# Capacity, Life, and Load Analysis of Reali-Slim Ball Bearings



## ABMA 9:1990/ISO 281:1990

Many bearing manufacturers calculate dynamic radial capacity in accordance with the formulas in ABMA Standard 9 and ISO 281-1990. However, in Kaydon's judgment these equations are overly optimistic because they assume certain design details that are not valid for thin section bearings.

The capacities of Kaydon bearings as calculated using these equations are included for comparison purposes only. Alongside these ABMA 9:1990/ISO 281:1990 capacities, readers will find Kaydon Radial Capacities, which are calculated using more realistic assumptions based on actual design details and validated by decades of fatigue life testing. Please see the Kaydon white paper "Not All Thin Section Bearings Are Created Equal," available at our website: http://www.kaydonbearings.com/white_papers_1B.htm.

## Increased Capacity

The values in Kaydon radial capacities are consistent with both ABMA Std. 9 and ISO 281 calculations, when the proper assumptions are considered. The increased capacities apply to bearings with standard internal clearance. The new values assume that a certain amount of clearance is left in the bearing after installation.

The biggest increase is in the radial capacity of four-point contact (Type X) bearings. Under the old rating system, four-point contact bearings were given the same capacity as radial (Type C) bearings. However, in this type of bearing the ball loads are distributed over two lines of contact on each race. This gives lower contact stress and longer life, as demonstrated by Kaydon testing.

## Life

The dynamic capacity values shown in this catalog are based on actual data from fatigue life testing. The capacities are based on 1,000,000 revolutions $L_{10}$ fatigue life. This is the industry standard that was established for ease of calculation. It is not advisable to apply loads equal to the dynamic capacities in an actual application. Continuous rotation under these conditions would not normally yield acceptable life.

$L_{10}$ fatigue life is that life which 90% of a representative group of identical bearings can be expected to achieve or exceed before evidence of subsurface material fatigue appears. The life of the remaining 10% is unpredictable. The life which 50% of the bearings may be expected to achieve or exceed is approximately 5 times the $L_{10}$ life. This is known as the $L_{50}$ or median life.

There is no significant difference between the dynamic capacity for inner race rotation versus outer race rotation. This is due to the relatively small ratio of ball diameter to pitch diameter in Reali-Slim bearings.

Static load capacities are shown in this catalog. However, the actual static load a Reali-Slim bearing can withstand is dependent upon the amount of support provided by the shaft and housing.

The published capacity numbers allow the user to quickly estimate the bearing $L_{10}$ life for a one-dimensional load case. The life can be estimated using one of the following equations:

$$L_{10} = \left(\frac{C}{P}\right)^3 \bullet 1{,}000{,}000 \text{ revolutions}$$

Where: $L_{10}$ = life in revolutions
$C$ = Kaydon dynamic rating
$P$ = Applied load (effective)

or

For determining the life in hours at a given speed of rotation the above formula can be changed to read:

$$L_h = \left(\frac{C}{P}\right)^3 \bullet \left(\frac{16{,}667}{S}\right) \text{ hours}$$

Where: $L_h$ = $L_{10}$ life in hours
$S$ = Speed in RPM

For multiple load cases or non-standard internal fits, the analysis becomes more complicated. Contact Kaydon Engineering for these cases or consult Reali-Design software available on our website: www.kaydonbearings.com.

It should be noted that the capacities published in this catalog are best used for comparison purposes. The actual value of a life calculation is only valid for an individual load case and the internal fitup for which the number was derived. Since it is very rare to have a truly radial or axial or moment load, these are not normally used for a life calculation.

## Load Analysis

Previous versions of this catalog have discussed applying the loads from a free body diagram to a bearing system and solving for each of four reactions. As there are generally three equations (one for radial, one for axial, one for moment loads) and four unknowns, one of the reactions has been assumed to be zero. Once the remaining reactions are resolved, the life of the bearing can be determined.

# Capacity, Life, and Load Analysis of Reali-Slim Ball Bearings (continued)



This method had several drawbacks, including:

- It suggested very low bearing life for systems with predominantly axial loads.
- Internal bearing fitup could not be included in the life calculation.
- All loading was assumed to be distributed around the bearing as though it were a pure radial load… regardless of its origin.

Modern computers and software allow for a more complicated and accurate method of determining life. Illustrated here are the results of this process. The actual loads are applied to the bearing and the resultant load on each and every ball in that bearing is determined. From this data, the static safety factor and dynamic $L_{10}$ life can be determined.

To better understand this, the following should be considered:

## Primary Radial Loading

- Larger clearances will have fewer balls carrying the loads, resulting in lower dynamic lives.
- Larger preloads may overload the bearing before the loads are applied.

