# Dodge Bearings: Effects of Axial Load on Fatigue Life

C.O. Engineering - Bearings and PT Components
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The primary purpose of any bearing is to support a moving body and reduce the friction acting on it. For mounted roller bearings, this load comes from the weight of a rotor, the tension on a belt pulley, or even the back pressure acting on a driven fan. Bearings must be selected such that they can support both the magnitude and direction of every load acting on the shaft.

Loads on a shaft are typically defined as radial (acting normal to the axis of rotation) or axial (acting parallel to the axis of rotation). See the figures below for examples of each type of load.

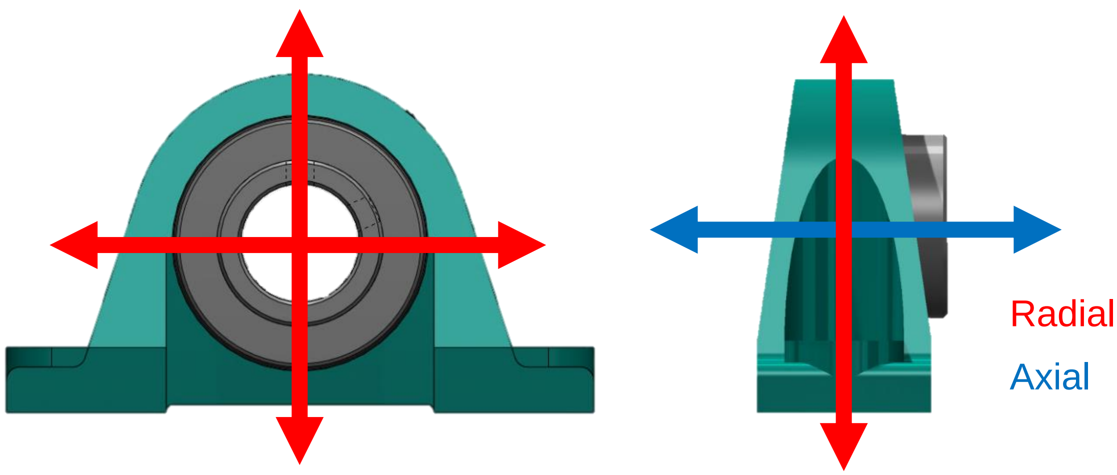


**Figure 1: Illustration of radial vs axial loads on a pillow block bearing**

Dodge primarily uses three types of roller bearings in its mounted units: deep-groove ball bearings, tapered roller bearings, and spherical roller bearings. All three of these bearing styles are primarily designed for radial loads, but can accommodate some amount of axial load if required. The allowable axial load is determined by one of three criteria: the $L_{10}$ fatigue life, the shaft attachment method, or the housing style. The limits of the shaft attachment and housing are fairly straightforward and usually provided for a given bearing. However, the effect of axial load on fatigue life requires some calculation.

When evaluating the $L_{10}$ life for a bearing with axial loading, the radial and axial loads must be combined into an equivalent radial load, *P*, using the equation below.

$$P = XF_R + YF_A$$

Where $F_R$ and $F_A$ are your radial and axial loads, respectively, and *X* and *Y* are load factors that describe how loads are distributed in the bearing. The *Y* factor describes how sensitive the bearing is to axial loading. A lower *Y* factor indicating less fatigue from axial loads, while a higher *Y* factor indicates that the bearing experiences greater fatigue from axial loads. The *X* and *Y* factors are primarily determined by the contact angle of the rollers, but also vary based on the ratio of radial and axial loads in a given application.

As seen in Table 1 below, each size of bearing has two distinct sets of load factors. The choice between the two sets of values is determined by comparing the ratio of axial and radial load to the value *e*. The *e* value is the point at which the axial load begins to shift the rollers to one side of the raceway and change how the load is distributed in the bearing. For roller bearings, each bearing type and size has its own values for *e, X*, and *Y*.

**Table 1: Load factors for some sizes of Dodge Type E bearings**

| Shaft Size | e | $F_A/FR<e$ | | $F_A/F_R>e$ | |
|---|---|---|---|---|---|
| | | X | Y | X | Y |
| 1-3/16<br>1-1/4 | 0.49 | 0.87 | 1.77 | 0.70 | 2.14 |
| 1-3/8<br>1-7/16 | 0.46 | 0.87 | 1.89 | 0.70 | 2.28 |
| 1-1/2<br>1-5/8<br>1-11/16 | 0.44 | 0.87 | 1.96 | 0.70 | 2.37 |

Mounted tapered roller bearings usually use a double-row design so that they can support pure axial loads in either direction. When loaded axially, the inner ring acts as a wedge, separating the rollers as it shifts to maintain contact with the outer races and support the radial and axial loads. Figure 2 below shows a visual representation of the load distribution as the axial load changes.

