as needed. If entering replies to more than one question, please number the questions and replies.
Background Information:	Provide the Committee with any background information that will assist the Committee in understanding the inquiry. The Inquirer may also include any plans or drawings that are necessary to explain the question; however, they should not contain proprietary names or information.

Requests that are not in the format described above may be rewritten in the appropriate format by the Committee prior to being answered, which may inadvertently change the intent of the original request.

Moreover, ASME does not act as a consultant for specific engineering problems or for the general application or understanding of the Standard requirements. If, based on the inquiry information submitted, it is the opinion of the Committee that the Inquirer should seek assistance, the inquiry will be returned with the recommendation that such assistance be obtained.

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Attending Committee Meetings. The SRB Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the SRB Standards Committee.

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DESIGN, INSTALLATION, MAINTENANCE, AND APPLICATION OF BALL SLEWING RING BEARINGS

1 SCOPE, PURPOSE, AND REFERENCES

1.1 Scope

This Standard applies to the design, application, installation, inspection requirements, and maintenance of slewing ring bearings (SRBs) using balls that do not require dynamic capacity-life ratings. These also may be called slewing rings. This is inclusive of four-point contact single-row and double-row ball bearings. Such bearings are used in, but not limited to, equipment such as hydraulic shovels, excavators, aerial platforms (manlifts), cranes, wind-power generators, building maintenance units (BMUs), and other equipment where one part of the structure must rotate with respect to another in an oscillating or indexing manner.

1.2 Purpose

The purpose of this Standard is to define standard methods to evaluate variables and establish practices for satisfactory performance in ball SRBs in oscillating or indexing applications. This will allow effective communication and exchange of data among the user, installer, and SRB manufacturer such that all parties understand each other's requirements and have a common point of reference.

Certain parameters are standardized to reduce the potential for confusion between the SRB manufacturer and the user. Acceptance criteria and guidelines are provided for SRB design, material, inspection requirements, and application.

1.3 References

The following publications are referenced in this Standard. Unless otherwise specified, the latest edition shall apply.

ABMA 10A, Metal Balls for Unground Bearings and Other Uses
Publisher: American Bearing Manufacturers Association (ABMA), 330 North Wabash Avenue, Suite 300, Chicago, IL 60611 (www.americanbearings.org)

ISO 3290-1, Rolling bearings — Balls — Part 1: Steel balls
Publisher: International Organization for Standardization (ISO), Chemin de Blandonnet 8, Case Postale 401, 1214 Vernier, Geneva, Switzerland (www.iso.org)

2 DEFINITIONS

2.1 Bearing Definitions

angular contact bearing: a rolling-element bearing with a nominal contact angle between 0 deg and 90 deg.

axial load: a force acting in a direction parallel with the bearing axis.

ball: a spherical rolling element.

ball grade: a specific combination of dimensional, form, surface roughness, and sorting tolerances for balls as defined in ABMA 10A or ISO 3290-1.

ball path: the area where the rolling elements (balls) ride between the races.

ball-path diameter: the diameter that corresponds to the centerline of the balls as shown in Figure 2.1-1.

bearing preload: the absence of internal clearances; can be described as either radial or axial.

bending moment: effect of an applied force at a distance from the axis of rotation.

conformance: ratio of ball-path radius to ball diameter.

contact angle: the angle between a plane perpendicular to the bearing axis and a line passing through the contact point and the center of the rolling elements (see Figure 2.1-1).

contact point: the point of contact between a ball and one raceway.

dynamic load: a load (constant or varying) acting on a bearing when its races rotate in relation to each other.

face: a surface of a race perpendicular to the axis of the race.

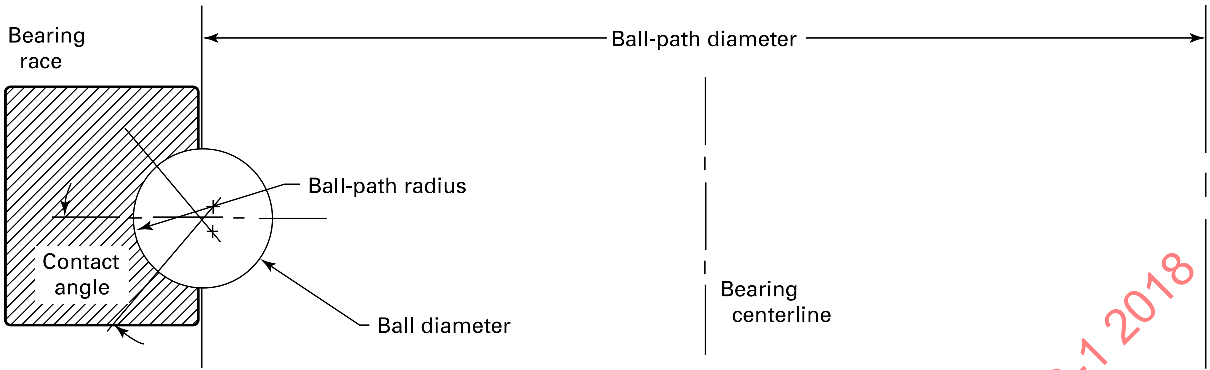
fixed quadrant slewing action: oscillating or intermittent slewing action that occurs 50% or more of the time in one 90-deg quadrant.

four-point contact ball bearing: a single-row angular contact ball bearing in which, when under purely radial load, each loaded ball makes contact with each of the two raceways at two points; under pure axial load, each loaded ball makes contact with each of the two raceways at one point.

inner race: a bearing race incorporating the rolling element raceway(s) on its outer diameter.

integral seal: a bearing sealing device that is an integral part of an assembled bearing.

