Dodge® mounted bearings: shaft expansion

Bearing failures and high operating temperatures can often be attributed to high thrust loads. Occasionally, these high thrust loads are not influenced by the application but rather by improper bearing selection. Shaft contraction and/or growth can place damaging thrust load on dual non-expansion bearings when a combination of an expansion bearing and a non-expansion bearing is required.

For example, consider a bearing application that is located outside with ambient temperatures anywhere from -20°F in the winter to 115°F in the summer. Also consider that the bearing bases are mounted on a concrete pedestal above the ground with a steel shaft connecting two non-expansion bearings. Throughout the year the connecting shaft between the bearings is longer in the summer and shorter in the winter due to linear thermal expansion. If this growth and contraction is not accounted for then the load created by the growth/contraction will place strain on the limited components.

All materials undergo some physical change due to change in temperature. Most materials expand or contract as temperature increases or decreases respectively. This dimensional change is based on the specific material being used.

Calculating the dimensional variation due to a change in temperature is fairly simple and the relationship between the parameters involved is linear. This relationship follows the following equation:

$$\Delta L = \propto \cdot \Delta T \cdot L_0 \quad \text{OR} \quad \Delta L = \propto \cdot (T_F - T_0) \cdot L_0$$

Where

ΔL = Change in length $= L_F - L_0$
L_F = Final length
L_0 = Original length
$\propto$ = Linear Coefficient of Thermal Expansion
ΔT = Change in Temperature $= L_F - L_0$
T_F = Final Temperature
T_0 = Original Temperature

864-284-5700 | engineering@dodgeindustrial.com | 1061 Holland Road, Simpsonville, SC 29681 USA | **dodgeindustrial.com**

The linear coefficient of thermal expansion is listed below for some materials which are commonly used in structural supports and industrial power transmission equipment.

Steel (1020) = 6.3 x 10^{-6} (in/in · °F)

Gray Cast Iron = 6.7 x 10^{-6} (in/in · °F)

Stainless Steel = 9.6 x 10^{-6} (in/in · °F)

Aluminum 6061-T6 = 13.5 x 10^{-6} (in/in · °F)

Concrete = 6.0 x 10^{-6} (in/in · °F)

Rubber = 42.8 x 10^{-6} (in/in · °F)

Consider the example above and resolve the overall growth where bearing centers are 80 inches (L_0) and assume the worst case scenario where the bearings were mounted at -20°F. The maximum temperature difference, ΔT, is 135°F [(115 – (-20)]. Also consider that the shaft material is 1020 steel.

$\alpha =$ 6.3 x 10-6 (in/in · °F) [For steel 1020]

$\Delta T =$ 135°F

$L_0 =$ 80 in

$\Delta L =$ 0.0000063 (in/in · °F) · 135°F · 80 in = 0.06804 inches

The above calculation shows that the shaft expansion is 0.06804 in between the bearings over the temperature range of -20 to 115 deg F. This shaft expansion can lead to failure of the bearing if it is not accounted for by placing undue thrust loads on the bearings.

To properly manage the shaft length variation an expansion bearing must be utilized. Expansion bearings allow the shaft to expand or float relative to the housing while maintaining a secure fit to the shaft itself. When expansion bearings are properly utilized in scenarios like this, it prevents thrust load from thermal growth/contraction on the bearing while still supporting the application's radial loads.

In the example above, it is also important to note that the temperature of the bearings when they were mounted plays a large role in the amount of thrust load imposed on the bearings. If the bearings were mounted in the dead of winter or in the middle of summer, then they would be subjected to the maximum thrust load caused by a change in shaft length. If the bearings were mounted at the mean temperature of 47.5°F then the shaft would expand or contract by only half the amount caused by the maximum temperature difference, or +/- 0.034". Therefore, it is important to anticipate movements when determining the internal location of the expansion bearing.

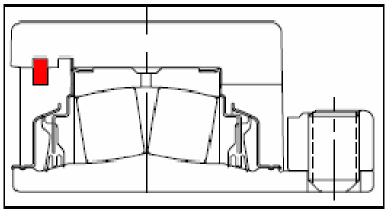
Not all applications require expansion bearing. Some of the applications which would not require expansion bearing are: shafts with short distances between bearing supports; applications with minor temperature variations; or continuous mounting structures that are of similar material as the shaft. Shafts with short distances between bearing supports are not likely to create much length variation unless exposed to severe temperature fluctuations. Applications with minor temperature variations, such as shafts in an indoor, temperature controlled environment, will not grow due to lack of temperature change.

After the need for an expansion bearing has been established it is important to determine where this expansion bearing should be located. The general rule is to locate the non expansion bearing closest to the drive and to locate the expansion bearing on the opposite end of the shaft. This allows the shaft to expand away from critical system components and prevents preloading motor bearings or couplings, misaligning belt drives, etc. Some applications like cutter blades require precision cuts and therefore require dimensional stability at the driven. In this case the non expansion would be placed on the drive end. It is best to always review the application and place the bearings accordingly.

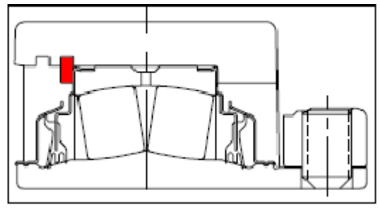
Every rotating shaft always needs at least one non expansion bearing. Any bearings beyond the non expansion bearing can be expansion. Never install expansion bearings exclusively on a shaft as this will allow the shaft to move without control. Dodge® offers expansion ball bearings in 205 (SC only), 206, 207, & 209 to 212 series GT, SC, SXR & DL.

All roller bearings are available in both expansion and non-expansion designs with the sole exception of the Type-E tapered roller bearing. Tapered roller bearings can not be field modified to change from either expansion to non expansion or vice versa. However, all spherical roller bearings can be field modified by either moving a snap ring or adding/removing stabilizing rings depending upon the design. The image below illustrates how a S2000 may be field modified from expansion to non expansion. When the snap ring is in the outermost groove the bearing has the ability to move laterally between the snap ring and the housing boss. When the snap ring is moved to the inner most groove the bearing is trapped and anchored in place.

Expansion



Non Expansion



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