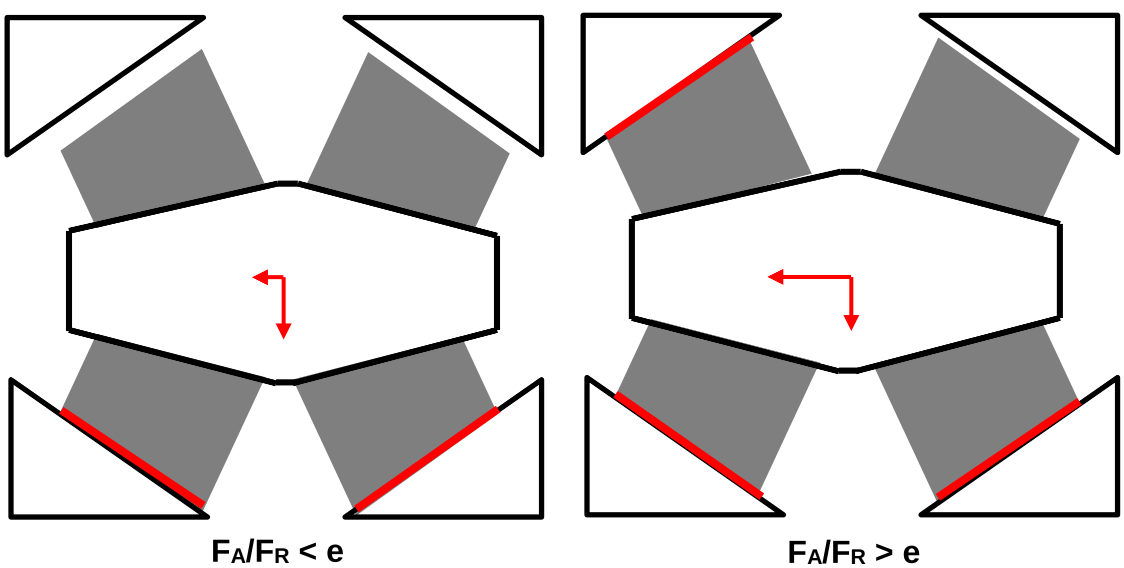


**Figure 2: Cross-section of tapered roller bearing under radial and axial loads**

In Table 2, the same types of values can be seen for Imperial bearings. However, note that the *Y* values for Imperials are much higher than Type E, suggesting that Imperials have less capacity for axial loads.

Table 2: Load factors for some sizes of Dodge Imperial bearings

| Shaft Size Inches | Basic Bearing Description | e | $F_A/F_R<e$ | | $F_A/F_R>e$ | |
|---|---|---|---|---|---|---|
| | | | X | Y | X | Y |
| 1-1/8<br>1-3/16<br>1-1/4<br>1-3/8<br>1-7/16<br>1-1/2 | 22208 | 0.28 | 1.0 | 2.4 | 0.67 | 3.6 |
| 1-1/2 **<br>1-5/8<br>1-11/16<br>1-3/4 | 22209 | 0.26 | 1.0 | 2.6 | 0.67 | 3.9 |
| 1-3/4 **<br>1-7/8<br>1-15/16<br>2 | 22210 | 0.24 | 1.0 | 2.8 | 0.67 | 4.2 |

The difference between the load factors of tapered and spherical roller bearings is due to the difference in roller contact angles. However, spherical bearings also require that the radial load is higher than the axial load. This is because a spherical raceway provides a wide contact area for distributing radial loads, but much less area for axial loads. As long as there is enough radial load to properly seat the rollers, the bearing can carry axial loads without issue. However, when the axial load outweighs the radial load, a spherical bearing will experience edge loading as the rollers are wedged into one side of the outer race. The diagrams below illustrate three conditions (from left to right): little to no axial load, axial load that is significant but less than the radial load, and axial load greater than radial load.