Figure 2.1-1 Single-Row Four-Point Contact Ball Bearing Definitions



GENERAL NOTE: Conformance is calculated as follows:

$$\text{conformance} = \frac{\text{ball-path radius}}{\text{ball diameter}}$$

intermittent oscillating slewing action: noncontinuous, bidirectional rotation of one race with respect to the other with rotational stops for extended periods (usually measured in minutes).

internal clearance: the distance through which one of the races is displaced relative to the other, from one extreme position to the opposite extreme position, while being subjected to a minimum force sufficient to move the race; can be defined as either radial or axial.

loading plug: a plug, typically radial, installed in one bearing race that when removed allows installation of the balls and spacers during assembly.

lubrication hole: the hole(s) in a bearing race or loading plug for conveying lubricant to the rolling elements and raceways.

mounting face: a surface on the inner or outer race perpendicular to the bearing axis that transfers the load to or from the rotating or stationary structure.

oscillating slewing action: continuous, bidirectional rotation of one race with respect to the other with rotational pauses only long enough to engage and disengage the load or to reverse direction (usually measured in seconds).

outer race: a bearing race incorporating the rolling element raceway(s) on its inner diameter.

qualified person: a person who, by possession of a recognized degree in an applicable field or certificate of professional standing, or who, by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

raceway: the load-supporting surface(s) on an inner or outer race, suitably prepared as a rolling path for the rolling elements.

radial load: load acting in a direction perpendicular to the bearing axis.

running torque: torque required to restrain motion of one bearing race while the other bearing race is rotating at a specified speed with a specified applied load.

runout (of assembled bearing): displacement of the surface of a bearing relative to a fixed point when one bearing race is rotated with respect to the other bearing race; is specified as radial or axial runout.

seal: a circular closure comprising one or several parts, affixed to one bearing race and extending towards the other race with which it makes contact or forms a narrow labyrinth-shaped gap, for the purpose of preventing leakage of lubricant or ingress of foreign substances.

slewing ring bearing (SRB): a rolling-element bearing used for transferring/supporting axial, radial, and bending moment loads, singularly or in combination, consisting of races mounted with varying means, relatively low speed, larger diameters, and usually having a gear integral with one of the rings.

spacer: a bearing part used to separate two rolling elements.

starting torque: torque required to start rotation of one bearing race with the other bearing race held stationary under a specified load condition.

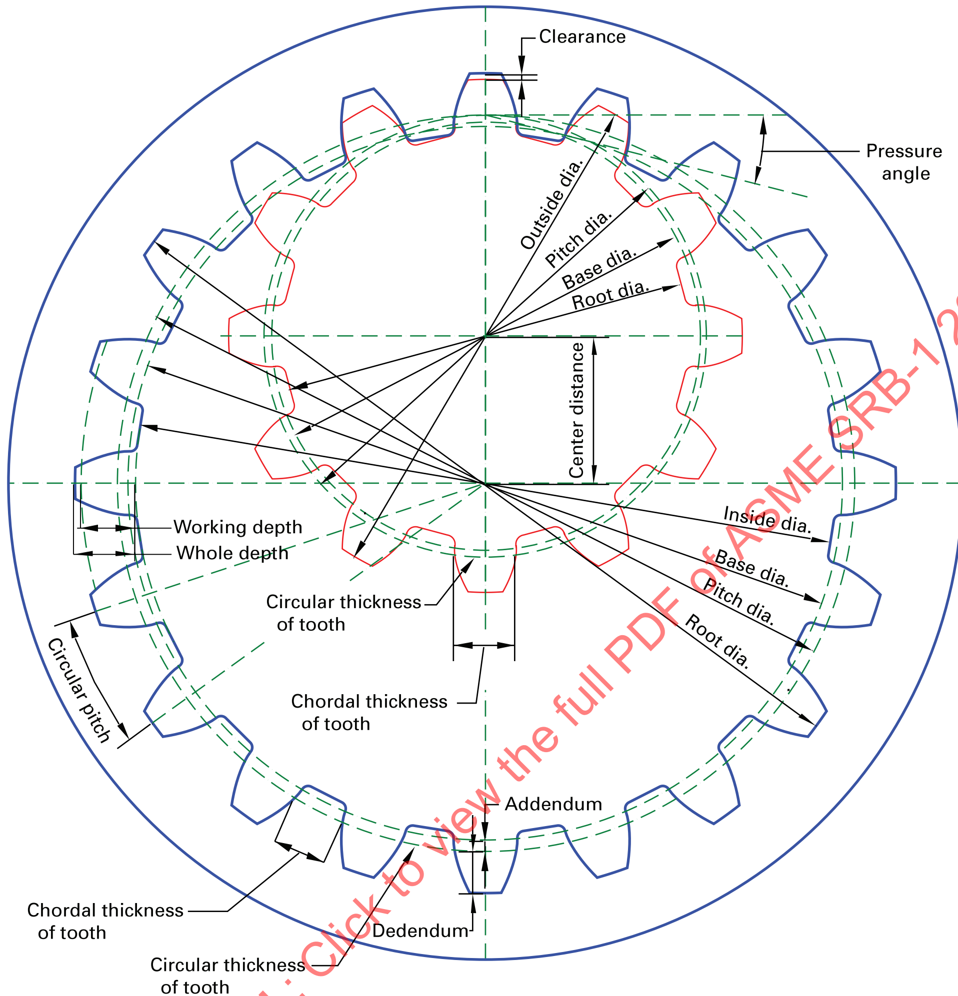
static load: load (constant or varying) acting on a bearing when its races are not rotating in relation to each other.

turntable bearing: a subset of slewing ring bearings used to rotate substantial axial and radial loads with little or no bending moment loading.

