Dodge® mounted bearings: reliability

The reliability of bearings is important. Here's why; every single rotating shaft or axle is supported, at minimum, by two bearings. The commonality of this component has allowed it to become a highly studied mechanism and the research behind these studies have produced life prediction models of them that aid users in determining component reliability, predicting maintenance schedules and setting warranty ceilings.

Through the years studies have shown that bearing fatigue failures can be predicted through a Weibull statistical distribution. This has allowed the implementation of prediction models based upon three primary contributing factors; the bearing's dynamic capacity, the bearing speed, and the equivalent load acting on the bearing.

The dynamic capacity is defined as the load at which 90% of a given group of bearings will meet or exceed one million revolutions (90 million revolutions for tapered roller bearings). This definition is strictly based upon cycles and does not account for speed. Bearing manufacturers calculate dynamic capacity based upon the number of rolling elements, the diameter and length of the rolling elements, geometry and other components such as material and manufacturing quality. Dynamic capacity is one of the best means to compare one type of bearing to another.

The equivalent load acting on the bearing is the other primary factor contributing to fatigue life prediction. Most often the equivalent load is based in the radial plane (perpendicular to shaft) rather than the axial plane (parallel to shaft). This equivalent radial load is a resultant load, or vector, that accounts for combined pure radial and pure axial loading scenarios. The type of bearing and bearing geometry will govern how the equivalent radial load is calculated.

The fatigue life prediction model for anti-friction bearings is referred to as L_{10} life. L_{10} life is the number of hours (and sometimes listed as cycles) that 90% of a given group of bearings will meet or exceed those particular applied load and speed conditions. For example, the following equation represents the L10 life relationships for ball bearings.

$$L_{10} = \left(\frac{C}{P}\right)^3 \times \frac{16{,}667}{RPM}$$

Where,

L_{10} = Life, hours

C = Dynamic Capacity, lbs. or N

P = Equivalent Radial Load, lbs. or N

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Note that the equations are different for spherical and tapered roller bearings but the general relationships between L_{10} life, applied load, speed and dynamic capacity are all the same. For the same bearing, as equivalent radial load or RPM increases the L_{10} life decreases. Conversely, as load or speed decreases the L_{10} life increases.

Since L_{10} life defines the fatigue life to a 90% success rate, 10% of bearings failing in a given application may not be reliable enough. Some applications require definition of life at reliabilities greater than 90%. For these scenarios adjustment factors, often referred to as a1 factors, are available. The following table lists life adjustment factors that are factored against L_{10} life for higher reliability.

Reliability %	L_n	Life Adjustment Factor, a_1
90	L_{10}	1
95	L_5	0.62
96	L_4	0.53
97	L_3	0.44
98	L_2	0.33
99	L_1	0.21

For example if the calculated L_{10} was 10,000 hours and the application required 98% confidence instead of 90% confidence, then the L_{10} (10,000 hours) should be multiplied by 0.33. Therefore the same application would yield 98% reliability for 3,300 hours.

The fatigue life prediction model can also be adjusted for efficient lubrication and application conditions. These adjustments to the L_{10} life, commonly referred to as a_{23} factors, account for the effect of material and lubrication combined with the type of loading and bearing design. Favorable adjustments are reached when a condition of hydrodynamic lubrication is achieved. Hydrodynamic lubrication prevents metal-on-metal contact between the rollers and raceways and extends bearing life. The process of adjusting with a_{23} factors is specific to the application and requires more in-depth analysis of the loads, temperatures and lubricants, but in some cases it is possible to double the L_{10} life with ideal conditions.

It is important to note that the life prediction models are based upon bearing material fatigue. It assumes that the bearings have been installed properly, maintained properly, and selected properly with the correct seals and lubrication for the application. Typically the service life of the grease is well below the L_{10} life of the bearing so proper maintenance is critical. In fact, bearing manufacturer studies have shown that over 92% of industrial bearings fail from problems related to maintenance, installation or lubrication. These factors include ineffective lubrication, incorrect lubricant, incompatible lubricants, insufficient lubricant, moisture contamination, particle contamination, misalignment, poor handling, and poor sealing.

Understanding the types of loads and speeds, plus following scheduled maintenance practices can help users achieve ideal bearing life and predict when bearings require replacement.