WP0273

Dodge® mounted bearings: internal bearing clearance effects

Dodge Customer/Order Engineering

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Rolling bearings are precision, anti-friction components that provide support and locate rotating shafts. Rolling bearings are comprised of balls or rollers which are fitted between an outer and inner ring. A cage is used to position and control the spacing between rolling elements. When bearings are manufactured and mounted, the clearances between these components are established. This clearance between rolling elements and rings is referred to as the internal bearing clearance.

Internal bearing clearance is defined as the total distance through which one ring can move relative to the other in either a radial or axial direction. See **Figure 1** showing radial and axial bearing clearance.

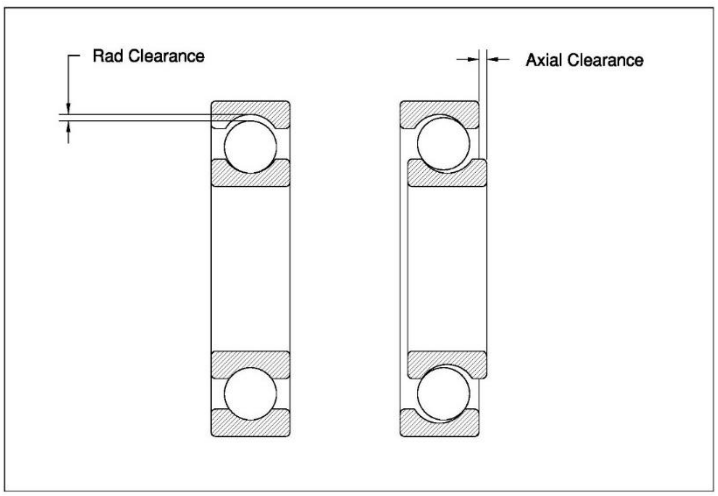

Figure 1. Internal radial and axial bearing clearance

When discussing internal bearing clearances, there are three distinct types:

- Initial Clearance – Unmounted clearance prior to mounting
- Mounted Clearance – Internal clearance after mounting, but prior to operation
- Operational Clearance – Internal clearance after the bearing is in operation, and has reached a stable temperature

Operational clearance plays a significant role in bearing performance and life. This clearance effects the size of the load zone, rotational friction, and fatigue life. Typically, the initial clearance will be greater than the operational clearance. This happens due to interference fits with shafts or housing bores, and thermal expansion of internal components as operational temperatures increase toward steady state after initial startup.

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Operational clearance has a significant effect on bearing life. The load supported by the bearing passes through one of the races, through the rolling elements, and to the other race. The number of rolling elements supporting a load effects the bearing performance and life. If the clearance is too great, fewer rollers actually support the load, creating higher stresses at their contact points with the raceways. This will lead to metal fatigue and shortened life. In applications where loads are light, excess clearance in the bearing can lead to roller sliding or skidding. This generates significant wear on the race ways, generating heat, and causing premature bearing failure.

If the internal clearance is negative, the bearing will be preloaded. Contact stresses between the rolling elements and races will be very high causing frictional heat, accelerated wear, and premature failure.

An operational clearance of zero, or very slightly negative, will result in maximum bearing life. With zero clearance, the load zone will be at its maximum angle, which distributes the load across the greatest number of rollers. This ideal condition is extremely difficult to achieve and maintain under normal operation conditions due to fluctuating temperatures during operation. Unequal expansion of bearing components can cause issues for a zero clearance bearing. Temperature changes can cause a slight negative clearance to change to a severe negative clearance or preload.

Bearings such as angular contact ball bearings, spherical roller thrust bearings, and tapered roller bearings are adjustable, and their internal clearance is determined when mounted. These bearings typically require a small amount of operational clearance. The internal clearance for this type of bearing is determined by locating outer and inner races relative to each other, and limiting their axial movement. This is referred to as setting the end play. Permitting a small amount of end play creates a slight radial internal clearance in the bearing. Bearings with adjusted clearances can be designed to have almost zero end play, making them desirable for applications where shaft movement needs to be limited. See **Figure 2** showing end play adjustment for a tapered roller bearing.