2.2 Gear Definitions

addendum: the height by which a tooth projects beyond (outside for external, inside for internal) the standard pitch circle or pitch line; also, the radial distance

Figure 2.2-1 Gear Definitions



between the pitch circle and the addendum circle (see Figure 2.2-1 for an internal gear).

backlash: the amount by which the width of a tooth space exceeds the thickness of the engaging tooth on the operating pitch circles.

center distance (operating): the shortest distance between nonintersecting axes; measured along the mutual perpendicular to the axes, called the line of centers (see Figure 2.2-1).

circular tooth thickness: length of arc between the two sides of a gear tooth, on the specified datum (usually standard pitch diameter) circle.

clearance: the distance between the root circle of a gear and the addendum circle of its mate (see Figure 2.2-1).

dedendum: the depth of a tooth below the standard (reference) pitch circle of pitch line; also, the radial distance between the pitch circle and the root circle (see Figure 2.2-1 for an internal gear).

diametral pitch: the ratio of the number of gear teeth to the standard pitch diameter in inches.

face width: the length of teeth in an axial plane.

gear ratio: the ratio of the larger to the smaller number of teeth in a pair of gears.

internal diameter (gear): the diameter of the addendum circle of an internal gear (see Figure 2.2-1).

module: the ratio of the pitch diameter in millimeters to the number of gear teeth.

operating pitch diameter: pitch diameter determined from the number of gear teeth of mating gears and the center distance at which gears operate; can be different from the standard pitch diameter.

outside diameter (gear): the diameter of the addendum circle of an external gear.

standard pitch diameter: the ratio of the number of gear teeth to the diametral pitch.

pressure angle: in general, the angle at a pitch point between the line of pressure normal to the tooth surface and the plane tangent to the pitch surface (see Figure 2.2-1); in the normal plane for spur gears.

whole depth (tooth depth): the total depth of a tooth space, equal to addendum plus dedendum; also equal to working depth plus clearance.

3 MARKING OF BEARINGS

3.1 Identification

All SRBs shall be marked with a part number and bearing manufacturer's serial number for traceability. These should be visible after installation of the bearing.

3.2 Raceway Soft Zone

Each SRB race that is induction-surface hardened may have a soft zone (an unhardened area between the induction hardening starting and ending points). The soft zone may be present since it is not recommended to have any overlap of the induction hardening zones. When the bearing is mounted, the soft zone should be positioned 90 deg from the maximum bending moment direction.

On bearing races without loading plugs, the location of the soft zone shall be indicated by the letter "S" or other permanent marking on the nonmounting face or other visible location as agreed upon by the SRB manufacturer and purchaser.

On bearing races with a loading plug, the soft zone shall be coincident with the loading plug. For bearing races without a raceway soft zone, the bearing manufacturer shall inform the equipment manufacturer.

3.3 Maximum Radial Runout of the Gear

It is recommended that the minimum backlash between the pinion gear and the bearing gear be set where the radial runout of the bearing gear is at maximum. In this case the maximum value shall be indicated by the letter "H" or other permanent marking on the nonmounting face or other visible location as agreed upon by the SRB manufacturer and purchaser. This location is defined as follows:

(a) For internal gear, the maximum radial runout is reached at the tooth that is closest to the rotational axis of the bearing.

(b) For external gear, the maximum radial runout is reached at the tooth that is the farthest rotational axis of the bearing.

4 REQUIRED APPLICATION DATA

4.1 Application Data Sheet

An application data sheet (ADS) conveys information about an SRB application. The information typically required includes the following:

(a) application description and required certification criteria

(b) axial and radial loads and bending moments (load and moment spectrums if applicable)

(c) rotating speed (rpm, load spectrum if applicable)

(d) type of rotation (fixed quadrant, intermittent, or continuous)

(e) environmental conditions (temperature, moisture, contaminants, corrosive elements, etc.)

(f) orientation

(g) size constraints

(h) gear design (internal, external, diametral pitch, etc.)

(i) mounting considerations

See Nonmandatory Appendix A for a typical format of an ADS.

4.2 Coordinate System for Externally Applied Loads

Loads such as static load, weight load, counterweight load, driving forces applied to equipment shall be resolved into an equivalent force system at the bearing. The equivalent force system shall be specified using the coordinate axis system and sign convention shown in Figure 4.2-1.

5 DESIGN

5.1 Raceway Design

5.1.1 Ball Path

(a) Operating in an oscillating or indexing manner, the SRB is rated by the static load capacity. The axial load static capacity, C_{sa}, and bending moment static capacity, C_{sm}, shall be calculated as follows:

