placed in such bearings, their load capacity is greater than that of the Conrad type. However, the presence of the notches limits the load-carrying capacity of these bearings in the axial direction.

High-carbon chromium steel 52100 and 440C stainless steel are used for balls and rings, and are treated to high strength and hardness. The surfaces are smoothly ground and polished. The commonly accepted minimum hardness for bearing components is 58 Rockwell C. This material is not suitable for temperatures over 350° F. For higher temperatures, steels especially developed for high-temperature service should be used. The dimensional tolerances are very small; the balls must be very uniform in size. The stresses are extremely high because of the small contact areas, and the yield point of the material may be exceeded at certain points. Because of the high values of the fluctuating stresses, antifriction bearings are not designed for unlimited life, but for some finite period of service determined by the fatigue strength of the materials. A specified speed and number of hours of expected service must therefore accompany the given load values for these bearings.

1.3 Bearing Selection Factors

Bearings are basically antifriction devices. For this reason, the friction characteristics of different bearing types have to be examined.

In addition to the rolling resistance, other factors which contribute to the friction are as follows:

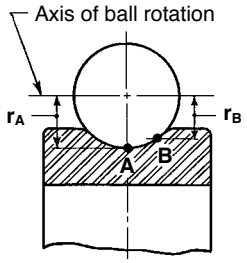

Fig. 1-5 Sliding caused by Geometry of Bearing

1. Sliding between the rolling elements and the race. When the rolling elements are curved, all points in contact do not have the same linear velocity, because of their differing radii of rotation. In Fig. 1-5, for example, a point A on the ball will have a definite linear velocity if no sliding occurs. However, a second point B on the ball will have less linear velocity than A because of its smaller radius of rotation. But point B on the race actually has a slightly greater linear velocity than A. This introduces sliding in both backward and forward directions. Other factors which introduce sliding are the inevitable inaccuracies in geometry and other deviations from true rolling.
2. The sliding action between the rolling element and the separator. Although contact takes place at the poles, where the velocity is lowest, some sliding action is present.
3. In roller bearings, the sliding action between the rolling elements and the guide flanges.
4. The losses between the bearing parts and the lubricant and between the different particles of the lubricant.

Palmgren[1] gives the following frictional coefficients for antifriction bearings:

Self-aligning ball bearings	f = 0.0010
Cylindrical roller bearing	f = 0.0011
Thrust ball bearings	f = 0.0013
Single-row deep-groove ball bearings	f = 0.0015
Tapered and spherical roller bearings	f = 0.0018
Needle bearings	f = 0.0045

All these coefficients are referred to the bearing bore. They are for run-in bearings, under

[1] See reference at the end of the Technical Section.

normal conditions, with good lubrication. When determining the total losses in a given application, the seal friction must not be ignored since it may be considerable.

In addition to considerations related to friction, attention must be given to speed requirements. Permissible speeds are influenced by bearing size, properties, lubrication detail and operating temperatures. The permissible speed varies inversely with mean bearing diameter.

Some guidelines for selecting bearings can be summarized as follows:

- Ball bearings are the less expensive choice in the smaller sizes and under lighter loads, while roller bearings are less expensive for larger sizes and heavier loads.
- Roller bearings are more satisfactory under shock or impact loading than ball bearings.
- Ball-thrust bearings are for pure thrust loading only. At high speeds, a deep-groove or angular-contact ball bearing usually will be a better choice, even for pure thrust loads.
- Self-aligning ball bearings and cylindrical roller bearings have very low friction coefficients.
- Deep-groove ball bearings are available with seals built into the bearing so that the bearing can be prelubricated to operate for long periods without attention.

The following **Table 1-1** attempts to summarize and tabulate various considerations which influence the selection of the appropriate bearings:

Table 1-1 Bearing Selection Factors*

Relative rating
- ■ good
- ◪ intermediate
- • poor
- ▬ none
- ⊠ does not apply
- □ not available or known

NOTE: This table is only a general guide – ratings may change when considering special types or treatments.

Selection Factors	Bearing Types: Ball						Roller						Journal						Thrust				Ext. press.⑤		Gas ⑤	
	2a deep groove	2b deep groove – fill	2c slot	2d angular contact	2e 2-row angular	2f contact	3a cylindrical	3b cylindrical–locating	3c barrel	3d spherical thrust	3e tapered	3f needle	8a full	8b partial	8c axial slotted	8d elliptical	8e three-lobed	8f pivoted shoe	12a parallel	12b step	12c tapered land	12d tilt shoe	capillary ⑥	variable flow	pneumostatic	pneumodynamic
Low starting friction	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	•	•	•	•	•	•	•	•	•	•	■	■	■	•
Low running friction	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	•	◪	◪	◪	■	◪	■	■
Low noise	•	•	•	•	•	•	•	•	•	•	•	•	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Small diameter ①	•	•	•	•	•	•	◪	◪	◪	◪	◪	■	■	■	■	■	■	◪	•	◪	◪	◪	◪	◪	•	•
Short length ①	■	■	■	◪	■	■	■	■	■	■	■	◪	◪	◪	◪	◪	◪	◪	■	■	■	◪	◪	◪	•	•
High accuracy	◪	•	■	■	◪	◪	◪	◪	◪	◪	◪	◪	•	•	•	•	•	◪	•	•	•	•	■	■	■	•
Most available	■	■	■	■	■	■	■	■	■	◪	■	■	■	■	•	◪	•	•	■	•	◪	•	•	•	•	•
High radial load ②	◪	◪	◪	◪	◪	▬	■	■	■	▬	■	▬	■	■	◪	◪	◪	◪	▬	▬	▬	▬	◪	◪	•	•
High thrust load ②	◪	•	■	■	•	■	▬	•	◪	■	■	▬	▬	▬	▬	▬	▬	▬	•	■	■	■	◪	◪	•	•
High dynamic load ②	◪	◪	◪	◪	◪	◪	■	■	■	■	■	■	◪	◪	◪	◪	•	◪	◪	◪	◪	◪	◪	◪	•	•
Tolerate misalignment	◪	◪	◪	•	■	◪	•	•	■	■	•	•	◪	◪	◪	◪	◪	■	◪	◪	◪	■	◪	◪	•	•
Tolerate dirt	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	■	■	■	■	■	■	■	■	■	■	•	◪	•	•
Low initial cost	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	■	■	■	◪	◪	•	■	■	■	•	•	•	•	◪
High speed	■	•	■	◪	◪	•	■	■	•	•	•	•	◪	◪	◪	■	■	■	•	■	■	■	■	■	■	■
High temperature ③	◪	□	□	□	□	□	◪	□	□	□	□	□	•	□	□	□	□	□	□	□	□	□	■	◪	■	◪
Simple lube system	■	■	■	■	■	■	■	■	■	■	■	■	◪	◪	◪	◪	◪	◪	◪	◪	◪	◪	•	•	•	■
High stability ④	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	•	•	◪	■	■	■	■	■	■	■	■	◪	•	•
Easy for designer	■	■	■	■	■	■	■	■	■	■	■	■	■	◪	◪	◪	◪	•	◪	◪	◪	◪	•	•	•	•

① with a given load (radial or thrust) ② with a given size ③ above 450°F ④ applies to high speed fluid-film bearings
⑤ journal or thrust type ⑥ restrictor controlled (liquid)

* See reference at the end of the Technical Section.