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Dodge® mounted bearings: thermal expansion in shafts
Dodge Customer/Order Engineering
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Does the following story sound familiar? Every summer Junior has trouble with his conveyor bearings. The conveyor is located outdoors and by the end of every summer he must replace the pulley bearings. Based upon his experience inspecting bearing raceways, Junior suspects the bearing failures are due to excessive thrust loading. He believes this axial loading is a result of the inability of his maintenance crew to properly align the conveyor pulleys. Junior assigns his new maintenance engineer, Eddie, to solve the problem. Eddie notices the bearing pedestals are mounted on solid ground and both bearings are non-expansion. Further, he discusses with Junior the seasonal nature of the failures at this location. Eddie suspects the thrust load is actually a result of shaft growth.

Is Eddie onto something? Of course he is. All materials react to changes in temperature. Most materials contract, or shrink, as temperature decreases and expand, or grow, as temperature increases. Additionally, the rate at which this dimensional change occurs is based on the specific material being considered.

Determining dimensional variation due to temperature change is not a difficult calculation. The change occurs as a linear relationship between the original dimension, the temperature change, and a material constant known as the linear coefficient of thermal expansion, α. This relationship can be expressed by the following equation:

$$\Delta L = \propto \cdot \Delta T \cdot L_0$$
$$\Delta L = \propto \cdot (T_F - T_0) \cdot L_0$$

Where

ΔL = change in length = $L_F - L_0$
$\propto$ = linear coefficient of thermal expansion
ΔT = Change in Temperature = $T_F - T_0$

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

Steel (1020) = 6.3×10^{-6} (in/in · °F)
Gray Cast Iron = 6.7×10^{-6} (in/in · °F)
Stainless Steel = 9.6×10^{-6} (in/in · °F)
Aluminum 6061-T6 = 13.5×10^{-6} (in/in · °F)
Concrete = 6.0×10^{-6} (in/in · °F)
Rubber = 42.8×10^{-6} (in/in · °F)

With this information in hand, solving Junior's bearing problem becomes trivial. Eddie can calculate the amount of shaft expansion that occurs throughout the year and compare that with the allowable limits of the bearing. He measures the center distance between both bearings, (L_0), to be 100 inches. The temperature can reach -15°F in the winter and 95°F in the summer. Therefore, the maximum temperature difference, (ΔT), is 110°F. The shaft material is low carbon steel and both bearing pedestals are mounted in concrete to the ground. The shaft expansion is calculated as follows:

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α = 6.3 x 10-6 (in/in · °F) [For low carbon steel]
ΔT = 110°F
L_0 = 100 in
ΔL = 0.0000063 (in/in · °F) · 110°F · 100 in = 0.0693 inches

The result is a possible shaft growth 0.0693" between the bearings over the course of the year. This variation in length can lead to premature bearing failures if it is not accounted for properly. With the inner rings fixed firmly to the shaft, any growth of the shaft beyond the expansion capabilities of the bearings will create increasing thrust load on the bearings.

Bearing manufacturers realize the potential for bearing failure in this type of situation and have designed expansion bearings to which allow the shaft to float. Using expansion bearings eliminates the buildup of thrust load absorbed by the bearing during shaft growth while still supporting bearing 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 40°F then the shaft would expand or contract by only half the amount caused by the maximum temperature difference, or +/- 0.035". Therefore, it is important to anticipate movements when determining the internal location of the expansion bearing.

While not every application requires an expansion bearing. Some of these applications include: 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 unlikely 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. Finally, continuous mounting structures such as steel I-beams or steel plate supporting mounted bearings and steel shafts will grow at the same rate from ambient temperature fluctuations as the shaft. Therefore expansion bearings are not required.

Once the need for an expansion bearing has been determined it is then necessary to decide the location of the non-expansion bearing. The general rule is to place the non-expansion bearing closest to the drive side of the shaft. This will allow more stability at the drive preventing preload on the motor bearings. It also minimizes the possibility of v-belt or synchronous belt misalignment created at seasonal peaks. However, this rule does not always apply. Some applications such as cutter blades producing consistent precision cuts require more dimensional stability at the driven end. It is always recommended to review the application requirements to establish the ideal location for the expansion bearing. It is rare that the addition of an expansion bearing on a shaft will cause problems. The best practice is to always have at least one non-expansion bearing on a shaft. All remaining bearings could be expansion.

Certain applications are more susceptible to problems created by shaft expansion, such as hollow shafts with hot water or steam flowing through the center, shafts connected to oven or dryer rolls, and conveyor rolls transporting hot product. However, it is always important to know which types of bearings are to be used and the location for each. Shaft expansion, while a simple concept, can cause major problems if not accounted for properly.

So, if you are experiencing bearing failures that are exposed to fluctuating, or extreme temperatures, you may want to review expansion bearing optimization in the application. As outlined in this article, choosing the right bearing for a specific location is important to prevent failures and control costs. Shaft expansion, while a simple concept, can cause major problems if not accounted for properly.

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