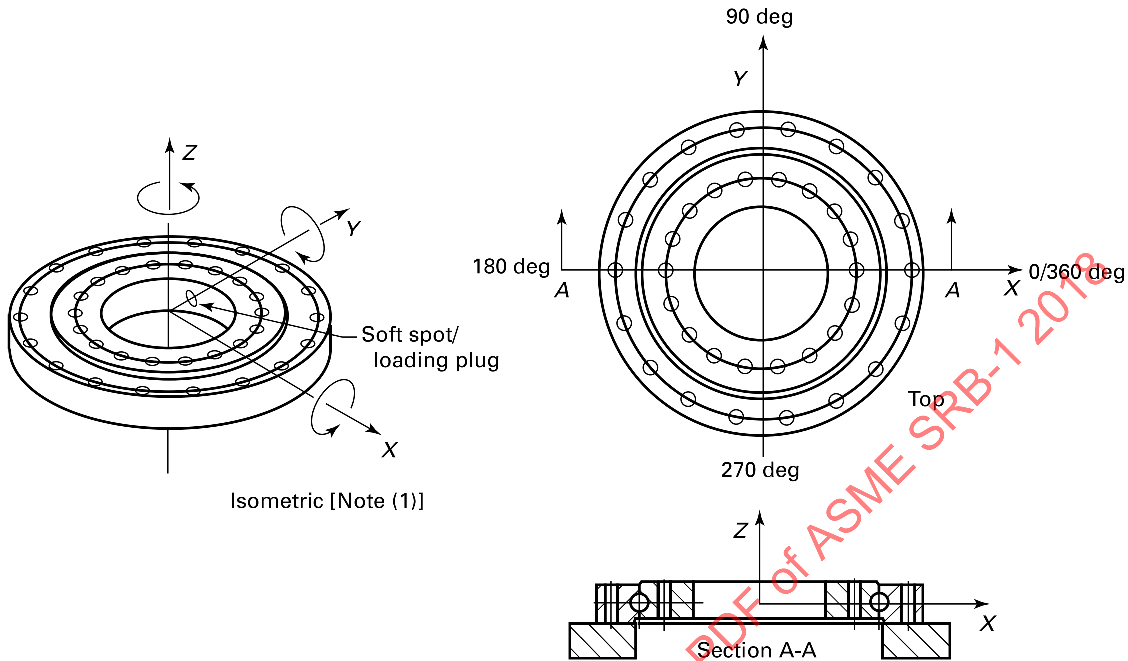
$$C_{sa} = \frac{2000iZD^2 \sin\alpha}{S_m} \left[\frac{2f\left(1 - \frac{D\cos\alpha}{d_m}\right)}{2f - 1} \right]^{0.5} \qquad (1)$$

$$C_{sm} = \frac{C_{sa} \times d_m}{4.37 \times 12} = 0.019\, C_{sa} \times d_m \qquad (2)$$

where

C_{sa} = axial load static capacity, lb
C_{sm} = bending moment static capacity, ft-lb
D = diameter of the ball, in.
d_m = ball-path diameter, in.
f = conformance; the ball-path radius divided by the ball diameter (limited between 0.52 and 0.54)

Figure 4.2-1 SRB Coordinate System



GENERAL NOTE: The coordinate system is fixed relative to the rotating ring. In this figure, the rotating ring is the inner ring.

NOTE: (1) Arrows indicate the positive force of direction.

i = number of rows of balls (1 for single-row, 2 for double-row bearing)
S_m = application service factor
= 1.0 for mobile equipment (tire-mounted) and light-duty industrial equipment
= 1.1 for crawler cranes
= 1.25 for pedestal cranes
= 1.5 for forestry equipment and heavy-duty industrial equipment
Z = number of balls in one row
α = contact angle (limited between 45 deg and 60 deg)

(b) The requirements include the following:

(1) There shall be no detrimental effects of ball-path hardness. Typical ball paths are induction hardened to a minimum surface hardness of 58 HRC. Use eq. (3) if either the inner race or the outer race surface hardness is less than 58 HRC to modify the rating. The axial load static capacity, C_{sa}, and the bending moment static capacity, C_{sm}, must be adjusted per eq. (4) and eq. (5) if either raceway surface is less than the 58 HRC minimum surface hardness assumed in eq. (1). This is accomplished by the hardness adjustment factor, C_h.

$$C_h = A\left(\frac{\mathrm{HV}}{800}\right)^2 \leq 1 \tag{3}$$

where
A = constant equal to 1.5 for a ball on groove
C_h = hardness adjustment factor (less than or equal to 1.0)
HV = Vickers hardness number

$$\text{adjusted } C_{sa} = C_{sa} \times C_h \tag{4}$$

$$\text{adjusted } C_{sm} = C_{sm} \times C_h \tag{5}$$

Several hardness adjustment factors are given in Table 5.1.1-1.

(2) The case depth is adequate. Subsurface shear stresses require a case depth that is approximately 10% of the ball diameter, but this is not always true. The case depth required must be verified for each application, and this is beyond the scope of this Standard. The depth of the case for an induction hardened part is defined as the depth below the surface at which the hardness drops 10 HRC from that at the surface. If the case depth is inadequate, it is beyond the scope of this Standard.

(3) The bearing is seated on a rigid structure and maintains circular and undistorted raceways. There shall be no detrimental distortions of the ball paths or "hard spots" in the supporting structure. Quantification of this may require a detailed finite element (or other method) structural analysis.

Table 5.1.1-1 Hardness Adjustment Factors, C_h

HRC	HV	Hardness Adjustment Factor, Four- and Eight-Point Ball, C_h
58	660	1.0
56	620	0.901
55	600	0.844
50	500	0.586

(4) The balls are 60 HRC or higher, of appropriate quality (grade), and uniform size.

(5) Axial loading is compressive on the bolted joint, and its effect is minimal.

(6) The radial component of loading shall be ignored as it is small, and shall be less than 10% of the axial load.

(7) The bearing races consist of adequately quenched and tempered, clean steel free of defects and a core hardness typically at 262 BHN or higher.

5.1.2 Fasteners. The SRB manufacturer shall not be responsible for the mounting fasteners but is often asked to provide guidance on their design. In fact, the fasteners may be a limiting factor in the design.

