Dodge® mounted tapered roller bearings: basic rating introduction

Recently Dodge Type E competition has increased the estimated L_{10} life for their bearing product line. In this white paper Dodge Engineering will discuss the importance of comparing multiple catalog ratings and how these ratings correlate to the actual bearing life in real world applications.

The L_{10} life is the bearing life prediction which 90% of a given group of bearings may meet or exceed, under given load and speed conditions. The L_{10} life is commonly expressed in units of hours and is referred to as the basic rating life L_{10} in ISO 281-2007 [2]. Per **Equation 1**, the L_{10} life is directly correlated to the dynamic capacity of the tapered roller bearing.

$$L_{10} = \left(\frac{C_{90}}{P}\right)^{\frac{10}{3}} \left(\frac{1,500,000}{RPM}\right)$$ Equation 1 [1]

Where:

L_{10} is the tapered roller bearing *L_{10}* life (hours) [1]

C_{90} is the dynamic capacity for a tapered roller bearing (lbs) [1]

P is the equivalent radial load (lbs) [1]

RPM is the bearing speed (rpm) [1]

The dynamic capacity for tapered roller bearings is the load which 90% of a given group of bearings can meet or exceed 90 million revolutions (3,000 hours at 500 RPM). ISO 281-2007 addresses the dynamic capacity as the basic dynamic radial load rating which is defined in **Equation 2**. The basic dynamic radial load rating is correlated to the tapered roller bearing dynamic capacity through **Equation 3**.

$$C_r = b_m f_c (iL_{we} cos\alpha)^{7/9} Z^{3/4} D_{we}^{29/27}$$ Equation 2 [2]

Where:

C_r is the constant stationary radial load which a rolling bearing can theoretically endure for a basic rating life of one million revolutions (N) [2]

b_m is the rating factor for contemporary, commonly used, high quality hardened bearing steel in accordance with good manufacturing practices, the value of which varies with bearing type and design [2]

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f_c is the factor which depends on the geometry of the bearing components, the accuracy to which various components are made, and the material [2]

i is the number of rows of rolling elements [2]

L_{we} is the effective roller length (mm) [2]

α is the is the nominal contact angle (degrees) [2]

Z is the number of rolling elements in a single-row bearing or the number of rolling elements p er row of a multi-row bearing with the same number of rolling elements per row [2]

D_{we} is the applicable roller diameter (mm) [2]

$$C_{90} = \frac{C_r * .259}{4.448}$$ Equation 3 [1]

The factors defined in **Equation 2**, with the exclusion of the factor b_m, are derived from the geometry of the bearing. Therefore if two bearings have the exact same geometry, the dynamic capacity could only differ due to the factor b_m. Due to the ISO 281-2007 definition of b_m, the factor can be a flexible coefficient and its value is generally verified through laboratory testing.

Although the dynamic capacity does directly affect the L_{10} life, the static capacity provides a truer rating of the bearing as all variables are determined by a bearing's geometry. The static capacity of the bearing is defined as theoretical load it takes to permanently deform the raceways by 0.0001" multiplied by the diameter of roller. The static capacity is called the basic static radial load rating per ISO 76-2006, and is defined in **Equation 4** [3].

$$C_{0_r} = 44\left(1 - \frac{D_{we}\cos(\alpha)}{D_{pw}}\right) iZL_{we}D_{we}cos\alpha$$ Equation 4 [3]

Where,

C_{0_r} is the basic static radial load rating (N) [3]

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D_{we} is the roller diameter (mm) [3]

D_{pw} is the pitch diameter of ball or roller (mm) [3]

i is the number of rows of rolling elements [3]

Z is number of rolling elements per row of a multi-row bearing [3]

L_{we} is the effective roller length (mm) [3]

α is the nominal contact angle (degrees) [3]

The L_{10} life is commonly increased through the inflation of the basic dynamic radial load rating, specifically the b_m factor, as the static capacity remains constant. Although the Type E's competition has recently modified its b_m factor, this is not a new phenomenon. The Tier 1 spherical roller bearing market has been modifying its b_m factor since 2000. This modification has resulted in maximized b_m factors as bearing manufacturers utilize the cleanest bearing grade steels available. Although the b_m factor is projected from testing and justified through enhanced material quality, it is also inherently conservative through the derivation of the basic dynamic radial load rating. Therefore with material quality maximized, continuously modifying the b_m factor begins to erode a manufacturer's engineering factor of safety. Table 1 illustrates the consistent static capacity and maximum speed ratings of the Type E competition with respect to an increase in dynamic capacity. With identical bearing geometry, determining if a bearing will meet or exceed the catalog L_{10} life is greatly dependent on minimizing the majority of bearing failures not merely projecting the fatigue life to meet laboratory testing.