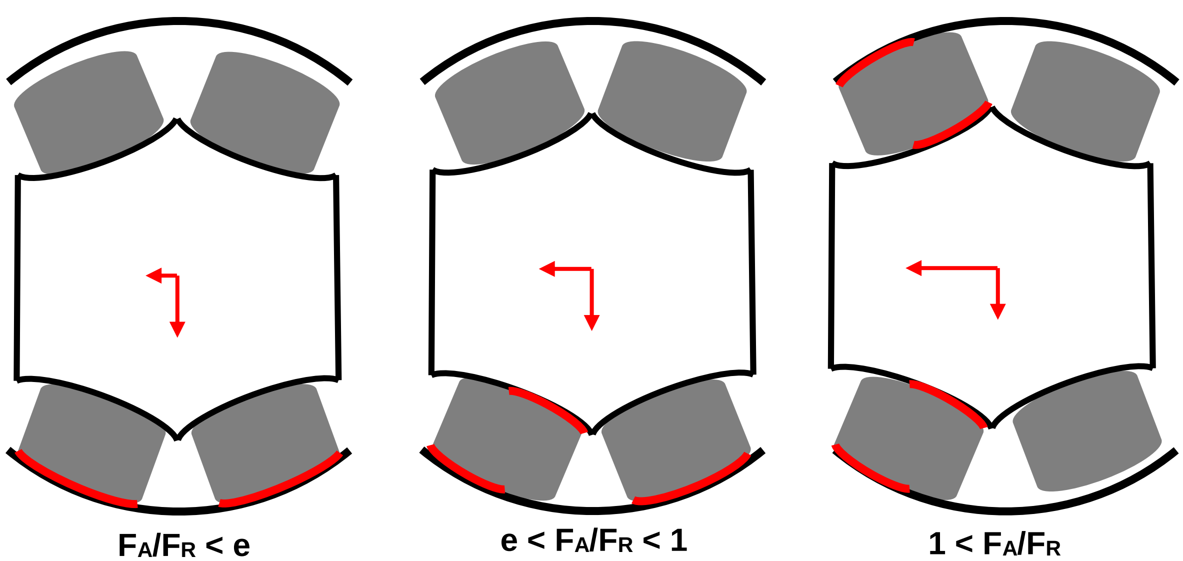


Figure 3: Cross-section of spherical roller bearing under different load conditions

For ball bearings, as shown in Table 3, load factors are not selected by the size of the bearing, but by the ratio of the axial load to the static capacity. This indicates that increasing the axial load changes how the load is carried by the bearing, changing the value of *e* as well as the axial load factor. The rest of the calculation works the same as for tapered or spherical roller bearings.

**Table 3: Example of *X* and *Y* factors for Dodge ball bearings**

| $F_A / C_0$ | e | Radial/Thrust Factors | | | |
|---|---|---|---|---|---|
| | | If $F_A/F_R$ is equal to or less than e | | If $F_A/F_R$ is greater than e | |
| | | $F_A/F_R <= e$ | | $F_A/F_R > e$ | |
| | | X | Y | X | Y |
| 0.014 | 0.19 | 1 | 0 | 0.56 | 2.30 |
| 0.021 | 0.21 | 1 | 0 | 0.56 | 2.15 |
| 0.028 | 0.22 | 1 | 0 | 0.56 | 1.99 |
| 0.042 | 0.24 | 1 | 0 | 0.56 | 1.85 |
| 0.056 | 0.26 | 1 | 0 | 0.56 | 1.71 |
| 0.070 | 0.27 | 1 | 0 | 0.56 | 1.63 |
| 0.084 | 0.28 | 1 | 0 | 0.56 | 1.55 |
| 0.110 | 0.30 | 1 | 0 | 0.56 | 1.45 |

When ball bearings are loaded radially, points of contact develop at the top and bottom of each loaded ball. When a sufficient axial load is applied, the balls roll with the inner ring as it shifts and the line of contact rotates with them (as shown in Figure 4). While this shifting load will increase the amount of fatigue on the raceway, the balls still maintain the same point contact and fully retains the inner ring. This is why deep-groove ball bearings can accept pure radial, combined, and pure axial loads.

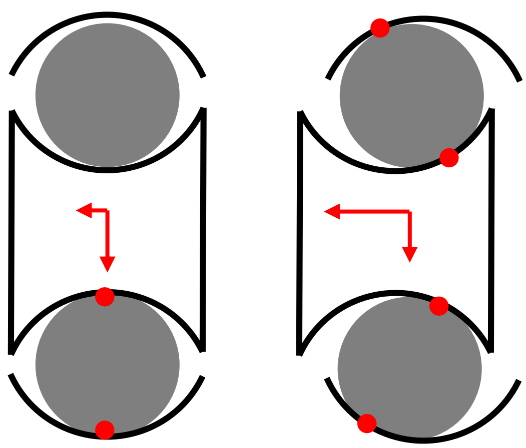


**Figure 4: Cross-section of ball bearing under radial and axial loads**

We can see that while most mounted bearings can handle loads in any direction, some bearings are more suitable for axial loads than others. For any application, all loads must be considered in order to determine the expected fatigue life and select the best bearing for the job.

For questions regarding Dodge bearing products and selection, please visit http://new.abb.com/mechanical-power-transmission or contact Dodge engineering by phone at 864-284-5700 or by email at brgpttechsupport@baldor.abb.com.