The following is only a guideline; each application should be examined individually and if possible, compared to other similar applications with proven performance.

In general, grade 8 fasteners with a proof strength, P_s, of 120,000 psi are used to mount the slewing ring bearing through both the inner and outer races. The proof load, P_l, is equal to the proof stress multiplied by the tensile stress area, A_t.

$$A_t = 0.785\left(d_b - \frac{0.97}{t_{pi}}\right)^2 \tag{6}$$

$$P_l = P_s \times A_t \tag{7}$$

where

A_t = tensile stress area, in.^{2}
d_b = nominal fastener diameter, in.
P_l = proof load, lb
P_s = proof strength, psi
t_{pi} = number of threads per inch

For equally spaced fasteners on a single bolt circle diameter (BCD) preloaded sufficiently to prevent joint separation while in service (commonly at 70% of the proof strength), the allowable bending moment (ABM) for the fasteners through the joint is estimated as follows:

$$\text{ABM} = \left(\frac{P_l \times \text{BCD} \times N}{108}\right) \tag{8}$$

where

ABM = allowable bending moment, ft-lb
BCD = bolt circle diameter, in.
N = number of fasteners

Note that the fasteners in both races must be checked. This allowable bending moment for the fasteners, ABM, is a limiting factor if it is less than the bending moment static capacity of the ball path, C_{sm}. If the fasteners are not equally spaced, an analysis is still required; this is beyond the scope of this Standard.

5.1.3 Graphical Representation. A graph can be created with C_{sm} on the x-axis, C_{sa} on the y-axis, with a straight diagonal line drawn between them; this is identified as the static load rating graph. For the design to be satisfactory, all combinations of actual bending moment and axial load conditions shall lie on or below this line. See Figure 5.1.3-1.

If the allowable bending moment (ABM) for the fasteners of either race is less than C_{sm}, this graph must be altered. In this case, the diagonal line from C_{sa} toward C_{sm} must be truncated when it reaches the smaller ABM. See Nonmandatory Appendix B for an example of the ball-path rating calculation.

5.2 Gear Design

Some applications require that gear teeth be cut into one of the races of the SRB. External gear teeth cut into the outer race are more common, but some SRBs have internal teeth cut into the inner race. These geared SRBs are almost always driven by one or more gear drives with overhung pinions.

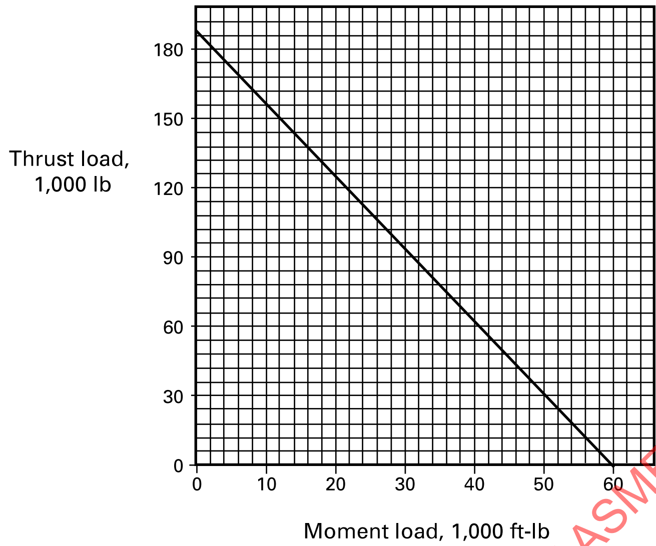
ISO and AGMA standards as well as finite element calculation methods have been used successfully for the design of slew ring gears. A considerable amount of experience is necessary to ensure that the correct design factors are applied to obtain adequate gear life.

Due to overhung pinions and their typically high deflection, load distribution can have a large impact on the gear performance. In order to ensure that the gear load calculations performed are valid, the deflection of the pinion with respect to the gear shall be properly accounted for.

Minimizing the pinion deflection in order to limit misalignment usually improves gear life. Methods used to minimize deflection include: minimizing the deflection of the structure supporting the pinion, minimizing the deflection of the pinion bearings, and keeping the pinion gear length short relative to its diameter. The effect of the deflection is taken into account in gear standards by the load distribution factor. It is also common to provide a tooth modification to allow for deflection. The gear design should be discussed with the SRB manufacturer to ensure that the load distribution is properly accounted for.

5.2.1 Geometry. Most SRB gears are cut with an involute spur profile with a 20-deg pressure angle, but other pressure angles may be used. Both standard whole depth and stub teeth are common. Gear tooth shape is defined either by the SI system (module) or U.S. Customary system (diametral pitch).

Figure 5.1.3-1 Static Load Rating Graph



GENERAL NOTES:
(a) Loading points on or below the line are within the rating.
(b) Radial loads of less than 10% of the thrust loading can be ignored.

Calculation methods for gear strength are beyond the scope of this Standard. The reader is referred to gear design textbooks and to AGMA/ISO standards. If questions arise regarding proper calculation methods, these should be discussed with the SRB manufacturer.

5.2.2 Addendum Modification. In some applications the pinion gear is cut with a modified addendum. The slew gear can also be cut with a modified addendum, but it is less commonly done.

Addendum modification is the displacement of the gear cutting tool from the standard diameter to produce thicker or thinner teeth than standard. The tip (outside for an external, inside for an internal) diameter is modified to provide full contact without interference with the mating gear. The center distance can be smaller than, equal to, or greater than the standard distance for gears with unmodified addenda.