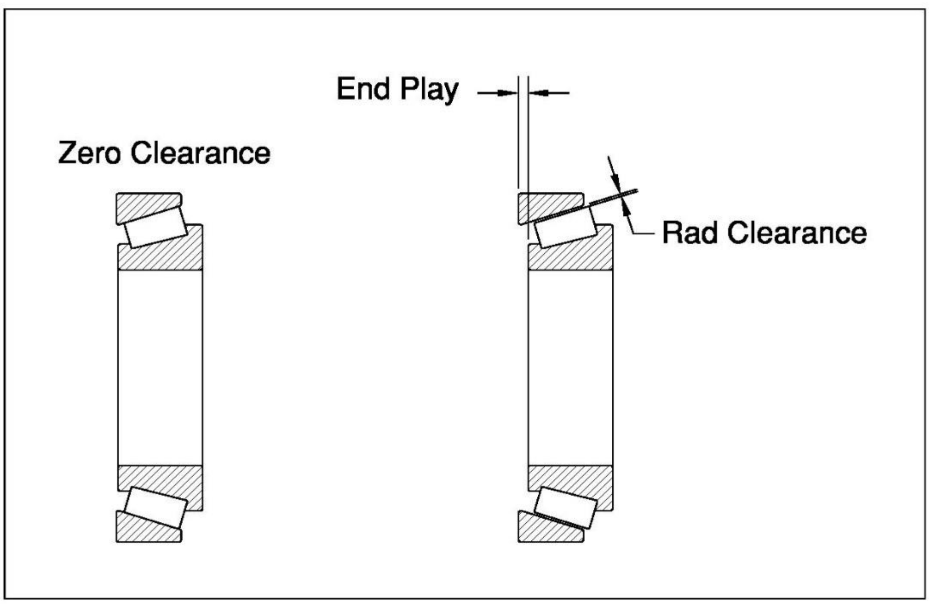

Figure 2. Tapered roller bearing with end play adjustment

Deep groove ball bearings and spherical roller bearings are manufactured with internal clearances between the rolling elements and inner and outer rings. Rolling elements are produced in various sizes which allows bearings to be assembled with several different ranges of internal clearance. The size of the rolling elements used during the assembly of the bearing determines the radial clearance of the assembled bearing. Ball bearings are designed to operate with almost zero operational clearance. Spherical roller bearings are designed to use a small amount of radial internal

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clearance. Typically, these bearings are designed to be mounted onto a shaft with an interference fit between the shaft and bearing inner ring. Sometimes, there may be an interference fit between the bearing outer ring and housing bore. In either case, the initial clearance in the bearing will be reduced after mounting.

Internal clearance for ball and spherical roller bearings is determined during the manufacturing process. Ball and spherical roller bearings are manufactured with internal clearances defined by ISO. Each clearance class specifies the range of clearance for each bearing type and size. Four of the most common clearance classes are shown below. **Table 1** shows radial internal clearance tolerances based on clearance class for a selected group of ball and spherical roller bearings

- C2 – Clearance less than normal
- C0 – Referred to as normal clearance
- C3 – Greater than normal clearance
- C4 – Greater than C3 clearance

SINGLE ROW DEEP GROOVE BALL BEARINGS (CYLINDRICAL BORE)									
Nominal Bore mm		C2 Less Than Normal Clearance µm		C0 Normal Clearance µm		C3 Greater Than Normal Clearance µm		C4 Greater Than C3 Clearance µm	
Over	*Incl.*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
30	40	-	11	6	20	15	33	28	46
40	50	-	11	6	23	18	36	30	51
50	65	-	15	8	28	23	43	38	61
65	80	-	15	10	30	25	51	46	71
80	100	-	18	12	36	30	58	53	85

SPHERICAL ROLLER BEARINGS (TAPERED BORE)									
Nominal Bore mm		C2 Less Than Normal Clearance µm		C0 Normal Clearance µm		C3 Greater Than Normal Clearance µm		C4 Greater Than C3 Clearance µm	
Over	*Incl.*	*Low*	*High*	*Low*	*High*	*Low*	*High*	*Low*	*High*
30	40	25	35	35	50	50	65	65	85
40	50	30	45	45	60	60	80	80	100
50	65	40	55	55	75	75	95	95	120
65	80	50	70	70	95	95	120	120	150
80	100	55	80	80	110	110	140	140	180

Table 1. ISO internal bearing clearances

Axial movement of ball and spherical roller bearings is approximately 5 to 10 times the mounted internal clearance. In some cases, C2 bearings are used to limit or control the end play in the bearing.

The ISO clearance classes are used to achieve an operational clearance that is slightly greater than zero. When these classes are combined with recommended shaft and housing fits, a desirable operational clearance can be obtained. Notice the clearance class values for ball bearings are less than spherical roller bearings. This is because ball bearings require less interference shaft fits than spherical roller bearings. Spherical roller bearings require greater initial clearances to handle the tighter shaft fits. Interference shaft fits not only set the correct bearing clearance, but they are also used to develop sufficient holding power on the shaft to prevent shaft spin and axial shaft movement.

C0 and C3 fits are commonly used today and will provide slight operational clearance when used with recommended shaft fits. Higher speeds generate significant frictional heat, and result in temperature differences between inner and

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outer rings. C3 bearings are typically used for high speed applications to accommodate these temperature differences.

C3 bearings are commonly used today because they work well in applications where significant interference shaft fits are used, and they can be used in slow and high speed applications. For these reasons, they are the most commonly produced bearings. Due to this versatility, all adapter mounted product from Dodge is supplied with C3 bearings.

Through the years, bearings have improved significantly regarding strength and load carrying capability. Supporting larger loads require tighter interference fits. It is not uncommon to use a C3 or C4 where a C0 may have been previously used. In applications where heat is conducted through the shaft from an external heat source, or where steam travels through a hollow shaft, the inner ring will expand significantly faster than the outer ring. C4 bearings are typically used for these types of applications.

When selecting bearings, it is imperative to understand the requirements of the application. Shaft speeds, operating temperatures, shaft fits, and running accuracy will influence the type of bearing required. If an existing bearing is replaced with a different model or style, these same application requirements need to be evaluated so that the new replacement bearing will perform well.

Please contact Dodge application engineering at 864-284-5700, or e-mail us at DodgeEngineering@abb.com, with any questions or comments.

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