## Primary Axial and Moment Loading

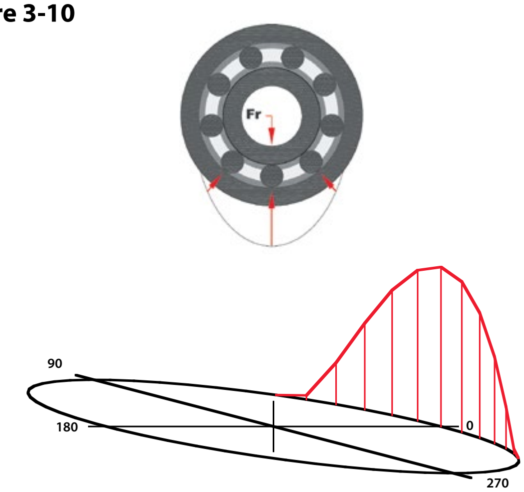
- Larger clearances will permit a higher contact angle than the ball has with the raceway, and thus better support the applied loading.
  - However, the ball-to-raceway contact area may spill over the edge of the race, causing other problems.
- Larger preloads may again overload the bearing before the loads are applied.

The method for calculating either a static safety factor or dynamic life requires a computer to determine the individual ball loads throughout the bearing. When these have been calculated, the maximum loaded ball is used to determine a maximum stress level and thus a static safety factor. All of the ball loads are used in a weighted analysis to determine the dynamic $L_{10}$ life.

Since these calculations require a computer, the mathematics required are not shown here. To complete such an analysis, utilize the Kaydon supplied software — Reali-Design or Reali-Design MM — available at www.kaydonbearings.com.

To better understand these principles, graphical representations of ball distribution around each of three common bearing types are shown in Figures 3-10 through 3-12. Here the ball load distribution and magnitude can be visualized. The higher the peak, the higher the loads.

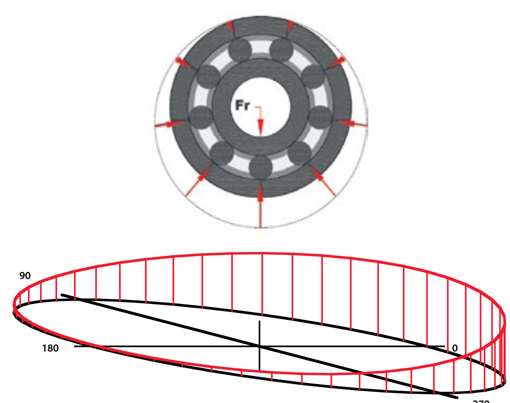
**Figure 3-10**




**KA040CP0 with 100 lbs. radial load**
Clearance in the bearing; few balls carry the load.

This radial bearing contains clearance. There are only three balls supporting this load, with a very high maximum value for the bottom ball.

**Figure 3-11**



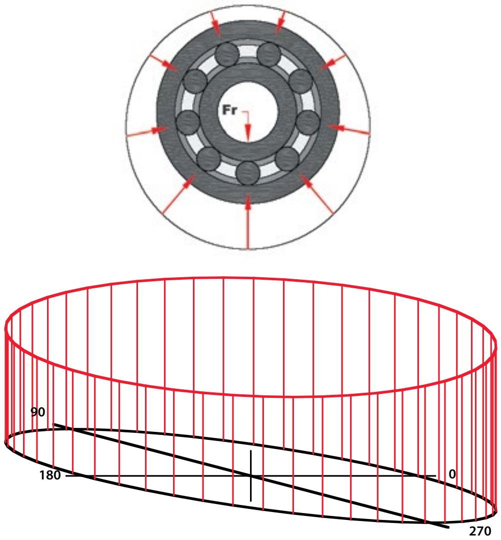

**KA040CP0K with 100 lbs. radial load**
Light preload in the bearing; all balls carry the load.

This radial bearing contains a light preload. All the balls have some load on them and, as can be seen, the bottom middle ball has far less load than the example above.

# Capacity, Life, and Load Analysis of Reali-Slim Ball Bearings (continued)



**Figure 3-12**



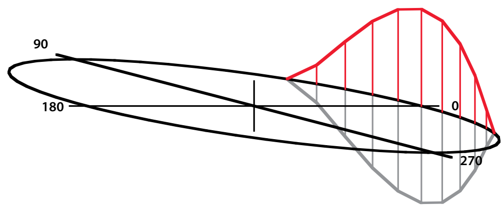

**KA040CP0P with 100 lbs. radial load.**
Heavy preload.

This radial contact bearing contains a very heavy preload. All the balls have load on them, and the load on the bottom ball is just as high as the bearing with clearance in the first example.