Addendum modification can be used to eliminate undercutting and increase bending strength of gear teeth. Addendum modification is often required to avoid interference with gear sets having pinions with low numbers of teeth.

5.3 Mounting Design

Most SRBs are installed with a bolted joint. The design of this joint, consisting of the mounting surfaces, fasteners, and SRB, is critical to the proper functioning of the bearing and is the responsibility of the equipment manufacturer.

The companion structures shall be designed and manufactured to minimize out-of-flatness. Out-of-flatness shall be gradual when it occurs.

Mounting holes within the structure shall have the same quantity and position as the mounting holes in the SRB with adequate tolerance to prevent distortion of the bearing. The SRB support structure shall be sufficiently rigid and free of distortion during operation to avoid uneven or localized loading on the bearing.

If the SRB design includes a locating pilot, the locating pilot shall be machined round. A configuration where either the bearing race or the mounting surface is threaded is acceptable, as is drilling through both and using flat washers and nuts.

For fixed center designs, the center distance spacing must take into account the tolerance stack up and runout of both the gears and the mounting arrangement. For adjustable center design, backlash is adjusted at installation. At a minimum, there must be sufficient backlash to prevent interference throughout the slewing range.

When the SRB is being designed, the lubricant ports should be located in the bearing race that does not rotate.

5.3.1 Stiffness. Supporting structures shall be designed to have sufficient rigidity while minimizing local distortions to adequately support the SRB.

The mounting structure shall be designed to limit deflection under load to prevent adversely affecting the bearing. The stiffness of the mounting structure should be uniform, and the mounting structure should avoid variances of stiffness and abrupt changes of deflection under the bearing. SRB manufacturers can provide equipment designers and equipment manufacturers with the loaded deflection tolerances required for specific bearing applications.

The important parameters are

(a) mounting surface flatness

(b) deflection in a direction parallel to the axis of rotation of the bearing

(c) torsional deflection of the mounting face

(d) out-of-round deflection

(e) mounting sequence

Upon request, SRB manufacturers should provide users with the mounting tolerances required for specific bearing applications.

5.3.2 Fasteners. The fasteners in an SRB application clamp the joint to prevent relative motion between the mounting surfaces and the bearing. This is accomplished by preloading the fasteners to the point that under the maximum design load, the joint remains clamped.

Either through bolts (or studs with nuts on both ends) in smooth holes or bolts with tapped holes can be used. Through bolts allow for better control of fastener tension and thereby better load distribution than fasteners used with threaded holes. Whenever possible, use fasteners with a length-to-diameter ratio of 5:1 or greater.

It is recommended that hardened flat washers be installed under the heads and nuts of fasteners. The use of lock-spring washers is not recommended.

5.3.3 Fastener Spacing Considerations. Fastener holes shall be spaced so that there is sufficient space between fasteners to allow the use of either a bolt tensioner (preferred) or torque wrench. All fasteners shall be accessible for tensioning or torquing when in service.

5.3.4 Commonly Used Materials. Commonly used materials for SRBs are listed in Nonmandatory Appendix C. This does not preclude the use of other suitable materials.

6 INSTALLATION

This section covers subjects that are normally the responsibility of the equipment manufacturer (or systems integrator, a purchaser of the SRB that installs the bearing in a product either for sale or own use) in conjunction with the SRB manufacturer.

6.1 Mounting Structure and Surfaces

SRB manufacturers may provide the pertinent specifications. Before mounting, remove all paint, grease, and other foreign substances from both the structures and the bearing, and check that the surface finish and flatness of the mounting surfaces are within specifications. The use of a smoothing stone to remove nicks is common. Shims, grout, or other fillers to flatten the mounting surface shall not be used.

6.2 Fasteners

(a) General. Fasteners should be able to be initially threaded by hand, ensuring that there is no interference between the fasteners, bearing, and mounting holes within the mounting structure. The bearing should not be distorted when inserting the fasteners through the bearing/mounting assembly. Tightening of the fasteners should follow a star pattern that will secure the bearing evenly to the mounting structure. Tensioning the fasteners within this star pattern is accomplished with incremental increases of tension to the final preload values.

Utilizing fewer than all SRB mounting holes requires analysis.

(b) Fastener Preload. The equipment manufacturer shall specify the required fastener tension and/or torque; 70% of the proof strength is common. All fasteners shall be accessible.

6.3 Gear Mesh

At installation, the alignment of the pinion with the gear should be checked by the equipment manufacturer.

For an adjustable center design, backlash is adjusted at installation. At a minimum, there must be sufficient backlash to prevent interference throughout the slewing range.

As with all gears, some backlash must be maintained between the gear and pinion; however, excessive backlash cannot be tolerated in some applications. The SRB supplier should provide a recommended minimum and maximum backlash.

When adjusting backlash, locate the point of maximum runout of the bearing ring gear. Adjust the pinion position to obtain the desired minimum backlash at this point. Rotate the bearing through the maximum rotation range, taking backlash measurements periodically during the rotation. Adjust the pinion position, if required, to ensure that the minimum actual backlash is sufficient.

6.4 Other Mounting Considerations

The SRB should be oriented such that the soft spot of each race is approximately 90 deg from the axis of the tilting load (or of the preferred work area), in an area of minimum stress.

It is recommended that SRBs not be installed by welding, and no welding is permitted that could ground through the SRB.

7 MAINTENANCE

There are two areas to lubricate an SRB — the ball path and the gear teeth if present. Most applications use grease for both areas, although oil has also been used. Contact the SRB manufacturer for the appropriate lubricant.