To extend the actual life of the Dodge Type E in the most aggressive environments, the bearing has been engineered beyond catalog ratings. Through years of experience as the market leader in the harshest applications, Dodge has innovated bearing life enhancements into the Type E. Each innovation targets the leading causes of bearing failure. Each bearing failure mode is illustrated in **Figure 1**. Mechanically pressed seals allow solid, liquid, and self-contamination to purge away from the rollers as well as replenish grease dams. XTS sealing with the E-Tect option minimizes contamination from entering the bearing, per **Figure 2**. **Figure 2** illustrates the decrease of slurry ingress on a 1-15/16" Type E bearing with triple lip rubbing seals compared to a competitor with double lip rubbing seals for 96 hours at 500 RPM without re-lubrication. To further protect Type E, end closures can isolate the bearing from contamination entirely. Bearing manuals outline recommended lubrication intervals which provide a basis for predicting grease life. Type E Bearings are shipped standard with Lithium-Complex grease engineered to meet the demands of the Type E's applications. Mechanically pressed seals allow bearing pressure to purge so that re-lubrication volumes have a visual metric. Dodge C.O. Engineering and Sales Teams ensure the proper bearing is selected for each unique application. Enhanced Dodge Type E product offerings simplify mounting by incorporating static misalignment and expansion capabilities. Every Type E bearing is noise and vibration inspected prior to shipment to ensure the highest standards

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of quality are met. Whereas increasing the b_m factor is limited to bearings that could theoretically meet their L_{10} life, engineering beyond catalog ratings can extend the life on 99% of all bearings so that they do achieve their L_{10} life [5] [6].

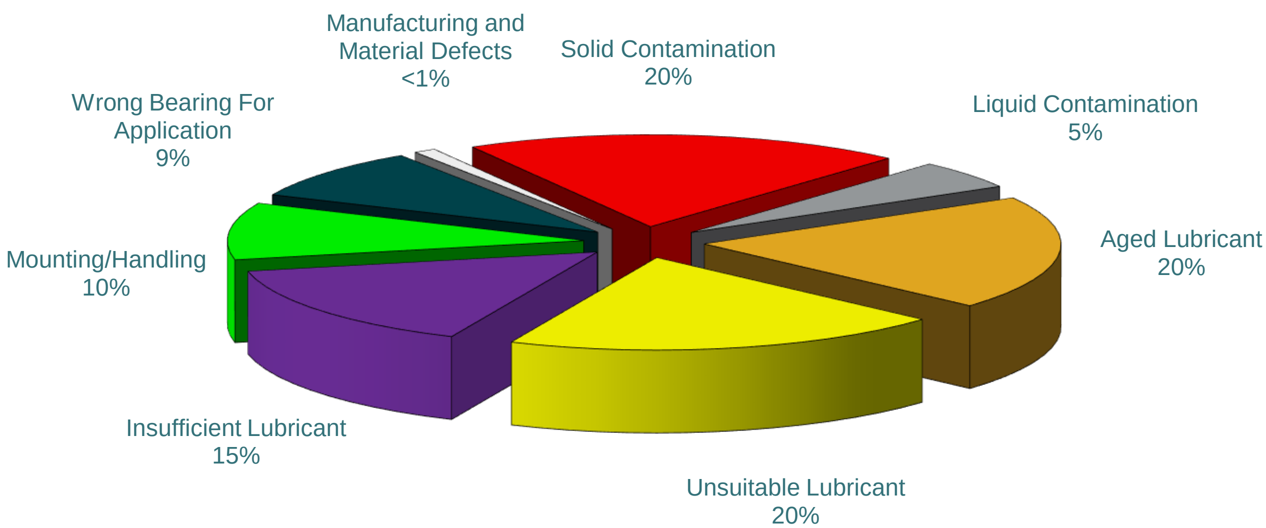

Figure 1. Industry Percentage of Bearing Failure Modes [5] [6]