- Increased Capacity
- Increased Life
- Backed by Theory and Testing

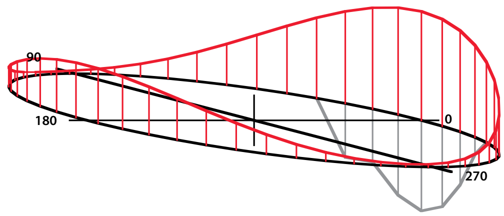
## Similar diagrams are shown below for other instances.

**Figure 3-13**



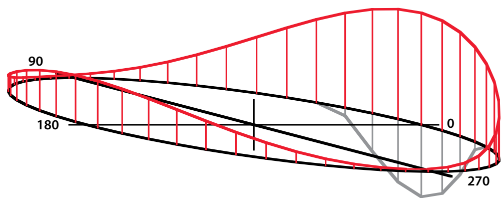

**KA040XP0 with 100 lbs. Radial Load**
Clearance in bearing; few balls carry the load.

**Figure 3-14**



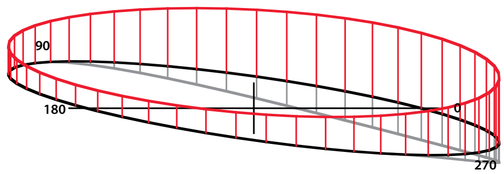

**KA040XP0 with**
**100 lbs. Radial Load, 100 lbs. Axial Load**
Lower ball contact, mostly unloaded.

**Figure 3-15**




**KA040XP0 with**
**100 lbs. Radial Load, 100 lbs. Axial Load**
**30 Inch-lbs. Moment Load**

**Figure 3-16**



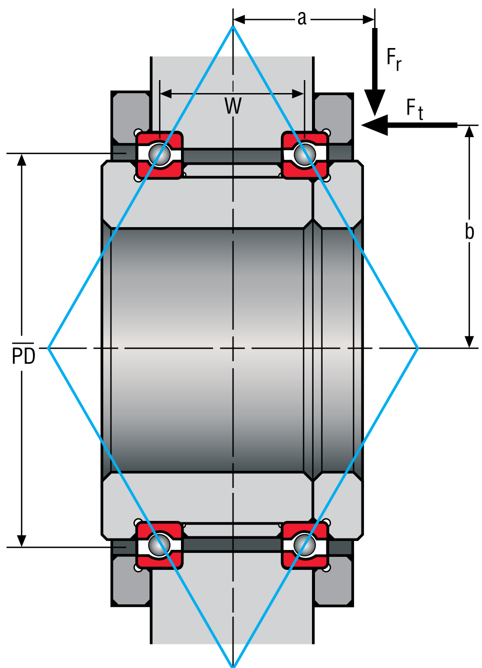

**KA040XP0K with**
**100 lbs. Radial Load, 100 lbs. Axial Load**
**30 Inch-lbs. Moment Load**

# Capacity, Life, and Load Analysis of Reali-Slim ball bearings (continued)



Figure 3-17 shows a typical mounting of two angular contact bearings subject to external forces $F_r$ and $F_t$.

**Figure 3-17**




**Load Diagram for a Back-to-Back Duplex Pair**

Radial Load = $F_r$
Axial Load = $F_t$
Moment Load = $F_r a - F_t b$

Consult Kaydon's exclusive Reali-Design software for resultant load calculations.

## Variable Load Cases

Often a bearing system must operate in several modes such as "idle" and "working." In this instance, the loads may vary substantially. It is advantageous to calculate the life of the bearing under the total loading spectrum. To do this, the individual life under each load case can be calculated alone, then combined to provide the system life for a particular duty cycle.

To perform this calculation, break the loading up into discrete sections which can have their respective percentage of revolutions represented as part of the total, such as:

| Case 1 | Case 2 | Case 3 |
|---|---|---|
| $\text{Radial}_1$ | $\text{Radial}_2$ | $\text{Radial}_3$ |
| $\text{Axial}_1$ | $\text{Axial}_2$ | $\text{Axial}_3$ |
| $\text{Moment}_1$ | $\text{Moment}_2$ | $\text{Moment}_3$ |
| $\%\ \text{time}_1$ | $\%\ \text{time}_2$ | $\%\ \text{time}_3$ |
| $L_1$ | $L_2$ | $L_3$ |

Substitute the individual "$L_n$" lives into the equation below with "$t_n$" where $t_n = \%\ \text{time}_n$

The total weighted $L_{10}$ life for this system =

$$L_{10w} = \frac{100}{\frac{t_1}{L_1} + \frac{t_2}{L_2} + \frac{t_3}{L_3}}$$