7.1 Ball-Path Lubrication

(a) Upon installation of a new SRB, the ball path shall be relubricated, as it is likely that the grease installed by the SRB manufacturer is not sufficient for full operation. It is important that any new grease that is added to the ball path is fully compatible with any grease currently in the bearing. Mixing incompatible greases can result in structural or consistency issues. Consult National Lubricating Grease Institute (NLGI) or a lubricant supplier for grease compatibility.

Relubrication should follow the original equipment manufacturer's recommendations, which can change with the operating environment. If this is not available, a common practice is to relubricate the ball path at 100 hr of operation or 3 months, whichever comes first, for SRBs with low to moderate loading, intermittent service, and where dry and clean operating conditions exist. For bearings subject to frequent dynamic loading, excessive vibrations, or dirty or wet operating conditions, the relubrication interval should be reduced, perhaps to every 50 hr of operation or monthly, whichever comes first.

(b) The recommended method for greasing the ball path involves slowly rotating one race, the one without the grease fittings, while pumping in the new grease through the grease fittings, perhaps two or three full revolutions. The proper amount of grease is determined when the new grease begins to show beneath the seals. If possible, leave the purged grease in place on top of the seals as it serves as a protective barrier from contaminants.

(c) Basic grease recommendations for ball paths are as follows:

(1) NLGI grade 1 or 2

(2) extreme pressure (EP), rust and corrosion protection, and antiwear additives

(3) base oil viscosity grade ISO 220–460

Special situations, such as operating temperatures out of the range of −40°F to 140°F (−40°C to 60°C) or operating speeds over 500 ft/min (2.54 m/sec), may dictate the use of other lubricants. These should be discussed with the SRB manufacturer and lubricant supplier.

(d) Automatic lubrication of the ball path can be provided for any size of SRB. It is particularly advantageous for larger bearings. Automatic lubrication systems should be designed to provide a metered flow of lubricant to each of the lubricant ports provided. Field observation indicates that manual lubrication of slewing bearings is difficult, particularly with larger diameter bearings. As bearing size increases, the probability of the bearing receiving sufficient lubricant decreases.

7.2 Gear Teeth Lubrication

If grease is used, the grease used to lubricate the gear teeth in an SRB is likely different than that used to lubricate the ball path. If the gearing is exposed, the lubricant for the gear teeth is made from very high viscosity base oil and is designed to be tacky and adhere to the teeth. The grease should be recommended by the lubricant supplier for open gearing based on the gear operating conditions. Typical lubricants include asphaltic type compounds and mining gear greases.

After installation of the SRB and prior to use, completely cover the gear teeth with lubricant. Relubrication of the gear teeth should be done per the equipment manufacturer's requirements. Automatic lubrication is also an option for the gear teeth.

8 INSPECTION

Inspection of an SRB shall be conducted by a designated person familiar with the design of the bearing and the testing and inspection procedures necessary to ascertain the condition of the bearing. The rate of inspection is important; it is recommended that SRB inspections be performed at least once a year, but more frequent inspections are required for some applications. Any deficiency identified shall be examined and a determination made by a qualified person as to whether it constitutes a hazard or functional problem.

8.1 Recommended Inspection Plan

An inspection plan should be developed for each SRB placed into service. For most applications, an increase in bearing internal clearance will occur as the bearing ages. Comparing measurements of the internal clearance of the bearing over time will give an indication of the condition and remaining life of the bearing.

(a) Recommended inspections include the following:

(1) General Inspection. The SRB shall be given a general visual and operational inspection for smooth operation, signs of gross damage, and abnormal noise during operation through its rotational limits in both directions. Seals shall be visually inspected for damage and signs of contamination.

(2) Internal Clearance. The equipment manufacturer shall provide the user with a procedure to measure the internal clearance for the SRB on the assembled equipment. The equipment manufacturer in conjunction with the SRB manufacturer shall provide the user with clearance values that allow the equipment to remain in service. The internal clearances should be taken after the fasteners are checked and tightened as required. When internal clearances are utilized as an inspection method, initial internal clearances should be measured after installation and before extensive operation of the bearing. These initial internal clearances should be recorded for reference during later inspections.

Inspections should be performed periodically, at least as often as recommended by the equipment manufacturer, to determine changes in internal clearances. The service inspection clearances should be recorded and compared to the initial reference clearances.

(3) *Supporting Structure Inspections.* The supporting structure shall be inspected for structural damage such as corrosion, cracks, distortion, etc.

(4) *Mounting Fastener Inspections.* All mounting fasteners shall be inspected for proper tightness or preload. The equipment manufacturer in conjunction with the SRB manufacturer shall provide the user with the proper fastener tension or torque values used for inspection purposes and any other specialized information required, such as when fastener replacement is required. Special tooling may be required for this inspection such as bolt tensioners, hydraulic torque wrenches, or torque multipliers.

(5) *Gear Inspection.* Gear teeth shall be visually inspected to assure that the lubricant is adequate and for evidence of abnormal wear or other damage. If abnormal or excessive wear is detected or suspected, tooth thickness and backlash measurements shall be taken and compared to original dimensions. Gear teeth flanks, root fillets, and rims shall be inspected for cracks. Gear teeth flanks shall also be inspected for pitting, spalling, scuffing, surface distress, and plastic flow.

(b) Further evaluations may include the following:

(1) *Lubricant Sampling*. A reference sample of each lubricant used should be known, or taken and submitted for analyses to determine an initial lubricant condition baseline. Representative samples of used lubricants that are either drained, purged, or otherwise removed or displaced from the bearing during relubrication should be analyzed and compared to initial lubricant condition baseline and known industry standards.