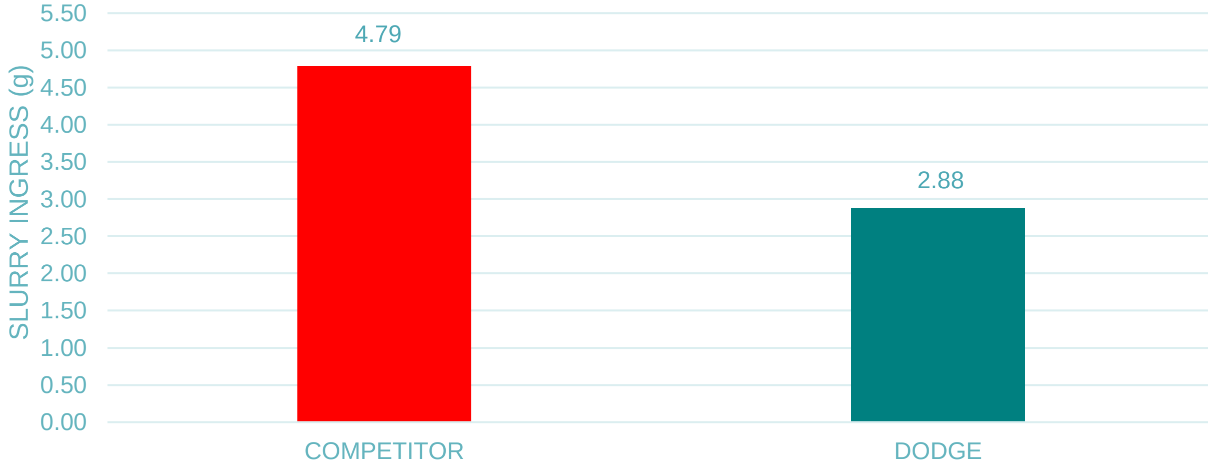

Figure 2. Slurry Ingress Seal Performance

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Shaft Size (in.)	Dynamic Capacity (C90)			Static Capacity (C0)			Maximum Rated Speed		
	DODGE Type E C90 (lbs) [1]	Competitor Current C90 (lbs) [4]	Competitor Previous C90 (lbs) [4]	DODGE Type E C0 (lbs) [1]	Competitor Current C0 (lbs) [4]	Competitor Previous C0 (lbs) [4]	DODGE Type E Max. RPM [1]	Competitor Current Max. RPM [4]	Competitor Previous Max. RPM [4]
1-3/16 1-1/4	3,450	3,810	3,400	15,760	15,760	15,760	4,490	4,490	4,490
1-3/8 1-7/16	5,500	6,100	5,430	26,000	26,000	26,000	3,820	3,820	3,820
1-1/2 1-5/8 1-11/16	7,070	7,860	7,000	33,000	33,000	33,000	3,320	3,320	3,320
1-3/4 1-7/8 1-15/16 2	9,300	10,300	9,200	43,000	43,000	43,000	3,050	3,050	3,050
2-3/16	9,850	10,900	9,740	48,200	48,200	48,200	2,730	2,730	2,730
2-1/4 2-7/16 2-1/2	10,600	11,600	10,400	54,000	54,000	54,000	2,420	2,420	2,420
2-11/16	11,120	12,300	10,900	61,200	61,200	61,200	2,060	2,060	2,060

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2-3/4 2-15/16 3									
3-3/16 3-1/4 3-7/16 3-1/2	17,750	19,600	17,400	108,600	108,600	108,600	1,640	1,640	1,640
3-15/16 4	24,400	26,900	23,900	154,000	154,000	154,000	1,530	1,530	1,530
4-7/16 4-1/2	30,000	33,000	29,400	188,400	184,000	188,400	1,360	1,360	1,360
4-15/16 5	41,310	45,500	40,500	266,000	266,000	266,000	1,200	1,200	1,200

References

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[2] ISO 281 Rolling bearings - Dynamic load ratings and rating life. (2007). Geneva, SZ: ISO.

[3] ISO 76 Rolling bearings – Static load ratings. (2006). Geneva, SZ: ISO.

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[5] FAG Bearing Antriebstechnik 18 (1979) No. 3, 71-74

[6] Rolling Bearing Damage: Recognition of damage and bearing inspection. (2010). Schaeffler Technologies GmbH & KG.