NOTE: Used grease analysis is not widely available; not all laboratories have the capability to process used grease samples. This is a destructive test for the sample. The grease must be analyzed as it comes in for National Lubricating Grease Institute (NLGI) grade (penetration), drop point, and appearance. Then the sample is chemically cut to determine thickener type (lithium, calcium, clay, polyurea, etc.), the base oil viscosities [at 104°F (40°C) and 212°F (100°C)], and elements (additive, wear, and contamination). Sometimes ferrography is used to determine the shape of the iron particles, which is an indicator of the type of wear (cutting, abrasive, adhesive, etc.). However, since grease does not circulate like oil, the contaminants and the wear metals may have been "milled" over by going through the bearing load zones many times; it is difficult to determine the type of wear.

(2) *Vibration Analysis.* A vibration analysis may be conducted. If this type of inspection is utilized, the analysis should be performed by a qualified person on a regular basis and compared with a baseline analysis performed when the SRB was initially installed.

(3) *Acoustic Emission Analysis.* An acoustic emission analysis may be conducted. If this type of inspection is utilized, the analysis should be performed by a qualified person on a regular basis and compared with a baseline analysis performed when the SRB was initially installed.

(4) *Ultrasonic Testing (UT) Inspection.* If this type of inspection is utilized, the analysis should be performed by a qualified person on a regular basis and compared with a baseline analysis performed when the SRB was initially installed.

(5) *Torque Required to Rotate.* A test that measures the torque required to rotate the machine in a specified loading condition may be conducted. Typically, the torque is not directly measured but instead the current, voltage, or pressure required from the mating gear drive motor is measured instead. If this type of inspection is utilized, the analysis should be compared to previous tests and to a baseline analysis performed when the SRB was initially installed.

(6) *Disassembly and Internal Visual Inspection.* When indicated by other inspections, bearing disassembly and internal inspection may be required. If this type of inspection is performed, it is recommended that a representative of the equipment manufacturer or qualified repair service be consulted in conjunction with the SRB manufacturer.

(7) *Nondestructive Testing of Gear Teeth.* When indicated by visual inspections, nondestructive testing (e.g., magnetic particle testing, liquid penetrant testing) of gear teeth may be required. If this type of inspection is performed, it shall be performed by a qualified person.

9 CRITERIA FOR DETERMINING THE END OF A BEARING'S USEFUL LIFE

9.1 Potential Failure Modes

SRBs may experience several failure modes. The useful life of the bearing ends before any of these failure modes are reached. The inspection plan to monitor for the inception of these failure modes and criteria must be developed to determine the end of the useful life of the bearing before any condition that renders the bearing and equipment unusable, or results in a catastrophic failure, is reached. Gradual failure results from failure of the rolling elements and race surfaces and may be exhibited by increasing torque, noise, and internal clearances, along with the presence of increasing size and amount of wear particles in the lubricant. Sometimes gear wear will also be present.

9.2 End of Useful Life

The end of the slewing ring bearing's useful life should be agreed upon by the owner or end user of the equipment and the equipment manufacturer in conjunction with the SRB manufacturer. The end of an SRB's useful life may be defined by any of the following:

(a) an increased level of bearing clearance determined by initial and periodic clearance measurements and inspections

(b) a noise or vibration level determined by initial and periodic measurements and inspections taken under established conditions

(c) a condition of the SRB gear that exhibits a significant level of noise or vibration during operation, excessive backlash or wear, or a cracked or damaged gear tooth

(d) the number of cycles, hours of operation, or other time period of use

(e) an alternate method of establishing failure or end of useful life based on periodic measurements and inspections taken under established conditions

It is recommended that a warning level be established prior to the end of useful life level to provide a period of time for the owner to plan for replacement of the SRB and ordering replacement components.

NONMANDATORY APPENDIX A
APPLICATION DATA SHEET

Form A-1 shows the typical format of an application data sheet.

FORM A-1 APPLICATION DATA SHEET

1. Application Description (please attach additional drawing or sketch)

Application ____

____

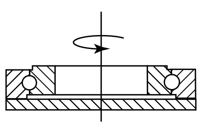
Other considerations ______________________________________

____

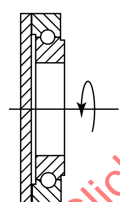
____

Position of rotation axis:

☐ Vertical



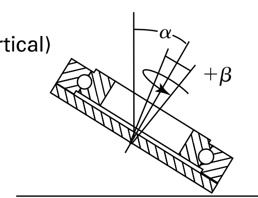
☐ Horizontal



☐ Inclined/variable

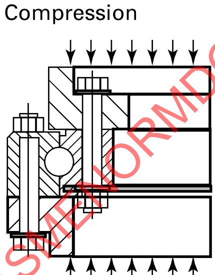
Nominal (relative to vertical)
α ______deg

Range
$+\beta$ _____deg

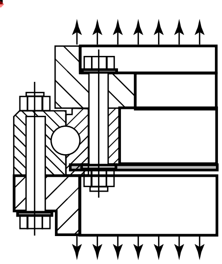


Axial load direction:

☐ Compression



☐ Tension



Ambient temperature Minimum ______°F Normal _______ °F Maximum _______°F

Seal required ☐No ☐Yes, against: ______________________________

Specific lubrication required ☐No ☐Yes, type: ______________________________

Special environmental considerations? ☐No ☐ Yes, describe: ______________________

____